SITE CHARACTERIZATION/REMEDIAL INVESTIGATION REPORT AREA OF INTEREST 7

SUNOCO, INC. (R&M) PHILADELPHIA REFINERY PHILADELPHIA, PENNSYLVANIA

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

Prepared by:
Langan Engineering & Environmental Services, Inc.
30 South 17th Street
Suite 1300
Philadelphia, Pennsylvania 19103

February 29, 2011
2574601

SITE CHARACTERIZATION/REMEDIAL INVESTIGATION REPORT
AOI 7

Prepared by:
Langan Engineering & Environmental Services, Inc.
30 South 17th Street
Suite 1300
Philadelphia, Pennsylvania 19103

Colleen Costello, P.G.
Senior Principal
PG-003736-E

Jason Hanna
Senior Project Manager, CHMM

Dennis E. Webster
Project Manager

February 29, 2012
2574601

TABLE OF CONTENTS

Page No.

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

1.0 INTRODUCTION

Sunoco Inc. (R&M) (Sunoco) and the Pennsylvania Department of Environmental Protection (PADEP) entered into a Consent Order & Agreement (CO&A) in December 2003 with respect to Sunoco's Philadelphia Refinery (refinery). Sunoco's Phase I Remedial Plan (Phase I Plan), dated November 2003, was included as an attachment to the CO&A. In accordance with the CO&A and Phase I Plan, a Current Conditions Report and Comprehensive Remedial Plan (CCR) was prepared by Sunoco in June 2004. The Phase I Plan and the CCR divided the facility into 11 Areas of Interest (AOIs), and presented a prioritization of the AOIs based on specific risk factors. The AOIs are shown in Figures 1 and 2 of this report. The CCR also presented the Phase II remedial approach and schedule to characterize each of the 11 AOIs, and to conduct Phase I and II corrective action activities in accordance with the 2003 CO&A and the Phase I Plan. Since 2003, Sunoco has completed site characterization activities at eleven AOIs (AOIs 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and 11). For each AOI that has been characterized, Sunoco has prepared and submitted a corresponding Site Characterization Report (SCR) in accordance with the Revised Phase II Corrective Action Activities schedule that was included in the CCR.

Sunoco submitted a Site Characterization Work Plan (Work Plan) for AOI 7 on May 26, 2010 to the PADEP and United States Environmental Protection Agency (EPA). This Work Plan summarized proposed activities to be completed to characterize AOI 7 in accordance with the objectives of the CCR. The Work Plan also included proposed activities to characterize the Resource, Conservation and Recovery Act (RCRA) Solid Waste Management Unit (SWMU) in AOI 7. The Work Plan was implemented between April and July, 2010 and the results were summarized in a SCR submitted to PADEP and EPA on September 28, 2010. In 2011 and 2012, additional site characterization activities were completed to investigate LNAPL in the vicinity of the No. 3 and 4 Separators.

This report is a combined Site Characterization/Remedial Investigation Report (SCR/RIR) which summarizes the site characterization work completed between 2010 and 2012. This SCR/RIR is being submitted to the PADEP and EPA in accordance with the provisions of Pennsylvania's Land Recycling and Environmental Remediation Standards Act (Act 2). In accordance with Act 2, Langan, on behalf of Sunoco, has prepared the required public and municipal notices as part of this report submittal. The notices and their proof of receipt/publication are included in Appendix A of this report.

1.1 Site Description

The Sunoco Philadelphia Refinery is located in southwest Philadelphia. AOI 7, also known as the Girard Point Fuels Processing Area, is located on the east side of the Schuylkill River. AOI 7 is bordered by Lanier Avenue to the east, Pennypacker Avenue to the south and Schuylkill River to the west and north (Figures 1 and 2). AOI 7 encompasses approximately 130 acres, and is covered by approximately 40% of impervious surfaces. The entire western and northern boundary of AOI 7 along the Schuylkill River is bound by a sheet pile wall which is keyed into the Middle Clay Unit. The extent of the sheet pile wall is shown in Figure 3.

There are a total of five SWMUs (SWMU Nos. 87, 88, 89, 90, and 91) located in AOI 7 that were addressed in several previous RCRA investigations as part of the EPA Corrective Action Process. The history and locations of the five SWMUs are discussed in detail in Section 2.1 below.

1.2 Site History

The Philadelphia refinery has a long history of petroleum transportation, storage, and processing. The oldest portion of the facility started petroleum related activities in the 1860's, when the Atlantic Refining Company was established as an oil distribution center. In the 1900's, crude oil processing began and full-scale gasoline production was initiated during World War II. In addition to refining crude oil, various chemicals, such as acids and ammonia, were also produced at the site for a time. Current operations at the refinery are limited to the production of fuels and basic petrochemicals for the chemical industry. The current and historic uses of AOI 7 are described on the current historic use figure located in Appendix B.

AOI 7 formerly contained a fluid catalytic cracker (FCC) unit, CO boiler, sulfur plant, East and West Sludge Basin - RCRA Tank, Hazardous Waste Incinerator, and crude units. Based on review of historical reports and aerial photographs, early refining units in AOI 7 were built in the 1940s. AOI 7 currently consists of crude units, FCC and alkylation units, flares, and above ground storage tanks (ASTs). The ASTs contain primarily naphtha crude, waste oil, and cat charge stocks. Eight liquefied petroleum gases (LPG) tanks are located in the south-central portion of this area. A wastewater treatment plant (WWTP) is located along the southwestern portion of AOI 7. Four RCRA hazardous waste ASTs are also located in the western portion of AOI 7 approximately 150 feet north of the WWTP.

1.3 Selection of Compounds of Concern and Applicable Standards

The compounds of concern (COCs) for soil and groundwater are listed in Table 1 of this report. The COCs for the ongoing and proposed investigation activities include the current constituents from the Pennsylvania Corrective Action Process (CAP) Regulation Amendments effective December 1, 2001; provided in Chapter VI, Section E of PADEP's Closure Requirements for Underground Storage Tank Systems. These COCs are the same as those listed in the CCR. In May 2009, Sunoco included two additional COCs 1,2,4-trimethylbenze and 1,3,5-trimethylbenzene. These two compounds were added to the list of COCs by Sunoco based on the PADEP's revisions to the petroleum short list of compounds at the request of the PADEP.

<u>Media of Concern</u>
The media of concern for AOI 7 include groundwater and soil. The potential indoor air quality and off-site vapor migration exposure pathways were evaluated through the PADEP's vapor intrusion guidance. Surface water was evaluated as a receptor in relation to facility activities.

<u>Act 2 Remediation Standards</u>
The approach for attaining Act 2 remediation standards for the media of concern is described below by media.

<u>Groundwater</u>
Groundwater sample results were screened against the PADEP non-residential, used-aquifer (TDS<2,500) statewide health groundwater medium-specific concentrations (MSCs). As summarized in the CCR, where constituent concentrations are above these statewide health MSCs, Sunoco evaluated application of the site-specific remediation standard using either the pathway elimination or calculated risk-based standard options.

<u>Shallow Soil – 0 to 2 Feet Interval</u>
Shallow (0-2 feet) soil samples were collected at each soil boring/monitoring well location that represents a potential complete direct contact exposure pathway to site workers (e.g., unpaved areas). These shallow soil results were screened against the

PADEP non-residential soil MSCs. Where constituent concentrations are above the PADEP non-residential soil MSCs, Sunoco evaluated application of the site-specific remediation standard using either the pathway elimination or calculated risk-based standard options.

Soil – 2 to 15 Feet Interval

A site-specific remediation standard using the pathway elimination option was applied for soil between 2 and 15 feet beneath the ground surface within the boundaries of AOI 7 based on Sunoco's existing permit program governing excavations. This permit program serves as an institutional control that prevents potential exposure to impacted soils greater than two feet beneath the ground surface. Soil at this depth is evaluated through the groundwater data.

Vapor Intrusion into Indoor Air

For the current occupied buildings in AOI 7 as depicted on current use figure in Appendix B, groundwater is less than five feet below the ground surface; therefore, the PA DEP USEPA-PA Default Non-Residential Permissible Exposure Limit (PEL) for Volatilization to Indoor Air for soil and groundwater screening criteria in the PADEP's guidance could not be used. As part of the Cleanup Plan for AOI 7, further evaluation (i.e., soil gas samples) will be necessary to assess the potential vapor intrusion into indoor air pathway for existing buildings. Because the site specific standard is being used for the refinery, groundwater within some portions of AOI 7 is shallower than five feet, underground utilities exist and sampling was not completed below areas with impervious covers, Sunoco will place a restriction in the Uniform Environmental Covenants Act (UECA covenant) for AOI 7 that will require further vapor site characterization activities and/or installation of a vapor mitigation systems for any new occupied buildings that will be constructed within AOI 7.

1.4 Overview of Investigative Framework and Remedial Approach for AOI 7

The current remediation program for the refinery is performed under the 2003 CO&A between PADEP and Sunoco. Below is a general summary of the regulatory frame work for the refinery:

- 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.

- In 2005, PADEP, EPA, and Sunoco 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.

- In October 2006, Sunoco submitted a notice of intent to remediate (NIR) to the PADEP for the refinery entering the refinery into the Act 2 program, excluding the Belmont Terminal. A copy of this NIR and the Act 2 report notifications for this SCR/RIR/Cleanup Plan are included in Appendix A.

- In September 2007, Sunoco held a public involvement meeting in South Philadelphia, Pennsylvania.

- On November 8, 2011, the EPA provided an acknowledgment letter to Sunoco formerly accepting the Sunoco Philadelphia Refinery into the One Cleanup Program. EPA acknowledges that Sunoco is currently operating under the one EPA ID Number (PAD049791098) for Point Breeze, Girard Point and Schuylkill River Tank Farm. 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.

- On November 30, 2011, Sunoco submitted a revised *Work Plan for Sitewide Approach Under the One Cleanup Program* (Work Plan for Sitewide Approach), to document the Sitewide remedial approach extending beyond the requirements of the 2003 CO&A. DEP and EPA have reviewed and provided input to this report. With this Work Plan for Sitewide Approach, Sunoco submitted a letter of commitment stating Sunoco will remediate the Philadelphia refinery site according to the Work Plan for Sitewide Approach.

2.0 ENVIRONMENTAL SETTING

AOI 7 is located in the southern portion of the refinery and is also known as part of the Girard Point Area. AOI 7 is located north of Pennypacker Avenue, east of Lanier Avenue, and south and east of the Schuylkill River (Figures 1 and 2). AOI 7 encompasses approximately 130 acres.

2.1 Historic and Current Use

<u>Historic Use</u>

Sunoco obtained available historical aerial photographs with coverage of AOI 7 from the City of Philadelphia Library and reviewed them to identify specific areas for characterization and to assist in determining previous uses of AOI 7. Aerial photos were reviewed for the following years: 1930, 1945, 1959, 1965, 1970, 1975, 1980, 1985, 1990, 1995 and 2005. A brief summary of each photograph was provided in the AOI 7 Work Plan, which was submitted to PADEP and EPA on May 26, 2010 and is provided in this report as Appendix J.

AOI 7 formerly contained a FCC unit, CO boiler, sulfur plant, East and West Sludge Basin - RCRA Tank, Hazardous Waste Incinerator, and crude units. These features are shown on the historic use figure in Appendix B. Based on the review of historical reports and aerial photographs, early refining units in AOI 7 were built in the 1940s.

Based on a review of historic RCRA reports, five SWMUs were identified in AOI 7 that required further characterization in accordance with the current remedial program. The RCRA reports identify these areas as the northwestern fill area (SWMUs 87, 88, and 89) and storage tank area (SWMUs 90 and 91). These SWMUs are shown in Figure 3 and on the historic use figure in Appendix B.

The northwestern fill area consists of SWMU 87 (Buried Lead Sludge Area No. 1), SWMU 88 (Buried Lead Sludge Area No. 2), and SWMU 89 (Buried Lead Sludge Area No. 3). These are areas where leaded tank bottoms may have been deposited. These three SWMUs are located adjacent to each other in the northwestern portion of AOI 7. A sheet pile wall keyed into the Middle Clay and the Schuylkill River borders these SWMUs to the north and west. The 1990 *RCRA Facility Investigation Work Plan* (RFIWP) reported that these three SWMUs received cooling tower sludge, leaded tank bottom sludge, and oily tank bottom sludge.

Two other potential areas of leaded tank bottoms disposal (388 Tank Basins - East and West) were formerly located in the southwest corner of SWMU 87. The 388 Tank Basins – East and West were properly closed under the PA storage tank program in November 1999. One Hazardous Waste Incinerator was formerly located in the in the southwest corner of AOI 7. This incinerator was properly closed in March 1999 and therefore was not part of the 2010 to 2012 site characterization activities.

The storage tank area is located in the southeastern portion of AOI 7 and contains SWMU 90 (Buried Lead Sludge Area No. 4) and SWMU 91 (Buried Lead Sludge Area No. 5), two other areas of potential leaded tank bottom disposal. SWMU 90 is located immediately north of SWMU 91 as shown in Figure 3 and on the historic use figure in Appendix B. AOI 3 borders SWMUs 90 and 91 to the east and AOI 6 borders the SWMUs to the south. The 1990 RFIWP reported that leaded sludge from tank bottoms was periodically removed from tanks in this area and disposed on the ground or in shallow excavations. These SWMUs reportedly received leaded sludge from the tank bottoms beginning in the 1960s and up until November 1980.

Historic reports have indicated that SWMUs 87, 88, 89, 90, and 91 have the potential to contain leaded tank bottom materials. Leaded tank bottom materials are distinguished by distinctive rusty-red to black, metallic mostly oxidized scale materials. Leaded tank bottoms also can be found in a matrix of petroleum wax sludge. Sunoco's general procedure to characterize the SWMUs in AOI 7 for the presence of leaded tank bottom materials is presented in Section 3.1 of this report and was described in the AOI 7 Work Plan.

<u>Current Use</u>

AOI 7 currently consists of crude units, FCC and alkylation units, flares, and ASTs. The ASTs contain primarily naphtha crude, waste oil, and cat charge stocks. Eight LPG tanks are located in the south-central portion of this area. A WWTP is located along the western portion of AOI 7 adjacent to the Schuylkill River. Four RCRA hazardous waste ASTs are located in the western portion of AOI 7 approximately 150 feet north of the WWTP.

A sheet pile wall, which is keyed into the Middle Clay, extends along the entire western boundary of the AOI 7 between the Schuylkill River and AOI 7. The extent of the wall is shown in Figure 3.

The existing monitoring well network in AOI 7 includes a total of 72 accessible existing monitoring points: 70 existing monitoring wells, 1 temporary well point, and one river gauge location. Fifteen new monitoring wells were installed in 2010 as part of the AOI 7 Work Plan and an additional 21 monitoring wells were installed in 2011 to investigate LNAPL in the vicinity of the No. 3 and 4 Separators. A well construction summary of AOI 7 monitoring points is included in Table 2. There are no active remediation systems in AOI 7. Groundwater gauging of select monitoring wells in AOI 7 occurs on an annual basis during the second quarter of each year. Annual gauging activities and results are reported to the PADEP and EPA in Quarterly Reports prepared by Sunoco.

No. 3 & 4 Separators

On July 12, 2011, Sunoco reported light non aqueous phase liquid (LNAPL) sheening on the Schuylkill River to the National Response Center. The sheen was directly adjacent to the Girard Point No. 3 Separator. In response to the sheen observed on the Schuylkill River, Sunoco has investigated the source of the LNAPL to the Schuylkill River through the installation of 21 monitoring wells and exploratory excavations around a process sewer junction box associated with the 137 Crude Unit and the No. 4 Separator. The newly installed monitoring wells have demonstrated measurable LNAPL on the shallow/intermediate groundwater table in the vicinity of the No. 3 Separator and the exploratory excavations revealed integrity issues with a 137 Crude Unit process sewer junction box.

Remedial actions completed to date have included:

- Sealed a penetration in the sheet pile wall adjacent to the junction box, eliminating groundwater flow to the Schuylkill River;
- Excavated around four sides of the junction box to inspect/verify connections and penetrations;
- Diverted flow from the junction box and associated excavation;
- Sealed the junction box on four sides with concrete;

- Installed 21 groundwater monitoring wells along the sheet pile wall between the No. 3 & 4 Separators and the sheet pile wall;
- Installed a 6 inch diameter recovery well between the No. 3 Separator and the sheet pile wall;
- Installed a continuous oil skimming system in the No. 3 Separator; and
- Maintained spill control equipment (absorbent booms) within the Schuylkill River in the Area of the No. 3 Separator to minimize impact of LNAPL to the river.

Future remedial actions in the No. 3 Separator area will include the design and installation of a hydraulic control system which will be documented in the AOI 7 Cleanup Plan.

2.2 Geology

To further characterize geology beneath AOI 7, Sunoco advanced 15 shallow/intermediate monitoring wells ranging in depths between 12 to 25 feet below ground surface (ft bgs) and three deep (Lower Sand) monitoring wells were installed to depths between 66 and 78 ft bgs in 2010. In 2011, 21 additional shallow/intermediate monitoring wells were installed along the northern portion of AOI 7 in the vicinity of the Girard Point No. 3 and 4 Separators. Soils beyond eight feet (depth of hole clearing) were continually logged at each well location and copies of the boring/well construction logs are included as Appendix C.

To illustrate the geology at AOI 7, three geologic cross sections (Figures 5a, 5b, and 5c) trending north-south, east-west, and northwest to southeast were prepared using historic and recently completed soil boring/well logs. The cross section locations are shown in Figure 4.

The following paragraphs describe the primary geologic units beneath AOI 7 beginning with the deepest units to the shallowest units.

Wissahickon Formation – Bedrock beneath the refinery and AOI 7 is identified as the Wissahickon Schist. This formation is a metamorphosed greenish-gray micaceous schist and quartzite. The competent bedrock of the Wissahickon Formation is overlain by weathered bedrock consisting of micaceous clay, which becomes increasingly sandy as the degree of weathering lessens and competent bedrock is encountered. Based on historic and recent deep monitoring well and soil borings completed in AOI 7, the Wissahickon Schist is located at depths ranging between 66 and 78 ft bgs. The bedrock depth is illustrated in Figures 5a, 5b and 5c.

Lower Sand Unit of the PRM – Throughout the majority of the refinery, the Wissahickon Formation is overlain by the Lower Sand, which is the lowest member of the Potomac-Raritan Magothy (PRM) Aquifer System. As shown in Figures 5a, 5b and 5c, the Lower Sand overlies bedrock throughout AOI 7.

Two deep (Lower Sand) groundwater monitoring wells (C-50D and C-65D) existed in AOI 7 prior to the recent characterization work. A total of three new deep groundwater monitoring wells (C-129D, C-134D and C-144D) were installed in AOI 7 as part of the recent site characterization activities. C-144D was installed to replace C-65D, as this well was damaged. The purpose of the additional deep (Lower Sand) monitoring wells was to obtain geologic information to refine the site conceptual model and obtain groundwater quality data for the Lower Sand. Based on interpretation of the geology as shown in Figures 5a, 5b, and 5c, deep monitoring wells in AOI 7 (with the exception of C-50D) are screened in the Lower Sand where the Lower/Middle Clay is present. Based on interpretation of geology as shown in Figures 5a, 5b and 5c, deep well (C-50D) in the western portion of AOI 7, near the AOI 3 eastern boundary is screened into the upper portion of the Lower Sand where the Lower/Middle Clay is interfingered with the Lower Sand.

The Lower Sand beneath AOI 7 is a reddish-brown, orange and/or yellowish-brown, fine to course gravel and fine to course sand that grades upward into medium-to-fine sands and contains layers of silts and clay. The Lower Sand is located approximately 20 ft bgs along the eastern boundary of AOI 7, and at 50-60 ft bgs along the eastern portion of AOI 7 and ranges in thickness between 20 and 70 feet. The extent of the Lower Sand beneath AOI 7 is generally consistent with the extent illustrated by USGS (USGS, 1961).

Middle/Lower Clay – The Middle/Lower Clay located beneath AOI 7 is characterized by low permeability reddish-brown, brown or gray clays, sandy clays, with trace amounts of organic matter. The Lower/Middle Clay overlies the Lower Sand throughout AOI 7 as shown in Figures 5a, 5b, and 5c. In the eastern portion of AOI 7, the Lower/Middle Clay appears to be interfingered with the Lower Sand.

The extent of the clay beneath AOI 7 as shown in Figures 5a, 5b and 5c is generally consistent with the extent illustrated by USGS (USGS, 1961), as interfingering of the clay is present. Plate 20 of the USGS publication includes a geologic cross section of the coastal plain deposits near AOI 7. This plate is provided in Appendix D of this report.

As shown in Figures 5a, 5b and 5c, the clay ranges in thickness between approximately 55 feet along the most western extent to approximately 5 feet in the eastern portion of AOI 7. The western boundary of AOI 7 is bound by a sheet pile wall which is keyed into the Middle/Lower Clay.

Trenton Gravel – Throughout most of the refinery, the Trenton Gravel typically overlies the Middle/Lower Clay and Lower Sand with thicknesses up to 80 feet and a typical thickness of 40 feet. The Trenton Gravel is of Pleistocene Age (Ice Age; less than 2 million years) and is a very heterogeneous unit comprised of a predominant brown to gray sand, gravel and minor amounts of clay (Owens and Minard, 1979). As shown in Figures 5a, 5b and 5c, the Trenton Gravel is undifferentiated from the fill/alluvium in AOI 7, and is present in the northwestern and northeastern area of AOI 7, near the Schuylkill River.

Recent Fill/Alluvium - Fill material in AOI 7 generally consisted of sands and gravels, silts, silty clays, cinder ash, brick, wood, and glass. The alluvium deposits in AOI 7 generally consist of dark brown silts and sands, with trace amounts of clay undifferentiated with fill material. Lesser amounts of fill are observed towards the western portions of AOI 7. As shown in Figures 5a, 5b and 5c, fill/alluvium deposits exist throughout AOI 7 and range in thickness between 10 and 25 feet.

In addition to the above descriptions, the following general observations can be made concerning the geology in AOI 7:

- The depth to bedrock beneath AOI 7 is at approximately 66 to 78 ft bgs. The depth to bedrock is generally consistent with previous geologic cross sections prepared by Dames & Moore and with the USGS's interpretation (USGS, 1961);
- The Lower Sand overlies bedrock throughout AOI 7 and is generally shallower in the eastern and northern portions of AOI 7;
- In the eastern portion of AOI 7, the Middle/Lower Clay appears to be interfingered with the Lower Sand;
- Trenton Gravel is undifferentiated from the fill/alluvium throughout AOI 7 and is only present in the northwestern and northeastern portions of AOI 7; and
- The fill/alluvium materials are present throughout AOI 7, and range in thickness between 10 to 25 feet.

2.3 Hydrogeology

2.3.1 Shallow/Intermediate Groundwater Occurrence and Flow

Groundwater gauging data collected by Aquaterra in January 2012 was used to generate a groundwater flow figure for the shallow/intermediate zone in AOI 7 (Figure 6). The groundwater elevation data from this gauging event is provided in Table 3. Monitoring well construction details for the monitoring wells are provided in Table 2 and boring/well construction logs for the newly installed monitoring wells are provided in Appendix C of this report. Historic boring/well logs for monitoring wells installed prior to the site characterization activities were provided in Appendix D of the CCR. Based on the groundwater elevations as shown in Figure 6, the following observations can be made.

- Groundwater in the shallow/intermediate monitoring wells occurs at depths ranging between approximately 0.8 and 9.0 ft above mean seal level (amsl);
- Based on the January 2012 groundwater gauging event, the hydraulic gradient in the shallow/intermediate monitoring wells ranged from 0.04 near C-142 in the northwest part of AOI 7 near the sheet pile wall to 0.001 near C-131 in the southeast part of AOI 7;
- The groundwater gradient in the central portion of AOI 7 is relatively flat;

- Along the western boundary of AOI 7, flow in the shallow/intermediate zone is generally towards the east-southeast, away from the sheet pile wall; and
- Generally, groundwater flow in the shallow/intermediate zone in AOI 7 is towards the west-northwest and groundwater flow in the northern portions of AOI 7 is north.

2.3.2 Deep Groundwater Occurrence and Flow

Five deep (Lower Sand) monitoring wells are located in AOI 7 which include C-50D, C-65D, C-129D, C-134D, and C-144D. Well construction details for these monitoring wells are provided in Table 2 and the available logs for these monitoring wells are provided in Appendix D of the CCR.

As part of the AOI 11 (site wide deep groundwater) site characterization activities, Aquaterra performed a refinery wide groundwater gauging event in July 2011 from all accessible deep monitoring wells. Deep groundwater data from this gauging event was used to generate groundwater flow figures for the deep groundwater zone in AOI 7 (Figure 7). The groundwater elevation data from this gauging event are provided in Table 3. Based on the refinery wide deep groundwater elevations as shown in Figure 7, the following observations for AOI 7 can be made.

- Groundwater flow in the deep zone is generally towards the north-west, in the direction of Schuylkill River;
- Water levels in the deep zone occur at depths between approximately 2.84 ft amsl (in northwestern portion of AOI 7) and 0.51 ft amsl (in the eastern portion of AOI 7);
- The deep groundwater gradient in the central portion of AOI 7 is relatively flat, with similar gradients observed throughout the site; and
- Groundwater elevations in the deep zone are lower than the shallow/intermediate zone, exhibiting a downward vertical hydraulic gradient.

2.4 Surface Water

No surface water features are located in AOI 7. The nearest surface water body to AOI 7 is the Schuylkill River which borders the western and northern AOI 7 boundaries. A sheet pile wall keyed into the Middle Clay exists between AOI 7 and the Schuylkill River as shown on Figure 3 and in cross-sectional view in Figures 5a, 5b and 5c. Shallow/intermediate groundwater interaction with surface water is limited by the sheet pile wall.

3.0 SITE CHARACTERIZATION ACTIVITIES

The following sections summarize the site characterization activities that were completed in AOI 7 in support of this report. Site characterization activities were performed in 2010 through January 2012, by Aquaterra Technologies, Inc. (Aquaterra) and Langan in coordination with Sunoco. The site characterization activities were executed in accordance with the AOI 7 Work Plan for Site Characterization which is included as Appendix J of this report

3.1 Shallow Soil Borings and Sampling in SWMU Areas

A detailed description of SWMUs 87, 88, 89, 90, and 91 and a summary of previous investigation work completed at these SWMUS were provided in Section 1.2 of the AOI 7 Work Plan. A total of 31 shallow soil borings were completed to a depth of two ft bgs via a stainless steel hand auger. Two additional shallow soil borings were advanced via split spoon samples for monitoring wells C-142 and C-143. Soil samples were collected from these 33 soil boring locations to supplement data previously collected as part of the historical RCRA investigations. No tank bottom materials were observed, therefore, none of the samples were analyzed for TCLP. Soil samples were collected at each soil boring location utilizing TerraCore samplers. No soil samples were collected as part of the 2011 well installation activities. Soil boring activities were performed in June 2010 by Total Quality Drilling, LLC (Total Quality Drilling) of Mullica Hills, New Jersey under the direct supervision of Aquaterra and Langan. The soils were evaluated to determine if leaded tank bottom materials were present and to characterize historic soil exceedances of site COCs within the SWMUs. Boring logs from each soil boring location are presented in Appendix C. Below is a summary of the number of soil borings completed in each SWMU area:

- SWMU 87 – Eight shallow soil borings;
- SWMU 88 – Six shallow soil borings;
- SWMU 89 – Six shallow soil borings;
- SWMU 90 – Eight shallow soil borings; and
- SWMU 91 – Five shallow soil borings.

The locations of the SWMUs and the soil borings are shown on Figure 3.

The five SWMUs were characterized during the site characterization efforts following the investigative approach outlined in Section 1.2.2 of the AOI 7 Work Plan as summarized below.

- If materials were encountered within the leaded tank bottom areas matching the physical description of the leaded tank bottoms, then Sunoco collected samples for lead;
- If the lead results were above 450 parts per million (ppm) (PADEP's non-residential soil MSC for lead) then samples were analyzed for lead via Toxicity Characteristic Leaching Procedure (TCLP), EPA Test Method 1311; and
- Delineated areas that had soils that physically resemble leaded tank bottoms, had lead concentrations greater than 450 ppm and failed the TCLP test for lead would retain the leaded tank bottom designation. If no soils were encountered that meet all three of the above mentioned criteria, then the area would no longer be classified as a leaded tank bottom area.

If no soils were encountered that meet all three of the criteria, then the area was no longer classified as a leaded tank bottom area.

Following the completion of 33 soil borings, there was no evidence of soil matching the physical description of leaded tank bottoms in the five SWMUs. A total of 33 soil samples were collected from the 33 soil boring locations since these areas were also being characterized due to historic soil exceedances, but none of the samples were analyzed for TCLP since tank bottom materials were not observed during the borings. The locations of all soil and monitoring well borings are shown on Figures 3 and 8.

Soil samples were submitted to Lancaster Laboratories, Inc. (LLI) of Lancaster, Pennsylvania for analysis of site COCs. A summary of the soil analytical results screened against the PADEP non-residential soil MSCs are provided in Table 4 and the results are further discussed in Section 5.0 below. A summary of soil samples above the non-residential soil MSCs are illustrated in Figure 8. The laboratory analytical reports are provided as Appendix E.

3.2 Shallow Soil Borings and Sampling in Non-SWMU Areas

A total of nine soil borings were advanced outside of the SWMU areas at unpaved monitoring well locations. The locations of soil and monitoring well borings are shown on Figures 3 and 8. Soil borings were advanced utilizing split-spoon sampling techniques. Soil borings were advanced to a maximum depth of two feet below grade at each unpaved location. Soil samples were collected at each soil boring location with a TerraCore sampler. No soil samples were collected as part of the 2011 well installation activities.

Soil samples were submitted to LLI for analysis of site COCs. A summary of the soil analytical results screened against the PADEP non-residential soil MSCs is provided as Table 4 and the results are further discussed in Section 5.0. The laboratory analytical reports are provided as Appendix E.

3.3 Installation of Groundwater Monitoring Wells

Well installation activities performed between May and July 2010 were completed by Parrat Wolff, Inc. (PWI) of East Syracuse, New York and East Coast Drilling (ECDI) of Moorestown, New Jersey under the direct supervision of Aquaterra and Langan in coordination with Sunoco. Monitoring wells installed in 2011 were completed by Total Quality Drilling under direction by Aquaterra and Sunoco. The locations of monitoring wells installed in 2010 and 2011 are shown on Figure 3. Monitoring wells were installed to monitor the shallow/intermediate and deep groundwater zones. The well installation activities are discussed in the following sections.

.

3.3.1 Fill/Alluvium (Shallow) and Trenton Gravel (Intermediate) Groundwater Monitoring Wells

Aquaterra and Langan provided direction and oversight to PWI to install 15 shallow/intermediate (fill/alluvium, and Trenton Gravel) groundwater monitoring wells in AOI 7 in 2010. Total Quality Drilling with oversight and direction by Aquaterra and Sunoco installed 21 monitoring wells in the vicinity of the No. 3 & 4 Separators in 2011.

Monitoring wells were installed and constructed in accordance with the AOI 7 Work Plan. Prior to the installation of monitoring wells, each well location was cleared for subsurface utilities between 8 to 10 ft bgs with a hydrovac excavator. Shallow/intermediate monitoring wells advanced by the drilling subcontractors utilized hollow stem augers and split spoon samplers to record lithology. Split spoon samples were collected at various intervals throughout the borings typically starting at 8 to 10 ft bgs. Shallow/intermediate monitoring wells were constructed to a maximum depth of 25 ft bgs with screen intervals of 10 to 15 feet. Monitoring wells were constructed with a flush mount manhole cover or with a stickup steel protective casing. Following construction, the monitoring wells were developed in accordance with the AOI 7 Work Plan. Well construction details are provided in Table 2. Boring logs, lithology, and monitoring well construction details are provided in Appendix C.

3.3.2 Lower Sand Groundwater Monitoring Wells

Two Lower Sand groundwater monitoring wells (C-50D and C-65D) had existed in AOI 7. C-50D was installed to a depth of approximately 30 ft bgs and the screen was set in the upper portion of the Lower Sand. C-65D is reported to have been drilled to a depth of 75 ft bgs; however the well is damaged and inaccessible.

Prior to installation of the deep monitoring wells (C-129D, C-134D and C-144D), each well location was cleared for subsurface utilities to a depth of 8 to 10 ft bgs with a hydro-excavator. Deep monitoring wells were advanced by ECDI utilizing hollow stem augers, mud rotary, and split spoon samplers to record lithology. Aquaterra and Langan provided direction and oversight to ECDI to install the three deep monitoring wells. Monitoring well C-134D was installed along the southern boundary of AOI 7 in AOI 6, due to access issues associated with the original proposed well location proposed along the southern boundary of AOI 7. The monitoring wells were installed with screened intervals set below the clay and into the Lower Sand. The purpose of the additional deep monitoring wells was to obtain lithologic information beneath AOI 7, and to characterize groundwater quality of the Lower Sand. The three deep monitoring wells were installed to depths ranging between 66 to 78 ft bgs, with well screened intervals of 15 feet. Monitoring well construction details are provided in Table 2 and boring logs, lithology, and monitoring well construction details are provided in Appendix C. Geologic information obtained from the deep soil borings completed in AOI 7 was used to prepare geologic cross sections provided as Figures 5a, 5b, and 5b.

3.4 Groundwater Monitoring

In January 2012, Aquaterra performed monitoring well gauging activities from all accessible monitoring points in AOI 7. Monitoring points were gauged for depth-to-water, and if applicable, depth-to-LNAPL in accordance with the AOI 7 Work Plan. The monitoring point gauging readings are summarized in Table 3.

The groundwater monitoring data from Table 3 was used to generate shallow/intermediate groundwater elevation contours provided as Figure 6. Groundwater gauging data from the deep monitoring wells in Table 3 was used to generate a groundwater contour figure for the deep (Lower Sand) groundwater zone in AOI 7 (Figure 7).

3.5 Groundwater Sampling

In June 2010, Aquaterra performed a complete round of groundwater sampling from 41 accessible monitoring wells in AOI 7. Five monitoring wells had measureable (>0.01 ft.) LNAPL and three monitoring wells were inaccessible. In January 2012, an additional round of groundwater sampling was conducted on 21 newly installed (installed in 2011) monitoring wells in the vicinity of the No. 3 and 4 Separators. Twelve of these new monitoring wells had measurable (>0.01 ft) LNAPL. The groundwater sampling activities were completed in accordance with the AOI 7 Work Plan. The monitoring well sampling summary data sheets are provided as Appendix F.

Following well purging activities, groundwater samples were collected by lowering a disposable bailer slowly into the monitoring well to minimize excess agitation. The bailer was filled with water from the top of the water table and retrieved. Samples were then collected in laboratory-prepared bottleware and immediately placed on ice. Samples were submitted to LLI for analysis of site COCs. Once the sample was collected, the bailer, bailer cord, and nitrile gloves used to obtain the sample were discarded. Sample date, time, number, and site name were recorded on the chain-of-custody and in field books. For groundwater samples analyzed for lead, LLI filtered the samples to analyze for dissolved lead concentrations.

The groundwater analytical results were screened against the PADEP non-residential groundwater MSCs and are presented in Table 5. The groundwater analytical results for the deep monitoring wells are presented in Table 6. The laboratory analytical reports are included as Appendix E.

3.6 LNAPL Sampling

During the AOI 7 July 2010 groundwater gauging event, five monitoring wells (C-65, C-97, C-106, C-107 and C-143) in AOI 7 had measurable LNAPL. LNAPL samples from monitoring wells C-65, C-106, and C-107 were previously collected and characterized as part of the 2004 CCR. One new monitoring well (C-143), which was installed as part of the 2010 site characterization activities contained measurable LNAPL. Stantec collected a LNAPL sample from C-143 using direct sampling methods in accordance with the AOI 7 Work Plan.

In January 2012, an additional groundwater gauging event was conducted and 18 monitoring wells (C-106, C-64, C-65, C-97, C-143, WP14-2, C-147, C-148, C-150, C-151, C-152, C-153, C-154, C-161, C-162, C-166, C-167, and C-168) had measurable LNAPL. Aquaterra collected samples via direct sampling methods from the 12 newly installed monitoring wells (C-147, C-148, C-150, C-151, C-152, C-153, C-154, C-161, C-162, C-166, C-167, and C-168) where LNAPL was present.

LNAPL samples collected were packaged in certified hazardous material shipping boxes and shipped to Torkelson Laboratories (Torkelson) of Tulsa, Oklahoma for LNAPL characterization. LNAPL characterization data included LNAPL types, density, proportions of LNAPL, degree of weathering, and similarities to other LNAPL samples collected at the refinery. Appendix H summarizes the LNAPL characterization results and also includes laboratory data packages.

3.7 Surveying Activities

Following completion of well installation and soil boring activities, the newly installed monitoring wells and soil boring locations were surveyed by Langan to establish the location and elevation of the inner and outer casing and ground surface at each point. Well elevations were determined to the nearest 0.01 foot relative to mean sea level. Survey activities were performed by a Pennsylvania-licensed surveyor and tied to the NAVD 88 datum. The new survey data for the monitoring wells is presented in Table 3. This new survey data was used to update the Geographic Information System (GIS) and site wide database for the refinery.

4.0 QUALITY ASSURANCE/QUALITY CONTROL

The following sections outline the field and laboratory quality assurance/quality control measures that were incorporated into the site characterization activities. Groundwater gauging and sampling activities were completed in accordance with the field sampling procedures presented in the AOI 7 Work Plan. The complete laboratory analytical data packages for the soil and groundwater sampling events are included in Appendix E.

4.1 Equipment Decontamination and Calibration

Sampling equipment was decontaminated in accordance with the field sampling procedures to prevent cross-contamination. Prior to sampling, the equipment was decontaminated with successive rinses of detergent and potable water and distilled deionized water. Down-hole equipment used in monitoring well purging, such as submersible pumps, was cleaned with an external non-phosphate detergent wash and tap water rinse. This cleaning process was followed by a flush of potable water. Prior to the use of sampling equipment (i.e. Horiba, PID, and electronic interface probe), the equipment was properly calibrated per the operating manual for that piece of equipment.

4.2 Sample Preservation

Samples were preserved, where necessary, with the addition of chemical preservatives, and by cooling the samples at 4°C before and during shipment to the laboratory. Chemical additives necessary for sample preservation were added to the sample containers by the analytical laboratory prior to releasing them to sampling personnel.

4.3 Laboratory Quality Assurance/Quality Control

For the purposes of this investigation, sample results were summarized in 13 sample delivery groups, provided by LLI, and are evaluated in the sections above for usability. Copies of the laboratory reports are provided in Appendix E.

The laboratory performed quality assurance and quality control (QA/QC) analyses, including laboratory control spikes and laboratory control spike duplicates, matrix spikes and matrix spike duplicates, surrogate spikes, method blanks and QA/QC checks such as GC/MS instrument tuning and mass calibration, as appropriate. Laboratory QA/QC summaries were completed by the laboratory and provided in each of the attached data packages. The analytical data, data qualifiers, and QC results provided in these reports were evaluated to determine the confidence with which the groundwater and soil data could be used in the Act 2 decision-making process.

Data quality indicators (DQIs) are qualitative and quantitative measures of data quality "attributes," which are descriptors used to express various properties of analytical data. Thus, DQIs are the various measures of the individual data characteristics that collectively comprise the general, all-encompassing term "data quality." Quality attributes used to assess the data usability include:

- Method selectivity/specificity;
- Accuracy (bias);
- Precision;
- Representativeness;
- Comparability; and
- Completeness.

Based on evaluation of the above mentioned indicators, the groundwater and soil data collected during this investigation are considered usable for characterizing the site, identifying compounds of concern, and delineating potential impacts, with the exceptions described below.

For compounds analyzed in soil 98% percent of the data is considered complete. The remaining 2% was qualified as estimated by the laboratory and flagged with a "J" qualifier. As detailed in the sections above, few concentrations should be considered as biased because MS/MSD and surrogate recoveries were beyond acceptable control limits. The following samples should not be used for the purpose of delineation because samples were diluted to the point that laboratory method detection limits were raised above the corresponding screening criteria (PADEP Soil MSCs) and no concentration was detected. Specifically, 1,2-dichloroethane in sample BH-10-27_1.5-2; and, ethylene dibromide in samples BH-10-08_1.5-2, BH-10-10_1.5-2, BH-10-11_1.5-2, BH-10-14_1.5-2, BH-10-16_1.5-2, BH-10-17_1.5-2, BH-10-24_1.5-2, BH-10-25_1.5-2, BH-10-27_1.5-2, BH-10-28_1.5-2, BH-10-30_1.5-2, BH-10-31_1.5-2, C-142_1-2 and C-143_1-2.

For compounds analyzed in groundwater, 90% percent of the data is considered complete and usable. The remaining 10% was qualified as estimated by the laboratory. As detailed in the sections above, few concentrations should be considered as biased because surrogate recoveries were beyond acceptable control limits and sample preservation requirements were not met. Preservation requirements were not met for samples C-49_071310, C-57_071410, C-131_071510 and C-142_072010 and VOC results are likely biased low.

The number of samples collected is expected to provide sufficient data to satisfy the objective defined in the AOI 7 Work Plan. In the event that initial results did not meet QC requirements, the volume of samples collected was sufficient to reanalyze samples as necessary. As detailed in Appendix E, few concentrations should be considered as biased because MS/MSD and surrogate recoveries were beyond acceptable control limits and preservation requirements were not met.

As detailed in Appendix E, where the LCS/LCSD, MS/MSD and surrogate recoveries were less than the lower recovery control limit the reported values should be considered as estimated low. Where the recoveries were greater than the upper recovery control limit the reported values should be considered as estimated high. The corresponding data are considered usable but should be considered slightly higher or lower in concentration than representative of the site and time collected.

4.4 Documentation

Chain-of-custody forms were maintained throughout the sampling program to document sample acquisition, possession and analysis. Chain-of-custody documentation accompanied samples from the field to the laboratory. Each sample was assigned a unique number that was recorded on permanent field sheet.

5.0 SITE CHARACTERIZATION ANALYTICAL RESULTS

The following sections discuss the analytical results of the site characterization activities performed in AOI 7.

5.1 Soil Analytical Results at SWMU Areas

A total of 33 shallow soil samples were collected within the five SWMUs and analyzed for site COCs to further characterize the SWMUs. As mentioned in Section 3.1, there was no evidence of leaded tank bottoms in any of the five SWMUs based on the data collected at the 33 shallow soil boring locations. The analytical results of the soil samples collected from within the SWMUs are provided in Table 4. Soil samples were collected between the ground surface and two ft bgs and no saturated soils were observed at these depths. The soil sample results were screened against the PADEP non-residential soil MSCs. Soil sample locations with results above their respective PADEP non-residential soil MSCs are shown in Figure 8.

Below is a general summary of the screening results for each of the five SWMUs.

SWMU 87 – Buried Lead Sludge Area No. 1

A total of eight shallow soil samples (BH-10-05 through BH-10-12) were collected in SWMU 87. A summary of the screening results is as follows:

- There were no soil samples with concentrations above the PADEP non-residential soil MSCs for site COCs in BH-10-05, BH-10-06, BH-10-07, BH-10-08, BH-10-11, and BH-10-12; and
- Lead was the only site COC detected in soil above its respective PADEP non-residential soil MSC in BH-10-09 (1,230 mg/kg) and BH-10-10 (725 mg/kg).

SWMU 88 – Buried Lead Sludge Area No. 2

A total of six shallow soil samples (BH-10-13 through BH-10-18) were collected in SWMU 88. A summary of the screening results is as follows:

- There were no soil samples with concentrations above the PADEP non-residential soil MSCs for site COCs in soil samples BH-10-13, BH-10-15, and BH-10-17;
- Lead was detected in soil above its respective PADEP non-residential soil MSC in BH-10-14 (531 mg/kg), BH-10-16 (616 mg/kg), and in BH-10-18 (478 mg/kg); and
- Benzene was detected in soil above its respective PADEP non-residential soil MSC in BH-10-16 (0.85 mg/kg).

SWMU 89 – Buried Lead Sludge Area No. 3

A total of six shallow soil samples (BH-10-19 through BH-10-22) were collected in SWMU 89. A summary of the screening results is as follows:

- There were no soil samples with concentrations above the PADEP non-residential soil MSCs for site COCs in soil samples BH-10-19, BH-10-20, and BH-10-22;
- Lead was detected in soil above its respective PADEP non-residential soil MSC in C-142 (1,370 mg/kg) and BH-10-21 (869 mg/kg); and
- Benzene was detected in soil above its respective PADEP non-residential soil MSC in C-143 (2 mg/kg).

SWMU 90 – Buried Lead Sludge Area No. 4

A total of eight shallow soil samples (BH-10-23, BH-10-24, BH-10-25, BH-10-26, BH-10-27, BH-10-28, BH-10-29 and BH-10-30) were collected in SWMU 90. A summary of the screening results is as follows:

- There were no soil samples with concentrations above the PADEP non-residential soil MSCs for site COCs in soil samples BH-10-24, BH-10-29, and BH-10-30;
- Lead was detected in soil above its respective PADEP non-residential soil MSC in BH-10-23 (623 mg/kg) and BH-10-26 (2,040 mg/kg);
- Benzene was detected in soil above its respective PADEP non-residential soil MSC in BH-10-25 (31 mg/kg) and BH-10-28 (1.6 mg/kg);
- 1,2,4-TMB was detected in soil above its respective PADEP non-residential soil MSC in BH-10-28 (280 mg/kg);
- 1,3,5-TMB was detected in soil above its respective PADEP non-residential soil MSC in BH-10-28 (130 mg/kg); and
- Naphthalene was detected in soil above its respective PADEP non-residential soil MSC in BH-10-28 (30 mg/kg).

SWMU 91 – Buried Lead Sludge Area No. 5

A total of five shallow soil samples (BH-10-31, BH-10-32, BH-10-33, BH-10-34, and BH-10-35) were collected in SWMU 91. A summary of the screening results is as follows:

- There were no soil samples with concentrations above the PADEP non-residential soil MSCs for site COCs in soil samples BH-10-32, BH-10-33, BH-10-34, and BH-10-35; and
- Lead was detected in soil above its respective PADEP non-residential soil MSC in BH-10-31 (610 mg/kg).

5.2 Soil Analytical Results at Non-SWMU Areas

A total of nine shallow soil samples (C-129, C-130, C-131, C-136, C-137, C-138, C-139, C-140, and BH-C-135) were collected in non-paved areas outside of the SWMUs in AOI 7. A summary of the screening results is as follows:

- There were no soil samples with concentrations above the PADEP non-residential soil MSCs for site COCs in soil samples C-129, C-131, C-136, C-137, C-138, C-139, C-140, and BH-C-135; and
- Lead was detected in soil above its respective PADEP non-residential soil MSC in C-130 (814 mg/kg).

5.3 Groundwater Results

The results of the groundwater samples collected from monitoring wells in AOI 7 are provided in Tables 5 and 6. The results were screened against the PADEP non-residential used aquifer (TDS<2,500) groundwater MSCs. Locations with concentrations above the groundwater MSCs are illustrated in Figure 9. A summary of the COC detected concentrations above the PADEP non-residential groundwater MSCs are presented below.

Shallow/Intermediate Monitoring Wells

COCs detected in shallow/intermediate monitoring wells at concentrations above their respective PADEP non-residential groundwater MSCs included the following:

- C-56 – lead (15 ug/l);
- C-57 – chrysene (3 ug/l);
- C-110 – chrysene (3 ug/l);
- C-111 – benzene (89 ug/L) and chrysene (3 ug/l)
- C-112 – chrysene (3 ug/l);
- C-114 – chrysene (2 ug/l);
- C-131 – chrysene (38 ug/l);
- C-133 – chrysene (8 ug/l);
- C-140 – chrysene (2 ug/l); and
- C-142 – chrysene (64 ug/l).

No other site COCs were detected in AOI 7 groundwater at concentrations above their respective PADEP non-residential groundwater MSCs.

Deep (Lower Sand) Monitoring Wells

There were no COCs detected in deep monitoring wells at concentrations above their respective PADEP non-residential groundwater MSCs.

5.4 LNAPL Characterization Results

As a part of the 2004 CCR, 2010 AOI 7 Work Plan, and the 2010 through 2012 site characterization activities, LNAPL samples were collected from 16 monitoring wells (C-65, C-106, and C-107 C-143 C-147, C-148, C-150, C-151, C-152, C-153, C-154, C-161, C-162, C-166, C-167, and C-168). LNAPL samples were submitted to and analyzed by Torkelson. The LNAPL characterization results are presented in Appendix H. The results of the LNAPL characterization analysis were used to separate the apparent LNAPL plumes by LNAPL types and to also assist in the calculations of LNAPL specific volume and mobility, as summarized in Appendix H. The extent of LNAPL in AOI 7, LNAPL types, as well as the apparent LNAPL thickness measured during the January 2012 gauging event, is illustrated in Figure 10. LNAPL thicknesses measured in January 2012 in AOI 7 ranged from a sheen (0.01 feet) to 5.41 feet.

As part of the AOI 7 SCR/RIR, LNAPL modeling was completed for 18 monitoring well locations that had measureable LNAPL during the January 2012 AOI 7 groundwater gauging event. Modeling was used to assess specific volume of LNAPL and estimate potential LNAPL mobility at each monitoring well location. For the LNAPL modeling at the refinery, the American Petroleum Institute (API) Publication Number 4682, "Free-Product Recovery of Petroleum Hydrocarbon Liquids," dated June 1999, was utilized as a guide for assessing LNAPL volume, mobility, and recoverability. An Excel spreadsheet (downloaded from the API website in December 2011) developed by the API entitled "van Genuchten-Mualem Model of LNAPL Distribution and Relative Permeability" (API Model) was used to calculate specific volume and relative permeability. A second Excel spreadsheet was constructed by Langan to calculate LNAPL seepage velocity using output from the API model. Supporting information including documentation of modeling procedures, model input, model output and spreadsheets used for calculations can be found in Appendix H.

Based on the LNAPL characterization performed by Torkelson, the LNAPL types present in AOI 7 consist of four different types or mixtures of LNAPL including residual oil, lube oil, middle distillate, and light crude oil. The four LNAPL types have a high degree of weathering. The physical properties of these LNAPL types (drawn from literature sources), soil types (AOI 7 boring logs) and recent LNAPL thickness measurements (January 2012) were entered into the API Model to estimate LNAPL specific volume and seepage velocity. Calculated LNAPL specific volumes ranged from 4.19 e-5 feet (C-151) to 0.571 feet at C-148. Monitoring well locations C-143, C-161, C-152, C-147, C-106, C-148 and C-167 had calculated specific volumes greater than 0.1 feet. All but one of these wells (C-106) is located near the No. 3 Separator area. The calculated LNAPL relative permeability ranges from 0.047% to 49.5 %. Fifteen of the 18 wells with measureable LNAPL have calculated relative permeability's greater than 1%. Relative permeability is the effective permeability of LNAPL; it is a modification to Darcy's Law that can be applied to a multi-phase systems (groundwater and LNAPL in this case). To calculate seepage velocity LNAPL conductivity at 100% pore saturation is multiplied by the relative permeability. Calculated LNAPL seepage velocities range 1.28e-6 ft/day (C-151) to 0.02 ft/day (WP-14). Thirteen wells have calculated LNAPL seepage velocities greater than 2.83e-4 ft/day and the LNAPL in these wells is considered to be potentially mobile. Twelve of these wells are located near the No. 3 Separator. One well, C-106, is located near the bulkhead about 600 feet southwest of the No. 3 Separator. Based on the LNAPL type in C-106 (extremely weathered lube oil), absence of LNAPL in the surrounding monitoring wells, groundwater flow direction, location of the sheet pile wall, indicates that LNAPL in C-106 is stable and immobile.

As shown in Appendix H, the specific volume calculations indicate significantly less LNAPL is present than is indicated by the apparent LNAPL figure (Figure 10). The input and output parameters of the updated API Model and seepage velocity calculations is presented in Appendix H. Figures depicting the results of the LNAPL modeling are included in Appendix H.

6.0 REMEDIAL SYSTEM UPDATE

There are no active remediation systems currently operating in AOI 7.

On July 12, 2011, Sunoco reported LNAPL sheening on the Schuylkill River to the National Response Center. The sheen was directly adjacent to the Girard Point No. 3 Separator. In response to the sheen observed on the Schuylkill River, Sunoco implemented interim remedial measures which included:

- Sealed a penetration in the sheet pile wall adjacent to the junction box, eliminating groundwater flow to the Schuylkill River;
- Excavated around four sides of the junction box to inspect/verify connections and penetrations;
- Diverted flow from the junction box and associated excavation;
- Sealed the junction box on four sides with concrete;
- Installed 21 groundwater monitoring wells along the sheet pile wall between the No. 3 & 4 Separators and the sheet pile wall;
- Installed a 6 inch diameter recovery well between the No. 3 Separator and the sheet pile wall;
- Installed a continuous oil skimming system in the No. 3 Separator; and
- Maintained spill control equipment (absorbent booms) within the Schuylkill River in the Area of the No. 3 Separator to minimize impact of LNAPL to the river.

Sunoco intends to design a hydraulic control system in the No.3 Separator area to address LNAPL in the shallow/intermediate groundwater. The proposed remedial system will be presented in the AOI 7 Cleanup Plan.

7.0 FATE AND TRANSPORT ANALYSIS

The following sections describe fate and transport modeling activities performed as part of AOI 7 site characterization.

7.1 Soil

No fate and transport modeling was completed for the soil analytical results since the only potential exposure pathway to shallow soil is by direct contact. The soil-to-groundwater pathway is evaluated through evaluation of groundwater data. Potential exposure pathways for AOI 7 are discussed in detail in Section 9.0.

7.2 Groundwater

Fate and transport calculations were completed for groundwater in AOI 7 to evaluate potential migration pathways/potential impacts to receptors.

Ten monitoring wells (C-56, C-57, C-110, C-111, C-112, C-114, C-131, C-133, C-140, and C-142) in AOI 7 exhibited groundwater concentrations of benzene, chrysene, and lead above their respective PA non-residential groundwater MSCs in the July 2010 and January 2012 groundwater sampling events. Based on the data usability assessment, four monitoring well locations (C-49, C-57, C-131 and C-142) had preservation requirements which were not met; therefore, reported results are likely biased low. However, for screening purposes these results were still evaluated in the fate and transport analysis for AOI 7.

To address the potential future migration of these COCs, a fate and transport analysis was performed using the Quick Domenico Version 2 (QD) model and the SWLOAD model used for fate and transport in groundwater and PENTOXSD to assess potential impacts of groundwater on surface water for organic constituents. Site-specific data was used to complete the fate and transport calculations, when available. A detailed summary of the procedures and calculations of the modeling procedures are presented in Appendix G. The approach and results of the modeling are discussed below.

<u>Screening and Approach to Fate and Transport Analysis</u>

Eight monitoring wells (C-56, C-57, C-110, C-111, C-112, C-114, C-131, and C-133) in AOI 7 had detections above PADEP non-residential groundwater MSCs which were located along or near the AOI 7 boundary. From a fate and transport perspective, it is important to recognize that there are numerous monitoring wells with no detections above the PADEP non-residential groundwater MSCs for site COCs between these well locations and the Schuylkill River as described in more detail below. The COCs that were detected above the PADEP non-residential groundwater MSCs included lead (C-56), benzene (C-111), and chrysene (C-57, C-110, C-111, C-112, C-114, C-131, and C-133).

- A QD model was constructed for lead at C-56 despite the limitation of the QD model with respect to inorganic constituents; this was done as a screening for lead to evaluate attenuation by dispersion only. There were no detections of lead above the PADEP non-residential groundwater MSC downgradient of C-56 detected during the July 2010 and January 2012 sampling.

- Monitoring well C-57 had a reported chrysene concentration of 3 ug/l but is surrounded by monitoring wells that had no data usability concerns without detections of chrysene above the PADEP non-residential groundwater MSCs, therefore, a QD analysis was not performed at this location.

- C-113 had no detections of any COCs above the PADEP non-residential groundwater MSCs, has useable data and is located between C-112, where chrysene was detected at 3 ug/l at the property boundary. Because C-113 had no chrysene detections above the PADEP non-residential groundwater MSCs, a QD assessment was not performed for C-112.

- QD simulations were performed for C-110, C-111, C-131, C-114, and C-133 to evaluate potential impacts beyond the AOI 7, AOI 3, and AOI 6 boundaries

- Two monitoring wells (C-140 and C-142) had detections of chrysene above the PADEP non-residential groundwater MSC and are located near the Schuylkill River. Chrysene concentrations above the PADEP non-residential groundwater MSC of 1.9 ug/l were detected at C-140 (2 ug/l) and C-142 (64 ug/l). C-140 is located approximately 55 feet from the sheet pile wall on the west side of AOI 7. C-142 is located approximately 150 feet from the sheet pile wall on the north side of AOI 7. Chrysene concentrations at both of these monitoring well locations do not exceed the PA Code Chapter 93.8c surface water quality criteria (SWQC) for acute fish exposure of 300 ug/l (a chronic criteria has not been derived). Chrysene concentrations at both monitoring well locations were detected above the target human health (THH) cancer risk level for chrysene of 0.0038 ug/l. To address the THH exceedence in surface water a QD and SWLOAD model was constructed for these wells.

- Groundwater results from monitoring well C-49 had preservation issues and no reported detections of any COCs were above the PADEP non-residential groundwater MSCs. To address potential transport at C-49 for chrysene, which is the principle COC along the eastern AOI 7 boundary, the maximum reported chrysene impact in AOI 7 of 64 ug/l (C-142) was assumed for C-49, this well will also be resampled and the fate and transport will be re-run based on the sample results.

- QD and SWLOAD simulations were created for monitoring wells located in between the No. 3 Separator and sheet pile wall. Monitoring wells in this area were not sampled due to the presence of LNAPL. A chrysene concentration equal to 1.9 ug/l which is the aqueous saturation, was used

Modeling results can be found in Appendix G (Table G.1). Individual QD models can be found in Appendix G (Tables G.2 through G.8).

<u>QD Modeling Results</u>

- Lead detected at C-56 (15.8 ug/l) is predicted to attenuate below its groundwater PADEP non-residential groundwater MSC of 5 ug/l in 345 feet. The distance from C-56 to the AOI 6 property boundary is 395 feet which indicates that dissolved concentrations of lead in groundwater are not predicted to reach the AOI 7 and/or AOI 6 property boundary. If dissolved concentrations of lead in groundwater at C-56 were to flow west towards the Schuylkill River (approximately 1,600 feet away), the lead concentration is likely to attenuate below its PADEP non-residential groundwater MSC before reaching the Schuylkill River.
- QD modeling results for seven monitoring wells (C-57, C-110, C-111, C-112, C-114, C-131, and C-133) located along the AOI 7 property boundary indicated that chrysene modeled typically less than one foot but can be as much as three feet (C-133). Based on these results, chrysene at these seven monitoring well locations does not have the potential to migrate beyond the AOI 7 boundary.
- Adjacent to the Schuylkill River, chrysene at C-140 (2 ug/l) is predicted to travel less than one foot to attenuate below its PADEP non-residential groundwater MSC of 1.9 ug/l (Table G.1). The SWLOAD simulation for chrysene at C-140 indicates a chrysene concentration of <0.001 ug/l at the Schuylkill River (approximately 55 feet away). Chrysene at C-140 is not predicted to reach the Schuylkill River at a concentration above its PADEP non-residential groundwater MSC.
- Adjacent to the Schuylkill River, chrysene at C-142 (reported as 64 ug/l) is predicted to travel five feet before it attenuates below its PADEP non-residential

groundwater MSC of 1.9 ug/l (Table G.1). The SWLOAD simulation for chrysene at C-142 indicates a chrysene concentration of <0.001 ug/l at the Schuylkill River (approximately 55 feet away). Chrysene at C-142 is not predicted to reach the Schuylkill River at a concentration above its PADEP non-residential groundwater MSC.

- Benzene detected at C-111 (89 ug/l) is located 33 feet from the AOI 7 and AOI 3 property boundary and is predicted to require 253 feet to attenuate below its PADEP non-residential groundwater MSC of 5 ug/l. Based on these results, benzene at C-111 has the potential to migrate from AOI 7 into AOI 3, however would not reach the AOI 3 eastern property boundary (refinery boundary).
- Chrysene at C-49 (assigned a proxy starting concentration of 64 ug/l as discussed earlier) is predicted to travel thirteen feet and therefore does not reach the AOI 7 boundary.

7.3 Surface Water

Given the QD simulations, groundwater flow direction in AOI 7 and the presence of the sheet pile wall located along the northern and western boundaries of AOI 7, groundwater concentrations above the PADEP non-residential groundwater MSC are not expected to reach the Schuylkill River. Based on QD simulations, the concentrations in groundwater which were detected above their respective PADEP non-residential groundwater MSCs will not reach the Schuylkill River or the refinery boundaries. Sunoco maintains spill control equipment (absorbent booms) within the Schuylkill River in the Area of the No. 3 Separator to minimize impact of LNAPL to the river.

7.4 LNAPL

As described in Appendix H, Sunoco evaluated LNAPL mobility across the site using the API LNAPL model, as a guide for assessing LNAPL volume, mobility, and recoverability across the refinery. Based on the LNAPL modeling, twelve monitoring wells in the vicinity of the No. 3 Separator have calculated LNAPL seepage velocities greater than 2.83e-4 ft/day and the LNAPL in these wells is considered to be potentially mobile. Sunoco intends to design a hydraulic control system in the No.3 Separator area to address

LNAPL in the shallow/intermediate groundwater. The proposed remedial system will be presented in the AOI 7 Cleanup Plan.

7.5 Vapor Intrusion to Indoor Air

There are 15 occupied buildings (potential indoor air receptors) located in AOI 7. These buildings are shown on Figure 10 and are operated by Sunoco and regulated by OSHA.

LNAPL in AOI 7 is located more than 100 feet away from the occupied buildings and there are no known preferential flow pathways connecting the LNAPL areas to the buildings.

For the current occupied buildings as depicted on Figure 10, groundwater is less than 5 feet below the ground surface; therefore, the PA DEP USEPA-PA Default Non-Residential PEL for Volatilization to Indoor Air for soil and groundwater screening criteria could not be used. Since the site specific standard is being applied, groundwater within some portions of AOI 7 is shallower than 5 feet, underground utilities exist and sampling was not completed below all areas with impervious covers, Sunoco will place a restriction in the UECA covenant for AOI 7 that will require further vapor site characterization activities and/or installation of a vapor mitigation systems for any new/existing occupied buildings within AOI 7.

8.0 SITE CONCEPTUAL MODEL

A preliminary site conceptual model (SCM) for the refinery, including AOI 7, was presented in the CCR. Data collected from the 2010 to 2012 site characterization activities performed in AOI 7 were used to refine the SCM for this area. The revised SCM for AOI 7 is described the following sections.

8.1 Description and Site Use

AOI 7 is located on the east side of the Schuylkill River within the main portion of the refinery. AOI 7 is commonly known as the Girard Point Fuels Processing Area, and is located north of Pennypacker Avenue, east of Lanier Avenue, and south and west of the Schuylkill River. AOI 7 encompasses approximately 130 acres, and approximately 40 percent of AOI 7 is covered by impervious surfaces. The entire western boundary of AOI 7 is bound by a sheet pile wall. There are of five RCRA SWMUs located in AOI 7 that were addressed in various stages of previous RCRA investigations as part of the EPA Corrective Action Process. The current, historic uses/investigations and approximate limits of impervious surfaces are depicted on Figure 11 and the current/historic use figure in Appendix B.

AOI 7 formerly contained a FCC unit, CO boiler, sulfur plant, East and West Sludge Basin - RCRA Tank, Hazardous Waste Incinerator, and crude units. Early refining units in AOI 7 were built in the 1940s. AOI 7 currently consists of crude units, cracking and alkylation units, flares, and ASTs. The ASTs contain primarily naphtha crude, waste oil, and cat charge stocks. Eight LPG tanks are located in the south-central portion of this area. The WWTP is located along the western portion of AOI 7 adjacent to the Schuylkill River.

AOI 7 is located within a fenced and secured area to prevent unauthorized access. Prior to any work being completed within AOI 7, appropriate work permits, safety and security measures must be approved by Sunoco Refinery personnel. AOI 7 is under the control of Sunoco's health and safety administrative procedures and is regulated by OSHA. Direct contact to site soils (soils greater than two feet beneath the ground surface) is controlled by Sunoco's on-site permit and personal protective equipment (PPE) procedures. The current and future intended use of AOI 7 is to remain non-residential.

8.2 Geology and Hydrogeology

The following summarizes relevant information concerning geology and hydrogeology in AOI 7.

- The depth to bedrock beneath AOI 7 is at approximately 66 to 78 ft bgs.
- The Lower Sand overlies bedrock throughout AOI 7 and is generally shallower in the eastern and northern portions of AOI 7.
- The Middle/Lower Clay appears to be interfingered with the Lower Sand in the eastern portion of AOI 7.

- Trenton Gravel is undifferentiated from the fill/alluvium throughout AOI 7, with the exception of areas in the northwestern and northeastern portions of AOI 7.
- The fill/alluvium materials are present throughout AOI 7, and range in thickness between 10 to 20 feet.
- Shallow/intermediate groundwater elevations occur at depths ranging between approximately 0.8 and 9.0 ft amsl.
- Generally, groundwater flow in the shallow/intermediate zone in AOI 7 is towards the west-northwest and ground flow in the shallow/intermediate zone in the northern portion of AOI 7 is to the north.
- The shallow/intermediate groundwater flow in the southern portion of AOI 7 is towards the east-southeast.
- A long the western boundary of AOI 7, flow in the shallow/intermediate zone is generally towards the east-southeast, away from the sheet pile wall.
- The groundwater gradient in the central portion of AOI 7 is relatively flat.
- Groundwater flow in the deep zone is generally towards the north-west, in the direction of Schuylkill River.
- Water levels in the deep zone occur at depths between approximately -2.84 (in northwestern portion of AOI 7) and 0.51 ft amsl (in the eastern portion of AOI 7).
- The deep groundwater gradient in the central portion of AOI 7 is relatively flat, with similar gradients observed throughout the site.
- Groundwater elevations in the deep zone are lower than the shallow/intermediate zone, exhibiting a downward vertical hydraulic gradient.

8.3 Compounds of Concern

The following summarizes relevant information concerning COCs in AOI 7.

- COCs which were detected in shallow soil at concentrations above their respective PADEP non-residential soil MSCs, included: benzene (four locations), lead (11 locations), 1,2,4-TMB (one location), 1,3,5-TMB (one location); and naphthalene (one location).
- 1,2-dichloroethane, cumene, ethylbenzene, ethylene dibromide, MTBE, toluene, xylenes, anthracene, benzo(a)anthracene, benzo(g,h,i)perylene, benzo(a)pyrene,

benzo(b)fluoranthene, chrysene, fluorene, phenanthrene and pyrene were not detected in AOI 7 shallow soil samples at concentrations above their respective PADEP non-residential soil MSCs.

- COCs detected in groundwater in the shallow/intermediate zone at concentrations above their respective PADEP non-residential groundwater MSCs included benzene (one location), chrysene (nine locations), and lead (one location).
- Pyrene, phenanthrene, naphthalene, cumene, toluene, ethylbenzene, ethylene dibromide, xylenes (total), fluorene, MTBE, and 1,2-dichoroethane were not detected in shallow/intermediate groundwater zone at concentrations above their respective PADEP non-residential groundwater MSCs.
- No deep (Lower Sand) monitoring wells had detected concentrations above their respective PADEP non-residential groundwater MSCs.

The exposure assessment completed for the COCs above the PADEP non-residential MSCs is discussed in Section 9.0 of this report.

8.4 LNAPL Distribution and LNAPL Mobility

The following summarizes relevant information concerning LNAPL distribution in AOI 7:

- Four different types or mixtures of LNAPL were identified in AOI 7 which included extremely weathered residual oil, lube oil, middle distillate, and light crude oil.
- LNAPL in AOI 7 is contained within the boundary of the refinery and does not appear to have to the potential to migrate off-site.

8.5 Fate and Transport of COCs

Fate and transport modeling was completed for shallow/intermediate monitoring wells that exhibited concentrations of dissolved phase COCs above the PADEP non-residential groundwater MSCs. Results of the July 2010 and January 2012 groundwater sampling indicated that three COCs (lead, benzene, and chrysene) were detected above their respective PADEP non-residential groundwater MSCs.

Input and result summary spreadsheets for each monitoring well modeled are included in Appendix G. A comparison between the model-predicted downgradient transport distance and the distance to the nearest property boundary is also included in Appendix G.

The QD modeling results indicated the following:

- QD modeling results for seven monitoring wells (C-57, C-110, C-111, C-112, C-114, C-131, and C-133) located along or near the AOI 7 boundary indicated that chrysene does not have the potential to migrate beyond the refinery boundary.
- Lead detected at C-56 (15.8 ug/l) is not predicted to reach the refinery boundary. If dissolved concentrations of lead in groundwater at C-56 were to flow west towards the Schuylkill River (approximately 1,600 feet away), lead is likely to attenuate below its PADEP non-residential groundwater MSC before reaching the Schuylkill River.
- Benzene concentrations at C-111 (89 ug/l) do not have the potential to migrate beyond the refinery boundary.
- Adjacent to the Schuylkill River, chrysene at C-140 (2 ug/l) and C-142 (64 ug/l) are not predicted to reach the Schuylkill River at a concentrations above the PADEP non-residential groundwater MSC, therefore, a PENTOXSD analysis was not required.
- The sheet pile wall located between AOI 7 and the Schuylkill River is keyed into the Lower/Middle Clay and acts as a boundary between shallow groundwater in AOI 7 and the Schuylkill River.

8.6 Potential Migration Pathways and Site Receptors

The following summarizes potential migration pathways and site receptors for AOI 7.

- AOI 7 is situated within a fenced, secured area to prevent unauthorized access.
- The potential direct contact pathway to soil greater than two feet is deemed incomplete based on Sunoco’s existing permitting procedures which protect against exposure to soil encountered in excavations. This pathway may be further evaluated based on future site redevelopment.

- The potential direct contact pathway to groundwater is deemed incomplete based on Sunoco's existing permitting procedures which prevent exposure to groundwater that may be encountered in excavations.
- The need for further vapor site characterization activities and/or the installation of vapor mitigation systems for future occupied buildings will be evaluated on a case by case basis.
- The area that has a surface soil detection of lead above the site specific criteria developed (as discussed in section 9.2 below) will be remediated by Sunoco to eliminate the potential exposure pathway and the proposed remediation will be presented in the AOI 7 Cleanup Plan.

9.0 HUMAN HEALTH EXPOSURE ASSESSMENT/RISK ASSESSMENT

Based on the current and future intended non-residential site use for AOI 7, an exposure assessment was conducted for compounds that were above the non-residential statewide health standards in AOI 7. Potential human health exposures for the refinery are for an industrial worker scenario. The media evaluated included groundwater, shallow soil, and subsurface soil (greater than two feet below grade).

The potential direct contact pathway for soil (greater than two feet), groundwater and LNAPL under the industrial scenario is eliminated through Sunoco's established excavation procedures, PPE requirements and soil handling procedures described in the CCR. However, because direct contact to shallow soils could occur outside of excavation activities, shallow soil samples were collected in non-paved areas of AOI 7 to assess this potential exposure pathway.

The following table serves as a summary of potential human health exposure pathways that can be reasonably expected under the current and intended future non-residential use for AOI 7. The table lists potentially contaminated media, potential receptors for these media, and a summary of whether any potentially complete exposure pathways exist at AOI 7 from the media to these receptors.

<u>Exposure Pathway Evaluation Summary</u>

Contaminated Media	Residents	Workers	Day Care	Construction	Trespassers	Recreation	Food
Groundwater	NA	No(1)	NA	No (2)	No	NA	NA
Air (indoor)	NA	No (3)	NA	No(3)	No	NA	NA
Soil <2 feet bgs.	NA	Yes	NA	Yes	No	NA	NA
Soil >2 feet bgs.	NA	No(4)	NA	No(4)	No	NA	NA
Surface Water	NA	No(5)	NA	No(5)	Na	NA	NA
Sediment	NA	NA	NA	NA	Na	NA	NA
LNAPL	NA	No(1)	NA	No (2)	Na	NA	NA

Notes:

(1) No complete groundwater or LNAPL pathways exist for workers that are not addressed through on-site permitting procedures and PPE.
(2) No complete groundwater or LNAPL pathway exists for construction workers that are not addressed through on-site permitting procedures and PPE.
(3) No current complete pathway to indoor air exists based on the evaluation described in Section 9.0.
(4) No complete pathway exists for site soil >2 feet deep that are not addressed through on-site permitting procedures and PPE.
(5) No complete pathway exists for surface water or sediment that is not addressed through on-site permitting procedures and PPE.

Na - Not applicable
No - No potential complete exposure pathway
Yes – Potential complete exposure pathway

A more detailed evaluation of each of these potential human health exposure pathways is presented in the following sections by media.

9.1 Surface Water

There is no surface water features located within AOI 7. The nearest surface water body to AOI 7 is the Schuylkill River which borders the western site boundary (Figure 2). A sheet pile wall is located along the western boundary of the site. Shallow/intermediate groundwater interaction with surface water is limited by the above referenced sheet pile wall.

Based on the location of the sheet pile wall, groundwater flow, and the results of the groundwater modeling for monitoring wells where groundwater COCs were detected above the PADEP non-residential groundwater MSCs, none of the constituents detected in groundwater will cause an in-stream violation of surface water quality criteria for the Schuylkill River. As part of the AOI 7 Cleanup Plan, Sunoco will implement a hydraulic control system to control LNAPL along the northwestern boundary of AOI 7 in the vicinity of the No. 3 Separator.

9.2 Shallow Soils (0-2 Feet Below Grade)

The soil-to-groundwater pathway is being addressed through the groundwater pathway discussed in Section 9.3.

Direct Contact Exposure

Shallow soil samples collected and analyzed as part of the AOI 7 site characterization activities exhibited concentrations of benzene, 1,2,4-TMB, 1,3,5-TMB, naphthalene, and lead above their respective PADEP non-residential direct contact soil MSCs. In accordance with Section IV of the PADEP's Technical Guidance Manual (TGM) (dated June 8, 2002), the COCs listed above were further screened against the EPA Region III Risk-Based Concentrations RBCs (aka, EPA Regional Screening Levels) for industrial soil to potentially reduce the list of compounds carried through the risk assessment. Concentrations of 1,3,5-TMB were below the EPA Region III RBC for industrial soil (10,000 mg/kg) and therefore site-specific criterion for 1,3,5-TMB was not developed. Concentrations of benzene, naphthalene, 1,2,4-TMB and lead were above the EPA Region III RBCs and therefore site-specific criteria were developed, as further described below.

For compounds that were detected above both the non-residential statewide health standards and EPA Region III RBCs, site-specific standards were calculated using PADEP default intake parameters for an on-site worker and, where appropriate, a risk level of 10^{-4}. The site-specific screening level for benzene was calculated based on inhalation using the PADEP calculation provided as provided in Appendix I. The site specific screening level for 1,2,4-TMB was calculated based on inhalation using the calculation specified in 25 Pa. Code § 250.307(a)(1) and the criteria for naphthalene was calculated based on ingestion using the calculation specified in 25 Pa. Code § 250.306(a). These calculations used the PADEP's default parameters, and an updated target risk level of 1E-4, in consideration of the site-specific conditions (PADEP's default target risk level is 1E-5).

For calculating a site-specific standard for on-site workers exposed to lead, Sunoco used the Society of Environmental Geochemistry and Health (SEGH) model used by PADEP to develop the non-residential MSC. A discussion of the variables used to calculate the lead criteria is provided in the section to follow.

The site-specific standards for these compounds (calculated in Appendix I in Tables I-1 through I-4) are as follows:

Compound	Calculated Site-Specific Standard (mg/kg)
Benzene	2,870
Naphthalene	56,780
1,2,4-TMB	560
Lead	1,708

Concentrations of benzene, naphthalene, and 1,2,4-TMB detected in the surface soil samples collected in AOI 7 are below these site-specific standards and, therefore, risk to an on-site worker due to exposure is considered to be within the acceptable Act 2 range.

The site-specific screening level for lead was calculated based on ingestion as presented in 25 Pa. Code § 250.306(e), Appendix A, Table 7. As described in 25 Pa. Code § 250.306(e), the non-residential soil screening value for lead is based on the method presented in the report 'The Society for Environmental Geochemistry and Health (SEGH) Task Force Approach to the Assessment of Lead in Soil' (Wixson, 1991). The model used by the PADEP and developed by SEGH was also used to calculate the site specific criterion for the refinery. Based on the SEGH model and PADEP's default parameters, PADEP's non-residential direct contact MSC default value for lead in surface soil is 1,000 mg/kg. To develop a site-specific criteria for lead, the values used by PADEP for the target blood lead concentration (T) and geometric mean background blood lead concentration (B) were revised in consideration of site-specific conditions and updated lead data collected by the US Center for Disease Control and Prevention (CDC). Revised values for these parameters are discussed in the following paragraphs.

As presented in Appendix I, based on the revised parameters, the derived site-specific standard for lead in soil is 1,708 mg/kg for a refinery worker. One location, BH-10-26, has a concentration of lead above this site specific lead criteria.

In addition to calculating the site-specific standards for benzene, naphthalene, 1,2,4-TMB, and lead, the cumulative risk of exposure was also calculated. Lead exposure is dependent on the blood/lead concentration and is not risk based; therefore, lead could not be incorporated into the cumulative risk calculation.

The cumulative hazard index is the combined index for exposure to non-carcinogenic compounds (naphthalene and 1,2,4-Trimethylbenzene), and should not exceed 1. For AOI 7, the cumulative hazard index for exposure to the non-carcinogenic compounds is 0.55 and is less than the PADEP's requirement of 1.0.

The total cumulative risk is the combined risk of exposure to the concentrations of carcinogenic compounds, which for AOI 7 is benzene. In accordance with the TGM, the total cumulative risk should not exceed 10^{-4}. As presented in Appendix I, the total cumulative risk of exposure to the carcinogenic compounds in AOI 7 is 3.18E-05, and therefore, no remedies are required for AOI 7 to address direct contact to benzene.

Only one location (BH-10-26) had a lead concentration above the site-specific standard, while all other samples were detected below the site-specific screening levels. Sunoco will delineate the soil concentrations above their PADEP non-residential soil MSCs to ensure that soil is below the calculated site-specific standard. The BH-10-26 soil location with a lead detection above the site-specific screening level will be addressed by Sunoco through implementation of a remedy which will either remediate or eliminate the potential pathway to onsite workers to this area.

9.3 Groundwater

Results of the groundwater sampling indicated COCs at concentrations above their respective PADEP non-residential groundwater MSCs, included benzene, chrysene, and lead. Based on the QD fate and transport analysis, there are no dissolved phase COCs in groundwater that appear to have the potential to extend beyond the refinery boundary. Based on the groundwater evaluation, there appears to be no unacceptable risk to ecological receptors in the Schuylkill River.

Excavations in AOI 7 are governed by Sunoco's permitting procedures which protect against potential exposures to groundwater that could be encountered in an excavation. Also, there are no complete direct contact exposure pathways for groundwater within

AOI 7 because of on-site refinery safety procedures and required PPE. Previous investigations and recent (2011) well searches verified that no monitoring wells located within 1.0 miles of the refinery are used for drinking water or agricultural use.

9.4 LNAPL

There are no complete direct contact exposure pathways for LNAPL within AOI 7 because of on-site procedures and required PPE.

9.5 Vapor

Further evaluation (i.e. soil gas samples) will be completed to assess the impact to indoor air or vapor mitigation systems will be installed in any occupied buildings constructed/used at the refinery dependent upon site redevelopment.

10.0 ECOLOGICAL ASSESSMENT

The majority of AOI 7 is covered with impervious surfaces as shown in Figure 11. Some areas are covered by soil and gravel; however, they are not likely to serve as a breeding area, migratory stopover, or primary habitat for wildlife. In January 2012, a survey of endangered, threatened and special concern wildlife was conducted by submitting a request to the Pennsylvania Natural Diversity Inventory (PNDI) data base. The PNDI search identified potential threatened and endangered species impacts that require further review. The first potential impact was for an endangered species identified by the PA Game Commission as the Great Egret. Historically, for the refinery the PA Game Commission has issued no effect letters for this species. A second potential conflict of an unidentified threatened species was listed by the PA Fish and Boat Commission, however a no effect letter was received from the PA Fish and Boat Commission on February 15, 2012. Historically, this unidentified threatened species has been identified as the Red Bellied Turtle.

No surface water features are located in AOI 7. The nearest surface water body to AOI 7 is the Schuylkill River which comprises the western and northern boundaries of AOI 7. A sheet pile wall which is keyed into the Middle Clay exists between AOI 7 and the Schuylkill River. Groundwater interaction with surface water is limited by the above referenced sheet pile wall. Based on QD simulations, the concentrations in groundwater which were detected above their respective PADEP non-residential groundwater MSCs will not reach the Schuylkill River or the refinery boundaries.

11.0 COMMUNITY RELATION ACTIVITIES

A Community Relation Plan (CRP) that includes public involvement with local residents to inform them of the anticipated investigations and remediation activities was completed as part of the NIR submittal in 2006. The purpose of this CRP is to provide a mechanism for the community, government officials, and other interested or affected citizens to be informed of on-site activities related to the investigation activities at the Site. This plan incorporates aspects of public involvement under both PADEP's Act 2 program and EPA's RCRA Corrective Action program. This report and future Act 2 reports will include the appropriate municipal and public notices in accordance with the provisions of Act 2. Notices will be published in the Pennsylvania Bulletin and a summary of the notice will appear in a local newspaper. As part of the CRP, Sunoco intends to hold an initial public meeting in the city of Philadelphia to present the strategy and give status updates of the project at the CAP meeting on an annual basis.

A copy of the NIR and the Act 2 report notifications for this SCR/RIR are included in Appendix A.

12.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the completed activities, the following conclusions and recommendations have been developed for AOI 7:

<u>SOIL</u>

- Concentrations of benzene, naphthalene, 1,2,4-TMB, and lead detected in surface soil samples collected in AOI 7 were above their respective PADEP non-residential soil MSCs; however all but one location (BH-10-26 for lead) were below the calculated site-specific standards. Therefore, risk to on-site workers due to exposure through direct contact to soil is within the acceptable tolerance range of Act 2. Sunoco will delineate the soil concentrations above their PADEP non-residential soil MSCs in these areas to ensure that soil is below the calculated site-specific standard.

- Potential exposure within the area of BH-10-26, which is above the lead site specific standard of 1,708 mg/kg will be addressed by Sunoco through implementation of a remedy which will either remediate or eliminate the potential pathway to onsite workers to this area. Sunoco will present the remedial activities for this area in the AOI 7 Cleanup Plan.
- With regard to the potential direct-contact pathway to deeper soil (i.e., greater than 2 feet deep) and the soil-to-groundwater pathway, the direct contact pathway to soil greater than 2 feet beneath the ground surface at the refinery is incomplete because of on-site procedures and PPE requirements that protect onsite workers from exposure. This pathway may be further evaluated under redevelopment scenarios. The soil-to-groundwater pathway was evaluated using shallow/intermediate groundwater data as is discussed below.

<u>RCRA SWMUs</u>

- No leaded tank bottom materials were observed in SWMUs 87, 88, 89, 90, and 91. Therefore Sunoco is requesting a comfort letter from EPA for these SWMUs.

<u>GROUNDWATER</u>

- Results of the July 2010 and January 2012 groundwater sampling indicates that one metal (lead) and two organic compounds (benzene and chrysene) were detected above their respective PADEP non-residential groundwater MSCs. QD simulation results indicate that concentrations above the PADEP non-residential groundwater MSCs are not predicted to reach the Schuylkill River or the refinery boundary at concentrations above their respective PADEP non-residential groundwater MSCs.
- Preservation requirements were not met for groundwater samples C-49_071310, C-57_071410, C-131_071510 and C-142_072010 and VOC results are likely biased low. Sunoco will resample these four monitoring well locations as part of their annual groundwater sampling event.

<u>VAPOR</u>

- As part of the Cleanup Plan for the current occupied buildings, further evaluation (i.e. soil gas samples) will be necessary to further assess the impact to indoor air.

- The need for further vapor related site characterization activities and/or the installation of vapor mitigation systems for future/existing occupied buildings will be performed as part of redevelopment activities, as necessary.

<u>LNAPL</u>

- An LNAPL plume consisting of light crude oil and determined by the API Model to be potentially mobile is located in the No. 3 Separator area. Sunoco will design and implement a hydraulic control system to recover LNAPL in the vicinity of the No. 3 Separator. Details pertaining to the design and implementation of this system will be documented in the AOI 7 Cleanup Plan.

13.0 SCHEDULE

The proposed schedule for future Site activities is:

- Submittal of a Cleanup Plan following PADEP approval of the SCR/RIR;
- Submittal of a Final Report; and
- Continue quarterly monitoring activities and reports.

14.0 SIGNATURES

The following parties are participating in the remediation at this time and are seeking relief from liability under Act 2 of 1995:

James Oppenheim
Sunoco Inc. (R&M)

This Act 2 RIR has been prepared in accordance with the final provisions of Act 2 and the June 8, 2002 Land Recycling Program Technical Guidance Manual.

15.0 REFERENCES

Groundwater Resources of the Coastal Plain Area of Southeastern Pennsylvania. Greenman, Topographic and Geologic Survey, Bulletin W-13, 375 pp., David W., Rima, Donald R., Lockwood, William N. and Meisler, Harold. 1961.

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

Draft Report – Volume II (Appendices) Site Assessment Investigation, Chevron-Gulf Refinery, Philadelphia, PA, Dames and Moore, February 13, 1987.

Final Report – Permeability Tests, Chevron-Gulf Refinery, Philadelphia, PA, Dames and Moore, September 4, 1987.

Phase II RCRA Facility Assessment, Chevron USA Inc (Gulf) Facility, Philadelphia, PA, A.T. Kearney, Inc., January 1989.

EPA Submittal – RCRA Facility Investigation Work Plan, Chevron Refinery, Philadelphia PA, Dames and Moore, April 16, 1990.

Remedial Action Plan Implementation, Chevron Refinery, Philadelphia, PA, Dames & Moore, September 30, 1993.

RCRA Facility Investigation, Chevron Refinery, Philadelphia, PA, Dames & Moore, November 24, 1993.

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

Phase II Work Plan – RCRA Facility Investigation, Sun Company, Inc (R&M), Philadelphia, PA, Dames and Moore, April 23, 1998.

Certification of Closure for Girard Point Processing Area Incinerator, Sunoco Philadelphia Refinery, Philadelphia, PA, Sunoco Company, Inc., March 4, 1999.

Site Assessment Report: Former Tanks M004/M005, 355 and 174, Sunoco, Inc (R&M) Philadelphia Refinery, Philadelphia, PA, Handex, March 2, 1999.

Closure of Sludge Storage Basins, Sunoco Philadelphia Refinery, Philadelphia, PA, Philip Services (PSC), November 1, 1999.

Above Ground Storage Tank No. 271 Closure Report, Sunoco Philadelphia Refinery, Philadelphia, PA, Secor, July 10, 2002.

URS Corporation, 2002, Act 2 Combined Report, Philadelphia Energy Center, Sunoco Philadelphia Refinery, Girard Point Processing Area.

Site Characterization Report, AST 271 Area, Girard Point Processing Area, Philadelphia Refinery, Philadelphia, PA, Secor, December 20, 2002.

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

Tank GP 270 Release – Site Characterization Letter Report, Sunoco Inc., Philadelphia Refinery, Philadelphia, PA, Stantec Consulting Corp., November 23, 2009.

TABLES

Table 1
Constituents of Concern for Groundwater
AOI 7 Site Characterization/Remedial Investigation Report
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
AOI 7 Site Characterization/Remedial Investigation Report
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 2
AOI-7 Existing Well Summary
Last Updated February 10, 2012
Sunoco Philadelphia Refinery

AOI #	Well ID	Former Well ID[3]	Well Status/ Description	Disposition of Well	Northing	Easting	Well Type	Well Classification (Shallow, Intermediate, Deep)[4]	Soil Boring Log Available (Y/N)	Construction Detail Available (Y/N)	Date of Well Completion	Well Construction Details[2]							
												Well Completion Depth (ft. bgs)	Well Diameter (in)	Top of Inner Casing Elevation (ft. msl) (NAVD88)	Ground Surface Elevation (ft.) (NAVD88)	Top of Screen Elevation (ft) (NAVD88)	Bottom of Screen Elevation (ft) (NAVD88)	Depth to Screen (ft. bgs)	Screen Length (ft.)
7	C-49	--			218494.960	2683022.450	Monitoring Well	Shallow	Y	Y	2/22/86	18	4	9.58	8.34	0.34	-9.66	8	10
7	C-50	--			219618.590	2682341.310	Monitoring Well	Shallow	Y	Y	2/22/86	15.5	4	12.77	9.33	3.83	-6.17	5.5	10
7	C-50D	--			219609.420	2682342.490	Monitoring Well	Deep	Y	Y	11/4/86	26	4	11.49	9.11	-6.89	-16.89	16	10
7	C-51	--			220073.270	2681621.380	Monitoring Well	Shallow	Y	Y	2/25/86	13	4	9.26	--	--	--	3	10
7	C-52	--			220206.460	2681216.480	Monitoring Well	Shallow	Y	Y	2/25/86	13	4	7.63	6.68	3.68	-6.32	3	10
7	C-53A	--			219939.830	2681030.760	Monitoring Well	Shallow	Y	Y	12/19/91	14	4	9.47	7.12	--	--	2	12
7	C-54	--			219458.970	2680975.300	Monitoring Well	Shallow	Y	Y	12/19/91	15	4	6.61	5.99	3.49	-8.51	2.5	12
7	C-55	--			218851.050	2680863.560	Monitoring Well	Shallow	Y	Y	2/24/86	15	4	9.41	6.49	1.49	-8.51	5	10
7	C-56	--			218775.795	2681367.141	Monitoring Well	Shallow	Y	Y	2/24/86	13	4	10.72	--	--	--	3	10
7	C-57	--			219572.120	2681650.570	Monitoring Well	Shallow	Y	Y	2/24/86	14.5	4	8.50	8.45	3.95	-6.05	4.5	10
7	C-58	--			219017.200	2681692.060	Monitoring Well	Shallow	Y	Y	2/29/86	13	4	7.42	7.39	4.39	-5.61	3	10
7	C-59	--	Unable to Locate		218657.752	2681702.651	Monitoring Well	Shallow	Y	Y	2/29/86	14	4	--	--	--	--	4	10
7	C-60	--			218657.010	2680150.700	Monitoring Well	Shallow	Y	Y	2/24/86	13	4	7.44	6.02	3.02	-6.98	3	10
7	C-61	--			219306.240	2679819.480	Monitoring Well	Shallow	Y	Y	2/25/86	13	4	7.93	7.88	4.88	-5.12	3	10
7	C-62	--			219889.700	2679892.080	Monitoring Well	Shallow	Y	Y	2/25/86	13	4	11.40	8.35	5.35	-4.65	3	10
7	C-63	--			219610.620	2680379.050	Monitoring Well	Shallow	Y	Y	2/24/86	13	4	7.41	4.17	1.17	-8.83	3	10
7	C-64	--			220166.660	2680430.900	Monitoring Well	Shallow	Y	Y	2/24/86	13	4	8.14	6.17	3.17	-6.83	3	10
7	C-65	--			220116.400	2680266.000	Monitoring Well	Shallow	Y	Y	2/25/86	13	4	10.84	7.47	4.47	-5.53	3	10
7	C-65D	--			220116.050	2680259.790	Monitoring Well	Deep	Y	Y	11/11/86	75	4	9.62	7.60	-57.40	-67.40	65	10
7	C-95	--			219112.670	2682673.580	Monitoring Well	Shallow	Y	Y	10/22/96	20	4	12.25	9.93	-10.07	-20.07	20	10
7	C-96	--			219529.380	2681979.800	Monitoring Well	Shallow	Y	Y	10/23/86	17	4	12.88	9.82	2.82	-7.18	7	10
7	C-97	--			220229.810	2680615.970	Monitoring Well	Shallow	Y	Y	10/23/86	15	4	10.52	7.55	2.55	-7.45	5	10
7	C-98	--			219208.250	2680220.180	Monitoring Well	Shallow	Y	Y	10/23/86	16.5	4	10.55	10.84	4.34	-5.66	6.5	10
7	C-104	--			219187.870	2679742.000	Monitoring Well	Shallow	--	--	--	--	--	9.53	6.84	--	--	--	--
7	C-105	--			219497.380	2679690.470	Monitoring Well	Shallow	--	--	--	--	--	9.17	6.60	--	--	--	--
7	C-106	--			219755.710	2679710.260	Monitoring Well	Shallow	--	--	--	--	--	11.54	7.90	--	--	--	--
7	C-107	--	Unable to Locate		220183.980	2680066.560	Monitoring Well	Shallow	--	--	--	--	--	10.43	7.78	--	--	--	--
7	C-108	--			219818.810	2680855.790	Monitoring Well	Shallow	--	--	--	--	--	8.27	5.37	--	--	--	--
7	C-109	--			219230.740	2682312.460	Monitoring Well	Shallow	--	--	--	--	--	10.00	7.79	--	--	--	--
7	C-110	--			219405.770	2682469.050	Monitoring Well	Shallow	--	--	--	--	--	12.58	9.20	--	--	--	--
7	C-111	--			219231.590	2682560.890	Monitoring Well	Shallow	--	--	--	--	--	12.17	9.35	--	--	--	--
7	C-112	--			218696.610	2682431.450	Monitoring Well	Shallow	--	--	--	--	--	10.96	8.38	--	--	--	--
7	C-113	--			218797.690	2682817.060	Monitoring Well	Shallow	--	--	--	--	--	11.65	9.16	--	--	--	--
7	C-114	--			218347.540	2683001.160	Monitoring Well	Shallow	--	--	--	--	--	10.96	8.59	--	--	--	--
7	C-127	--			220182.150	2680897.060	Monitoring Well	Shallow	Y	Y	8/20/92	16	4	9.80	6.70	1.70	-8.30	5	10
7	C-128	--	Damaged		219916.236	2681231.109	Monitoring Well	Shallow	Y	Y	8/12/92	16	4	13.57	--	--	--	5	10
7	PH-40	--	Destroyed		219766.990	2681683.823	Monitoring Well	--	--	--	--	--	--	--	--	--	--	--	--
7	PH-41	--	Destroyed		219112.637	2681758.395	Monitoring Well	--	--	--	--	--	--	--	--	--	--	--	--
7	WP13-1	--	Destroyed		--	--	Temporary Well Point	--	Y	Y	5/27/93	10.5	--	--	--	--	--	0.5	10
7	WP13-2	--	Destroyed		--	--	Temporary Well Point	--	Y	Y	5/27/93	10.5	--	--	--	--	--	0.5	10
7	WP13-3	--	Destroyed		--	--	Temporary Well Point	--	Y	Y	5/27/93	10.5	--	--	--	--	--	0.5	10
7	WP14-1	--	Destroyed		--	--	Temporary Well Point	--	Y	Y	5/27/93	10.5	--	--	--	--	--	0.5	10
7	WP14-2	--			220196.340	2680218.310	Temporary Well Point	Shallow	Y	Y	5/27/93	10.5	--	8.01	8.13	7.63	-2.37	0.5	10
7	WP14-3	--	Destroyed		--	--	Temporary Well Point	--	Y	Y	5/27/93	10.5	--	--	--	--	--	0.5	10
7	WP14-4	--	Destroyed		--	--	Temporary Well Point	--	Y	Y	5/27/93	10.5	--	--	--	--	--	0.5	10
7	WP14-5	--	Destroyed		--	--	Temporary Well Point	--	Y	Y	5/27/93	10.5	--	--	--	--	--	0.5	10
7	WP15-1	--	Destroyed		--	--	Temporary Well Point	--	Y	Y	5/27/93	10.5	--	--	--	--	--	0.5	10
7	WP15-2	--	Destroyed		--	--	Temporary Well Point	--	Y	Y	5/27/93	10.5	--	--	--	--	--	0.5	10
7	WP15-3	--	Destroyed		--	--	Temporary Well Point	--	Y	Y	5/27/93	10.5	--	--	--	--	--	0.5	10
7	C-53	--	Destroyed		--	--	Monitoring Well	Shallow	Y	Y	2/24/86	15	4	--	--	--	--	5	10
7	PH-35	--	Destroyed		--	--	Monitoring Well	--	--	--	--	--	--	--	--	--	--	--	--
7	PH-38	--	Destroyed		--	--	Monitoring Well	--	--	--	--	--	--	--	--	--	--	--	--
7	River 4	River Gauge GP-2			220253.806	2680258.638	Staff Gauge	--	--	--	--	--	--	--	8.56	--	--	--	--
7	C-129	--			220497.185	2681937.365	Monitoring Well	Shallow/Intermediate	Y	Y	6/2/10	12	4	8.94	7.20	5.20	-4.80	2	10
7	C-129D	--			220492.006	2681929.233	Monitoring Well	Deep	Y	Y	6/25/10	66	4	9.19	6.85	-44.15	-59.15	51	15
7	C-130	--			219981.051	2682139.561	Monitoring Well	Shallow	Y	Y	6/2/10	15	4	11.98	10.29	5.29	-4.71	5	10
7	C-131	--			218971.277	2682328.675	Monitoring Well	Shallow	Y	Y	6/3/10	14	4	10.14	8.28	4.28	-5.72	4	10
7	C-132	--			218271.326	2682247.680	Monitoring Well	Shallow	Y	Y	6/21/10	14	4	9.97	8.09	4.09	-5.91	4	10
7	C-133	--			218336.074	2681693.849	Monitoring Well	Shallow	Y	Y	6/21/10	14	4	7.73	8.18	4.18	-5.82	4	10
6	C-134D	--			218306.504	2681164.764	Monitoring Well	Deep	Y	Y	6/18/10	70	4	9.40	6.86	-48.15	-63.15	55	15
7	C-136	--			219217.045	2680990.761	Monitoring Well	Shallow	Y	Y	5/28/10	14	4	8.85	6.79	2.79	-7.22	4	10
7	C-137	--			219098.264	2680719.078	Monitoring Well	Shallow	Y	Y	5/27/10	14	4	6.51	4.72	0.72	-9.29	4	10
7	C-138	--			218657.809	2680452.928	Monitoring Well	Shallow	Y	Y	5/27/10	12	4	6.95	4.48	2.48	-7.52	2	10
7	C-139	--			219443.936	2680633.143	Monitoring Well	Shallow	Y	Y	6/2/10	12	4	7.32	5.47	3.47	-6.53	2	10
7	C-140	--			218857.817	2679799.125	Monitoring Well	Shallow	Y	Y	5/26/10	12	4	7.55	7.99	5.99	-4.01	2	10
7	C-142	--			220134.108	2680659.962	Monitoring Well	Shallow/Intermediate	Y	Y	6/3/10	14	4	11.35	9.62	5.62	-4.38	4	10
7	C-143	--			220232.931	2680321.403	Monitoring Well	Shallow/Intermediate	Y	Y	6/3/10	14	4	8.70	7.06	3.06	-6.94	4	10
7	C-144D	--			220107.599	2680336.839	Monitoring Well	Deep	Y	Y	7/9/10	78	4	8.96	6.14	-56.86	-71.86	63	15
7	C-145	--			220222.267	2681007.478	Monitoring Well	Shallow	Y	Y	8/9/10	15	4	6.92	7.36	-7.64	-17.64	15	10
7	C-146	--			220254.825	2680639.828	Monitoring Well	Shallow	Y	Y	8/10/10	15	4	6.74	7.20	-7.80	-17.80	15	10

Table 2
AOI-7 Existing Well Summary
Last Updated February 10, 2012
Sunoco Philadelphia Refinery

AOI #	Well ID	Former Well ID[3]	Well Status/ Description	Disposition of Well	Northing	Easting	Well Type	Well Classification (Shallow, Intermediate, Deep)[4]	Soil Boring Log Available (Y/N)	Construction Detail Available (Y/N)	Date of Well Completion	Well Construction Details[2]							
												Well Completion Depth (ft. bgs)	Well Diameter (in)	Top of Inner Casing Elevation (ft. msl) (NAVD88)	Ground Surface Elevation (ft.) (NAVD88)	Top of Screen Elevation (ft) (NAVD88)	Bottom of Screen Elevation (ft) (NAVD88)	Depth to Screen (ft. bgs)	Screen Length (ft.)
7	C-147	--			220262.747	2680516.947	Monitoring Well	Shallow	Y	Y	8/10/10	15	4	6.87	7.31	-7.69	-17.69	15	10
7	C-148	--	Destroyed		220266.672	2680540.203	Monitoring Well	Shallow	Y	Y	5/23/11	18	4	9.34	6.89	3.89	-11.11	3	15
7	C-149	--	Destroyed		220269.615	2680524.161	Monitoring Well	Shallow	Y	Y	5/23/11	11	4	9.33	7.49	3.49	-3.51	4	7
7	C-150	--			220262.743	2680607.068	Monitoring Well	Shallow	N	N	--	25	--	8.19	6.76	--	--	--	--
7	C-151	--			220255.074	2680490.079	Monitoring Well	Shallow	N	N	--	22	--	7.91	7.21	--	--	--	--
7	C-152	--			220265.627	2680476.565	Monitoring Well	Shallow	N	N	--	25	--	9.38	7.36	--	--	--	--
7	C-153	--			220219.944	2680514.198	Monitoring Well	Shallow	N	N	--	21	--	8.27	6.56	--	--	--	--
7	C-154	--			220189.491	2680516.314	Monitoring Well	Shallow	N	N	--	22	--	7.89	6.51	--	--	--	--
7	C-155	--			220082.150	2680524.532	Monitoring Well	Shallow	N	N	--	25	--	9.17	7.29	--	--	--	--
7	C-156	--		Cleared to 10', backfilled with sand	220254.474	2681408.164	Monitoring Well	Shallow	N	Y	8/30/11	23.5	4	9.08	7.09	3.09	-16.91	4	20
7	C-157	--		Cleared to 10', backfilled with sand	220255.107	2681432.423	Monitoring Well	Shallow/Intermediate	Y	Y	8/31/11	24	4	8.63	6.83	2.83	-17.17	4	20
7	C-158	--		Cleared to 10', backfilled with sand	220261.400	2681457.300	Monitoring Well	Shallow/Intermediate	Y	Y	9/1/11	24	4	8.96	6.94	2.94	-17.06	4	20
7	C-159	--		Cleared to 10', backfilled with sand	220269.235	2681506.198	Monitoring Well	Shallow/Intermediate	Y	Y	9/6/11	24	4	9.14	6.90	2.90	-17.10	4	20
7	C-160	--	Damaged	TIC broken/filled in with gravel	--	--	Monitoring Well	Shallow	Y	Y	9/7/11	10	4					0	10
7	C-161	--			220266.206	2680460.174	Monitoring Well	Shallow	Y	Y	9/7/11	10	4	9.07	7.30	7.30	-2.70	0	10
7	C-162	--			220197.288	2680323.697	Monitoring Well	Shallow	N	N	--	10	--	8.50	6.47	--	--	--	--
7	C-163	--			220248.194	2681331.620	Monitoring Well	Shallow	N	N	--	8	--	7.50	7.25	--	--	--	--
7	C-164	--			220252.467	2681359.225	Monitoring Well	Shallow	N	N	--	14	--	9.13	7.18	--	--	--	--
7	C-165	--			220255.493	2681386.442	Monitoring Well	Shallow	N	N	--	14	--	8.46	7.31	--	--	--	--
7	C-166	--			220241.930	2680285.122	Monitoring Well	Shallow	N	N	--	10	--	10.01	7.26	--	--	--	--
7	C-167	--			220238.583	2680255.748	Monitoring Well	Shallow	N	N	--	15	--	10.66	7.99	--	--	--	--
7	C-168	--			220174.341	2679988.805	Monitoring Well	Shallow	N	N	--	12	--	10.08	7.46	--	--	--	--

NOTES:

-- Data could not be located or determined based on available reports

AOI - Area of Interest

ft. - feet

bgs - below ground surface

in. - inches

msl - elevation relative to mean sea level

g/cc - grams per cubic centimeter

NA - Data not available

*Product type percentage data not available

1. For wells that have not been surveyed by Langan, the pre-existing elevations (in NVGD 29) were converted to NAVD 88 (conversion factor is 1.05 ft).
2. Well construction details were taken directly from well boring logs provided by Handex, Secor, Aquaterra or collected from available historic reports. Where no well boring logs exist, no well construction or lithologic data is listed.
3. Former well IDs were derived from handwritten notes on the logs themselves or the referenced report.
4. Well classification based on the formation in which the well was screened in. Wells screened within the Middle Clay or the Farrington Sand were classified as deep wells.
   Well classification for wells screened above the Lower/Middle Clay were based on the following: screened in Fill/Alluvium - Shallow, screened in Trenton Gravel - Intermediate, screened in Fill/Alluvium & Trenton Gravel - Shallow/Intermediate
5. Product characterization data obtained from Sunoco's 2004 CCR and 2005 through 2012 Site Characterization Activities.

Table 3
Summary of AOI 7 Groundwater and LNAPL Elevations
January 2012
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Monitoring Point ID	Northing	Easting	Well Type	Well Classification[1]	Specific Gravity (g/cc) Used for GW Elevation Correction		Depth to Product (ft btic)	Depth to GW (ft btic)[4]	Apparent LNAPL Thickness (ft)	LNAPL Elevation (ft amsl)	GW Elevation (ft amsl)	Corrected GW Elevation (ft amsl)	TIC Elevation (ft amsl)	Static/Pumping
					S.G.[2]	Source[3]								
AOI 7														
C-49	218494.960	2683022.450	Monitoring Well	Shallow			–	5.82			3.76	3.76	9.58	Static
C-50	219618.590	2682341.310	Monitoring Well	Shallow			–	7.43			5.34	5.34	12.77	Static
C-50D	219609.420	2682342.490	Monitoring Well	Deep			–	10.98			0.51	0.51	11.49	Static
C-51	220073.270	2681621.380	Monitoring Well	Shallow			–	3.45			5.81	5.81	9.26	Static
C-52	220206.460	2681216.480	Monitoring Well	Shallow			–	5.4			2.23	2.23	7.63	Static
C-53A	219939.830	2681030.760	Monitoring Well	Shallow			–	4.1			5.37	5.37	9.47	Static
C-54	219458.970	2680975.300	Monitoring Well	Shallow			–	0.7			5.91	5.91	6.61	Static
C-55	218851.050	2680863.560	Monitoring Well	Shallow			–	4.88			4.53	4.53	9.41	Static
C-56	218775.795	2681367.141	Monitoring Well	Shallow			–	1.83			8.89	8.89	10.72	Static
C-57	219572.120	2681650.570	Monitoring Well	Shallow			–	2.37			6.13	6.13	8.50	Static
C-58	219017.200	2681692.060	Monitoring Well	Shallow			–	1.34			6.08	6.08	7.42	Static
C-60	218657.010	2680150.700	Monitoring Well	Shallow			–	3.48			3.96	3.96	7.44	Static
C-61	219306.240	2679819.480	Monitoring Well	Shallow			–	3.06			4.87	4.87	7.93	Static
C-62	219889.700	2679892.080	Monitoring Well	Shallow			–	4.29			7.11	7.11	11.40	Static
C-63	219610.620	2680379.050	Monitoring Well	Shallow			–	6.25			1.16	1.16	7.41	Static
C-64	220166.660	2680430.900	Monitoring Well	Shallow	0.9162	C-65	6.92	8.05	1.13	1.22	0.09	1.13	8.14	Static
C-65	220116.400	2680266.000	Monitoring Well	Shallow	0.9162	C-65	4.22	5.28	1.06	6.62	5.56	6.53	10.84	Static
C-95	219112.670	2682673.580	Monitoring Well	Shallow			–	5.6			6.65	6.65	12.25	Static
C-96	219529.380	2681979.800	Monitoring Well	Shallow			–	5.42			7.46	7.46	12.88	Static
C-97	220229.810	2680615.970	Monitoring Well	Shallow	0.9162	C-65	9.73	9.84	0.11	0.79	0.68	0.78	10.52	Static
C-98	219208.250	2680220.180	Monitoring Well	Shallow			–	5.45			5.10	5.10	10.55	Static
C-104	219187.870	2679742.000	Monitoring Well	Shallow			–	6.9			2.63	2.63	9.53	Static
C-105	219497.380	2679690.470	Monitoring Well	Shallow			–	2.89			6.28	6.28	9.17	Static
C-106	219755.710	2679710.260	Monitoring Well	Shallow	0.9306	C-106	7.69	9.45	1.76	3.85	2.09	3.73	11.54	Static
C-107	220183.980	2680066.560	Monitoring Well	Shallow			NM	NM			NM	NM	10.43	Static
C-108	219818.810	2680855.790	Monitoring Well	Shallow			–	4.72			3.55	3.55	8.27	Static
C-109	219230.740	2682312.460	Monitoring Well	Shallow			–	3.98			6.02	6.02	10.00	Static
C-110	219405.770	2682469.050	Monitoring Well	Shallow			–	5.15			7.43	7.43	12.58	Static
C-111	219231.590	2682560.890	Monitoring Well	Shallow			–	3.84			8.33	8.33	12.17	Static
C-112	218696.610	2682431.450	Monitoring Well	Shallow			NM	NM			NM	NM	10.96	Static
C-113	218797.690	2682817.060	Monitoring Well	Shallow			–	4.36			7.29	7.29	11.65	Static
C-114	218347.540	2683001.160	Monitoring Well	Shallow			–	3.74			7.22	7.22	10.96	Static
C-127	220182.150	2680897.060	Monitoring Well	Shallow			–	7.66			2.14	2.14	9.80	Static
WP14-2	220196.340	2680218.310	Temporary Well Point Location	Shallow	0.8601	C-167	5.92	6.98	1.06	2.09	1.03	1.94	8.01	Static
River 4	220253.806	2680258.638	Staff Gauge				NM	NM			NM	NM	–	Static
C-129	220497.185	2681937.365	Monitoring Well	Shallow/Intermediate			–	4.88			4.06	4.06	8.94	Static
C-129D	220492.006	2681929.233	Monitoring Well	Deep			–	9.54			-0.35	-0.35	9.19	Static
C-130	219981.051	2682139.561	Monitoring Well	Shallow			–	2.38			9.60	9.60	11.98	Static
C-131	218971.277	2682328.675	Monitoring Well	Shallow			–	3.12			7.02	7.02	10.14	Static
C-132	218271.326	2682247.680	Monitoring Well	Shallow			–	2.73			7.24	7.24	9.97	Static
C-133	218336.074	2681693.849	Monitoring Well	Shallow			–	1.54			6.19	6.19	7.73	Static
C-134D	218306.504	2681164.764	Monitoring Well	Deep			–	7.33			2.07	2.07	9.40	Static
C-136	219217.045	2680990.761	Monitoring Well	Shallow			–	4.42			4.43	4.43	8.85	Static
C-137	219098.264	2680719.078	Monitoring Well	Shallow			–	3.57			2.94	2.94	6.51	Static
C-138	218658.109	2680452.799	Monitoring Well	Shallow			–	4.02			3.04	3.04	7.06	Static
C-139	219443.936	2680633.143	Monitoring Well	Shallow			–	4.35			2.97	2.97	7.32	Static
C-140	218857.817	2679799.125	Monitoring Well	Shallow			–	1.53			6.02	6.02	7.55	Static
C-142	220134.108	2680659.962	Monitoring Well	Shallow/Intermediate			–	5.37			5.98	5.98	11.35	Static
C-143	220233.709	2680321.499	Monitoring Well	Shallow/Intermediate	0.8676	C-143	7.11	9.52	2.41	1.882	-0.53	1.56	8.99	Static
C-144D	220107.413	2680336.744	Monitoring Well	Deep			–	11.51			-2.84	-2.84	8.67	Static
C-145	220222.267	2681007.478	Monitoring Well	Shallow			–	4.72			2.20	2.20	6.92	Static
C-146	220254.825	2680639.828	Monitoring Well	Shallow			–	5.74			1.00	1.00	6.74	Static

Table 3
Summary of AOI 7 Groundwater and LNAPL Elevations
January 2012
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Monitoring Point ID	Northing	Easting	Well Type	Well Classification[1]	Specific Gravity (g/cc) Used for GW Elevation Correction		Depth to Product (ft btic)	Depth to GW (ft btic)[4]	Apparent LNAPL Thickness (ft)	LNAPL Elevation (ft amsl)	GW Elevation (ft amsl)	Corrected GW Elevation (ft amsl)	TIC Elevation (ft amsl)	Static/Pumping
					S.G.[2]	Source[3]								
C-147	220262.747	2680516.947	Monitoring Well	Shallow	0.8409	C-147	5.41	8.72	3.31	1.464	-1.85	0.94	6.87	Static
C-148	220266.672	2680540.203	Monitoring Well	Shallow	0.8512	C-148	7.38	12.69	5.31	1.961	-3.35	1.17	9.34	Static
C-149	220269.615	2680524.161	Monitoring Well	Shallow			NM	NM			NM	NM	9.33	Static
C-150	220262.743	2680607.068	Monitoring Well	Shallow	0.8428	C-150	6.82	7.14	0.32	1.37	1.05	1.32	8.19	Static
C-151	220255.074	2680490.079	Monitoring Well	Shallow	0.8597	C-152	7.02	7.06	0.04	0.89	0.85	0.88	7.91	Static
C-152	220265.627	2680476.565	Monitoring Well	Shallow	0.8597	C-152	7.64	10.18	2.54	1.74	-0.80	1.38	9.38	Static
C-153	220219.944	2680514.198	Monitoring Well	Shallow	0.862	C-153	7.37	7.84	0.47	0.9	0.43	0.84	8.27	Static
C-154	220189.491	2680516.314	Monitoring Well	Shallow	0.8807	C-154	6.95	7.04	0.09	0.94	0.85	0.93	7.89	Static
C-155	220082.150	2680524.532	Monitoring Well	Shallow			--	5.29			3.88	3.88	9.17	Static
C-156	220254.474	2681408.164	Monitoring Well	Shallow			--	6.56			2.52	2.52	9.08	Static
C-157	220255.107	2681432.423	Monitoring Well	Shallow			--	5.26			3.37	3.37	8.63	Static
C-158	220261.400	2681457.300	Monitoring Well	Shallow			--	5.55			3.41	3.41	8.96	Static
C-159	220269.235	2681506.198	Monitoring Well	Shallow			--	4.95			4.19	4.19	9.14	Static
C-161	220266.206	2680460.174	Monitoring Well	Shallow	0.8737	C-161	7.56	8.34	0.78	1.51	0.73	1.41	9.07	Static
C-162	220197.288	2680323.697	Monitoring Well	Shallow	0.8833	C-162	6.82	7.85	1.03	1.68	0.65	1.56	8.50	Static
C-163	220248.194	2681331.620	Monitoring Well	Shallow			--	4.99			2.51	2.51	7.50	Static
C-164	220252.467	2681359.225	Monitoring Well	Shallow			--	6.721			2.41	2.41	9.13	Static
C-165	220255.493	2681386.442	Monitoring Well	Shallow			--	5.65			2.81	2.81	8.46	Static
C-166	220241.930	2680285.122	Monitoring Well	Shallow	0.8486	C-166	8.11	8.84	0.73	1.9	1.17	1.79	10.01	Static
C-167	220238.583	2680255.748	Monitoring Well	Shallow	0.8601	C-167	8.36	13.77	5.41	2.3	-3.11	1.54	10.66	Static
C-168	220174.341	2679988.805	Monitoring Well	Shallow	0.8487	C-168	5.72	6.05	0.33	4.36	4.03	4.31	10.08	Static

Notes:
1. Well classification was chosen based on the formation in which the well was screened. Wells screened within the Middle Clay or the Farrington Sand were classified as deep wells. Based on their total depth, wells screened above the Middle Clay were classified as either a shallow and/or intermediate well.
2. Specific Gravity (S.G.) values were determined from LNAPL samples collected by Aquaterra/Stantec as part of CCR and/or SCR/RIR.
3. For wells with no direct LNAPL density measurements, the density value in the nearest well with LNAPL data was used.
4. Depth to water and depth to LNAPL provided by Stantec January 2012.

g/cc = grams per cubic centimeter
<.01 = Sheen or film of product on groundwater.
LNAPL = Light Non-Aqueous Phase Liquid
ft amsl = Feet Above Mean Sea Level
GW = Groundwater
NA = Not Applicable
NM = Not Measured
NP = No Product
ft btic = Feet Below

Table 4
Summary of Soil Analytical Results
AOI 7
Site Characterization/Remedial Investigation Report
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Chemical Name	CAS No	PADEP Non-Residential Used Aquifer Soil MSCs (TDS<2,500)	Location	BH-10-05				BH-10-06				BH-10-07				BH-10-08				BH-10-09				BH-10-10			
			Sample ID	BH-10-05_1.5-2.0				BH-10-06_1.2-1.7				BH-10-07_1.0-1.5				BH-10-08_1.5-2.0				BH-10-09_1.2-1.7				BH-10-10_1.5-2.0			
			Sample Date	6/9/2010				6/9/2010				6/10/2010				6/10/2010				6/10/2010				6/10/2010			
			Sample Matrix	SO				SO				SO				SO				SO				SO			
			Sample Depth (Ft.)	1.5-2				1.2-1.7				1-1.5				1.5-2				1.2-1.7				1.5-2			
			Units	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF
Volatile Organic Compounds																											
1,2,4-Trimethylbenzene	95-63-6	35	mg/kg	0.007	J	0.002	1.36	0.002	J	0.001	0.98	ND	U	0.005	0.9	0.21	J	0.092	66.74	ND	U	0.001	1.05	0.89		0.093	78.47
1,2-Dibromoethane (ethylene dibromide)	106-93-4	0.005	mg/kg	ND	U	0.002	1.36	ND	U	0.001	0.98	ND	U	0.005	0.9	ND	U	**0.092**	66.74	ND	U	0.001	1.05	ND	U	**0.093**	78.47
1,2-Dichloroethane	107-06-2	0.5	mg/kg	ND	U	0.002	1.36	ND	U	0.001	0.98	ND	U	0.005	0.9	ND	U	0.092	66.74	ND	U	0.001	1.05	ND	U	0.093	78.47
1,3,5-Trimethylbenzene (mesitylene)	108-67-8	9.3	mg/kg	0.006	J	0.002	1.36	ND	U	0.001	0.98	ND	U	0.005	0.9	ND	U	0.092	66.74	ND	U	0.001	1.05	0.099	J	0.093	78.47
Benzene	71-43-2	0.5	mg/kg	0.003	J	0.0008	1.36	0.0007	J	0.0006	0.98	ND	U	0.005	0.9	0.37	J	0.046	66.74	0.002	J	0.0007	1.05	0.16	J	0.047	78.47
Dimethyl Benzene/Xylenes, Total	1330-20-7	1,000	mg/kg	0.017		0.002	1.36	ND	U	0.001	0.98	ND	U	0.005	0.9	0.69		0.092	66.74	0.002	J	0.001	1.05	0.57		0.093	78.47
Ethylbenzene	100-41-4	70	mg/kg	0.002	J	0.002	1.36	ND	U	0.001	0.98	ND	U	0.005	0.9	0.15	J	0.092	66.74	ND	U	0.001	1.05	0.18	J	0.093	78.47
Isopropyl Benzene (Cumene)	98-82-8	2,500	mg/kg	0.004	J	0.002	1.36	ND	U	0.001	0.98	ND	U	0.005	0.9	27		0.092	66.74	ND	U	0.001	1.05	0.18	J	0.093	78.47
Tert-Butyl Methyl Ether	1634-04-4	2.0	mg/kg	ND	U	0.0008	1.36	ND	U	0.0006	0.98	ND	U	0.005	0.9	ND	U	0.046	66.74	ND	U	0.0007	1.05	ND	U	0.047	78.47
Toluene	108-88-3	100	mg/kg	0.005	J	0.002	1.36	0.002	J	0.001	0.98	ND	U	0.005	0.9	0.12	J	0.092	66.74	0.003	J	0.001	1.05	0.7		0.093	78.47
Semi-Volatile Organic Compounds																											
Anthracene	120-12-7	350	mg/kg	0.54		0.039	1	0.87		0.042	1	ND	U	1.9	10	2.5		0.46	10	1.5		0.042	1	1.2		0.04	1
Benzo(A)Anthracene	56-55-3	320	mg/kg	1.1		0.039	1	1.9		0.042	1	ND	U	1.9	10	2.6		0.46	10	2.6		0.042	1	1.4		0.04	1
Benzo(A)Pyrene	50-32-8	46	mg/kg	1		0.039	1	1.9		0.042	1	ND	U	1.9	10	2.2	J	0.46	10	2.7		0.042	1	1.4		0.04	1
Benzo(B) Fluoranthene	205-99-2	170	mg/kg	1.3		0.039	1	2.5		0.042	1	ND	U	1.9	10	2.1	J	0.46	10	3.4		0.042	1	1.7		0.04	1
Benzo(G,H,I)Perylene	191-24-2	180	mg/kg	0.96		0.039	1	1.6		0.042	1	ND	U	1.9	10	1.6	J	0.46	10	1.9		0.042	1	1		0.04	1
Chrysene	218-01-9	230	mg/kg	1.1		0.039	1	2		0.042	1	ND	U	1.9	10	8.3		0.46	10	2.6		0.042	1	1.8		0.04	1
Fluorene	86-73-7	3,800	mg/kg	0.34		0.039	1	0.36		0.042	1	ND	U	1.9	10	35		0.46	10	0.57		0.042	1	0.93		0.04	1
Naphthalene	91-20-3	25	mg/kg	1		0.039	1	3.3		0.042	1	ND	U	1.9	10	ND	U	0.46	10	4.6		0.042	1	3.3		0.04	1
Phenanthrene	85-01-8	10,000	mg/kg	1.2		0.039	1	2.3		0.042	1	ND	U	1.9	10	20		0.46	10	3.4		0.042	1	2		0.04	1
Pyrene	129-00-0	2,200	mg/kg	1.7		0.039	1	2.8		0.042	1	ND	U	1.9	10	8.9		0.46	10	3.2		0.042	1	3		0.04	1
Metals																											
Lead	7439-92-1	450	mg/kg	411		0.0563	10	266		0.0604	10	305		1.12	10	444		0.0688	10	**1230**		0.158	25	**725**		0.117	20
General Chemistry																											
Moisture, Percent	MOIST	NC	Percent	14.6		0.5	1	20.4		0.5	1	13		0.5	1	27.3		0.5	1	20.9		0.5	1	15.7		0.5	1

Notes:
PADEP - Pennsylvania Department of Environmental Protection
mg/kg - milligram per kilogram
ug/kg - microgram per kilogram
MSC - PADEP's Medium Specific Concentration for Soil
RL - Reporting Limit
ND - Not Detected
NC - No Criteria
NA - Not Analyzed
DF- Dilution Factor
SO- Soil
Ft- Feet

Qualifiers:
Q - Lab Qualifier
U - The analyte was analyzed but not detected
E - The analyte exceeded the calibration range of the instrument
J = Estimated value. The result is ≥ MDL and ≤ LOQ.

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

Table 4
Summary of Soil Analytical Results
AOI 7
Site Characterization/Remedial Investigation Report
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Chemical Name	CAS No	PADEP Non-Residential Used Aquifer Soil MSCs (TDS<2,500)	Location	BH-10-11				BH-10-12				BH-10-13				BH-10-14				BH-10-15			
			Sample ID	BH-10-11_1.5-2.0				BH-10-12_1.5-2.0				BH-10-13_1.5-2.0				BH-10-14_1.5-2.0				BH-10-15_1.4-1.9			
			Sample Date	6/10/2010				6/10/2010				6/9/2010				6/9/2010				6/9/2010			
			Sample Matrix	SO				SO				SO				SO				SO			
			Sample Depth (Ft.)	1.5-2				1.5-2				1.5-2				1.5-2				1.4-1.9			
			Units	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF
Volatile Organic Compounds																							
1,2,4-Trimethylbenzene	95-63-6	35	mg/kg	0.43		0.053	46.25	0.006	J	0.001	1.12	ND	U	0.001	1	0.29	J	0.081	69.08	ND	U	0.001	1.03
1,2-Dibromoethane (ethylene dibromide)	106-93-4	0.005	mg/kg	ND	U	**0.053**	46.25	ND	U	0.001	1.12	ND	U	0.001	1	ND	U	**0.081**	69.08	ND	U	0.001	1.03
1,2-Dichloroethane	107-06-2	0.5	mg/kg	ND	U	0.053	46.25	ND	U	0.001	1.12	ND	U	0.001	1	ND	U	0.081	69.08	ND	U	0.001	1.03
1,3,5-Trimethylbenzene (mesitylene)	108-67-8	9.3	mg/kg	0.085	J	0.053	46.25	0.003	J	0.001	1.12	ND	U	0.001	1	0.12	J	0.081	69.08	ND	U	0.001	1.03
Benzene	71-43-2	0.5	mg/kg	0.056	J	0.026	46.25	0.004	J	0.0007	1.12	0.002	J	0.0006	1	0.26	J	0.04	69.08	0.004	J	0.0006	1.03
Dimethyl Benzene/Xylenes, Total	1330-20-7	1,000	mg/kg	0.3		0.053	46.25	0.007		0.001	1.12	ND	U	0.001	1	1.1		0.081	69.08	ND	U	0.001	1.03
Ethylbenzene	100-41-4	70	mg/kg	0.09	J	0.053	46.25	ND	U	0.001	1.12	ND	U	0.001	1	0.22	J	0.081	69.08	ND	U	0.001	1.03
Isopropyl Benzene (Cumene)	98-82-8	2,500	mg/kg	ND	U	0.053	46.25	ND	U	0.001	1.12	ND	U	0.001	1	ND	U	0.081	69.08	ND	U	0.001	1.03
Tert-Butyl Methyl Ether	1634-04-4	2.0	mg/kg	ND	U	0.026	46.25	ND	U	0.0007	1.12	ND	U	0.0006	1	ND	U	0.04	69.08	ND	U	0.0006	1.03
Toluene	108-88-3	100	mg/kg	0.19	J	0.053	46.25	0.007	J	0.001	1.12	0.003	J	0.001	1	0.95		0.081	69.08	0.002	J	0.001	1.03
Semi-Volatile Organic Compounds																							
Anthracene	120-12-7	350	mg/kg	1.3		0.038	1	1.7		0.04	1	1.6		0.038	1	1		0.039	1	0.57		0.038	1
Benzo(A)Anthracene	56-55-3	320	mg/kg	3.3		0.038	1	2.4		0.04	1	5		0.38	10	1.3		0.039	1	1.7		0.038	1
Benzo(A)Pyrene	50-32-8	46	mg/kg	2.7		0.038	1	2.1		0.04	1	4.2		0.038	1	1.2		0.039	1	1.4		0.038	1
Benzo(B) Fluoranthene	205-99-2	170	mg/kg	3.6		0.038	1	2.7		0.04	1	5.7		0.38	10	1.6		0.039	1	2		0.038	1
Benzo(G,H,I)Perylene	191-24-2	180	mg/kg	1.4		0.038	1	1.5		0.04	1	2.9		0.038	1	1.1		0.039	1	0.97		0.038	1
Chrysene	218-01-9	230	mg/kg	3.4		0.038	1	2.5		0.04	1	4.6		0.38	10	1.4		0.039	1	1.6		0.038	1
Fluorene	86-73-7	3,800	mg/kg	0.64		0.038	1	1.3		0.04	1	0.53		0.038	1	0.41		0.039	1	0.23		0.038	1
Naphthalene	91-20-3	25	mg/kg	1.5		0.038	1	3.8		0.04	1	1		0.038	1	4.9		0.39	10	0.31		0.038	1
Phenanthrene	85-01-8	10,000	mg/kg	2.9		0.038	1	3.8		0.04	1	4.5		0.038	1	2.6		0.039	1	2.4		0.038	1
Pyrene	129-00-0	2,200	mg/kg	6.6		0.38	10	4.5		0.04	1	7.3		0.38	10	1.8		0.039	1	2.7		0.038	1
Metals																							
Lead	7439-92-1	450	mg/kg	184		0.0278	5	414		0.0583	10	320		0.0561	10	**531**		0.142	25	280		0.0553	10
General Chemistry																							
Moisture, Percent	MOIST	NC	Percent	12.6		0.5	1	15.9		0.5	1	11.8		0.5	1	14.3		0.5	1	11.3		0.5	1

Notes:
PADEP - Pennsylvania Department of Environmental Protection
mg/kg - milligram per kilogram
ug/kg - microgram per kilogram
MSC - PADEP's Medium Specific Concentration for Soil
RL - Reporting Limit
ND - Not Detected
NC - No Criteria
NA - Not Analyzed
DF- Dillution Factor
SO- Soil
Ft- Feet

Qualifiers:
Q - Lab Qualifier
U - The analyte was analyzed but not detected
E - The analyte exceeded the calibration range of the instrument
J = Estimated value. The result is ≥ MDL and ≤ LOQ.

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

Chemical Name	CAS No	PADEP Non-Residential Used Aquifer Soil MSCs (TDS<2,500)	Location	BH-10-16				BH-10-17				BH-10-18				BH-10-19				BH-10-20				BH-10-21			
			Sample ID	BH-10-16_1.5-2.0				BH-10-17_1.5-2.0				BH-10-18_1.5-2.0				BH-10-19_0.5-1.0				BH-10-20_1.3-1.8				BH-10-21_1.0-1.5			
			Sample Date	6/9/2010				6/9/2010				6/9/2010				6/9/2010				6/8/2010				6/8/2010			
			Sample Matrix	SO				SO				SO				SO				SO				SO			
			Sample Depth (Ft.)	1.5-2				1.5-2				1.5-2				0.5-1				1.3-1.8				1-1.5			
			Units	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF
Volatile Organic Compounds																											
1,2,4-Trimethylbenzene	95-63-6	35	mg/kg	0.24	J	0.18	133.55	4.4		0.057	52.52	ND	U	0.001	1.1	ND	U	0.005	0.87	ND	U	0.001	1.01	ND	U	0.001	1.06
1,2-Dibromoethane (ethylene dibromide)	106-93-4	0.005	mg/kg	ND	U	**0.18**	133.55	ND	U	**0.057**	52.52	ND	U	0.001	1.1	ND	U	0.005	0.87	ND	U	0.001	1.01	ND	U	0.001	1.06
1,2-Dichloroethane	107-06-2	0.5	mg/kg	ND	U	0.18	133.55	ND	U	0.057	52.52	ND	U	0.001	1.1	ND	U	0.005	0.87	ND	U	0.001	1.01	ND	U	0.001	1.06
1,3,5-Trimethylbenzene (mesitylene)	108-67-8	9.3	mg/kg	ND	U	0.18	133.55	2.4		0.057	52.52	ND	U	0.001	1.1	ND	U	0.005	0.87	ND	U	0.001	1.01	ND	U	0.001	1.06
Benzene	71-43-2	0.5	mg/kg	**0.85**	J	0.088	133.55	0.46		0.029	52.52	0.0008	J	0.0007	1.1	ND	U	0.005	0.87	0.003	J	0.0006	1.01	ND	U	0.0007	1.06
Dimethyl Benzene/Xylenes, Total	1330-20-7	1,000	mg/kg	0.69	J	0.18	133.55	7.5		0.057	52.52	ND	U	0.001	1.1	ND	U	0.005	0.87	ND	U	0.001	1.01	0.001	J	0.001	1.06
Ethylbenzene	100-41-4	70	mg/kg	ND	U	0.18	133.55	0.8		0.057	52.52	ND	U	0.001	1.1	ND	U	0.005	0.87	ND	U	0.001	1.01	ND	U	0.001	1.06
Isopropyl Benzene (Cumene)	98-82-8	2,500	mg/kg	9.1		0.18	133.55	0.3		0.057	52.52	ND	U	0.001	1.1	ND	U	0.005	0.87	ND	U	0.001	1.01	ND	U	0.001	1.06
Tert-Butyl Methyl Ether	1634-04-4	2.0	mg/kg	ND	U	0.088	133.55	ND	U	0.029	52.52	ND	U	0.0007	1.1	ND	U	0.005	0.87	ND	U	0.0006	1.01	ND	U	0.0007	1.06
Toluene	108-88-3	100	mg/kg	0.34	J	0.18	133.55	2.3		0.057	52.52	0.002	J	0.001	1.1	ND	U	0.005	0.87	0.001	J	0.001	1.01	ND	U	0.001	1.06
Semi-Volatile Organic Compounds																											
Anthracene	120-12-7	350	mg/kg	1.9	J	0.44	10	0.57		0.036	1	1		0.044	1	0.67		0.18	1	0.88		0.037	1	2.9		0.044	1
Benzo(A)Anthracene	56-55-3	320	mg/kg	3.5		0.44	10	0.58		0.036	1	1.4		0.044	1	2.1		0.18	1	1.8		0.037	1	4.4		0.044	1
Benzo(A)Pyrene	50-32-8	46	mg/kg	2.8		0.44	10	0.51		0.036	1	1.5		0.044	1	2.3		0.18	1	1.7		0.037	1	3.8		0.044	1
Benzo(B) Fluoranthene	205-99-2	170	mg/kg	3.5		0.44	10	0.54		0.036	1	1.7		0.044	1	3.1		0.18	1	2.3		0.037	1	4.5		0.044	1
Benzo(G,H,I)Perylene	191-24-2	180	mg/kg	2.2	J	0.44	10	0.32		0.036	1	1.2		0.044	1	2.5		0.18	1	1.4		0.037	1	2.9		0.044	1
Chrysene	218-01-9	230	mg/kg	4.7		0.44	10	0.93		0.036	1	1.6		0.044	1	2.2		0.18	1	1.7		0.037	1	4.7		0.044	1
Fluorene	86-73-7	3,800	mg/kg	ND	U	0.44	10	0.9		0.036	1	0.53		0.044	1	0.19		0.18	1	0.32		0.037	1	0.97		0.044	1
Naphthalene	91-20-3	25	mg/kg	ND	U	0.44	10	1.4		0.036	1	3.1		0.044	1	ND	U	0.18	1	1.2		0.037	1	9.2		0.44	10
Phenanthrene	85-01-8	10,000	mg/kg	11		0.44	10	2.3		0.036	1	2.4		0.044	1	2.5		0.18	1	2.6		0.037	1	4.2		0.044	1
Pyrene	129-00-0	2,200	mg/kg	8		0.44	10	1.4		0.036	1	2.4		0.044	1	3.5		0.18	1	2.8		0.037	1	7.7		0.44	10
Metals																											
Lead	7439-92-1	450	mg/kg	**616**		0.131	20	47.8		0.0109	2	**478**		0.0634	10	365		1.07	10	179		0.0274	5	**869**		0.128	20
General Chemistry																											
Moisture, Percent	MOIST	NC	Percent	23.9		0.5	1	8.3		0.5	1	23.4		0.5	1	9.3		0.5	1	10.7		0.5	1	24.7		0.5	1

Notes:
PADEP - Pennsylvania Department of Environmental Protection
mg/kg - milligram per kilogram
ug/kg - microgram per kilogram
MSC - PADEP's Medium Specific Concentration for Soil
RL - Reporting Limit
ND - Not Detected
NC - No Criteria
NA - Not Analyzed
DF- Dilution Factor
SO- Soil
Ft- Feet

Qualifiers:
Q - Lab Qualifier
U - The analyte was analyzed but not detected
E - The analyte exceeded the calibration range of the instrument
J = Estimated value. The result is ≥ MDL and ≤ LOQ.

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

Table 4
Summary of Soil Analytical Results
AOI 7
Site Characterization/Remedial Investigation Report
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Chemical Name	CAS No	PADEP Non-Residential Used Aquifer Soil MSCs (TDS<2,500)	Location	BH-10-22				BH-10-23				BH-10-24				BH-10-25				BH-10-26			
			Sample ID	BH-10-22_1.5-2.0				BH-10-23_1.0-1.5				BH-10-24_1.0-1.5				BH-10-25_1.2-1.7				BH-10-26_1.5-2.0			
			Sample Date	6/8/2010				6/7/2010				6/7/2010				6/7/2010				6/7/2010			
			Sample Matrix	SO				SO				SO				SO				SO			
			Sample Depth (Ft.)	1.5-2				1-1.5				1-1.5				1.2-1.7				1.5-2			
			Units	**Result**	**Q**	**RL**	**DF**	**Result**	**Q**	**RL**	**DF**	**Result**	**Q**	**RL**	**DF**	**Result**	**Q**	**RL**	**DF**	**Result**	**Q**	**RL**	**DF**
Volatile Organic Compounds																							
1,2,4-Trimethylbenzene	95-63-6	35	mg/kg	ND	U	0.001	1.16	ND	U	0.002	1.48	0.83		0.073	66.83	0.2	J	0.097	66.14	ND	U	0.001	0.92
1,2-Dibromoethane (ethylene dibromide)	106-93-4	0.005	mg/kg	ND	U	0.001	1.16	ND	U	0.002	1.48	ND	U	**0.073**	66.83	ND	U	**0.097**	66.14	ND	U	0.001	0.92
1,2-Dichloroethane	107-06-2	0.5	mg/kg	ND	U	0.001	1.16	ND	U	0.002	1.48	ND	U	0.073	66.83	ND	U	0.097	66.14	ND	U	0.001	0.92
1,3,5-Trimethylbenzene (mesitylene)	108-67-8	9.3	mg/kg	ND	U	0.001	1.16	ND	U	0.002	1.48	0.34	J	0.073	66.83	ND	U	0.097	66.14	ND	U	0.001	0.92
Benzene	71-43-2	0.5	mg/kg	0.005	J	0.0007	1.16	0.019		8E-04	1.48	0.094	J	0.036	66.83	**31**		0.49	661.42	0.003	J	0.0006	0.92
Dimethyl Benzene/Xylenes, Total	1330-20-7	1,000	mg/kg	0.002	J	0.001	1.16	0.003	J	0.002	1.48	0.89		0.073	66.83	1.3		0.097	66.14	ND	U	0.001	0.92
Ethylbenzene	100-41-4	70	mg/kg	ND	U	0.001	1.16	ND	U	0.002	1.48	0.78		0.073	66.83	0.51		0.097	66.14	ND	U	0.001	0.92
Isopropyl Benzene (Cumene)	98-82-8	2,500	mg/kg	ND	U	0.001	1.16	ND	U	0.002	1.48	0.28	J	0.073	66.83	ND	U	0.097	66.14	ND	U	0.001	0.92
Tert-Butyl Methyl Ether	1634-04-4	2.0	mg/kg	ND	U	0.0007	1.16	ND	U	8E-04	1.48	ND	U	0.036	66.83	ND	U	0.049	66.14	ND	U	0.0006	0.92
Toluene	108-88-3	100	mg/kg	0.014		0.001	1.16	0.01		0.002	1.48	0.18	J	0.073	66.83	2.8		0.097	66.14	0.002	J	0.001	0.92
Semi-Volatile Organic Compounds																							
Anthracene	120-12-7	350	mg/kg	0.79		0.038	1	0.052	J	0.037	1	0.083	J	0.036	1	0.45		0.049	1	3.6		0.041	1
Benzo(A)Anthracene	56-55-3	320	mg/kg	1.1		0.038	1	0.2		0.037	1	0.27		0.036	1	0.36		0.049	1	5.8		0.21	5
Benzo(A)Pyrene	50-32-8	46	mg/kg	1.1		0.038	1	0.24		0.037	1	0.31		0.036	1	0.38		0.049	1	4.3		0.041	1
Benzo(B) Fluoranthene	205-99-2	170	mg/kg	1.6		0.038	1	0.32		0.037	1	0.43		0.036	1	0.77		0.049	1	6.1		0.21	5
Benzo(G,H,I)Perylene	191-24-2	180	mg/kg	1.2		0.038	1	0.14	J	0.037	1	0.18		0.036	1	0.27		0.049	1	1.2		0.041	1
Chrysene	218-01-9	230	mg/kg	1.3		0.038	1	0.21		0.037	1	0.28		0.036	1	0.44		0.049	1	5.4		0.21	5
Fluorene	86-73-7	3,800	mg/kg	0.25		0.038	1	ND	U	0.037	1	0.08	J	0.036	1	0.17	J	0.049	1	1.1		0.041	1
Naphthalene	91-20-3	25	mg/kg	3.7		0.038	1	0.11	J	0.037	1	1.4		0.036	1	5.5		0.049	1	3.3		0.041	1
Phenanthrene	85-01-8	10,000	mg/kg	2		0.038	1	0.17	J	0.037	1	0.48		0.036	1	1.6		0.049	1	2.8		0.041	1
Pyrene	129-00-0	2,200	mg/kg	1.5		0.038	1	0.31		0.037	1	0.44		0.036	1	0.54		0.049	1	8.2		0.21	5
Metals																							
Lead	7439-92-1	450	mg/kg	304		0.0564	10	**623**		0.11	20	411		0.0528	10	79.4		0.0144	2	**2040**		0.307	50
General Chemistry																							
Moisture, Percent	MOIST	NC	Percent	12.2		0.5	1	8.8		0.5	1	8		0.5	1	32.1		0.5	1	19.3		0.5	1

Notes:
PADEP - Pennsylvania Department of Environmental Protection
mg/kg - milligram per kilogram
ug/kg - microgram per kilogram
MSC - PADEP's Medium Specific Concentration for Soil
RL - Reporting Limit
ND - Not Detected
NC - No Criteria
NA - Not Analyzed
DF- Dillution Factor
SO- Soil
Ft- Feet

Qualifiers:
Q - Lab Qualifier
U - The analyte was analyzed but not detected
E - The analyte exceeded the calibration range of the instrument
J = Estimated value. The result is ≥ MDL and ≤ LOQ.

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

Table 4
Summary of Soil Analytical Results
AOI 7
Site Characterization/Remedial Investigation Report
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Chemical Name	CAS No	PADEP Non-Residential Used Aquifer Soil MSCs (TDS<2,500)	Location	BH-10-27				BH-10-28				BH-10-29				BH-10-30				BH-10-31			
			Sample ID	BH-10-27_1.5-2.0				BH-10-28_1.5-2.0				BH-10-29_0.7-1.2				BH-10-30_1.5-2.0				BH-10-31_1.5-2.0			
			Sample Date	6/8/2010				6/7/2010				6/7/2010				6/7/2010				6/8/2010			
			Sample Matrix	SO				SO				SO				SO				SO			
			Sample Depth (Ft.)	1.5-2				1.5-2				0.7-1.2				1.5-2				1.5-2			
			Units	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF
Volatile Organic Compounds																							
1,2,4-Trimethylbenzene	95-63-6	35	mg/kg	16		0.92	720.59	**280**		7.5	6010.08	ND	U	0.005	0.99	0.24	J	0.088	69	1.1		0.098	68.05
1,2-Dibromoethane (ethylene dibromide)	106-93-4	0.005	mg/kg	ND	U	**0.92**	720.59	ND	U	**0.075**	60.1	ND	U	0.005	0.99	ND	U	**0.088**	69	ND	U	**0.098**	68.05
1,2-Dichloroethane	107-06-2	0.5	mg/kg	ND	U	**0.92**	720.59	ND	U	0.075	60.1	ND	U	0.005	0.99	ND	U	0.088	69	ND	U	0.098	68.05
1,3,5-Trimethylbenzene (mesitylene)	108-67-8	9.3	mg/kg	8		0.92	720.59	**130**		0.75	601.01	ND	U	0.005	0.99	ND	U	0.088	69	0.45	J	0.098	68.05
Benzene	71-43-2	0.5	mg/kg	ND	U	0.46	720.59	**1.6**		0.037	60.1	0.01		0.005	0.99	0.38	J	0.044	69	0.47	J	0.049	68.05
Dimethyl Benzene/Xylenes, Total	1330-20-7	1,000	mg/kg	9		0.92	720.59	250		0.75	601.01	0.006		0.005	0.99	0.81		0.088	69	3.8		0.098	68.05
Ethylbenzene	100-41-4	70	mg/kg	2.4	J	0.92	720.59	27		0.75	601.01	ND	U	0.005	0.99	0.29	J	0.088	69	0.63		0.098	68.05
Isopropyl Benzene (Cumene)	98-82-8	2,500	mg/kg	6.5		0.92	720.59	2.1		0.075	60.1	ND	U	0.005	0.99	ND	U	0.088	69	0.17	J	0.098	68.05
Tert-Butyl Methyl Ether	1634-04-4	2.0	mg/kg	ND	U	0.46	720.59	ND	U	0.037	60.1	ND	U	0.005	0.99	ND	U	0.044	69	ND	U	0.049	68.05
Toluene	108-88-3	100	mg/kg	1.7	J	0.92	720.59	6.5		0.075	60.1	0.028		0.005	0.99	1.7		0.088	69	1.7		0.098	68.05
Semi-Volatile Organic Compounds																							
Anthracene	120-12-7	350	mg/kg	2.6		0.43	10	ND	U	0.41	10	ND	U	0.18	1	1		0.042	1	0.82		0.048	1
Benzo(A)Anthracene	56-55-3	320	mg/kg	3.4		0.43	10	0.61	J	0.41	10	0.21		0.18	1	1.3		0.042	1	0.61		0.048	1
Benzo(A)Pyrene	50-32-8	46	mg/kg	3.8		0.43	10	0.6	J	0.41	10	0.23		0.18	1	1.5		0.042	1	0.61		0.048	1
Benzo(B) Fluoranthene	205-99-2	170	mg/kg	5.5		0.43	10	1.3	J	0.41	10	0.36		0.18	1	2.3		0.042	1	0.91		0.048	1
Benzo(G,H,I)Perylene	191-24-2	180	mg/kg	3.4		0.43	10	0.64	J	0.41	10	ND	U	0.18	1	0.74		0.042	1	0.66		0.048	1
Chrysene	218-01-9	230	mg/kg	4.4		0.43	10	0.68	J	0.41	10	0.24		0.18	1	1.6		0.042	1	0.8		0.048	1
Fluorene	86-73-7	3,800	mg/kg	1.7	J	0.43	10	0.59	J	0.41	10	ND	U	0.18	1	0.5		0.042	1	0.32		0.048	1
Naphthalene	91-20-3	25	mg/kg	21		0.43	10	**30**		0.41	10	0.2		0.18	1	11		0.21	5	7.3		0.48	10
Phenanthrene	85-01-8	10,000	mg/kg	8.9		0.43	10	1.8	J	0.41	10	0.21		0.18	1	2.9		0.042	1	2.5		0.048	1
Pyrene	129-00-0	2,200	mg/kg	6.5		0.43	10	1.3	J	0.41	10	0.29		0.18	1	1.7		0.042	1	0.77		0.048	1
Metals																							
Lead	7439-92-1	450	mg/kg	393		0.0631	10	155		0.0307	5	395		1.08	10	250		0.061	10	**610**		0.0713	10
General Chemistry																							
Moisture, Percent	MOIST	NC	Percent	21.6		0.5	1	19.4		0.5	1	9.2		0.5	1	21.2		0.5	1	30.6		0.5	1

Notes:
PADEP - Pennsylvania Department of Environmental Protection
mg/kg - milligram per kilogram
ug/kg - microgram per kilogram
MSC - PADEP's Medium Specific Concentration for Soil
RL - Reporting Limit
ND - Not Detected
NC - No Criteria
NA - Not Analyzed
DF- Dillution Factor
SO- Soil
Ft- Feet

Qualifiers:
Q - Lab Qualifier
U - The analyte was analyzed but not detected
E - The analyte exceeded the calibration range of the instrument
J = Estimated value. The result is ≥ MDL and ≤ LOQ.

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

Table 4
Summary of Soil Analytical Results
AOI 7
Site Characterization/Remedial Investigation Report
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Chemical Name	CAS No	PADEP Non-Residential Used Aquifer Soil MSCs (TDS<2,500)	Location	BH-10-32				BH-10-33				BH-10-34				BH-10-35				C-129				C-130			
			Sample ID	BH-10-32_0.5-1.0				BH-10-33_1.5-2.0				BH-10-34_1.0-1.5				BH-10-35_1.3-1.7				C-129_1-2				C-130_1-2			
			Sample Date	6/8/2010				6/8/2010				6/8/2010				6/8/2010				6/2/2010				6/2/2010			
			Sample Matrix	SO				SO				SO				SO				SO				SO			
			Sample Depth (Ft.)	0.5-1				1.5-2				1-1.5				1.3-1.7				1-2				1-2			
			Units	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF
Volatile Organic Compounds																											
1,2,4-Trimethylbenzene	95-63-6	35	mg/kg	0.002	J	0.001	0.93	ND	U	0.005	0.93	ND	U	0.005	0.97	ND	U	0.005	0.83	ND	U	0.001	0.93	ND	U	0.005	0.81
1,2-Dibromoethane (ethylene dibromide)	106-93-4	0.005	mg/kg	ND	U	0.001	0.93	ND	U	0.005	0.93	ND	U	0.005	0.97	ND	U	0.005	0.83	ND	U	0.001	0.93	ND	U	0.005	0.81
1,2-Dichloroethane	107-06-2	0.5	mg/kg	ND	U	0.001	0.93	ND	U	0.005	0.93	ND	U	0.005	0.97	ND	U	0.005	0.83	ND	U	0.001	0.93	ND	U	0.005	0.81
1,3,5-Trimethylbenzene (mesitylene)	108-67-8	9.3	mg/kg	ND	U	0.001	0.93	ND	U	0.005	0.93	ND	U	0.005	0.97	ND	U	0.005	0.83	ND	U	0.001	0.93	ND	U	0.005	0.81
Benzene	71-43-2	0.5	mg/kg	0.004	J	0.0006	0.93	ND	U	0.005	0.93	ND	U	0.005	0.97	ND	U	0.005	0.83	0.003	J	0.0006	0.93	ND	U	0.005	0.81
Dimethyl Benzene/Xylenes, Total	1330-20-7	1,000	mg/kg	0.009		0.001	0.93	ND	U	0.005	0.93	ND	U	0.005	0.97	ND	U	0.005	0.83	ND	U	0.001	0.93	ND	U	0.005	0.81
Ethylbenzene	100-41-4	70	mg/kg	ND	U	0.001	0.93	ND	U	0.005	0.93	ND	U	0.005	0.97	ND	U	0.005	0.83	ND	U	0.001	0.93	ND	U	0.005	0.81
Isopropyl Benzene (Cumene)	98-82-8	2,500	mg/kg	ND	U	0.001	0.93	ND	U	0.005	0.93	ND	U	0.005	0.97	ND	U	0.005	0.83	ND	U	0.001	0.93	ND	U	0.005	0.81
Tert-Butyl Methyl Ether	1634-04-4	2.0	mg/kg	ND	U	0.0006	0.93	ND	U	0.005	0.93	ND	U	0.005	0.97	ND	U	0.005	0.83	ND	U	0.0006	0.93	ND	U	0.005	0.81
Toluene	108-88-3	100	mg/kg	0.007		0.001	0.93	ND	U	0.005	0.93	ND	U	0.005	0.97	ND	U	0.005	0.83	0.012		0.001	0.93	ND	U	0.005	0.81
Semi-Volatile Organic Compounds																											
Anthracene	120-12-7	350	mg/kg	0.13	J	0.04	1	ND	U	0.18	1	ND	U	0.18	1	0.29		0.18	1	0.83		0.042	1	2.7		1.9	10
Benzo(A)Anthracene	56-55-3	320	mg/kg	0.18	J	0.04	1	ND	U	0.18	1	ND	U	0.18	1	0.79		0.18	1	1.9		0.042	1	9.6		1.9	10
Benzo(A)Pyrene	50-32-8	46	mg/kg	0.21		0.04	1	ND	U	0.18	1	ND	U	0.18	1	0.82		0.18	1	2.3		0.042	1	8.4		1.9	10
Benzo(B) Fluoranthene	205-99-2	170	mg/kg	0.27		0.04	1	ND	U	0.18	1	ND	U	0.18	1	0.84		0.18	1	3.1		0.042	1	11		1.9	10
Benzo(G,H,I)Perylene	191-24-2	180	mg/kg	0.25		0.04	1	ND	U	0.18	1	ND	U	0.18	1	0.61		0.18	1	0.87		0.042	1	4.9		1.9	10
Chrysene	218-01-9	230	mg/kg	0.27		0.04	1	ND	U	0.18	1	ND	U	0.18	1	0.85		0.18	1	1.8		0.042	1	8.7		1.9	10
Fluorene	86-73-7	3,800	mg/kg	ND	U	0.04	1	ND	U	0.18	1	ND	U	0.18	1	ND	U	0.18	1	0.28		0.042	1	ND	U	1.9	10
Naphthalene	91-20-3	25	mg/kg	0.64		0.04	1	ND	U	0.18	1	ND	U	0.18	1	ND	U	0.18	1	4.2		0.042	1	ND	U	1.9	10
Phenanthrene	85-01-8	10,000	mg/kg	0.3		0.04	1	ND	U	0.18	1	ND	U	0.18	1	0.84		0.18	1	2.6		0.042	1	7.3		1.9	10
Pyrene	129-00-0	2,200	mg/kg	0.29		0.04	1	ND	U	0.18	1	0.19		0.18	1	1.7		0.18	1	3.6		0.042	1	13		1.9	10
Metals																											
Lead	7439-92-1	450	mg/kg	298		0.0601	10	43.1		0.214	2	84.2		0.216	2	92.5		0.215	2	252		0.063	10	**814**		4.67	40
General Chemistry																											
Moisture, Percent	MOIST	NC	Percent	17.6		0.5	1	9.1		0.5	1	9.4		0.5	1	9.7		0.5	1	21.4		0.5	1	14.3		0.5	1

Notes:
PADEP - Pennsylvania Department of Environmental Protection
mg/kg - milligram per kilogram
ug/kg - microgram per kilogram
MSC - PADEP's Medium Specific Concentration for Soil
RL - Reporting Limit
ND - Not Detected
NC - No Criteria
NA - Not Analyzed
DF- Dilution Factor
SO- Soil
Ft- Feet

Qualifiers:
Q - Lab Qualifier
U - The analyte was analyzed but not detected
E - The analyte exceeded the calibration range of the instrument
J = Estimated value. The result is ≥ MDL and ≤ LOQ.

Exceedance Summary:

10	Result exceeds the PADEP Non-Residential Soil MSC
10	RL exceeds the PADEP Non-Residential Soil MSC

Table 4
Summary of Soil Analytical Results
AOI 7
Site Characterization/Remedial Investigation Report
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Chemical Name	CAS No	PADEP Non-Residential Used Aquifer Soil MSCs (TDS<2,500)	Location	C-131				BH-C-135				C-136				C-137				C-138				C-139			
			Sample ID	C-131_1-2				BH-C-135_0-2				C-136_1-2				C-137_1-2				C-138_1-2				C-139_1-2			
			Sample Date	6/3/2010				6/10/2010				5/28/2010				5/27/2010				5/27/2010				6/2/2010			
			Sample Matrix	SO				SO				SO				SO				SO				SO			
			Sample Depth (Ft.)	1-2				0-2				1-2				1-2				1-2				1-2			
			Units	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF
Volatile Organic Compounds																											
1,2,4-Trimethylbenzene	95-63-6	35	mg/kg	ND	U	0.001	0.94	ND	U	0.005	0.88	ND	U	0.005	0.87	ND	U	0.005	0.76	0.014		0.002	1.53	ND	U	0.004	0.8
1,2-Dibromoethane (ethylene dibromide)	106-93-4	0.005	mg/kg	ND	U	0.001	0.94	ND	U	0.005	0.88	ND	U	0.005	0.87	ND	U	0.005	0.76	ND	U	0.002	1.53	ND	U	0.004	0.8
1,2-Dichloroethane	107-06-2	0.5	mg/kg	ND	U	0.001	0.94	ND	U	0.005	0.88	ND	U	0.005	0.87	ND	U	0.005	0.76	ND	U	0.002	1.53	ND	U	0.004	0.8
1,3,5-Trimethylbenzene (mesitylene)	108-67-8	9.3	mg/kg	ND	U	0.001	0.94	ND	U	0.005	0.88	ND	U	0.005	0.87	ND	U	0.005	0.76	0.007	J	0.002	1.53	ND	U	0.004	0.8
Benzene	71-43-2	0.5	mg/kg	ND	U	0.0006	0.94	ND	U	0.005	0.88	0.007		0.005	0.87	ND	U	0.005	0.76	0.012	J	0.001	1.53	ND	U	0.004	0.8
Dimethyl Benzene/Xylenes, Total	1330-20-7	1,000	mg/kg	ND	U	0.001	0.94	ND	U	0.005	0.88	ND	U	0.005	0.87	ND	U	0.005	0.76	0.072		0.002	1.53	ND	U	0.004	0.8
Ethylbenzene	100-41-4	70	mg/kg	ND	U	0.001	0.94	ND	U	0.005	0.88	ND	U	0.005	0.87	ND	U	0.005	0.76	0.014		0.002	1.53	ND	U	0.004	0.8
Isopropyl Benzene (Cumene)	98-82-8	2,500	mg/kg	ND	U	0.001	0.94	ND	U	0.005	0.88	ND	U	0.005	0.87	0.009		0.005	0.76	0.003	J	0.002	1.53	ND	U	0.004	0.8
Tert-Butyl Methyl Ether	1634-04-4	2.0	mg/kg	0.017		0.0006	0.94	ND	U	0.005	0.88	ND	U	0.005	0.87	ND	U	0.005	0.76	ND	U	0.001	1.53	ND	U	0.004	0.8
Toluene	108-88-3	100	mg/kg	0.003	J	0.001	0.94	ND	U	0.005	0.88	8		0.005	0.87	ND	U	0.005	0.76	0.054		0.002	1.53	ND	U	0.004	0.8
Semi-Volatile Organic Compounds																											
Anthracene	120-12-7	350	mg/kg	0.94	J	0.22	5	ND	U	0.17	1	ND	U	0.18	1	1.9		0.21	1	0.094	J	0.051	1	ND	U	0.18	1
Benzo(A)Anthracene	56-55-3	320	mg/kg	1.3		0.22	5	ND	U	0.17	1	0.37		0.18	1	2.3		0.21	1	0.24	J	0.051	1	ND	U	0.18	1
Benzo(A)Pyrene	50-32-8	46	mg/kg	1.5		0.22	5	ND	U	0.17	1	0.38		0.18	1	1.9		0.21	1	0.2	J	0.051	1	ND	U	0.18	1
Benzo(B) Fluoranthene	205-99-2	170	mg/kg	2.2		0.22	5	ND	U	0.17	1	0.55		0.18	1	2.2		0.21	1	0.32		0.051	1	ND	U	0.18	1
Benzo(G,H,I)Perylene	191-24-2	180	mg/kg	0.64	J	0.22	5	ND	U	0.17	1	0.39		0.18	1	1.3		0.21	1	0.15	J	0.051	1	ND	U	0.18	1
Chrysene	218-01-9	230	mg/kg	1.6		0.22	5	ND	U	0.17	1	0.41		0.18	1	2.3		0.21	1	0.3		0.051	1	ND	U	0.18	1
Fluorene	86-73-7	3,800	mg/kg	0.35	J	0.22	5	ND	U	0.17	1	ND	U	0.18	1	1.8		0.21	1	ND	U	0.051	1	ND	U	0.18	1
Naphthalene	91-20-3	25	mg/kg	6.5		0.22	5	ND	U	0.17	1	0.55		0.18	1	5.4		2.1	10	0.11	J	0.051	1	ND	U	0.18	1
Phenanthrene	85-01-8	10,000	mg/kg	2.9		0.22	5	ND	U	0.17	1	0.36		0.18	1	4.4		2.1	10	0.24	J	0.051	1	ND	U	0.18	1
Pyrene	129-00-0	2,200	mg/kg	1.9		0.22	5	ND	U	0.17	1	0.44		0.18	1	ND	U	0.21	1	0.36		0.051	1	0.25		0.18	1
Metals																											
Lead	7439-92-1	450	mg/kg	396		0.0647	10	4.31		0.202	2	218		1.09	10	251		0.617	5	103		0.0462	2	98.7		0.212	2
General Chemistry																											
Moisture, Percent	MOIST	NC	Percent	24.2		0.5	1	3		0.5	1	9.7		0.5	1	20.5		0.5	1	35.1		0.5	1	9.5		0.5	1

Notes:
PADEP - Pennsylvania Department of Environmental Protection
mg/kg - milligram per kilogram
ug/kg - microgram per kilogram
MSC - PADEP's Medium Specific Concentration for Soil
RL - Reporting Limit
ND - Not Detected
NC - No Criteria
NA - Not Analyzed
DF- Dillution Factor
SO- Soil
Ft- Feet

Qualifiers:
Q - Lab Qualifier
U - The analyte was analyzed but not detected
E - The analyte exceeded the calibration range of the instrument
J = Estimated value. The result is ≥ MDL and ≤ LOQ.

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

Table 4
Summary of Soil Analytical Results
AOI 7
Site Characterization/Remedial Investigation Report
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Chemical Name	CAS No	PADEP Non-Residential Used Aquifer Soil MSCs (TDS<2,500)	Location	C-140				C-142				C-143			
			Sample ID	C-140_1-2				C-142_1-2				C-143_1-2			
			Sample Date	5/26/2010				6/3/2010				6/3/2010			
			Sample Matrix	SO				SO				SO			
			Sample Depth (Ft.)	1-2				1-2				1-2			
			Units	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF
Volatile Organic Compounds															
1,2,4-Trimethylbenzene	95-63-6	35	mg/kg	ND	U	0.005	0.85	0.18	J	0.061	54.59	0.25	J	0.067	62.48
1,2-Dibromoethane (ethylene dibromide)	106-93-4	0.005	mg/kg	ND	U	0.005	0.85	ND	U	**0.061**	54.59	ND	U	**0.067**	62.48
1,2-Dichloroethane	107-06-2	0.5	mg/kg	ND	U	0.005	0.85	ND	U	0.061	54.59	ND	U	0.067	62.48
1,3,5-Trimethylbenzene (mesitylene)	108-67-8	9.3	mg/kg	ND	U	0.005	0.85	0.09	J	0.061	54.59	0.24	J	0.067	62.48
Benzene	71-43-2	0.5	mg/kg	ND	U	0.005	0.85	0.1	J	0.031	54.59	**2**		0.033	62.48
Dimethyl Benzene/Xylenes, Total	1330-20-7	1,000	mg/kg	ND	U	0.005	0.85	0.22	J	0.061	54.59	0.57		0.067	62.48
Ethylbenzene	100-41-4	70	mg/kg	ND	U	0.005	0.85	0.072	J	0.061	54.59	0.15	J	0.067	62.48
Isopropyl Benzene (Cumene)	98-82-8	2,500	mg/kg	ND	U	0.005	0.85	0.078	J	0.061	54.59	5.6		0.067	62.48
Tert-Butyl Methyl Ether	1634-04-4	2.0	mg/kg	ND	U	0.005	0.85	ND	U	0.031	54.59	ND	U	0.033	62.48
Toluene	108-88-3	100	mg/kg	ND	U	0.005	0.85	0.63		0.061	54.59	0.22	J	0.067	62.48
Semi-Volatile Organic Compounds															
Anthracene	120-12-7	350	mg/kg	0.38		0.19	1	2		0.19	5	0.17	J	0.036	1
Benzo(A)Anthracene	56-55-3	320	mg/kg	1.2		0.19	1	3.1		0.19	5	0.42		0.036	1
Benzo(A)Pyrene	50-32-8	46	mg/kg	1.2		0.19	1	3.4		0.19	5	0.52		0.036	1
Benzo(B) Fluoranthene	205-99-2	170	mg/kg	1.4		0.19	1	4.8		0.19	5	0.62		0.036	1
Benzo(G,H,I)Perylene	191-24-2	180	mg/kg	1		0.19	1	1.3		0.19	5	0.43		0.036	1
Chrysene	218-01-9	230	mg/kg	1.3		0.19	1	2.9		0.19	5	0.6		0.036	1
Fluorene	86-73-7	3,800	mg/kg	ND	U	0.19	1	1.6		0.19	5	0.062	J	0.036	1
Naphthalene	91-20-3	25	mg/kg	0.47		0.19	1	2		0.19	5	0.27		0.036	1
Phenanthrene	85-01-8	10,000	mg/kg	0.99		0.19	1	7.1		0.19	5	0.49		0.036	1
Pyrene	129-00-0	2,200	mg/kg	1.9		0.19	1	5.9		0.19	5	0.93		0.036	1
Metals															
Lead	7439-92-1	450	mg/kg	98.6		0.557	5	**1370**		0.222	40	164		0.0513	10
General Chemistry															
Moisture, Percent	MOIST	NC	Percent	12.9		0.5	1	10.9		0.5	1	6.2		0.5	1

Notes:

PADEP - Pennsylvania Department of Environmental Protection
mg/kg - milligram per kilogram
ug/kg - microgram per kilogram
MSC - PADEP's Medium Specific Concentration for Soil
RL - Reporting Limit
ND - Not Detected
NC - No Criteria
NA - Not Analyzed
DF- Dillution Factor
SO- Soil
Ft- Feet

Qualifiers:

Q - Lab Qualifier
U - The analyte was analyzed but not detected
E - The analyte exceeded the calibration range of the instrument
J = Estimated value. The result is ≥ MDL and ≤ LOQ.

Exceedance Summary:

10	Result exceeds the PADEP Non-Residential Soil MSC
10	RL exceeds the PADEP Non-Residential Soil MSC

Table 5
Summary of Shallow Groundwater Analytical Results
AOI-7
Site Characterization/Remediatl Investigation Report
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Chemical Name	Cas No	PADEP Non-residential Used Aquifer TDS<2500 mg/l	Location	C-64				C-49				C-50				C-51			
			Sample ID	C-44_071910				C-49_071310				C-50_071210				C-51_071410			
			Sample Date	7/19/2010				7/13/2010				7/12/2010				7/14/2010			
			Sample Matrix	WG				WG				WG				WG			
			Unit	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF
Volatile Organic Compounds																			
1,2,4-Trimethylbenzene	95-63-6	62	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
1,2-Dibromoethane (ethylene dibromide)	106-93-4	0.05	ug/l	ND	U	0.0097	1	ND	U	0.0096	1	ND	U	0.0095	1	ND	U	0.0097	1
1,2-Dichloroethane	107-06-2	5	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
1,3,5-Trimethylbenzene (mesitylene)	108-67-8	53	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
Benzene	71-43-2	5	ug/l	3		0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
Dimethyl Benzene/Xylenes, Total	1330-20-7	10000	ug/l	0.8	J	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
Ethylbenzene	100-41-4	700	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
Isopropyl Benzene (Cumene)	98-82-8	3500	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
Tert-Butyl Methyl Ether	1634-04-4	20	ug/l	ND	U	0.5	1	0.5	J	0.5	1	ND	U	0.5	1	ND	U	0.5	1
Toluene	108-88-3	1000	ug/l	3		0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
Semi-Volatile Organic Compounds																			
Chrysene	218-01-9	1.90	ug/l	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1
Fluorene	86-73-7	1900	ug/l	ND	U	1	1	ND	U	1	1	1	J	1	1	3	J	1	1
Naphthalene	91-20-3	100	ug/l	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1
Phenanthrene	85-01-8	1100	ug/l	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1
Pyrene	129-00-0	130	ug/l	ND	U	1	1	ND	U	1	1	2	J	1	1	2	J	1	1
Naphthalene	91-20-3	100	ug/l	NA				NA				NA				NA			
Metals																			
Lead	7439-92-1	5	ug/l	ND	U	0.00005	1	ND	U	0.00005	1	ND	U	0.00005	1	ND	U	0.00005	1

Chemical Name	C-52				C-53A				C-54				C-55			
	C-52_071510				C-53A_071610				C-54_071510				C-55_071610			
	7/15/2010				7/16/2010				7/15/2010				7/16/2010			
	WG				WG				WG				WG			
	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF
Volatile Organic Compounds																
1,2,4-Trimethylbenzene	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
1,2-Dibromoethane (ethylene dibromide)	ND	U	0.0098	1	ND	U	0.0097	1	ND	U	0.0097	1	ND	U	0.0098	1
1,2-Dichloroethane	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
1,3,5-Trimethylbenzene (mesitylene)	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
Benzene	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
Dimethyl Benzene/Xylenes, Total	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
Ethylbenzene	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
Isopropyl Benzene (Cumene)	1	J	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
Tert-Butyl Methyl Ether	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
Toluene	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
Semi-Volatile Organic Compounds																
Chrysene	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1
Fluorene	ND	U	1	1	3	J	1	1	ND	U	1	1	ND	U	1	1
Naphthalene	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1
Phenanthrene	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1
Pyrene	ND	U	1	1	2	J	1	1	ND	U	1	1	ND	U	1	1
Naphthalene	NA				NA				NA				NA			
Metals																
Lead	ND	U	0.00005	1	ND	U	0.00005	1	0.068	J	0.00005	1	0.069	J	0.00005	1

Notes:

PADEP - Pennsylvania Department of Environmental Protection
ug/l - micrograms per liter
mg/L - milligram per liter
RL - Reporting Limit
ND - Not Detected
DF - Dilution Factor
NA - Not Analyzed
WG- Groundwater

Qualifiers:

Q - Qualifier
U - The analyte was analyzed but not detected
J - The analyte was detected below the RL. The result should be considered an estimate.
D - The sample was diluted.

Exceedance Summary:

10 - RL exceeds the PADEP Non-Residential Used Aquifer Groundwater Criteria TDS<2,500 mg/l
10 - Result exceeds the PADEP Non-Residential Used Aquifer Groundwater Criteria TDS<2,500 mg/l

Table 5
Summary of Shallow Groundwater Analytical Results
AOI-7
Site Characterization/Remediatl Investigation Report
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Chemical Name	Cas No	PADEP Non-residential Used Aquifer TDS<2500 mg/l	Location	C-56				C-57				C-58				C-60				C-61				C-62				C-63				C-95			
			Sample ID	C-56_072710				C-57_071410				C-58_071410				C-60_071610				C-61_071910				C-62_072010				C-63_071610				C-95_071310			
			Sample Date	7/27/2010				7/14/2010				7/14/2010				7/16/2010				7/19/2010				7/20/2010				7/16/2010				7/13/2010			
			Sample Matrix	WG				WG				WG				WG				WG				WG				WG				WG			
			Unit	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF
Volatile Organic Compounds																																			
1,2,4-Trimethylbenzene	95-63-6	62	ug/l	29		0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
1,2-Dibromoethane (ethylene dibromide)	106-93-4	0.05	ug/l	ND	U	0.0098	1	ND	U	0.0098	1	ND	U	0.0097	1	ND	U	0.0098	1	ND	U	0.0096	1	ND	U	0.0097	1	ND	U	0.0097	1	ND	U	0.0097	1
1,2-Dichloroethane	107-06-2	5	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
1,3,5-Trimethylbenzene (mesitylene)	108-67-8	53	ug/l	13		0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
Benzene	71-43-2	5	ug/l	0.7	J	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
Dimethyl Benzene/Xylenes, Total	1330-20-7	10000	ug/l	23		0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	1		0.5	1	0.6	J	0.5	1	ND	U	0.5	1	2		0.5	1
Ethylbenzene	100-41-4	700	ug/l	2		0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
Isopropyl Benzene (Cumene)	98-82-8	3500	ug/l	2	J	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	0.5	J	0.5	1	ND	U	0.5	1	19		0.5	1
Tert-Butyl Methyl Ether	1634-04-4	20	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	3		0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
Toluene	108-88-3	1000	ug/l	1		0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
Semi-Volatile Organic Compounds																																			
Chrysene	218-01-9	1.90	ug/l	ND	U	1	1	3	J	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1
Fluorene	86-73-7	1900	ug/l	29		1	1	6		1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1	1	J	1	1	ND	U	1	1	ND	U	1	1
Naphthalene	91-20-3	100	ug/l	15		1	1	4	J	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1
Phenanthrene	85-01-8	1100	ug/l	72		1	1	8		1	1	2	J	1	1	ND	U	1	1	ND	U	1	1	2	J	1	1	ND	U	1	1	ND	U	1	1
Pyrene	129-00-0	130	ug/l	8		1	1	5	J	1	1	1	J	1	1	ND	U	1	1	ND	U	1	1	1	J	1	1	ND	U	1	1	ND	U	1	1
Naphthalene	91-20-3	100	ug/l	NA				NA				NA				NA				NA				NA				NA				NA			
Metals																																			
Lead	7439-92-1	5	ug/l	15.8		0.00005	1	ND	U	0.00005	1	ND	U	0.00005	1	ND	U	0.00005	1	ND	U	0.00005	1	0.17	J	0.00005	1	0.42	J	0.00005	1	ND	U	0.00005	1

Notes:

PADEP - Pennsylvania Department of Environmental Protection
ug/l - micrograms per liter
mg/L - milligram per liter
RL - Reporting Limit
ND - Not Detected
DF - Dilution Factor
NA - Not Analyzed
WG- Groundwater

Qualifiers:

Q - Qualifier
U - The analyte was analyzed but not detected
J - The analyte was detected below the RL. The result should be considered an estimate.
D - The sample was diluted.

Exceedance Summary:

10 - RL exceeds the PADEP Non-Residential Used Aquifer Groundwater Criteria TDS<2,5(
10 - Result exceeds the PADEP Non-Residential Used Aquifer Groundwater Criteria TDS<

Table 5
Summary of Shallow Groundwater Analytical Results
AOI-7
Site Characterization/Remediatl Investigation Report
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Chemical Name	Cas No	PADEP Non-residential Used Aquifer TDS<2500 mg/l	Location	C-96				C-98				C-104				C-105				C-108				C-109				C-110				C-111			
			Sample ID	C-96_071310				C-98_071610				C-104_071910				C-105_071910				C-108_071610				C-109_071310				C-110_072710				C-111_072710			
			Sample Date	7/13/2010				7/16/2010				7/19/2010				7/19/2010				7/16/2010				7/13/2010				7/27/2010				7/27/2010			
			Sample Matrix	WG				WG				WG				WG				WG				WG				WG				WG			
			Unit	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF
Volatile Organic Compounds																																			
1,2,4-Trimethylbenzene	95-63-6	62	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
1,2-Dibromoethane (ethylene dibromide)	106-93-4	0.05	ug/l	ND	U	0.0096	1	ND	U	0.0097	1	ND	U	0.0096	1	ND	U	0.0096	1	ND	U	0.0097	1	ND	U	0.0096	1	ND	U	0.0096	1	ND	U	0.0097	1
1,2-Dichloroethane	107-06-2	5	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
1,3,5-Trimethylbenzene (mesitylene)	108-67-8	53	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	3		0.5	1
Benzene	71-43-2	5	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	89		0.5	1
Dimethyl Benzene/Xylenes, Total	1330-20-7	10000	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	12		0.5	1
Ethylbenzene	100-41-4	700	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	1		0.5	1
Isopropyl Benzene (Cumene)	98-82-8	3500	ug/l	ND	U	0.5	1	ND	U	0.5	1	0.5	J	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	130		0.5	1
Tert-Butyl Methyl Ether	1634-04-4	20	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
Toluene	108-88-3	1000	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	15		0.5	1
Semi-Volatile Organic Compounds																																			
Chrysene	218-01-9	1.90	ug/l	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1	1	J	1	1	2	J	1	1	3	J	0.9	1
Fluorene	86-73-7	1900	ug/l	3	J	1	1	1	J	1	1	9		1	1	1	J	1	1	ND	U	1	1	2	J	1	1	2	J	1	1	2	J	0.9	1
Naphthalene	91-20-3	100	ug/l	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1	2	J	1	1	2	J	0.9	1
Phenanthrene	85-01-8	1100	ug/l	4	J	1	1	1	J	1	1	1	J	1	1	ND	U	1	1	ND	U	1	1	2	J	1	1	3	J	1	1	7		0.9	1
Pyrene	129-00-0	130	ug/l	3	J	1	1	1	J	1	1	3	J	1	1	ND	U	1	1	ND	U	1	1	4	J	1	1	4	J	1	1	7		0.9	1
Naphthalene	91-20-3	100	ug/l	NA				NA				NA				NA				NA				NA				NA				NA			
Metals																																			
Lead	7439-92-1	5	ug/l	ND	U	0.00005	1	ND	U	0.00005	1	ND	U	0.00005	1	ND	U	0.00005	1	ND	U	0.00005	1	ND	U	0.00005	1	ND	U	0.00005	1	1.3		0.00005	1

Notes:

PADEP - Pennsylvania Department of Environmental Protection
ug/l - micrograms per liter
mg/L - milligram per liter
RL - Reporting Limit
ND - Not Detected
DF - Dilution Factor
NA - Not Analyzed
WG- Groundwater

Qualifiers:

Q - Qualifier
U - The analyte was analyzed but not detected
J - The analyte was detected below the RL. The result should be considered an estimate.
D - The sample was diluted.

Exceedance Summary:

10 - RL exceeds the PADEP Non-Residential Used Aquifer Groundwater Criteria TDS<2,5(
10 - Result exceeds the PADEP Non-Residential Used Aquifer Groundwater Criteria TDS<

Table 5
Summary of Shallow Groundwater Analytical Results
AOI-7
Site Characterization/Remediatl Investigation Report
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Chemical Name	Cas No	PADEP Non-residential Used Aquifer TDS<2500 mg/l	Location	C-112				C-113				C-114				C-127				C-129				C-130				C-131				C-132			
			Sample ID	C-112_071410				C-113_071310				C-114_071410				C-127_071510				C-129_071210				C-130_071210				C-131_071510				C-132_071510			
			Sample Date	7/14/2010				7/13/2010				7/14/2010				7/15/2010				7/12/2010				7/12/2010				7/15/2010				7/15/2010			
			Sample Matrix	WG				WG				WG				WG				WG				WG				WG				WG			
			Unit	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF
Volatile Organic Compounds																																			
1,2,4-Trimethylbenzene	95-63-6	62	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	0.7	J	0.5	1
1,2-Dibromoethane (ethylene dibromide)	106-93-4	0.05	ug/l	ND	U	0.0097	1	ND	U	0.0096	1	ND	U	0.0098	1	ND	U	0.0098	1	ND	U	0.0095	1	ND	U	0.0096	1	ND	U	0.0096	1	ND	U	0.0098	1
1,2-Dichloroethane	107-06-2	5	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
1,3,5-Trimethylbenzene (mesitylene)	108-67-8	53	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
Benzene	71-43-2	5	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
Dimethyl Benzene/Xylenes, Total	1330-20-7	10000	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	1		0.5	1
Ethylbenzene	100-41-4	700	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	0.7	J	0.5	1
Isopropyl Benzene (Cumene)	98-82-8	3500	ug/l	1	J	0.5	1	ND	U	0.5	1	0.7	J	0.5	1	7		0.5	1	ND	U	0.5	1	ND	U	0.5	1	1	J	0.5	1	28		0.5	1
Tert-Butyl Methyl Ether	1634-04-4	20	ug/l	ND	U	0.5	1	ND	U	0.5	1	16		0.5	1	6		0.5	1	ND	U	0.5	1	ND	U	0.5	1	7		0.5	1	ND	U	0.5	1
Toluene	108-88-3	1000	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
Semi-Volatile Organic Compounds																																			
Chrysene	218-01-9	1.90	ug/l	3	J	1	1	ND	U	1	1	2	J	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1	38	J	**10**	1	ND	U	1	1
Fluorene	86-73-7	1900	ug/l	13		1	1	3	J	1	1	5		1	1	5		1	1	ND	U	1	1	ND	U	1	1	30	J	10	1	3	J	1	1
Naphthalene	91-20-3	100	ug/l	1	J	1	1	ND	U	1	1	2	J	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1	36	J	10	1	ND	U	1	1
Phenanthrene	85-01-8	1100	ug/l	19		1	1	4	J	1	1	5	J	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1	100		10	1	ND	U	1	1
Pyrene	129-00-0	130	ug/l	9		1	1	3	J	1	1	5		1	1	2	J	1	1	ND	U	1	1	ND	U	1	1	78		10	1	2	J	1	1
Naphthalene	91-20-3	100	ug/l	NA				NA				NA				NA				NA				NA				NA				NA			
Metals																																			
Lead	7439-92-1	5	ug/l	ND	U	0.00005	1	ND	U	0.00005	1	ND	U	0.00005	1	ND	U	0.00005	1	2.5		0.00005	1	ND	U	0.00005	1	0.7	J	0.00005	1	0.11	J	0.00005	1

Notes:
PADEP - Pennsylvania Department of Environmental Protection
ug/l - micrograms per liter
mg/L - milligram per liter
RL - Reporting Limit
ND - Not Detected
DF - Dilution Factor
NA - Not Analyzed
WG- Groundwater

Qualifiers:
Q - Qualifier
U - The analyte was analyzed but not detected
J - The analyte was detected below the RL. The result should be considered an estimate.
D - The sample was diluted.

Exceedance Summary:
$\boxed{10}$ - RL exceeds the PADEP Non-Residential Used Aquifer Groundwater Criteria TDS<2,5(
10 - Result exceeds the PADEP Non-Residential Used Aquifer Groundwater Criteria TDS<

Table 5
Summary of Shallow Groundwater Analytical Results
AOI-7
Site Characterization/Remediatl Investigation Report
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Chemical Name	Cas No	PADEP Non-residential Used Aquifer TDS<2500 mg/l	Location	C-133				C-137				C-138				C-140				C-142				C-145				C-146				C-155			
			Sample ID	C-133_071510				C-137_071510				C-138_071610				C-140_072010				C-142_072010				C-145_01132012				C-146_01132012				C-155_01122012			
			Sample Date	7/15/2010				7/15/2010				7/16/2010				7/20/2010				7/20/2010				1/13/2012				1/13/2012				1/12/2012			
			Sample Matrix	WG				WG				WG				WG				WG				WG				WG				WG			
			Unit	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF
Volatile Organic Compounds																																			
1,2,4-Trimethylbenzene	95-63-6	62	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	3		0.5	1	ND	U	5	10	ND	U	2	1	35		2	1	ND	U	2	1
1,2-Dibromoethane (ethylene dibromide)	106-93-4	0.05	ug/l	ND	U	0.0097	1	ND	U	0.0098	1	ND	U	0.0097	1	ND	U	0.0097	1	ND	U	0.0096	1	ND	U	0.029	1	ND	U	0.029	1	ND	U	0.029	1
1,2-Dichloroethane	107-06-2	5	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	5	10	ND	U	1	1	ND	U	1	1	ND	U	1	1
1,3,5-Trimethylbenzene (mesitylene)	108-67-8	53	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	0.8	J	0.5	1	ND	U	5	10	ND	U	2	1	24		2	1	ND	U	2	1
Benzene	71-43-2	5	ug/l	ND	U	0.5	1	0.8	J	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	5	10	ND	U	1	1	ND	U	1	1	ND	U	1	1
Dimethyl Benzene/Xylenes, Total	1330-20-7	10000	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	2		0.5	1	ND	U	5	10	3		1	1	92		1	1	ND	U	1	1
Ethylbenzene	100-41-4	700	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	1		0.5	1	ND	U	5	10	ND	U	1	1	ND	U	1	1	ND	U	1	1
Isopropyl Benzene (Cumene)	98-82-8	3500	ug/l	0.7	J	0.5	1	4		0.5	1	ND	U	0.5	1	2		0.5	1	78		5	10	ND	U	2	1	14		2	1	ND	U	2	1
Tert-Butyl Methyl Ether	1634-04-4	20	ug/l	ND	U	0.5	1	1		0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	5	10	1		1	1	ND	U	1	1	ND	U	1	1
Toluene	108-88-3	1000	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	5	10	ND	U	1	1	ND	U	1	1	ND	U	1	1
Semi-Volatile Organic Compounds																																			
Chrysene	218-01-9	1.90	ug/l	8		1	1	ND	U	1	1	ND	U	1	1	2	J	1	1	64		**10**	10	0.7		0.5	1	0.6		0.5	1	ND	U	0.5	1
Fluorene	86-73-7	1900	ug/l	8		1	1	1	J	1	1	ND	U	1	1	4	J	1	1	39	J	10	10	ND	U	0.5	1	0.7		0.5	1	ND	U	0.5	1
Naphthalene	91-20-3	100	ug/l	8		1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1	32	J	10	10	ND	U	0.5	1	8		0.5	1	ND	U	0.5	1
Phenanthrene	85-01-8	1100	ug/l	17		1	1	5	J	1	1	ND	U	1	1	ND	U	1	1	140		10	10	ND	U	0.5	1	0.7		0.5	1	ND	U	0.5	1
Pyrene	129-00-0	130	ug/l	17		1	1	ND	U	1	1	ND	U	1	1	6		1	1	110		10	10	1		0.5	1	2		0.5	1	ND	U	0.5	1
Naphthalene	91-20-3	100	ug/l	NA				NA				NA				NA				NA				NA				NA				NA			
Metals																																			
Lead	7439-92-1	5	ug/l	0.14	J	0.00005	1	ND	U	0.00005	1	1		0.00005	1	0.098	J	0.00005	1	0.96	J	0.00005	1	ND	U	1	1	2.7		1	1	ND	U	1	1

Notes:

PADEP - Pennsylvania Department of Environmental Protection
ug/l - micrograms per liter
mg/L - milligram per liter
RL - Reporting Limit
ND - Not Detected
DF - Dilution Factor
NA - Not Analyzed
WG- Groundwater

Qualifiers:

Q - Qualifier
U - The analyte was analyzed but not detected
J - The analyte was detected below the RL. The result should be considered an estimate.
D - The sample was diluted.

Exceedance Summary:

10 - RL exceeds the PADEP Non-Residential Used Aquifer Groundwater Criteria TDS<2,5
10 - Result exceeds the PADEP Non-Residential Used Aquifer Groundwater Criteria TDS<

Table 5
Summary of Shallow Groundwater Analytical Results
AOI-7
Site Characterization/Remediatl Investigation Report
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Chemical Name	Cas No	PADEP Non-residential Used Aquifer TDS<2500 mg/l	Location	C-156				C-157				C-158				C-159				C-163				C-164				C-165			
			Sample ID	C-156_01122012				C-157_01122012				C-158_01122012				C-159_01122012				C-163_01122012				C-164_01122012				C-165_01122012			
			Sample Date	1/12/2012				1/12/2012				1/12/2012				1/12/2012				1/12/2012				1/12/2012				1/12/2012			
			Sample Matrix	WG				WG				WG				WG				WG				WG				WG			
			Unit	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF
Volatile Organic Compounds																															
1,2,4-Trimethylbenzene	95-63-6	62	ug/l	ND	U	2	1	ND	U	2	1	ND	U	2	1	ND	U	2	1	ND	U	2	1	ND	U	2	1	ND	U	2	1
1,2-Dibromoethane (ethylene dibromide)	106-93-4	0.05	ug/l	ND	U	0.029	1	ND	U	0.029	1	ND	U	0.029	1	ND	U	0.029	1	ND	U	0.029	1	ND	U	0.029	1	ND	U	0.029	1
1,2-Dichloroethane	107-06-2	5	ug/l	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1
1,3,5-Trimethylbenzene (mesitylene)	108-67-8	53	ug/l	ND	U	2	1	ND	U	2	1	ND	U	2	1	ND	U	2	1	ND	U	2	1	ND	U	2	1	ND	U	2	1
Benzene	71-43-2	5	ug/l	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1
Dimethyl Benzene/Xylenes, Total	1330-20-7	10000	ug/l	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1
Ethylbenzene	100-41-4	700	ug/l	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1
Isopropyl Benzene (Cumene)	98-82-8	3500	ug/l	ND	U	2	1	ND	U	2	1	ND	U	2	1	ND	U	2	1	ND	U	2	1	ND	U	2	1	ND	U	2	1
Tert-Butyl Methyl Ether	1634-04-4	20	ug/l	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1	6		1	1	1		1	1
Toluene	108-88-3	1000	ug/l	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1
Semi-Volatile Organic Compounds																															
Chrysene	218-01-9	1.90	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
Fluorene	86-73-7	1900	ug/l	ND	U	0.5	1	ND	U	0.5	1	0.5		0.5	1	ND	U	0.5	1	ND	U	0.5	1	2		0.5	1	ND	U	0.5	1
Naphthalene	91-20-3	100	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
Phenanthrene	85-01-8	1100	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	1		0.5	1	ND	U	0.5	1
Pyrene	129-00-0	130	ug/l	0.7		0.5	1	ND	U	0.5	1	0.7		0.5	1	ND	U	0.5	1	0.7		0.5	1	ND	U	0.5	1	ND	U	0.5	1
Naphthalene	91-20-3	100	ug/l	NA				NA				NA				NA				NA				NA				NA			
Metals																															
Lead	7439-92-1	5	ug/l	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1

Notes:
PADEP - Pennsylvania Department of Environmental Protection
ug/l - micrograms per liter
mg/L - milligram per liter
RL - Reporting Limit
ND - Not Detected
DF - Dilution Factor
NA - Not Analyzed
WG- Groundwater

Qualifiers:
Q - Qualifier
U - The analyte was analyzed but not detected
J - The analyte was detected below the RL. The result should be considered an estimate.
D - The sample was diluted.

Exceedance Summary:
$\boxed{10}$ - RL exceeds the PADEP Non-Residential Used Aquifer Groundwater Criteria TDS<2,5(
10 - Result exceeds the PADEP Non-Residential Used Aquifer Groundwater Criteria TDS<

Table 6
Summary of Deep Groundwater Analytical Results
AOI 7
Site Characterization/Remedial Investigation Report
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Chemical Name	Cas No	PADEP Non-residential Used Aquifer TDS<2500 mg/l GWQC	Location	C-129D				C-134D				C-144D				C-50D			
			Sample ID	C-129D_071210				C-134D_072010				C-144D_071910				C-50D_071310			
			Sample Date	7/12/2010				7/20/2010				7/19/2010				7/13/2010			
			Sample Matrix	WG				WG				WG				WG			
			Unit	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF	Result	Q	RL	DF
Volatile Organic Compounds																			
1,2,4-Trimethylbenzene	95-63-6	62	ug/l	ND	U	0.5	1	0.5	J	0.5	1	ND	U	0.5	1	ND	U	0.5	1
1,2-Dibromoethane (ethylene dibromide)	106-93-4	0.05	ug/l	ND	U	0.0096	1	ND	U	0.0097	1	ND	U	0.0096	1	ND	U	0.0096	1
1,2-Dichloroethane	107-06-2	5	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
1,3,5-Trimethylbenzene (mesitylene)	108-67-8	53	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
Benzene	71-43-2	5	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
Dimethyl Benzene/Xylenes, Total	1330-20-7	10000	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
Ethylbenzene	100-41-4	700	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
Isopropyl Benzene (Cumene)	98-82-8	3500	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
Tert-Butyl Methyl Ether	1634-04-4	20	ug/l	0.7	J	0.5	1	1		0.5	1	0.9	J	0.5	1	ND	U	0.5	1
Toluene	108-88-3	1000	ug/l	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1	ND	U	0.5	1
Semi-Volatile Organic Compounds																			
Chrysene	218-01-9	1.90	ug/l	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1
Fluorene	86-73-7	1900	ug/l	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1
Naphthalene	91-20-3	100	ug/l	1	J	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1
Phenanthrene	85-01-8	1100	ug/l	2	J	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1
Pyrene	129-00-0	130	ug/l	ND	U	1	1	ND	U	1	1	ND	U	1	1	ND	U	1	1
Naphthalene	91-20-3	100	ug/l	NA				NA				NA				NA			
Metals																			
Lead	7439-92-1	5	ug/l	ND	U	0.00005	1	ND	U	0.00005	1	ND	U	0.00005	1	ND	U	0.00005	1

Notes:

PADEP - Pennsylvania Department of Environmental Protection
ug/l - micrograms per liter
mg/L - milligram per liter
RL - Reporting Limit
ND - Not Detected
DF - Dilution Factor
NA - Not Analyzed
WG- Groundwater

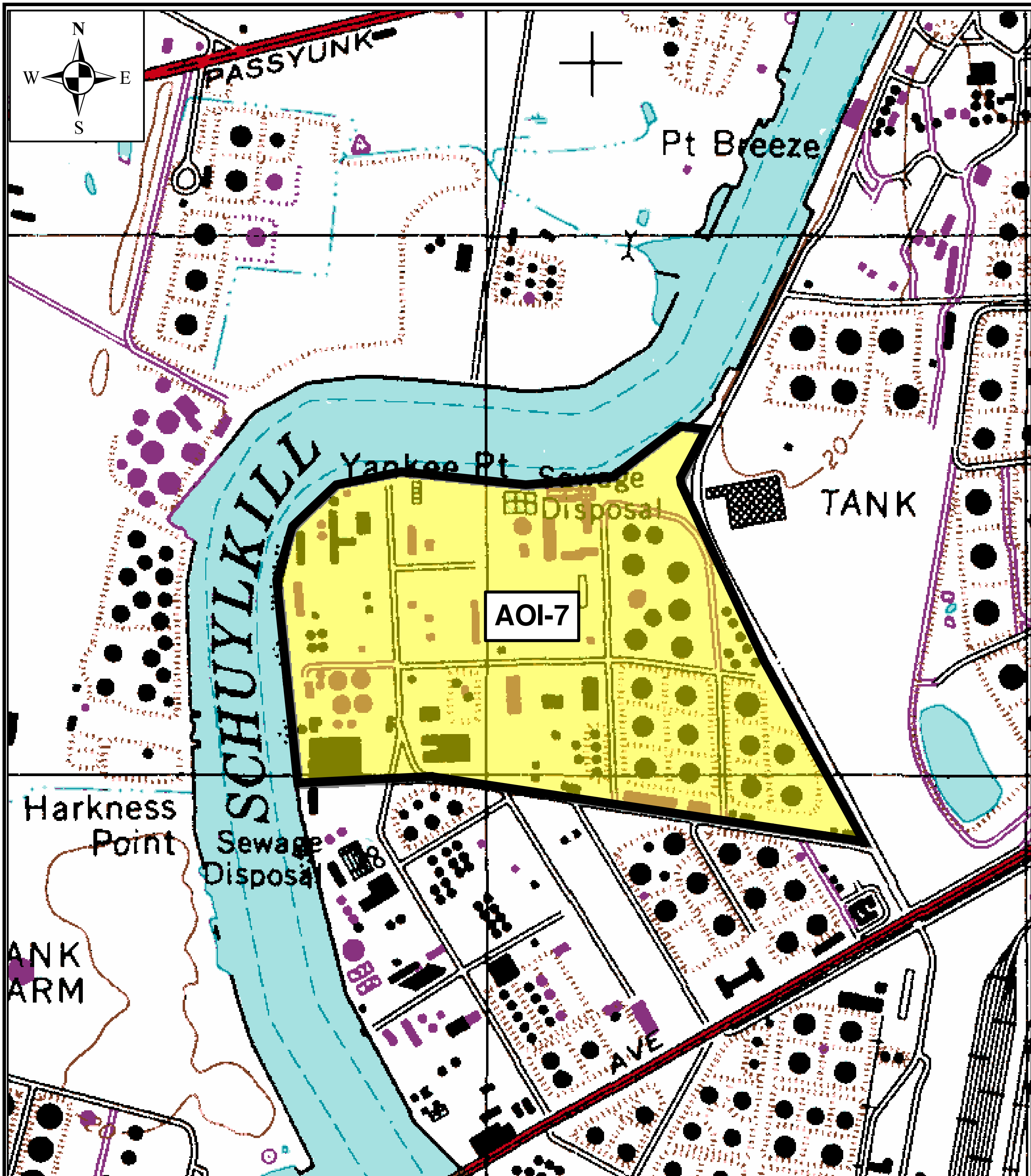
Qualifiers:

Q - Qualifier
U - The analyte was analyzed but not detected
J - The analyte was detected below the RL. The result should be considered an estimate.
D - The sample was diluted.

Exceedance Summary:

10 - RL exceeds the PADEP Non-Residential Used Aquifer Groundwater Criteria TDS<2,500 mg/l
10 - Result exceeds the PADEP Non-Residential Used Aquifer Groundwater Criteria TDS<2,500 mg/l

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-7
AOI-7 Site Characterization Report/
Remedial Investigation Report

Philadelphia — Pennsylvania

Job Number	Scale: 1" = 800'	Date
2574601	0 400 800 Feet	July 1, 2010

Q:\data6\2574601\ArcGIS\MapDocuments\AOI 7 SCR\Figure 1- Site Location Map - AOI7.mxd

N
W
E
S

Legend

AOI Boundary

Notes:
1. Bing Maps aerial imagery provided by © 2010 Microsoft Corporation and its data suppliers and obtained under the licensing agreement with ESRI.

Figure 2: Site Plan
AOI-7 Site Characterization Report/
Remedial Investigation Report
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: February 10, 2012
DRN. BY: MH
CKD. BY: DW
JOB#: 2574601

N
W
E
S

Legend

- C-129D — New Deep Monitoring Well Location With No Shallow Soil Sample
- C-129 — New Shallow/Intermediate Groundwater Monitoring Well With Shallow Soil Sample
- C-132 — New Shallow/Intermediate Groundwater Monitoring Well With No Soil Sample
- BH-10-01 — New Shallow Soil Boring and Sample Locations (0-2 ft.)
- C-65D — Deep Monitoring Well
- C-104 — Shallow Monitoring Well
- C-128 — Abandoned/Damaged/Unable to Locate
- RIVER 4 — Staff Gauge
- Bulkhead
- Solid Waste Management Unit
- Area of Interest (AOI)

Notes:
1. Bing Maps aerial imagery provided by © 2010 Microsoft Corporation and its data suppliers and obtained under the licensing agreement with ESRI.

Figure 3 - Completed Activities Plan
AOI-7 Site Characterization Report/
Remedial Investigation Report
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: 2/10/2012
DRN. BY: MH
CKD. BY: DW
JOB#: 2574601

Legend

- Deep Monitoring Well
- Intermediate Monitoring Well
- Shallow Monitoring Well
- Shallow/Intermediate Monitoring Well
- Shallow/Intermediate Recovery Well
- Intermediate Recovery Well
- Piezometer
- Damaged/Abandoned/Unable to Locate
- Staff Gauge
- Cross Section Location (AA - AA')
- Cross Section Location (CC - CC')
- Cross Section Location (Z - Z')
- Area of Interest (AOI) Boundary

Notes:
1. Bing Maps aerial imagery provided by © 2010 Microsoft Corporation and its data suppliers and obtained under the licensing agreement with ESRI.

Figure 4 - Cross Section Location Plan
AOI-7 Site Characterization Report/
Remedial Investigation Report
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

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

0 100 200 400 Feet

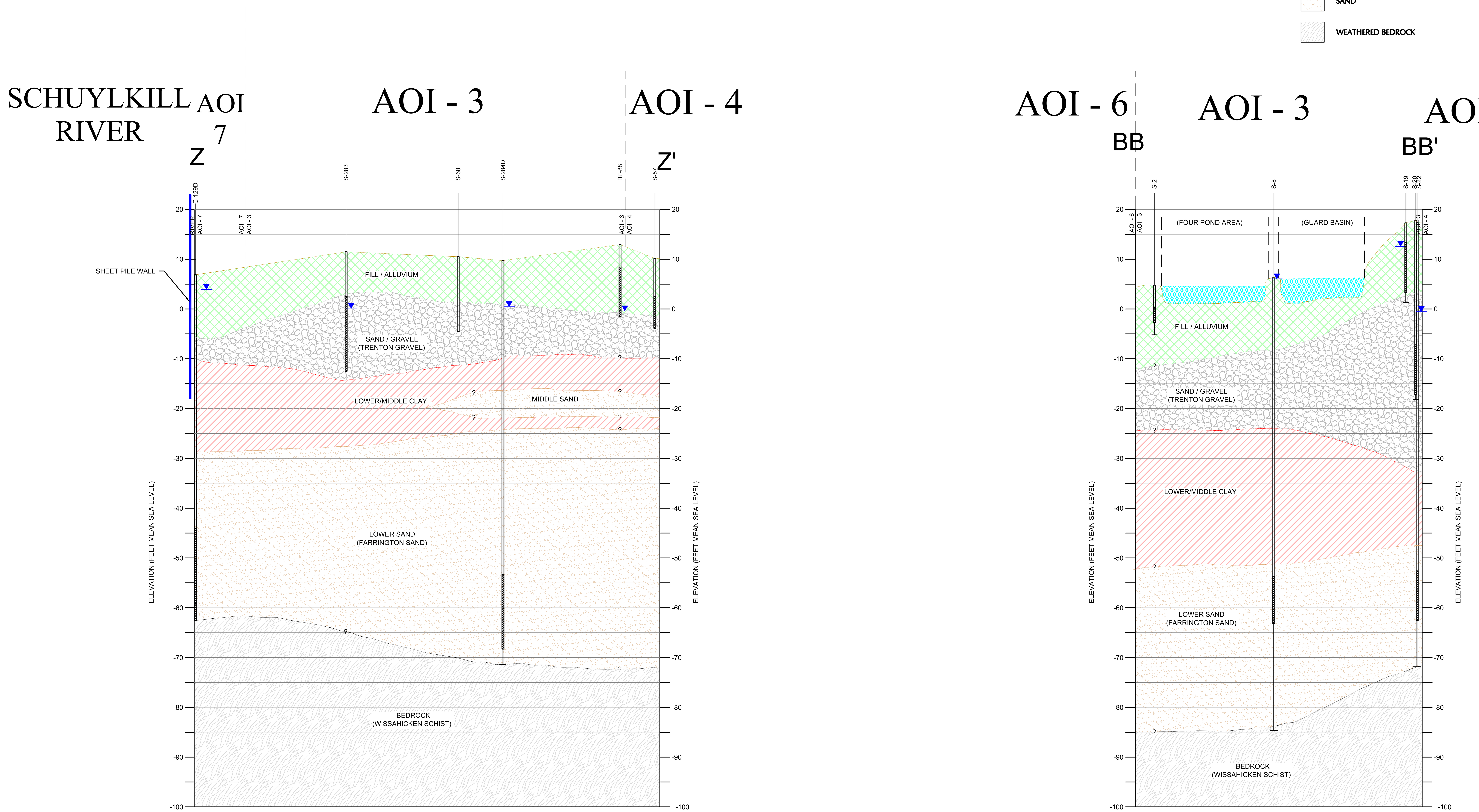
SCALE: 1" = 200'
DATE: February 10, 2012
DRN. BY: MH
CKD. BY: DW
JOB#: 2574601

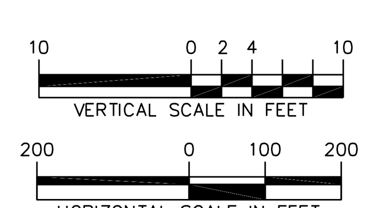
LEGEND:

- WATER
- FILL / ALLUVIUM
- TRENTON GRAVEL
- CLAY
- SAND
- WEATHERED BEDROCK
- C-129D — LOCATION ID
- WELL CASING/BOREHOLE
- WELL SCREEN
- BOTTOM OF BOREHOLE
- INFERRED CONTACTS
- GROUNDWATER LEVEL
- SHEET PILE WALL

NOTES:

1. LITHOLOGY BASED ON INTERPOLATION FROM AVAILABLE NEW AND HISTORIC WELL / SOIL BORING LOGS.
2. WELL SCREEN INTERVAL INFORMATION NOT AVAILABLE FOR S-2 AND S-68
3. DEPTH OF SHEET PILE WAS DETERMINED FROM FIGURE 2-8 GENERALIZED GEOLOGICAL CROSS SECTION A-C DATED NOVEMBER 13, 1992 FROM DAMES AND MOORE, RCRA VERIFICATION INVESTIGATION REPORT, CHEVERON REFINERY, 1992, CROSS SECTION RENAMED C-J IN CCR.
4. GROUNDWATER ELEVATIONS COLLECTED IN JULY 2010.





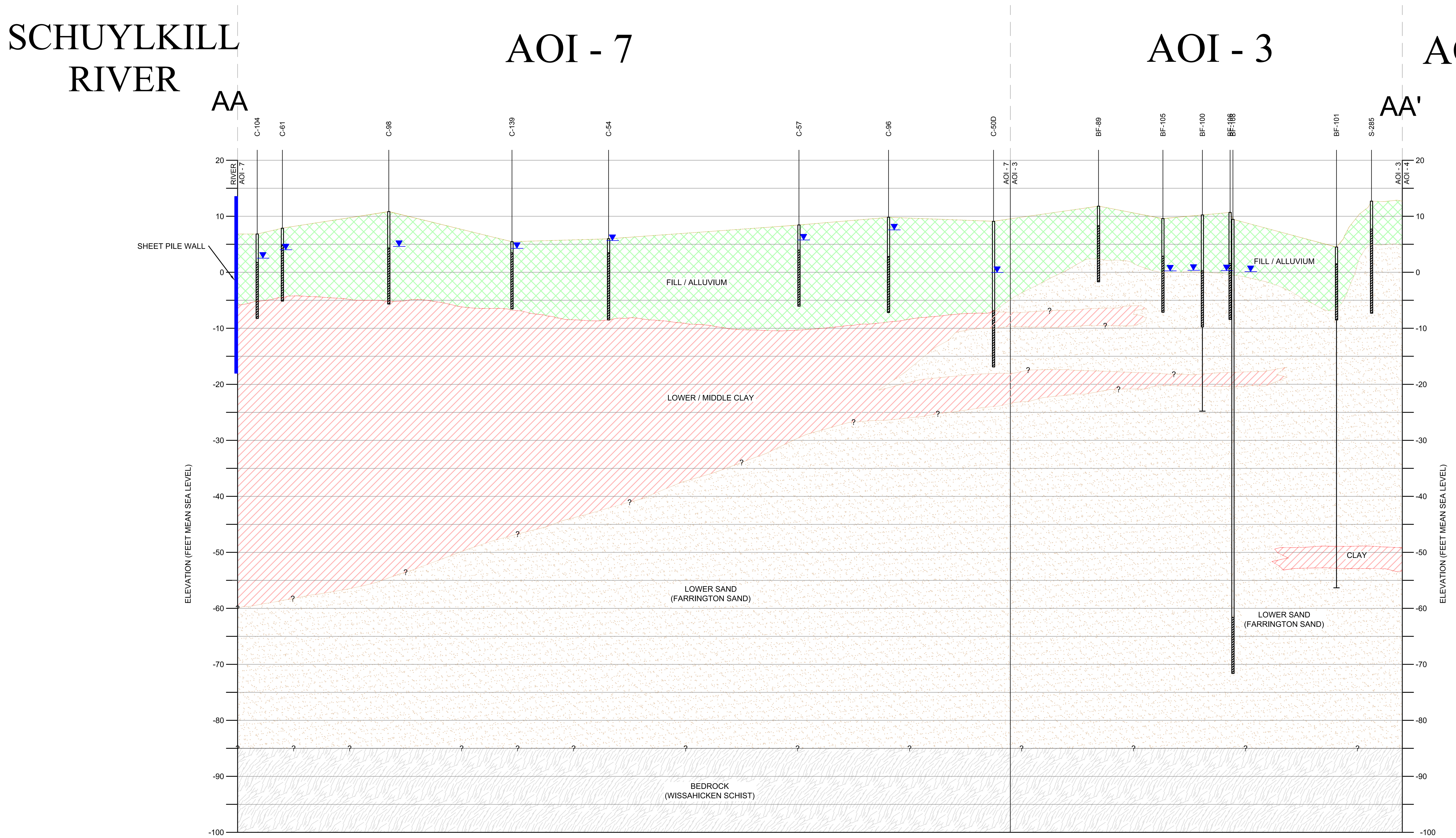
Project	Drawing Title	Project No. 2574601	Figure No.
SUNOCO PHILADELPHIA REFINERY PHILADELPHIA COUNTY PENNSYLVANIA	GEOLOGIC CROSS SECTION Z-Z' & GEOLOGIC CROSS SECTION BB-BB'	Date 8/26/10 Scale 1" = 200' HOR. 1" = 10' VER. Drn. By JEM Last Revised X	5A Of

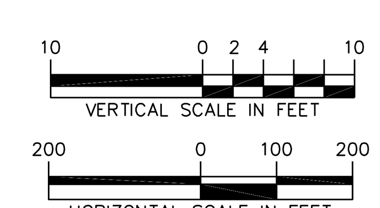
Filename: Q:\data6\2574601\Cadd Data - 2574601\Dwg\Geologic Cross-Sections\Cross-Section Z-Z'.dwg Date: 9/16/2010 Time: 10:29 User: jmoy Style Table: Langan.stb Layout: 5A

NOTES:
1. LITHOLOGY BASED ON INTERPOLATION FROM AVAILABLE NEW AND HISTORIC WELL / SOIL BORING LOGS.
2. DEPTH OF SHEET PILE WAS DETERMINED FROM FIGURE 2-8 GENERALIZED GEOLOGICAL CROSS SECTION A-C DATED NOVEMBER 13, 1992 FROM DAMES AND MOORE, RCRA VERIIFICATION INVESTIGATION REPORT, CHEVERON REFINERY, 1992, CROSS SECTION RENAMED C-J IN CCR
3. GROUNDWATER ELEVATIONS COLLECTED IN JULY 2010.
4. THICKNESS OF LOWER / MIDDLE CLAY IN AOI-7 IS ESTIMATED FROM DEEP MONITORING WELLS C-144D, C-134D, AND C-50D.

LEGEND:

FILL / ALLUVIUM
SAND / GRAVEL (TRENTON GRAVEL)
CLAY
SAND
BEDROCK (WISSAHICKON SCHIST)
C-129D LOCATION ID
WELL CASING/BOREHOLE
WELL SCREEN
BOTTOM OF BOREHOLE
INFERRED CONTACTS
GROUNDWATER LEVEL
SHEET PILE WALL





Project	Drawing Title	Project No. 2574601	Figure No.
SUNOCO PHILADELPHIA REFINERY	GEOLOGIC CROSS SECTION AA-AA'	Date 8/26/10	5B
PHILADELPHIA COUNTY PENNSYLVANIA		Scale 1" = 200' HOR. 1" = 10' VER.	
		Drn. By JEM	
		Last Revised X	Of

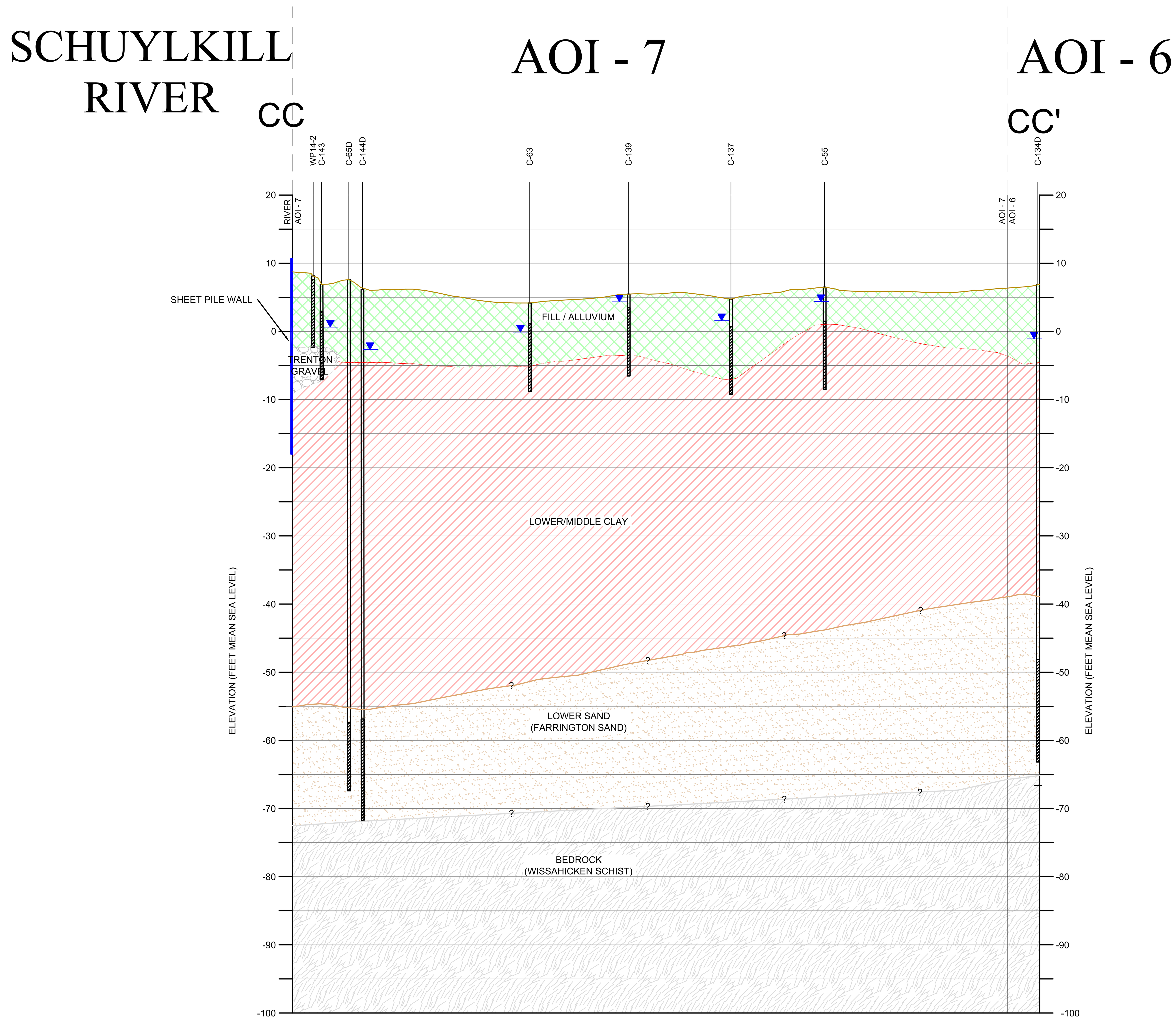
Filename: Q:\data6\2574601\Cadd Data – 2574601\Dwg\Geologic Cross-Sections\Cross-Section AA-AA'.dwg Date: 9/17/2010 Time: 11:04 User: jmay Style Table: Langan.stb Layout: 5B

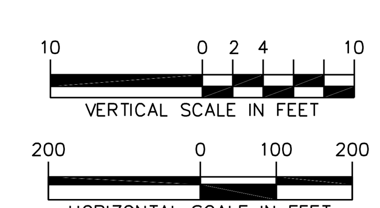
NOTES:

1. LITHOLOGY BASED ON INTERPOLATION FROM AVAILABLE NEW AND HISTORIC WELL / SOIL BORING LOGS.
2. DEPTH OF SHEET PILE WAS DETERMINED FROM FIGURE 2-8 GENERALIZED GEOLOGICAL CROSS SECTION A-C DATED NOVEMBER 13, 1992 FROM DAMES AND MOORE, RCRA VERIIFICATION INVESTIGATION REPORT, CHEVERON REFINERY, 1992, CROSS SECTION RENAMED C-J IN CCR
3. GROUNDWATER ELEVATIONS COLLECTED IN JULY 2010.

LEGEND:

- FILL / ALLUVIUM
- SAND / GRAVEL (TRENTON GRAVEL)
- CLAY
- SAND
- WEATHERED BEDROCK (WISSAHICKON SCHIST)
- C-129D LOCATION ID
- WELL CASING/BOREHOLE
- WELL SCREEN
- BOTTOM OF BOREHOLE
- ? ? INFERRED CONTACTS
- GROUNDWATER LEVEL
- SHEET PILE WALL





Project: SUNOCO PHILADELPHIA REFINERY PHILADELPHIA COUNTY PENNSYLVANIA	Drawing Title: GEOLOGIC CROSS SECTION CC-CC'	Project No. 2574601 Date 8/26/10 Scale 1" = 200' HOR. 1" = 10' VER. Drn. By JEM Last Revised X	Figure No. 5C Of

Filename: Q:\data6\2574601\Cadd Data - 2574601\Dwg\Geologic Cross-Sections\Cross-Section CC-CC'.dwg Date: 8/31/2010 Time: 16:50 User: jmay Style Table: Langan.stb Layout: 5C

N
W E
S

Legend

- Shallow Monitoring Well and Groundwater Elevation (ft. amsl) (C-56 8.89)
- Shallow/Intermediate Monitoring Well and Groundwater Elevation (ft. amsl) (C-130 9.6)
- Abandoned/Damaged/Unable to Locate (PH-40)
- Groundwater Contour (ft. amsl)
- Groundwater Contour Depression (ft. amsl)
- Bulkhead
- Solid Waste Management Unit (SWMU)
- Area of Interest (AOI) Boundary

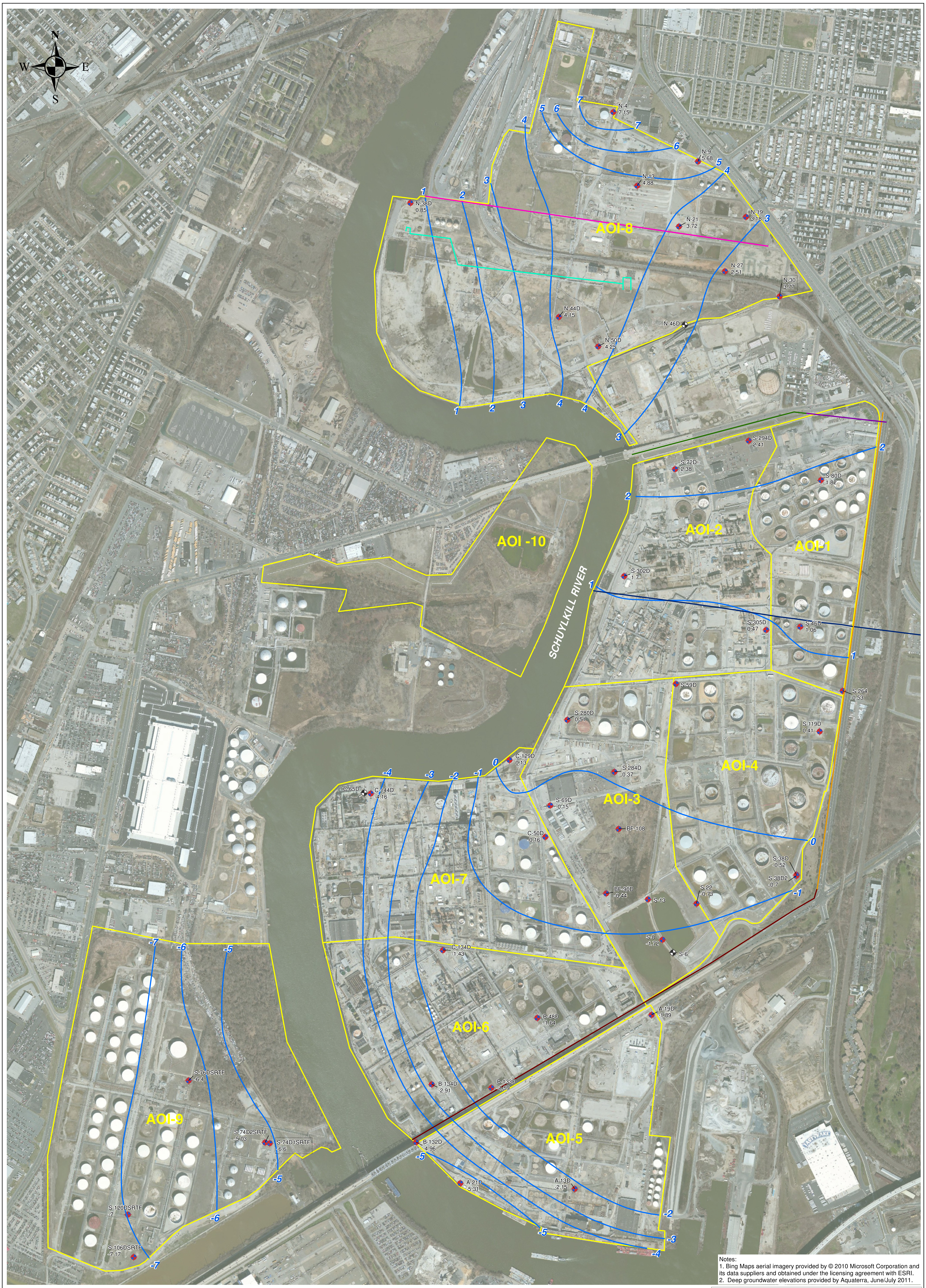
Notes:
1. Bing Maps aerial imagery provided by © 2010 Microsoft Corporation and its data suppliers and obtained under the licensing agreement with ESRI.
2. Groundwater elevations based on groundwater gauging data provided by Aquaterra, January 2012.

Figure 6 - Shallow/Intermediate Groundwater Elevation Contour Plan - January 2012
AOI-7 Site Characterization Report/
Remedial Investigation Report
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

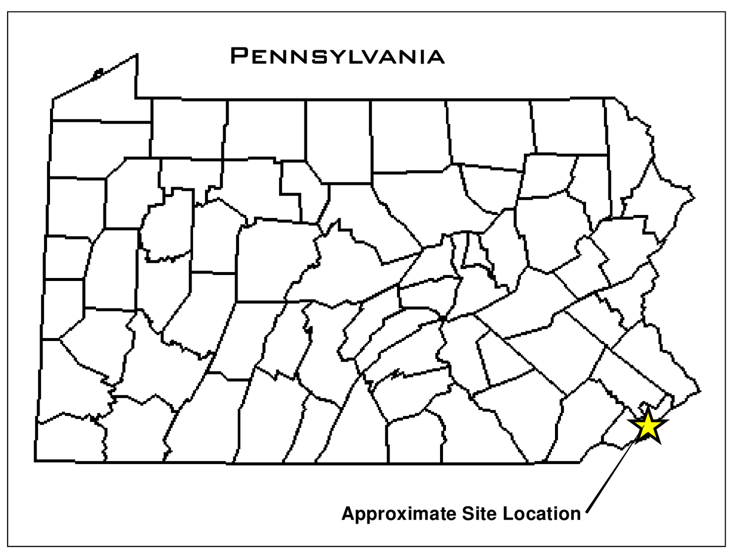
Sunoco, Inc. (R&M)
Philadelphia Refinery
3144 Passyunk Avenue
Philadelphia, PA.
19145

0 70 140 280 Feet

SCALE: 1" = 140'
DATE: February 13, 2012
DRN. BY: MH
CKD. BY: DW
JOB#: 2574601



Notes:
1. Bing Maps aerial imagery provided by © 2010 Microsoft Corporation and its data suppliers and obtained under the licensing agreement with ESRI.
2. Deep groundwater elevations provided by Aquaterra, June/July 2011.



Legend

S-119D 0.41	Deep Groundwater Monitoring Well and Groundwater Elevation
N-46D	Damaged/Abandoned/Unable to Locate
	Deep Groundwater Contour
	Penrose Avenue Sewer
	Pollock Street Sewer
	Passyunk Avenue Sewer
	Shunk Street Sewer
	26th Street Sewer
	Rambo Creek Sewer
	Jackson Street Sewer
	Area of Interest (AOI)
N-30 3.77	Wells Omitted From Contouring

Figure 7 - Site Wide Deep Groundwater Elevation Contour Plan - June/July 2011
AOI-7 Site Characterizaton Report/
Remedial Investigation Report
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

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

0 250 500 1,000 Feet

Path: \\langan.com\data\DT\data6\2574601\ArcGIS\MapDocuments\AOI 7 SCR\SCR_RIR\Figure 7 - AOI-7 Deep GW Contours_2-13-12.mxd

N
W E
S

Legend

- New Shallow Soil Boring Location With No Exceedance of PADEP Non-Res Soil MSCs
- New Shallow Soil Boring Location With Exceedance of PADEP Non-Res Soil MSCs
- New Monitoring Well Location With Shallow Soil Sample Not Exceeding PADEP Non-Res Soil MSCs
- New Monitoring Well Location With Shallow Soil Sample Exceeding PADEP Non-Res Soil MSCs
- New Monitoring Well Location With No Shallow Soil Sample Collected
- Existing Monitoring Point
- Existing Recovery Well
- Abandoned/Damaged/Unable to Locate
- Bulkhead
- Area of Interest (AOI) Boundary
- Solid Waste Management Unit (SWMU)
- Lead Exceedance of Site Specific Standard (1,708 mg/kg)

PADEP Non-Residential Used Aquifer TDS <2,500 mg/L Soil MSCs

Benzene = 0.5 mg/kg
1,3,5 TMB = 9.3 mg/kg
1,2,4 TMB = 35 mg/kg
Napthalene = 25 mg/kg
Lead = 450 mg/kg

Site-Specific Standards Derived From Risk Assessment Analysis:

Benzene = 2,870 mg/kg
1,2,4 TMB = 560 mg/kg
Napthalene = 56,780 mg/kg
Lead = 1,708 mg/kg

Notes:
1. Bing Maps aerial imagery provided by © 2010 Microsoft Corporation and its data suppliers and obtained under the licensing agreement with ESRI.
2. Soil Samples collected in May-June 2010.

Figure 8 - Summary of Soil Sample Exceedances
May to June 2010
AOI-7 Site Characterization Report/
Remedial Investigation Report
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

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

0 70 140 280
Feet

N
W
E
S

Legend

- Shallow/Intermediate Monitoring Wells With Exceedance of PADEP Non-Res Groundwater MSCs
- Shallow/Intermediate Monitoring Well With LNAPL Occurrence
- Shallow/Intermediate Monitoring Well With No Exceedance of PADEP Non-Res Groundwater MSCs
- Deep (Lower Sand) Monitoring Well With No Exceedance of PADEP Non-Res Groundwater MSCs
- Monitoring Point Not Sampled
- Bulkhead
- Solid Waste Management Unit
- Area of Interest (AOI) Boundary

Notes:
1. Bing Maps aerial imagery provided by © 2010 Microsoft Corporation and its data suppliers and obtained under the licensing agreement with ESRI.
2. Groundwater samples collected in July 2010 and January 2012 by Aquaterra.

Figure 9 - Summary of Groundwater Sample Exceedances - July 2010 and January 2012
AOI-7 Site Characterization Report/ Remedial Investigation Report
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

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

0 70 140 280
Feet

Legend

- Shallow/Intermediate Monitoring Well with Apparent LNAPL Thickness (ft.)
- Shallow Monitoring Well with Apparent LNAPL Thickness (ft.)
- Monitoring Wells with No LNAPL
- Monitoring Wells Destroyed/Unable to Locate
- Staff Gauge Location
- Bulkhead
- Occupied Buildings
- Solid Waste Management Unit
- Area of Interest (AOI) Boundary

Light Non-Aqueous Phase Liquids (LNAPL) Types

- Lube Oil
- Residual Oil
- Middle Distillate
- Light Crude Oil

Notes:
1. Bing Maps aerial imagery provided by © 2010 Microsoft Corporation and its data suppliers and obtained under the licensing agreement with ESRI.
2. LNAPL thickness based on the January 2012 groundwater gauging event.

Figure 10 - Apparent LNAPL Thickness and Type
AOI-7 Site Characterization Report/
Remedial Investigation Report
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: February 13, 2012
DRN. BY: MH
CKD. BY: DW
JOB#: 2574601

N
W E
S

Legend

- Bulkhead
- Impervious Surfaces
- Area of Interest (AOI) Boundary

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

Figure 11 - Impervious Surfaces
AOI-7 Site Characterization/
Remedial Investigation Report
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: 8/10/2010
DRN. BY: MH
CKD. BY: DW
JOB#: 2574601

APPENDIX A

Notice of Intent to Remediate and Public Notices

Philadelphia Refinery

Sunoco Inc.
3144 Passyunk Avenue
Philadelphia PA 19145-5299
215 339 2000

October 12, 2006

Mr. Robert Day-Lewis
Pennsylvania DEP
2 East Main Street
Norristown, PA 19401

Mr. Steve O'Neil
Pennsylvania DEP
2 East Main Street
Norristown, PA 19401

Re: Sunoco Inc. (R&M) Philadelphia Refinery
Philadelphia, Philadelphia County

Dear Mr. Day-Lewis and Mr. O'Neil:

In accordance with the Land Recycling and Environmental Remediation Standards Act (Act 2), enclosed are two copies of a Notice of Intent to Remediate (NIR) for the Sunoco Inc. (R&M) Philadelphia Refinery. This NIR covers remediation being done as part of the 2003 Consent Order and Agreement (CO&A) at Point Breeze, Girard Point and Schuylkill River Tank Farm. Remediation at Belmont Terminal, which is part of the CO&A, is not part of this NIR since this site is not subject to RCRA Corrective Action. Sunoco is considering submitting a separate NIR for this area under the Act 2 program only.

This NIR is being submitted with the intent to enter the Sunoco Philadelphia Refinery into the One Cleanup Program with PaDEP and the USEPA. All remediation work at the Philadelphia refinery will be completed under the 2003 Consent Order & Agreement (CO&A), however, RCRA Corrective Action measures will be addressed concurrently with work performed under the CO&A and within the Act 2 program.

Please call me at 610-859-1881 or email me at jroppenheim@sunocoinc.com with any questions or comments.

Best Regards,

James Oppenheim, PE
Sr. Environmental Consultant

Cc: Sunoco Legal Dept.
Philadelphia Refinery Environmental Central File
David Burke, PADEP
Walter Payne, PADEP
Hon Lee, USEPA Region III
Colleen Costello, Langan

2530-FM-BWM0019 Rev. 4/2004

Will remediation be to a site-specific standard ☒ or as a special industrial area ☐? If so, the municipality or municipalities must be provided 30-day comment period.
Remediator/Property Owner/Consultant. For each of these recipients of the approval of the final report, complete form below.

Remediator
Contact Person: James R. Oppenheim
Relationship to site (e.g. owner, remediator, participating in cleanup, consultant): Remediation Project Manager
Phone Number: (610) 859-1881
Company Name: Sunoco, Inc. (R&M)
Address (street, city, state, zip): 100 Green St., Marcus Hook, PA 19061
Email Address: jroppenheim@sunocoinc.com
Property Owner
Contact Person: Scott Baker
Relationship to site (e.g. owner, remediator, participating in cleanup, consultant): Environmental Manager
Phone Number: (215) 339-2074
Company Name: Sunoco, Inc. (R&M)
Address (street, city, state, zip): 3144 Passyunk Ave. Philadelphia, PA 19145
Email Address: sabaker@sunocoinc.com
Consultant
Contact Person: Colleen Costello
Relationship to site (e.g. owner, remediator, participating in cleanup, consultant): Consultant
Phone Number: (215) 864-0640
Company Name: Langan Engineering and Environmental Services
Address (street, city, state, zip): 30 South 17th St., Suite 1500, Philadelphia, PA 19103
Email Address: ccostello@langan.com

Preparer of Notice of Intent to Remediate:

Name: James Oppenheim

Address: 100 Green Street
Marcus Hook, PA 19061

Email Address: jroppenheim@sunocoinc.com

Title: Project Manager

Telephone: (610) 859-1881

Email Image File of Site Map showing property lines and general area of site(s) to be remediated to: (landrecycling@state.pa.us)

Philadelphia Refinery

Sunoco Inc.
3144 Passyunk Avenue
Philadelphia PA 19145-5299
215 339 2000

October 12, 2006

Manager
Philadelphia Department of Public Health
Environmental Health Services
321 University Avenue
Philadelphia, PA 19104

Re: Sunoco, Inc. (R&M) Philadelphia Refinery
Philadelphia, Philadelphia County

Dear Sir/Madam:

The Land Recycling and Environmental Remediation Standards Act (Act 2) requires that a Notice of Intent to Remediate (NIR) be provided to the municipality in which the site is located when a site is being remediated to a site-specific Standard. The municipality is afforded a 30-day comment period. In accordance with this provision of the Act, Sunoco, Inc. (R&M) is formally notifying you of its intent to remediate the subject site under Act 2. A copy of the NIR, which will be sent to the Pennsylvania Department of Environmental Protection (PaDEP), is enclosed. This notice will also be published in the Pennsylvania Bulletin, and a summary of the notice appeared in the Philadelphia Daily News on October 16, 2006.

Publication of this notice in the Philadelphia Daily News initiates the 30-day public and municipal comment period. During the next thirty days, your municipality may request to become involved in the development of the remediation plans for the site. If the municipality wishes to become involved in this project, please send your comments to Sunoco to my attention.

Please call me at (610) 859-1881 if you have any questions concerning the proposed remediation.

Best Regards,

James R. Oppenheim, P.E.
Senior Environmental Consultant

Cc: Sunoco Legal Dept.
Philadelphia Refinery Environmental Central File
Steve O'Neil, PaDEP
Colleen Costello, Langan

Will remediation be to a site-specific standard ☒ or as a special industrial area ☐? If so, the municipality or municipalities must be provided 30-day comment period.
Remediator/Property Owner/Consultant. For each of these recipients of the approval of the final report, complete form below.

Remediator
Contact Person: James R. Oppenheim
Relationship to site (e.g. owner, remediator, participating in cleanup, consultant): Remediation Project Manager
Phone Number: (610) 859-1881
Company Name: Sunoco, Inc. (R&M)
Address (street, city, state, zip): 100 Green St., Marcus Hook, PA 19061
Email Address: jroppenheim@sunocoinc.com
Property Owner
Contact Person: Scott Baker
Relationship to site (e.g. owner, remediator, participating in cleanup, consultant): Environmental Manager
Phone Number: (215) 339-2074
Company Name: Sunoco, Inc. (R&M)
Address (street, city, state, zip): 3144 Passyunk Ave. Philadelphia, PA 19145
Email Address: sabaker@sunocoinc.com
Consultant
Contact Person: Colleen Costello
Relationship to site (e.g. owner, remediator, participating in cleanup, consultant): Consultant
Phone Number: (215) 864-0640
Company Name: Langan Engineering and Environmental Services
Address (street, city, state, zip): 30 South 17th St., Suite 1500, Philadelphia, PA 19103
Email Address: ccostello@langan.com

Preparer of Notice of Intent to Remediate:

Name: James Oppenheim

Title: Project Manager

Address: 100 Green Street
Marcus Hook, PA 19061

Telephone: (610) 859-1881

Email Address: jroppenheim@sunocoinc.com

Email Image File of Site Map showing property lines and general area of site(s) to be remediated to: (landrecycling@state.pa.us)

Proof of Publication in The Philadelphia Daily News
Under Act. No 587, Approved May 16, 1929

STATE OF PENNSYLVANIA
COUNTY OF PHILADELPHIA

Anna Dickerson being duly sworn, deposes and says that **The Philadelphia Daily News** is a newspaper published daily, except Sunday, at Philadelphia, Pennsylvania, and was established in said city in 1925, since which date said newspaper has been regularly issued in said County, and that a copy of the printed notice of publication is attached hereto exactly as the same was printed and published in the regular editions and issues of the said newspaper on the following dates:

October 16, 2006

Affiant further deposes and says that he is an employee of the publisher of said newspaper and has been authorized to verify the foregoing statement and that he is not interested in the subject matter of the aforesaid notice of publication, and that all allegations in the foregoing statement as to time, place and character of publication are true.

Anna Dickerson

Sworn to and subscribed before me this 16th day of October 2006

Mary Anne Logan
Notary Public

My Commission Expires:

NOTARIAL SEAL
Mary Anne Logan, Notary Public
City of Philadelphia, Phila. County
My Commission Expires March 30, 2009

Copy of Notice of Publication

Newspaper Notice of Intent to Remediate to an Environmental Standard. (Sections 302(e)(1)(ii), 303(h)(1)(ii), 304(n)(1)(i), and 305(c)(1))

Pursuant to the Land Recycling and Environmental Remediation Standards Act (Act), the act of May 19, 1995, P.L. 4, No. 1995-2., notice is hereby given that Sunoco Inc.(R&M) has submitted to the Pennsylvania Department of Environmental Protection a Notice of Intent to Remediate a site located at 3144 Passyunk Ave., Philadelphia, Philadelphia County, Pennsylvania. This Notice of Intent to Remediate states that the site is a petroleum refinery. It has been determined that petroleum compounds have impacted soil and groundwater at the site. Sunoco Inc. (R&M) has indicated that proposed remediation measures will include source re-duction and engineered boundary controls. The proposed future use of the property is industrial for continued operation as a petroleum refinery.

Sunoco Inc. (R&M) plans to use the site-specific remediation standard at the site. The Act provides for a 30-day public comment period for site-specific standard remediation. The 30-day comment period is initiated with the publication of this notice. Until November 16, 2006, the City of Philadelphia may submit a request to Sunoco Inc. (R&M) to be involved in the development of the remediation and reuse plans for the site. The City of Philadelphia may also submit a request to Sunoco Inc. (R&M) during this 30-day comment period to develop and implement a public involvement plan. Copies of these requests and of any comments should also be submitted to the Department of Environmental Protection at 2 East Main Street, Norristown, PA 19401 to the attention of Mr. Walter Payne. All correspondence with Sunoco Inc. (R&M) should be addressed to the Public Relations Dept., Sunoco Inc. (R&M) at 3144 Passyunk Ave, Philadelphia, PA, 19145.

LEGAL NOTICES

Newspaper Notice of Intent to Remediate
to an Environmental Standard.
(Sections 302(e)(1)(ii), 303(h)(1)(ii),
304(n)(1)(i), and 305(c)(1))

Pursuant to the Land Recycling and Environmental Remediation Standards Act (Act), the act of May 19, 1995, P.L. 4, No. 1995-2., notice is hereby given that Sunoco Inc.(R&M) has submitted to the Pennsylvania Department of Environmental Protection a Notice of Intent to Remediate a site located at 3144 Passyunk Ave., Philadelphia, Philadelphia County, Pennsylvania. This Notice of Intent to Remediate states that the site is a petroleum refinery. It has been determined that petroleum compounds have impacted soil and groundwater at the site. Sunoco Inc. (R&M) has indicated that proposed remediation measures will include source reduction and engineered boundary controls. The proposed future use of the property is industrial for continued operation as a petroleum refinery.

Sunoco Inc. (R&M) plans to use the site-specific remediation standard at the site. The Act provides for a 30-day public comment period for site-specific standard remediation. The 30-day comment period is initiated with the publication of this notice. Until November 16, 2006, the City of Philadelphia may submit a request to Sunoco Inc. (R&M) to be involved in the development of the remediation and reuse plans for the site. The City of Philadelphia may also submit a request to Sunoco Inc. (R&M) during this 30-day comment period to develop and implement a public involvement plan. Copies of these requests and of any comments should also be submitted to the Department of Environmental Protection at 2 East Main Street, Norristown, PA 19401 to the attention of Mr. Walter Payne. All correspondence with Sunoco Inc. (R&M) should be addressed to the Public Relations Dept., Sunoco Inc. (R&M) at 3144 Passyunk Ave, Philadelphia, PA, 19145.

Appeared in: ***Philadelphia Inquirer & Philadelphia Daily News*** on Monday, 10/16/2006

Back

LANGAN
ENGINEERING & ENVIRONMENTAL SERVICES

January 24, 2012

CERTIFIED MAIL
RETURN RECEIPT REQUESTED

Manager
Philadelphia Department of Public Health
Environmental Health Services
321 University Avenue
Philadelphia, Pennsylvania 19104

RE: **Notice of Submittal of Site Characterization/**
Remedial Investigation Report
Area of Interest (AOI) 7
Sunoco, Inc. (R&M) Philadelphia Refinery
Philadelphia, Philadelphia County, Pennsylvania
Langan Project No.: 2574601

Dear Sir/Madam:

Notice is hereby given that Sunoco, Inc. (R&M) (Sunoco) is in the process of submitting a Site Characterization/Remedial Investigation Report to the Pennsylvania Department of Environmental Protection for AOI 7 located at the Sunoco Philadelphia Refinery, Philadelphia, Philadelphia County, Pennsylvania. The report indicates that the remediation planned will attain compliance with a combination of site-specific and the statewide health cleanup standards.

This notice is made under the provision of the Land Recycling and Environmental Standards Act, the Act of May 19, 1995, P.L. #4, No. 2.

Sincerely,
Langan Engineering and Environmental Services, Inc.

Colleen Costello

Colleen Costello, P.G.
Senior Principal

cc: Jim Oppenheim, Sunoco
Kevin Dunleavy, Sunoco

\\langan.com\data\DT\data6\2574601\Office Data\Reports\Repackaged SCR_RIR\AOI 7\Appendices\Appendix A - NIR and Notices\RIR Municipal Notice_012412.DOC

SENDER: *COMPLETE THIS SECTION*

- Complete items 1, 2, and 3. Also complete item 4 if Restricted Delivery is desired.
- Print your name and address on the reverse so that we can return the card to you.
- Attach this card to the back of the mailpiece, or on the front if space permits.

1. Article Addressed to:

Manager
Philadelphia Dept. of Public Health
Environmental Health Services
321 University Avenue
Philadelphia, Pennsylvania 19104

COMPLETE THIS SECTION ON DELIVERY

A. Signature
X [signature] ☑ Agent ☐ Addressee

B. Received by (*Printed Name*) Joaquin Kent

C. Date of Delivery 1/26/12

D. Is delivery address different from item 1? ☐ Yes
If YES, enter delivery address below: ☑ No

3. Service Type
☑ Certified Mail ☐ Express Mail
☐ Registered ☑ Return Receipt for Merchandise
☐ Insured Mail ☐ C.O.D.

4. Restricted Delivery? *(Extra Fee)* ☐ Yes

2. Article Number
(Transfer from service label) 7011 1150 0001 9432 0713

PS Form 3811, February 2004 Domestic Return Receipt 102595-02-M-1540

7011 1150 0001 9432 0713

U.S. Postal Service™
CERTIFIED MAIL™ RECEIPT
(Domestic Mail Only; No Insurance Coverage Provided)

For delivery information visit our website at www.usps.com®

OFFICIAL USE

Postage	$ .45
Certified Fee	2.95
Return Receipt Fee (Endorsement Required)	2.35
Restricted Delivery Fee (Endorsement Required)	
Total Postage & Fees	$ 5.75

Postmark Here

USPS DOYLESTOWN JAN 24 2012

Cindy

Sent To Manager
Philadelphia Dept. of Public Health
~~Environmental Health Services~~

Street, Apt. No.; or PO Box No. 321 University Avenue

City, State, ZIP+4 Philadelphia, Pennsylvania 19104

PS Form 3800, August 2006 See Reverse for Instructions

Proof of Publication in The Philadelphia Daily News
Under Act. No 587, Approved May 16, 1929

STATE OF PENNSYLVANIA
COUNTY OF PHILADELPHIA

Anna Dickerson being duly sworn, deposes and says that **The Philadelphia Daily News** is a newspaper published daily, except Sunday, at Philadelphia, Pennsylvania, and was established in said city in 1925, since which date said newspaper has been regularly issued in said County, and that a copy of the printed notice of publication is attached hereto exactly as the same was printed and published in the regular editions and issues of the said newspaper on the following dates:

January 30, 2012

Affiant further deposes and says that she is an employee of the publisher of said newspaper and has been authorized to verify the foregoing statement and that she is not interested in the subject matter of the aforesaid notice of publication, and that all allegations in the foregoing statement as to time, place and character of publication are true.

Anna Dickerson

Sworn to and subscribed before me this 30th day of January, 2012.

Mary Anne Logan
Notary Public

My Commission Expires:

NOTARIAL SEAL
Mary Anne Logan, Notary Public
City of Philadelphia, Phila. County
My Commission Expires March 30, 2013

Copy of Notice of Publication

Notification of Receipt of Site Characterization/ Remedial Investigation Report

Notice is hereby given that Sunoco Inc. (R&M) (Sunoco) is in the process of submitting a Site Characterization / Remedial Investigation Report to the Pennsylvania Department of Environmental Protection (PADEP), Southeast Regional Office for Area of Interest (AOI 7) located at the Sunoco Philadelphia Refinery, Philadelphia, Pennsylvania. Sunoco has indicated in the report that site characterization activities have been completed at AOI 7 in accordance with the Land Recycling and Environmental Remediation Standards Act and the 2004 Memorandum of Agreement between the PADEP and U.S. Environmental Protection Agency (EPA) (a.k.a., the PA One Cleanup Program). This notice is made under the provision of the Land Recycling and Environmental Remediation Standards Act, the Act of May 19, 1995, P.L. #4, No. 2.

APPENDIX B

Current and Historic Use Plan

Legend

- New Deep Monitoring Well Location With No Shallow Soil Sample (C-129D)
- New Shallow/Intermediate Groundwater Monitoring Well With Shallow Soil Sample (C-129)
- New Shallow/Intermediate Groundwater Monitoring Well With No Soil Sample (C-132)
- New Shallow Soil Boring and Sample Locations (0-2 ft.) (BH-10-01)
- Deep Monitoring Well (C-65D)
- Shallow Monitoring Well (C-104)
- Abandoned/Damaged/Unable to Locate (C-128)
- Staff Gauge (GP-2)
- Bulkhead
- Area of Interest (AOI)

Existing, Historical Investigation and Historic Use Areas

- Impervious Surfaces
- Tank 270 Historic Investigation Area
- Tank 271 Historic Investigation Area
- Occupied Buildings
- Historic Use Areas
- Solid Waste Management Unit (SWMU)

Notes:
1. Bing Maps aerial imagery provided by © 2010 Microsoft Corporation and its data suppliers and obtained under the licensing agreement with ESRI.

Appendix B - Current and Historic Use/Historic Investigation Areas
AOI-7 Site Characterization Report/
Remedial Investigation Report
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: February 14, 2012
DRN. BY: MH
CKD. BY: DW
JOB#: 2574601

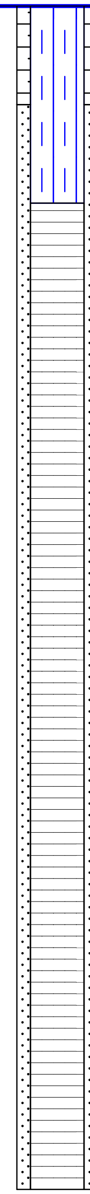
APPENDIX C

Soil Boring Logs and Monitoring Well Construction Summaries

MONITORING WELL LOG: C-129

PRO[illegible]ECT:	Sunoco-Philadelphia Refinery	DRILLING CO[illegible]	Parratt Wolff
SITE LOCATION:	AOI-7	DRILLING METHOD:	Hollow Stem Auger
[illegible]OB NO[illegible]		SAMPLING METHOD:	Split Spoon
LOGGED BY:	Shaun Sykes	SCREEN/RISER DIAMETER:	4"
DATES DRILLED:	6/2/2010	WELLBORE DIAMETER:	6"
TOTAL DEPTH:	12'	ELEVATION:	N/A

D[illegible] ([illegible])	OVM ([illegible])	USCS	LITHOLOGY	COMMENTS	WELL CONSTRUCTION	WELL DIAGRAM
0			6[illegible] [illegible] [illegible] [illegible] [illegible] [illegible]	H[illegible] [illegible] [illegible] 8'		
			A[illegible]1' [illegible] 3' [illegible] S[illegible]		4' PVC R[illegible]	
-5					S[illegible] 0-12'	
	0[illegible]0		25[illegible] [illegible] - M[illegible] [illegible]		10' PVC S[illegible]	
	0[illegible]0					
-10	0[illegible]0		25[illegible] [illegible] - W[illegible] [illegible]			
	0[illegible]0			H[illegible] [illegible] 14'		
	0[illegible]0		100[illegible] [illegible] - D[illegible] [illegible]/[illegible]/[illegible]/[illegible] [illegible] (13') B[illegible] [illegible]			
	0[illegible]0					



Aquaterra Technologies, Inc.

MONITORING WELL LOG: C-129 D

PRO[illegible]ECT	Sunoco-Philadelphia Refinery	DRILLING CO[illegible]	ECDI
SITE LOCATION	AOI-7	DRILLING METHOD	Hollow Stem Auger & Mud Rotary
[illegible]OB NO[illegible]		SAMPLING METHOD	Split Spoon
LOGGED BY	Tiffani Doerr/Shaun Sikes	SCREEN/RISER DIAMETER	4-inch
DATES DRILLED	6/22/10-6/25/10	WELLBORE DIAMETER	6.25"
TOTAL DEPTH	66'	ELEVATION	NA

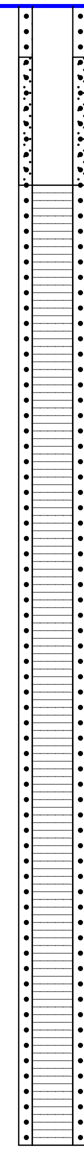
D[illegible] ([illegible])	OVM ([illegible])	USCS	LITHOLOGY	COMMENTS	WELL CONSTRUCTION	WELL DIAGRAM
0			C[illegible] 6[illegible]- [illegible] W[illegible] [illegible]3' [illegible]	H[illegible] 8'		
-5						
-10	0[illegible]0		(BC[illegible]12-21-18-12) 10[illegible] R[illegible] - [illegible]/[illegible] ([illegible])		G[illegible]/[illegible] (0'-47')	
	0[illegible]0					
	0[illegible]0		(BC[illegible]8-10-12-8) 12[illegible]R[illegible]- [illegible] 12[illegible]5'[illegible] R[illegible]/[illegible] SAND[illegible] 14'[illegible]			
	0[illegible]0					
	0[illegible]1		(BC[illegible]10-7-9-12) C[illegible]			
-15	0[illegible]0					
	1[illegible]0		(BC[illegible]9-15-18-21) 16'-17' [illegible] A[illegible]17' - D[illegible]/[illegible] CLAY [illegible]			
	0[illegible]9					
	0[illegible]0		(BC[illegible]2-2-1-2) S[illegible] - 19'-20' [illegible]/[illegible] C[illegible] S[illegible]			
	0[illegible]0					
-20	0[illegible]0		(BC[illegible]3-2-1-1) S[illegible] C[illegible] S[illegible]/[illegible] CLAY [illegible]			
	0[illegible]0					

MONITORING WELL LOG: C-129 D

D[illegible] ([illegible])	OVM ([illegible])	USCS	LITHOLOGY	COMMENTS	WELL CONSTRUCTION	WELL DIAGRAM
	0[illegible]0		(BC[illegible]1-2-2-1) S[illegible] [illegible] 22[illegible]5' - [illegible] [illegible]-[illegible] S[illegible] [illegible]			
	0[illegible]0					
	0[illegible]0		(BC[illegible]3-2-2-1) D[illegible]/[illegible] CLAY [illegible]			
-25	0[illegible]0					
	0[illegible]0		(BC[illegible]2-2-2-1) S[illegible] [illegible]			
	0[illegible]0					
	0[illegible]0		(BC[illegible]3-2-1-2) S[illegible]			
	0[illegible]0					
-30	0[illegible]0		(BC[illegible]1-1-1-2) S[illegible] [illegible]			
	0[illegible]0					
	0[illegible]0		(BC[illegible]1-1-2-3) S[illegible] [illegible]			
	0[illegible]0					
	0[illegible]0		(BC[illegible]4-8-9-5) S[illegible] 35'[illegible] A[illegible] 35' [illegible]/[illegible] SAND [illegible] GRAVEL[illegible]			
-35	0[illegible]0					
			(BC[illegible]5-5-8-12) N[illegible] [illegible]-[illegible]			
			(BC[illegible]3-8-7-8) S[illegible] [illegible]/[illegible] ([illegible]-[illegible])[illegible]			
	0[illegible]0					
-40			(BC[illegible]9-9-8-14) S[illegible] [illegible]/ [illegible]			
	0[illegible]0					
-45			(BC[illegible]28-42-100/5) 8[illegible]R[illegible] - 1[illegible] SILT/[illegible] SAND [illegible] 1[illegible] CLAY [illegible]			
	0[illegible]0					
					[illegible]00 S[illegible] (47'-49')	

MONITORING WELL LOG: C-129 D

D[illegible] ([illegible])	OVM ([illegible])	USCS	LITHOLOGY	COMMENTS	WELL CONSTRUCTION	WELL DIAGRAM
-50			(BC[illegible]8-14-22-24) V[illegible] [illegible] [illegible] - [illegible] [illegible](1-2[illegible]) [illegible] [illegible] [illegible] [illegible] [illegible]		[illegible]1 S[illegible] (49'-66') S[illegible] (51'-66')	
-55	0[illegible]0		(BC[illegible]18-17-42-50/2) 6[illegible] R[illegible] - [illegible]-[illegible] SAND [illegible] [illegible] [illegible] [illegible] [illegible]			
-60			S[illegible] [illegible] [illegible] [illegible]	M[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] 69'		
-65			S[illegible] [illegible] [illegible] [illegible]			



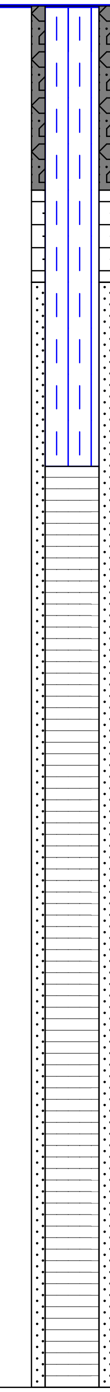
MONITORING WELL LOG: C-130

Aquaterra Technologies, Inc.

PRO[illegible]ECT[illegible]	Sunoco-Philadelphia Refinery	DRILLING CO[illegible]	Parratt Wolff
SITE LOCATION[illegible]	AOI-7	DRILLING METHOD[illegible]	Hollow Stem Auger
[illegible]OB NO[illegible]		SAMPLING METHOD[illegible]	Split Spoon
LOGGED BY[illegible]	Shaun Sykes	SCREEN/RISER DIAMETER[illegible]	4"
DATES DRILLED[illegible]	6/2/2010	WELLBORE DIAMETER[illegible]	6"
TOTAL DEPTH[illegible]	15'	ELEVATION[illegible]	N/A

D[illegible] ([illegible])	OVM ([illegible])	USCS	LITHOLOGY	COMMENTS	WELL CONSTRUCTION
0				H[illegible] [illegible] [illegible] 8'	
	0[illegible]0		100[illegible] [illegible] - G[illegible] [illegible] [illegible] [illegible] (2') B[illegible] [illegible] [illegible] [illegible] [illegible]		
	2[illegible]2		C[illegible] [illegible] 8' - [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]		5' PVC R[illegible]
-5					
					S[illegible] 0-12'
			W[illegible]7'		
	0[illegible]0		50[illegible] [illegible] - D[illegible] [illegible] [illegible]/[illegible] [illegible] [illegible] [illegible] [illegible]		10' PVC S[illegible]
	0[illegible]0				
-10	0[illegible]0		25[illegible] [illegible] - D[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]		
	0[illegible]0			H[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] 15'	
	0[illegible]0		100[illegible] [illegible] - D[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]		
	0[illegible]0				
	0[illegible]0		25[illegible] [illegible] - S[illegible] [illegible] [illegible] [illegible]		
-15					

WELL DIAGRAM



MONITORING WELL LOG: C-131

Aquaterra Technologies, Inc.

PRO[illegible]ECT	Sunoco-Philadelphia Refinery	DRILLING CO[illegible]	Parratt Wolff
SITE LOCATION	AOI-7	DRILLING METHOD	Hollow Stem Auger
[illegible]OB NO[illegible]		SAMPLING METHOD	Split Spoon
LOGGED BY	Shaun Sykes	SCREEN/RISER DIAMETER	4"
DATES DRILLED	6/3/2010	WELLBORE DIAMETER	6"
TOTAL DEPTH	14'	ELEVATION	N/A

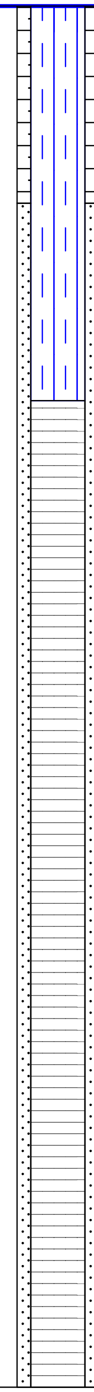
D[illegible] ([illegible])	OVM ([illegible])	USCS	LITHOLOGY	COMMENTS	WELL CONSTRUCTION	WELL DIAGRAM
0				H[illegible] 8'		
	0[illegible]0		50[illegible] - G[illegible] (2) B[illegible]			
	0[illegible]0		C[illegible] 8' - [illegible]/[illegible]			
-5					4' PVC R[illegible]	
	0[illegible]0		100[illegible] - D[illegible]/[illegible]		B[illegible] 0-2'	
	0[illegible]4				S[illegible] 2-14"	
-10	-		25[illegible] - S[illegible]			
	-					
	0[illegible]0		100[illegible] - S[illegible]			
	0[illegible]0			H[illegible] 14'		

Aquaterra Technologies, Inc.

MONITORING WELL LOG: C-132

PRO□ECT□	Sunoco-Philadelphia Refinery	DRILLING CO□□	Parratt Wolff
SITE LOCATION□	AOI-7	DRILLING METHOD□	Hollow Stem Auger
□OB NO□□		SAMPLING METHOD□	Split Spoon
LOGGED BY□	Shaun Sykes	SCREEN/RISER DIAMETER□	4"
DATES DRILLED□	6/15/2010	WELLBORE DIAMETER□	6"
TOTAL DEPTH□	14'	ELEVATION□	N/A

D□□□□ (□□□□)	OVM (□□□)	USCS	LITHOLOGY	COMMENTS	WELL CONSTRUCTION	WELL DIAGRAM
0			N□ 0-2' S□□ □□□	H□□□ □□□□□□□ □□ 8'		
			C□□□□□□ □□ 8' - F□□□□□□□ □□ □□□□□ □□□□□□ □□□□□ □□□□□□□□ □□□□□□□□□□□□□□□ □□□□□□□□□□□□□ □ □□□□□□ □□□□□□□□□			
-5					4' PVC R□□□□	
	33□6		100□ □□□□□□□□□ - D□□□ □□□□/□□□□□□□□□□□□□ □□□□□□□□□□□□□ □ □□□□□□□□□□□ □□□□□□□□□□□□□□		B□□□□□□□□ 0-2'	
	57□2				S□□□□ 2-14"	
-10	27□2		100□ □□□□□□□□□ - S□□ □ □□ □□□□□		10' PVC S□□□□□	
	18□1					
	9□6		100□ □□□□□□□□□ - S□□ □ □□ □□□□□			
	32□1			H□□□□ □□□□ □□□□□ □□□□ □□□□□□□□□□ □ 14'		

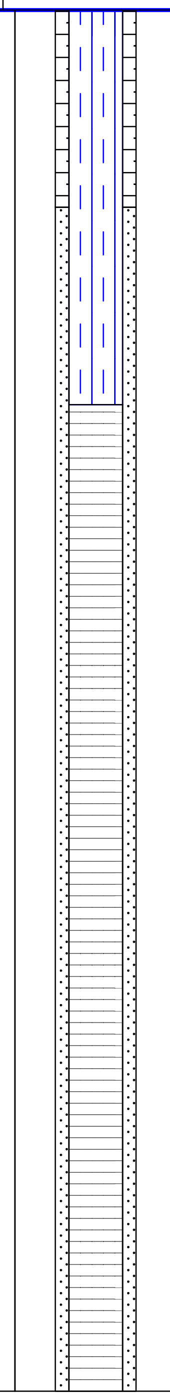


MONITORING WELL LOG: C-133

Aquaterra Technologies, Inc.

PRO[illegible]ECT[illegible]	Sunoco-Philadelphia Refinery	DRILLING CO[illegible]	Parratt Wolff
SITE LOCATION[illegible]	AOI-7	DRILLING METHOD[illegible]	Hollow Stem Auger
[illegible]OB NO[illegible]		SAMPLING METHOD[illegible]	Split Spoon
LOGGED BY[illegible]	Shaun Sykes	SCREEN/RISER DIAMETER[illegible]	4"
DATES DRILLED[illegible]	6/15/2010	WELLBORE DIAMETER[illegible]	6"
TOTAL DEPTH[illegible]	14'	ELEVATION[illegible]	N/A

D[illegible] ([illegible])	OVM ([illegible])	USCS	LITHOLOGY	COMMENTS	WELL CONSTRUCTION	WELL DIAGRAM
0			N[illegible] 0-2' [illegible] ([illegible])[illegible]	H[illegible] 8'		
			C[illegible] 8' - F[illegible]			
-5					4' PVC R[illegible]	
	33[illegible]6		100[illegible] - D[illegible] / [illegible]		B[illegible] 0-2'	
	57[illegible]2				S[illegible] 2-14"	
-10	27[illegible]2		100[illegible] - S[illegible]			
	18[illegible]1					
	9[illegible]6		100[illegible] - S[illegible]			
	32[illegible]1			H[illegible] 14'		



Aquaterra Technologies, Inc.

MONITORING WELL LOG: C-134 D

PRO□ECT□	**Sunoco-Philadelphia Refinery**	DRILLING CO□□	**ECDI**
SITE LOCATION□	**AOI-7**	DRILLING METHOD□	**Hollow Stem Auger & Mud Rotary**
□OB NO□□		SAMPLING METHOD□	**Split Spoon**
LOGGED BY□	**Tiffani Doerr/Shaun Sikes**	SCREEN/RISER DIAMETER□	**4-inch**
DATES DRILLED□	**6/11/10-6/22/10**	WELLBORE DIAMETER□	**6.25"**
TOTAL DEPTH□	**70'**	ELEVATION□	**NA**

D□□□□ (□□□□)	OVM (□□□□)	USCS	LITHOLOGY	COMMENTS	WELL CONSTRUCTION	WELL DIAGRAM
0			C□□□□□□ □□ 10' - □□□□□ □□□□□□ □□□ □□□ □ □□□□□□□□□	H□□□ □□□□□□□ □□ 8'		
-5						
-10	0□0		(BC□4-4-5-6) 10□R□□□□□□□- □□□□ □ □□□□□□□□ □□□□ CLAY □/□□□□□□□□ (□□□□□□□)□L□□□1/2□ □□□□□□□ □□□ □□□□□□ □□□□ □□□□□		G□□□□/□□□□□□□□□ □□□□□ (0'-51')	
	0□0					
	0□0		(BC□5-3-2-2) 10 R□□□□□□□- □□□ □ □□ □□□□□ - □□□□□□□□□ □□□□□□□ □□□□□□□□30□ □			
	0□0					
	0□0		(BC□3-4-4-4) 20□R□□□□□□□- □□□ □ □□ □□□□□ 30-40□ □□□□□□□□			
-15	0□0					
	0□0		(BC□3-2-2-2) 18□R□□□□□□□- □□□ □ □□ □□□□□ - □□□□□□□ □□□□□			
	0□0					
	0□0		(BC□2-2-3-3) 18□R□□□□□□□- □□□ □ □□ □□□□□ □ □□ □□□□			

MONITORING WELL LOG: C-134 D

D[illegible] ([illegible])	OVM ([illegible])	USCS	LITHOLOGY	COMMENTS	WELL CONSTRUCTION	WELL DIAGRAM
	0[illegible]0		[illegible] [illegible]10[illegible] [illegible]			
-20	0[illegible]0		(BC[illegible]2-1-1-1) S[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]5[illegible] [illegible] [illegible] [illegible] [illegible] ([illegible])[illegible]			
	0[illegible]0					
	0[illegible]0		(BC-1-1-1-1) S[illegible] [illegible] [illegible] [illegible]			
	0[illegible]0					
	0[illegible]0		(BC[illegible]1-1-2-2) S[illegible] [illegible] [illegible] [illegible]			
-25	0[illegible]0					
	0[illegible]0		(BC[illegible]2-3-4-4) S[illegible] [illegible] [illegible] [illegible]			
	0[illegible]0					
	0[illegible]0		(BC[illegible]1-1-2-2) S[illegible] [illegible] [illegible] [illegible]			
	0[illegible]0					
-30	0[illegible]0		(BC[illegible]2-2-2-2) S[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]- [illegible] [illegible] 20[illegible] [illegible]			
	0[illegible]0					
	0[illegible]0		(BC[illegible]4-2-3-2) S[illegible] [illegible] [illegible] [illegible]			
	0[illegible]0					
	0[illegible]0		(BC[illegible]3-2-2-3) S[illegible] [illegible] [illegible] [illegible]			
-35	0[illegible]0					
	0[illegible]0					
	0[illegible]0					
	0[illegible]0		(BC[illegible]1-1-1-1) 10[illegible]R[illegible]- [illegible] [illegible] [illegible] [illegible]			
	0[illegible]0					
-40	0[illegible]0		(BC[illegible]2-1-1-1) 18[illegible]R[illegible]- [illegible] [illegible] [illegible] [illegible]			
	0[illegible]0					

MONITORING WELL LOG: C-134 D

D[illegible] ([illegible])	OVM ([illegible])	USCS	LITHOLOGY	COMMENTS	WELL CONSTRUCTION	WELL DIAGRAM
	0[illegible]0		(BC[illegible]2-2-4-3) S[illegible] 3[illegible] [illegible] 42[illegible]5'[illegible]			
	0[illegible]0					
	0[illegible]0		(BC[illegible]9-14-17-17) 10[illegible]R[illegible] - R[illegible]-[illegible] SAND [illegible]/[illegible]-[illegible]-[illegible] SAND [illegible]/[illegible] GRAVEL ([illegible]-[illegible]/[illegible]-[illegible])[illegible]			
-45	0[illegible]0					
	0[illegible]0		(BC[illegible]12-24-19-15) 8[illegible]R[illegible] - F[illegible]-[illegible] 1-2[illegible] ([illegible])[illegible]			
	0[illegible]0				[illegible]00 S[illegible] (51'-53')	
-50						
					[illegible]1 S[illegible] (53'-70')	
			(BC[illegible]48-100-50/2) 10[illegible]R[illegible] - C[illegible] 2[illegible] ([illegible])[illegible]			
-55	0[illegible]0		12[illegible]R[illegible] - S[illegible] ([illegible] - [illegible])		S[illegible] (55'-70')	
	0[illegible]0					
			(BC[illegible]52-64-76-37) 10[illegible] R[illegible] - S[illegible]			
	0[illegible]0					
-60				M[illegible] [illegible]72'		

MONITORING WELL LOG: C-134 D

D[illegible] ([illegible])	OVM ([illegible])	USCS	LITHOLOGY	COMMENTS	WELL CONSTRUCTION	WELL DIAGRAM
-65						
-70						
			W[illegible] [illegible]- [illegible] [illegible] [illegible]/[illegible] [illegible] [illegible] [illegible] [illegible]			

Aquaterra Technologies, Inc.

MONITORING WELL LOG: C-135

PRO[illegible]ECT:	Sunoco-Philadelphia Refinery	DRILLING CO:	Parratt Wolff
SITE LOCATION:	AOI-7	DRILLING METHOD:	Hollow Stem Auger
[illegible]OB NO:		SAMPLING METHOD:	Split Spoon
LOGGED BY:	Shaun Sykes	SCREEN/RISER DIAMETER:	4"
DATES DRILLED:	6/10/2010	WELLBORE DIAMETER:	6"
TOTAL DEPTH:	10'	ELEVATION:	N/A

D[illegible] ([illegible])	OVM ([illegible])	USCS	LITHOLOGY	COMMENTS	WELL CONSTRUCTION	WELL DIAGRAM
0			50[illegible] [illegible] - G[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]	H[illegible] [illegible] [illegible] 8'		
			C[illegible] [illegible] 8' - [illegible] [illegible] [illegible] [illegible]			
-5						
				R[illegible]10' [illegible] [illegible] [illegible] [illegible] N[illegible] [illegible]		
	24[illegible]5		90[illegible] [illegible] - S[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]			
	146					
-10						

Aquaterra Technologies, Inc.

MONITORING WELL LOG: C-136

PRO□ECT□	Sunoco-Philadelphia Refinery	DRILLING CO□□	Parratt Wolff
SITE LOCATION□	AOI-7	DRILLING METHOD□	Hollow Stem Auger
□OB NO□□		SAMPLING METHOD□	Split Spoon
LOGGED BY□	Shaun Sykes	SCREEN/RISER DIAMETER□	4"
DATES DRILLED□	5/28/2010	WELLBORE DIAMETER□	6"
TOTAL DEPTH□	14'	ELEVATION□	N/A

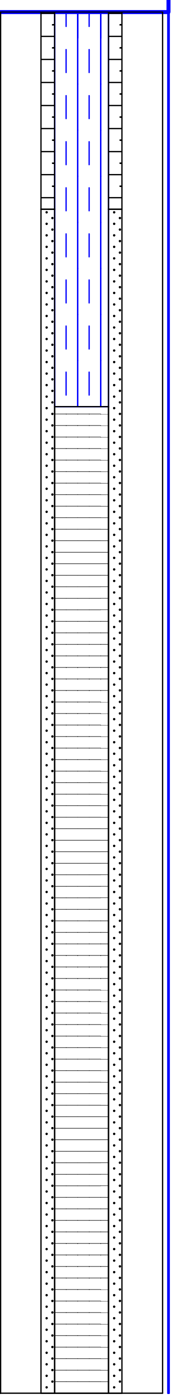
D□□□□ (□□□□)	OVM (□□□)	USCS	LITHOLOGY	COMMENTS	WELL CONSTRUCTION	WELL DIAGRAM
0			25□ □□□□□□□ - G□□□□□□□□□ □□□□ □□□□□□□ □□□□□□□□□□□□□	H□□□ □□□□□□ □□ 8'		
	0□0					
	0□0		C□□□□□□ □□ 8' - F□□□□□□□ □□□□□□ □□□□□ 1□5'□□□□ □□□□ □□□□□□ □□ □□□□□□□□□□□□□□□□□□□□□□□□□□□ □ □□□□□ 4'□4'-8' □□□□ □□□□ □□□□□ □□□□□□□ W□□□□□ 5' □□□□□ □□□□□□□		4' PVC R□□□□	
-5					S□□□ 0-14'	
	-		25□ □□□□□□□ - D□□□ □□□□ □ □□□□□ □□□□□□□ □□□□□□□□□□□□ □ □□□□□ □ □□□□□ □□□□□		10' PVC S□□□□□	
	0□0					
-10	3□5		100□ □□□□□□□ - S□□ □ □□ □□□□□□□ □□			
	8□2			H□□□□ □□□□ □□□□□ □□□□ □□□□□□□□□ □ 14'		
	2□3		100□ □□□□□□□ - D□□□ □□□□ □□ □□□□□□□□□ □□□□□□ □□□□□ □□□□			
	2□1					

MONITORING WELL LOG: C-137

PRO□ECT□	Sunoco-Philadelphia Refinery	DRILLING CO□□	Parratt Wolff
SITE LOCATION□	AOI-7	DRILLING METHOD□	Hollow Stem Auger
□OB NO□□		SAMPLING METHOD□	Split Spoon
LOGGED BY□	Shaun Sykes	SCREEN/RISER DIAMETER□	4"
DATES DRILLED□	5/27/2010	WELLBORE DIAMETER□	6"
TOTAL DEPTH□	14'	ELEVATION□	N/A

D□□□□ (□□□□)	OVM (□□□□)	USCS	LITHOLOGY	COMMENTS	WELL CONSTRUCTION
0				H□□□ □□□□□□□ □□ 8'	
			100□ □□□□□□□□ - D□□□ □□□□ □/□□□□□□□□ □□□□□□□□□□□□□ □□□□□□□□□□□□□□□□□□□□		
	0□0				
	18□0		C□□□□□□ □□ 8' - □□ □□□□□□□□□□		4' PVC R□□□□
-5					
					S□□□□ 2-14'
	0□3		100□ □□□□□□□□ - D□□□ □□□□/□□□□□□□□□□ □□□ □□□□□□□□ □ □□□□□□□□□ □ □□□□		10' PVC S□□□□□
	3□0				
-10	-		0□ □□□□□□□□		
	-			H□□□□ □□□□ □□□□□□ □□□□ □□□□□□□□□ □ 14'	
	2□1				
	1□7				

WELL DIAGRAM

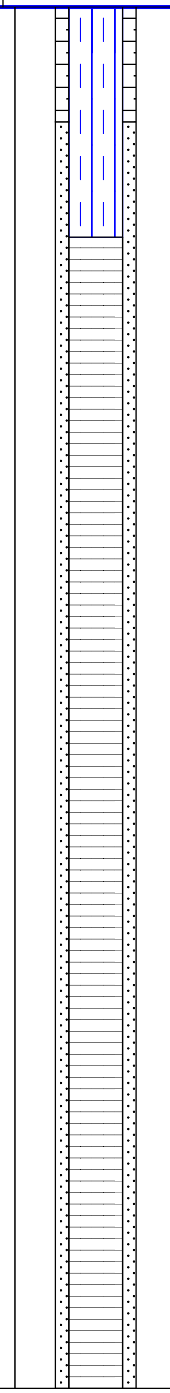


MONITORING WELL LOG: C-138

Aquaterra Technologies, Inc.

PRO[illegible]ECT:	Sunoco-Philadelphia Refinery	DRILLING CO:	Parratt Wolff
SITE LOCATION:	AOI-7	DRILLING METHOD:	Hollow Stem Auger
[illegible]OB NO:		SAMPLING METHOD:	Split Spoon
LOGGED BY:	Shaun Sykes	SCREEN/RISER DIAMETER:	4"
DATES DRILLED:	5/27/2010	WELLBORE DIAMETER:	6"
TOTAL DEPTH:	12'	ELEVATION:	N/A

D[illegible] ([illegible])	OVM ([illegible])	USCS	LITHOLOGY	COMMENTS	WELL CONSTRUCTION	WELL DIAGRAM
0				H[illegible] 8'		
			100[illegible] - G[illegible] / [illegible] (1.5) D[illegible] / [illegible]			
	0.0					
	0.0		C[illegible] 8' - S[illegible]		2' PVC R[illegible]	
-5						
					S[illegible] 1-12'	
	1.9		25[illegible] - B[illegible]		10' PVC S[illegible]	
	5.0					
-10	0.0		100[illegible] - D[illegible]			
	0.0			H[illegible] 12'		



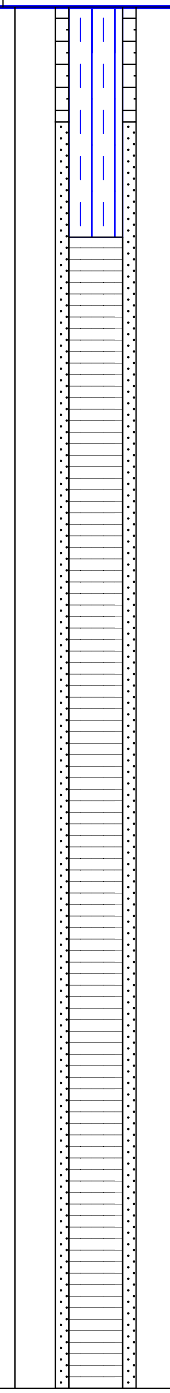
Aquaterra Technologies, Inc.

MONITORING WELL LOG: C-139

PRO□ECT□	Sunoco-Philadelphia Refinery	DRILLING CO□	Parratt Wolff
SITE LOCATION□	AOI-7	DRILLING METHOD□	Hollow Stem Auger
□OB NO□		SAMPLING METHOD□	Split Spoon
LOGGED BY□	Shuan Sykes	SCREEN/RISER DIAMETER□	4"
DATES DRILLED□	6/2/2010	WELLBORE DIAMETER□	6"
TOTAL DEPTH□	12'	ELEVATION□	N/A

D□□□ (□□□)	OVM (□□□)	USCS	LITHOLOGY	COMMENTS	WELL CONSTRUCTION
0				H□□□ □□□□□□ □□ 8'	
			50□ □□□□□□□ - B□□ □□□□□□□□ □□□□□ □□□□□□□□□ □□□□(1□5) D□□ □□□ □□□□□□ □□□ □□□□□□ □□□□ □□□□□ □□□□		
	0□0				
	0□0				2' PVC R□□□□
			W□□□□□□3'		
-5					
					S□□□ 1-12'
	1□0		100□ □□□□□□□ - D□□□ □□□□/□□□□□□□□□ □□□□□□□□ □ □□□□ □□□□□□□□(11') S□□ □ □□ □□□□□□□□□□□□ □ □□□□□□		10' PVC S□□□□□
	0□0				
-10	0□4		100□ □□□□□□□ - S□□ □ □□ □□□□□		
	0□0			H□□□□ □□□□ □□□□□ □□□□ □□□□□□□□ □ 12'	

WELL DIAGRAM



MONITORING WELL LOG: C-140

PRO□ECT□	Sunoco-Philadelphia Refinery	DRILLING CO□□	Parratt Wolff
SITE LOCATION□	AOI-7	DRILLING METHOD□	Hollow Stem Auger
□OB NO□□		SAMPLING METHOD□	Split Spoon
LOGGED BY□	Shaun Sykes	SCREEN/RISER DIAMETER□	4"
DATES DRILLED□	5/26/2010	WELLBORE DIAMETER□	6"
TOTAL DEPTH□	12'	ELEVATION□	N/A

D□□□□ (□□□□)	OVM (□□□□)	USCS	LITHOLOGY	COMMENTS	WELL CONSTRUCTION	WELL DIAGRAM
0				H□□□ □□□□□□□ □□ 8'		
	0□0		100□ □□□□□□□□ - G□□□□□□□□□ □□□□ □/□□□□□□□□□□□ □□□□□□ □□□□□□□□ □□□□2'		2' PVC R□□□□	
	0□0					
-5						
					S□□□ 0-12'	
	3□5		25□ □□□□□□□□ - L□□□□□□□□□ □ □□□□□ □□□□ □□□ □□□□□□□□□□ □□□ □ □□□□□□□ □ □□□□□□□□ □□		10' PVC S□□□□□	
	2□4					
-10	1□2		100□ □□□□□□□□ - S□□ □ □□ □□□□□		F□□□□ □ □□□□□	
	2□3			H□□□□ □□□□ □□□□□ □□□□ □□□□□□□□□ □ 12'		

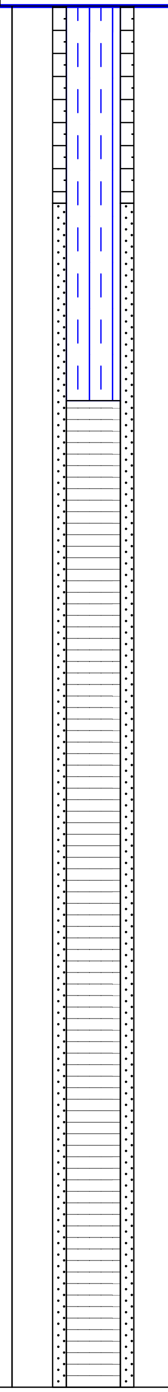
P[illegible] 1 [illegible]1

MONITORING WELL LOG: C-142

PRO[illegible]ECT	Sunoco - Philadelphia Refinery	DRILLING CO[illegible]	Parratt Wolff
SITE LOCATION	AOI-7	DRILLING METHOD	Hollow Stem Auger
[illegible]OB NO[illegible]		SAMPLING METHOD	Split Spoon
LOGGED BY	Shaun Sykes	SCREEN/RISER DIAMETER	4"
DATES DRILLED	6/3/2010	WELLBORE DIAMETER	6"
TOTAL DEPTH	14'	ELEVATION	N/A

D[illegible] ([illegible])	OVM ([illegible])	USCS	LITHOLOGY	COMMENTS	WELL CONSTRUCTION
0				H[illegible] 8'	
	0.0		20[illegible] - D[illegible]		B[illegible] 0-2'
	8.7				
			F[illegible] 8' - G[illegible]/ [illegible]		S[illegible] 2-14"
-5					4' PVC R[illegible]
	6.7		100[illegible] - D[illegible] [illegible]/[illegible]/[illegible]		
	8.6				10' PVC S[illegible]
-10	269		50[illegible] - B[illegible] ([illegible])[illegible]		
	312				
	27.6		100[illegible] - S[illegible]		
	6.4			H[illegible] 14'	

WELL DIAGRAM

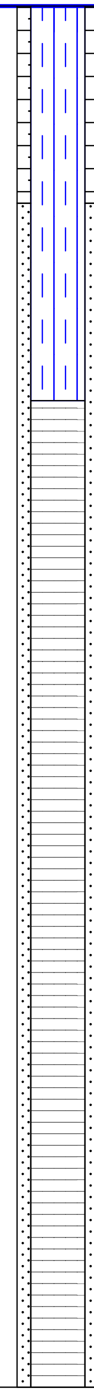


Aquaterra Technologies, Inc.

MONITORING WELL LOG: C-143

PRO[illegible]ECT[illegible]	Sunoco - Philadelphia Refinery	DRILLING CO[illegible]	Parratt Wolff
SITE LOCATION[illegible]	AOI-7	DRILLING METHOD[illegible]	Hollow Stem Auger
[illegible]OB NO[illegible]		SAMPLING METHOD[illegible]	Split Spoon
LOGGED BY[illegible]	Shaun Sykes	SCREEN/RISER DIAMETER[illegible]	4"
DATES DRILLED[illegible]	6/3/2010	WELLBORE DIAMETER[illegible]	6"
TOTAL DEPTH[illegible]	14'	ELEVATION[illegible]	N/A

D[illegible] ([illegible])	OVM ([illegible])	USCS	LITHOLOGY	COMMENTS	WELL CONSTRUCTION	WELL DIAGRAM
0				H[illegible] [illegible] [illegible] 8'		
			20[illegible] [illegible] - L[illegible] [illegible]/[illegible] [illegible] [illegible](1[illegible]5') D[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]			
	45[illegible]0					
	76[illegible]7					
			C[illegible] [illegible] 8' - [illegible] [illegible] [illegible]/ [illegible] [illegible] [illegible] [illegible] W[illegible] 5' [illegible] [illegible]			
-5					4' PVC R[illegible]	
	-		0[illegible] [illegible] - W[illegible]		B[illegible] 0-2'	
	-				S[illegible] 2-14"	
-10	65[illegible]4		25[illegible] [illegible] - B[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]			
	52[illegible]1					
	30[illegible]7		100[illegible] [illegible] - S[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]			
	23[illegible]4			H[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] 14'		



Aquaterra Technologies, Inc.

MONITORING WELL LOG: C-144 D

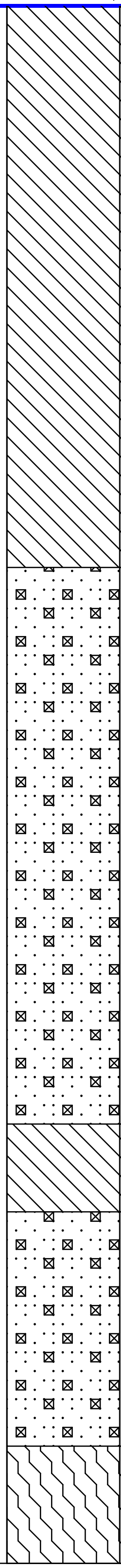
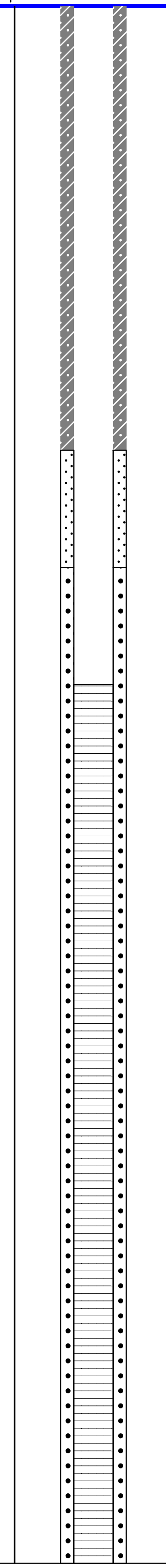
PROJECT:	Sunoco-Philadelphia Refinery	DRILLING CO:	ECDI
SITE LOCATION:	AOI-7	DRILLING METHOD:	Hollow Stem Auger & Mud Rotary
JOB NO:		SAMPLING METHOD:	Split Spoon
LOGGED BY:	Tiffani Doerr/Shaun Sikes	SCREEN/RISER DIAMETER:	4-inch
DATES DRILLED:	6/28/10-7/9/10	WELLBORE DIAMETER:	6.25"
TOTAL DEPTH:	78'	ELEVATION:	NA

Depth (feet)	OVM (ppm)	USCS	LITHOLOGY	COMMENTS	WELL CONSTRUCTION	WELL DIAGRAM
0			C[illegible] 8' - [illegible] / [illegible] W[illegible] 4' [illegible]	H[illegible] 8'		
-5						
-10	11.7		(BC: 3-2-1-1) B[illegible] CLAY [illegible]		G[illegible]/[illegible] (0'-59')	
	11.4					
	0.0		(BC: 3-2-1-2) D[illegible] CLAY [illegible]/[illegible] 10[illegible]			
	0.0					
	0.0		(BC: 1-1-2-1) S[illegible]			
-15	0.0					
	0.0		(BC: 1-2-2-2) 16" R[illegible]- [illegible]			
	0.0					
	0.7		(BC: 1-2-1-1) 20" R[illegible]- [illegible]			
	0.0					
-20	0.0		(BC: WOH/1'-1-1) 4" R[illegible]- [illegible]			
	0.0					
	0.0		(BC: WOH/6"-1-1-1) G[illegible] 20-30[illegible]			

MONITORING WELL LOG: C-144 D

D□□□□ (□□□□)	OVM (□□□)	USCS	LITHOLOGY	COMMENTS	WELL CONSTRUCTION	WELL DIAGRAM
	0□0		(□□□□□□□)□			
	0□0		(BC□1-1-3-3) S□□ □ □□ □□□□□ - □□□□ □□□□□□□□			
-25	0□0					
	0□0		(BC□WOH/1'-1-1) S□□ □ □□ □□□□□□			
	0□0					
	0□0					
-30	0□0		(BC□WOH/2') S□□ □ □□ □□□□□ - □□ □□□□□□□ □□□ □□□□□□□ □□ □ □□□ □□□□□ □□ □□□□6□(□□□□ □□□□ □□□□ □□□□□□□□□ □□□□□□ □□□□ □□□□□□ □□□□□□□)			
	0□0					
-35	0□0		(BC□WOH/2') 12□R□□□□□□□ - G□□□CLAY□□□ □□□□□□□□□□□□□□ □ □□□ □□□□□□□			
	0□0					
-40	0□0		(BC□WOH/2') 18□R□□□□□□□ - □□□□ □□□□ □ □□□ □□□□ □□□□ □□□□ □□□□□ □□□□ □□□□ □□□ □□□□□□□□□ (□ □□□□ □□□□ □□ □1/4□□□□□□□□)			
	0□0					
-45	0□0		(BC□WOH/1'-1-1) S□□ □ □□ □□□□□□			
	0□0					
-50	0□0		(BC□WOH/2') N□ □□□□□□□□ - R□□□ □□□□ □□ □□□ □□□□□□□□□			
	0□0					

MONITORING WELL LOG: C-144 D

D[illegible] ([illegible])	OVM ([illegible])	USCS	LITHOLOGY	COMMENTS	WELL CONSTRUCTION	WELL DIAGRAM
-55	0[illegible]0		(BC[illegible]WOH/2') S[illegible] [illegible]-[illegible]9[illegible]			
	0[illegible]0					
					[illegible]00 S[illegible] (59'-61')	
-60	0[illegible]0		(BC[illegible]8-5-5-7) 18[illegible]R[illegible]-[illegible]/[illegible] CLAY[illegible]	M[illegible] [illegible] 78'	[illegible]1 S[illegible] (61'-78')	
	0[illegible]0		R[illegible]-[illegible] SAND [illegible]61[illegible]5'-62'[illegible] S[illegible]		S[illegible] (63'-78')	
-65			(BC[illegible]18-14-6-5) N[illegible] R[illegible] C[illegible] 62-65' ([illegible]/[illegible])			
-70	0[illegible]0		(BC[illegible]5-4-3-3) T[illegible] 4[illegible]-[illegible] SAND[illegible] R[illegible]/[illegible] CLAY[illegible]-[illegible]			
	0[illegible]0					
			H[illegible] - 73'-75' ([illegible])			
-75	0[illegible]0		(BC[illegible]14-23-90-61) 20[illegible] R[illegible]-[illegible]-[illegible]-[illegible] SAND [illegible]-[illegible]-[illegible] GRAVEL B[illegible] S[illegible]76'[illegible]			
	0[illegible]0					

SUBSURFACE BORING LOG

BOREHOLE NO□**BH-10-05**

P□□□ 1 □□1

PRO□ECT□	**Sunoco - Philadelphia Refinery**	DRILLING CO□□	**Total Quality Drilling**
SITE LOCATION□	**AOI-7**	DRILLING METHOD	**2" Diameter Stainless Steel Hand Auger**
□OB NO□□		SAMPLING METHOD	**Terracore**
LOGGED BY□	**Dennis Webster (Langan)**	TOTAL DEPTH□	**2'**
DATES DRILLED□	**6/9/10**		

DEPTH (□□□□)	SAMPLE INTERVAL	PID (□□□)	LITHOLOGY DESCRIPTION	LITH-OLOGY	COMMENTS
0			T□□-□□□□ C-SA □□□□□(□□□)		
		0□0	B□□□-□□□□ □ F-C □□□□□ □□□□□□ □ C-SA □□□□□□□ □□□□□□□□□□ □□□□ (□ □□□)		
		0□0			
			S□□ □ □□ □□□□□ □ □□ □□□ □ □□□□		S□□□□ □□□□1□2-2'
	S□□ □□□ □□□ □□□□□□□ □□□□ 1□5-2' □□□ □□□□□□□□□ □□□□□□	0□0			
		5□2			

SUBSURFACE BORING LOG

Aquaterra Technologies, Inc.

BOREHOLE NO[illegible] **BH-10-06**

P[illegible] 1 [illegible]1

PRO[illegible]ECT[illegible]	**Sunoco - Philadelphia Refinery**	DRILLING CO[illegible]	**Total Quality Drilling**
SITE LOCATION[illegible]	**AOI-7**	DRILLING METHOD	**2" Diameter Stainless Steel Hand Auger**
[illegible]OB NO[illegible]		SAMPLING METHOD	**Terracore**
LOGGED BY[illegible]	**Dennis Webster (Langan)**	TOTAL DEPTH[illegible]	**2'**
DATES DRILLED[illegible]	**6/9/10**		

DEPTH ([illegible])	SAMPLE INTERVAL	PID ([illegible])	LITHOLOGY DESCRIPTION	LITH-OLOGY	COMMENTS
0			T[illegible]-[illegible] C-SA [illegible] ([illegible])		
		0[illegible]0	B[illegible] F-M [illegible] [illegible] F-SA [illegible] ([illegible])		
		10[illegible]2			
			S[illegible]		S[illegible] 1[illegible]2-2'
	S[illegible] 1[illegible]2-1[illegible]7' [illegible]	2[illegible]2	B[illegible] ([illegible])		
		0[illegible]0			

SUBSURFACE BORING LOG

BOREHOLE NO **BH-10-07**

P 1 1

PRO ECT	**Sunoco - Philadelphia Refinery**	DRILLING CO	**Total Quality Drilling**
SITE LOCATION	**AOI-7**	DRILLING METHOD	**2" Diameter Stainless Steel Hand Auger**
OB NO		SAMPLING METHOD	**Terracore**
LOGGED BY	**Dennis Webster (Langan)**	TOTAL DEPTH	**2'**
DATES DRILLED	**6/10/10**		

DEPTH ( )	SAMPLE INTERVAL	PID ( )	LITHOLOGY DESCRIPTION	LITH-OLOGY	COMMENTS
0			T [illegible] - [illegible] ( )		
		0 0			
		0 0			
	S [illegible] 1 0-1 5' [illegible]	0 0	D [illegible] ( )		
		0 0			

SUBSURFACE BORING LOG

Aquaterra Technologies, Inc.

BOREHOLE NO[illegible] **BH-10-08**

P[illegible] 1 [illegible]1

PRO[illegible]ECT[illegible]	**Sunoco - Philadelphia Refinery**	DRILLING CO[illegible]	**Total Quality Drilling**
SITE LOCATION[illegible]	**AOI-7**	DRILLING METHOD	**2" Diameter Stainless Steel Hand Auger**
[illegible]OB NO[illegible]		SAMPLING METHOD	**Terracore**
LOGGED BY[illegible]	**Dennis Webster (Langan)**	TOTAL DEPTH[illegible]	**2'**
DATES DRILLED[illegible]	**6/10/10**		

DEPTH ([illegible])	SAMPLE INTERVAL	PID ([illegible])	LITHOLOGY DESCRIPTION	LITH-OLOGY	COMMENTS
0			B[illegible] [illegible]-[illegible] -[illegible] [illegible]/[illegible] ([illegible])		
		0[illegible]0			
		0[illegible]0			
	S[illegible] [illegible] 1[illegible]5-2' [illegible]	155	D[illegible] [illegible]/[illegible] ([illegible])		S[illegible] 1[illegible]7-2'

Aquaterra Technologies, Inc.

SUBSURFACE BORING LOG

BOREHOLE NO: **BH-10-09**

P[illegible] 1 [illegible]1

PROJECT:	**Sunoco - Philadelphia Refinery**	DRILLING CO.:	**Total Quality Drilling**
SITE LOCATION:	**AOI-7**	DRILLING METHOD	**2" Diameter Stainless Steel Hand Auger**
JOB NO.:		SAMPLING METHOD	**Terracore**
LOGGED BY:	**Dennis Webster (Langan)**	TOTAL DEPTH:	**2'**
DATES DRILLED:	**6/10/10**		

DEPTH ([illegible])	SAMPLE INTERVAL	PID ([illegible])	LITHOLOGY DESCRIPTION	LITH-OLOGY	COMMENTS
0			B[illegible] -[illegible] -[illegible] ([illegible])		
		0.0			
1		0.0	D[illegible] ([illegible])		
	S[illegible] 1[illegible]2-1[illegible]7' [illegible]	0.0			
2		0.0			

SUBSURFACE BORING LOG

Aquaterra Technologies, Inc.

BOREHOLE NO: **BH-10-10**

Page 1 of 1

PROJECT:	**Sunoco - Philadelphia Refinery**	DRILLING CO.:	**Total Quality Drilling**
SITE LOCATION:	**AOI-7**	DRILLING METHOD	**2" Diameter Stainless Steel Hand Auger**
JOB NO.:		SAMPLING METHOD	**Terracore**
LOGGED BY:	**Dennis Webster (Langan)**	TOTAL DEPTH:	**2'**
DATES DRILLED:	**6/10/10**		

DEPTH ([illegible])	SAMPLE INTERVAL	PID ([illegible])	LITHOLOGY DESCRIPTION	LITH-OLOGY	COMMENTS
0			B[illegible] -[illegible] ([illegible])		
		0.0	Y[illegible]-[illegible] -[illegible] ([illegible])		
		42.4			
			D[illegible] -[illegible] ([illegible])		S[illegible] 1.3-2'
	S[illegible] 1.5-2' [illegible]	141			

SUBSURFACE BORING LOG

BOREHOLE NO: **BH-10-11**

P[illegible] 1 [illegible] 1

PROJECT:	**Sunoco - Philadelphia Refinery**	DRILLING CO.:	**Total Quality Drilling**
SITE LOCATION:	**AOI-7**	DRILLING METHOD	**2" Diameter Stainless Steel Hand Auger**
JOB NO.:		SAMPLING METHOD	**Terracore**
LOGGED BY:	**Dennis Webster (Langan)**	TOTAL DEPTH:	**2'**
DATES DRILLED:	**6/10/10**		

DEPTH ([illegible])	SAMPLE INTERVAL	PID ([illegible])	LITHOLOGY DESCRIPTION	LITH-OLOGY	COMMENTS
0		0.0	D[illegible] -[illegible] ([illegible]-[illegible])		
		0.0			O[illegible] 0-2'
	S[illegible] 1.5-2' [illegible]	0.0			
		10.1			

SUBSURFACE BORING LOG

Aquaterra Technologies, Inc.

BOREHOLE NO: **BH-10-12**

P[illegible] 1 [illegible]1

PRO[illegible]ECT:	**Sunoco - Philadelphia Refinery**	DRILLING CO:	**Total Quality Drilling**
SITE LOCATION:	**AOI-7**	DRILLING METHOD	**2" Diameter Stainless Steel Hand Auger**
[illegible]OB NO:		SAMPLING METHOD	**Terracore**
LOGGED BY:	**Dennis Webster (Langan)**	TOTAL DEPTH:	**2'**
DATES DRILLED:	**6/10/10**		

DEPTH ([illegible])	SAMPLE INTERVAL	PID ([illegible])	LITHOLOGY DESCRIPTION	LITH-OLOGY	COMMENTS
0		0.0	B[illegible] [illegible]-[illegible] [illegible]-[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] ([illegible])		
1		0.0	B[illegible] [illegible]-[illegible] [illegible] [illegible] [illegible] [illegible]-[illegible] [illegible] [illegible] [illegible]([illegible])		S[illegible] [illegible] 1.0-2'
	S[illegible] [illegible] [illegible] [illegible] [illegible] 1.5-2' [illegible] [illegible] [illegible]	0.0			
2		0.0			

SUBSURFACE BORING LOG

BOREHOLE NO[illegible] **BH-10-13**

P[illegible] 1 [illegible]1

PRO[illegible]ECT[illegible]	**Sunoco - Philadelphia Refinery**	DRILLING CO[illegible]	**Total Quality Drilling**
SITE LOCATION[illegible]	**AOI-7**	DRILLING METHOD	**2" Diameter Stainless Steel Hand Auger**
[illegible]OB NO[illegible]		SAMPLING METHOD	**Terracore**
LOGGED BY[illegible]	**Dennis Webster (Langan)**	TOTAL DEPTH[illegible]	**2'**
DATES DRILLED[illegible]	**6/9/10**		

DEPTH ([illegible])	SAMPLE INTERVAL	PID ([illegible])	LITHOLOGY DESCRIPTION	LITH-OLOGY	COMMENTS
0			B[illegible] -[illegible] -[illegible] ([illegible])		
		0[illegible]0			
		0[illegible]0	S[illegible]		
	S[illegible] [illegible] [illegible] 1[illegible]5-2' [illegible] [illegible]	0[illegible]0			
		0[illegible]0			

SUBSURFACE BORING LOG

BOREHOLE NO: **BH-10-14**

Page 1 of 1

PROJECT:	**Sunoco - Philadelphia Refinery**	DRILLING CO.:	**Total Quality Drilling**
SITE LOCATION:	**AOI-7**	DRILLING METHOD	**2" Diameter Stainless Steel Hand Auger**
JOB NO.:		SAMPLING METHOD	**Terracore**
LOGGED BY:	**Dennis Webster (Langan)**	TOTAL DEPTH:	**2'**
DATES DRILLED:	**6/9/10**		

DEPTH ([illegible])	SAMPLE INTERVAL	PID ([illegible])	LITHOLOGY DESCRIPTION	LITH-OLOGY	COMMENTS
0			L[illegible] ([illegible])		
		0.0			
		0.0	B[illegible] ([illegible])		
	S[illegible] 1.5-2' [illegible]	0.0			
		0.0			

SUBSURFACE BORING LOG

BOREHOLE NO[illegible] **BH-10-15**

P[illegible] 1 [illegible]1

PRO[illegible]ECT[illegible]	**Sunoco - Philadelphia Refinery**	DRILLING CO[illegible]	**Total Quality Drilling**
SITE LOCATION[illegible]	**AOI-7**	DRILLING METHOD	**2" Diameter Stainless Steel Hand Auger**
[illegible]OB NO[illegible]		SAMPLING METHOD	**Terracore**
LOGGED BY[illegible]	**Dennis Webster (Langan)**	TOTAL DEPTH[illegible]	**1.9'**
DATES DRILLED[illegible]	**6/9/10**		

DEPTH ([illegible])	SAMPLE INTERVAL	PID ([illegible])	LITHOLOGY DESCRIPTION	LITH-OLOGY	COMMENTS
0			G[illegible] -[illegible] [illegible]-[illegible] ([illegible])		
		0[illegible]0			
		0[illegible]0	S[illegible]/[illegible]		
	S[illegible] 1[illegible]5-2' [illegible]	0[illegible]0			R[illegible] 1[illegible]9' [illegible]

SUBSURFACE BORING LOG

BOREHOLE NO: **BH-10-16**

P[illegible] 1 [illegible] 1

PROJECT:	**Sunoco - Philadelphia Refinery**	DRILLING CO.:	**Total Quality Drilling**
SITE LOCATION:	**AOI-7**	DRILLING METHOD	**2" Diameter Stainless Steel Hand Auger**
JOB NO.:		SAMPLING METHOD	**Terracore**
LOGGED BY:	**Dennis Webster (Langan)**	TOTAL DEPTH:	**2'**
DATES DRILLED:	**6/9/10**		

DEPTH ([illegible])	SAMPLE INTERVAL	PID ([illegible])	LITHOLOGY DESCRIPTION	LITH-OLOGY	COMMENTS
0			G[illegible]-[illegible] [illegible]-[illegible] [illegible] ([illegible])		
		0.0			
		0.0	D[illegible]-[illegible] [illegible] [illegible] [illegible] [illegible] ([illegible])		S[illegible] [illegible] 1.2-2'
	S[illegible] [illegible] [illegible] [illegible] 1.5-2' [illegible] [illegible] [illegible]	25.9			
		11.2			

SUBSURFACE BORING LOG

Aquaterra Technologies, Inc.

BOREHOLE NO: **BH-10-17**

P[illegible] 1 [illegible] 1

PRO[illegible]ECT: **Sunoco - Philadelphia Refinery**
SITE LOCATION: **AOI-7**
[illegible]OB NO:
LOGGED BY: **Dennis Webster (Langan)**
DATES DRILLED: **6/9/10**

DRILLING CO: **Total Quality Drilling**
DRILLING METHOD: **2" Diameter Stainless Steel Hand Auger**
SAMPLING METHOD: **Terracore**
TOTAL DEPTH: **2'**

DEPTH ([illegible])	SAMPLE INTERVAL	PID ([illegible])	LITHOLOGY DESCRIPTION	LITH-OLOGY	COMMENTS
0			L[illegible]/ [illegible] [illegible]-[illegible] [illegible]([illegible])		
		0[illegible]0	B[illegible]-[illegible] [illegible]-[illegible] [illegible] [illegible] [illegible]([illegible] [illegible]-[illegible] [illegible])		
		421			
					S[illegible] [illegible] 0[illegible]8-2'
	S[illegible] [illegible] [illegible] [illegible] [illegible] 1[illegible]5-2' [illegible] [illegible] [illegible]	535			
		600			S[illegible] [illegible] [illegible] 2'

SUBSURFACE BORING LOG

BOREHOLE NO [illegible] **BH-10-18**

P[illegible] 1 [illegible]1

PRO[illegible]ECT[illegible]	**Sunoco - Philadelphia Refinery**	DRILLING CO[illegible]	**Total Quality Drilling**
SITE LOCATION[illegible]	**AOI-7**	DRILLING METHOD	**2" Diameter Stainless Steel Hand Auger**
[illegible]OB NO[illegible]		SAMPLING METHOD	**Terracore**
LOGGED BY[illegible]	**Dennis Webster (Langan)**	TOTAL DEPTH[illegible]	**2'**
DATES DRILLED[illegible]	**6/9/10**		

DEPTH ([illegible])	SAMPLE INTERVAL	PID ([illegible])	LITHOLOGY DESCRIPTION	LITH-OLOGY	COMMENTS
0			L[illegible]/[illegible] -[illegible]		
			B[illegible] -[illegible] ([illegible])		
		0[illegible]0			
		0[illegible]0			
	S[illegible] 1[illegible]5-2' [illegible]	48[illegible]7	B[illegible]-[illegible] -[illegible] ([illegible])		S[illegible] 1[illegible]5-2'

SUBSURFACE BORING LOG

Aquaterra Technologies, Inc.

BOREHOLE NO: **BH-10-19**

Page 1 of 1

PROJECT:	**Sunoco - Philadelphia Refinery**	DRILLING CO.:	**Total Quality Drilling**
SITE LOCATION:	**AOI-7**	DRILLING METHOD	**2" Diameter Stainless Steel Hand Auger**
JOB NO.:		SAMPLING METHOD	**Terracore**
LOGGED BY:	**Dennis Webster (Langan)**	TOTAL DEPTH:	**1.2'**
DATES DRILLED:	**6/9/10**		

DEPTH ([illegible])	SAMPLE INTERVAL	PID ([illegible])	LITHOLOGY DESCRIPTION	LITH-OLOGY	COMMENTS
0	S[illegible] [illegible] 0.5-1' [illegible]	0.0 0.0	T[illegible] ([illegible]) D[illegible]		R[illegible] 1.2' [illegible]

SUBSURFACE BORING LOG

BOREHOLE NO[illegible] **BH-10-20**

P[illegible] 1 [illegible]1

PRO[illegible]ECT[illegible]	**Sunoco - Philadelphia Refinery**	DRILLING CO[illegible]	**Total Quality Drilling**
SITE LOCATION[illegible]	**AOI-7**	DRILLING METHOD	**2" Diameter Stainless Steel Hand Auger**
[illegible]OB NO[illegible]		SAMPLING METHOD	**Terracore**
LOGGED BY[illegible]	**Dennis Webster (Langan)**	TOTAL DEPTH[illegible]	**1.8'**
DATES DRILLED[illegible]	**6/8/10**		

DEPTH ([illegible])	SAMPLE INTERVAL	PID ([illegible])	LITHOLOGY DESCRIPTION	LITH-OLOGY	COMMENTS
0			G[illegible]/[illegible] -[illegible] ([illegible])		
		0[illegible]0	Y[illegible]-[illegible] ([illegible])		
		0[illegible]0	D[illegible] -[illegible] -[illegible] ([illegible])		
	S[illegible] 1[illegible]3-1[illegible]8' [illegible]	0[illegible]0			R[illegible] 1[illegible]8' [illegible]

SUBSURFACE BORING LOG

BOREHOLE NO□ **BH-10-21**

P□□□ 1 □□1

PRO□ECT□	**Sunoco - Philadelphia Refinery**	DRILLING CO□□	**Total Quality Drilling**
SITE LOCATION□	**AOI-7**	DRILLING METHOD	**2" Diameter Stainless Steel Hand Auger**
□OB NO□□		SAMPLING METHOD	**Terracore**
LOGGED BY□	**Dennis Webster (Langan)**	TOTAL DEPTH□	**2'**
DATES DRILLED□	**6/8/10**		

DEPTH (□□□□)	SAMPLE INTERVAL	PID (□□□□)	LITHOLOGY DESCRIPTION	LITH-OLOGY	COMMENTS
0		2□1	G□□□/□□□□ □ -□ □□□□□ □□□□□□ □ □□□ □□ □□□□□(□□□)		
	S□□ □□□ □□□ □□□□□□□□ □□□□ 1□0-1□5' □□□ □□□□□□□□□ □□□□□□□	10□9	D□□□ □□□□□ □□□□ □□□□□□□□ □ □□□/□□□□□□ □□□□□ (□ □□□□)		S□□□□□ □□□□□□□□ 1□0-2'

SUBSURFACE BORING LOG

Aquaterra Technologies, Inc.

BOREHOLE NO: **BH-10-22**

P[illegible] 1 [illegible] 1

PRO[illegible]ECT:	**Sunoco - Philadelphia Refinery**	DRILLING CO:	**Total Quality Drilling**
SITE LOCATION:	**AOI-7**	DRILLING METHOD	**2" Diameter Stainless Steel Hand Auger**
[illegible]OB NO:		SAMPLING METHOD	**Terracore**
LOGGED BY:	**Dennis Webster (Langan)**	TOTAL DEPTH:	**2'**
DATES DRILLED:	**6/8/10**		

DEPTH ([illegible])	SAMPLE INTERVAL	PID ([illegible])	LITHOLOGY DESCRIPTION	LITH-OLOGY	COMMENTS
0			D[illegible] -[illegible] ([illegible])		
		0[illegible]0			
			S[illegible]/[illegible] ([illegible])		
		0[illegible]0	D[illegible] -[illegible] -[illegible] ([illegible])		
	S[illegible] 1[illegible]5-2' [illegible]	0[illegible]0			

SUBSURFACE BORING LOG

BOREHOLE NO: **BH-10-23**

Page 1 of 1

PROJECT:	**Sunoco - Philadelphia Refinery**	DRILLING CO:	**Total Quality Drilling**
SITE LOCATION:	**AOI-7**	DRILLING METHOD	**2" Diameter Stainless Steel Hand Auger**
JOB NO:		SAMPLING METHOD	**Terracore**
LOGGED BY:	**Dennis Webster (Langan)**	TOTAL DEPTH:	**1.5'**
DATES DRILLED:	**6/7/10**		

DEPTH ([illegible])	SAMPLE INTERVAL	PID ([illegible])	LITHOLOGY DESCRIPTION	LITH-OLOGY	COMMENTS
0		0.0	L[illegible] (...)		
	S[illegible] 1.0-1.5' [illegible]	0.0	D[illegible] (...)		
		0.0			R[illegible] 1.5' [illegible]

SUBSURFACE BORING LOG

BOREHOLE NO[illegible] **BH-10-24**

P[illegible] 1 [illegible]1

PRO[illegible]ECT[illegible]	**Sunoco - Philadelphia Refinery**	DRILLING CO[illegible]	**Total Quality Drilling**
SITE LOCATION[illegible]	**AOI-7**	DRILLING METHOD	**2" Diameter Stainless Steel Hand Auger**
[illegible]OB NO[illegible]		SAMPLING METHOD	**Terracore**
LOGGED BY[illegible]	**Dennis Webster (Langan)**	TOTAL DEPTH[illegible]	**1.6'**
DATES DRILLED[illegible]	**6/7/10**		

DEPTH ([illegible])	SAMPLE INTERVAL	PID ([illegible])	LITHOLOGY DESCRIPTION	LITH-OLOGY	COMMENTS
0		0[illegible]0	G[illegible]/[illegible] -[illegible] ([illegible])		
	S[illegible] 1[illegible]0-1[illegible]5' [illegible]	2[illegible]5	B[illegible]/[illegible] ([illegible])		
		3[illegible]5			R[illegible] 1[illegible]6' [illegible]

SUBSURFACE BORING LOG

Aquaterra Technologies, Inc.

BOREHOLE NO[illegible] **BH-10-25**

P[illegible] 1 [illegible]1

PRO[illegible]ECT[illegible]	**Sunoco - Philadelphia Refinery**	DRILLING CO[illegible]	**Total Quality Drilling**
SITE LOCATION[illegible]	**AOI-7**	DRILLING METHOD	**2" Diameter Stainless Steel Hand Auger**
[illegible]OB NO[illegible]		SAMPLING METHOD	**Terracore**
LOGGED BY[illegible]	**Dennis Webster (Langan)**	TOTAL DEPTH[illegible]	**2'**
DATES DRILLED[illegible]	**6/7/10**		

DEPTH ([illegible])	SAMPLE INTERVAL	PID ([illegible])	LITHOLOGY DESCRIPTION	LITH-OLOGY	COMMENTS
0			L[illegible] -[illegible] [illegible] -[illegible] [illegible]([illegible])		
		0[illegible]0			
	S[illegible] [illegible] [illegible] 1[illegible]2-1[illegible]7' [illegible] [illegible]	0[illegible]0			
			B[illegible]/[illegible] [illegible] -[illegible] [illegible] -[illegible] [illegible]([illegible])		S[illegible] 1[illegible]2-1[illegible]7'
		0[illegible]0			
			D[illegible] -[illegible] [illegible]([illegible])		
		2[illegible]5			

SUBSURFACE BORING LOG

Aquaterra Technologies, Inc.

BOREHOLE NO [illegible] **BH-10-26**

P[illegible] 1 [illegible] 1

PRO[illegible]ECT	**Sunoco - Philadelphia Refinery**	DRILLING CO[illegible]	**Total Quality Drilling**
SITE LOCATION	**AOI-7**	DRILLING METHOD	**2" Diameter Stainless Steel Hand Auger**
[illegible]OB NO[illegible]		SAMPLING METHOD	**Terracore**
LOGGED BY	**Dennis Webster (Langan)**	TOTAL DEPTH	**2'**
DATES DRILLED	**6/7/10**		

DEPTH ([illegible])	SAMPLE INTERVAL	PID ([illegible])	LITHOLOGY DESCRIPTION	LITH-OLOGY	COMMENTS
0			D[illegible]/[illegible] -[illegible] [illegible] ([illegible])		
		0[illegible]0			
			R[illegible]/[illegible]/[illegible] ([illegible])		
		0[illegible]5			
	S[illegible] [illegible] [illegible] 1[illegible]5-2' [illegible] [illegible]	1[illegible]5	D[illegible]/[illegible] -[illegible] ([illegible])		S[illegible] 1[illegible]5-2'

SUBSURFACE BORING LOG

BOREHOLE NO [illegible] **BH-10-27**

P[illegible] 1 [illegible]1

PRO[illegible]ECT[illegible]	**Sunoco - Philadelphia Refinery**	DRILLING CO[illegible]	**Total Quality Drilling**
SITE LOCATION[illegible]	**AOI-7**	DRILLING METHOD	**2" Diameter Stainless Steel Hand Auger**
[illegible]OB NO[illegible]		SAMPLING METHOD	**Terracore**
LOGGED BY[illegible]	**Dennis Webster (Langan)**	TOTAL DEPTH[illegible]	**2'**
DATES DRILLED[illegible]	**6/8/10**		

DEPTH ([illegible])	SAMPLE INTERVAL	PID ([illegible])	LITHOLOGY DESCRIPTION	LITH-OLOGY	COMMENTS
0		0[illegible]0	L[illegible] -[illegible] [illegible]-[illegible] ([illegible])		
	S[illegible] [illegible] 1[illegible]5-2' [illegible]	38[illegible]9	D[illegible] -[illegible] -[illegible]		
		1179			S[illegible] 1[illegible]2-2'

SUBSURFACE BORING LOG

Aquaterra Technologies, Inc.

BOREHOLE NO: **BH-10-28**

Page 1 of 1

PROJECT:	**Sunoco - Philadelphia Refinery**	DRILLING CO.:	**Total Quality Drilling**
SITE LOCATION:	**AOI-7**	DRILLING METHOD	**2" Diameter Stainless Steel Hand Auger**
JOB NO.:		SAMPLING METHOD	**Terracore**
LOGGED BY:	**Dennis Webster (Langan)**	TOTAL DEPTH:	**2'**
DATES DRILLED:	**6/7/10**		

DEPTH ([illegible])	SAMPLE INTERVAL	PID ([illegible])	LITHOLOGY DESCRIPTION	LITH-OLOGY	COMMENTS
0		0.0	G[illegible] - [illegible] ([illegible])		
		200	D[illegible] [illegible]/[illegible] - [illegible] - [illegible] ([illegible])		
	S[illegible] [illegible] 1.5-2' [illegible]	1,200	D[illegible] - [illegible] ([illegible])		S[illegible] 1.5-2"

SUBSURFACE BORING LOG

BOREHOLE NO: **BH-10-29**

P[illegible] 1 [illegible] 1

PROJECT:	**Sunoco - Philadelphia Refinery**	DRILLING CO.:	**Total Quality Drilling**
SITE LOCATION:	**AOI-7**	DRILLING METHOD	**2" Diameter Stainless Steel Hand Auger**
JOB NO.:		SAMPLING METHOD	**Terracore**
LOGGED BY:	**Dennis Webster (Langan)**	TOTAL DEPTH:	**1.4'**
DATES DRILLED:	**6/7/10**		

DEPTH ([illegible])	SAMPLE INTERVAL	PID ([illegible])	LITHOLOGY DESCRIPTION	LITH-OLOGY	COMMENTS
0			L[illegible] -[illegible] ([illegible])		
		0[illegible]0			
1	S[illegible] 0[illegible]7-1[illegible]2' [illegible]	200	B[illegible] -[illegible] ([illegible])		
					R[illegible] 1[illegible]4' [illegible]

SUBSURFACE BORING LOG

BOREHOLE NO: **BH-10-30**

P[illegible] 1 [illegible]1

PROJECT: **Sunoco - Philadelphia Refinery**
SITE LOCATION: **AOI-7**
JOB NO:
LOGGED BY: **Dennis Webster (Langan)**
DATES DRILLED: **6/7/10**

DRILLING CO: **Total Quality Drilling**
DRILLING METHOD: **2" Diameter Stainless Steel Hand Auger**
SAMPLING METHOD: **Terracore**
TOTAL DEPTH: **2'**

DEPTH ([illegible])	SAMPLE INTERVAL	PID ([illegible])	LITHOLOGY DESCRIPTION	LITH-OLOGY	COMMENTS
0			L[illegible] -[illegible] -[illegible] ([illegible])		
		0[illegible]0			
		2[illegible]5			
			D[illegible] ([illegible])		
	S[illegible] 1[illegible]5-2' [illegible]	10[illegible]1			S[illegible] 1[illegible]5-2[illegible]0'

SUBSURFACE BORING LOG

BOREHOLE NO[illegible] BH-10-31

P[illegible] 1 [illegible] 1

PRO[illegible]ECT[illegible]	**Sunoco - Philadelphia Refinery**	DRILLING CO[illegible]	**Total Quality Drilling**
SITE LOCATION[illegible]	**AOI-7**	DRILLING METHOD	**2" Diameter Stainless Steel Hand Auger**
[illegible]OB NO[illegible]		SAMPLING METHOD	**Terracore**
LOGGED BY[illegible]	**Dennis Webster (Langan)**	TOTAL DEPTH[illegible]	**2'**
DATES DRILLED[illegible]	**6/8/10**		

DEPTH ([illegible])	SAMPLE INTERVAL	PID ([illegible])	LITHOLOGY DESCRIPTION	LITH-OLOGY	COMMENTS
0		0[illegible]0	B[illegible]/[illegible] -[illegible] [illegible] -[illegible] [illegible] ([illegible])		
	S[illegible] [illegible] 1[illegible]5-2' [illegible]	6[illegible]0	B[illegible] -[illegible] ([illegible])		S[illegible] 1[illegible]0-2[illegible]0'

SUBSURFACE BORING LOG

Aquaterra Technologies, Inc.

BOREHOLE NO: **BH-10-32**

Page 1 of 1

PROJECT:	**Sunoco - Philadelphia Refinery**	DRILLING CO.:	**Total Quality Drilling**
SITE LOCATION:	**AOI-7**	DRILLING METHOD	**2" Diameter Stainless Steel Hand Auger**
JOB NO.:		SAMPLING METHOD	**Terracore**
LOGGED BY:	**Dennis Webster (Langan)**	TOTAL DEPTH:	**2'**
DATES DRILLED:	**6/8/10**		

DEPTH ([illegible])	SAMPLE INTERVAL	PID ([illegible])	LITHOLOGY DESCRIPTION	LITH-OLOGY	COMMENTS
0			B[illegible]/[illegible] [illegible] -[illegible] ([illegible])		
	S[illegible] [illegible] [illegible] 0.5-1' [illegible]	0.0			
			S[illegible] -[illegible] ([illegible])		
		0.0			
		0.0			
			R[illegible]/[illegible] -[illegible] -[illegible] ([illegible])		
		0.0			

SUBSURFACE BORING LOG

BOREHOLE NO: **BH-10-33**

Page 1 of 1

PROJECT:	**Sunoco - Philadelphia Refinery**	DRILLING CO:	**Total Quality Drilling**
SITE LOCATION:	**AOI-7**	DRILLING METHOD	**2" Diameter Stainless Steel Hand Auger**
JOB NO:		SAMPLING METHOD	**Terracore**
LOGGED BY:	**Dennis Webster (Langan)**	TOTAL DEPTH:	**2'**
DATES DRILLED:	**6/8/10**		

DEPTH (feet)	SAMPLE INTERVAL	PID (ppm)	LITHOLOGY DESCRIPTION	LITH-OLOGY	COMMENTS
0			D[illegible] ([illegible])		
	S[illegible] 1.5-2' [illegible]	0.0	R[illegible] ([illegible])		
		11.9	D[illegible] ([illegible])		
		5.4			
		12.8			

SUBSURFACE BORING LOG

BOREHOLE NO: **BH-10-34**

P[illegible] 1 [illegible] 1

PROJECT:	**Sunoco - Philadelphia Refinery**	DRILLING CO.:	**Total Quality Drilling**
SITE LOCATION:	**AOI-7**	DRILLING METHOD	**2" Diameter Stainless Steel Hand Auger**
JOB NO.:		SAMPLING METHOD	**Terracore**
LOGGED BY:	**Dennis Webster (Langan)**	TOTAL DEPTH:	**1.5'**
DATES DRILLED:	**6/8/10**		

DEPTH ([illegible])	SAMPLE INTERVAL	PID ([illegible])	LITHOLOGY DESCRIPTION	LITH- OLOGY	COMMENTS
0			D[illegible] [illegible] [illegible] [illegible] [illegible] - [illegible] [illegible] ([illegible])		
		0.0			
			G[illegible]/[illegible] [illegible] - [illegible] [illegible] [illegible] - [illegible] [illegible] [illegible] ([illegible] [illegible])		
	S[illegible] [illegible] [illegible] [illegible] [illegible] 1.0-1.5' [illegible] [illegible] [illegible]	0.0			
		0.0			R[illegible] [illegible] 1.5' [illegible] [illegible] [illegible] [illegible]

SUBSURFACE BORING LOG

BOREHOLE NO. **BH-10-35**

Page 1 of 1

PROJECT:	**Sunoco - Philadelphia Refinery**	DRILLING CO.:	**Total Quality Drilling**
SITE LOCATION:	**AOI-7**	DRILLING METHOD	**2" Diameter Stainless Steel Hand Auger**
JOB NO.:		SAMPLING METHOD	**Terracore**
LOGGED BY:	**Dennis Webster (Langan)**	TOTAL DEPTH:	**2'**
DATES DRILLED:	**6/8/10**		

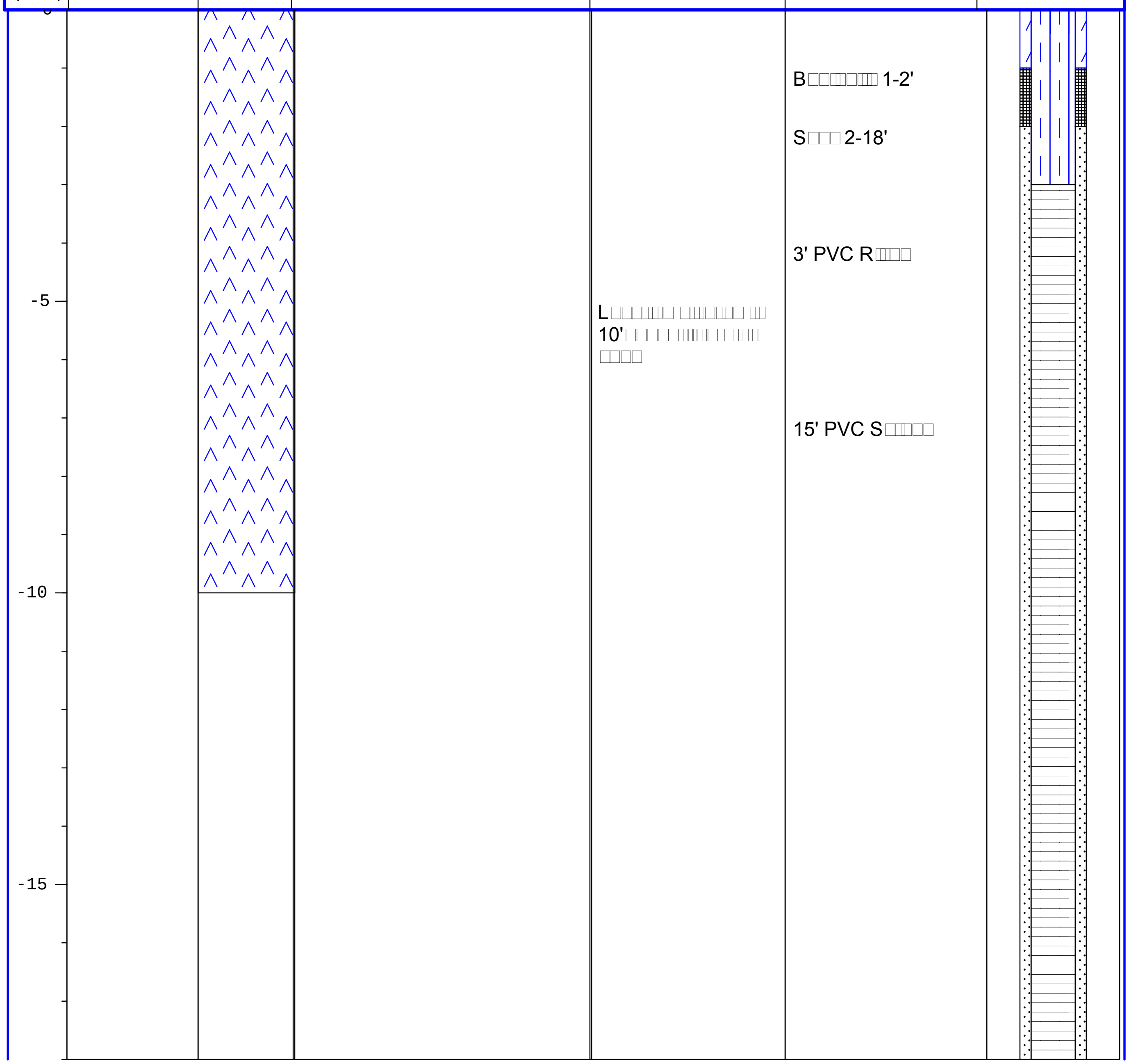
DEPTH ([illegible])	SAMPLE INTERVAL	PID ([illegible])	LITHOLOGY DESCRIPTION	LITH-OLOGY	COMMENTS
0			B[illegible]		
		4.8			
	S[illegible] 1.3-1.7' [illegible]	0.5			
			D[illegible]		
		27.8			

MONITORING WELL LOG: C-148

Aquaterra Technologies, Inc.

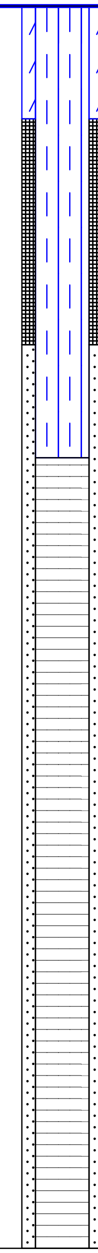
PRO□ECT□	Sunoco - Philadelphia Refinery	DRILLING CO□□	Total Quality Drilling
SITE LOCATION□	AOI-7	DRILLING METHOD□	6" Hollow Stem Auger
□OB NO□□		SAMPLING METHOD□	Split Spoon
LOGGED BY□	Tiffani Doerr	SCREEN/RISER DIAMETER□	4"
DATES DRILLED□	23 May 2011	WELLBORE DIAMETER□	6"
TOTAL DEPTH□	18'	ELEVATION□	-

D□□□□ (□□□□)	OVM (□□□)	USCS	LITHOLOGY	COMMENTS	WELL CONSTRUCTION	WELL DIAGRAM



MONITORING WELL LOG: C-149

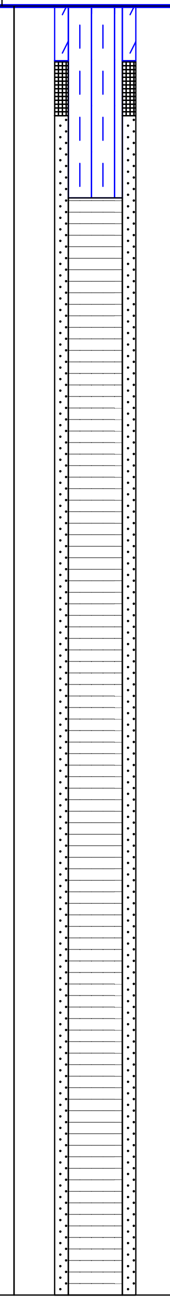
PROJECT:	Sunoco - Philadelphia Refinery	DRILLING CO:	Total Quality Drilling
SITE LOCATION:	AOI-7	DRILLING METHOD:	6" Hollow Stem Auger
JOB NO:		SAMPLING METHOD:	Split Spoon
LOGGED BY:	Tiffani Doerr	SCREEN/RISER DIAMETER:	4"
DATES DRILLED:	23 May 2011	WELLBORE DIAMETER:	6"
TOTAL DEPTH:	11'	ELEVATION:	-

D[illegible] ([illegible])	OVM ([illegible])	USCS	LITHOLOGY	COMMENTS	WELL CONSTRUCTION	WELL DIAGRAM
0					B[illegible] 1-2'	
					S[illegible] 3-11'	
					4' PVC R[illegible]	
-5				L[illegible] [illegible] [illegible] 10'[illegible] [illegible] [illegible] [illegible]		
					7' PVC S[illegible]	
-10			(10-11')B[illegible]			

MONITORING WELL LOG: C-156

PRO□ECT□	Sunoco - Philadelphia Refinery	DRILLING CO□□	Total Quality Drilling
SITE LOCATION□	AOI-7	DRILLING METHOD□	6" Hollow Stem Auger
□OB NO□□		SAMPLING METHOD□	-
LOGGED BY□	Tiffani Doerr	SCREEN/RISER DIAMETER□	4"
DATES DRILLED□	30 August 2011	WELLBORE DIAMETER□	6"
TOTAL DEPTH□	23.5'	ELEVATION□	-

D□□□□ (□□□□)	OVM (□□□)	USCS	LITHOLOGY	COMMENTS	WELL CONSTRUCTION	WELL DIAGRAM
0					B□□□□□□□ 1-2' S□□□ 2-23□5' 3□5' PVC R□□□□	
-5				L□□□□□□□ □□□□□□□ □□ 10'□□□□□□□□□□ □ □□□ □□□□	20' PVC S□□□□□	
-10						
-15						
-20						

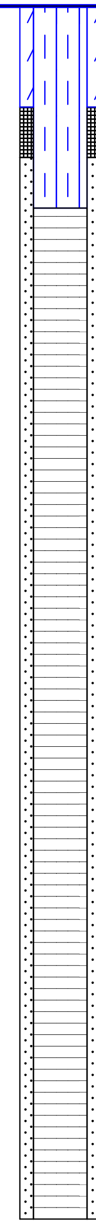


MONITORING WELL LOG: C-157

PRO[illegible]ECT[illegible]	**Sunoco - Philadelphia Refinery**	DRILLING CO[illegible]	**Total Quality Drilling**
SITE LOCATION[illegible]	**AOI-7**	DRILLING METHOD[illegible]	**6" Hollow Stem Auger**
[illegible]OB NO[illegible]		SAMPLING METHOD[illegible]	**Split Spoon**
LOGGED BY[illegible]	**Tiffani Doerr**	SCREEN/RISER DIAMETER[illegible]	**4"**
DATES DRILLED[illegible]	**31 August 2011**	WELLBORE DIAMETER[illegible]	**6"**
TOTAL DEPTH[illegible]	**24'**	ELEVATION[illegible]	**-**

D[illegible] ([illegible])	OVM ([illegible])	USCS	LITHOLOGY	COMMENTS	WELL CONSTRUCTION
0					B[illegible] 2-3' S[illegible] 3-26' 4' PVC R[illegible]
-5				L[illegible] [illegible] [illegible] 10'[illegible] [illegible] [illegible] [illegible]	20' PVC S[illegible]
-10	17[illegible]2		(10-12') F[illegible]R[illegible]A[illegible] [illegible] [illegible]		
	10[illegible]5				
	7[illegible]5		(12-14') F[illegible]R[illegible]N[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]		
	15[illegible]6		(14-16') 10[illegible]R[illegible]S[illegible] [illegible] [illegible] [illegible]		
-15	0[illegible]0				
			(16-18') 10[illegible]R[illegible]S[illegible] [illegible] [illegible] [illegible]		
	0[illegible]3				
			(18-20') 8[illegible]R[illegible]S[illegible] [illegible] [illegible] [illegible]		
-20	0[illegible]0				
			(20-22') F[illegible]R[illegible]S[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] ([illegible] [illegible])		
	0[illegible]0				
			(22-24') F[illegible]R[illegible]S[illegible] [illegible] [illegible] [illegible]		
	0[illegible]0				
			(24-26') F[illegible]R[illegible]S[illegible] [illegible] [illegible] [illegible]	W[illegible] 24'[illegible] [illegible] [illegible] 26'	
-25	0[illegible]0				

WELL DIAGRAM



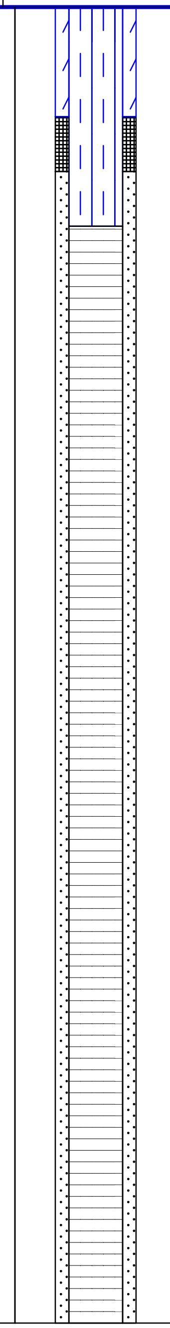
MONITORING WELL LOG: C-158

Aquaterra Technologies, Inc.

PRO[illegible]ECT	Sunoco - Philadelphia Refinery	DRILLING CO[illegible]	Total Quality Drilling
SITE LOCATION	AOI-7	DRILLING METHOD	6" Hollow Stem Auger
[illegible]OB NO[illegible]		SAMPLING METHOD	Split Spoon
LOGGED BY	Tiffani Doerr	SCREEN/RISER DIAMETER	4"
DATES DRILLED	1 September 2011	WELLBORE DIAMETER	6"
TOTAL DEPTH	24'	ELEVATION	-

D[illegible] ([illegible])	OVM ([illegible])	USCS	LITHOLOGY	COMMENTS	WELL CONSTRUCTION
0					B[illegible] 2-3'
					S[illegible] 3-24'
					4' PVC R[illegible]
-5				L[illegible] 10'[illegible]	
					20' PVC S[illegible]
-10	0.3		(10-12') 8"R[illegible]D[illegible] w/ [illegible]		
			(12-14') 6"R[illegible]S[illegible] w/ [illegible]		
	0.0				
-15	1.4		(14-16') 10"R[illegible]S[illegible]1[illegible]([illegible]) [illegible] w/ [illegible]		
			(16-18') S[illegible] 14-16'		
	1.0				
	0.3		(18-20') 20"R[illegible]D[illegible]		
	0.0				
-20	0.0		(20-22') F[illegible]R[illegible]S[illegible]		
	0.0				
	0.0		(22-24') S[illegible] w/ [illegible] (1/4[illegible] 1") [illegible]		
	0.0			W[illegible] 24'	

WELL DIAGRAM



Aquaterra Technologies, Inc.

MONITORING WELL LOG: C-159

PROJECT:	Sunoco - Philadelphia Refinery	DRILLING CO:	Total Quality Drilling
SITE LOCATION:	AOI-7	DRILLING METHOD:	6" Hollow Stem Auger
JOB NO:		SAMPLING METHOD:	Split Spoon
LOGGED BY:	Tiffani Doerr	SCREEN/RISER DIAMETER:	4"
DATES DRILLED:	6 September 2011	WELLBORE DIAMETER:	6"
TOTAL DEPTH:	24'	ELEVATION:	-

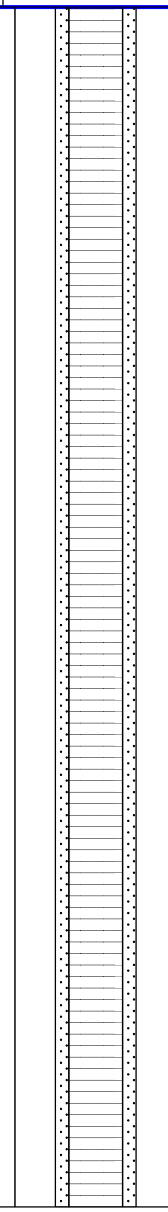
Depth (feet)	OVM (ppm)	USCS	LITHOLOGY	COMMENTS	WELL CONSTRUCTION
0					
2					Bentonite 2-3'
3					Sand 3-24'
4					4' PVC Riser
-5				L[illegible] 10' [illegible]	
7					20' PVC Screen
-10			(10-12') No Recovery		
12			(12-14') No Recovery		
14	0.0		(14-16') 20 R[illegible] D[illegible] [illegible] ([illegible]) 15.5' - 1[illegible] (26.6 [illegible])		
-15	0.0				
16			(16-18') F[illegible] R[illegible] S[illegible] 17' - [illegible] / [illegible] - [illegible] / [illegible] - [illegible] / [illegible] 17-18'		
17	0.7				
18	4.7		(18-20') F[illegible] R[illegible] M[illegible] / [illegible] / [illegible] ([illegible])		
19	0.1				
-20	0.1		(20-22') S[illegible]		
21	0.1				
22	0.1		(22-24') S[illegible]		
23	0.3			W[illegible] 24'	

MONITORING WELL LOG: C-160

Aquaterra Technologies, Inc.

PRO□ECT□	**Sunoco - Philadelphia Refinery**	DRILLING CO□□	**Total Quality Drilling**
SITE LOCATION□	**AOI-7**	DRILLING METHOD□	**6" Hollow Stem Auger**
□OB NO□□		SAMPLING METHOD□	**Split Spoon**
LOGGED BY□	**Tiffani Doerr**	SCREEN/RISER DIAMETER□	**4"**
DATES DRILLED□	**7 September 2011**	WELLBORE DIAMETER□	**6"**
TOTAL DEPTH□	**10'**	ELEVATION□	**-**

D□□□□ (□□□□)	OVM (□□□)	USCS	LITHOLOGY	COMMENTS	WELL CONSTRUCTION	WELL DIAGRAM
0					S□□□ 0-10'	
-5				L□□□□□□ □□□□□□ □□ 10'□□□□□□□□□ □ □□ □□□□	10' PVC S□□□□□	
-10				W□□□□□□□ 10'		



MONITORING WELL LOG: C-161

PROJECT:	Sunoco - Philadelphia Refinery	DRILLING CO.:	Total Quality Drilling
SITE LOCATION:	AOI-7	DRILLING METHOD:	6" Hollow Stem Auger
JOB NO.:		SAMPLING METHOD:	Split Spoon
LOGGED BY:	Tiffani Doerr	SCREEN/RISER DIAMETER:	4"
DATES DRILLED:	7 September 2011	WELLBORE DIAMETER:	6"
TOTAL DEPTH:	10'	ELEVATION:	-

Depth (feet)	OVM (ppm)	USCS	LITHOLOGY	COMMENTS	WELL CONSTRUCTION	WELL DIAGRAM
0					S[illegible] 0-10'	
-5				L[illegible] 10' [illegible]	10' PVC S[illegible]	
				W[illegible] 10'		
-10						

APPENDIX D

USGS Plate 20

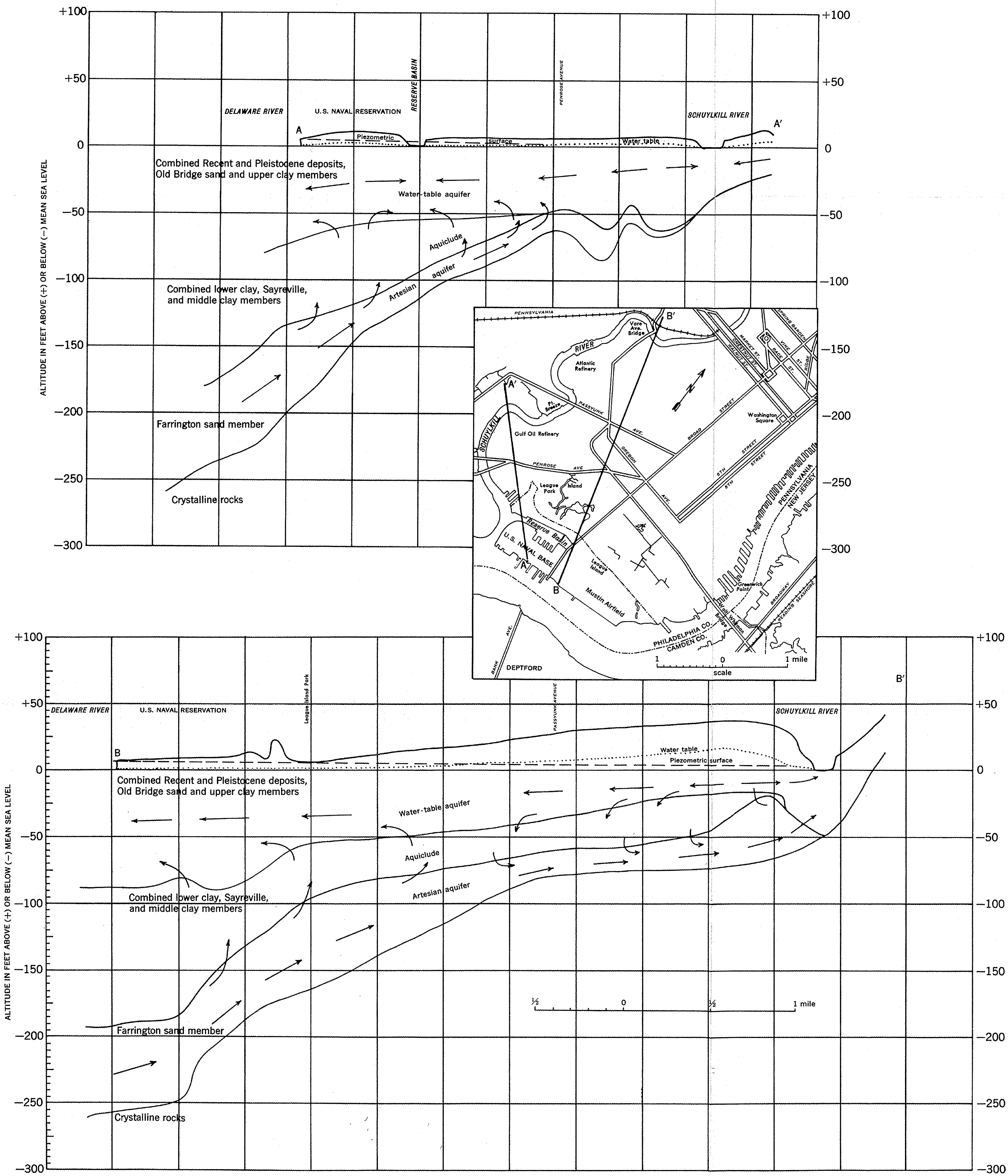


Plate 20 Cross sections showing probable directions of ground water movement in and between aquifers under natural conditions near the junction of the Delaware and Schuylkill Rivers in Pennsylvania.

APPENDIX E

Soil and Groundwater Analytical Reports (on CD)

Appendix E: Data Usability Assessment

Data usability is the process of evaluating the laboratory data results and determining the confidence with which any data point may be used. Data usability is evaluated to ensure that the opportunity for incorporating unacceptable and unmanageable error into the decision-making process is minimized to the extent possible. Usability is determined by evaluating the data qualifiers applied by the laboratory or data validator and the project data quality objectives. Reported results may be considered to have a high degree of confidence because the method performance criteria were achieved or, alternatively, the results may be considered estimates and flagged by the lab. These flags include "J" qualifiers to indicate a reported result is estimated below the laboratory reporting limit; "UJ" qualifiers to indicate a reported non-detect result may be biased because the associated detection limits are inaccurate; and "B" qualifiers to indicate a reported result may be biased high due to blank contamination.

For the purposes of this investigation, groundwater and soil results were summarized in thirteen laboratory reports, provided by Lancaster Laboratories, and are evaluated in the sections below for usability. These samples were collected in 2010 and 2012 by Aquaterra Tech. on behalf of Sunoco, Inc. and analyzed for volatile organic compounds (VOC), semi-volatile organic compounds (SVOC), ethylene dibromide (EDB), metals and wet chemistry parameters. Copies of the laboratory reports are provided in this appendix for your reference. Any analytical data, data qualifiers, and QC results provided in these reports were evaluated to determine the confidence with which this groundwater data could be used in the decision-making process. The criteria used in the data usability summary are presented in the following sections.

Data Quality Indicators

Data quality indicators (DQIs) are qualitative and quantitative measures of data quality "attributes," which are descriptors used to express various properties of analytical data. Thus, DQIs are the various measures of the individual data characteristics that collectively comprise the general, all-encompassing term "data quality." Quality attributes used to assess the data usability include:

- Method selectivity/specificity
- Accuracy (bias)
- Precision
- Representativeness
- Comparability
- Completeness

These indicators, as they relate to the data collected during the site characterization, are described in more detail below.

<u>Method Selectivity/Specificity</u>

Method selectivity/specificity is defined as the compound type or class that can be detected by the instrument or detector. Instruments that are used to detect a compound class (i.e., hydrocarbons) are said to be selective. Instruments that are used to detect a specific element group (e.g., halogens) are said to be specific. Groundwater, soil, and indoor air samples, as well as field QC blanks, were analyzed for the following parameters using the listed selective and specified methods:

- GC/MS Volatiles via EPA Method and SW-846 8260B,
- GC/MS Semi-volatiles in water via EPA Method SW-846 8270C,
- Ethylene Dibromide via EPA Method SW-846 8011,
- Metals via EPA Method SW-846 6010B and SW-846 6020, and
- Wet Chemistry via EPA Methods EPA 300.0, SM20 5310C, SM20 2320B, SM20 2540C, SM20 4500 S2D, SM20 4500NH3 B/C modified and SM20 2540G.

Accuracy (Bias)

Accuracy is defined as the amount of agreement between the laboratory's reported concentration and the true concentration of an analyte in an environmental sample. An evaluation of accuracy provides an estimate of bias. Bias is considered to be high or low, which means that the "actual" concentration is likely lower or higher (respectively) than the laboratory result indicates. While bias direction can be estimated for data quality impacts the degree to which bias impacts the laboratory result cannot be estimated.

Indicators of accuracy include, but are not limited to, surrogate spike recoveries, laboratory control spike recoveries, matrix spike recoveries, and matrix spike duplicate recoveries. The acceptable ranges of accuracy for each of the above listed indicators are method specific and are defined within the published analytical test methods specified in the section above. For the purposes of this assessment, accuracy [or bias] was evaluated by reviewing the following indicators:

- *Sample hold times* to ensure all samples were analyzed within method specific timeframes. If hold times are exceeded, reported concentrations may be biased low.

- *Lab and field blank samples* to ensure no analytes were detected: if analytes were detected in blank samples, the concentrations of these analytes in the normal environmental samples may be biased high.

- *Percent recovery of surrogate spikes* (synthetic compounds injected into each sample) to ensure that these compounds were recovered within the range deemed acceptable by the analytic method. If surrogates are recovered below this range then concentrations reported for the target analytes may be biased low: likewise, if surrogates are recovered above this range then concentrations reported for the target analytes may be biased high.

- *Percent recovery of each compound analyzed in the lab QC samples [Laboratory Control Spike (LCS) and Laboratory Control Spike Duplicate*

(LCSD)] and field QC samples [Matrix Spike (MS) and Matrix Spike Duplicate (MSD)].

LCS and LCSD samples are samples of DI water spiked with known concentrations of the target analytes. LCS and LCSD samples are run at a rate of one per sample batch (approximately 20 samples) and are indicators of method performance. If compounds within the LCS or LCSD are recovered above or below the acceptable ranges than concentrations of those compounds may be biased in each of the normal environmental samples within the corresponding batch.

MS and MSD samples are normal environmental samples collected at the project site and spiked with known concentrations of the target analytes. MS and MSD samples are typically run at the same frequency as LCS and LCSD samples but are indicators of potential bias based on the sampling matrix. If compounds within the MS or MSD are recovered above or below the acceptable ranges than concentrations of those compounds may be biased in each of the normal environmental samples within the corresponding batch.

Each laboratory sample delivery group (SDG) was evaluated for accuracy based on the components listed above. A complete list of SDGs included in the evaluation is as follows:

1202808	1204282	1197775
1203026	1204283	1198981
1203256	1205094	1198982
1203491	1285228	
1203664	1196722	

Generally, the data provided in each of these laboratory SDGs meet the criteria for accuracy [listed below]. Exceptions and indicators of potential bias are listed by data package in the sections to follow.

- Trip and field blanks weren't submitted for analysis and therefore can't be used to evaluate potential bias related to sample collection or transportation.
- Samples were analyzed within sample hold times removing potential bias.
- Target compounds weren't detected above the limit of quantitation ("LOQ") in the lab blank removing potential bias.
- Recoveries in LCS/LCSD and MS/MSD samples were between acceptable recovery control limits removing potential bias.
- Surrogate recoveries were between acceptable recovery control limits removing potential bias.

Indicators of potential bias (by SDG):

Sample Delivery Group 1202808:

- Recovery of the surrogate 1,1,2,2-tetrachloroethane in analysis of VOCs in sample C-129D_071210 (lab sample 6030839) was less than the lower control limit resulting in potential negative bias.

Sample Delivery Group 1203026:

- Sample C-49_071310 (lab sample 6031963) did not meet minimum requirements for preservation for analysis of VOCs resulting in potential negative bias.

Sample Delivery Group 1203256:

- Sample C-57_071410 (lab sample 6033027) did not meet the minimum requirements for preservation for analysis of VOCs resulting in potential negative bias.

Sample Delivery Group 1203491:

- Sample C-131_071510 (lab sample 6034560) did not meet the minimum requirements for preservation for analysis of VOCs resulting in potential negative bias.

Sample Delivery Group 1204582:

- Sample C-142 (lab sample 6039476) did not meet the minimum requirements for preservation for analysis of VOCs resulting in potential negative bias.

Sample Delivery Group 1197775:

- The following MS/MSD samples were not within acceptable recovery control limits.
    - Low MS recovery of benzo(ghi)perylene in batch 10160SLA026 (corresponding to samples C-129_ 1-2 and C-139_ 1-2 (lab samples 6000420 - 6000421) resulting in potential negative bias.
    - Low MS recovery of benzo(ghi)perylene in batch 10160SLX026 (corresponding to samples C-130_ 1-2, C-142_ 1-2 and C-131_ 1-2 (lab samples 6000419, 6000423 – 6000424 respectively) resulting in potential negative bias.
    - High MS recovery of phenanthrene in batch 10160SLA026 (corresponding to samples C-129_ 1-2 and C-139_ 1-2 (lab samples 6000420 - 6000421) resulting in potential positive bias.
    - High MS recovery of phenanthrene in batch 10160SLX026 (corresponding to samples C-130_ 1-2, C-142_ 1-2 and C-131_ 1-2 (lab samples 6000419, 6000423 – 6000424 respectively) resulting in potential positive bias.
    - Low MSD recovery of anthracene, benzo(ghi)perylene and fluoranthene in batch 10160SLA026 (corresponding to samples C-129_ 1-2 and C-139_ 1-2 (lab samples 6000420 - 6000421) resulting in potential negative bias.

- Low MSD recovery of anthracene in batch 10160SLX026 (corresponding to samples C-130_ 1-2, C-142_ 1-2 and C-131_ 1-2 (lab samples 6000419, 6000423 – 6000424 respectively) resulting in potential negative bias.
- High MS recovery of benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(ghi)perylene, chrysene, phenanthrene and pyrene in batch 10168SLA026 (corresponding to sample C-143_ 1-2 (lab sample 6000422) resulting in potential positive bias.

Sample Delivery Group 1198982:

- Sample BH-10-23_1.0-1.5 (lab sample 6007703) was analyzed for VOCs outside of the acceptable holding time resulting in potential negative bias.
- Recovery of the surrogate 1,2-dichloroethane in analysis of VOCs in sample BH-10-30_1.5-2.0 (lab sample 6007707); dibromofluoromethane in sample BH-10-27_1.5-2.0 (lab sample 6007709); 4-bromofluorobenzene in samples BH-10-22_1.5-2.0, BH-10-18_1.5-2.0, BH-10-06_1.2-1.7, BH-10-13_1.5-2.0 and BH-10-12_1.5-2.0 (lab samples 6007715, 6007719, 6007721, 6007723 and 6007727 respectively); and, 2-fluorobiphenyl in analysis of SVOCs in sample BH-10-08_1.5-2.0 (lab sample 6007730) were less than the lower control limit resulting in potential negative bias.
- Recovery of the surrogate toluene-d8 in analysis of VOCs in sample BH-10-22_1.5-2.0 (lab sample 6007715); dibromofluoromethane in sample BH-10-05_1.5-2.0 (lab sample 6007722); 1,2-dichloroethane in samples BH-10-05_1.5-2.0 and BH-10-12_1.5-2.0 (lab samples 6007722 and 6007727); and, 4-bromofluorobenzene in sample BH-10-16_1.5-2.0 (lab sample 6007726) were greater than the upper control limit resulting in potential positive bias.

<u>Precision</u>

Precision is defined as the ability to reproduce analytical results and is the measure of variability between individual sample measurements under prescribed conditions. Precision is assessed by the analysis of duplicate samples and expressed in terms of relative percent difference (RPD). For this project, analytical variability was measured as the relative percent difference (RPD) between 1) analytical laboratory duplicates (LCS and LCSD), and 2) the matrix spike (MS) and matrix spike duplicate (MSD). Field duplicate samples are not required under the sampling guidelines and were not collected.

Each laboratory sample delivery group listed in the section above was evaluated for precision. Generally, the LCS/LCSD and MS/MSD in each of these laboratory SDGs for each parameter group [VOCs, SVOCs, metals, EDB and wet chemistry] are below the maximum allowable RPD and meet the criteria for precision. Exceptions are listed by data package in the sections to follow.

Sample Delivery Group 1197775:

- Benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(ghi)perylene, chrysene and phenanthrene in batch 10160SLA026 (corresponding to samples C-129_ 1-2 and C-139_ 1-2 (lab samples 6000420 and 6000421).
- Benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(ghi)perylene, chrysene, phenanthrene and pyrene in batch 10160SLX026 (corresponding to samples C-130_ 1-2, C-142_ 1-2 and C-131_ 1-2 (lab samples 6000419, 6000423 - 6000424).
- Lead in batch 101616150001A (corresponding to lab samples 6000419 - 6000424). Please see table E-1 for a complete list of lab sample IDs and corresponding client sample IDs.

Representativeness

Representativeness is the degree to which data accurately and precisely represents a characteristic of a population, parameter variations at a sampling point, or an environmental condition. Representativeness is a qualitative parameter most concerned with the proper design of the sampling program. The representativeness criteria may be satisfied by making certain the sampling locations are selected properly and that a sufficient number of samples are collected to fulfill program objectives.

Groundwater and soil samples were collected from locations biased to potential source areas and/or sensitive receptors (surface water bodies, occupied buildings, and residential properties). The compounds analyzed in groundwater and soil samples include the compounds currently identified in the Pennsylvania Corrective Action Process (CAP) Regulation Amendments effective December 1, 2001; provided in Chapter VI, Section E of PADEP's Closure Requirements for Underground Storage Tank Systems (with exception for the waste oil parameters since waste oil is only stored in small tanks within the facility maintenance garages). These compounds are the same as those listed for groundwater in the Current Conditions Report (Langan, 2004).

The data collected during this investigation is considered representative of groundwater and soil in AOI 7 based on the distribution of the monitoring wells and soil boring sampling locations within the sampling program, the frequency of sample collection, and the suite of parameters analyzed.

Comparability

Comparability is the degree to which data from one study can be compared with data from other similar studies, reference values (such as background), reference materials, and screening values. This goal was achieved by using standard techniques to collect and analyze representative samples and reporting analytical results in appropriate units. The sample collection methods used were based on PADEP's guidelines summarized in the Groundwater Monitoring Guidance Manual dated December 1, 2001 and the Groundwater Sampling and Analysis Plan, dated January 17, 2008. The analytical methods used are EPA solid waste methods or Standard Methods.

Based on this data quality analysis the data are considered comparable to other groundwater and soil data collected as part of other sampling programs.

Completeness

Completeness is defined as the percentage of usable data in the total data population generated. Completeness was calculated for each compound where data were qualified as estimated and for compounds that were affected by blank contamination. Completeness is determined as the difference between the total number of data points and the number of data points qualified divided by the total number of data points.

For compounds analyzed in soil 98% percent of the data is considered complete. The remaining 2% was qualified as estimated by the laboratory and flagged with a "J" qualifier. As detailed in the sections above, few concentrations should be considered as biased because MS/MSD and surrogate recoveries were beyond acceptable control limits. The following samples should not be used for the purpose of delineation because samples were diluted to the point that laboratory method detection limits were raised above the corresponding screening criteria (PADEP Soil MSCs) and no concentration was detected. Specifically, 1,2-dichloroethane in sample BH-10-27_1.5-2; and, ethylene dibromide in samples BH-10-08_1.5-2, BH-10-10_1.5-2, BH-10-11_1.5-2, BH-10-14_1.5-2, BH-10-16_1.5-2, BH-10-17_1.5-2, BH-10-24_1.5-2, BH-10-25_1.5-2, BH-10-27_1.5-2, BH-10-28_1.5-2, BH-10-30_1.5-2, BH-10-31_1.5-2, C-142_1-2 and C-143_1-2.

For compounds analyzed in groundwater 90% percent of the data is considered complete. The remaining 10% was qualified as estimated by the laboratory and flagged with a "J" qualifier. As detailed in the sections above, few concentrations should be considered as biased because surrogate recoveries were beyond acceptable control limits and sample preservation requirements were not met. Preservation requirements were not met for samples C-49_071310, C-57_071410, C-131_071510 and C-142.

Summary and Conclusions

For the purposes of this investigation, sample results were summarized in thirteen sample delivery groups, provided by Lancaster Laboratories, and are evaluated in the sections above for usability. Copies of the laboratory reports are provided in this appendix for your reference.

The laboratory performed quality assurance and quality control (QA/QC) analyses, including laboratory control spikes and laboratory control spike duplicates, matrix spikes and matrix spike duplicates, surrogate spikes, and method blanks. Laboratory QA/QC summaries were completed by the laboratory and provided in each data package, attached. The analytical data, data qualifiers, and QC results provided in these reports were evaluated to determine the confidence with which this groundwater and soil data could be used in the decision-making process.

Data quality indicators (DQIs) are qualitative and quantitative measures of data quality "attributes," which are descriptors used to express various properties of analytical data. Thus, DQIs are the various measures of the individual data characteristics that collectively comprise the general, all encompassing term "data quality." Quality attributes used to assess the data usability include:

- Method selectivity/specificity
- Accuracy (bias)
- Precision
- Representativeness
- Comparability
- Completeness

Based on evaluation of these indicators the groundwater and soil data collected during this investigation is considered usable with the exception of those samples specifically identified above for characterizing the site, identifying compounds of concern, and delineating potential impacts. As detailed in the sections above, few concentrations should be considered as biased because MS/MSD and surrogate recoveries were beyond acceptable control limits and preservation requirements were not met. Samples where the RPD exceeds the maximum limit may indicate that the sample matrix may affect reproducibility of the environmental sample.

Where the surrogate, LCS/LCSD and MS/MSD recoveries were less than the lower recovery control limit the reported values should be considered as estimated low. Where the recoveries were greater than the upper recovery control limit the reported values should be considered as estimated high. The corresponding data are considered usable but should be considered slightly higher or lower in concentration than representative of the site and time collected.

Table E-1 - Laboratory and Client Sample Names
AOI-7
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Lab Report Number 1202808	
Client Sample ID	**Laboratory Sample ID**
C-129_071210	6030838
C-129D_071210	6030839
C-130_071210	6030840
C-50_071210	6030841
Lab Report Number 1203026	
Client Sample ID	**Laboratory Sample ID**
C-96_071310	6031959
C-50D_071310	6031960
C-95_071310	6031961
C-113_071310	6031962
C-49_071310	6031963
C-109_071310	6031964
Lab Report Number 1203256	
Client Sample ID	**Laboratory Sample ID**
C-112_071410	6033025
C-114_071410	6033026
C-57_071410	6033027
C-58_071410	6033028
C-51_071410	6033029
Lab Report Number 1203491	
Client Sample ID	**Laboratory Sample ID**
C-127_071510	6034558
C-52_071510	6034559
C-131_071510	6034560
C-132_071510	6034561
C-133_071510	6034562
C-137_071510	6034563
C-54_071510	6034564
Lab Report Number 1203664	
Client Sample ID	**Laboratory Sample ID**
C-55_071610	6035583
C-138_071610	6035584
C-60_071610	6035585
C-98_071610	6035586
C-63_071610	6035587
C-108_071610	6035588
C-53A_071610	6035589
Lab Report Number 1204282	
Client Sample ID	**Laboratory Sample ID**
C-62	6039473
C-134D	6039474
C-140	6039475
C-142	6039476
Lab Report Number 1204283	
Client Sample ID	**Laboratory Sample ID**
C-61_071910	6039477
C-44_071910	6039478
C-104_071910	6039479
C-105_071910	6039480
C-144D_071910	6039481
Lab Report Number 1205094	
Client Sample ID	**Laboratory Sample ID**
C-110_072710	6044724
C-111_072710	6044725
C-56_072710	6044726

Lab Report Number 1285228	
Client Sample ID	**Laboratory Sample ID**
C-155_01122012	6523032
C-156_01122012	6523033
C-157_01122012	6523034
C-158_01122012	6523035
C-159_01122012	6523036
C-163_01122012	6523037
C-164_01122012	6523038
C-165_01122012	6523039
C-145_01122012	6523040
C-146_01122012	6523041
Lab Report Number 1197775	
Client Sample ID	**Laboratory Sample ID**
C-130_ 1-2	6000419
C-129_ 1-2	6000420
C-139_ 1-2	6000421
C-143_ 1-2	6000422
C-142_ 1-2	6000423
C-131_ 1-2	6000424
Lab Report Number 1198981	
Client Sample ID	**Laboratory Sample ID**
S-307_0-2	6007699
S-135_0-2	6007700
S-299_0-2	6007701
Lab Report Number 1198982	
Client Sample ID	**Laboratory Sample ID**
BH-10-24_1.0-1.5	6007702
BH-10-23_1.0-1.5	6007703
BH-10-25_1.2-1.7	6007704
BH-10-26_1.5-2.0	6007705
BH-10-29_0.7-1.2	6007706
BH-10-30_1.5-2.0	6007707
BH-10-28_1.5-2.0	6007708
BH-10-27_1.5-2.0	6007709
BH-10-33_1.5-2.0	6007710
BH-10-35_1.3-1.7	6007711
BH-10-34_1.0-1.5	6007712
BH-10-32_0.5-1.0	6007713
BH-10-31_1.5-2.0	6007714
BH-10-22_1.5-2.0	6007715
BH-10-21_1.0-1.5	6007716
BH-10-20_1.3-1.8	6007717
BH-10-19_0.5-1.0	6007718
BH-10-18_1.5-2.0	6007719
BH-10-17_1.5-2.0	6007720
BH-10-06_1.2-1.7	6007721
BH-10-05_1.5-2.0	6007722
BH-10-13_1.5-2.0	6007723
BH-10-14_1.5-2.0	6007724
BH-10-15_1.4-1.9	6007725
BH-10-16_1.5-2.0	6007726
BH-10-12_1.5-2.0	6007727
BH-10-11_1.5-2.0	6007728
BH-10-10_1.5-2.0	6007729
BH-10-08_1.5-2.0	6007730
BH-10-09_1.2-1.7	6007731
BH-10-07_1.0-1.5	6007732

APPENDIX F

July 2010 Groundwater Sampling Field Summary Report

Appendix F
July 2010 Groundwater Sampling Field Summary
AOI 7
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

WELL INFO					FIELD READINGS (pre-purge)						FIELD READINGS (post-purge)								FIELD READINGS (sampling)	
Location ID	Depth to Bottom (ft bgs)	Depth to Water (ft btic)(1)	Depth to Product (ft btic)	Product Thickness (ft)	Purge Start	Temp. (°C)	DO (mg/L)	ORP (mv)	pH	Conductivity (mS/cm)	Purge Complete	Approx. Purge Rate (gpm)(2)	Volume Purged (gal)	Temp. (°C)	DO (mg/L)	ORP (mv)	pH	Conductivity (mS/cm)	Date Sampled	Sample Time
C-104	17.76	6.16	NP	NP	12:20	16.80	8.27	-67.8	5.99	1.325	12:55	2.00	22.70	17.68	8.34	-47.9	6.06	1.316	7/19/2010	12:55
C-105	17.40	3.65	NP	NP	13:20	17.50	9.10	-44.6	6.10	0.959	13:35	2.00	26.90	18.99	13.85	-37.8	6.39	0.960	7/19/2010	13:35
C-106	NM	product	8.85	1.25	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
C-107	NM	product	8.30	2.19	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
C-108	17.18	4.13	NP	NP	13:15	19.19	12.07	4.30	5.84	1.134	13:40	2.00	25.50	22.11	9.55	-15.5	6.01	1.121	7/16/2010	13:40
C-109	17.84	6.75	NP	NP	14:20	16.92	3.23	-46.6	6.41	2.840	14:55	2.00	18.70	18.86	1.77	-31.5	6.23	2.855	7/13/2010	14:55
C-110	17.48	5.13	NP	NP	9:40	18.46	8.99	14.99	7.23	0.936	10:00	1.50	24.00	17.86	2.32	16.20	7.09	0.001	7/27/2010	10:00
C-111	16.96	4.46	NP	NP	10:40	18.34	6.72	12.20	7.21	0.912	11:00	1.50	24.50	17.77	1.90	17.30	7.11	0.001	7/27/2010	8:55
C-112	16.78	3.64	NP	NP	8:30	16.11	5.48	-51.5	6.28	1.996	8:55	2.00	22.20	17.53	2.15	-51.9	6.22	1.855	7/14/2010	8:55
C-114	18.84	3.32	NP	NP	10:00	16.91	4.35	-55.0	6.59	1.102	10:25	2.00	30.40	19.22	3.70	-25.1	6.19	1.046	7/14/2010	10:25
C-127	16.78	7.61	NP	NP	8:20	22.29	5.05	-31.05	6.64	1.258	8:50	2.00	17.90	21.28	6.09	-38.2	6.56	0.720	7/15/2010	8:50
C-50	18.85	7.75	NP	NP	14:25	18.41	2.45	-71.8	6.43	0.714	14:50	2.00	21.80	20.21	1.20	-94.3	6.87	0.635	7/12/2010	14:45
C-50D	28.73	11.25	NP	NP	10:55	18.51	1.89	-29.2	6.55	0.693	11:05	2.00	14.80	19.31	2.76	-15.6	6.40	1.374	7/13/2010	11:05
C-51	13.28	3.36	NP	NP	13:00	18.58	3.93	-22.1	6.19	0.628	13:35	2.00	19.40	21.43	6.73	-8.8	6.37	0.531	7/14/2010	13:35
C-52	14.15	4.86	NP	NP	9:10	21.79	3.78	-37.3	6.52	0.735	9:30	2.00	15.70	35.01	4.03	-39.2	6.54	0.717	7/15/2010	9:30
C-53A	16.80	3.68	NP	NP	14:00	17.45	8.64	-22.3	5.75	1.599	14:30	2.00	22.10	19.53	8.84	-22.5	6.13	1.585	7/16/2010	14:30
C-54	12.32	<1	NP	NP	14:00	21.16	13.54	-21.2	6.21	1.426	14:35	2.00	22.10	26.32	17.06	71.20	6.28	0.965	7/15/2010	12:35
C-55	16.87	4.45	NP	NP	8:40	18.16	10.98	24.00	6.72	0.511	9:00	2.00	24.30	21.30	10.65	55.10	6.50	0.554	7/16/2010	9:00
C-56	13.85	2.23	NP	NP	11:40	19.65	5.45	11.10	6.97	0.873	12:00	1.50	23.00	18.23	2.12	12.40	6.93	0.001	7/27/2010	12:00
C-57	13.25	1.93	NP	NP	11:00	20.28	3.19	-33.0	5.99	1.572	11:20	2.00	22.20	24.12	2.19	-47.3	6.23	1.612	7/14/2010	11:20
C-58	11.97	1.01	NP	NP	12:15	28.07	2.96	-50.5	6.49	0.755	12:40	2.00	21.10	28.97	5.44	-34.0	6.41	0.637	7/14/2010	12:40
C-60	13.98	3.58	NP	NP	10:40	19.79	7.04	80.40	5.48	4.231	11:05	2.00	20.30	23.49	9.73	26.10	6.09	1.634	7/16/2010	11:05
C-61	12.85	2.95	NP	NP	14:00	19.45	12.12	-21.8	5.91	0.979	14:20	2.00	19.40	23.73	13.59	-39.5	6.41	0.957	7/19/2010	14:20
C-62	15.47	4.19	NP	NP	12:00	18.61	5.42	-0.4	6.94	1.621	12:30	2.00	22.10	19.88	10.47	-40.2	6.97	1.541	7/20/2010	12:30
C-63	16.11	5.46	NP	NP	12:25	23.43	13.96	-16.3	6.36	0.708	12:55	2.00	20.80	23.37	13.83	-17.7	6.43	0.729	7/16/2010	12:55
C-64	11.37	6.17	NP	NP	11:40	19.82	7.10	-64.2	6.34	0.629	11:55	2.00	10.20	20.54	7.26	-51.6	6.25	0.828	7/19/2010	11:55
C-65	7.15	product	4.90	0.46	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
C-65D	NM	Damaged	NP	NP	NS-blockage in well		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C-95	32.16	5.19	NP	NP	11:45	15.70	2.54	-71.4	6.08	1.629	12:10	2.00	33.30	NM	NM	NM	NM	NM	7/13/2010	12:15
C-96	19.30	4.80	NP	NP	9:40	16.78	1.95	-78.5	6.48	1.528	10:10	2.00	29.20	16.34	1.93	-93.2	6.73	1.641	7/13/2010	10:05
C-97	NM	product	10.70	0.25	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
C-98	19.68	4.86	NP	NP	11:15	18.61	8.89	-50.3	6.09	1.731	11:55	2.00	28.30	18.15	9.20	-54.4	6.04	1.456	7/16/2010	11:55
C-49	19.09	4.64	NP	NP	8:24	15.51	4.19	-55.5	6.03	2.063	09:00	2.00	28.30	NM	NM	NM	NM	NM	7/13/2010	13:55
C-113	17.53	3.54	NP	NP	13:00	17.45	1.36	-58.7	17.47	0.744	13:20	2.00	27.40	NM	NM	NM	NM	NM	7/13/2010	13:25
C-129	12.00	5.07	NP	NP	10:20	22.47	3.59	27.00	7.56	0.814	10:45	2.00	13.60	23.70	3.39	157.10	7.44	0.752	7/12/2010	10:45
C-129D	66.00	10.41	NP	NP	11:20	18.52	3.47	-18.8	11.58	2.073	12:30	2.00	108.40	19.82	1.33	-123.3	7.26	1.044	7/12/2010	12:30
C-130	15.00	7.02	NP	NP	14:20	20.81	1.99	-39.0	5.97	1.211	14:30	2.00	15.64	18.92	2.71	-30.4	6.02	1.744	7/12/2010	14:30
C-131	14.00	5.17	NP	NP	10:10	20.37	6.16	-65.8	6.47	2.952	10:40	2.00	21.20	19.37	282.00	-35.5	6.28	2.392	7/15/2010	10:40
C-132	14.00	2.60	NP	NP	11:25	20.17	4.95	-48.0	6.84	0.624	11:45	2.00	22.30	24.43	5.09	-20.8	6.98	0.505	7/15/2010	11:45
C-133	14.00	1.25	NP	NP	12:05	20.11	6.13	73.20	6.31	3.634	12:30	2.00	24.90	21.81	7.90	63.40	6.24	4.391	7/15/2010	12:30
C-134D	72.00	10.26	NP	NP	10:00	18.96	4.13	-440.6	11.48	4.567	11:30	2.00	121.00	19.46	6.94	-236.8	9.53	0.860	7/20/2010	11:30
C-136	14.00	5.05	NP	NP	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C-137	14.00	1.95	NP	NP	13:15	24.83	11.73	-19.2	6.43	1.272	13:35	2.00	23.60	27.00	12.15	-28.0	6.35	1.357	7/18/2010	13:35
C-138	12.00	3.47	NP	NP	10:00	21.34	12.20	-43.4	7.06	0.572	10:25	2.00	16.70	26.17	13.57	-22.4	7.64	0.625	7/16/2010	10:25
C-139	12.00	3.00	NP	NP	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C-140	12.00	1.10	NP	NP	11:40	25.32	8.07	-174.2	8.91	1.147	11:50	2.00	21.40	23.92	10.54	-110.6	8.13	1.236	7/20/2010	11:50
C-142	14.00	5.20	NP	NP	13:00	23.24	8.56	-72.4	6.99	1.926	13:25	2.00	17.20	17.51	9.57	-50.6	6.89	1.676	7/20/2010	13:25
C-143	14.00	9.20	8.22	0.80	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
C-144D	80.11	11.35	NP	NP	10:10	22.37	5.31	-87.1	6.42	0.000	11:30	2.00	116.20	18.29	3.86	-57.1	6.10	0.844	7/19/2010	11:10

Notes:
(1) - Measured prior to purging
(2) - Wells purged with whale pump unless otherwise noted
Groundwater quality readings collected using a YSI
Blocked - Well was blocked and unable to lower pump
A minimum of 3 well volumes were purged at each well location, unless well went dry during purging
All wells were sampled using poly bailers
Hand - Well purged using bailer
ft btic - Feet below top of inner casing
ft bgs - Feet below ground surface
mg/L - Milligrams per Liter
^{0}C - Degrees celsius
mV - Milli volts
mS/cm - Milli siemens per cm
NM - Not measured
NP - No measurable (>0.01 ft) product
NS-P - Not sampled due to measurable (>0.01 ft) product
NS-Dry - Not sampled well was dry
gpm - Gallons per minute
NM - Total depth of well not measured due to the presence of light non aqueous phase liquid (LNAPL)

Appendix F
January 2012 Groundwater Sampling Field Summary
AOI 7
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

WELL INFO					FIELD READINGS (pre-purge)						FIELD READINGS (post-purge)								FIELD READINGS (sampling)	
Location ID	Depth to Bottom (ft bgs)	Depth to Water (ft btic)(1)	Depth to Product (ft btic)	Product Thickness (ft)	Purge Start	Temp. (°C)	DO (mg/L)	ORP (mv)	pH	Conductivity (mS/cm)	Purge Complete	Approx. Purge Rate (gpm)(2)	Volume Purged (gal)	Temp. (°C)	DO (mg/L)	ORP (mv)	pH	Conductivity (mS/cm)	Date Sampled	Sample Time
C-104	17.76	6.90	–	–	'---- GAUGE ONLY ----															
C-105	17.40	2.89	–	–	'---- GAUGE ONLY ----															
C-106	NM	9.45	7.69	1.76	'---- GAUGE ONLY ----															
C-107	NM	Could not locate			'---- GAUGE ONLY ----															
C-108	17.18	4.72	–	–	'---- GAUGE ONLY ----															
C-109	17.84	3.98	–	–	'---- GAUGE ONLY ----															
C-110	17.48	5.15	–	–	'---- GAUGE ONLY ----															
C-111	16.96	3.84	–	–	'---- GAUGE ONLY ----															
C-112	16.78	Flooded- Inaccessable			'---- GAUGE ONLY ----															
C-114	18.84	3.74	–	–	'---- GAUGE ONLY ----															
C-127	16.78	7.66	–	–	'---- GAUGE ONLY ----															
C-50	18.85	7.43	–	–	'---- GAUGE ONLY ----															
C-50D	28.73	10.98	–	–	'---- GAUGE ONLY ----															
C-51	13.28	3.45	–	–	'---- GAUGE ONLY ----															
C-52	14.15	5.40	–	–	'---- GAUGE ONLY ----															
C-53A	16.80	4.10	–	–	'---- GAUGE ONLY ----															
C-54	12.32	0.70	–	–	'---- GAUGE ONLY ----															
C-55	16.87	4.88	–	–	'---- GAUGE ONLY ----															
C-56	13.85	1.83	–	–	'---- GAUGE ONLY ----															
C-57	13.25	2.37	–	–	'---- GAUGE ONLY ----															
C-58	11.97	1.34	–	–	'---- GAUGE ONLY ----															
C-60	13.98	3.48	–	–	'---- GAUGE ONLY ----															
C-61	12.85	3.06	–	–	'---- GAUGE ONLY ----															
C-62	15.47	4.29	–	–	'---- GAUGE ONLY ----															
C-63	16.11	6.25	–	–	'---- GAUGE ONLY ----															
C-64	11.37	8.05	6.92	1.13	'---- GAUGE ONLY ----															
C-65	NM	5.28	4.22	1.06	'---- GAUGE ONLY ----															
C-65D	7.15	2.22	–	–	'---- GAUGE ONLY ----															
C-95	32.16	5.60	–	–	'---- GAUGE ONLY ----															
C-96	19.30	5.42	–	–	'---- GAUGE ONLY ----															
C-97	NM	9.84	9.73	0.11	'---- GAUGE ONLY ----															
C-98	19.68	5.45	–	–	'---- GAUGE ONLY ----															
C-49	19.09	5.82	–	–	'---- GAUGE ONLY ----															
C-113	17.53	4.36	–	–	'---- GAUGE ONLY ----															
C-129	12.00	4.88	–	–	'---- GAUGE ONLY ----															
C-129D	66.00	9.54	–	–	'---- GAUGE ONLY ----															
C-130	15.00	2.38	–	–	'---- GAUGE ONLY ----															
C-131	14.00	3.12	–	–	'---- GAUGE ONLY ----															
C-132	14.00	2.73	–	–	'---- GAUGE ONLY ----															
C-133	14.00	1.54	–	–	'---- GAUGE ONLY ----															
C-134	no well installed																			
C-134D	72.00	7.33	–	–	'---- GAUGE ONLY ----															
C-135	no well installed																			
C-136	14.00	4.42	–	–	'---- GAUGE ONLY ----															
C-136D	no well installed																			
C-137	14.00	3.57	–	–	'---- GAUGE ONLY ----															
C-138	12.00	4.02	–	–	'---- GAUGE ONLY ----															
C-139	12.00	4.35	–	–	'---- GAUGE ONLY ----															
C-140	12.00	1.53	–	–	'---- GAUGE ONLY ----															
C-140D	no well installed																			
C-141	no well installed																			
C-142	14.00	5.37	–	–	'---- GAUGE ONLY ----															
C-143	14.00	9.52	7.11	2.41	'---- GAUGE ONLY ----															
C-144D	78.00	11.51	–	–	'---- GAUGE ONLY ----															
WP14-2	-	6.98	5.92	1.06	'---- GAUGE ONLY ----															
C-145	15.00	4.72	–	–	0:00	14.05	5.23	32.70	7.55	0.470	0:00	2.00	20.00	15.57	4.93	11.60	7.88	0.48	1/13/2012	920
C-146	15.00	5.74	–	–	0:00	21.47	4.87	2.90	7.96	0.438	0:00	2.00	18.00	21.92	4.52	-8.80	8.07	0.49	1/13/2012	845
C-147	15.00	8.72	5.41	3.31	NS-P															
C-148	18.00	12.69	7.38	5.31	NS-P															
C-149	11.00	Destroyed during excavation																		
C-150	24.60	7.14	6.82	0.32	NS-P															
C-151	22.10	7.06	7.02	0.04	NS-P															
C-152	25.00	10.18	7.64	2.54	NS-P															
C-153	21.20	7.84	7.37	0.47	NS-P															
C-154	21.80	7.04	6.95	0.09	NS-P															
C-155	24.60	5.29	–	–	0:00	13.92	0.23	54.40	5.88	0.450	0:00	2.00	40.00	13.56	9.49	402.40	6.61	1.00	1/12/2012	1420
C-156	24.40	6.56	–	–	0:00	15.70	0.05	-80.60	6.93	0.602	0:00	2.00	35.00	14.64	0.80	-50.60	6.51	0.64	1/12/2012	1202
C-157	24.30	5.26	–	–	0:00	12.25	0.68	76.40	5.90	0.452	0:00	2.00	40.00	9.18	4.29	87.60	5.95	0.33	1/12/2012	1135
C-158	24.30	5.55	–	–	0:00	14.05	2.09	32.00	5.73	0.922	0:00	2.00	40.00	13.13	2.53	21.80	6.02	0.81	1/12/2012	1100
C-159	23.60	4.95	–	–	0:00	11.98	8.45	133.50	5.51	0.202	0:00	2.00	40.00	10.37	8.81	135.40	5.33	0.19	1/12/2012	950

Appendix F
January 2012 Groundwater Sampling Field Summary
AOI 7
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

WELL INFO					FIELD READINGS (pre-purge)						FIELD READINGS (post-purge)								FIELD READINGS (sampling)	
Location ID	Depth to Bottom (ft bgs)	Depth to Water (ft btic)[1]	Depth to Product (ft btic)	Product Thickness (ft)	Purge Start	Temp. (°C)	DO (mg/L)	ORP (mv)	pH	Conductivity (mS/cm)	Purge Complete	Approx. Purge Rate (gpm)[2]	Volume Purged (gal)	Temp. (°C)	DO (mg/L)	ORP (mv)	pH	Conductivity (mS/cm)	Date Sampled	Sample Time
C-160	10.40	Could Not Locate - Most likely destroyed																		
C-161	15.40	8.34	7.56	0.78	NS-P															
C-162	9.68	7.85	6.82	1.03	NS-P															
C-163	7.80	4.99	--	--	0:00	12.42	0.15	-33.50	6.00	1.111	0:00	2.00	6.00	13.73	0.10	-45.20	6.07	0.33	1/12/2012	1310
C-164	13.85	6.72	--	--	0:00	13.77	0.51	-25.90	5.92	1.570	0:00	2.00	15.00	14.25	0.95	-33.60	5.87	1.63	1/12/2012	1250
C-165	13.80	5.65	--	--	0:00	13.12	0.37	844.00	5.98	0.843	0:00	2.00	40.00	13.61	0.70	-9.00	5.98	0.94	1/12/2012	1230
C-166	-	8.84	8.11	0.73	NS-P															
C-167	-	13.77	8.36	5.41	NS-P															
C-168	-	6.05	5.72	0.33	NS-P															
C-169																				

Notes:
(1) - Measured prior to purging
(2) - Wells purged with whale pump unless otherwise noted
Groundwater quality readings collected using a YSI
Blocked - Well was blocked and unable to lower pump
A minimum of 3 well volumes were purged at each well location, unless well went dry during purging
All wells were sampled using poly bailers
Hand - Well purged using bailer
ft btic - Feet below top of inner casing
ft bgs - Feet below ground surface
mg/L - Milligrams per Liter
^{0}C - Degrees celsius
mV - Milli volts
mS/cm - Milli siemens per cm
NM - Not measured
NP - No measurable (>0.01 ft) product
NS-P - Not sampled due to measurable (>0.01 ft) product
NS-Dry - Not sampled well was dry
gpm - Gallons per minute
NM - Total depth of well not measured due to the presence of light non aqueous phase liquid (LNAPL)

APPENDIX G

Fate and Transport Analysis

APPENDIX G

FATE AND TRANSPORT MODELING PROCEDURES

AOI 7: SUNOCO PHILADELPHIA REFINERY

PHILADELPHIA, PENNSYLVNIA

G.1 INTRODUCTION

Fate and transport calculations were completed for groundwater in Area of Interest (AOI) 7 to evaluate potential migration pathways/potential impacts to receptors.

Ten wells (C-56, C-57, C-110, C-111, C-112, C-114, C-131, C-133, C-140, and C-142) in AOI 7 exhibited concentrations of groundwater compounds of concern (COCs) above their respective Pennsylvania groundwater medium specific concentrations (MSCs) in July 2010 and the January 2012 groundwater sampling events. The COCs detected above their respective MSC are benzene, chrysene and lead.

To address the potential future migration of these COCs, a fate and transport analysis was performed. A fate and transport analysis done as part of the Act 2 Program typically uses three models developed by PADEP: the Quick Domenico Version 2 (QD) model and the SWLOAD model used for fate and transport in groundwater; PENTOXSD used when assessing potential impacts of groundwater on surface water for organic constituents. Site-specific data was used to complete the fate and transport calculations, when available.

G.2 MODEL OVERVIEW

The QD Model is a Microsoft Excel spreadsheet application based on the analytical contaminant transport equation developed by P.A. Domenico in *"An Analytical Model For Multidimensional Transport of a Decaying Contaminant Species,"* Journal of Hydrology, 91 (1987), pp. 49-58. The QD model calculates contaminant concentrations at any down-gradient location after a specified interval of time. The model incorporates the processes of advection, first order decay, retardation, and dispersion to describe fate and transport of compounds. In addition, the QD model displays the results as a two dimensional chart to facilitate interpretation of the results.

G.3 MODEL LIMITATIONS

Limitations of the QD model include:

- Groundwater flow is assumed to be steady state, and one-dimensional;
- Aquifer properties are assumed to be reasonably uniform;
- Applicable only to unconsolidated aquifers;
- Intended for use primarily with dissolved organic compounds;
- Does not account for the transformation of parent compounds into daughter products as the result of biodegradation;
- Compounds are considered individually, and are assumed to not react with each other; and
- The contaminant source is limited to a single and continuous source concentration.

G.4 SCREENING AND APPROACH TO FATE AND TRANSPORT ANALYSIS

Fate and transport calculations were completed for groundwater in AOI 7 to evaluate potential migration pathways/potential impacts to receptors.

Ten monitoring wells (C-56, C-57, C-110, C-111, C-112, C-114, C-131, C-133, C-140, and C-142) in AOI 7 exhibited groundwater concentrations of benzene, chrysene, and lead above their respective PA non-residential groundwater MSCs in the July 2010 and January 2012 groundwater sampling events. Based on the data usability assessment, four monitoring well locations (C-49, C-57, C-131 and C-142) had preservation requirements which were not met; therefore, reported results are likely biased low. However, for screening purposes these results were still evaluated in the fate and transport analysis for AOI 7.

To address the potential future migration of these COCs, a fate and transport analysis was performed using the Quick Domenico Version 2 (QD) model and the SWLOAD model used for fate and transport in groundwater and PENTOXSD to assess potential impacts of groundwater on surface water for organic constituents. Site-specific data was used to complete the fate and transport calculations, when available. The approach and results of the modeling are discussed below. Modeling results can be found in Table G.1. Individual QD models can be found in Tables G.2 through G.8.

<u>Screening and Approach to Fate and Transport Analysis</u>

Eight monitoring wells (C-56, C-57, C-110, C-111, C-112, C-114, C-131, and C-133) in AOI 7 had detections above PADEP non-residential groundwater MSCs which were located along or near the AOI 7 boundary. From a fate and transport perspective, it is important to recognize that there are numerous monitoring wells with no detections above the PADEP non-residential groundwater MSCs for site COCs between these well locations and the Schuylkill River as described in more detail below. The COCs that were detected above the PADEP non-residential groundwater MSCs included lead (C-56), benzene (C-111), and chrysene (C-57, C-110, C-111, C-112, C-114, C-131, and C-133).

- A QD model was constructed for lead at C-56 despite the limitation of the QD model with respect to inorganic constituents; this was done as a screening for lead to evaluate attenuation by dispersion only. There were no detections of lead above the PADEP non-residential groundwater MSC downgradient of C-56 detected during the July 2010 and January 2012 sampling.

- Monitoring well C-57 had a reported chrysene concentration of 3 ug/l but is surrounded by monitoring wells that had no data usability concerns without detections of chrysene above the PADEP non-residential groundwater MSCs, therefore, a QD analysis was not performed at this location.

- C-113 had no detections of any COCs above the PADEP non-residential groundwater MSCs, has useable data and is located between C-112, where chrysene was detected at 3 ug/l at the property boundary. Because C-113 had no chrysene detections above the PADEP non-residential groundwater MSCs, a QD assessment was not performed for C-112.

- QD simulations were performed for C-110, C-111, C-131, C-114, and C-133 to evaluate potential impacts beyond the AOI 7 boundary.

- Two monitoring wells (C-140 and C-142) had detections of chrysene above the PADEP non-residential groundwater MSC and are located near the Schuylkill River. Chrysene concentrations above the PADEP non-residential groundwater MSC of 1.9 ug/l were detected at C-140 (2 ug/l) and C-142 (64 ug/l). C-140 is located approximately 55 feet from the sheet pile wall on the west side of AOI 7. C-142 is located approximately 150 feet from the sheet pile wall on the north side of AOI 7. Chrysene concentrations at both of these monitoring well locations do not exceed the PA Code Chapter 93.8c surface water quality criteria (SWQC) for acute fish exposure of 300 ug/l (a chronic criteria has not been derived). Chrysene concentrations at both monitoring well locations were detected above the target human health (THH) cancer risk level for chrysene of 0.0038 ug/l. To address the THH exceedence in surface water a QD and SWLOAD model was constructed for these wells.

- Groundwater results from monitoring well C-49 had preservation issues and no reported detections of any COCs were above the PADEP non-residential groundwater MSCs. To address potential transport at C-49 for chrysene, which is the principle COC along the eastern AOI 7 boundary, the maximum reported chrysene impact in AOI 7 of 64 ug/l (C-142) was assumed for C-49, this well will also be resampled and the fate and transport will be re-run based on the sample results.

- QD and SWLOAD simulations were created for monitoring wells located in between the No. 3 Seperator and sheet pile wall. Monitoring wells in this area were not sampled due to the presence of LNAPL. A chrysene concentration equal to 1.9 ug/l which is the aqueous saturation, was used.

- QD and SWLOAD simulations were created for the No. 3 Separator Area to address the potential migration of chrysene in the area between the bulkhead and the No. 3 Separator Area. Wells in this area were not sampled due to the presence of LNAPL a chrysene concentration equal to 1.9 ug/l, its aqueous saturation, was used.

G.4 MODEL INPUT PARAMTERS

In preparation of this report, input values for the QD and SWLOAD models were compiled from available site-specific data. When no site-specific data was available, estimated input values from the PADEP spreadsheet "Number Please!," which is based on PA Code, Chapter 250, Appendix A, Table 5, or other acceptable literature sources, were utilized. The input parameters for all QD and SWLOAD models can be found in Tables G2 though G.14 in this appendix. An Excel spreadsheet interface was used to construct the QD simulations. This interface allowed the simulation of all relevant compounds at each well location to be constructed and saved in a single electronic file.

G.4.1 Source Concentration

Results of the July 2010 groundwater sampling for benzene, chrysene and lead were used as the starting concentration for the AOI 7 QD and SWLOAD simulations. Starting concentration for each QD and SWLOAD simulation for this analysis can be found in Table G.1. For the simulation between the No. 3 Separator and bulkhead the aqueous saturation concentration for chrysene of 1.9 ug/l was used as the starting concentration.

G.4.2 Distance to Location of Concern (x)

Distance to the Location of Concern (distance) for the current simulations for wells C-56, C-57, C-110, C-111, C-112, C-114, C-131, C-133 are the distances to the AOI 7 –AOI 3 or AOI 6 boundary from each location. For wells C-142, C-140 and wells between the No.3 Seperator and sheet pile wall, the distance to the location of concern is the distance to the Schuylkill River. The results of QD simulations are estimates of the distances required at each well locations for COC concentration to fall below respective groundwater MSCs under steady-state plume conditions. The distance is iteratively entered in the QD model until the location where the COC concentration reaches the MSC is identified. This step is performed using a large simulation time of 1×10^{99} days to ensure that the plume has reached steady-state. The results of the SWLOAD simulations predict COC concentrations at the Schuylkill River and indicate if PENTOXSD will be needed.

G.4.3 Dispersivity

Dispersivity is the tendency of a dissolved plume to “spread out” as it moves down-gradient.

- Transverse dispersivity (A_Y) occurs in the same plane as longitudinal dispersivity but perpendicular to the direction of groundwater flow; and
- Vertical dispersivity (A_Z) occurs in the upward direction, normal to the plane in which longitudinal and transverse dispersivity occur (Vertical dispersivity is usually negligible and is typically omitted from most QD analyses).

Dispersivity estimates are difficult to quantify and are commonly estimated from the following relationships:

1. $A_X = X/10$ (where, X is the distance a contaminant has traveled by advective transport)

2. $A_Y = A_X/10$
3. $A_Z = A_X/20$ to $A_X/100$ (generally, it is recommended that A_Z be a very small number (0.001) unless vertical monitoring can reliably justify a larger number. Additionally, a value of 0.0001 is suggested for uncalibrated or conceptual applications).

As stated above the value for A_Y was estimated to be 10 percent of A_X. A value of 0.001 was used as a value for A_Z.

G.4.4 Lambda

Lambda is the first order decay constant. It is determined by dividing 0.693 by the half-life of the compound. The value can typically be estimated for shrinking plumes by evaluating at concentrations versus time or distance. Lambda can also sometimes be estimated for stable plumes by evaluating concentration versus time using the methodology outlined in Buscheck and Alcantar (1995). Important considerations to estimating Lambda from site data include:

1. Are the measured concentrations along the centerline of the plume?
2. Are the measured concentrations the result of the single source area?
3. Are there no remedial systems and/or activities that effected the migration of the plume during the time interval of evaluation?

If the answer is yes to these questions, then the methodologies outlined in Buscheck and Alcantar may be utilized to estimate a site-specific lambda from site data.

Based on review of the available site data, the criteria necessary to calculate a site-specific lambda could not be met; therefore, a default value for lambda (when appropriate and available) was obtained from the PADEP spreadsheet "Number Please! 2011" which is based on PA Code, Chapter 250, Appendix A, Table 5. A lambda value of zero was used for the inorganic constituent lead to reflecting its inability to biodegrade.

G.4.5 Source Dimensions

Source width is the maximum width of the area measured perpendicular to the direction of groundwater flow. Source thickness is the thickness of the contaminated soils below the water table that contribute contamination to groundwater. In addition to the saturated zone, fluctuation in groundwater elevation may create a smear zone in the unsaturated portion of an aquifer. As an estimate of the thickness of the smear zone, average fluctuation can be used. Since no plumes have been delineated, a source width of 100 ft was used. The source thicknesses used was 15 feet (ft), which is the average thickness of the upper unconfined aquifer. For the wells between the No. 3 Seperator and sheet pile wall, simulation the source width was 300 feet which corresponds to the distance between C-150 to C-167 where LNAPL was detected.

G.4.6 Hydraulic Conductivity (k)

The hydraulic conductivity of a geologic material is a measure of its ability to transmit water. A hydraulic conductivity of 4.64 ft/d was used in the AOI 7 QD simulations. This value was the average hydraulic conductivity of the fill/alluvium at the site, obtained from the CCR. Along the bulkhead in AOI 7 the migration of groundwater and contaminants through the alluvium/fill towards the Schuylkill River is limited by the hydraulic conductivity of the bulkhead. Groundwater behind the bulkhead can move towards the Schuylkill River no faster than the bulkhead permits because the unsealed bulkhead hydraulic conductivity (0.283 ft/d or 10^{-5} cm/sec, Waterloo Barrier, Inc.) is lower than the alluvium/fill (4.64 ft/d). The lower hydraulic conductivity of the bulkhead compared to the alluvium/fill causes groundwater to mound up behind it. To account for the presence of the bulkhead in the QD and SWLOAD models the hydraulic conductivity used for simulating locations along the bulkhead was 0.283 ft/d (10^{-5} cm/sec).

G.4.7 Hydraulic Gradient

Hydraulic gradient is the change in hydraulic head relative to the distance between head measurement locations. The hydraulic gradient is measured parallel to the direction of ground water flow assuming horizontal flow and a uniform gradient. Using the groundwater elevations collected in January 2012, the hydraulic gradient value was estimated between each well with an exceedence and a down gradient or up gradient well (along the best approximation of a groundwater flow line) within the same aquifer. To be conservative the measured direction of groundwater flow at each modeled location is assumed to be towards the nearest property boundary or the Schuylkill River.

G.4.8 Porosity (n)

Porosity is measured as the ratio of the volume of void space in a geologic material to the total volume of material. Porosity values used in the fate and transport modeling for AOI 7 were based on historical geotechnical analysis.

G.4.9 Soil Bulk Density (ρ_b)

Soil bulk density is the dry weight of a sample divided by the total volume of the sample in an undisturbed state. Soil bulk density can either be determined by a laboratory or by the equation

$$\rho_b = 2.65 * (1 - n).$$

Soil bulk density values used in the fate and transport modeling were based on historical geotechnical analysis.

G.4.10 Organic Carbon Partition Coefficient (KOC)

The organic carbon partition coefficient is chemical specific and is provided in the PADEP EP spreadsheet "Number Please! 2011" which is based on PA Code, Chapter 250, Appendix A, Table 5. These values were used in the fate and transport modeling.

G.4.11 Fraction Organic Carbon (foc)

The fraction of organic carbon is the organic carbon content of a soil. A laboratory using ASTM methods can determine this value. Samples for organic carbon are taken from the same soil horizon in which the contaminant occurs, but outside of the impacted area. Since no site specific fraction of organic carbon data was available for the site, the fate and transport modeling used the model-recommended default concentration of 0.005, which is a conservative value based on the description of site soils.

G.4.12 Time (t)

'Time zero' is the point at which contamination was introduced into the aquifer. Time since 'time zero' is measured in days. The final simulation time of 1×10^{99} days was used to ensure that a steady-state plume was simulated.

G.5 OUTPUT DATA AND RESULTS

The following presents the QD modeling results.

- Lead detected at C-56 (15.8 ug/l) is predicted to attenuate below its groundwater PADEP non-residential groundwater MSC of 5 ug/l in 345 feet. The distance from C-56 to the AOI 6 property boundary is 395 feet which indicates that dissolved concentrations of lead in groundwater are not predicted to reach the AOI 7 and/or AOI 6 property boundary. If dissolved concentrations of lead in groundwater at C-56 were to flow west towards the Schuylkill River (approximately 1,600 feet away), the lead concentration is likely to attenuate below its PADEP non-residential groundwater MSC before reaching the Schuylkill River.

- QD modeling results for seven monitoring wells (C-57, C-110, C-111, C-112, C-114, C-131, and C-133) located along the AOI 7 property boundary indicated that chrysene modeled typically less than one foot but can be as much as three feet (C-133). Based on these results, chrysene at these seven monitoring well locations does not have the potential to migrate beyond the AOI 7 property boundary.

- Adjacent to the Schuylkill River, chrysene at C-140 (2 ug/l) is predicted to travel less than one foot to attenuate below its PADEP non-residential groundwater MSC of 1.9 ug/l (Table G.1). The SWLOAD simulation for chrysene at C-140 indicates a chrysene concentration of <0.001 ug/l at the Schuylkill River (approximately 55 feet away). Chrysene at C-140 is not predicted to reach the Schuylkill River at a concentration above its PADEP non-residential groundwater MSC.

- Adjacent to the Schuylkill River, chrysene at C-142 (reported as 64 ug/l) is predicted to travel five feet before it attenuates below its PADEP non-residential groundwater MSC of 1.9 ug/l (Table G.1). The SWLOAD simulation for chrysene at C-142 indicates a chrysene concentration of <0.001 ug/l at the Schuylkill River (approximately 55 feet away). Chrysene at C-142 is not predicted to reach the Schuylkill River at a concentration above its PADEP non-residential groundwater MSC.

- Benzene detected at C-111 (89 ug/l) is located 33 feet from the AOI 7 and AOI 3 property boundary and is predicted to require 253 feet to attenuate below its PADEP non-residential groundwater MSC of 5 ug/l. Based on these results, benzene at C-111 has the potential to migrate from AOI 7 into AOI 3, however would not reach the AOI 3 eastern property boundary (refinery boundary).

- Chrysene at C-49 (assigned a proxy starting concentration of 64 ug/l as discussed earlier) is predicted to travel thirteen feet and therefore does not reach the AOI 7 boundary.

Table G.1
Quick Domenico and SWLOAD Results
Sunoco Philadehphia Refinery AOI 7
Philadelphia, Pennsylvania

Well ID	Compound	Groundwater Medium Specific Concentration for QD	Groundwater Edge Criterion for SWLOAD(1)	Chronic Fish Criterion	Acute Fish Criterion	Human Health Risk Level	QD/SWLOAD Starting Groundwater Concentration	Measured Distance to Point of Concern	QD Predicted Distance to Achieve MSC	SWLOAD Maximum Groundwater Concentration at Receptor	Acute Fish Criterion Wasteload Allocation	Chronic Fish Criterion Wasteload Allocation	Human Health Level CRL Wasteload Allocation
		ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	feet	feet	ug/l	ug/l	ug/l	ug/l
C-49	chrysene	1.9		NA	300	0.0038	64	15	13				
C-56	lead	5		2.5	6.5	NA	15.8	395	345				
C-110	chrysene	1.9		NA	300	0.0038	2	35	<1				
C-111	chrysene	1.9	NA	NA	300	0.0038	3	33	1	NA	NA	NA	NA
	benzene	5		130	640	1.2	89	33	253				
C-114	chrysene	1.9		NA	300	0.0038	2	107	<1				
C-131	chrysene	1.9		NA	300	0.0038	38	375	2				
C-133	chrysene	1.9		NA	300	0.0038	8	20	3				
C-140	chrysene	1.9	0.477	NA	300	0.0038	2	55	<1	<0.001			
C-142	chrysene	1.9	0.477	NA	300	0.0038	64	113	5	<0.001	NA	NA	NA
No. 3 Sep	chrysene	1.9	0.477	NA	300	0.0380	2	30	<1	<0.001			

NOTES:
Groundwater MSC = ACT 2 TGM, Appendix A, Table 1 MSC for a Non-residential Used Aquifer with Total Dissolved Solids less than or equal to 2500.
QD = Quick Domenico
Edge criteria for **chrysene** (ACT 2 TGM Table IV-3), If both the lowest surface water compliance value (0.0044 ug/l) and the Act 2 MSC (1.9 ug/l) are below the SW-846 PQL (10 ug/l), set the SWLOAD edge criterion equal to 3.18 times the lowest Chapter 16 method detection limit (0.15 ug/l x 3.18 = 0.477 ug/l) or the lowest surface water criterion (0.0038 ug/l),
NA = Not Applicable.

Table G.2
Quick Domenico
Fate and Transport Model Input and Output
AOI-7 Shallow Groundwater
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Project	2574601 - Sunoco Philadelphia Refinery
Prepared by	TS
Date Prepared	2/10/2012

Generic Input Parameters				**Data Source**
Source Identification (or Well ID)			**C-49**	
Sample Date			**7/13/2010**	
Source Width		ft	100	Delineated LNAPL (100' default if no plume is present)
Source Thickness		ft	15	Estimated from AOI 7 Cross Sections
Longitudinal Dispersivity	A_x	ft	200	Estimate based on knowledge of site geology and contaminants present
Transverse Dispersivity	A_y	ft	20.0	Quick Domenico User's Manual
Vertical Dispersivity	A_z	ft	0.0001	Quick Domenico User's Manual
Hydraulic Conductivty	k	ft/day	4.64	Secor (2002b) (average based on site-wide slug testing
Hydraulic Gradient	i	ft/ft	0.0231	January 2012 C-49/C-114
Porosity	n	decimal fraction	0.35	Site soil analyses
Soil Bulk Density	p_b	g/cm3	1.7225	ACT 2 TGM Default
Fraction of Organic Carbon	f_{OC}	decimal fraction	0.005	ACT 2 TGM Default
Time		days	1.00E+99	Steady-State Conditions

Chemical Specific Input Parameters				**Data Source**
Sim 1				
Contaminant			Chrysene	
Source Concentration (mg/L)		mg/L	0.0640	July 2010 Sampling
Lambda (per day)		day^{-1}	3.452E-04	PADEP Number Please! 2011 Spreadsheet
KOC			490000	PADEP Number Please! 2011 Spreadsheet

Output (Distance from Source Where Concentration Equals Respective Ground Water MSC)				
Contaminant	**Starting Concentration (mg/L)**	**GW MSC[1] Non-Residential (mg/L)**	**Predicted Concentration (mg/L)**	**Predicted Distance to Meet Non-Residential GW MSC (Rounded to the Nearest foot)**
Sim 1 - Chrysene	0.0640	0.0019	0.0019	**13**

[1] ACT 2 TGM, Appendix A, Table 1 MSC for a Non-residential Used Aquifer with Total Dissolved Solids less than or equal to 2500.

ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION,1ST ORDER DECAY and RETARDATION - WITH CALIBRATION TOOL

Project:	2574601 - Sunoco Philadelphia Refinery		
Date:	2/10/2012	Prepared by:	TS
		Contaminant:	**Chrysene source concentration = 0.064 mg/l**

NEW QUICK_DOMENICO.XLS

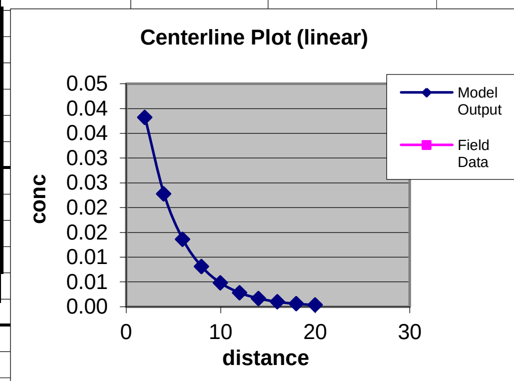
SPREADSHEET APPLICATION OF "AN ANALYTICAL MODEL FOR MULTIDIMENSIONAL TRANSPORT OF A DECAYING CONTAMINANT SPECIES"
P.A. Domenico (1987)
Modified to Include Retardation

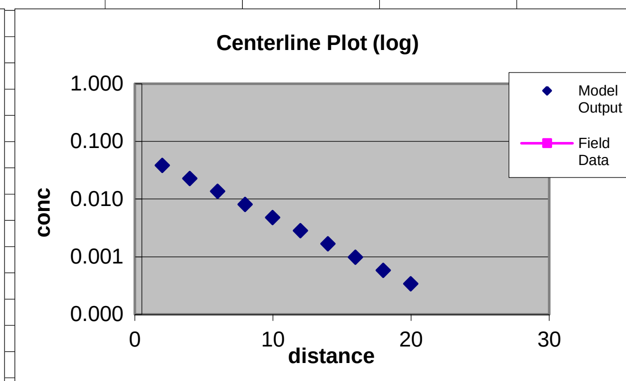
SOURCE CONC (MG/L)	Ax (ft)	Ay (ft)	Az (ft) >=.001	LAMBDA day-1	SOURCE WIDTH (ft)	SOURCE THICKNESS (ft)	Time (days) (days)
0	2.00E+02	2.00E+01	1.00E-04	0.00034521	100	15	1E+99

Hydraulic Cond (ft/day)	Hydraulic Gradient (ft/ft)	Porosity (dec. frac.)	Soil Bulk Density (g/cm^3)	KOC	Frac. Org. Carb.	Retard-ation (R)	V (=K*i/n*R) (ft/day)
4.64E+00	0.0231	0.35	1.7225	490000	5.00E-03	12058.5	2.53962E-05

Point Concentration

x(ft)	y(ft)	z(ft)	
13.4	0	0	
	x(ft)	**y(ft)**	**z(ft)**
Conc. At	13.4	0	0
at	1E+99	days =	**0.002** mg/l





AREAL CALCULATION
MODEL DOMAIN

Length (ft)	20
Width (ft)	100

	2	4	6	8	10	12	14	16	18	20
100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
50	0.019	0.011	0.007	0.004	0.002	0.001	0.001	0.001	0.000	0.000
0	0.038	0.023	0.014	0.008	0.005	0.003	0.002	0.001	0.001	0.000
-50	0.019	0.011	0.007	0.004	0.002	0.001	0.001	0.001	0.000	0.000
-100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Field Data:	**Centerline C Concentration**							
	Distance from Source							

Table G.02 C-49 Chry QD
SIM 1

Table G.3
Quick Domenico
Fate and Transport Model Input and Output
AOI-7 Shallow Groundwater
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Project	2574601 - Sunoco Philadelphia Refinery
Prepared by	TS
Date Prepared	2/10/2012

Generic Input Parameters				**Data Source**
Source Identification (or Well ID)			**C-56**	
Sample Date			**7/27/2010**	
Source Width		ft	100	Delineated LNAPL (100' default if no plume is present)
Source Thickness		ft	15	Based on AOI 7 & Cross-Sections
Longitudinal Dispersivity	A_x	ft	200	Estimate based on knowledge of site geology and contaminants present
Transverse Dispersivity	A_y	ft	20.0	Quick Domenico User's Manual
Vertical Dispersivity	A_z	ft	0.0001	Quick Domenico User's Manual
Hydraulic Conductivty	k	ft/day	4.64	Secor (2002b) (average based on site-wide slug testing
Hydraulic Gradient	i	ft/ft	0.0051	January 2012 C-56/C-133
Porosity	n	decimal fraction	0.35	Site soil analyses
Soil Bulk Density	p_b	g/cm3	1.7225	ACT 2 TGM Default
Fraction of Organic Carbon	f_{OC}	decimal fraction	0.005	ACT 2 TGM Default
Time		days	1.00E+99	Steady-State Conditions

Chemical Specific Input Parameters				**Data Source**
Sim 1				
Contaminant			Lead	
Source Concentration (mg/L)		mg/L	0.0158	July 2010 Sampling
Lambda (per day)		day^{-1}	1.000E-05	PADEP Number Please! 2011 Spreadsheet
Koc			0.00001	PADEP Number Please! 2011 Spreadsheet

Output (Distance from Source Where Concentration Equals Respective Ground Water MSC)

Contaminant	**Starting Concentration (mg/L)**	**GW MSC[1] Non-Residential (mg/L)**	**Predicted Concentration (mg/L)**	**Predicted Distance to Meet Non-Residential GW MSC (Rounded to the Nearest foot)**
Sim 1 - Lead	0.0158	0.0050	0.0050	**345**

[1] ACT 2 TGM, Appendix A, Table 1 MSC for a Non-residential Used Aquifer with Total Dissolved Solids less than or equal to 2500.

ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION,1ST ORDER DECAY and RETARDATION - WITH CALIBRATION TOOL

Project:	2574601 - Sunoco Philadelphia Refinery		
Date:	2/10/2012	Prepared by:	TS
		Contaminant:	AOI 7 C-56 Lead Source Concentration = 0.0158 mg/l

NEW QUICK_DOMENICO.XLS

SPREADSHEET APPLICATION OF
"AN ANALYTICAL MODEL FOR
MULTIDIMENSIONAL TRANSPORT OF A DECAYING
CONTAMINANT SPECIES"
P.A. Domenico (1987)
Modified to Include Retardation

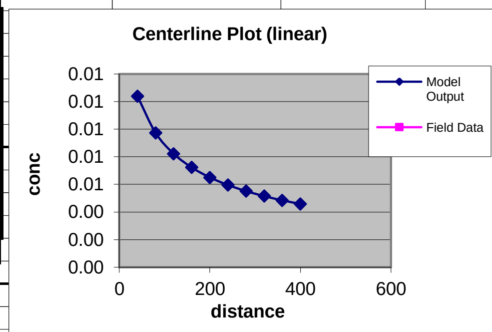
SOURCE CONC (MG/L)	Ax (ft)	Ay (ft)	Az (ft) >=.001	LAMBDA day-1	SOURCE WIDTH (ft)	SOURCE THICKNESS (ft)	Time (days) (days)
0	2.00E+02	2.00E+01	1.00E-04	0.00001	100	15	1E+99

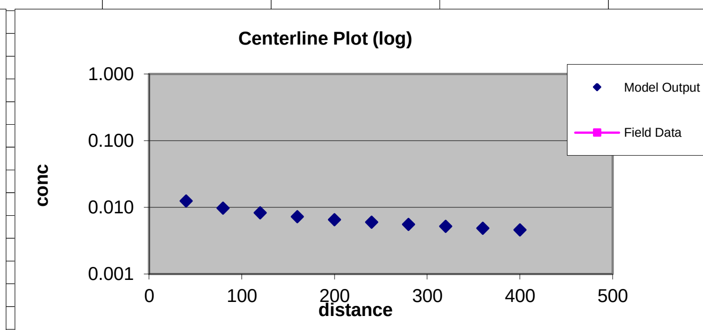
Hydraulic Cond (ft/day)	Hydraulic Gradient (ft/ft)	Porosity (dec. frac.)	Soil Bulk Density (g/cm³)	KOC	Frac. Org. Carb.	Retard-ation (R)	V (=K*i/n*R) (ft/day)
4.64E+00	0.0051	0.35	1.7225	0.00001	5.00E-03	1.000000246	0.067611412

Point Concentration

x(ft)	y(ft)	z(ft)
345	0	0

	x(ft)	y(ft)	z(ft)
Conc. At	345	0	0
at	1E+99	days =	0.005 mg/l





AREAL MODEL	CALCULATION DOMAIN
Length (ft)	400
Width (ft)	100

	40	80	120	160	200	240	280	320	360	400
100	0.002	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.003	0.003
50	0.008	0.007	0.007	0.006	0.006	0.005	0.005	0.005	0.004	0.004
0	0.012	0.010	0.008	0.007	0.007	0.006	0.006	0.005	0.005	0.005
-50	0.008	0.007	0.007	0.006	0.006	0.005	0.005	0.005	0.004	0.004
-100	0.002	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.003	0.003

Field Data:	Centerline C Concentration							
	Distance from Source							

Table G.4
Quick Domenico
Fate and Transport Model Input and Output
AOI-7 Shallow Groundwater
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Project	2574601 - Sunoco Philadelphia Refinery
Prepared by	Terrance Stanley
Date Prepared	2/10/2012

Generic Input Parameters				Data Source
Source Identification (or Well ID)			**C-110**	
Sample Date			**7/27/2010**	
Source Width		ft	100	Delineated LNAPL (100' default if no plume is present)
Source Thickness		ft	15	Based on AOI 7 Cross Sections
Longitudinal Dispersivity	A_x	ft	200	Estimate based on knowledge of site geology and contaminants present
Transverse Dispersivity	A_y	ft	20.0	Quick Domenico User's Manual
Vertical Dispersivity	A_z	ft	0.0001	Quick Domenico User's Manual
Hydraulic Conductivty	k	ft/day	4.64	Secor (2002b) (average based on site-wide slug testing
Hydraulic Gradient	i	ft/ft	0.006	January 2012 C-110/C-109
Porosity	n	decimal fraction	0.35	Site soil analyses
Soil Bulk Density	p_b	g/cm3	1.7225	ACT 2 TGM Default
Fraction of Organic Carbon	f_{OC}	decimal fraction	0.005	ACT 2 TGM Default
Time		days	1.00E+99	Steady-State Conditions

Chemical Specific Input Parameters				Data Source
Sim 1				
Contaminant			Chrysene	
Source Concentration (mg/L)		mg/L	0.0020	July 2010 Sampling
Lambda (per day)		day^{-1}	3.452E-04	PADEP Number Please! 2011 Spreadsheet
KOC			490000	PADEP Number Please! 2011 Spreadsheet

Output (Distance from Source Where Concentration Equals Respective Ground Water MSC)

Contaminant	Starting Concentration (mg/L)	GW MSC[1] Non-Residential (mg/L)	Predicted Concentration (mg/L)	Predicted Distance to Meet Non-Residential GW MSC (Rounded to the Nearest foot)
Sim 1 - Chrysene	0.0020	0.0019	0.0019	**0**

[1] ACT 2 TGM, Appendix A, Table 1 MSC for a Non-residential Used Aquifer with Total Dissolved Solids less than or equal to 2500.

ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION,1ST ORDER DECAY and RETARDATION - WITH CALIBRATION TOOL

Project: 2574601 - Sunoco Philadelphia Refinery
Date: 2/10/2012 Prepared by: Terrance Stanley
Contaminant: Chrysene source concentration = 0.002 mg/l

NEW QUICK_DOMENICO.XLS

SPREADSHEET APPLICATION OF "AN ANALYTICAL MODEL FOR MULTIDIMENSIONAL TRANSPORT OF A DECAYING CONTAMINANT SPECIES" P.A. Domenico (1987) Modified to Include Retardation

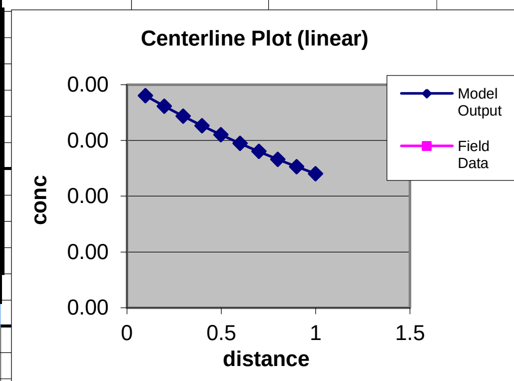
SOURCE CONC (MG/L)	Ax (ft)	Ay (ft)	Az (ft) >=.001	LAMBDA day-1	SOURCE WIDTH (ft)	SOURCE THICKNESS (ft)	Time (days) (days)
0	2.00E+02	2.00E+01	1.00E-04	0.00034521	100	15	1E+99

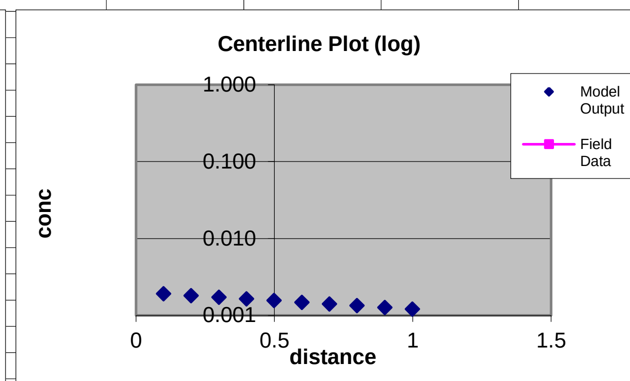
Hydraulic Cond (ft/day)	Hydraulic Gradient (ft/ft)	Porosity (dec. frac.)	Soil Bulk Density (g/cm^3)	KOC	Frac. Org. Carb.	Retard-ation (R)	V (=K*i/n*R) (ft/day)
4.64E+00	0.006	0.35	1.7225	490000	5.00E-03	12058.5	6.59641E-06

Point Concentration

x(ft)	y(ft)	z(ft)
0.1	0	0

	x(ft)	y(ft)	z(ft)
Conc. At	0.1	0	0
at 1E+99	days =		**0.002** mg/l





AREAL CALCULATION
MODEL DOMAIN
Length (ft) 1
Width (ft) 100

	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
50	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
0	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001
-50	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
-100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Field Data: Centerline C Concentration
Distance from Source

Table G.04 C-110 Chry QD
SIM 1

Table G.5
Quick Domenico
Fate and Transport Model Input and Output
AOI 7 Shallow Grounwater
Philadelphia, Pennsylvania

Project	2574601 - Sunoco Philadelphia Refinery
Prepared by	TS
Date Prepared	2/10/2012

Generic Input Parameters				**Data Source**
Source Identification (or Well ID)			**C-111**	
Sample Date			7/27/2010	
Source Width		ft	100	Delineated LNAPL (100' default if no plume is present)
Source Thickness		ft	15	Based on AOI 7 Cross Sections
Longitudinal Dispersivity	A_x	ft	200	From CCR QD Simulations
Transverse Dispersivity	A_y	ft	20.0	Quick Domenico User's Manual
Vertical Dispersivity	A_z	ft	0.0001	Quick Domenico User's Manual
Hydraulic Conductivty	k	ft/day	4.64	Secor (2002d) Average based on site-wide slug tests
Hydraulic Gradient		ft/ft	0.0092	January 2012 C-111/C-109
Porosity		decimal fraction	0.35	Site soil analyses
Soil Bulk Density	p_b	g/cm3	1.7225	ACT 2 TGM Default
Fraction of Organic Carbon	f_{OC}	decimal fraction	0.005	ACT 2 TGM Default
Time		days	1.00E+99	Steady-State Conditions

Chemical Specific Input Parameters				**Data Source**
Sim 1				
Contaminant			Chrysene	
Source Concentration (mg/L)		mg/L	0.0030	July-08
Lambda (per day)		day^{-1}	0.000	PADEP Number Please!2011 Spreadsheet
KOC			490000	PADEP Number Please!2011 Spreadsheet
Sim 2				
Contaminant			Benzene	
Source Concentration (mg/L)		mg/L	0.0890	July-08
Lambda (per day)		day^{-1}	0.001	PADEP Number Please!2011 Spreadsheet
KOC			58	PADEP Number Please!2011 Spreadsheet

Output (Distance from Source Where Concentration Equals Respective Ground Water MSC)				
Contaminant	**Starting Concentration (mg/L)**	**GW MSC[1] Non-Residential (mg/L)**	**Predicted Concentration (mg/L)**	**Predicted Distance to Meet Non-Residential GW MSC (Rounded to the Nearest foot)**
Sim 1 - Chrysene	0.003000	0.002	0.002	**1**
Sim 2 - Benzene	0.089000	0.005	0.005	**253**

[1] ACT 2 TGM, Appendix A, Table 1 MSC for a Non-residential Used Aquifer with Total Dissolved Solids less than or equal to 2500 ug/l.

ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION,1ST ORDER DECAY and RETARDATION - WITH CALIBRATION TOOL

Project:	2574601 - Sunoco Philadelphia Refinery		
Date:	2/10/2012	Prepared by:	TS
		Contaminant:	**Chrysene starting concentration = 0.003 mg/L**

NEW QUICK_DOMENICO.XLS

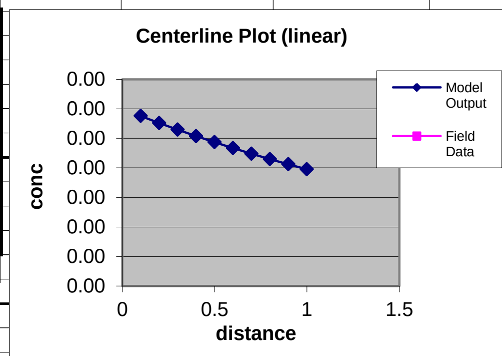
SPREADSHEET APPLICATION OF
"AN ANALYTICAL MODEL FOR
MULTIDIMENSIONAL TRANSPORT OF A
DECAYING CONTAMINANT SPECIES"
P.A. Domenico (1987)
Modified to Include Retardation

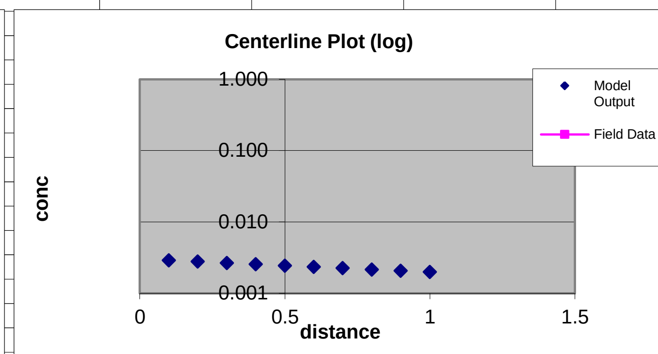
SOURCE CONC (MG/L)	Ax (ft)	Ay (ft)	Az (ft) >=.001	LAMBDA day-1	SOURCE WIDTH (ft)	SOURCE THICKNESS (ft)	Time (days) (days)
0	2.00E+02	2.00E+01	1.00E-04	0.00035616	100	15	1E+99

Hydraulic Cond (ft/day)	Hydraulic Gradient (ft/ft)	Porosity (dec. frac.)	Soil Bulk Density (g/cm^3)	KOC	Frac. Org. Carb.	Retard-ation (R)	V (=K*i/n*R) (ft/day)
4.64E+00	0.0092	0.35	1.7225	490000	5.00E-03	12058.5	1.01145E-05

Point Concentration

x(ft)	y(ft)	z(ft)	
0.97	0	0	
	x(ft)	**y(ft)**	**z(ft)**
Conc. At	0.97	0	0
at	1E+99	days =	**0.002** mg/l





AREAL CALCULATION
MODEL DOMAIN

Length (ft)	1
Width (ft)	1

	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
1	0.003	0.003	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002
0.5	0.003	0.003	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002
0	0.003	0.003	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002
-0.5	0.003	0.003	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002
-1	0.003	0.003	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002

Field Data:	**Centerline C Concentration**							
	Distance from Source							

Table G.05 C-111 Chry Ben QD
SIM 1

ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION,1ST ORDER DECAY and RETARDATION - WITH CALIBRATION TOOL

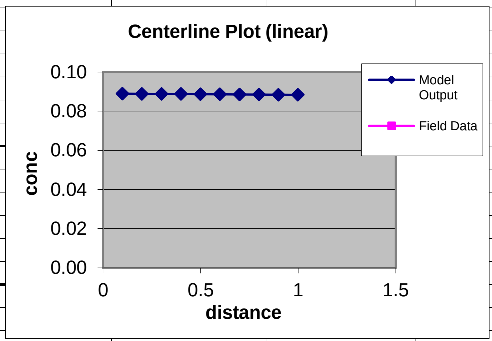
Project:	2574601 - Sunoco Philadelphia Refinery						
Date:	2/10/2012	Prepared by:	TS				
		Contaminant:	Benzene starting concentration = 0.089 mg/L				
SOURCE CONC (MG/L)	Ax (ft)	Ay (ft)	Az (ft) >=.001	LAMBDA day-1	SOURCE WIDTH (ft)	SOURCE THICKNESS (ft)	Time (days) (days)
0	2.00E+02	2.00E+01	1.00E-04	0.0009589	100	15	1E+99
Hydraulic Cond (ft/day)	Hydraulic Gradient (ft/ft)	Porosity (dec. frac.)	Soil Bulk Density (g/cm^3)	KOC	Frac. Org. Carb.	Retard-ation (R)	V (=K*i/n*R) (ft/day)
4.64E+00	0.0092	0.35	1.7225	58	5.00E-03	2.427214286	0.050249257

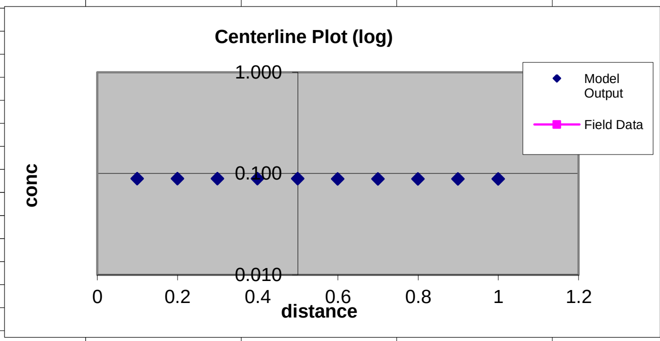
NEW QUICK_DOMENICO.XLS

SPREADSHEET APPLICATION OF
"AN ANALYTICAL MODEL FOR
MULTIDIMENSIONAL TRANSPORT OF A DECAYING
CONTAMINANT SPECIES"
P.A. Domenico (1987)
Modified to Include Retardation

Point Concentration

x(ft)	y(ft)	z(ft)	
252.5348335	0	0	
	x(ft)	y(ft)	z(ft)
Conc. At	252.5348335	0	0
at	1E+99	days =	
			0.005 mg/l





AREAL MODEL CALCULATION DOMAIN

Length (ft)	1
Width (ft)	1

	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
1	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.088	0.088	0.088
0.5	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.088	0.088	0.088
0	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.088	0.088	0.088
-0.5	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.088	0.088	0.088
-1	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.088	0.088	0.088

Field Data:	Centerline Conc. Concentration							
	Distance from Source							

Table G.6
Quick Domenico
Fate and Transport Model Input and Output
AOI-7 Shallow Groundwater
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Project	2574601 - Sunoco Philadelphia Refinery
Prepared by	TS
Date Prepared	2/10/2012

Generic Input Parameters				Data Source
Source Identification (or Well ID)			**C-114**	
Sample Date			**7/14/2010**	
Source Width		ft	100	Delineated LNAPL (100' default if no plume is present)
Source Thickness		ft	15	Estimated from AOI 7 Cross Sections
Longitudinal Dispersivity	A_x	ft	200	Estimate based on knowledge of site geology and contaminants present
Transverse Dispersivity	A_y	ft	20.0	Quick Domenico User's Manual
Vertical Dispersivity	A_z	ft	0.0001	Quick Domenico User's Manual
Hydraulic Conductivty	k	ft/day	4.64	Secor (2002b) (average based on site-wide slug testing
Hydraulic Gradient	i	ft/ft	0.0231	January 2012 C-49/C-114
Porosity	n	decimal fraction	0.35	Site soil analyses
Soil Bulk Density	p_b	g/cm3	1.7225	ACT 2 TGM Default
Fraction of Organic Carbon	f_{OC}	decimal fraction	0.005	ACT 2 TGM Default
Time		days	1.00E+99	Steady-State Conditions

Chemical Specific Input Parameters				Data Source
Sim 1				
Contaminant			Chrysene	
Source Concentration (mg/L)		mg/L	0.0020	July 2010 Sampling
Lambda (per day)		day^{-1}	3.452E-04	PADEP Number Please! 2011 Spreadsheet
KOC			490000	PADEP Number Please! 2011 Spreadsheet

Output (Distance from Source Where Concentration Equals Respective Ground Water MSC)				
Contaminant	**Starting Concentration (mg/L)**	**GW MSC[1] Non-Residential (mg/L)**	**Predicted Concentration (mg/L)**	**Predicted Distance to Meet Non-Residential GW MSC (Rounded to the Nearest foot)**
Sim 1 - Chrysene	0.0020	0.0019	0.0019	**0**

[1] ACT 2 TGM, Appendix A, Table 1 MSC for a Non-residential Used Aquifer with Total Dissolved Solids less than or equal to 2500.

ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION,1ST ORDER DECAY and RETARDATION - WITH CALIBRATION TOOL

Project: 2574601 - Sunoco Philadelphia Refinery
Date: 2/10/2012 Prepared by: TS
Contaminant: Chrysene source concentration = 0.064 mg/l

NEW QUICK_DOMENICO.XLS

SPREADSHEET APPLICATION OF "AN ANALYTICAL MODEL FOR MULTIDIMENSIONAL TRANSPORT OF A DECAYING CONTAMINANT SPECIES" P.A. Domenico (1987) Modified to Include Retardation

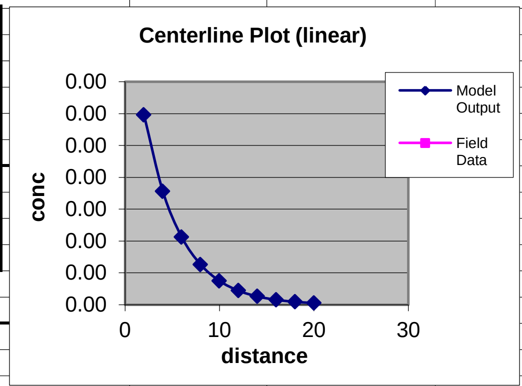
SOURCE CONC (MG/L)	Ax (ft)	Ay (ft)	Az (ft) >=.001	LAMBDA day-1	SOURCE WIDTH (ft)	SOURCE THICKNESS (ft)	Time (days) (days)
0	2.00E+02	2.00E+01	1.00E-04	0.00034521	100	15	1E+99

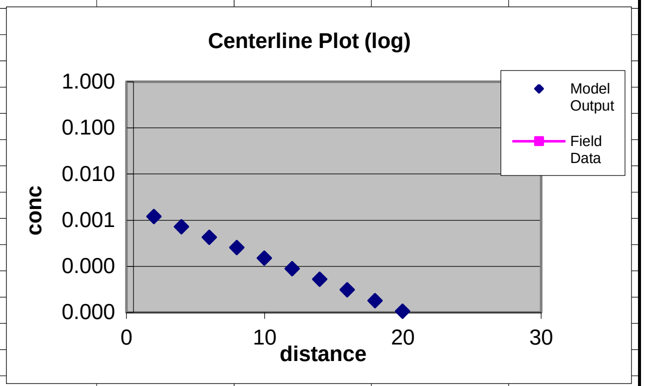
Hydraulic Cond (ft/day)	Hydraulic Gradient (ft/ft)	Porosity (dec. frac.)	Soil Bulk Density (g/cm^3)	KOC	Frac. Org. Carb.	Retard-ation (R)	V (=K*i/n*R) (ft/day)
4.64E+00	0.0231	0.35	1.7225	490000	5.00E-03	12058.5	2.53962E-05

Point Concentration

x(ft)	y(ft)	z(ft)
0.3	0	0

	x(ft)	y(ft)	z(ft)
Conc. At	0.3	0	0
at	1E+99	days =	**0.002** mg/l





AREAL CALCULATION MODEL DOMAIN

Length (ft) 20
Width (ft) 100

	2	4	6	8	10	12	14	16	18	20
100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
50	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
-50	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
-100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Field Data:	**Centerline C Concentration**							
	Distance from Source							

Table G.7
Quick Domenico
Fate and Transport Model Input and Output
AOI-7 Shallow Groundwater
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Project	2574601 - Sunoco Philadelphia Refinery
Prepared by	Terrance Stanley
Date Prepared	2/10/2012

Generic Input Parameters				**Data Source**
Source Identification (or Well ID)			**C-131**	
Sample Date			**July 15, 2010**	
Source Width		ft	100	Delineated LNAPL (100' default if no plume is present)
Source Thickness		ft	15	Estimated from AOI 7 cross sections
Longitudinal Dispersivity	A_x	ft	200	Estimate based on knowledge of site geology and contaminants present
Transverse Dispersivity	A_y	ft	20.0	Quick Domenico User's Manual
Vertical Dispersivity	A_z	ft	0.0001	Quick Domenico User's Manual
Hydraulic Conductivty	k	ft/day	4.64	Secor (2002b) (average based on site-wide slug testing
Hydraulic Gradient	i	ft/ft	0.001	January 2012 C-131/C-95
Porosity	n	decimal fraction	0.35	Site soil analyses
Soil Bulk Density	p_b	g/cm3	1.7225	ACT 2 TGM Default
Fraction of Organic Carbon	f_{OC}	decimal fraction	0.005	ACT 2 TGM Default
Time		days	1.00E+99	Steady-State Conditions

Chemical Specific Input Parameters				**Data Source**
Sim 1				
Contaminant			Chrysene	
Source Concentration (mg/L)		mg/L	0.0380	July 2010 Sampling
Lambda (per day)		day^{-1}	3.452E-04	PADEP Number Please! 2011 Spreadsheet
KOC			490000	PADEP Number Please! 2011 Spreadsheet

Output (Distance from Source Where Concentration Equals Respective Ground Water MSC)

Contaminant	Starting Concentration (mg/L)	GW MSC[1] Non-Residential (mg/L)	Predicted Concentration (mg/L)	Predicted Distance to Meet Non-Residential GW MSC (Rounded to the Nearest foot)
Sim 1 - Chrysene	0.0380	0.0019	0.0019	**2**

[1] ACT 2 TGM, Appendix A, Table 1 MSC for a Non-residential Used Aquifer with Total Dissolved Solids less than or equal to 2500.

ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION,1ST ORDER DECAY and RETARDATION - WITH CALIBRATION TOOL

Project: 2574601 - Sunoco Philadelphia Refinery
Date: 2/10/2012 Prepared by: Terrance Stanley
Contaminant: **Chrysene source concentration = 0.038 mg/l**

SOURCE CONC (MG/L)	Ax (ft)	Ay (ft)	Az (ft) >=.001	LAMBDA day-1	SOURCE WIDTH (ft)	SOURCE THICKNESS (ft)	Time (days)
0	2.00E+02	2.00E+01	1.00E-04	0.00034521	100	15	1E+99

Hydraulic Cond (ft/day)	Hydraulic Gradient (ft/ft)	Porosity (dec. frac.)	Soil Bulk Density (g/cm^3)	KOC	Frac. Org. Carb.	Retardation (R)	V (=K*i/n*R) (ft/day)
4.64E+00	0.001	0.35	1.7225	490000	5.00E-03	12058.5	1.0994E-06

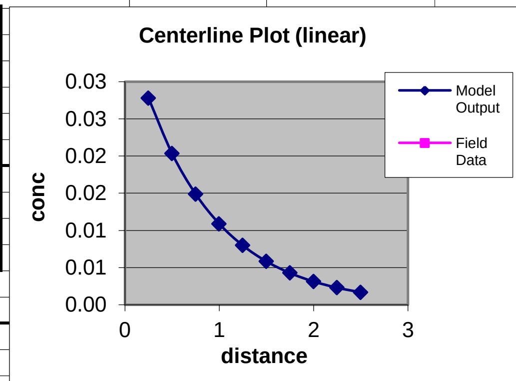
NEW QUICK_DOMENICO.XLS

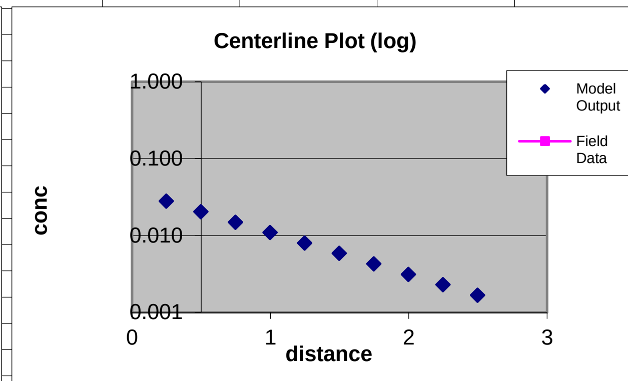
SPREADSHEET APPLICATION OF "AN ANALYTICAL MODEL FOR MULTIDIMENSIONAL TRANSPORT OF A DECAYING CONTAMINANT SPECIES" P.A. Domenico (1987) Modified to Include Retardation

Point Concentration

x(ft)	y(ft)	z(ft)
2.39608614	0	0

	x(ft)	y(ft)	z(ft)
Conc. At	2.39608614	0	0
at	1E+99	days =	**0.002** mg/l





AREAL CALCULATION
MODEL DOMAIN
Length (ft) 2.5
Width (ft) 100

	0.25	0.5	0.75	1	1.25	1.5	1.75	2	2.25	2.5
100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
50	0.014	0.010	0.007	0.005	0.004	0.003	0.002	0.002	0.001	0.001
0	0.028	0.020	0.015	0.011	0.008	0.006	0.004	0.003	0.002	0.002
-50	0.014	0.010	0.007	0.005	0.004	0.003	0.002	0.002	0.001	0.001
-100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Field Data: **Centerline C Concentration**
Distance from Source

Table G.07 C-131 Chry QD
SIM 1

Table G.8
Quick Domenico
Fate and Transport Model Input and Output
AOI-7 Shallow Groundwater
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Project 2574601 - Sunoco Philadelphia Refinery
Prepared by TS
Date Prepared 2/10/2012

Generic Input Parameters				**Data Source**
Source Identification (or Well ID)			**C-133**	
Sample Date			**July 15, 2010**	
Source Width		ft	100	Delineated LNAPL (100' default if no plume is present)
Source Thickness		ft	15	Estimated from AOI 7 cross sections
Longitudinal Dispersivity	A_x	ft	200	Estimate based on knowledge of site geology and contaminants present
Transverse Dispersivity	A_y	ft	20.0	Quick Domenico User's Manual
Vertical Dispersivity	A_z	ft	0.0001	Quick Domenico User's Manual
Hydraulic Conductivty	k	ft/day	4.64	Secor (2002b) (average based on site-wide slug testing
Hydraulic Gradient	i	ft/ft	0.0051	January 2012 C-56/C-133
Porosity	n	decimal fraction	0.35	Site soil analyses
Soil Bulk Density	p_b	g/cm3	1.7225	ACT 2 TGM Default
Fraction of Organic Carbon	f_{OC}	decimal fraction	0.005	ACT 2 TGM Default
Time		days	1.00E+99	Steady-State Conditions

Chemical Specific Input Parameters				**Data Source**
Sim 1				
Contaminant			Chrysene	
Source Concentration (mg/L)		mg/L	0.0080	July 2010 Sampling
Lambda (per day)		day^{-1}	3.452E-04	PA DEP Number Please! 2011 Spreadsheet
KOC			490000	PA DEP Number Please! 2011 Spreadsheet

Output (Distance from Source Where Concentration Equals Respective Ground Water MSC)				
Contaminant	**Starting Concentration (mg/L)**	**GW MSC[1] Non-Residential (mg/L)**	**Predicted Concentration (mg/L)**	**Predicted Distance to Meet Non-Residential GW MSC (Rounded to the Nearest foot)**
Sim 1 - Chrysene	0.0080	0.0019	0.0019	**3**

[1] ACT 2 TGM, Appendix A, Table 1 MSC for a Non-residential Used Aquifer with Total Dissolved Solids less than or equal to 2500.

ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION,1ST ORDER DECAY and RETARDATION - WITH CALIBRATION TOOL

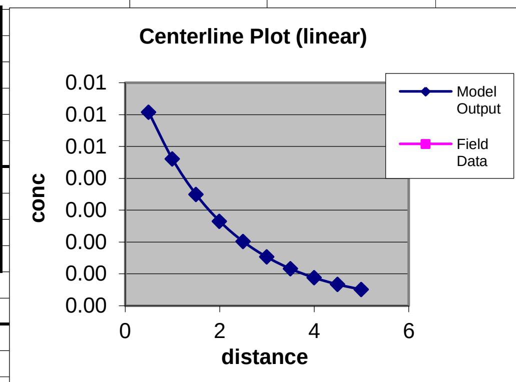
Project:	2574601 - Sunoco Philadelphia Refinery						
Date:	2/10/2012	Prepared by:	TS				
		Contaminant:	Chrysene source concentration = 0.008 mg/l				
SOURCE CONC (MG/L)	Ax (ft)	Ay (ft)	Az (ft) >=.001	LAMBDA day-1	SOURCE WIDTH (ft)	SOURCE THICKNESS (ft)	Time (days) (days)
0	2.00E+02	2.00E+01	1.00E-04	0.00034521	100	15	1E+99
Hydraulic Cond (ft/day)	Hydraulic Gradient (ft/ft)	Porosity (dec. frac.)	Soil Bulk Density (g/cm^3)	KOC	Frac. Org. Carb.	Retard-ation (R)	V (=K*i/n*R) (ft/day)
4.64E+00	0.0051	0.35	1.7225	490000	5.00E-03	12058.5	5.60695E-06

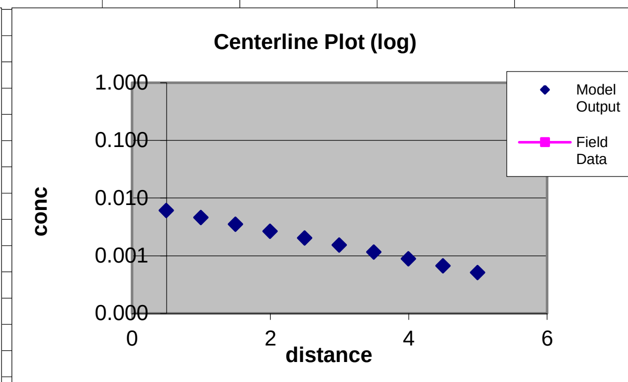
NEW QUICK_DOMENICO.XLS

SPREADSHEET APPLICATION OF "AN ANALYTICAL MODEL FOR MULTIDIMENSIONAL TRANSPORT OF A DECAYING CONTAMINANT SPECIES" P.A. Domenico (1987) Modified to Include Retardation

Point Concentration

x(ft)	y(ft)	z(ft)	
2.603414472	0	0	
	x(ft)	y(ft)	z(ft)
Conc. At	2.603414472	0	0
at	1E+99	days =	0.002 mg/l





AREAL CALCULATION
MODEL DOMAIN
Length (ft) 5
Width (ft) 100

	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5
100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
50	0.003	0.002	0.002	0.001	0.001	0.001	0.001	0.000	0.000	0.000
0	0.006	0.005	0.003	0.003	0.002	0.002	0.001	0.001	0.001	0.001
-50	0.003	0.002	0.002	0.001	0.001	0.001	0.001	0.000	0.000	0.000
-100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Field Data: **Centerline C Concentration**
Distance from Source

Table G.08 C-133 Chry QD sim 1
SIM 1

Table G.9
Quick Domenico
Fate and Transport Model Input and Output
AOI-7 Shallow Groundwater
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Project	2574601 - Sunoco Philadelphia Refinery
Prepared by	Terrance Stanley
Date Prepared	2/10/2012

Generic Input Parameters				Data Source
Source Identification (or Well ID)			**C-140**	
Sample Date			**July 20, 2010**	
Source Width		ft	100	Delineated LNAPL (100' default if no plume is present)
Source Thickness		ft	15	URS, 2002 (average thickness of the UUA)
Longitudinal Dispersivity	A_x	ft	200	Estimate based on knowledge of site geology and contaminants present
Transverse Dispersivity	A_y	ft	20.0	Quick Domenico User's Manual
Vertical Dispersivity	A_z	ft	0.0001	Quick Domenico User's Manual
Hydraulic Conductivty	k	ft/day	0.283	Estimated Hydraulic Conductivity of Bulkhead
Hydraulic Gradient	i	ft/ft	0.0017	January 2012 C-140/C-98
Porosity	n	decimal fraction	0.35	Site soil analyses
Soil Bulk Density	p_b	g/cm3	1.7225	ACT 2 TGM Default
Fraction of Organic Carbon	f_{OC}	decimal fraction	0.005	ACT 2 TGM Default
Time		days	1.00E+99	Steady-State Conditions

Chemical Specific Input Parameters				Data Source
Sim 1				
Contaminant			Chrysene	
Source Concentration (mg/L)		mg/L	0.0020	July 2010 Sampling
Lambda (per day)		day^{-1}	3.452E-04	PADEP Number Please! 2011 Spreadsheet
KOC			490000	PADEP Number Please! 2011 Spreadsheet

Output (Distance from Source Where Concentration Equals Respective Ground Water MSC)				
Contaminant	**Starting Concentration (mg/L)**	**GW MSC[1] Non-Residential (mg/L)**	**Predicted Concentration (mg/L)**	**Predicted Distance to Meet Non-Residential GW MSC (Rounded to the Nearest foot)**
Sim 1 - Chrysene	0.0020	0.0019	0.0019	**0**

[1] ACT 2 TGM, Appendix A, Table 1 MSC for a Non-residential Used Aquifer with Total Dissolved Solids less than or equal to 2500.

ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION,1ST ORDER DECAY and RETARDATION - WITH CALIBRATION TOOL

Project: 2574601 - Sunoco Philadelphia Refinery
Date: 2/10/2012 Prepared by: Terrance Stanley
Contaminant: Chrysene source concentration = 0.002 mg/l

NEW QUICK_DOMENICO.XLS

SPREADSHEET APPLICATION OF "AN ANALYTICAL MODEL FOR MULTIDIMENSIONAL TRANSPORT OF A DECAYING CONTAMINANT SPECIES" P.A. Domenico (1987) Modified to Include Retardation

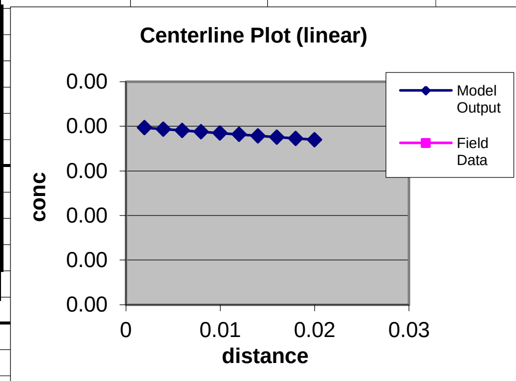
SOURCE CONC (MG/L)	Ax (ft)	Ay (ft)	Az (ft) >=.001	LAMBDA day-1	SOURCE WIDTH (ft)	SOURCE THICKNESS (ft)	Time (days)
0	2.00E+02	2.00E+01	1.00E-04	0.00034521	100	15	1E+99

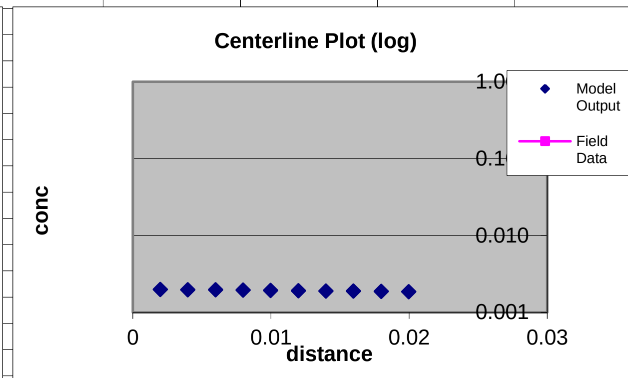
Hydraulic Cond (ft/day)	Hydraulic Gradient (ft/ft)	Porosity (dec. frac.)	Soil Bulk Density (g/cm^3)	KOC	Frac. Org. Carb.	Retardation (R)	V (=K*i/n*R) (ft/day)
2.83E-01	0.0017	0.35	1.7225	490000	5.00E-03	12058.5	1.13992E-07

Point Concentration

x(ft)	y(ft)	z(ft)
0.013377268	0	0

	x(ft)	y(ft)	z(ft)
Conc. At	0.013377268	0	0
at 1E+99	days =		**0.002** mg/l





AREAL CALCULATION MODEL DOMAIN
Length (ft) 0.02
Width (ft) 50

	0.002	0.004	0.006	0.008	0.01	0.012	0.014	0.016	0.018	0.02
50	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
25	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
0	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
-25	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
-50	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Field Data:							
Centerline Concentration							
Distance from Source							

Table G.09 C-140 Chry QD
SIM 1

Table G.10
AOI 7
Appendix G
Chrysene at C-140

METHOD FOR ESTIMATNG FLOW, AVERAGE CONCENTRATION AND MASS LOADING TO SURFACE WATER FROM GROUNDWATER

Project: Sunoco AOI 7 F&T
Date: 2/5/2002
Contaminant: **Chrysene at C-140**
Prepared by: **TS**

PA DEPARTMENT
OF ENVIRONMENTAL PROTECTION
SWLOAD5B.XLS
A METHOD FOR ESTIMATING
COMTAMINANT LOADING TO SURFACE
WATER
based on
P.A. Domenico (1987)
Modified to Include Retardation

SOURCE CONC (units) mg/l	Ax (ft) >.0001	Ay (ft) >.0001	Az (ft) >=.0001	LAMBDA day-1	SOURCE WIDTH (ft)	SOURCE THICKNESS (ft)	Time (days)
0.002	200	20	1.00E-04	3.54E-04	100	15	1.00E+99

Hydraulic Cond (ft/day)	Hydraulic Gradient (ft/ft)	Porosity (dec. frac.)	Soil Bulk Density (g/cm3)	KOC	Frac. Org. Carb.	Retard-ation (R)	V (=K*i/n*R) (ft/day)
2.83E-01	0.0017	0.35	1.7225	490000	5.00E-03	12058.5	1.14E-07

			-50	-40	-30	-20	-10	0	10	20	30	40	50
Edge Criterion (mg/l)	**0.00048**	0	7.86E-98	9.052E-98	1.01E-97	1.091E-97	1.142E-97	1.16E-97	1.142E-97	1.091E-97	1.009E-97	9.05E-98	7.86E-98
Higest modeled conc.	**1.2E-97**	-1.5	7.86E-98	9.052E-98	1.01E-97	1.091E-97	1.142E-97	1.16E-97	1.142E-97	1.091E-97	1.009E-97	9.05E-98	7.86E-98
		-3	7.86E-98	9.052E-98	1.01E-97	1.091E-97	1.142E-97	1.16E-97	1.142E-97	1.091E-97	1.009E-97	9.05E-98	7.86E-98
SURFACE WATER LOADING GRID		-4.5	7.86E-98	9.052E-98	1.01E-97	1.091E-97	1.142E-97	1.16E-97	1.142E-97	1.091E-97	1.009E-97	9.05E-98	7.86E-98
Distance to Stream (ft)	**55**	-6	7.86E-98	9.052E-98	1.01E-97	1.091E-97	1.142E-97	1.16E-97	1.142E-97	1.091E-97	1.009E-97	9.05E-98	7.86E-98
Plume View Width (ft)	**100**	-7.5	7.86E-98	9.052E-98	1.01E-97	1.091E-97	1.142E-97	1.16E-97	1.142E-97	1.091E-97	1.009E-97	9.05E-98	7.86E-98
Plume View Depth (ft)	**15**	-9	7.86E-98	9.052E-98	1.01E-97	1.091E-97	1.142E-97	1.16E-97	1.142E-97	1.091E-97	1.009E-97	9.05E-98	7.86E-98
		-10.5	7.86E-98	9.052E-98	1.01E-97	1.091E-97	1.142E-97	1.16E-97	1.142E-97	1.091E-97	1.009E-97	9.05E-98	7.86E-98
		-12	7.86E-98	9.052E-98	1.01E-97	1.091E-97	1.142E-97	1.16E-97	1.142E-97	1.091E-97	1.009E-97	9.05E-98	7.86E-98
PENTOX NOT NEEDED		-13.5	7.86E-98	9.052E-98	1.01E-97	1.091E-97	1.142E-97	1.16E-97	1.142E-97	1.091E-97	1.009E-97	9.05E-98	7.86E-98
		-15	3.93E-98	4.526E-98	5.05E-98	5.453E-98	5.711E-98	5.799E-98	5.711E-98	5.453E-98	5.047E-98	4.53E-98	3.93E-98

Average Groundwater Concentration #DIV/0! mg/l

Plume Flow 0.00000 cfs 0 MGD

Mass Loading to Stream #DIV/0! mg/day

Table G.11
Quick Domenico
Fate and Transport Model Input and Output
AOI-7 Shallow Groundwater
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Project	2574601 - Sunoco Philadelphia Refinery
Prepared by	Terrance Stanley
Date Prepared	2/10/2012

Generic Input Parameters				Data Source
Source Identification (or Well ID)			**C-142**	
Sample Date			**July 15, 2010**	
Source Width		ft	100	Delineated LNAPL (100' default if no plume is present)
Source Thickness		ft	15	URS, 2002 (average thickness of the UUA)
Longitudinal Dispersivity	A_x	ft	200	Estimate based on knowledge of site geology and contaminants present
Transverse Dispersivity	A_y	ft	20.0	Quick Domenico User's Manual
Vertical Dispersivity	A_z	ft	0.0001	Quick Domenico User's Manual
Hydraulic Conductivty	k	ft/day	0.283	Estimated hydraulic conductivity of the bulkhead
Hydraulic Gradient	i	ft/ft	0.0441	January 2012 C-142/C-146
Porosity	n	decimal fraction	0.35	Site soil analyses
Soil Bulk Density	p_b	g/cm3	1.7225	ACT 2 TGM Default
Fraction of Organic Carbon	f_{OC}	decimal fraction	0.005	ACT 2 TGM Default
Time		days	1.00E+99	Steady-State Conditions

Chemical Specific Input Parameters				Data Source
Sim 1				
Contaminant			Chrysene	
Source Concentration (mg/L)		mg/L	0.0640	July 2010 Sampling
Lambda (per day)		day^{-1}	3.452E-04	PADEP Number Please! 2011 Spreadsheet
KOC			490000	PADEP Number Please! 2011 Spreadsheet

Output (Distance from Source Where Concentration Equals Respective Ground Water MSC)

Contaminant	Starting Concentration (mg/L)	GW MSC[1] Non-Residential (mg/L)	Predicted Concentration (mg/L)	Predicted Distance to Meet Non-Residential GW MSC (Rounded to the Nearest foot)
Sim 1 - Chrysene	0.0640	0.0019	0.0019	**5**

[1] ACT 2 TGM, Appendix A, Table 1 MSC for a Non-residential Used Aquifer with Total Dissolved Solids less than or equal to 2500.

ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION,1ST ORDER DECAY and RETARDATION - WITH CALIBRATION TOOL

Project: 2574601 - Sunoco Philadelphia Refinery
Date: 2/10/2012 Prepared by: Terrance Stanley
Contaminant: Chrysene source concentration = 0.064 mg/l

NEW QUICK_DOMENICO.XLS

SPREADSHEET APPLICATION OF "AN ANALYTICAL MODEL FOR MULTIDIMENSIONAL TRANSPORT OF A DECAYING CONTAMINANT SPECIES" P.A. Domenico (1987) Modified to Include Retardation

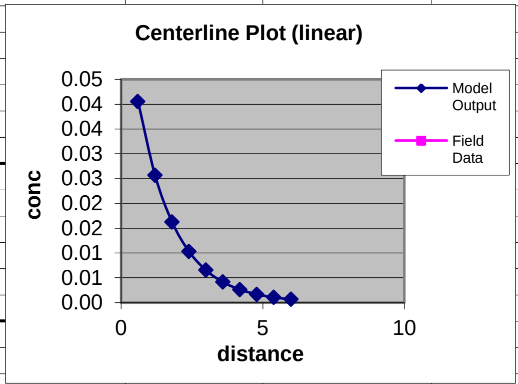
SOURCE CONC (MG/L)	Ax (ft)	Ay (ft)	Az (ft) >=.001	LAMBDA day-1	SOURCE WIDTH (ft)	SOURCE THICKNESS (ft)	Time (days)
0	2.00E+02	2.00E+01	1.00E-04	0.00034521	100	15	1E+99

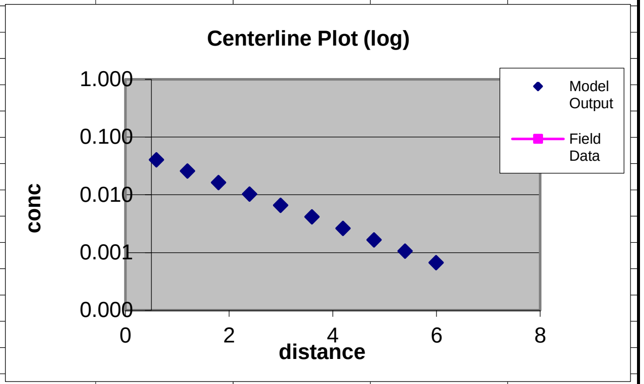
Hydraulic Cond (ft/day)	Hydraulic Gradient (ft/ft)	Porosity (dec. frac.)	Soil Bulk Density (g/cm^3)	KOC	Frac. Org. Carb.	Retardation (R)	V (=K*i/n*R) (ft/day)
2.83E-01	0.0441	0.35	1.7225	490000	5.00E-03	12058.5	2.95708E-06

Point Concentration

x(ft)	y(ft)	z(ft)
4.618448277	0	0

	x(ft)	y(ft)	z(ft)
Conc. At	4.618448277	0	0
at	1E+99	days =	0.002 mg/l





AREAL CALCULATION
MODEL DOMAIN
Length (ft) 6
Width (ft) 50

	0.6	1.2	1.8	2.4	3	3.6	4.2	4.8	5.4	6
50	0.020	0.013	0.008	0.005	0.003	0.002	0.001	0.001	0.001	0.000
25	0.041	0.026	0.016	0.010	0.006	0.004	0.003	0.002	0.001	0.001
0	0.041	0.026	0.016	0.010	0.007	0.004	0.003	0.002	0.001	0.001
-25	0.041	0.026	0.016	0.010	0.006	0.004	0.003	0.002	0.001	0.001
-50	0.020	0.013	0.008	0.005	0.003	0.002	0.001	0.001	0.001	0.000

Field Data:								
Centerline C Concentration								
Distance from Source								

Table G.11 C-142 Chry QD
SIM 1

Table G.12
AOI 7
Appendix G
Chrysene at C-142

METHOD FOR ESTIMATNG FLOW, AVERAGE CONCENTRATION AND MASS LOADING TO SURFACE WATER FROM GROUNDWATER

Project: Sunoco AOI 7 F&T
Date: 2/5/2002
Contaminant: Chrysene at C-142
Prepared by: TS

PA DEPARTMENT
OF ENVIRONMENTAL PROTECTION
SWLOAD5B.XLS
A METHOD FOR ESTIMATING
COMTAMINANT LOADING TO SURFACE
WATER
based on
P.A. Domenico (1987)
Modified to Include Retardation

SOURCE CONC (units)	Ax (ft)	Ay (ft)	Az (ft)	LAMBDA	SOURCE WIDTH (ft)	SOURCE THICKNESS (ft)	Time (days)
mg/l	>.0001	>.0001	>=.0001	day-1			
0.064	200	20	1.00E-04	3.54E-04	100	15	1.00E+99

Hydraulic Cond (ft/day)	Hydraulic Gradient (ft/ft)	Porosity (dec. frac.)	Soil Bulk Density (g/cm3)	KOC	Frac. Org. Carb.	Retard-ation (R)	V (=K*i/n*R) (ft/day)
2.83E-01	0.0441	0.35	1.7225	490000	5.00E-03	12058.5	2.957E-06

Edge Criterion (mg/l): 0.00048
Higest modeled conc.: 4.8E-40

SURFACE WATER LOADING GRID

Distance to Stream (ft): 113
Plume View Width (ft): 100
Plume View Depth (ft): 15

PENTOX NOT NEEDED

	-50	-40	-30	-20	-10	0	10	20	30	40	50
0	3.85E-40	4.178E-40	4.46E-40	4.664E-40	4.794E-40	4.839E-40	4.794E-40	4.664E-40	4.455E-40	4.18E-40	3.85E-40
-1.5	3.85E-40	4.178E-40	4.46E-40	4.664E-40	4.794E-40	4.839E-40	4.794E-40	4.664E-40	4.455E-40	4.18E-40	3.85E-40
-3	3.85E-40	4.178E-40	4.46E-40	4.664E-40	4.794E-40	4.839E-40	4.794E-40	4.664E-40	4.455E-40	4.18E-40	3.85E-40
-4.5	3.85E-40	4.178E-40	4.46E-40	4.664E-40	4.794E-40	4.839E-40	4.794E-40	4.664E-40	4.455E-40	4.18E-40	3.85E-40
-6	3.85E-40	4.178E-40	4.46E-40	4.664E-40	4.794E-40	4.839E-40	4.794E-40	4.664E-40	4.455E-40	4.18E-40	3.85E-40
-7.5	3.85E-40	4.178E-40	4.46E-40	4.664E-40	4.794E-40	4.839E-40	4.794E-40	4.664E-40	4.455E-40	4.18E-40	3.85E-40
-9	3.85E-40	4.178E-40	4.46E-40	4.664E-40	4.794E-40	4.839E-40	4.794E-40	4.664E-40	4.455E-40	4.18E-40	3.85E-40
-10.5	3.85E-40	4.178E-40	4.46E-40	4.664E-40	4.794E-40	4.839E-40	4.794E-40	4.664E-40	4.455E-40	4.18E-40	3.85E-40
-12	3.85E-40	4.178E-40	4.46E-40	4.664E-40	4.794E-40	4.839E-40	4.794E-40	4.664E-40	4.455E-40	4.18E-40	3.85E-40
-13.5	3.85E-40	4.178E-40	4.46E-40	4.664E-40	4.794E-40	4.839E-40	4.794E-40	4.664E-40	4.455E-40	4.18E-40	3.85E-40
-15	1.92E-40	2.089E-40	2.23E-40	2.332E-40	2.397E-40	2.419E-40	2.397E-40	2.332E-40	2.228E-40	2.09E-40	1.92E-40

Average Groundwater Concentration #DIV/0! mg/l

Plume Flow 0.00000 cfs 0 MGD

Mass Loading to Stream #DIV/0! mg/day

Table G.12
Quick Domenico
Fate and Transport Model Input and Output
AOI-7 Shallow Groundwater
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Project 2574601 - Sunoco Philadelphia Refinery
Prepared by Terrance Stanley
Date Prepared 2/22/2012

Generic Input Parameters				**Data Source**
Source Identification (or Well ID)			**SCUA**	No. 3 Separator - 137 Crude Unit Area
Sample Date			**July 15, 2010**	
Source Width		ft	300	Distance between C-150 to C-167
Source Thickness		ft	15	URS, 2002 (average thickness of the UUA)
Longitudinal Dispersivity	A_x	ft	200	Estimate based on knowledge of site geology and contaminants present
Transverse Dispersivity	A_y	ft	20.0	Quick Domenico User's Manual
Vertical Dispersivity	A_z	ft	0.0001	Quick Domenico User's Manual
Hydraulic Conductivty	k	ft/day	0.283	Estimated hydraulic conductivity of the bulkhead
Hydraulic Gradient	i	ft/ft	0.0441	January 2012 C-142/C-146
Porosity	n	decimal fraction	0.35	Site soil analyses
Soil Bulk Density	p_b	g/cm3	1.7225	ACT 2 TGM Default
Fraction of Organic Carbon	f_{OC}	decimal fraction	0.005	ACT 2 TGM Default
Time		days	1.00E+99	Steady-State Conditions

Chemical Specific Input Parameters				**Data Source**
Sim 1				
Contaminant			Chrysene	
Source Concentration (mg/L)		mg/L	0.0019	Aqueous saturation
Lambda (per day)		day^{-1}	3.452E-04	PADEP Number Please! 2011 Spreadsheet
KOC			490000	PADEP Number Please! 2011 Spreadsheet

Output (Distance from Source Where Concentration Equals Respective Ground Water MSC)				
Contaminant	**Starting Concentration (mg/L)**	**GW MSC[1] Non-Residential (mg/L)**	**Predicted Concentration (mg/L)**	**Predicted Distance to Meet Non-Residential GW MSC (Rounded to the Nearest foot)**
Sim 1 - Chrysene	0.0019	0.0019	0.0019	**0**

[1] ACT 2 TGM, Appendix A, Table 1 MSC for a Non-residential Used Aquifer with Total Dissolved Solids less than or equal to 2500.

Table G.14
AOI 7
Appendix G
Chrysene at SCUA

METHOD FOR ESTIMATNG FLOW, AVERAGE CONCENTRATION AND MASS LOADING TO SURFACE WATER FROM GROUNDWATER

Project: Sunoco AOI 7 F&T
Date: 2/5/2002
Contaminant: Chrysene at SCUA
Prepared by: TS

PA DEPARTMENT
OF ENVIRONMENTAL PROTECTION
SWLOAD5B.XLS
A METHOD FOR ESTIMATING
COMTAMINANT LOADING TO SURFACE
WATER
based on
P.A. Domenico (1987)
Modified to Include Retardation

SOURCE CONC (units) mg/l	Ax (ft) >.0001	Ay (ft) >.0001	Az (ft) >=.0001	LAMBDA day-1	SOURCE WIDTH (ft)	SOURCE THICKNESS (ft)	Time (days)
0.0019	200	20	1.00E-04	3.54E-04	300	15	1.00E+99

Hydraulic Cond (ft/day)	Hydraulic Gradient (ft/ft)	Porosity (dec. frac.)	Soil Bulk Density (g/cm^3)	KOC	Frac. Org. Carb.	Retard-ation (R)	V (=K*i/n*R) (ft/day)
2.83E-01	0.0023	0.35	1.7225	490000	5.00E-03	12058.5	1.542E-07

			-50	-40	-30	-20	-10	0	10	20	30	40	50
Edge Criterion (mg/l)	0.00048	0	1.44E-47	1.446E-47	1.45E-47	1.447E-47	1.447E-47	1.447E-47	1.447E-47	1.447E-47	1.447E-47	1.45E-47	1.44E-47
Higest modeled conc.	1.4E-47	-1.5	1.44E-47	1.446E-47	1.45E-47	1.447E-47	1.447E-47	1.447E-47	1.447E-47	1.447E-47	1.447E-47	1.45E-47	1.44E-47
		-3	1.44E-47	1.446E-47	1.45E-47	1.447E-47	1.447E-47	1.447E-47	1.447E-47	1.447E-47	1.447E-47	1.45E-47	1.44E-47
SURFACE WATER LOADING GRID		-4.5	1.44E-47	1.446E-47	1.45E-47	1.447E-47	1.447E-47	1.447E-47	1.447E-47	1.447E-47	1.447E-47	1.45E-47	1.44E-47
Distance to Stream (ft)	30	-6	1.44E-47	1.446E-47	1.45E-47	1.447E-47	1.447E-47	1.447E-47	1.447E-47	1.447E-47	1.447E-47	1.45E-47	1.44E-47
Plume View Width (ft)	100	-7.5	1.44E-47	1.446E-47	1.45E-47	1.447E-47	1.447E-47	1.447E-47	1.447E-47	1.447E-47	1.447E-47	1.45E-47	1.44E-47
Plume View Depth (ft)	15	-9	1.44E-47	1.446E-47	1.45E-47	1.447E-47	1.447E-47	1.447E-47	1.447E-47	1.447E-47	1.447E-47	1.45E-47	1.44E-47
		-10.5	1.44E-47	1.446E-47	1.45E-47	1.447E-47	1.447E-47	1.447E-47	1.447E-47	1.447E-47	1.447E-47	1.45E-47	1.44E-47
		-12	1.44E-47	1.446E-47	1.45E-47	1.447E-47	1.447E-47	1.447E-47	1.447E-47	1.447E-47	1.447E-47	1.45E-47	1.44E-47
PENTOX NOT NEEDED		-13.5	1.44E-47	1.446E-47	1.45E-47	1.447E-47	1.447E-47	1.447E-47	1.447E-47	1.447E-47	1.447E-47	1.45E-47	1.44E-47
		-15	7.22E-48	7.231E-48	7.23E-48	7.235E-48	7.236E-48	7.236E-48	7.236E-48	7.235E-48	7.234E-48	7.23E-48	7.22E-48

Average Groundwater Concentration #DIV/0! mg/l

Plume Flow 0.00000 cfs 0 MGD

Mass Loading to Stream #DIV/0! mg/day

APPENDIX H

LNAPL Modeling Procedures and Results

ATTACHMENT H
LNAPL MODELING PROCEDURES
AOI 7: SUNOCO PHILADELPHIA REFINERY
PHILADELPHIA, PENNSYLVANIA

H.1 INTRODUCTION AND OVERVIEW

Models which assess volume, mobility, and recoverability of light non-aqueous phase liquid (LNAPL) contamination have progressed beyond simply extrapolating LNAPL monitoring well thicknesses into the surrounding geologic materials. Instead, these models incorporate the physical properties of groundwater, LNAPL, and soil, in conjunction with an improved understanding of how fluids interact with each other and the surrounding geologic materials, and provide better estimates of LNAPL volume, mobility, and recoverability. These scientific improvements have allowed more realistic endpoints to be set during the remediation process.

For the LNAPL modeling in AOI 7 at the Sunoco Refinery in Philadelphia, PA (the Facility), Langan utilized the American Petroleum Institute (API) Publication Number 4682, "Free-Product Recovery of Petroleum Hydrocarbon Liquids," dated June 1999, as a guide for assessing LNAPL volume, mobility, and recoverability. The parameters discussed in subsequent sections are presented in API Publication 4682 as the significant variables and parameters needed to evaluate the nature and extent of free LNAPL. An updated version of the API model found in the API publication "API Interactive LNAPL Guide," version 2.0.4, dated July 2004, was used. These parameters and the API model were utilized to estimate the specific volume and mobility of LNAPL at the Facility.

H.2 INPUT PARAMETERS

Representative values obtained from the API's LNAPL and Environmental Canada's Reference Database were used to identify input parameters. Table H-1 of this attachment summarizes the LNAPL modeling input parameters used for this phase of the project. The individual input parameters used for the LNAPL models are described in detail below.

H.3 FLUID PROPERTIES

The fluids of concern in LNAPL modeling are LNAPL, groundwater, and air. Key physical properties of these fluids are density (ρ), interfacial tension (σ) and viscosity (μ). Chromatographic and mass spectroscopic hydrocarbon LNAPL characterization analyses were conducted on collected LNAPL samples in an attempt to identify and categorize LNAPLs on site.

H.3.1 Fluid Density and Specific Gravity

Fluid density,ρ, is the mass of fluid per unit volume. Specific gravity, ρ_r, is the relative density of LNAPL with respect to the density of water. The density of LNAPL is related to its specific gravity through the following relationship:

$$\rho_r = \rho_o/\rho_w \qquad \text{(H.1)}$$

where ρ_o and ρ_w are the LNAPL and water densities, respectively.

Density estimates for LNAPL samples collected from wells within the Facility were determined from LNAPL and groundwater density data. If a density value was not available for the LNAPL in a particular monitoring well, a value was assigned based on the physical characteristics of the LNAPL observed in neighboring wells.

H.3.2 LNAPL Viscosity

Viscosity is the measure of friction between molecules within a given fluid. The dynamic (or absolute) viscosity, μ, is defined as the ratio of the shear stress to the strain rate for a Newtonian fluid (Newtonian fluids have constant viscosity and flow immediately on the application of a force). The kinematic viscosity (ν) is the ratio of the dynamic viscosity to the density of a fluid.

If a kinematic viscosity value was not available for the LNAPL within a monitoring well, a value was assigned based on the physical characteristics of the LNAPL in relation to neighboring monitor wells, or a representative viscocity value was selected from the API or Environmental Canada Database chosen based upon other LNAPL physical characteristics.

H.4 FORMATION PHYSICAL PROPERTIES

Where available, site-specific geologic and hydrogeologic data were obtained from site soil boring investigations, monitoring and recovery wells installation and sampling activities, and aquifer characteristic testing. All remaining physical property input values were obtained from reference literature.

Variations in soil type were noted from boring log descriptions. For the purpose of determining modeling parameters, generalizations of the geologic characteristics were made based on the occurrence and distribution of soil types within the LNAPL wetted screen interval of monitoring wells. Consistent with the API guidance publication, the geologic parameters of interest include: soil texture, porosity, bulk density, fluid saturation, capillary pressure relationships, and total organic carbon (TOC). These parameters are discussed in detail below.

H.4.1 Formation Texture

One of the most important parameters in determining the properties of porous media is the size range of particles in a soil, which is referred to as soil texture. Grain size is closely related to soil texture, and a grain size distribution gives the relative percentage of grain sizes within a formation.

Where available, historic site-specific grain size distribution data were used to describe the relative percentage of grain size within the various geologic units at the Facility. Regions with similar grain size distributions were grouped together, and representative values were selected. Soil within the historic maximum LNAPL wetted interval was used for this selection. Note, however, that in any given boring log, the soil type spanning the LNAPL wetted interval may actually include a range of soil types. In addition to the grain size analyses, the soil Atterberg Limits were referenced for select soil types. The Atterberg limits were used to correlate and characterize the fine-grained soil (i.e., silt and clay) in conjunction with the grain size distribution analyses.

H.4.2 Porosity

The ratio of the volume of void space in a soil to the total volume is defined as the porosity (n), which is usually written as a fraction or a percent of void space. Generally, wider variations in particle sizes result in smaller porosity values, as the void space between the larger particles are filled by smaller particles. The effective porosity (or kinematic porosity) refers to the volume of interconnected pore spaces through which fluids can flow.

H.4.3 Bulk Density

Bulk density is a measure of the weight of the soil per unit volume, usually given on an oven-dry (110° C) basis. Variation in bulk density is attributable to the relative proportion and specific gravity of solid organic and inorganic particles and to the porosity of the soil. Most mineral soils have bulk densities between 1.0 and 2.0.

H.4.4 Fluid Saturation

According to the API guidance documents, the void space of a natural porous medium affected by an LNAPL release is filled with water, air and LNAPL. The fraction of the pore space of a representative volume of material that is occupied by a particular fluid is called the fluid saturation. The fluid saturation of each phase can range from 0 to 1, and the sum of the three phases must equal 1.

H.4.5 Capillary Pressure Relationships

According to the API guidance document, molecules located near the interface between two fluids (i.e. water and LNAPL) in one void space have a greater energy than molecules of the same fluid located within the bulk volume due to cohesive forces between the molecules. The excess energy associated with a fluid interface results in interfacial tension between the fluids, and surface tension between the liquid and vapor.

These relationships are incorporated into the API model for determining formation specific volume under vertical equilibrium.

H.5 LNAPL EFFECTIVE PERMEABILITY

Water, air, and LNAPL are in competition for the interstitial spaces within the formation. Relative permeability describes the ability of one fluid to flow in the presence of other fluids, compared to the ability of the fluid to flow if it were the only fluid present. Typically, these differences in permeability between water and LNAPL are observed as LNAPL reaches the water table in sufficient quantities, pools, and spreads laterally as a floating layer.

The API modeling approach is to predict the LNAPL saturation and relative permeability distributions under vertical equilibrium conditions. The effective saturation and relative permeability values depend on the LNAPL thicknesses within the formation, for which the apparent monitoring well LNAPL thicknesses serve as a useful measure. The modeling objective is to replace the layer with varying saturation and relative permeability with an equivalent layer with vertically uniform characteristics.

For each well with reported apparent LNAPL thickness, the API model was run to determine the effective relative permeability of LNAPL within that well. As a first approximation, the residual saturation of LNAPL (the portion of LNAPL that is adhered to soil and not recoverable) was considered to be zero for the calculation of effective relative permeability. The residual saturation of LNAPL will be determined based on the soil grain size, fluid saturation and capillary curves for the recoverability analysis.

H.6 SOIL INTRINSIC PERMEABILITY

The intrinsic permeability of the soil was estimated using the following equation:

$$k_{soil} = \frac{K_W \mu_W}{\rho_W g} \qquad \text{(H.2)}$$

where,

k_{soil} = permeability of soil

K_w = hydraulic conductivity of groundwater for fill horizon

μ_w = dynamic viscosity of water

p_w = density of water

g = gravity

The estimates of the ground water density and viscosity were used to determine the intrinsic soil permeability. The gravity constant was assumed to be 32.2 feet/s^2 (9.81 m/s^2).

H.7 LNAPL HYDRAULIC CONDUCTIVITY AT SATURATION

To estimate the seepage velocity of the free-phase LNAPL, the hydraulic conductivity of the formation with respect to LNAPL must be known. The hydraulic conductivity of LNAPL is first calculated at 100% saturation at the LNAPL phase. Then it is corrected from the effective LNAPL relative permeability. This corrected hydraulic conductivity of LNAPL is the hydraulic conductivity of LNAPL in the formation at the estimated saturation of LNAPL. This can be estimated based on the following equation:

$$K_{oil} = k_{ro} \frac{k_{soil} \rho_{oil} g}{\mu_{oil}} \qquad \text{(H.3)}$$

where,

K_{oil} = hydraulic conductivity of LNAPL in the soil at saturation

k_{ro} = effective LNAPL relative permeability

k_{soil} = permeability of soil relative to groundwater (Equation D.2)

μ_{oil} = dynamic viscosity of LNAPL

p_{oil} = density of LNAPL

g = gravity

H.8 LNAPL SPECIFIC DISCHARGE

The result of the corrected hydraulic conductivity for LNAPL saturation (Equation H.3) was used to calculate the specific velocity of the LNAPL based on hydraulic gradient of the groundwater using the following equation:

$$q_{oil} = K_{oil} \times i_W \qquad \text{(H.4)}$$

where,

q_{oil} = LNAPL specific velocity of LNAPL discharge

K_{oil} = hydraulic conductivity of LNAPL in the soil at the corrected saturation

i_w = water table gradient

The water table gradient was assumed to be similar to the LNAPL table gradient. Based on the groundwater monitoring data collected to date, average water table gradients were selected.

The seepage velocity or mobility of the LNAPL was calculated based on the specific velocity calculated in Equation H.4, and correcting it for the effective porosity of the formation as follows:

$$v_{oil} = \frac{q_{oil}}{\phi_{eff}} \quad \text{(H.5)}$$

where,

v_{oil} = LNAPL seepage velocity

q_{oil} = LNAPL specific velocity of LNAPL discharge

ϕ_{eff} = effective porosity

The specific velocity of the LNAPL discharge from the previous calculation was divided by the effective porosity to determine the seepage velocity of LNAPL for all wells. For this calculation, total porosity values associated with each soil type were reduced for use as an effective porosity for LNAPL mobility.

H.9 LNAPL MODELING RESULTS

Calculated LNAPL specific volumes range 4.19 e-5 feet (C-151) to 0.571 feet at C-148. Well locations with calculated specific volumes greater than 0.1 feet are C-143, C-161, C-152, C-147, C-106, C-148 and C-167. The majority of these are located near the 137 Crude Unit and No. 3 Separator. The calculated LNAPL relative permeabilities range 0.047 % to 49.5 %. Fifteen of the eighteen wells with measureable LNAPL have calculated relative permeabilities greater than 1%.

Calculated LNAPL seepage velocities range 1.28e-6 (C-151) to 0.02 ft/d (WP-14). Thirteen wells have calculated LNAPL seepage velocities greater than 1e-7 cm/s (2.83e-4 ft/d). Located in Tables H.2 and H.3 are the output results of the LNAPL modeling. Located in Table H.4 of this attachment is the LNAPL characterization data provided by Torkelson Laboratories.

APPENDIX H

LNAPL Characterization Data

ATTACHMENT H
LNAPL MODELING PROCEDURES
AOI 7: SUNOCO PHILADELPHIA REFINERY
PHILADELPHIA, PENNSYLVANIA

H.1 INTRODUCTION AND OVERVIEW

Models which assess volume, mobility, and recoverability of light non-aqueous phase liquid (LNAPL) contamination have progressed beyond simply extrapolating LNAPL monitoring well thicknesses into the surrounding geologic materials. Instead, these models incorporate the physical properties of groundwater, LNAPL, and soil, in conjunction with an improved understanding of how fluids interact with each other and the surrounding geologic materials, and provide better estimates of LNAPL volume, mobility, and recoverability. These scientific improvements have allowed more realistic endpoints to be set during the remediation process.

For the LNAPL modeling in AOI 7 at the Sunoco Refinery in Philadelphia, PA (the Facility), Langan utilized the American Petroleum Institute (API) Publication Number 4682, "Free-Product Recovery of Petroleum Hydrocarbon Liquids," dated June 1999, as a guide for assessing LNAPL volume, mobility, and recoverability. The parameters discussed in subsequent sections are presented in API Publication 4682 as the significant variables and parameters needed to evaluate the nature and extent of free LNAPL. An updated version of the API model found in the API publication "API Interactive LNAPL Guide," version 2.0.4, dated July 2004, was used. These parameters and the API model were utilized to estimate the specific volume and mobility of LNAPL at the Facility.

H.2 INPUT PARAMETERS

Representative values obtained from the API's LNAPL and Environmental Canada's Reference Database were used to identify input parameters. Table H-1 of this attachment summarizes the LNAPL modeling input parameters used for this phase of the project. The individual input parameters used for the LNAPL models are described in detail below.

H.3 FLUID PROPERTIES

The fluids of concern in LNAPL modeling are LNAPL, groundwater, and air. Key physical properties of these fluids are density (ρ), interfacial tension (σ) and viscosity (μ). Chromatographic and mass spectroscopic hydrocarbon LNAPL characterization analyses were conducted on collected LNAPL samples in an attempt to identify and categorize LNAPLs on site.

H.3.1 Fluid Density and Specific Gravity

Fluid density,ρ, is the mass of fluid per unit volume. Specific gravity, ρ_r, is the relative density of LNAPL with respect to the density of water. The density of LNAPL is related to its specific gravity through the following relationship:

$$\rho_r = \rho_o/\rho_w \qquad \text{(H.1)}$$

where ρ_o and ρ_w are the LNAPL and water densities, respectively.

Density estimates for LNAPL samples collected from wells within the Facility were determined from LNAPL and groundwater density data. If a density value was not available for the LNAPL in a particular monitoring well, a value was assigned based on the physical characteristics of the LNAPL observed in neighboring wells.

H.3.2 LNAPL Viscosity

Viscosity is the measure of friction between molecules within a given fluid. The dynamic (or absolute) viscosity, μ, is defined as the ratio of the shear stress to the strain rate for a Newtonian fluid (Newtonian fluids have constant viscosity and flow immediately on the application of a force). The kinematic viscosity (ν) is the ratio of the dynamic viscosity to the density of a fluid.

If a kinematic viscosity value was not available for the LNAPL within a monitoring well, a value was assigned based on the physical characteristics of the LNAPL in relation to neighboring monitor wells, or a representative viscocity value was selected from the API or Environmental Canada Database chosen based upon other LNAPL physical characteristics.

H.4 FORMATION PHYSICAL PROPERTIES

Where available, site-specific geologic and hydrogeologic data were obtained from site soil boring investigations, monitoring and recovery wells installation and sampling activities, and aquifer characteristic testing. All remaining physical property input values were obtained from reference literature.

Variations in soil type were noted from boring log descriptions. For the purpose of determining modeling parameters, generalizations of the geologic characteristics were made based on the occurrence and distribution of soil types within the LNAPL wetted screen interval of monitoring wells. Consistent with the API guidance publication, the geologic parameters of interest include: soil texture, porosity, bulk density, fluid saturation, capillary pressure relationships, and total organic carbon (TOC). These parameters are discussed in detail below.

H.4.1 Formation Texture

One of the most important parameters in determining the properties of porous media is the size range of particles in a soil, which is referred to as soil texture. Grain size is closely related to soil texture, and a grain size distribution gives the relative percentage of grain sizes within a formation.

Where available, historic site-specific grain size distribution data were used to describe the relative percentage of grain size within the various geologic units at the Facility. Regions with similar grain size distributions were grouped together, and representative values were selected. Soil within the historic maximum LNAPL wetted interval was used for this selection. Note, however, that in any given boring log, the soil type spanning the LNAPL wetted interval may actually include a range of soil types. In addition to the grain size analyses, the soil Atterberg Limits were referenced for select soil types. The Atterberg limits were used to correlate and characterize the fine-grained soil (i.e., silt and clay) in conjunction with the grain size distribution analyses.

H.4.2 Porosity

The ratio of the volume of void space in a soil to the total volume is defined as the porosity (n), which is usually written as a fraction or a percent of void space. Generally, wider variations in particle sizes result in smaller porosity values, as the void space between the larger particles are filled by smaller particles. The effective porosity (or kinematic porosity) refers to the volume of interconnected pore spaces through which fluids can flow.

H.4.3 Bulk Density

Bulk density is a measure of the weight of the soil per unit volume, usually given on an oven-dry (110° C) basis. Variation in bulk density is attributable to the relative proportion and specific gravity of solid organic and inorganic particles and to the porosity of the soil. Most mineral soils have bulk densities between 1.0 and 2.0.

H.4.4 Fluid Saturation

According to the API guidance documents, the void space of a natural porous medium affected by an LNAPL release is filled with water, air and LNAPL. The fraction of the pore space of a representative volume of material that is occupied by a particular fluid is called the fluid saturation. The fluid saturation of each phase can range from 0 to 1, and the sum of the three phases must equal 1.

H.4.5 Capillary Pressure Relationships

According to the API guidance document, molecules located near the interface between two fluids (i.e. water and LNAPL) in one void space have a greater energy than molecules of the same fluid located within the bulk volume due to cohesive forces between the molecules. The excess energy associated with a fluid interface results in interfacial tension between the fluids, and surface tension between the liquid and vapor.

These relationships are incorporated into the API model for determining formation specific volume under vertical equilibrium.

H.5 LNAPL EFFECTIVE PERMEABILITY

Water, air, and LNAPL are in competition for the interstitial spaces within the formation. Relative permeability describes the ability of one fluid to flow in the presence of other fluids, compared to the ability of the fluid to flow if it were the only fluid present. Typically, these differences in permeability between water and LNAPL are observed as LNAPL reaches the water table in sufficient quantities, pools, and spreads laterally as a floating layer.

The API modeling approach is to predict the LNAPL saturation and relative permeability distributions under vertical equilibrium conditions. The effective saturation and relative permeability values depend on the LNAPL thicknesses within the formation, for which the apparent monitoring well LNAPL thicknesses serve as a useful measure. The modeling objective is to replace the layer with varying saturation and relative permeability with an equivalent layer with vertically uniform characteristics.

For each well with reported apparent LNAPL thickness, the API model was run to determine the effective relative permeability of LNAPL within that well. As a first approximation, the residual saturation of LNAPL (the portion of LNAPL that is adhered to soil and not recoverable) was considered to be zero for the calculation of effective relative permeability. The residual saturation of LNAPL will be determined based on the soil grain size, fluid saturation and capillary curves for the recoverability analysis.

H.6 SOIL INTRINSIC PERMEABILITY

The intrinsic permeability of the soil was estimated using the following equation:

$$k_{soil} = \frac{K_W \mu_W}{\rho_W g} \qquad \text{(H.2)}$$

where,

k_{soil} = permeability of soil

K_w = hydraulic conductivity of groundwater for fill horizon

μ_w = dynamic viscosity of water

p_w = density of water

g = gravity

The estimates of the ground water density and viscosity were used to determine the intrinsic soil permeability. The gravity constant was assumed to be 32.2 feet/s^2 (9.81 m/s^2).

H.7 LNAPL HYDRAULIC CONDUCTIVITY AT SATURATION

To estimate the seepage velocity of the free-phase LNAPL, the hydraulic conductivity of the formation with respect to LNAPL must be known. The hydraulic conductivity of LNAPL is first calculated at 100% saturation at the LNAPL phase. Then it is corrected from the effective LNAPL relative permeability. This corrected hydraulic conductivity of LNAPL is the hydraulic conductivity of LNAPL in the formation at the estimated saturation of LNAPL. This can be estimated based on the following equation:

$$K_{oil} = k_{ro} \frac{k_{soil} \rho_{oil} g}{\mu_{oil}} \qquad \text{(H.3)}$$

where,

K_{oil} = hydraulic conductivity of LNAPL in the soil at saturation

k_{ro} = effective LNAPL relative permeability

k_{soil} = permeability of soil relative to groundwater (Equation D.2)

μ_{oil} = dynamic viscosity of LNAPL

p_{oil} = density of LNAPL

g = gravity

H.8 LNAPL SPECIFIC DISCHARGE

The result of the corrected hydraulic conductivity for LNAPL saturation (Equation H.3) was used to calculate the specific velocity of the LNAPL based on hydraulic gradient of the groundwater using the following equation:

$$q_{oil} = K_{oil} \times i_W \qquad \text{(H.4)}$$

where,

q_{oil} = LNAPL specific velocity of LNAPL discharge

K_{oil} = hydraulic conductivity of LNAPL in the soil at the corrected saturation

i_w = water table gradient

The water table gradient was assumed to be similar to the LNAPL table gradient. Based on the groundwater monitoring data collected to date, average water table gradients were selected.

The seepage velocity or mobility of the LNAPL was calculated based on the specific velocity calculated in Equation H.4, and correcting it for the effective porosity of the formation as follows:

$$v_{oil} = \frac{q_{oil}}{\phi_{eff}} \qquad \text{(H.5)}$$

where,

v_{oil} = LNAPL seepage velocity

q_{oil} = LNAPL specific velocity of LNAPL discharge

ϕ_{eff} = effective porosity

The specific velocity of the LNAPL discharge from the previous calculation was divided by the effective porosity to determine the seepage velocity of LNAPL for all wells. For this calculation, total porosity values associated with each soil type were reduced for use as an effective porosity for LNAPL mobility.

H.9 LNAPL MODELING RESULTS

Calculated LNAPL specific volumes range 4.19 e-5 feet (C-151) to 0.571 feet at C-148. Well locations with calculated specific volumes greater than 0.1 feet are C-143, C-161, C-152, C-147, C-106, C-148 and C-167. The majority of these are located near the 137 Crude Unit and No. 3 Separator. The calculated LNAPL relative permeabilities range 0.047 % to 49.5 %. Fifteen of the eighteen wells with measureable LNAPL have calculated relative permeabilities greater than 1%.

Calculated LNAPL seepage velocities range 1.28e-6 (C-151) to 0.02 ft/d (WP-14). Thirteen wells have calculated LNAPL seepage velocities greater than 1e-7 cm/s (2.83e-4 ft/d). Located in Tables H.2 and H.3 are the output results of the LNAPL modeling. Located in Table H.4 of this attachment is the LNAPL characterization data provided by Torkelson Laboratories.

Table H.1
API Model Input Parameters, Soil Type and LNAPL Thickness
AOI 7 Site Characterization Report
Sunoco Philadelphia Refinery and Belmont Terminal
Philadelphia, Pennsylvania

Well ID	Apparent LNAPL Thickness Field Measurement(1)		API Database					LNAPL Density (Torkelson Geochemistry) (gm/cc)	LNAPL Type or Surrogate LNAPL Type (Torkelson Geochemistry)	Interfacial/Surface Tension			Interfacial/Surface Tension Source
	meter	feet	Effective Porosity Well ID (unitless)	USCS Soil Type Surrounding Well Screen(2)	van Genuchten "N" (unitless)	van Genuchten "a" [m^{-1}]	Irreducible Water Saturation(3) (unitless)			Air/Water Surface Tension(4) (dynes/cm)	Air/LNAPL Surface Tension (dynes/cm)	LNAPL/Water Interfacial Tension (dynes/cm)	
C-65	0.323	1.060	0.328	(SW)g	1.550	7.830	0.290	0.9126	Lubrication Oil	65.000	31.000	24.400	Gasoline Engine Lube Oil ETC Database
C-106	0.536	1.760						0.9306					
C-107	0.101	0.330						0.8487	Residual Oil	65.000	32.100	30.200	Residual Fuel Oil #4 ETC Database
C-143	0.735	2.410						0.8676	Middle Distillate	65.000	27.300	24.000	Diesel Fuel Oil - Southern USA (15°C) API Interactive LNAPL Guide
C-64	0.344	1.130						.8807 (C-154)	Light Crude	65.000	26.600	21.900	West Texas Intermediate (15°C) API Interactive LNAPL Guide
C-97	0.034	0.110						.8428 (C-150)					
C-147	1.009	3.310						0.8409					
C-148	1.618	5.310						0.8512					
C-150	0.098	0.320						0.8428					
C-151	0.012	0.040						0.8597 (C-152)					
C-152	0.774	2.540						0.8597					
C-153	0.143	0.470						0.8620					
C-154	0.027	0.090						0.8807					
C-161	0.238	0.780						0.8737					
C-162	0.314	1.030						0.8833					
C-166	0.223	0.730						0.8486					
C-167	1.649	5.410						0.8601					
WP-14	0.323	1.060						0.8601 (C-167)					

NOTES:
(1) Groundwater/LNAPL gauging event January 2012.
(2) Unified Soil Classification System - Soil type was determined from C-142, C-143 and C-144D boring logs.

USCS Symbol	API Database Version e / Folk Description
(SW)g	Well graded sand with graval

(3) Residual LNAPL saturation in the saturated and vadose zones are considered to be negligible.
(4) SPL Interfacial Tensions:

NAPL Type	Source
Lube Oil	Environment Canada ETC Database(Gasoline Engine)
Middle Distillate	Environment Canada ETC Database (Diesel)
Residual Oil	Environment Canada ETC Database (Residual Fuel Oil #4)
Light Crude	Environment Canada ETC Database (South Louisiana Crude)

Table H.2
API Model Results
AOI 7 Site Characterization Report
Sunoco Philadelphia Refinery and Belmont Terminal
Philadelphia, Pennsylvania

Well ID	Apparent LNAPL Thickness Field Measurement[1]		Specific Volume (D_o)		LNAPL Relative Permeability (k_{ro})
	meter	feet	meters	feet	unitless
C-151	0.012	0.040	1.3E-05	4.2E-05	0.047%
C-154	0.027	0.090	1.5E-05	4.8E-05	0.163%
C-97	0.034	0.110	6.5E-05	2.1E-04	0.641%
C-107	0.101	0.330	5.3E-04	0.002	2.372%
C-150	0.098	0.320	9.0E-04	0.003	4.222%
C-153	0.143	0.470	1.7E-03	0.006	5.967%
C-65	0.323	1.060	4.3E-03	0.014	6.761%
C-166	0.223	0.730	5.7E-03	0.019	13.902%
C-162	0.314	1.030	7.4E-03	0.024	12.335%
C-64	0.344	1.130	9.4E-03	0.031	14.628%
WP-14	0.323	1.060	1.0E-02	0.033	13.834%
C-143	0.735	2.410	4.2E-02	0.138	27.981%
C-161	0.238	0.780	4.8E-02	0.158	30.494%
C-152	0.774	2.540	5.2E-02	0.170	32.323%
C-147	1.009	3.310	8.9E-02	0.294	42.386%
C-106	0.536	1.760	1.1E-01	0.346	33.537%
C-148	1.618	5.310	1.7E-01	0.569	50.830%
C-167	1.649	5.410	1.7E-01	0.571	49.521%

Table H.3
LNAPL Seepage Velocity Calculations
AOI 7 Site Characterization Report
Sunoco Philadelphia Refinery and Belmont Terminal
Philadelphia, Pennsylvania

Well_ID	LNAPL Type	Effective Soil Porosity	Groundwater Density (15°C)	Groundwater Dynamic Viscosity (15°C)	Soil Permeability		Calculated Relative Permeability (k_{ro})	Hydraulic Gradient	LNAPL Density (15°C)	LNAPL Dynamic Viscosity (15°C)		LNAPL Conductivity at 100% Pore Saturation	Corrected LNAPL Conductivity		LNAPL Specific Discharge		LNAPL Seepage Velocity		
		unitless	kg/m^3	$(N·s)/m^2$	mD	m^2	unitless	unitless	kg/m^3	cP	$(N·s)/m^2$	m/d	m/d	ft/d	m/d	ft/d	m/yr	ft/yr	ft/d
		1	2	3	1	Calculated	4	5	6	3 or 7	Calculated	Calculated	Calculated		Calculated		Calculated		
C-65	Lubrication Oil	32.8%	999.19	1.14E-03	2.87E+03	2.83E-12	6.8%	0.0497	913	175.00	1.75E-01	1.25E-02	8.46E-04	2.777E-03	4.21E-05	1.38E-04	**4.68E-02**	**1.536E-01**	**4.208E-04**
C-106		32.8%	999.19	1.14E-03	2.87E+03	2.83E-12	33.5%	0.0148	931	175.00	1.75E-01	1.28E-02	4.28E-03	1.405E-02	6.35E-05	2.08E-04	**7.06E-02**	**2.317E-01**	**6.349E-04**
C-107	Residual Oil	32.8%	999.19	1.14E-03	2.87E+03	2.83E-12	2.4%	0.0494	849	35.00	3.50E-02	5.82E-02	1.38E-03	4.530E-03	6.81E-05	2.24E-04	**7.58E-02**	**2.488E-01**	**6.817E-04**
C-143	Middle Distillate	32.8%	999.19	1.14E-03	2.87E+03	2.83E-12	28.0%	0.0034	868	4.00	4.00E-03	5.21E-01	1.46E-01	4.780E-01	5.00E-04	1.64E-03	**5.57E-01**	**1.826E+00**	**5.003E-03**
C-64	Light Crude	32.8%	999.19	1.14E-03	2.87E+03	2.83E-12	14.6%	0.0220	881	7.00	7.00E-03	3.02E-01	4.42E-02	1.450E-01	9.72E-04	3.19E-03	**1.08E+00**	**3.549E+00**	**9.723E-03**
C-97		32.8%	999.19	1.14E-03	2.87E+03	2.83E-12	0.6%	0.0065	843	7.00	7.00E-03	2.89E-01	1.85E-03	6.079E-03	1.20E-05	3.93E-05	1.33E-02	4.377E-02	1.199E-04
C-147		32.8%	999.19	1.14E-03	2.87E+03	2.83E-12	42.4%	0.0110	841	7.00	7.00E-03	2.88E-01	1.22E-01	4.010E-01	1.34E-03	4.41E-03	**1.50E+00**	**4.909E+00**	**1.345E-02**
C-148		32.8%	999.19	1.14E-03	2.87E+03	2.83E-12	50.8%	0.0022	851	7.00	7.00E-03	2.92E-01	1.48E-01	4.868E-01	3.32E-04	1.09E-03	**3.70E-01**	**1.213E+00**	**3.323E-03**
C-150		32.8%	999.19	1.14E-03	2.87E+03	2.83E-12	4.2%	0.0022	843	7.00	7.00E-03	2.89E-01	1.22E-02	4.003E-02	2.73E-05	8.96E-05	3.04E-02	9.974E-02	2.733E-04
C-151		32.8%	999.19	1.14E-03	2.87E+03	2.83E-12	0.0%	0.0009	860	7.00	7.00E-03	2.95E-01	1.37E-04	4.505E-04	1.28E-07	4.19E-07	1.42E-04	4.663E-04	1.278E-06
C-152		32.8%	999.19	1.14E-03	2.87E+03	2.83E-12	32.3%	0.0110	860	7.00	7.00E-03	2.95E-01	9.53E-02	3.127E-01	1.05E-03	3.44E-03	**1.17E+00**	**3.827E+00**	**1.049E-02**
C-153		32.8%	999.19	1.14E-03	2.87E+03	2.83E-12	6.0%	0.0009	862	7.00	7.00E-03	2.96E-01	1.76E-02	5.788E-02	1.64E-05	5.38E-05	1.83E-02	5.991E-02	1.641E-04
C-154		32.8%	999.19	1.14E-03	2.87E+03	2.83E-12	0.2%	0.0030	881	7.00	7.00E-03	3.02E-01	4.91E-04	1.611E-03	1.47E-06	4.83E-06	1.64E-03	5.377E-03	1.473E-05
C-161		32.8%	999.19	1.14E-03	2.87E+03	2.83E-12	30.5%	0.0079	874	7.00	7.00E-03	3.00E-01	9.14E-02	2.998E-01	7.23E-04	2.37E-03	**8.05E-01**	**2.641E+00**	**7.236E-03**
C-162		32.8%	999.19	1.14E-03	2.87E+03	2.83E-12	12.3%	0.0038	883	7.00	7.00E-03	3.03E-01	3.74E-02	1.226E-01	1.40E-04	4.60E-04	**1.56E-01**	**5.116E-01**	**1.402E-03**
C-166		32.8%	999.19	1.14E-03	2.87E+03	2.83E-12	13.9%	0.0034	849	7.00	7.00E-03	2.91E-01	4.05E-02	1.327E-01	1.39E-04	4.56E-04	**1.55E-01**	**5.071E-01**	**1.389E-03**
C-167		32.8%	999.19	1.14E-03	2.87E+03	2.83E-12	49.5%	0.0069	860	7.00	7.00E-03	2.95E-01	1.46E-01	4.793E-01	1.01E-03	3.31E-03	**1.12E+00**	**3.678E+00**	**1.008E-02**
WP-14		32.8%	999.19	1.14E-03	2.87E+03	2.83E-12	13.8%	0.0494	860	7.00	7.00E-03	2.95E-01	4.08E-02	1.339E-01	2.01E-03	6.61E-03	**2.24E+00**	**7.353E+00**	**2.015E-02**

NOTES:
1 - API Parameter Database Version e.
2 - CRC Handbook of Chemistry and Physics, 68th Edition, 1987 - 88.
3 - API Interactive LNAPL User's Guide, July 2004.
4 - Results of the van Genuchten-Mualem Model of LNAPL Ditribution and Relative Permeability (API, 2003) using January 2012 LNAPL thickness values.
5 - Calculated from groundwater elevations gauged July 2011.
6 - Determined from representative sample for each impacted area. LNAPL sample analyzed by Lancaster Labs, Inc., August 2011.
7 - Environmental Canada Oil Properties Database.
$(N·s)/m^2$ = Newton-seconds per square meter
mD = millidarcy
cP = centipoise
kg = kilogram
m = meter
d = day
yr = year
Bold = seepage velocity greater than 1e-7 cm/sec = 3.154e-2m/yr = 2.83e-4 ft/d

Appendix H
Table H.4
AOI 7 LNAPL Characterization Summary Table
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Interpretation of Product Types, Proportions, and Weathering						Similarities to Other Samples in Study		
Characterization Results Compiled for CCR (TGI Job No. 04046 - Analyzed in March 2004)								
Well ID	**Density g/cc (60°F)**	**LNAPL Type(s)**	**Torkelson LNAPL Type(s)**	**Proportion (%)**	**Weathering**	**Quite Similar To**	**Fairly Similar To**	**Somewhat Similar To**
C-65	0.9162	Lube Oil	Lube Oil	60	Extreme	C-106 & PZ-204		All other lube oils in study
			Residual Oil	40	Severe			All other residual oils in study except A-133
C-106	0.9306	Lube Oil	Lube Oil	60	Extreme	C-65 & PZ-204		All other lube oils in study
			Middle Distillate	35		A-136 & B-43	N-68 & S-104	All other middle distillates in study
			Gasoline	5				All other gasolines in study
C-107	0.9371	Residual Oil	Residual Oil	100	Extreme		N-14	All other residual oils in study except A-133
Characterization Results Compiled for AOI 7 Site Characterization Activities (TGI Job No. 10099 - Analyzed in July 2010)								
C-143	0.8676	Middle Distillate	Middle Distillate	50	Extreme	Unique		S-297
			Heavier Virgin Naphtha	30	Severe			
			Heavier Material	20	Extreme			All other heavier materials in study
Characterization Results Compiled for AOI 7 Site Characterization Activities (TGI Job No. 12005 - Analyzed in February 2012)								
C-147	0.8409	Light Crude Oil	Light Crude	100	Severe		C-148 and C-166	C-152
C-148	0.8512	Light Crude Oil	Light Crude	100	Severe		C-147 and C-166	C-152
C-150	0.8428	Light Crude Oil	Light Crude	100	Extreme-Severe	Unique		
C-151	QNS	Light Crude Oil	Light Crude	100	Extreme-Severe		C-154 and C-161	C-167
C-152	0.8597	Light Crude Oil	Light Crude	100	Severe			C-147, C-148, and C-166
C-153	0.8620	Light Crude Oil	Light Crude	100	Extreme	Unique		
C-154	0.8807	Light Crude Oil	Light Crude	100	Extreme		C-151 and C-161	C-167
C-161	0.8737	Light Crude Oil	Light Crude	100	Extreme		C-154 and C-151	C-157
C-162	0.8833	Light Crude Oil	Light Crude	100	Extreme	Unique		
C-166	0.8486	Light Crude Oil	Light Crude	100	Severe		C-147 and C-148	C-152
C-167	0.8601	Light Crude Oil	Light Crude	100	Extreme			C-151, C-154, and C-161
C-168	0.8487	Very Light Crude Oil	Light Crude	100	High-Severe	Unique		

Heavier material could either be crude oil or residual oil
g/cc - Grams per cubic centimeter
TGI - Torkelson Geochemistry, Inc.
NA - Not Applicable
QNS - Not enough quantity of sample to perform density analysis
CCR - 2004 Sunoco Current Conditions Report
LNAPL - Light Non Aqueous Phase Liquid
All LNAPL results reported were analyzed by TGI
Product interpretations were provided by TGI

Torkelson Geochemistry, Inc.

2528 S. Columbia Place
Tulsa, OK 74114-3233
Phone: 918-749-8441 e-mail: BTorkelson@torkelsongeochemistry.com
Fax: 918-749-6005

CHAIN-OF-CUSTODY RECORD

Project: Sunoco, Inc. Philadelphia Refinery
Location: 3144 Passyunk Avenue, Philadlephia, PA 19145

Proj. No.: AOIs 2, 3, & 7 SCRs/RIRs
P.O.:
Sampled By: Tim Delk

Report/Bill To: Langan Engineering & Env'l Services
Address: P.O. Box 1569
Doylestown, PA 18901-0219

Phone: 215.491.6500
Fax: 215.491.6501
e-mail: dwebster@langan.com

Additional Instructions
Samples to be analyzed for Fingerprint (GC Characterization) and Density. Include a "Brief Description/Interpretation" of LNAPL, to be consistent with existing LNAPL types for Sunoco Philadelphia. Must have data results no later than July 30, 2010.

Requested Turn-Around Time: Data needed by July 30th

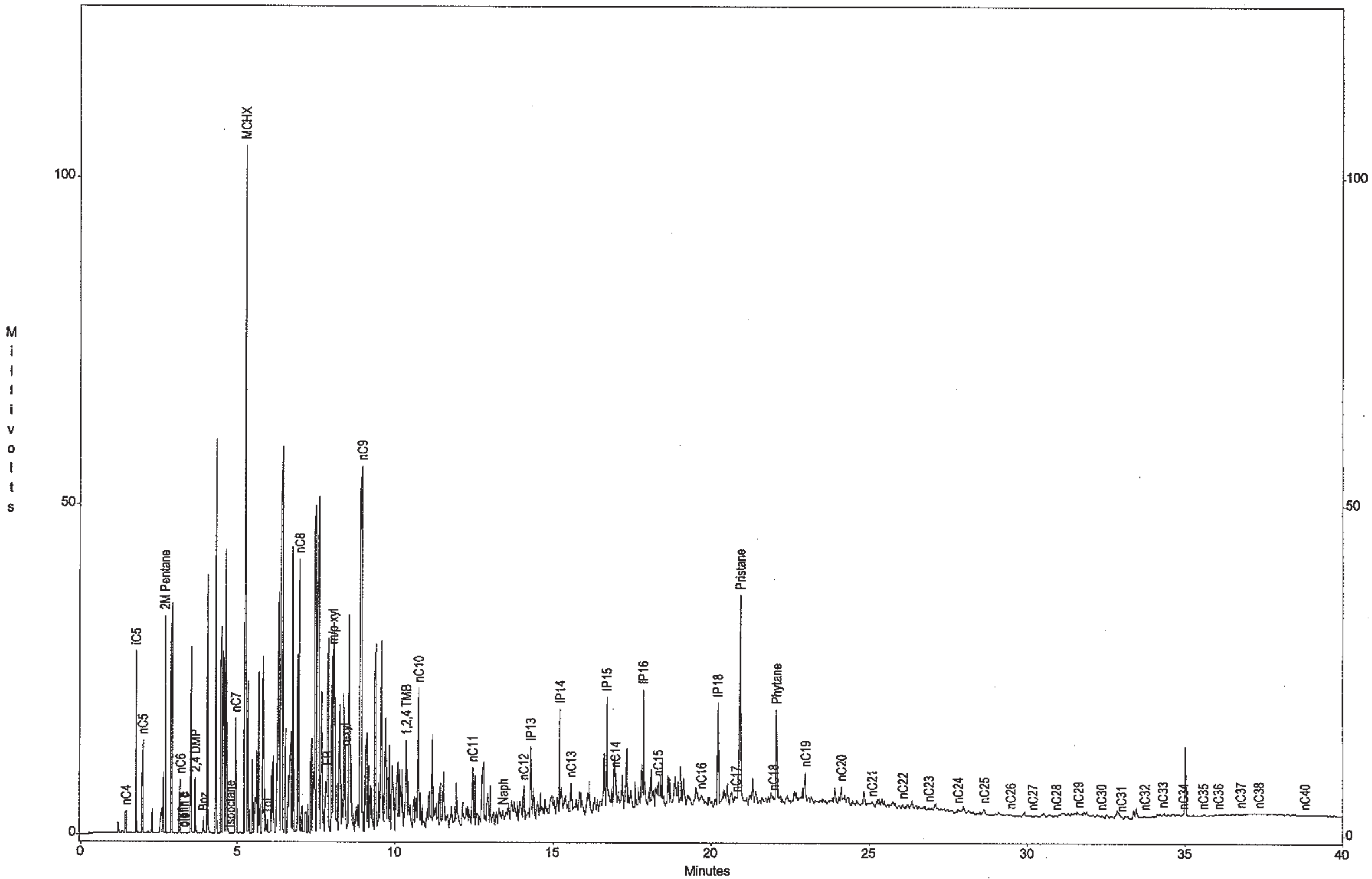
	ITEM NO.	SAMPLE DESCRIPTION	DATE	MATRIX	LAB NO.	Total # OF Vials	PRESERVATIVES: None	Fingerprint-GC Characterization	Density	Viscosity	Water Surface Tension	NAPL Surface Tension	NAPL/Water Interfac. Tens.	Lead	Sulfur	REMARKS
AOI-3	1	S-282	7/15/10	Prod		1	X	X	X							Include a "Brief Description/Interpretation" of LNAPL, to be
AOI-3	2	S-285				1										consistent with existing LNAPL types for Sunoco Philadelphia.
AOI 2	3	S-297				1										
AOI 2	4	S-313				1										Times S-282-0950
AOI 2	5	S-315				1										S-285-1115
AOI-7	6	C-143	7/15/10	Prod		1	X	X	X							S-297-1100
	7															S-313-1035
	8															S-315-1020
	9															C-143-1130
	10															

RELINQUISHED BY	ACCEPTED BY	DATE	TIME
[signature]	T S DRAKE WAREHOUSE	07-16	
RELEASED TO FED EX EXP.	SAME DATE		
	[signature]	7-19/10	0845

Torkelson Geochemistry, Inc.

Sunoco, Inc., Philadelphia Refinery
Sample ID : C-143
Acquired : Jul 20, 2010 11:28:51

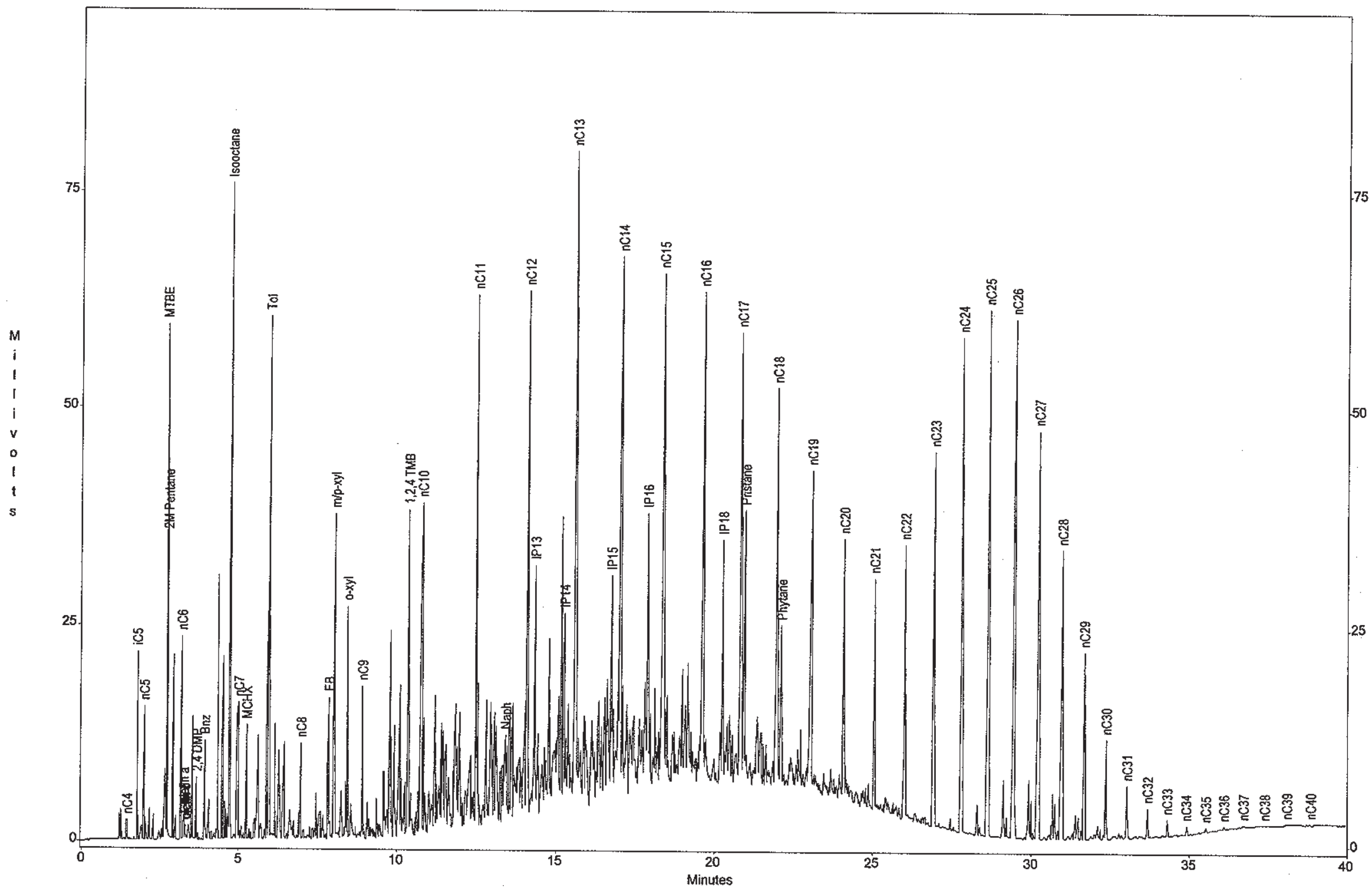
c:\ezchrom\chrom\10099\c-143 – Channel A



Torkelson Geochemistry, Inc.

Sunoco, Inc., Philadelphia Refinery
Sample ID : Gas/Dies/Wax std
Acquired : Jul 20, 2010 09:47:53

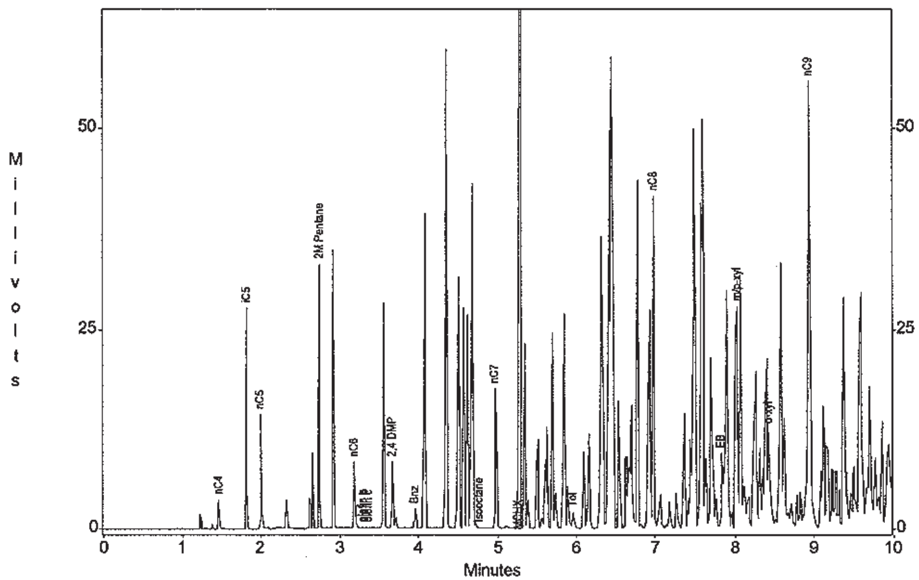
c:\ezchrom\chrom\10099\gadiwax2 -- Channel A



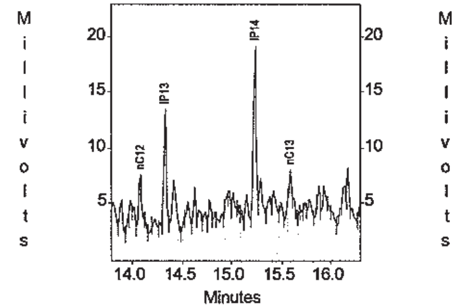
Torkelson Geochemistry, Inc.

Sunoco, Inc., Philadelphia Refinery
Sample ID : C-143
Acquired : Jul 20, 2010 11:28:51

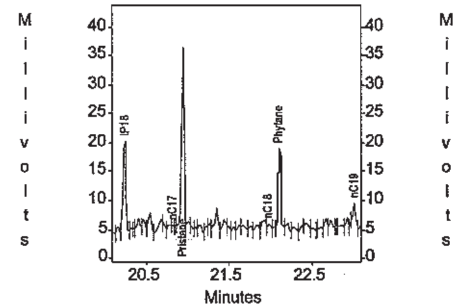
c:\ezchrom\chrom\10099\c-143 – Channel A



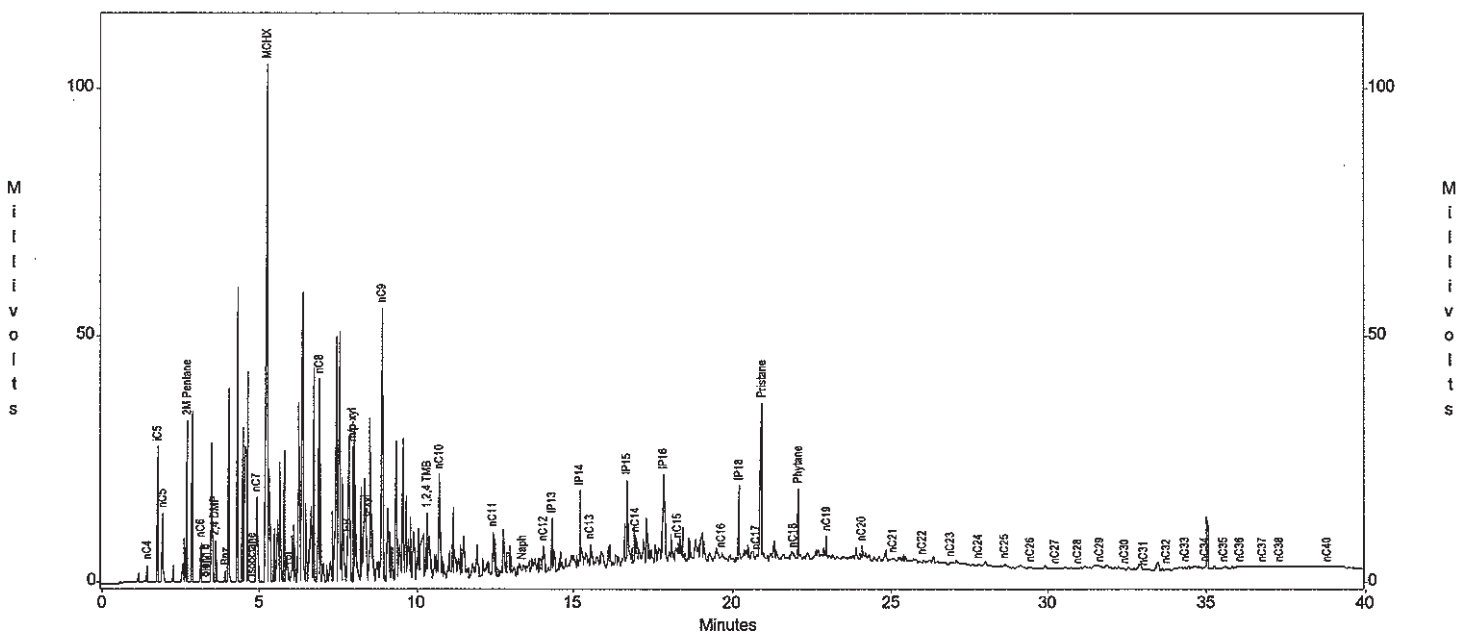
c:\ezchrom\chrom\10099\c-143 – Channel A



c:\ezchrom\chrom\10099\c-143 – Channel A



c:\ezchrom\chrom\10099\c-143 – Channel A



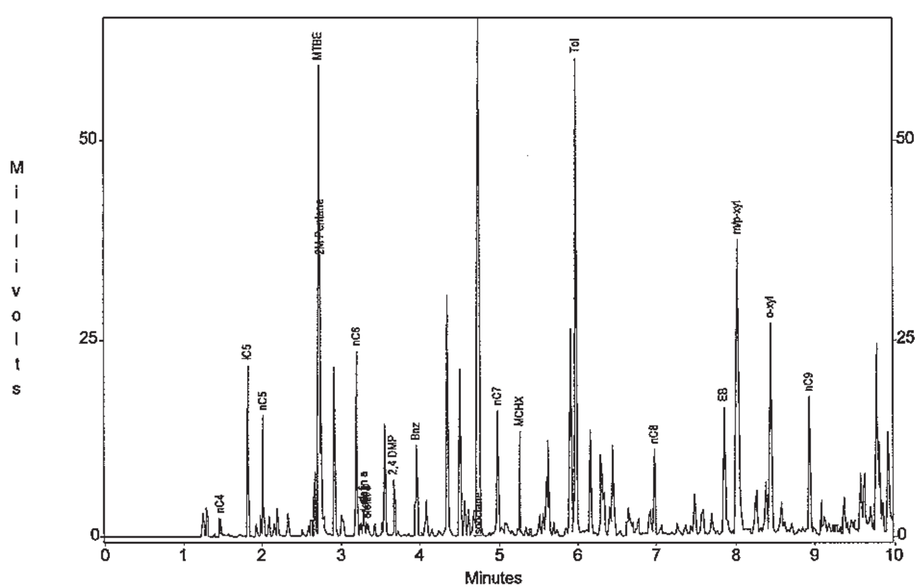
Channel A Results

Peak	Area	Height
nC4	2466	3538
iC5	20859	27746
nC5	11629	14336
MTBE	0	0
2M Pentane	30030	33150
nC6	8194	8347
olefin a	31	22
olefin b	87	79
olefin c	170	131
2.4 DMP	8824	8480
Bnz	3262	2470
Isooctane	66	28
nC7	20862	17512
MCHX	175772	104822
Tol	3534	2045
nC8	56205	41636
EB	13984	9360
m/p-xyl	48704	27779
o-xyl	27084	12423
nC9	103249	55760
1.2.4 TMB	21432	13604
nC10	35696	21414
nC11	18458	9121
Naph	5146	2309
nC12	13846	5931
IP13	23181	11735
IP14	30530	17192
nC13	12747	6018
IP15	37102	18746
nC14	22855	7069
IP16	37790	19641
nC15	19382	5566
nC16	7722	3124
IP18	42487	17021
nC17	5390	2594
Pristane	81585	33254
nC18	6651	2466
Phytane	41071	15565
nC19	18528	5838
nC20	8963	3423
nC21	2753	766
nC22	2350	782
nC23	1492	493
nC24	1618	483
nC25	2799	700
nC26	1023	328
nC27	200	104
nC28	304	155
nC29	741	432
nC30	386	214
nC31	93	36
nC32	333	172
nC33	1103	305
nC34	46	61
nC35	190	102
nC36	147	91
nC37	30	46
nC38	39	44
nC39	0	0
nC40	108	28

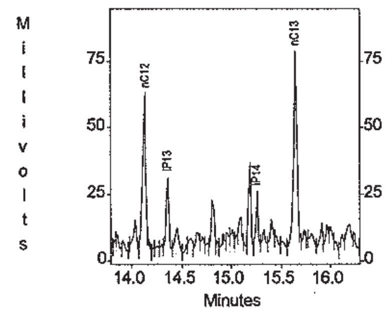
Torkelson Geochemistry, Inc.

Sunoco, Inc., Philadelphia Refinery
Sample ID : Gas/Dies/Wax std
Acquired : Jul 20, 2010 09:47:53

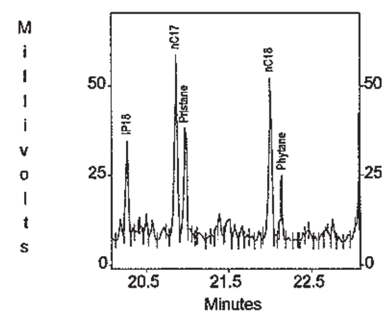
c:\ezchrom\chrom\10099\gadiwax2 -- Channel A



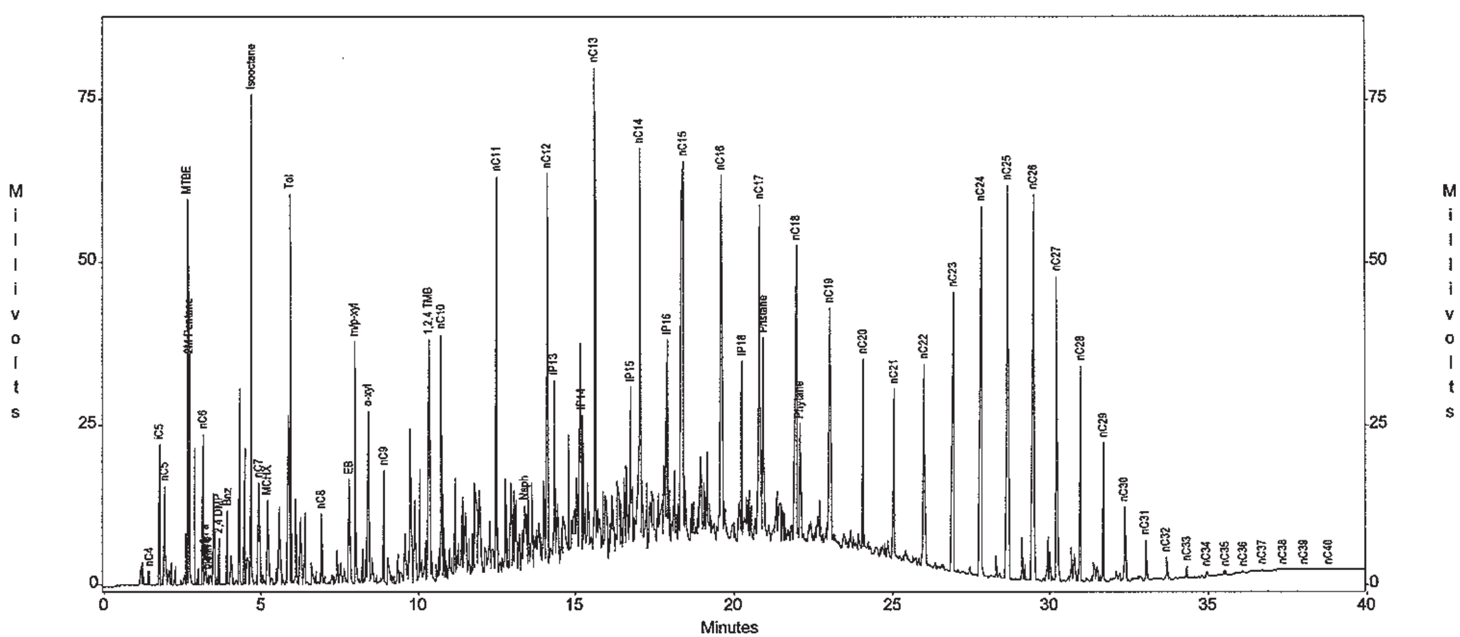
c:\ezchrom\chrom\10099\gadiwax2 -- Channel A



c:\ezchrom\chrom\10099\gadiwax2 -- Channel A



c:\ezchrom\chrom\10099\gadiwax2 -- Channel A



Channel A Results

Peak	Area	Height
nC4	1984	2368
iC5	15414	21815
nC5	11667	15453
MTBE	49307	59479
2M Pentane	33096	34918
nC6	22200	23338
olefin a	3612	3418
olefin b	1724	1722
olefin c	1971	1548
2.4 DMP	7274	7143
Bnz	14167	11489
Isooctane	105230	75635
nC7	19179	15820
MCHX	15682	13181
Tol	85518	60313
nC8	13430	11072
EB	23107	16349
m/p-xyl	81108	37519
o-xyl	39737	26870
nC9	24717	17590
1.2.4 TMB	68131	37505
nC10	61257	38172
nC11	124394	61224
Naph	19825	9956
nC12	128262	60646
IP13	52562	28790
IP14	40766	22703
nC13	176610	75744
IP15	39477	24563
nC14	151755	60419
IP16	75003	32151
nC15	156310	59696
nC16	142887	57295
IP18	65882	28620
nC17	129725	52397
Pristane	74492	31831
nC18	97720	45871
Phytane	40775	18464
nC19	83344	36711
nC20	61701	30048
nC21	54890	26638
nC22	68336	31525
nC23	106107	43174
nC24	160461	57025
nC25	186168	60645
nC26	183641	59685
nC27	134561	46943
nC28	82385	33357
nC29	45276	21535
nC30	21360	11336
nC31	11214	6091
nC32	6031	3388
nC33	3267	1886
nC34	1852	992
nC35	1084	567
nC36	546	285
nC37	326	167
nC38	241	92
nC39	236	68
nC40	153	45

Torkelson Geochemistry, Inc.				
Density Measurements				
Paar DMA 512 / DMA 60		ASTM Method 4052		
Sample	Density gm/ml	Temp. of Measurement	Job Number	Date
C-143	0.8676	60F	10099	7/20/10
S-282	0.8104	60F	10099	7/20/10
S-285	0.8921	60F	10099	7/20/10
S-297	0.8229	60F	10099	7/20/10
S-313	0.8694	60F	10099	7/20/10
S-315	0.8552	60F	10099	7/20/10

Torkelson Geochemistry, Inc.

2528 S. Columbia Place
Tulsa, OK 74114-3233
Phone: 918-749-8441
Fax: 918-749-6005
e-mail: BTorkelson@aol.com

CHAIN-OF-CUSTODY RECORD

Project: Sun- Philadelphia Refinery COA
Location: Philadelphia, PA

Proj. No.:
P.O.:
Sampled By: M. Brad Spancake & Tim Delk

Report/Bill To: Colleen Costell0
Address: 30 South 17th St, Suite 1500
Philadelphia, PA 19103

Phone: 215.864.0640
Fax: 215.864.0671
e-mail:

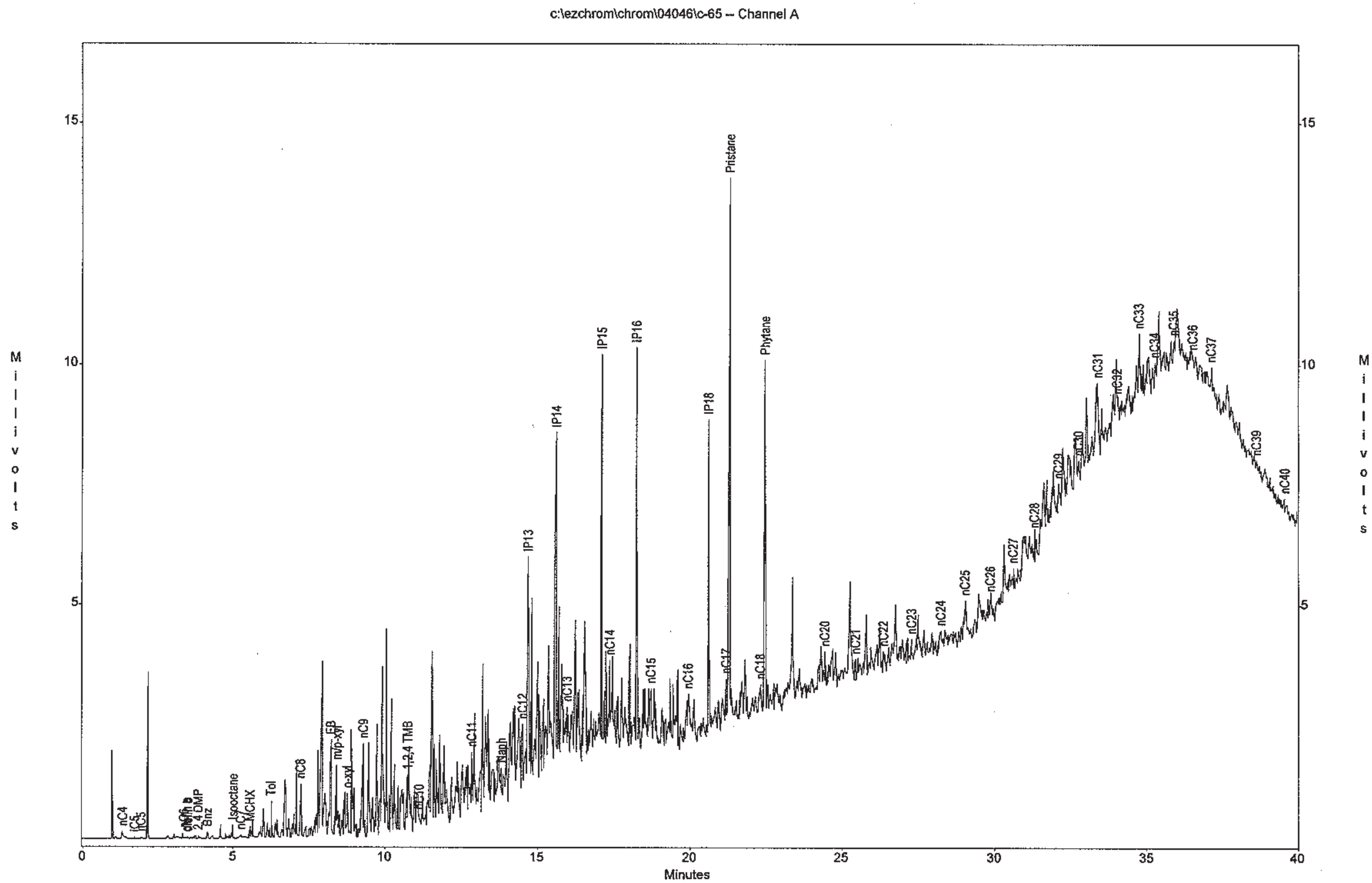
Additional Instructions

Requested Turn-Around Time:

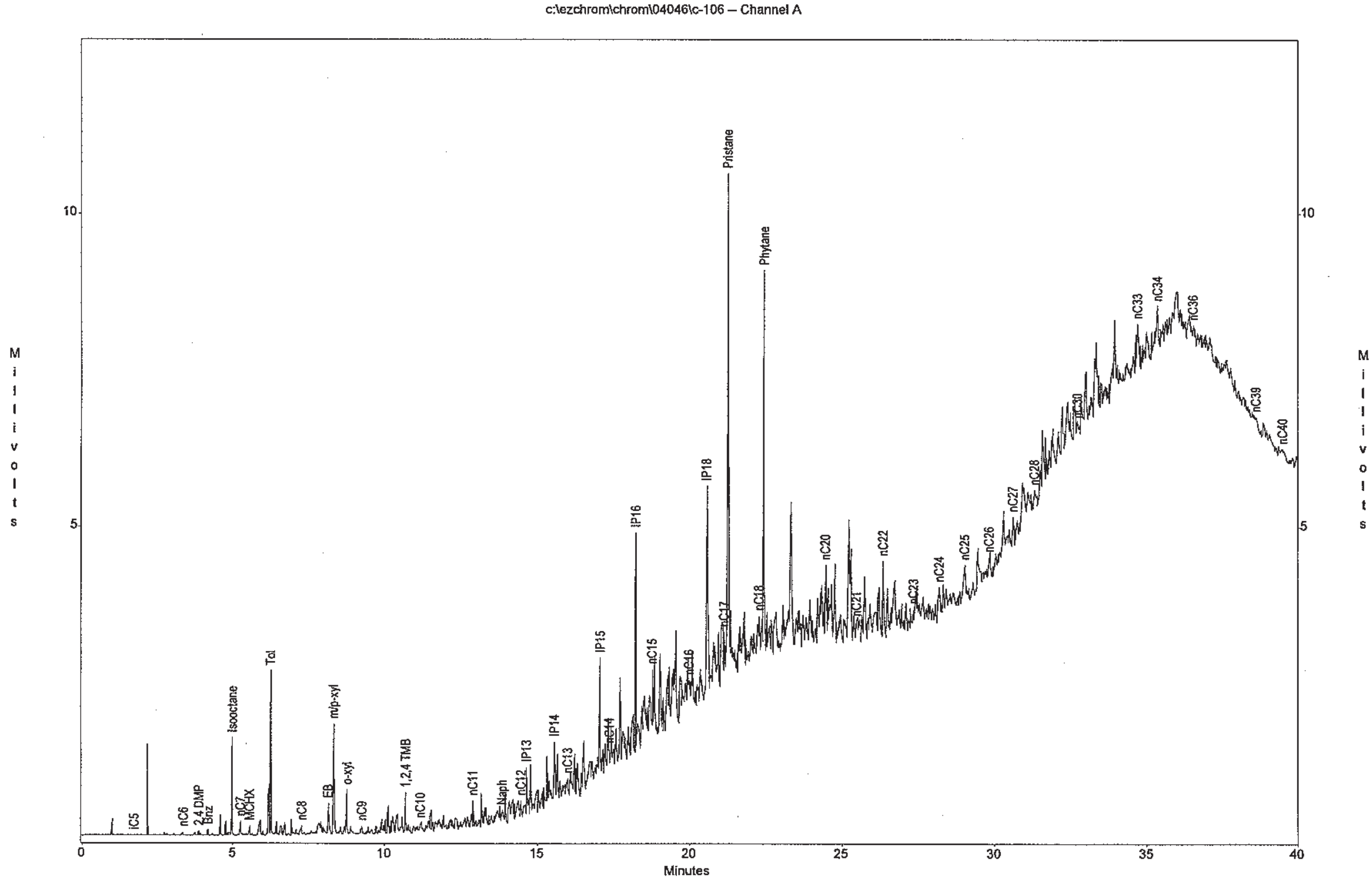
ITEM NO.	SAMPLE DESCRIPTION	DATE	MATRIX	LAB NO.	Total # OF Vials	PRESERVATIVES: None				ANALYSES REQUESTED: GC Characterization	Specific Gravity											REMARKS
1	West Yard W8	2/27/04	Product		1	X				X	X											
2	A-13				1	X				X	X											
3	B-144				1	X				X	X											
4	C-106				1	X				X	X											
5	A-133				1	X				X	X											
6	C-65				1	X				X	X											
7	B-43				1	X				X	X											
8	B-39				1	X				X	X											
9	A-136				1	X				X	X											Sorbent Pad Sample
10	C-107				1	X				X	X											

RELINQUISHED BY	ACCEPTED BY	DATE	TIME
M. Brad [signature]	FED EX	3/1/04	
	[signature]	3-2-04	1705

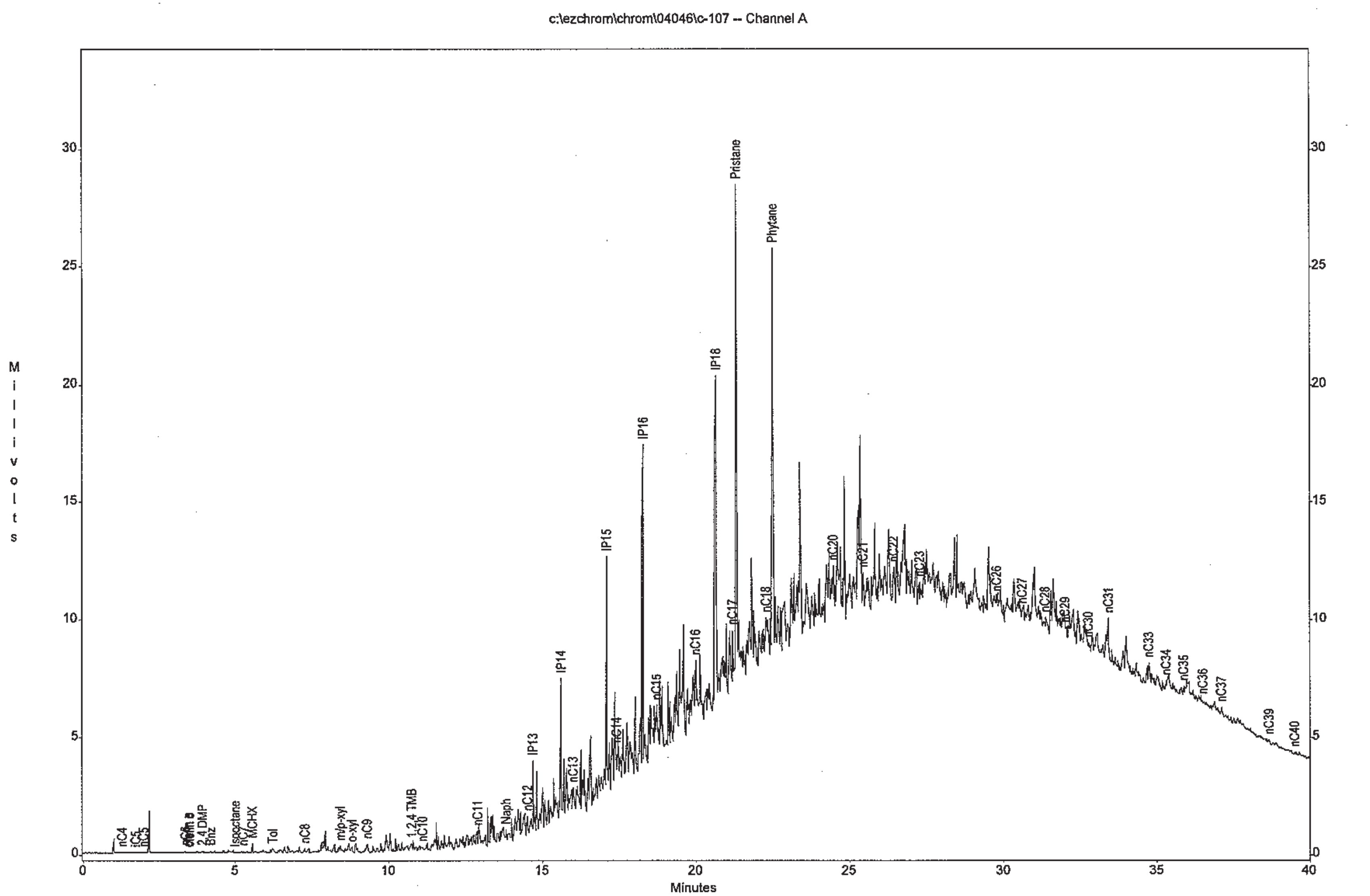
Sun - Philadelphia Refinery COA
Sample ID : C-65
Acquired : Mar 07, 2004 17:16:51



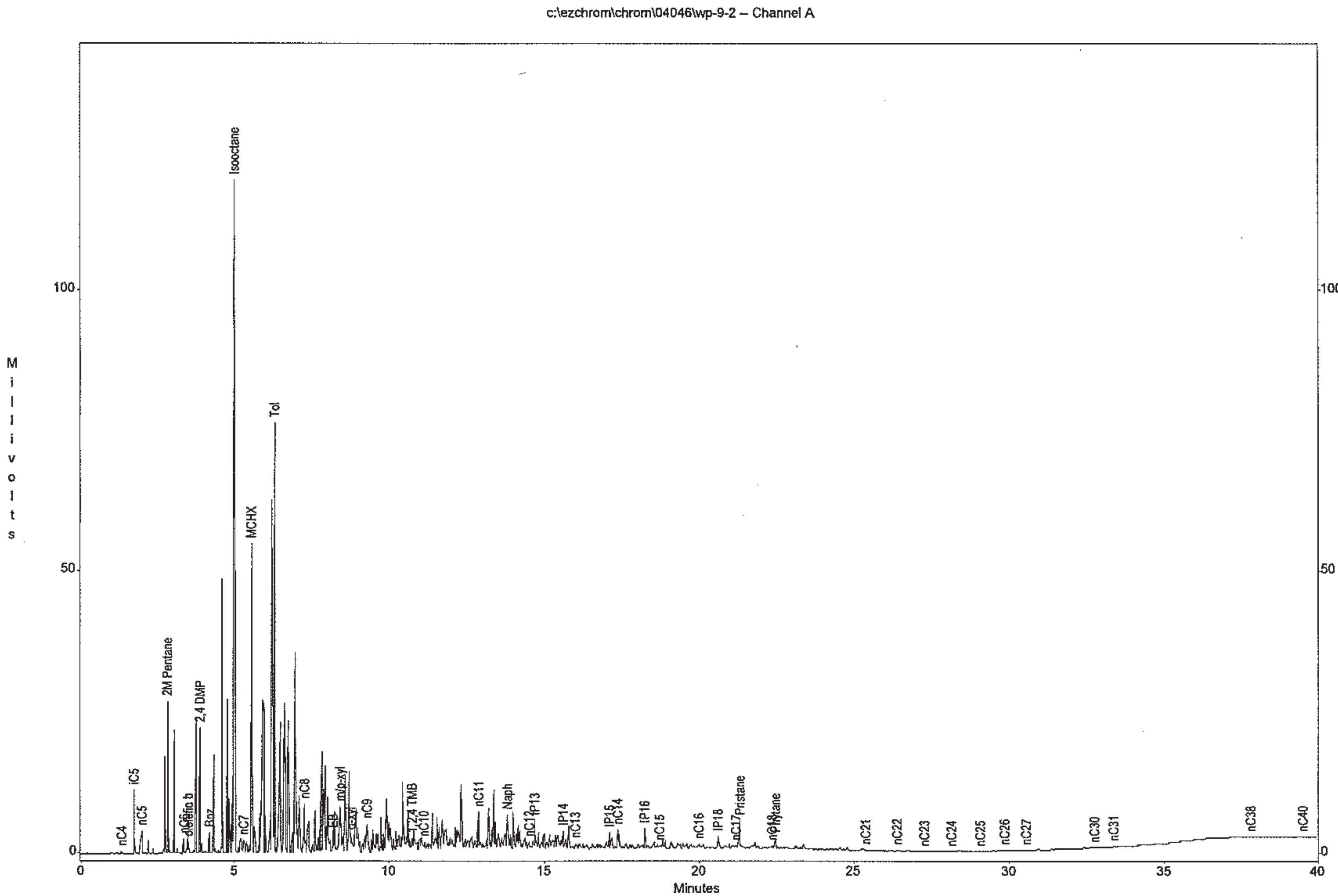
Sun - Philadelphia Refinery COA
Sample ID : C-106
Acquired : Mar 08, 2004 17:35:42



Sun - Philadelphia Refinery COA
Sample ID : C-107
Acquired : Mar 06, 2004 18:02:57



Sun - Philadelphia Refinery COA
Sample ID : WP 9-2
Acquired : Mar 08, 2004 07:50:05



Torkelson Geochemistry, Inc.
2528 S. Columbia Place
Tulsa, OK 74114-3233
Phone: 918-749-8441
Fax: 918-749-6005
e-mail: BTorkelson@torkelsongeochemistry.com

CHAIN-OF-CUSTODY RECORD

Project: SUNOCO PHILA REFINERY AOI-7
Location:
Proj. No.:
P.O.:
Sampled By: Shawn Sykes

Report/Bill To: Bill to td@aquaterra-tech.com
Address:
Report to:
Phone:
Fax: td@aquaterra-tech.com &
e-mail: Dwebster@langan.com

Additional Instructions: Please include a brief interpretation of product type consistent with other samples from the Philly refinery
Requested Turn-Around Time:

ITEM NO.	SAMPLE DESCRIPTION	DATE	MATRIX	LAB NO.	Total # OF Vials	PRESERVATIVES: None					ANALYSES REQUESTED: GC Characterization	Density	Viscosity	Water Surface Tension	NAPL Surface Tension	NAPL/Water Interfac. Tens.	Lead	Sulfur						REMARKS
1	C-147	1/13/12			1						X	X												
2	C-148	1/13/12			1						X	X												(2) Boxes / Cans
3	C-150	1/13/12			1						X	X												
4	C-151	1/13/12			1						X	X												
5	C-152	1/13/12			1						X	X												
6	C-153	1/13/12			1						X	X												
7	C-154	1/13/12			1						X	X												
8	C-161	1/13/12			1						X	X												
9	C-162	1/13/12			1						X	X												
10	C-166	1/13/12			1						X	X												

RELINQUISHED BY	DATE	TIME	ACCEPTED BY	DATE	TIME
[signature] / Aquaterra	1/13/12	1400	AQUATERRA SAMPLE REFRIGERATOR	1/13/12	1400
[signature] / AQUATERRA	1/16/12	1450	FED EX	1/16/12	1450
			[signature]	1-19-12	1420

Torkelson Geochemistry, Inc.

2528 S. Columbia Place
Tulsa, OK 74114-3233
Phone: 918-749-8441
Fax: 918-749-6005
e-mail: BTorkelson@torkelsongeochemistry.com

CHAIN-OF-CUSTODY RECORD

Project: SUNOCO PHILA REFINERY AOI-7
Location:

Proj. No.:
P.O.:
Sampled By: Shawn Sykes

Report/Bill To:
Address:

Phone:
Fax: tde@aquaterra-tech.com
e-mail: Dwebster@langan.com

Additional Instructions

Requested Turn-Around Time:

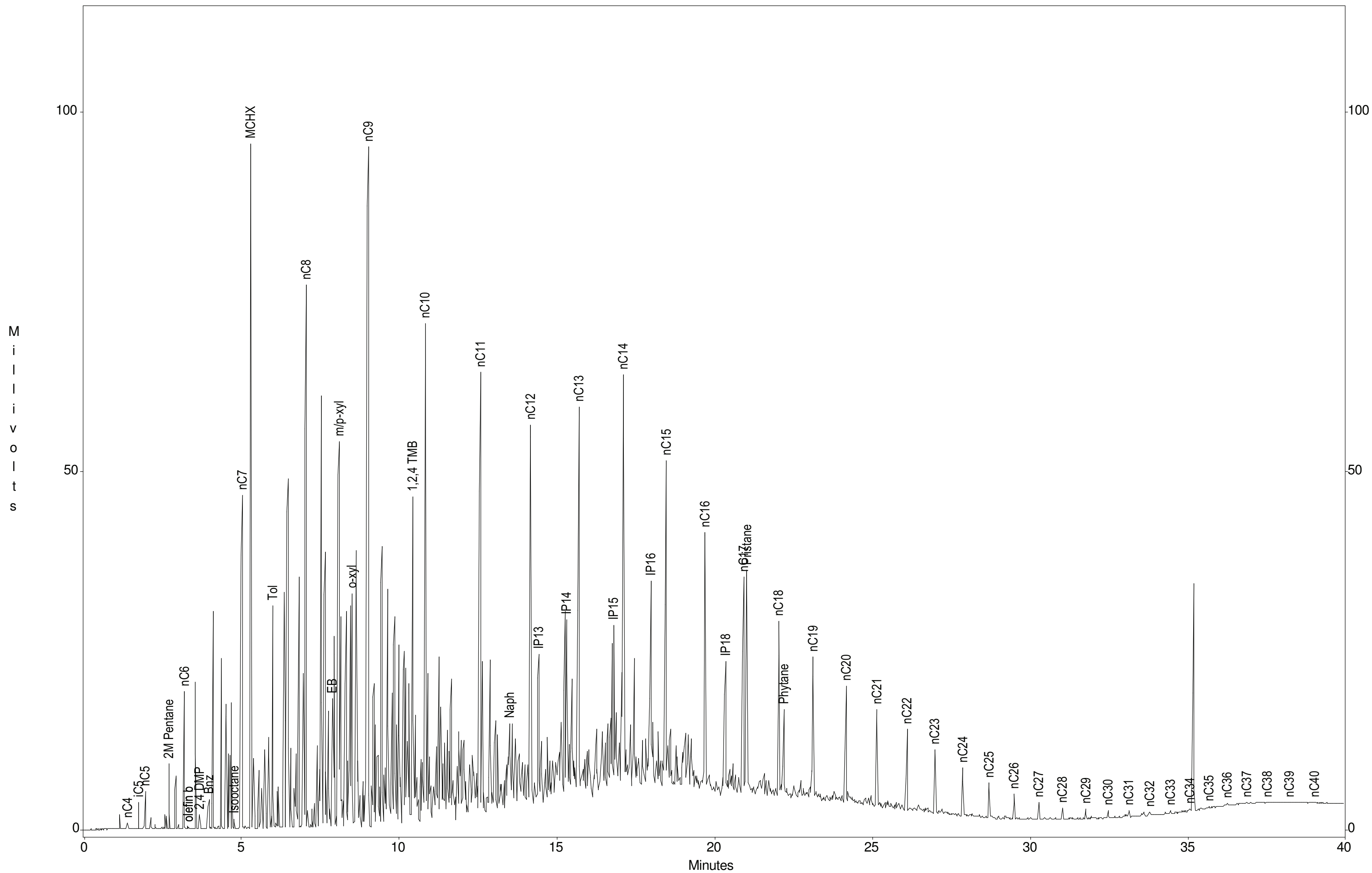
ITEM NO.	SAMPLE DESCRIPTION	DATE	MATRIX	LAB NO.	Total # OF Vials	PRESERVATIVES: None					ANALYSES REQUESTED: GC Characterization	Density	Viscosity	Water Surface Tension	NAPL Surface Tension	NAPL/Water Interfac. Tens	Lead	Sulfur						REMARKS
1	C-167	1/13/12			1						X	X												
2	C-168	1/13/12			1						X	X												
3																								
4																								
5																								
6																								
7																								
8																								
9																								
10																								

RELINQUISHED BY	DATE	TIME	ACCEPTED BY	DATE	TIME
[signature] / AQUATERRA	1/13/12	1400	AQUATERRA SAMPLE REFRIGERATOR	1/13/12	1400
[signature] / AQUATERRA	1/16/12	1450	FED EX	1/16/12	1450

Torkelson Geochemistry, Inc.

Sunoco Philadelphia Refinery, AOI-7
Sample ID : C-147
Acquired : Jan 24, 2012 18:07:21

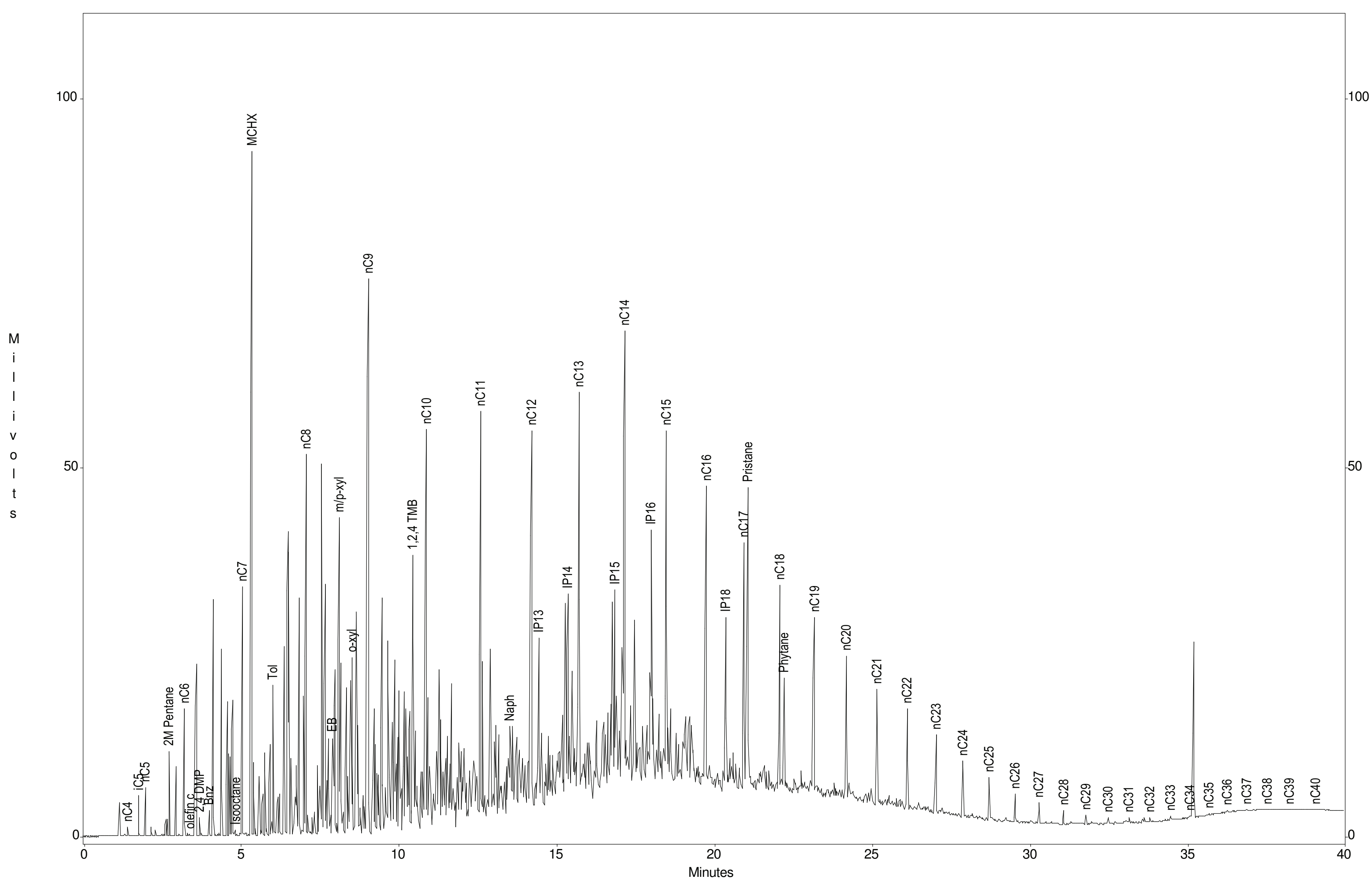
c:\ezchrom\chrom\12005\c-147 -- Channel A



Torkelson Geochemistry, Inc.

Sunoco Philadelphia Refinery, AOI-7
Sample ID : C-148
Acquired : Jan 24, 2012 10:59:28

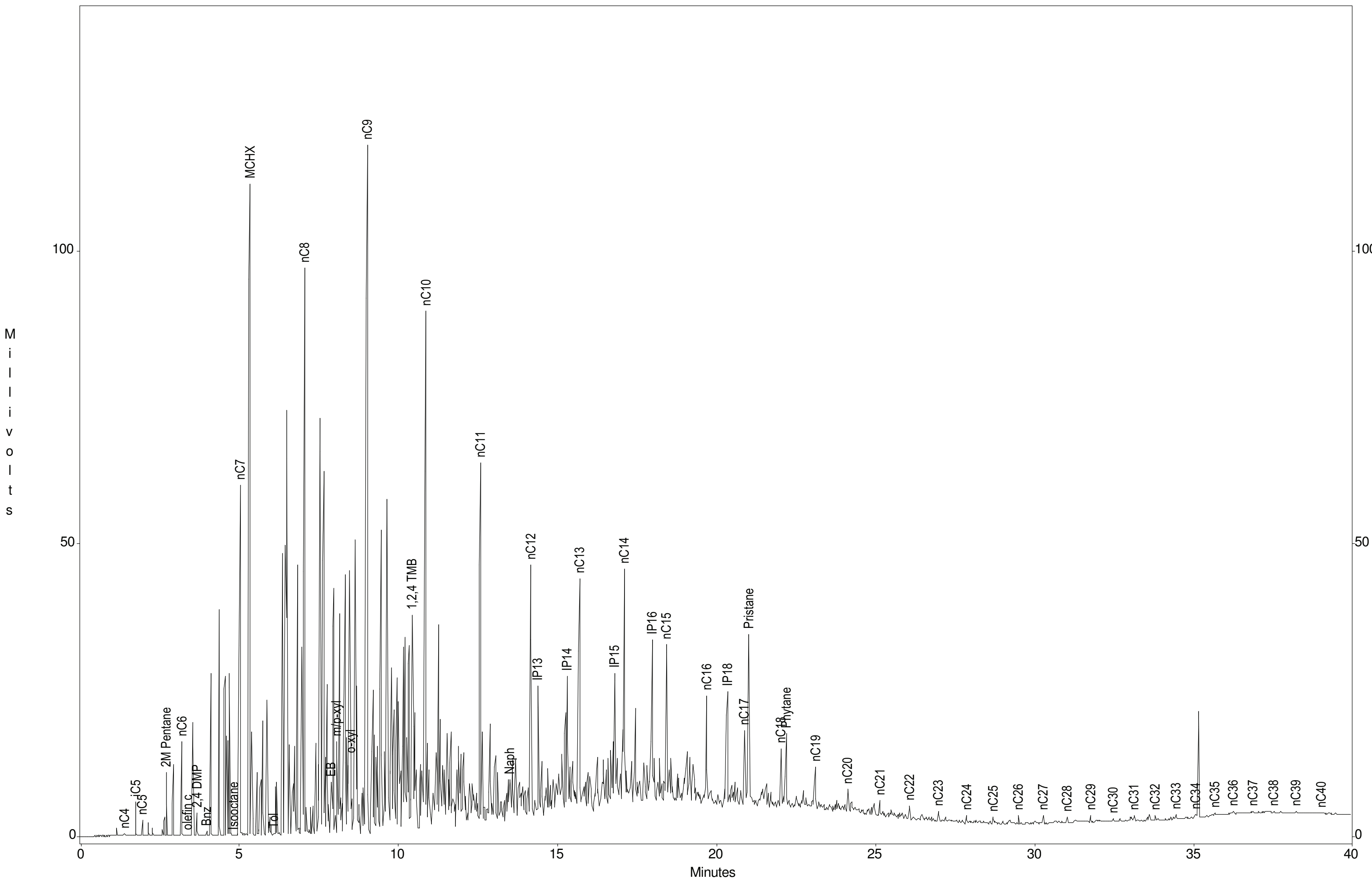
c:\ezchrom\chrom\12005\c-148 -- Channel A



Torkelson Geochemistry, Inc.

Sunoco Philadelphia Refinery, AOI-7
Sample ID : C-150
Acquired : Jan 24, 2012 19:46:11

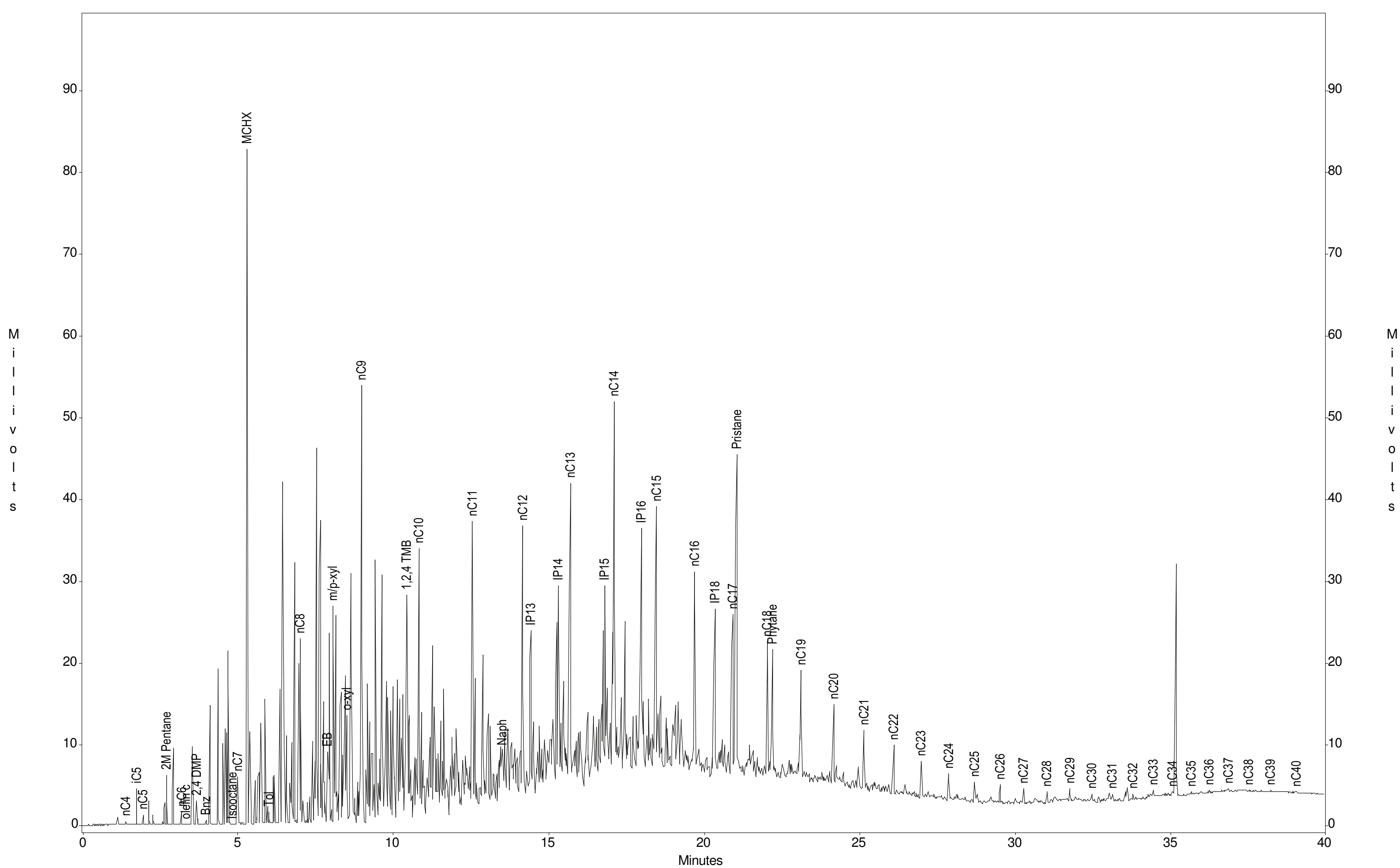
c:\ezchrom\chrom\12005\c-150 -- Channel A



Torkelson Geochemistry, Inc.

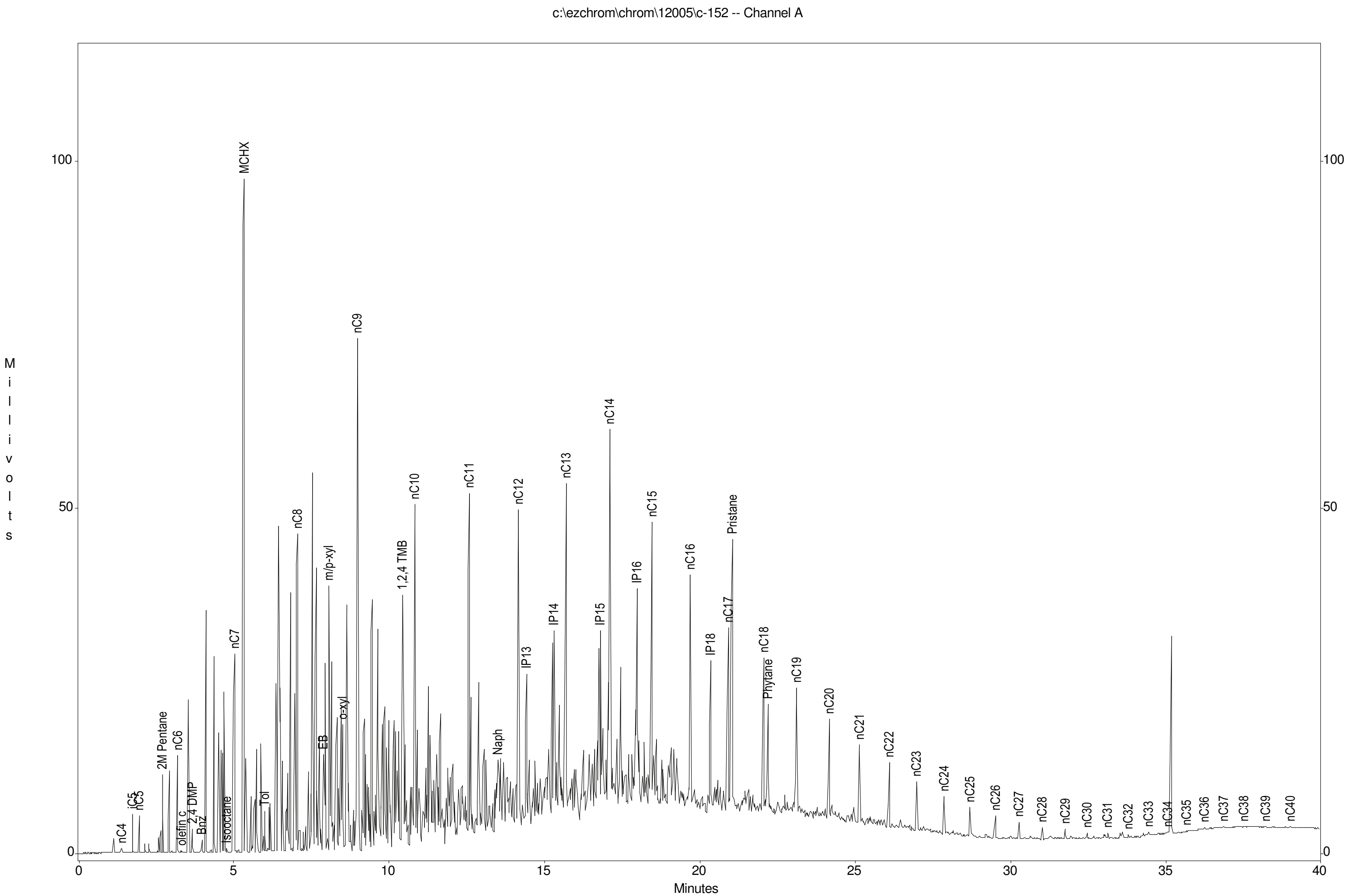
Sunoco Philadelphia Refinery, AOI-7
Sample ID : C-151
Acquired : Jan 24, 2012 15:57:06

c:\ezchrom\chrom\12005\c-151 -- Channel A



Torkelson Geochemistry, Inc.

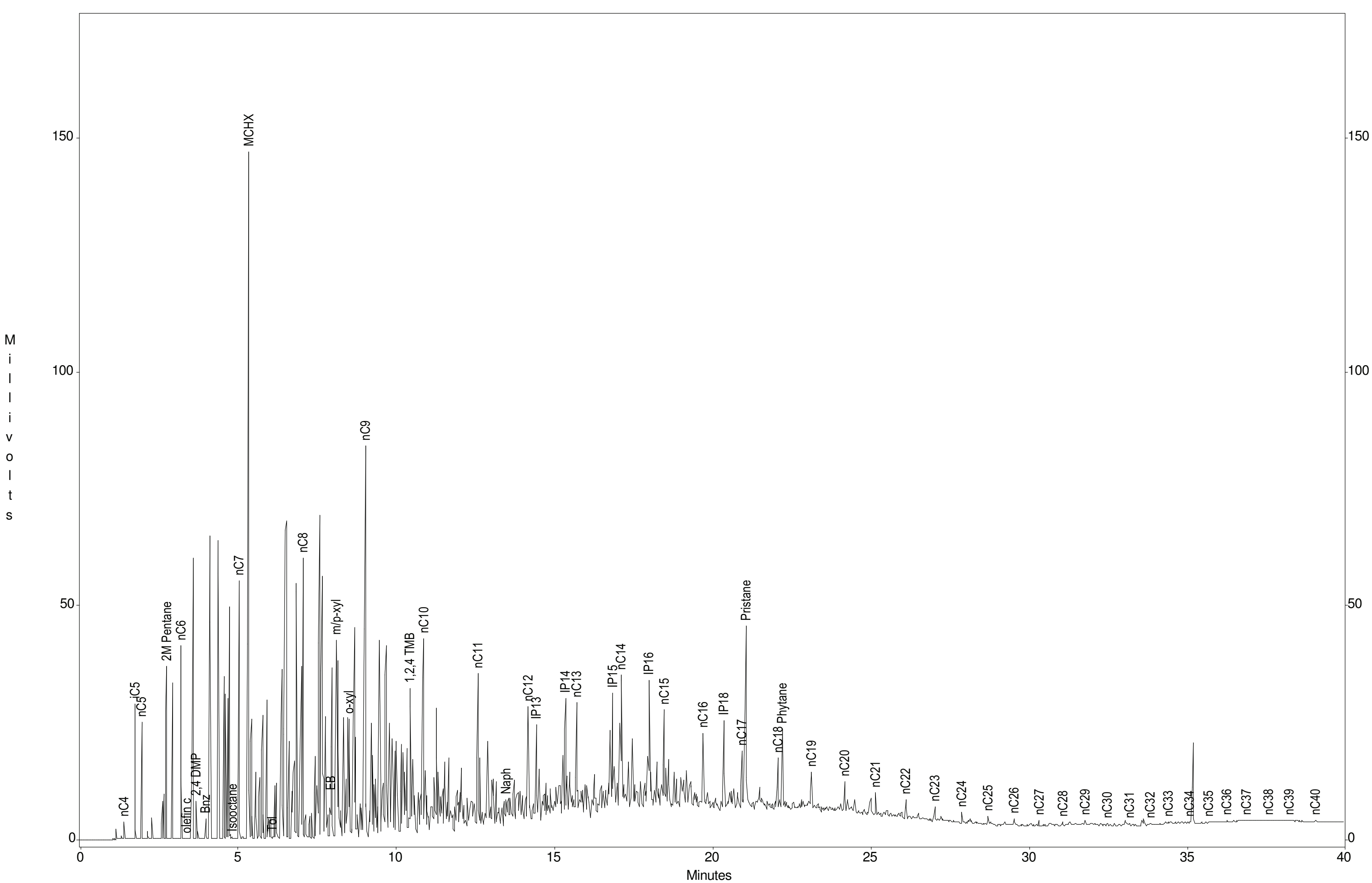
Sunoco Philadelphia Refinery, AOI-7
Sample ID : C-152
Acquired : Jan 24, 2012 14:19:23



Torkelson Geochemistry, Inc.

Sunoco Philadelphia Refinery, AOI-7
Sample ID : C-153
Acquired : Jan 24, 2012 10:10:30

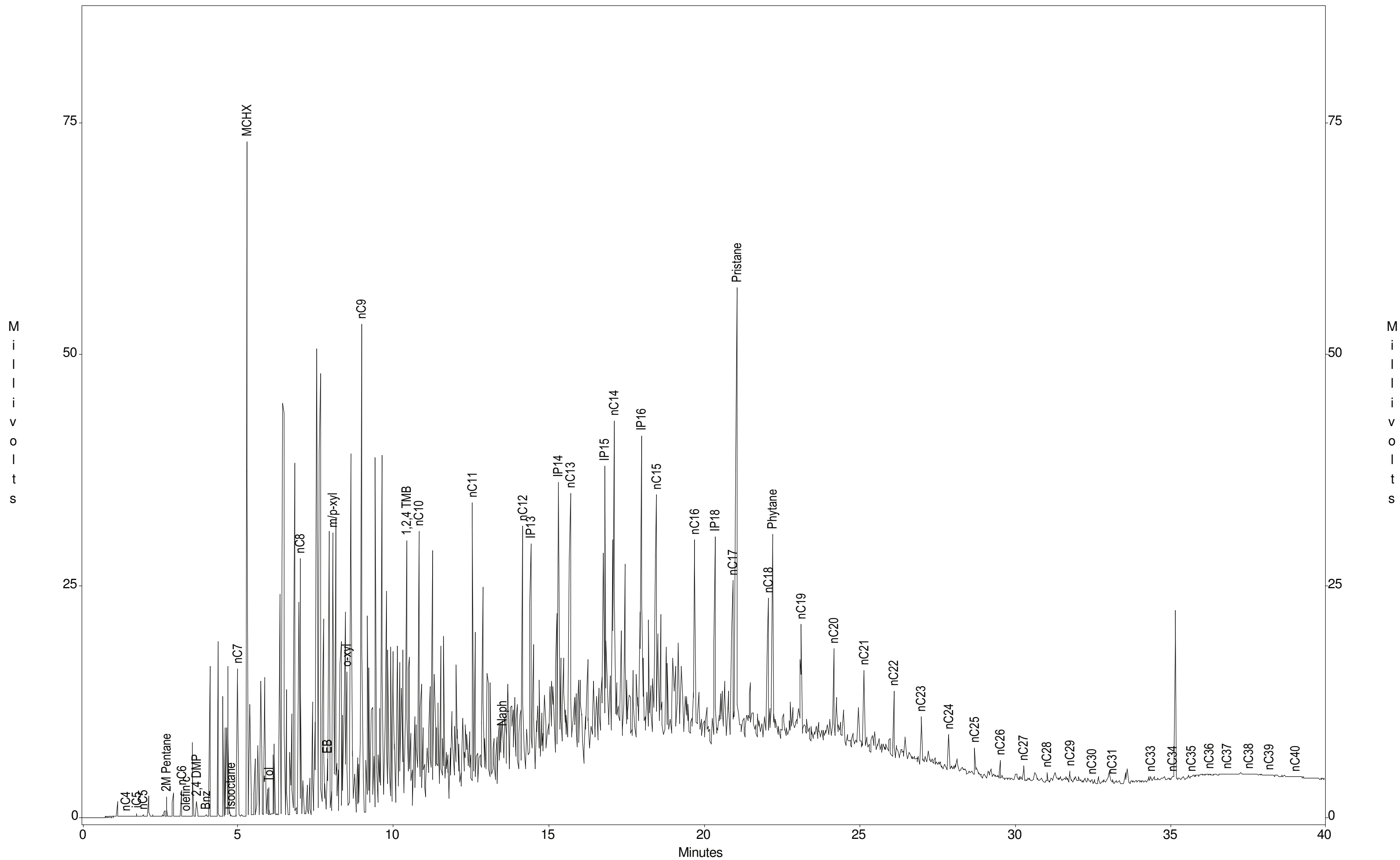
c:\ezchrom\chrom\12005\c-153 -- Channel A



Torkelson Geochemistry, Inc.

Sunoco Philadelphia Refinery, AOI-7
Sample ID : C-154
Acquired : Jan 24, 2012 21:25:45

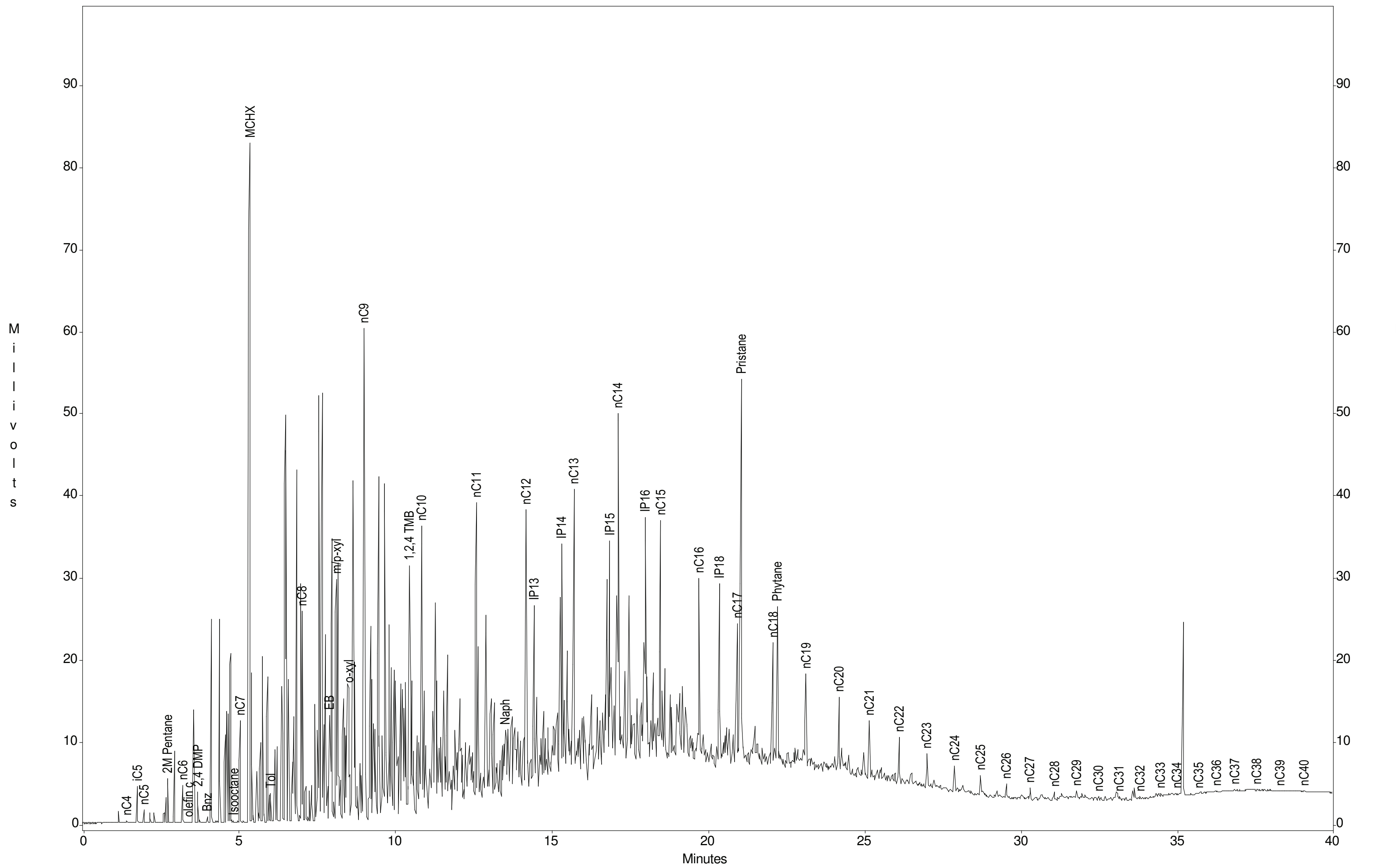
c:\ezchrom\chrom\12005\c-154 -- Channel A



Torkelson Geochemistry, Inc.

Sunoco Philadelphia Refinery, AOI-7
Sample ID : C-161
Acquired : Jan 24, 2012 11:49:58

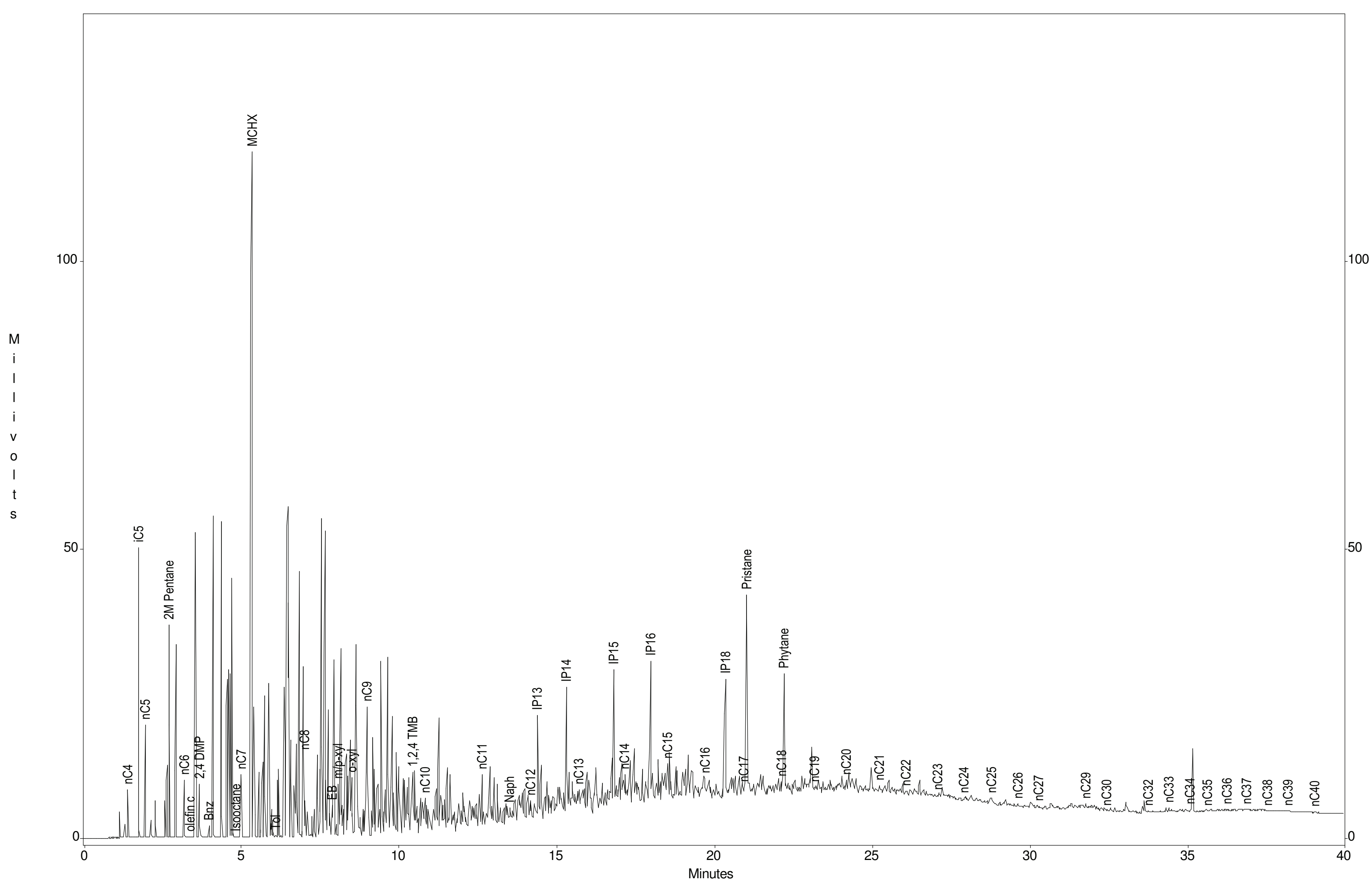
c:\ezchrom\chrom\12005\c-161 -- Channel A



Torkelson Geochemistry, Inc.

Sunoco Philadelphia Refinery, AOI-7
Sample ID : C-162
Acquired : Jan 24, 2012 18:57:14

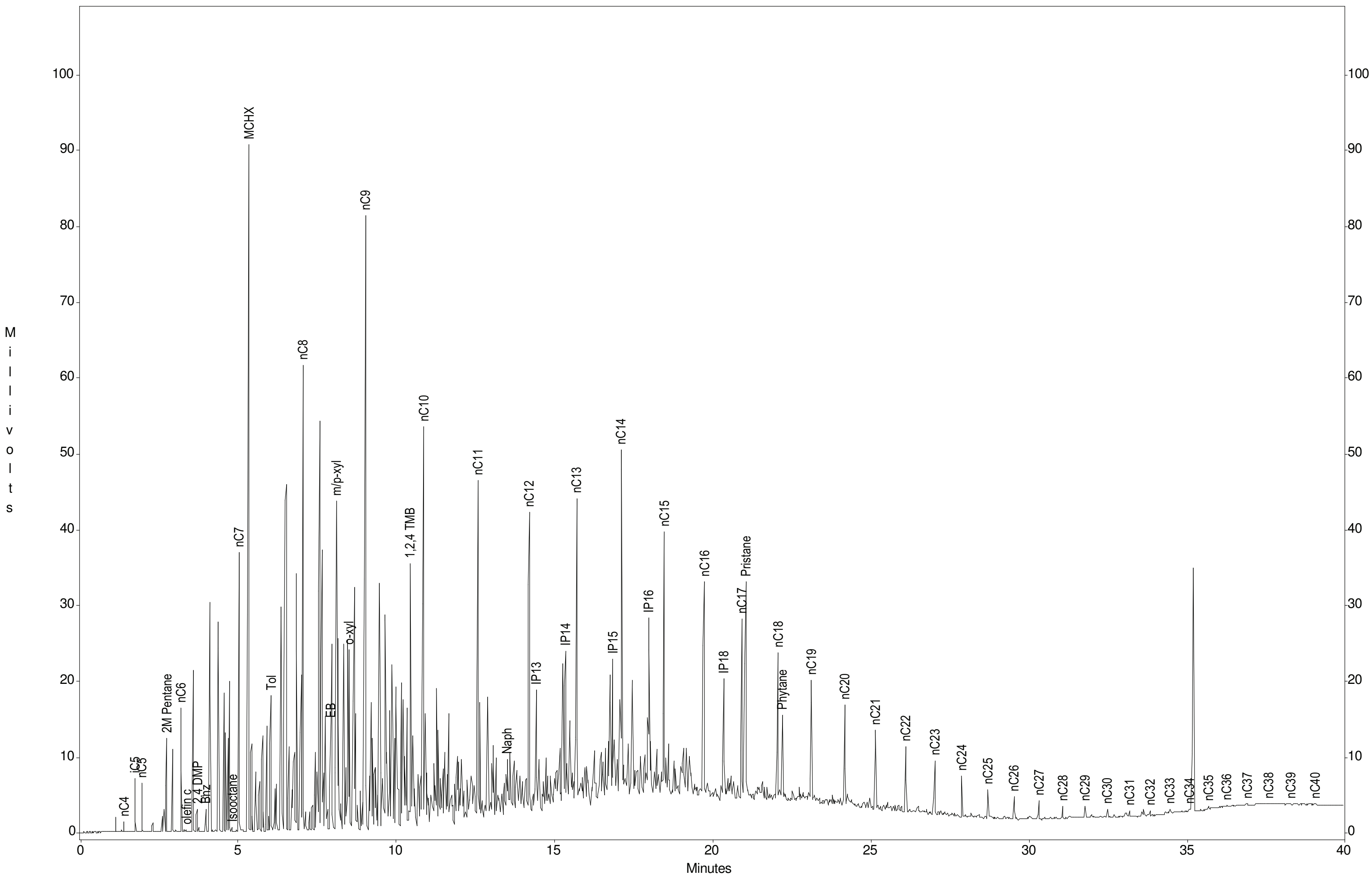
c:\ezchrom\chrom\12005\c-162 -- Channel A



Torkelson Geochemistry, Inc.

Sunoco Philadelphia Refinery, AOI-7
Sample ID : C-166
Acquired : Jan 24, 2012 09:20:57

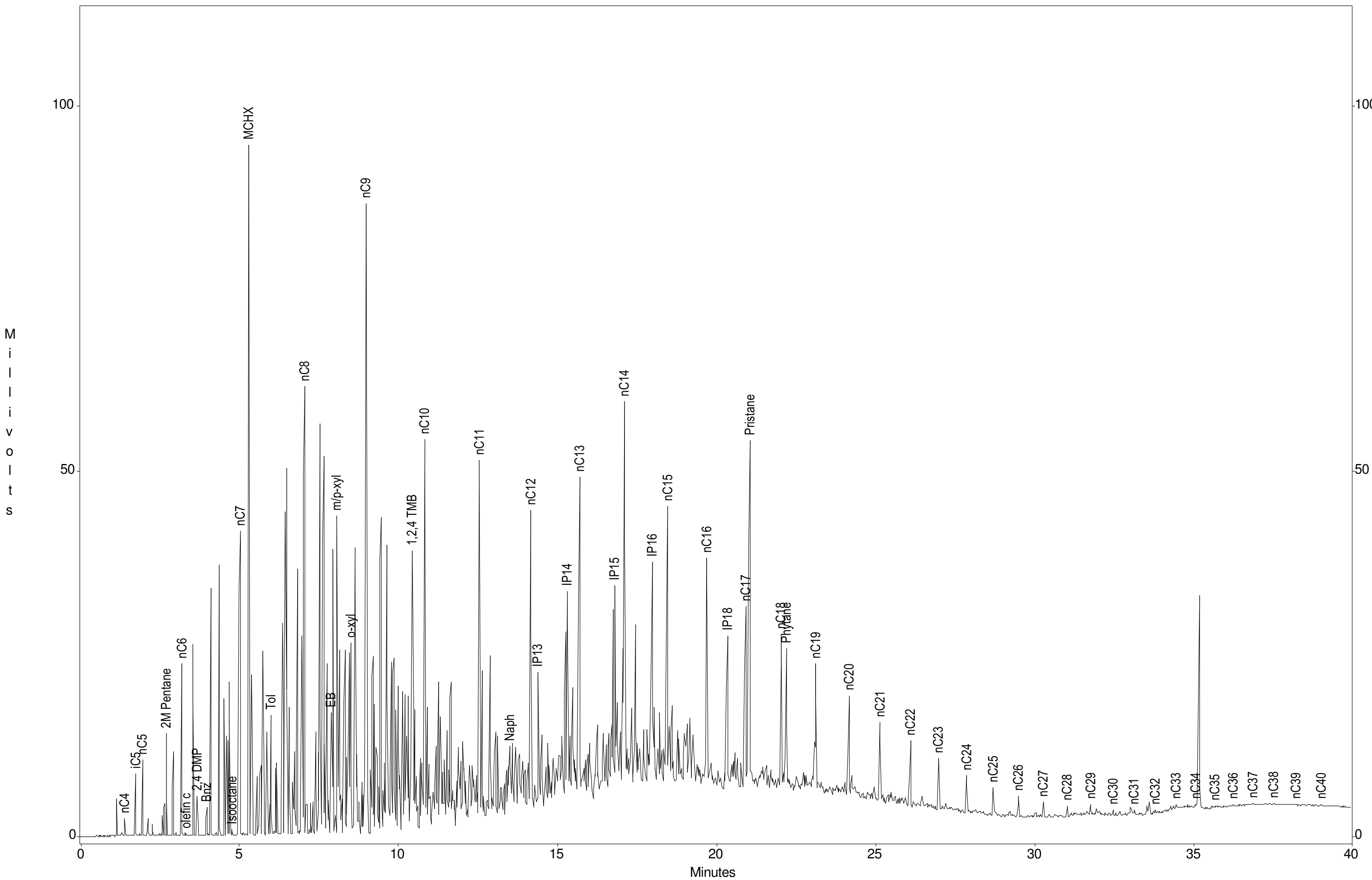
c:\ezchrom\chrom\12005\c-166 -- Channel A



Torkelson Geochemistry, Inc.

Sunoco Philadelphia Refinery, AOI-7
Sample ID : C-167
Acquired : Jan 24, 2012 20:35:48

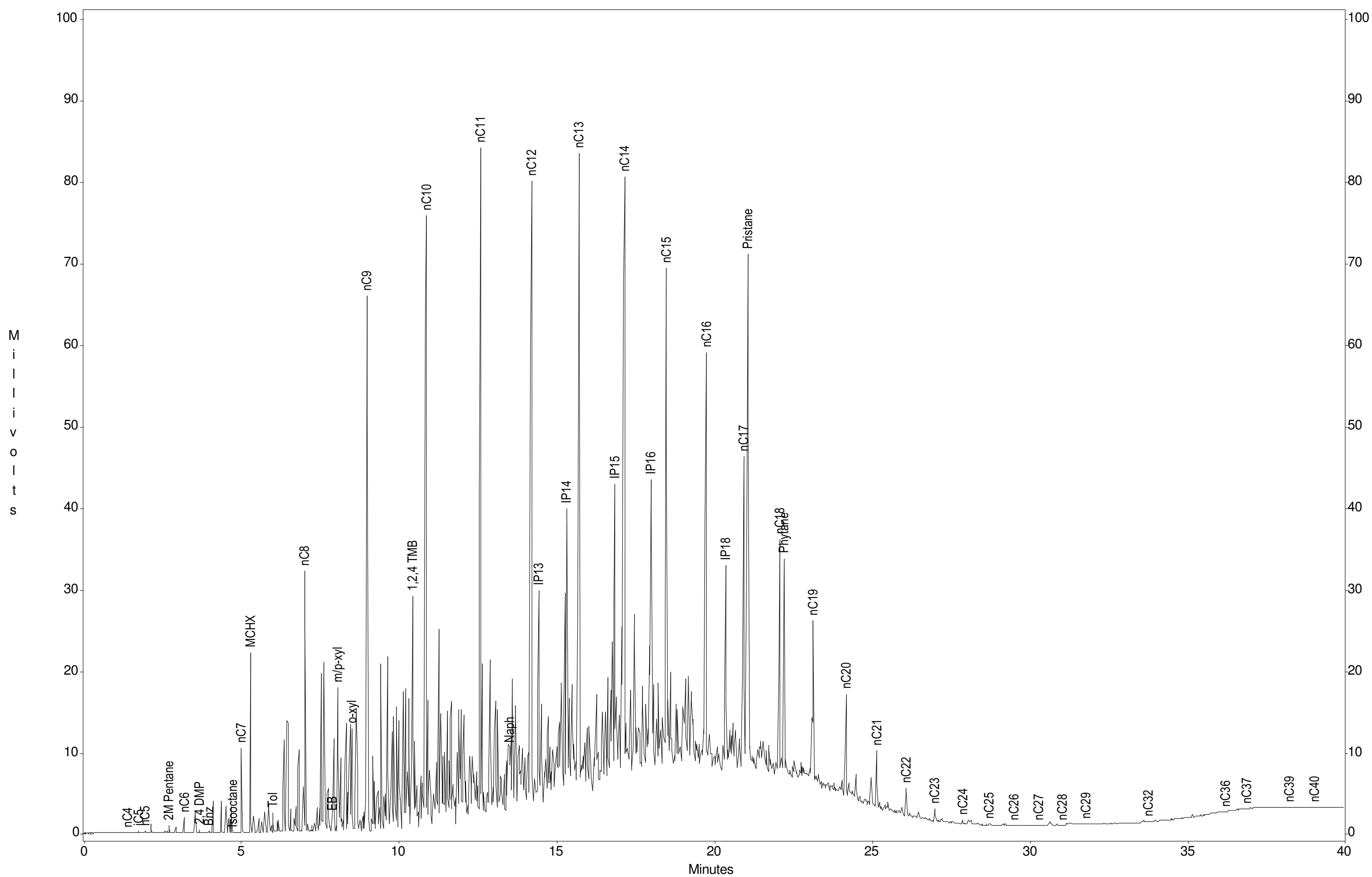
c:\ezchrom\chrom\12005\c-167 -- Channel A



Torkelson Geochemistry, Inc.

Sunoco Philadelphia Refinery, AOI-7
Sample ID : C-168
Acquired : Jan 24, 2012 15:09:04

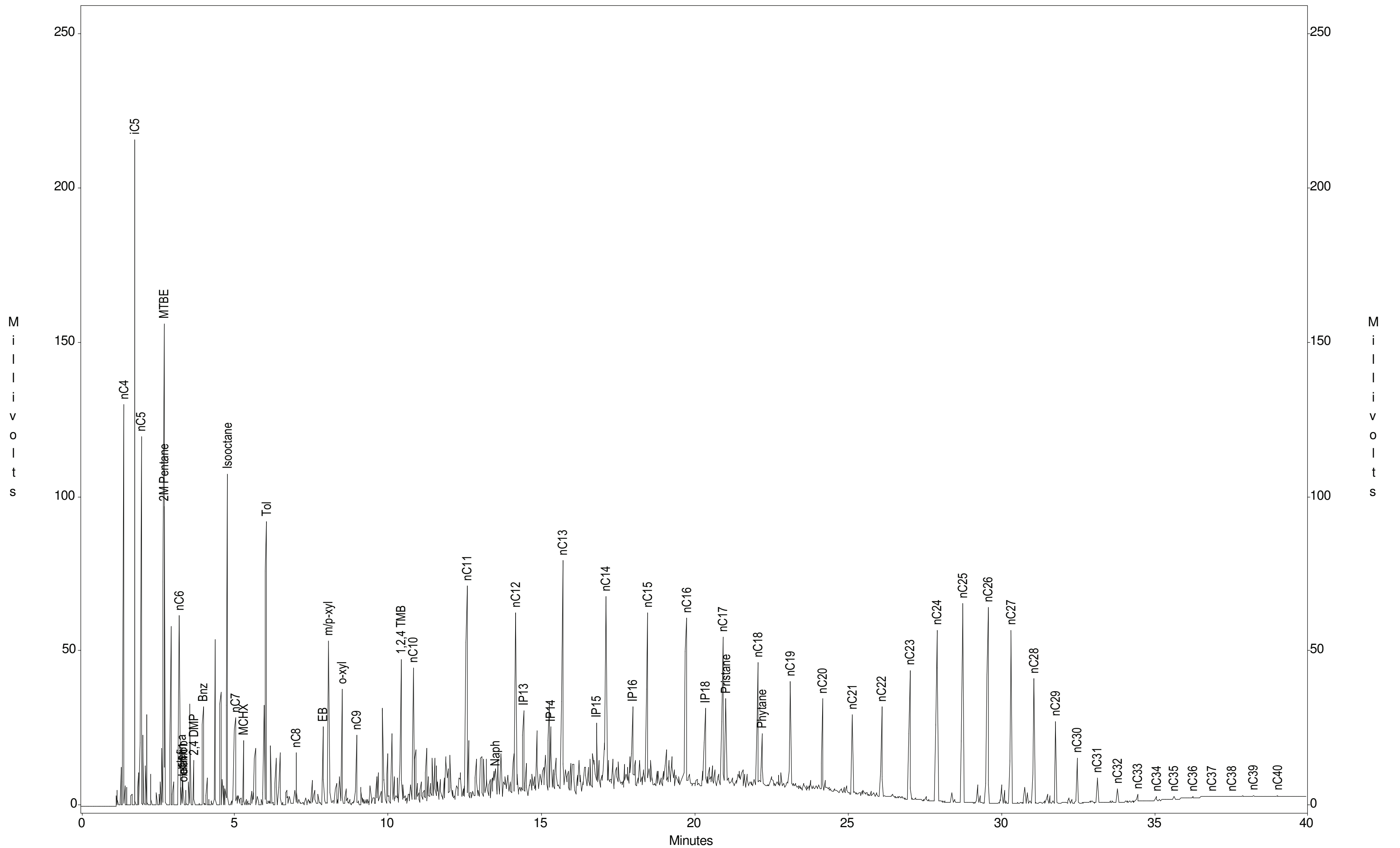
c:\ezchrom\chrom\12005\c-168 -- Channel A



Torkelson Geochemistry, Inc.

Sunoco Philadelphia Refinery, AOI-7
Sample ID : Gas/Dies/Wax std
Acquired : Jan 24, 2012 13:30:21

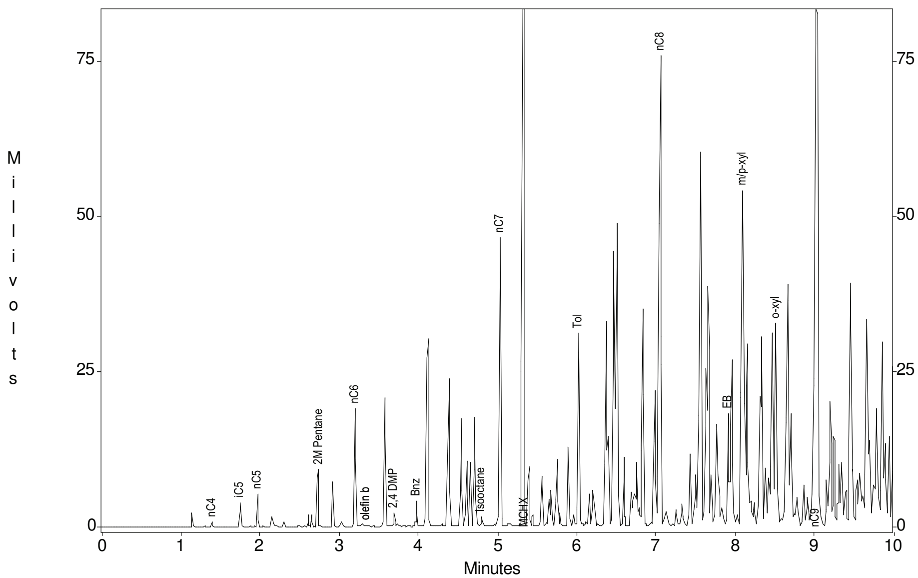
c:\ezchrom\chrom\12005\gadiwax2.2 -- Channel A



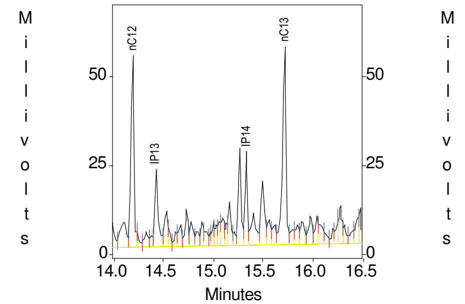
Torkelson Geochemistry, Inc.

Sunoco Philadelphia Refinery, AOI-7
Sample ID : C-147
Acquired : Jan 24, 2012 18:07:21

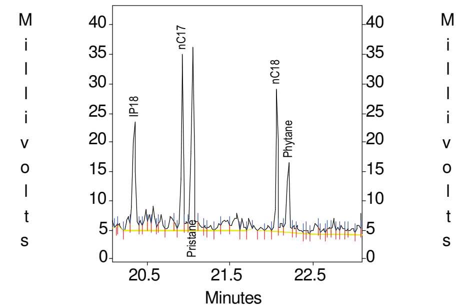
c:\ezchrom\chrom\12005\c-147 -- Channel A



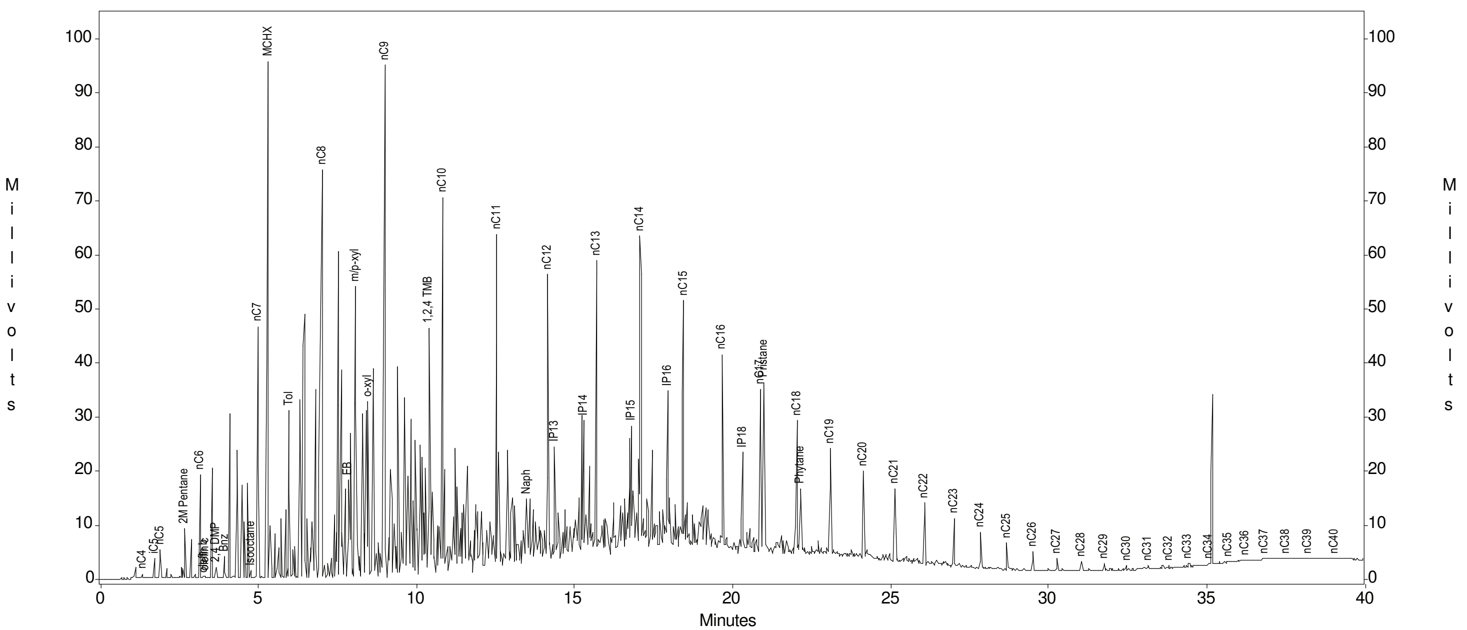
c:\ezchrom\chrom\12005\c-147 -- Channel A



c:\ezchrom\chrom\12005\c-147 -- Channel A



c:\ezchrom\chrom\12005\c-147 -- Channel A



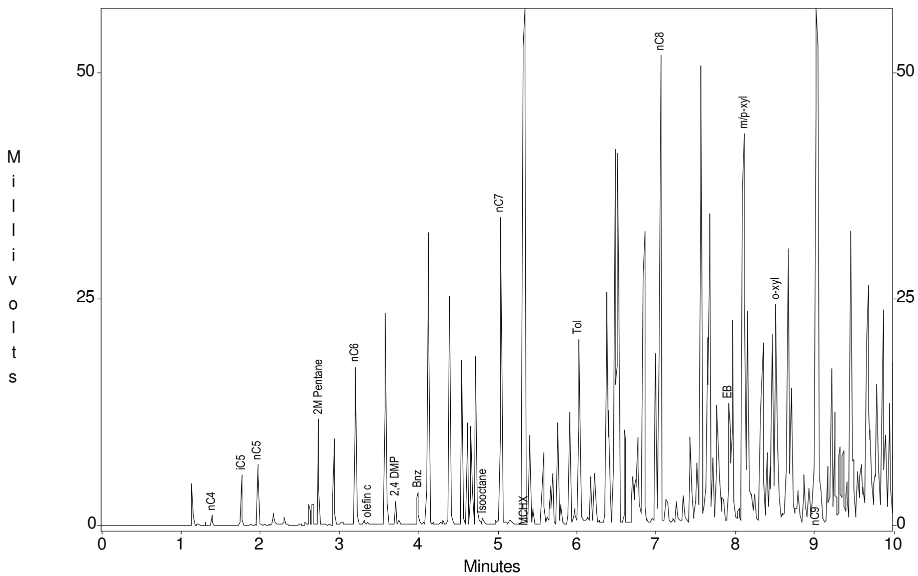
Channel A Results

Peak	Area	Height
nC4	454	766
iC5	2598	3802
nC5	3965	5352
MTBE	0	0
2M Pentane	8032	9158
nC6	17971	19104
olefin a	0	0
olefin b	127	149
olefin c	349	274
2,4 DMP	2112	2046
Bnz	5186	3978
Isooctane	1667	1381
nC7	55890	46471
MCHX	142794	95372
Tol	38514	30867
nC8	121850	75589
EB	25978	17963
m/p-xyl	116673	53726
o-xyl	60368	32475
nC9	227880	94801
1,2,4 TMB	99927	45581
nC10	130939	69473
nC11	108843	62080
Naph	37305	12641
nC12	104288	53920
IP13	49209	21930
IP14	46835	26257
nC13	123840	55712
IP15	43818	24617
nC14	125767	59480
IP16	61258	30370
nC15	98917	46883
nC16	72718	36207
IP18	41466	18694
nC17	58473	30374
Pristane	75622	31421
nC18	46306	24443
Phytane	26004	12035
nC19	38533	19870
nC20	29739	16207
nC21	23694	13568
nC22	19038	11383
nC23	15504	8834
nC24	10986	6671
nC25	10724	4918
nC26	6248	3443
nC27	4262	2433
nC28	3053	1709
nC29	2578	1379
nC30	1662	927
nC31	1236	745
nC32	858	498
nC33	906	457
nC34	410	234
nC35	295	189
nC36	297	161
nC37	443	207
nC38	551	145
nC39	340	97
nC40	490	154

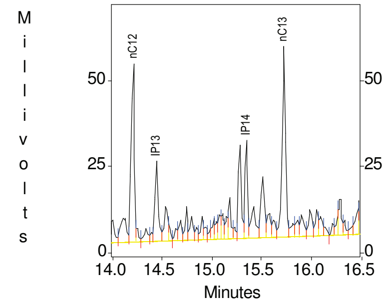
Torkelson Geochemistry, Inc.

Sunoco Philadelphia Refinery, AOI-7
Sample ID : C-148
Acquired : Jan 24, 2012 10:59:28

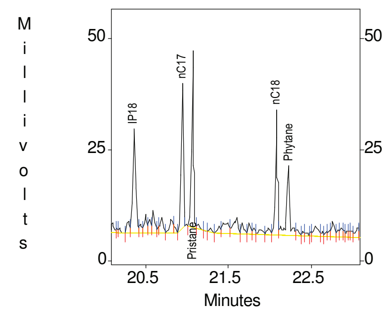
c:\ezchrom\chrom\12005\c-148 -- Channel A



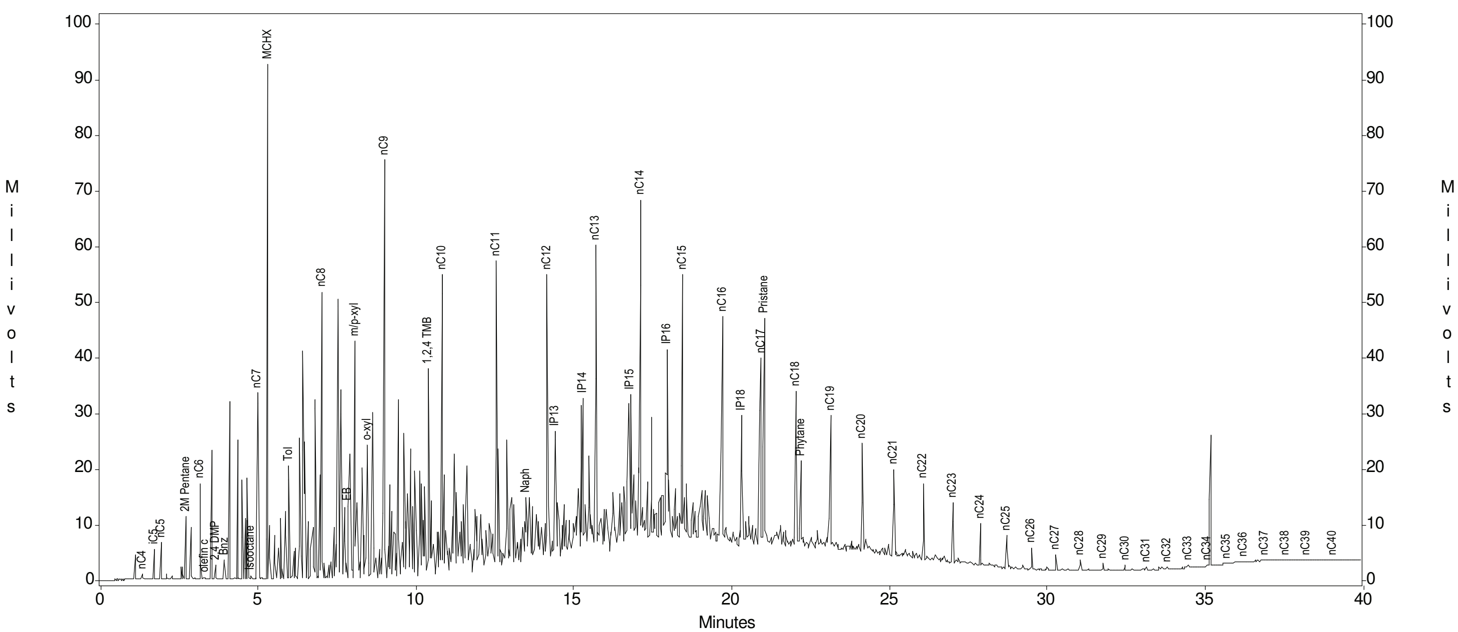
c:\ezchrom\chrom\12005\c-148 -- Channel A



c:\ezchrom\chrom\12005\c-148 -- Channel A



c:\ezchrom\chrom\12005\c-148 -- Channel A



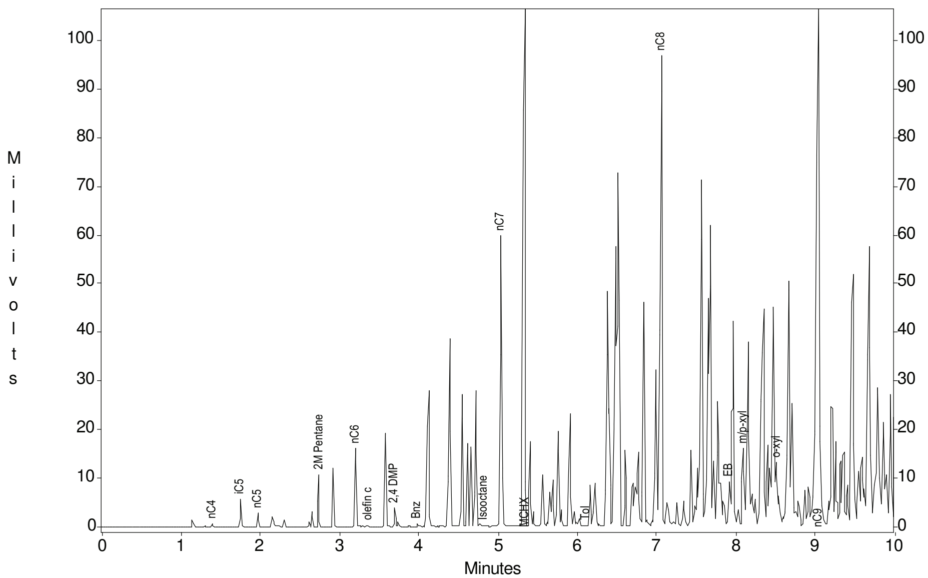
Channel A Results

Peak	Area	Height
nC4	695	1111
iC5	3790	5428
nC5	5082	6558
MTBE	0	0
2M Pentane	10504	11521
nC6	16629	17335
olefin a	0	0
olefin b	0	0
olefin c	594	300
2,4 DMP	2608	2487
Bnz	4812	3462
Isooctane	924	664
nC7	39771	33697
MCHX	138326	92607
Tol	26152	20338
nC8	72027	51509
EB	19420	13087
m/p-xyl	86389	42816
o-xyl	43119	23989
nC9	139965	75226
1,2,4 TMB	64732	37169
nC10	94706	53651
nC11	98152	55602
Naph	38066	12038
nC12	99376	51486
IP13	50390	23277
IP14	50934	28322
nC13	121970	55442
IP15	48836	27540
nC14	127644	62317
IP16	69462	34552
nC15	99761	47613
nC16	81256	40741
IP18	52268	23508
nC17	61111	32377
Pristane	92300	39745
nC18	54452	28055
Phytane	44372	15454
nC19	43761	24206
nC20	35020	19447
nC21	28257	15643
nC22	23199	13723
nC23	18834	10792
nC24	13224	7776
nC25	13388	5777
nC26	7321	3898
nC27	4906	2957
nC28	3293	1843
nC29	2548	1318
nC30	1489	800
nC31	1174	673
nC32	758	454
nC33	956	400
nC34	273	152
nC35	305	167
nC36	327	172
nC37	547	175
nC38	395	135
nC39	526	84
nC40	295	104

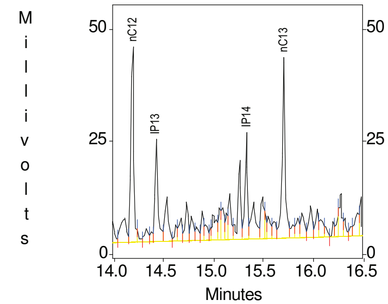
Torkelson Geochemistry, Inc.

Sunoco Philadelphia Refinery, AOI-7
Sample ID : C-150
Acquired : Jan 24, 2012 19:46:11

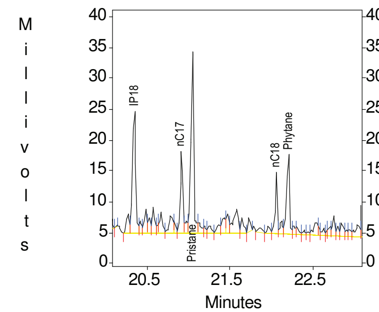
c:\ezchrom\chrom\12005\c-150 -- Channel A



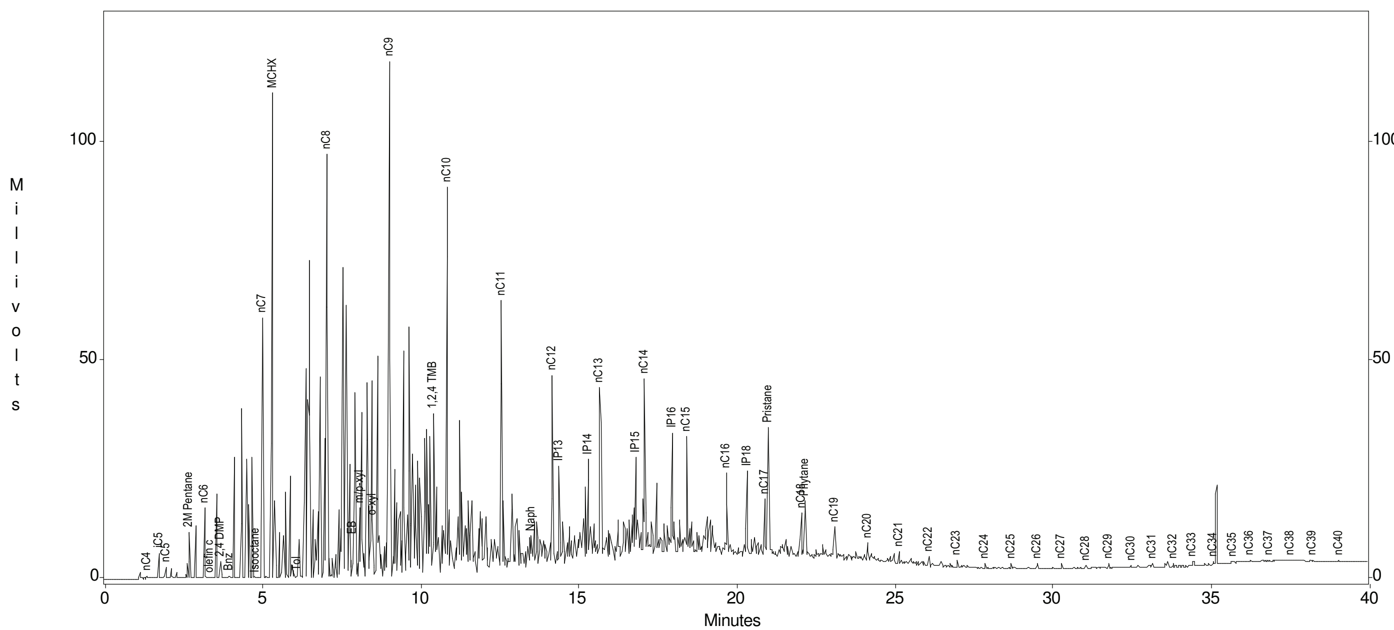
c:\ezchrom\chrom\12005\c-150 -- Channel A



c:\ezchrom\chrom\12005\c-150 -- Channel A



c:\ezchrom\chrom\12005\c-150 -- Channel A



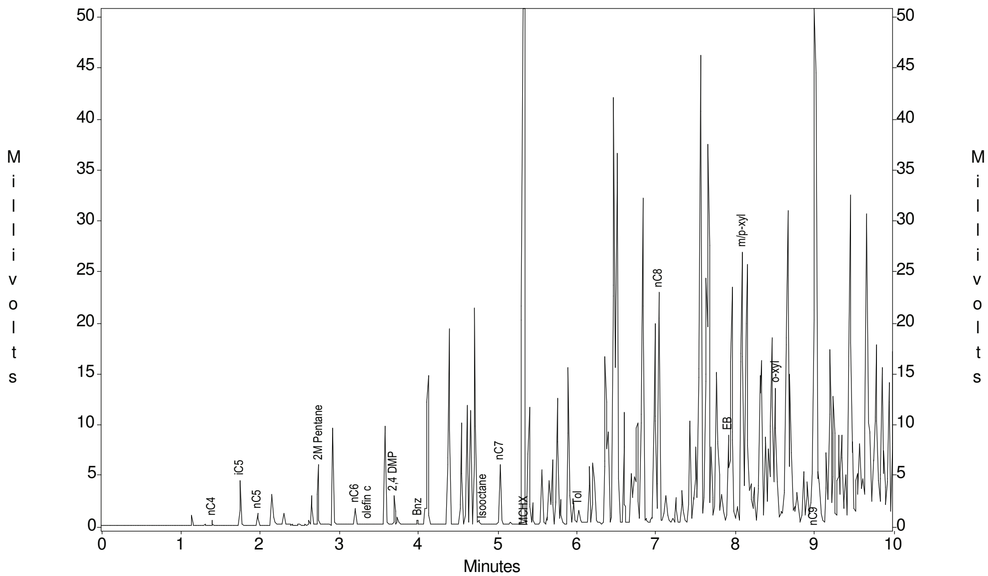
Channel A Results

Peak	Area	Height
nC4	315	465
iC5	4254	5773
nC5	2183	2674
MTBE	0	0
2M Pentane	9764	10718
nC6	15769	16123
olefin a	0	0
olefin b	0	0
olefin c	86	50
2,4 DMP	4017	3823
Bnz	906	645
Isooctane	178	72
nC7	77934	59716
MCHX	177463	111151
Tol	531	259
nC8	176839	96759
EB	13873	8788
m/p-xyl	31055	15657
o-xyl	17623	12876
nC9	339609	117682
1,2,4 TMB	64623	36652
nC10	197109	88428
nC11	108184	61721
Naph	18052	7065
nC12	80409	43360
IP13	43968	22535
IP14	40933	23692
nC13	86456	40035
IP15	38519	22997
nC14	77262	40620
IP16	54090	27731
nC15	44811	25221
nC16	34029	18524
IP18	45175	19730
nC17	27163	13188
Pristane	70534	29459
nC18	19689	9937
Phytane	28430	12735
nC19	12690	7396
nC20	8034	3992
nC21	4579	2716
nC22	4312	2294
nC23	3612	1729
nC24	2163	1272
nC25	1748	1048
nC26	2538	1357
nC27	2451	1250
nC28	2052	1026
nC29	2408	1042
nC30	1242	615
nC31	1260	724
nC32	1146	715
nC33	1752	804
nC34	731	409
nC35	542	339
nC36	903	347
nC37	504	255
nC38	539	207
nC39	311	114
nC40	603	165

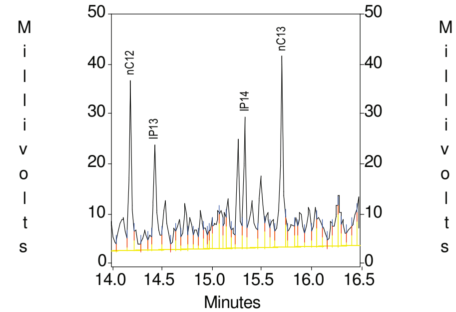
Torkelson Geochemistry, Inc.

Sunoco Philadelphia Refinery, AOI-7
Sample ID : C-151
Acquired : Jan 24, 2012 15:57:06

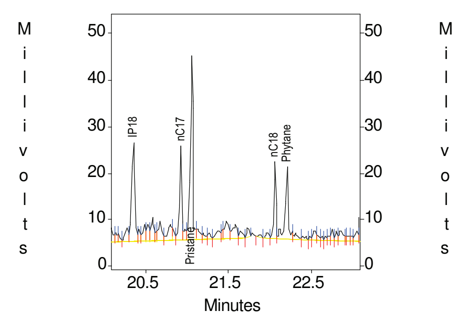
c:\ezchrom\chrom\12005\c-151 -- Channel A



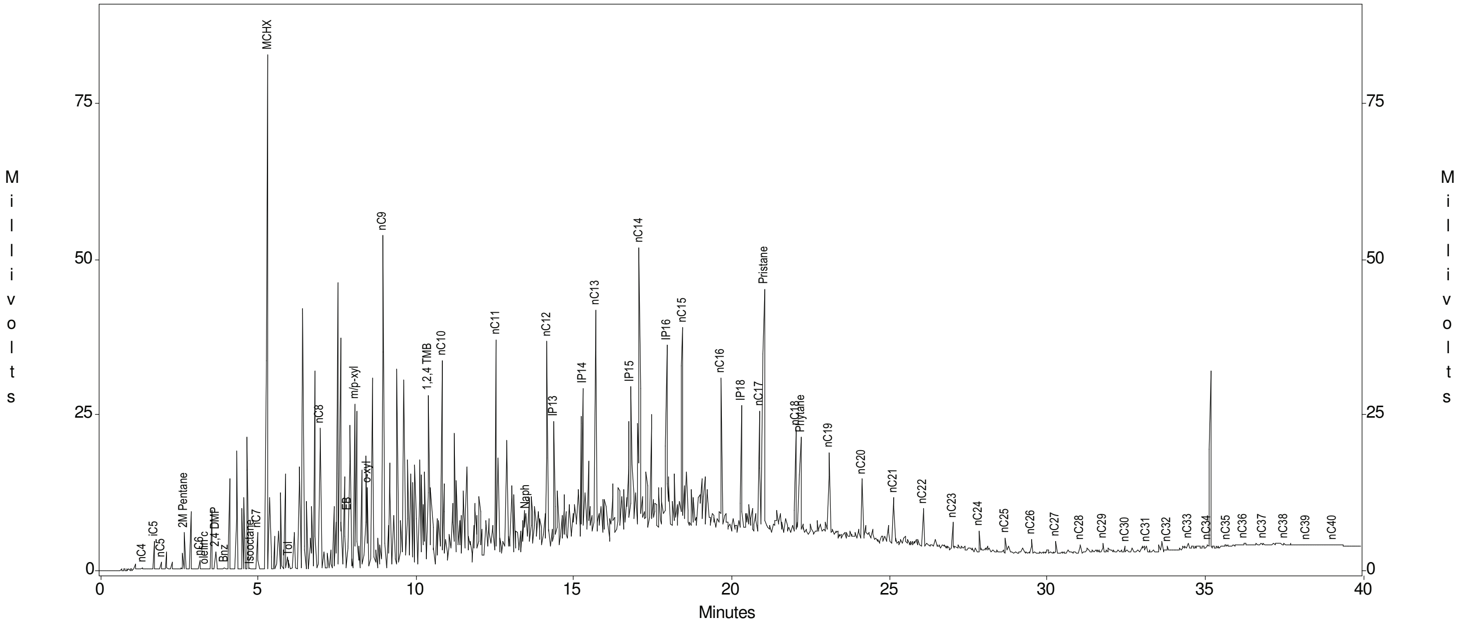
c:\ezchrom\chrom\12005\c-151 -- Channel A



c:\ezchrom\chrom\12005\c-151 -- Channel A



c:\ezchrom\chrom\12005\c-151 -- Channel A



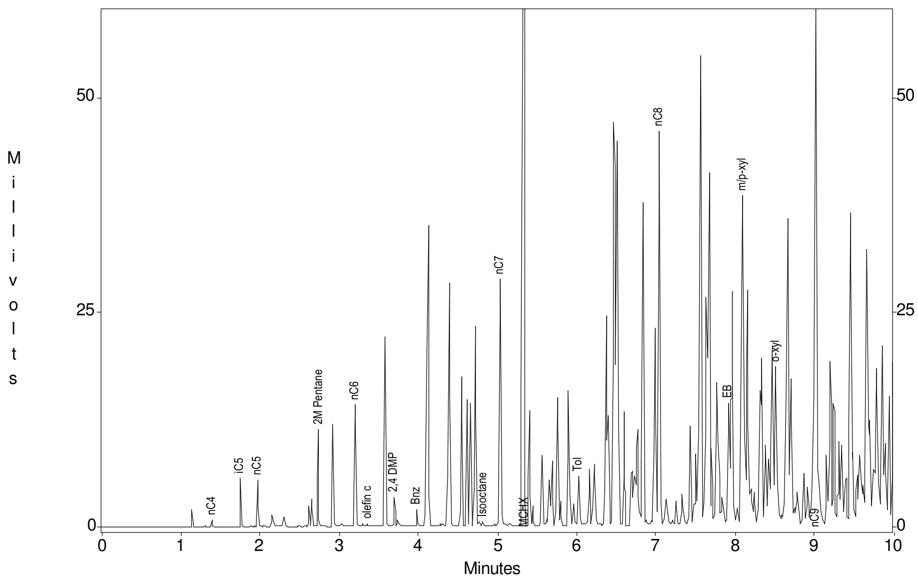
Channel A Results

Peak	Area	Height
nC4	234	382
iC5	3046	4460
nC5	914	1165
MTBE	0	0
2M Pentane	5331	5974
nC6	1640	1574
olefin a	0	0
olefin b	0	0
olefin c	103	62
2,4 DMP	2896	2848
Bnz	716	473
Isooctane	66	41
nC7	7070	5885
MCHX	118750	82641
Tol	2252	1424
nC8	28418	22630
EB	12738	8628
m/p-xyl	49388	26527
o-xyl	22471	13114
nC9	90754	53509
1,2,4 TMB	45846	27374
nC10	59247	32814
nC11	64170	35415
Naph	25829	6928
nC12	66253	34264
IP13	49845	21255
IP14	49850	26282
nC13	85330	38589
IP15	49383	25688
nC14	96552	48075
IP16	64590	32007
nC15	78059	34515
nC16	57676	25869
IP18	49948	21225
nC17	41749	20133
Pristane	95597	39594
nC18	31526	16497
Phytane	40586	15549
nC19	22901	13550
nC20	16982	9688
nC21	12912	7307
nC22	10640	6098
nC23	8570	4483
nC24	5305	3193
nC25	4746	2503
nC26	4705	2277
nC27	3767	1875
nC28	2875	1453
nC29	2716	1438
nC30	1655	812
nC31	1395	784
nC32	1163	683
nC33	1597	727
nC34	695	318
nC35	462	292
nC36	639	314
nC37	448	209
nC38	594	196
nC39	564	134
nC40	536	144

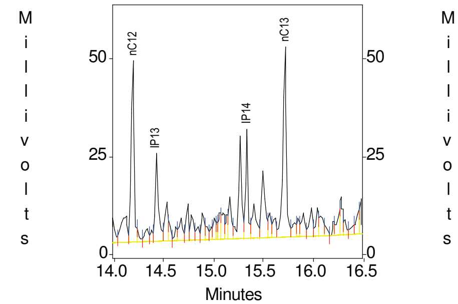
Torkelson Geochemistry, Inc.

Sunoco Philadelphia Refinery, AOI-7
Sample ID : C-152
Acquired : Jan 24, 2012 14:19:23

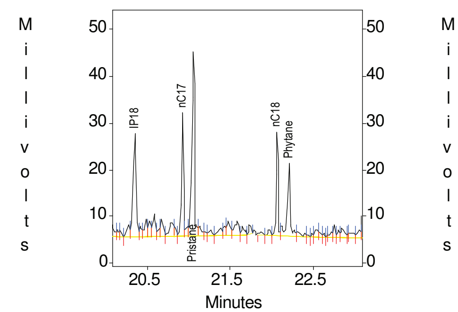
c:\ezchrom\chrom\12005\c-152 -- Channel A



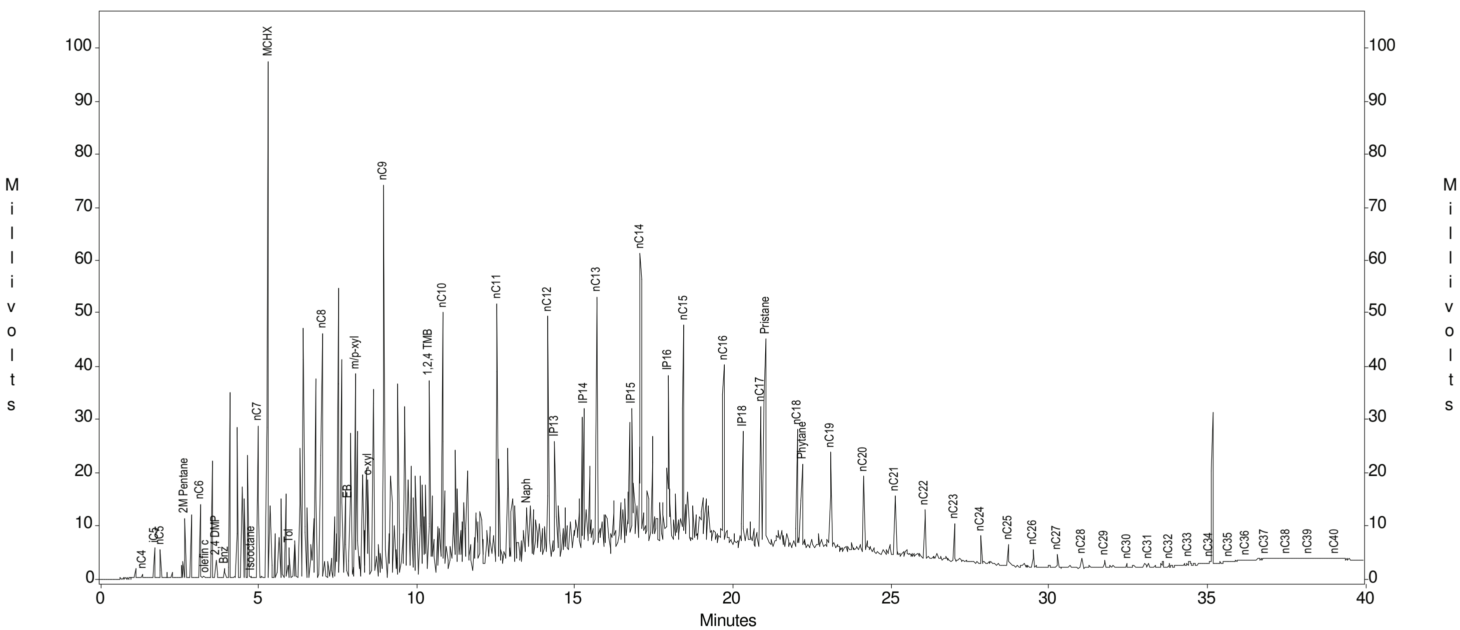
c:\ezchrom\chrom\12005\c-152 -- Channel A



c:\ezchrom\chrom\12005\c-152 -- Channel A



c:\ezchrom\chrom\12005\c-152 -- Channel A



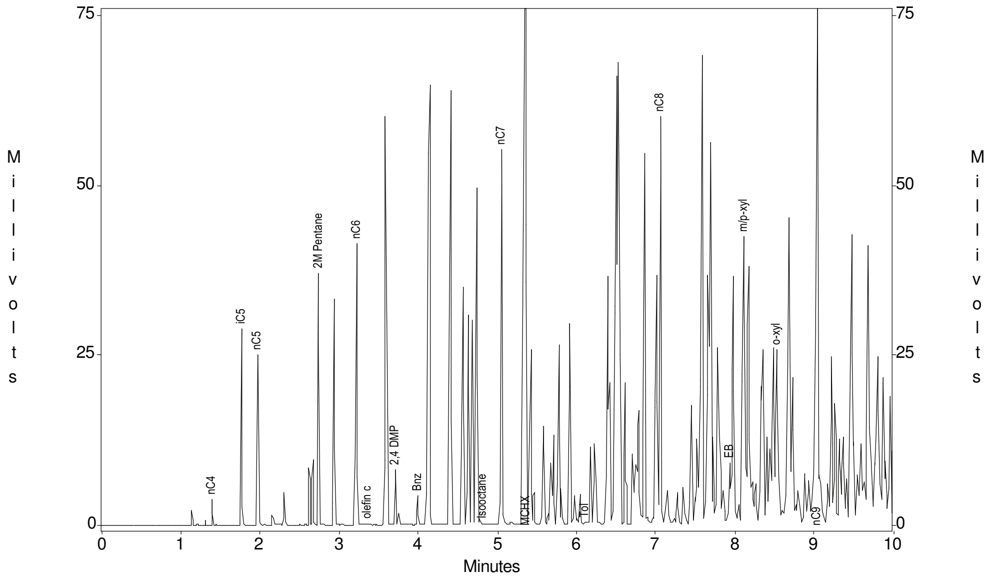
Channel A Results

Peak	Area	Height
nC4	462	744
iC5	3889	5647
nC5	4112	5394
MTBE	0	0
2M Pentane	10100	11310
nC6	13461	14036
olefin a	0	0
olefin b	0	0
olefin c	384	201
2,4 DMP	3530	3404
Bnz	2718	1888
Isooctane	684	515
nC7	33655	28728
MCHX	148823	97236
Tol	8082	5766
nC8	62197	45873
EB	20398	14063
m/p-xyl	74676	38228
o-xyl	30990	18345
nC9	135072	73968
1,2,4 TMB	61303	36440
nC10	86821	49317
nC11	86273	49931
Naph	37482	10700
nC12	86280	46328
IP13	48312	22379
IP14	49035	27821
nC13	106150	48719
IP15	44813	26301
nC14	106816	54836
IP16	53484	29371
nC15	80599	40839
nC16	64754	34020
IP18	48153	21884
nC17	51822	26524
Pristane	96786	39449
nC18	41638	22424
Phytane	41760	15716
nC19	33689	18447
nC20	25021	14275
nC21	19781	11317
nC22	15997	9477
nC23	12959	7195
nC24	9159	5434
nC25	10796	4164
nC26	6248	3218
nC27	4241	2476
nC28	3085	1735
nC29	2606	1435
nC30	1559	796
nC31	1072	670
nC32	764	466
nC33	983	427
nC34	161	116
nC35	290	180
nC36	351	141
nC37	362	153
nC38	341	113
nC39	494	89
nC40	452	145

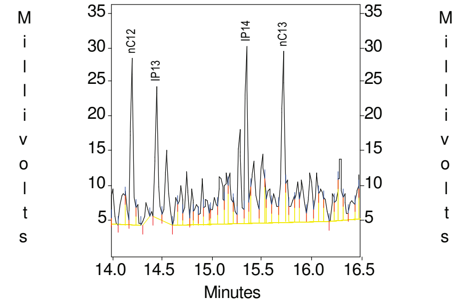
Torkelson Geochemistry, Inc.

Sunoco Philadelphia Refinery, AOI-7
Sample ID : C-153
Acquired : Jan 24, 2012 10:10:30

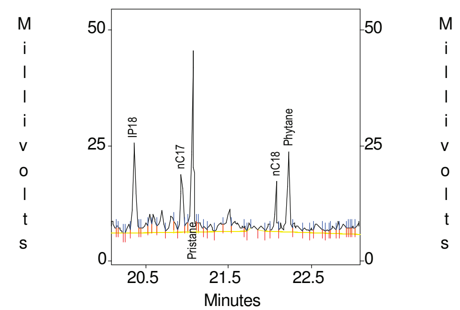
c:\ezchrom\chrom\12005\c-153 -- Channel A



c:\ezchrom\chrom\12005\c-153 -- Channel A



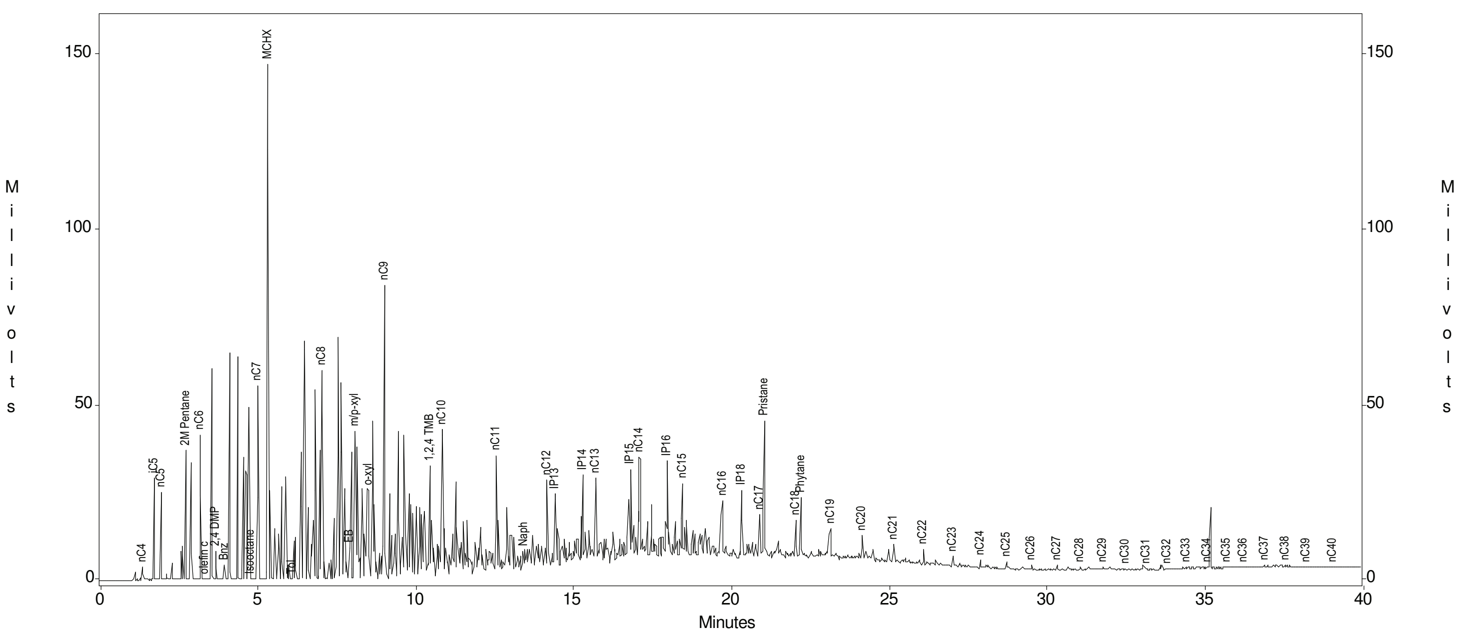
c:\ezchrom\chrom\12005\c-153 -- Channel A



Channel A Results

Peak	Area	Height
nC4	2190	3740
iC5	19153	28836
nC5	18270	25068
MTBE	0	0
2M Pentane	32203	36952
nC6	39425	41355
olefin a	0	0
olefin b	0	0
olefin c	329	126
2,4 DMP	8260	8029
Bnz	5514	4272
Isooctane	335	216
nC7	71245	55127
MCHX	270068	147082
Tol	418	217
nC8	87418	59848
EB	13744	8885
m/p-xyl	84121	42150
o-xyl	48745	25370
nC9	155698	83545
1,2,4 TMB	53195	31270
nC10	76181	41624
nC11	55349	32314
Naph	7585	4391
nC12	42356	24198
IP13	35057	19202
IP14	45266	25820
nC13	48329	24768
IP15	44133	25971
nC14	60351	29396
IP16	50791	27072
nC15	32409	18803
nC16	35029	16444
IP18	42784	19430
nC17	26992	12578
Pristane	94491	39270
nC18	22015	10867
Phytane	41748	17286
nC19	14220	8504
nC20	14403	6825
nC21	9976	5150
nC22	8069	4178
nC23	6640	3170
nC24	4281	2412
nC25	7681	1948
nC26	3044	1489
nC27	2141	1195
nC28	1886	850
nC29	2115	960
nC30	888	378
nC31	565	345
nC32	406	226
nC33	688	335
nC34	139	120
nC35	94	66
nC36	218	121
nC37	177	95
nC38	207	83
nC39	182	31
nC40	324	95

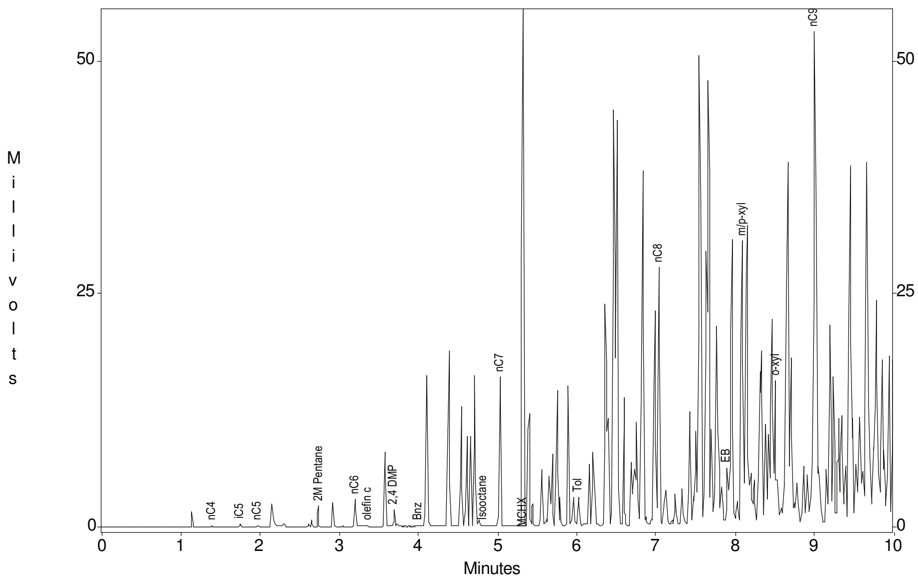
c:\ezchrom\chrom\12005\c-153 -- Channel A



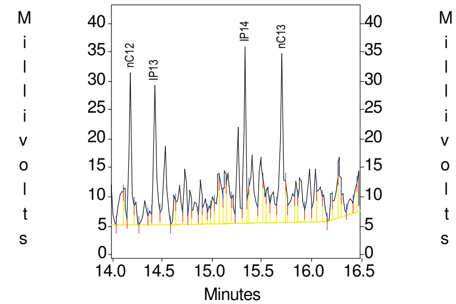
Torkelson Geochemistry, Inc.

Sunoco Philadelphia Refinery, AOI-7
Sample ID : C-154
Acquired : Jan 24, 2012 21:25:45

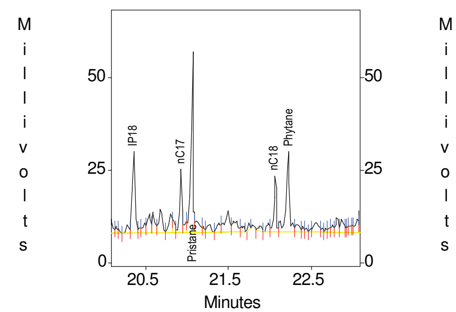
c:\ezchrom\chrom\12005\c-154 -- Channel A



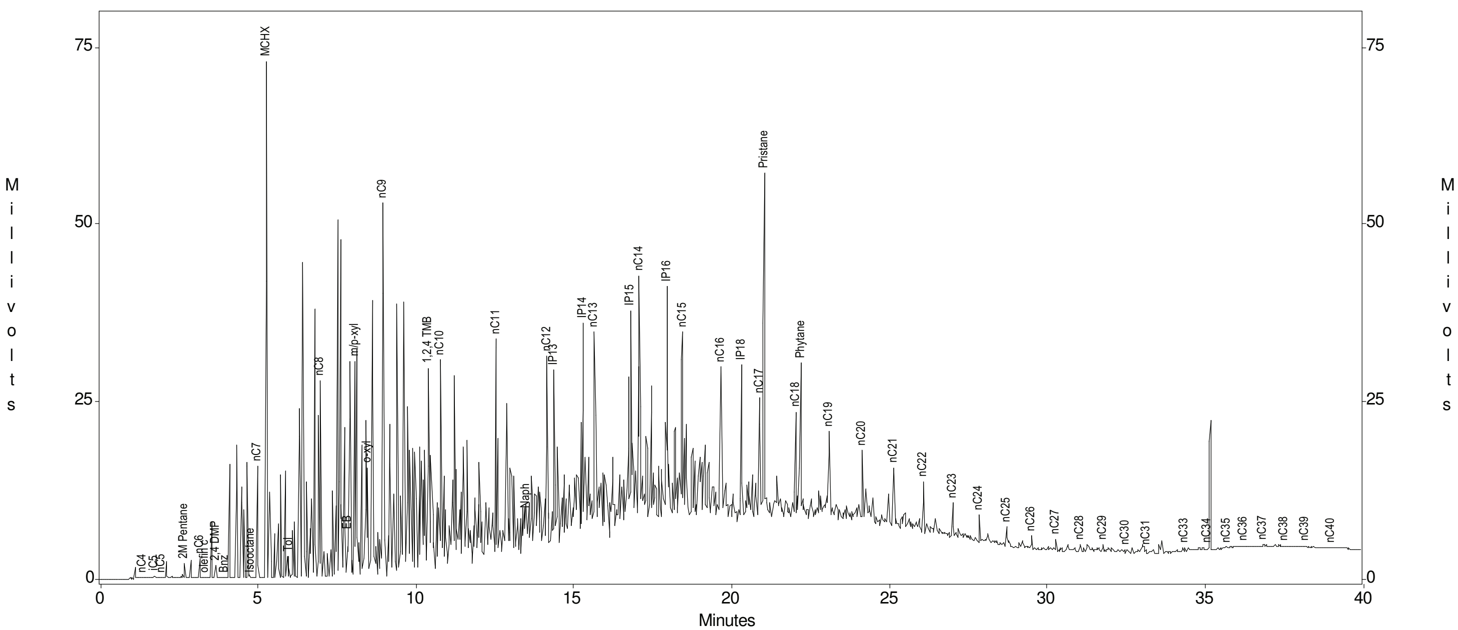
c:\ezchrom\chrom\12005\c-154 -- Channel A



c:\ezchrom\chrom\12005\c-154 -- Channel A



c:\ezchrom\chrom\12005\c-154 -- Channel A

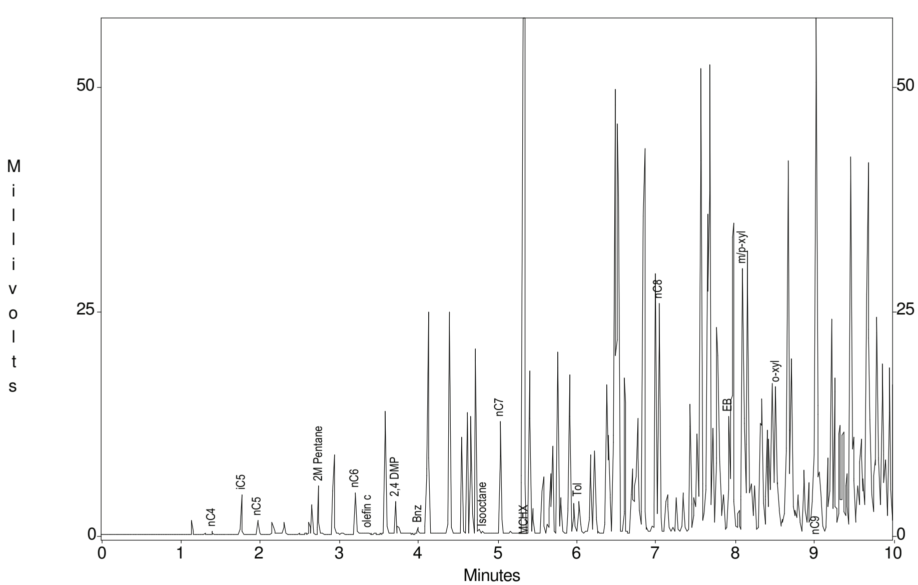


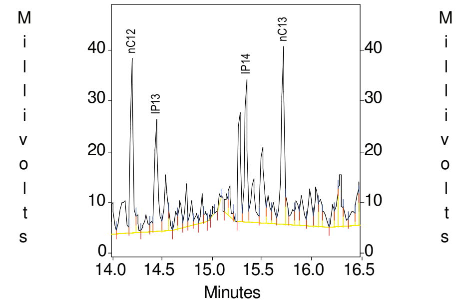
Channel A Results

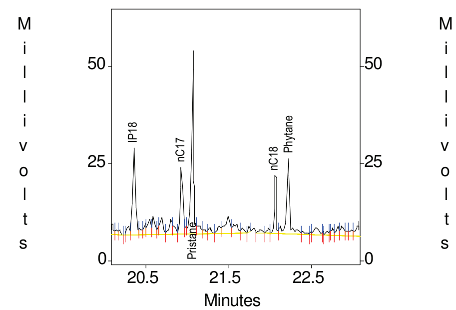
Peak	Area	Height
nC4	44	46
iC5	272	382
nC5	150	182
MTBE	0	0
2M Pentane	1934	2128
nC6	2878	2845
olefin a	0	0
olefin b	0	0
olefin c	49	26
2,4 DMP	1744	1686
Bnz	272	172
Isooctane	214	145
nC7	18152	15855
MCHX	100718	72707
Tol	4124	3037
nC8	34763	27560
EB	9772	5965
m/p-xyl	56112	30345
o-xyl	22931	15224
nC9	98393	52581
1,2,4 TMB	45923	28539
nC10	55143	29386
nC11	54519	30408
Naph	13238	3582
nC12	48569	26245
IP13	49609	24268
IP14	55503	30601
nC13	63092	29269
IP15	35413	24907
nC14	63745	33401
IP16	61686	32500
nC15	62764	26318
nC16	46330	21837
IP18	49320	22215
nC17	35904	17194
Pristane	118888	48774
nC18	31040	14962
Phytane	62345	21968
nC19	19904	12493
nC20	21231	10254
nC21	16674	8596
nC22	13350	7172
nC23	11069	5163
nC24	6797	3850
nC25	11756	2950
nC26	3342	1890
nC27	2977	1586
nC28	2587	1002
nC29	2245	1063
nC30	930	342
nC31	423	285
nC32	0	0
nC33	858	417
nC34	210	123
nC35	49	48
nC36	279	142
nC37	212	50
nC38	64	31
nC39	20	21
nC40	343	85

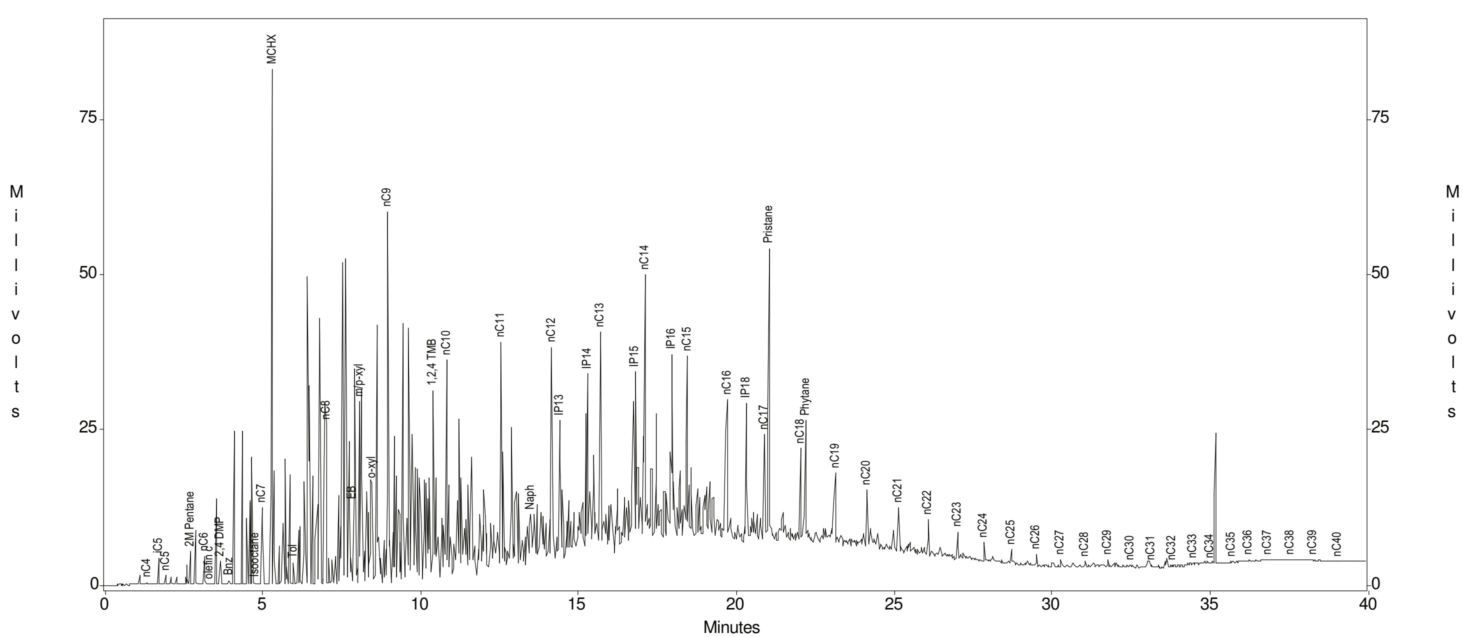
Torkelson Geochemistry, Inc.

Sunoco Philadelphia Refinery, AOI-7
Sample ID : C-161
Acquired : Jan 24, 2012 11:49:58









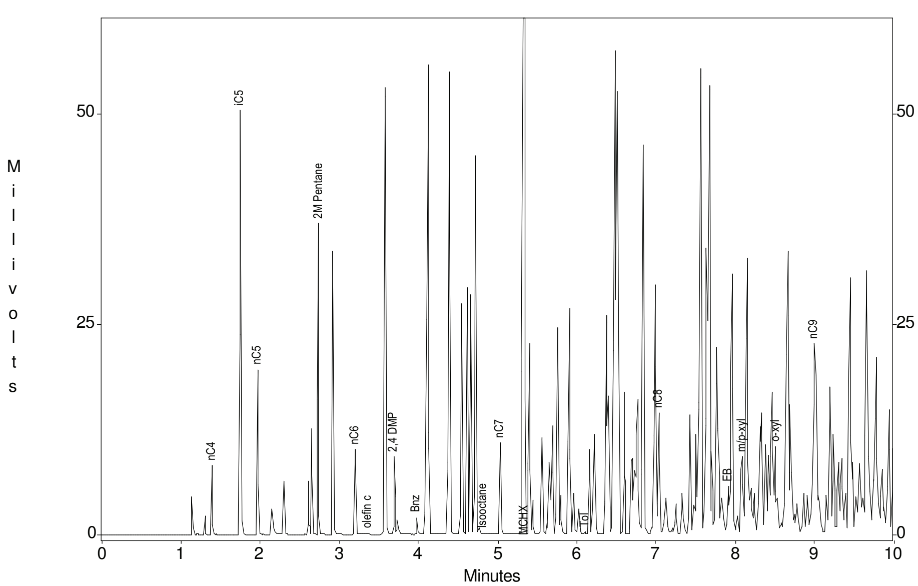
Channel A Results

Peak	Area	Height
nC4	192	295
iC5	3108	4432
nC5	1280	1566
MTBE	0	0
2M Pentane	4790	5341
nC6	4592	4525
olefin a	0	0
olefin b	0	0
olefin c	139	79
2,4 DMP	3768	3665
Bnz	1055	699
Isooctane	338	238
nC7	14510	12415
MCHX	118853	82776
Tol	4921	3495
nC8	32266	25587
EB	18849	12839
m/p-xyl	55592	29323
o-xyl	24985	16142
nC9	105492	59845
1,2,4 TMB	49675	30289
nC10	62050	34655
nC11	64488	36741
Naph	26151	7897
nC12	60568	34128
IP13	46636	22159
IP14	47509	27957
nC13	69877	35052
IP15	51900	28408
nC14	85909	43627
IP16	59616	30029
nC15	59367	29202
nC16	45574	22645
IP18	48569	22451
nC17	35324	17348
Pristane	113068	47189
nC18	28624	14947
Phytane	55560	19465
nC19	19544	11671
nC20	16992	9088
nC21	12759	7188
nC22	10831	5807
nC23	8749	4287
nC24	5524	3188
nC25	9398	2504
nC26	4033	1837
nC27	2621	1329
nC28	1967	887
nC29	1938	968
nC30	1021	391
nC31	467	275
nC32	429	260
nC33	904	277
nC34	227	118
nC35	128	93
nC36	280	142
nC37	138	76
nC38	61	44
nC39	70	53
nC40	253	90

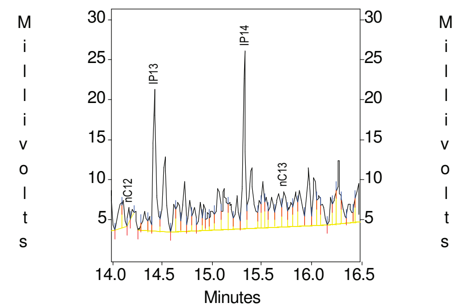
Torkelson Geochemistry, Inc.

Sunoco Philadelphia Refinery, AOI-7
Sample ID : C-162
Acquired : Jan 24, 2012 18:57:14

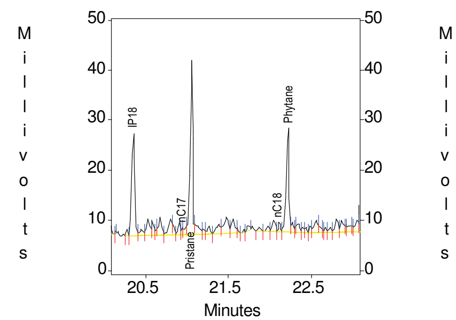
c:\ezchrom\chrom\12005\c-162 -- Channel A



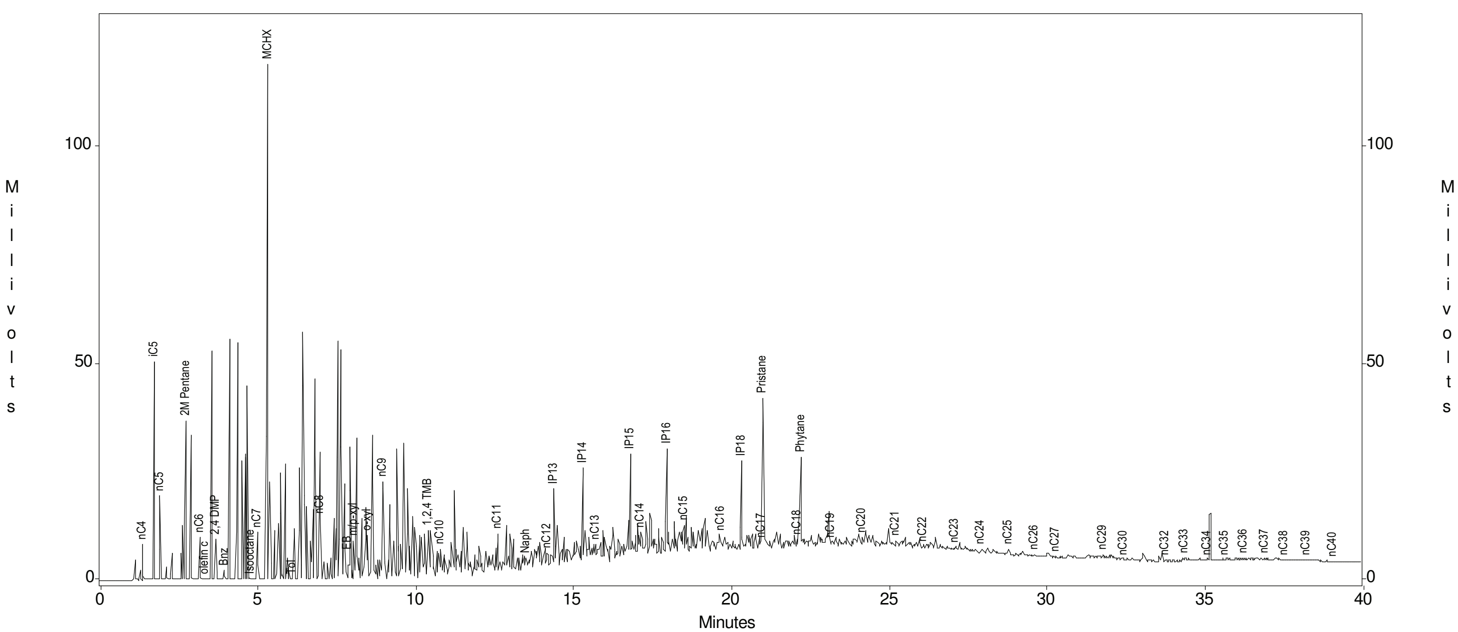
c:\ezchrom\chrom\12005\c-162 -- Channel A



c:\ezchrom\chrom\12005\c-162 -- Channel A



c:\ezchrom\chrom\12005\c-162 -- Channel A



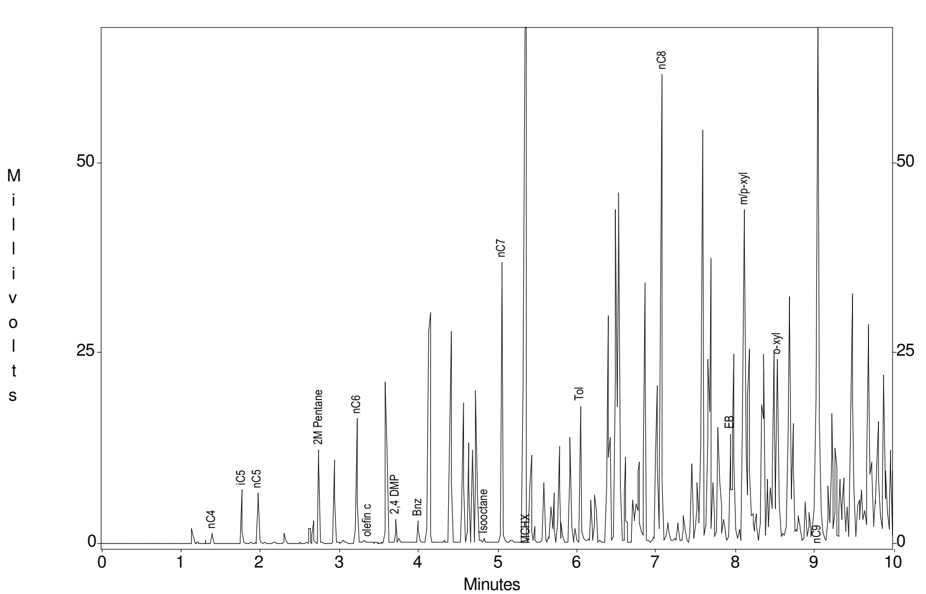
Channel A Results

Peak	Area	Height
nC4	4799	8182
iC5	33723	50217
nC5	14378	19603
MTBE	0	0
2M Pentane	32518	36865
nC6	9711	9997
olefin a	0	0
olefin b	0	0
olefin c	156	62
2,4 DMP	9366	9217
Bnz	2635	1998
Isooctane	63	32
nC7	13020	10805
MCHX	198829	118768
Tol	344	146
nC8	17411	14202
EB	8671	5527
m/p-xyl	17343	9020
o-xyl	14859	10194
nC9	53706	22467
1,2,4 TMB	16981	10727
nC10	16900	6012
nC11	12757	8650
Naph	5132	1717
nC12	2601	2040
IP13	34664	17800
IP14	37324	22287
nC13	11699	4283
IP15	41264	24255
nC14	12307	5595
IP16	44195	24282
nC15	10174	4921
nC16	6927	3232
IP18	45930	20442
nC17	2253	1664
Pristane	81826	34787
nC18	3252	1815
Phytane	44062	20564
nC19	2459	874
nC20	5918	1941
nC21	3843	1287
nC22	2635	600
nC23	2200	683
nC24	4587	634
nC25	8372	1173
nC26	1932	566
nC27	1015	440
nC28	0	0
nC29	2065	794
nC30	164	0
nC31	0	0
nC32	513	195
nC33	1263	595
nC34	17	0
nC35	137	80
nC36	324	117
nC37	100	97
nC38	129	81
nC39	118	37
nC40	271	73

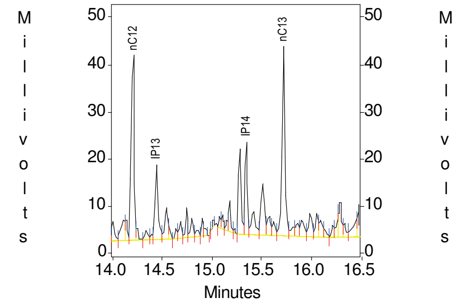
Torkelson Geochemistry, Inc.

Sunoco Philadelphia Refinery, AOI-7
Sample ID : C-166
Acquired : Jan 24, 2012 09:20:57

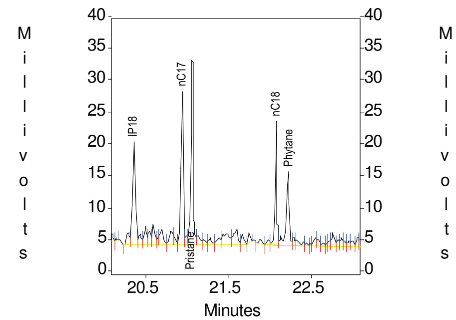
c:\ezchrom\chrom\12005\c-166 -- Channel A



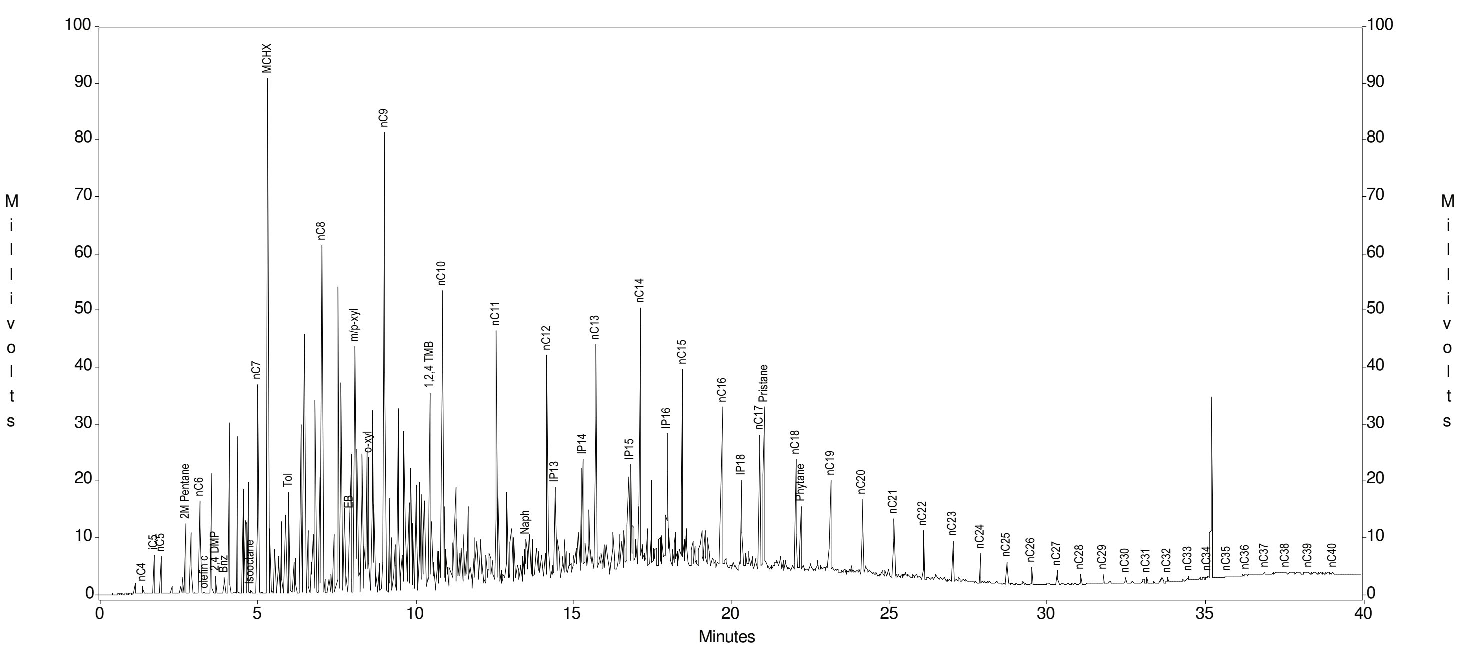
c:\ezchrom\chrom\12005\c-166 -- Channel A



c:\ezchrom\chrom\12005\c-166 -- Channel A



c:\ezchrom\chrom\12005\c-166 -- Channel A



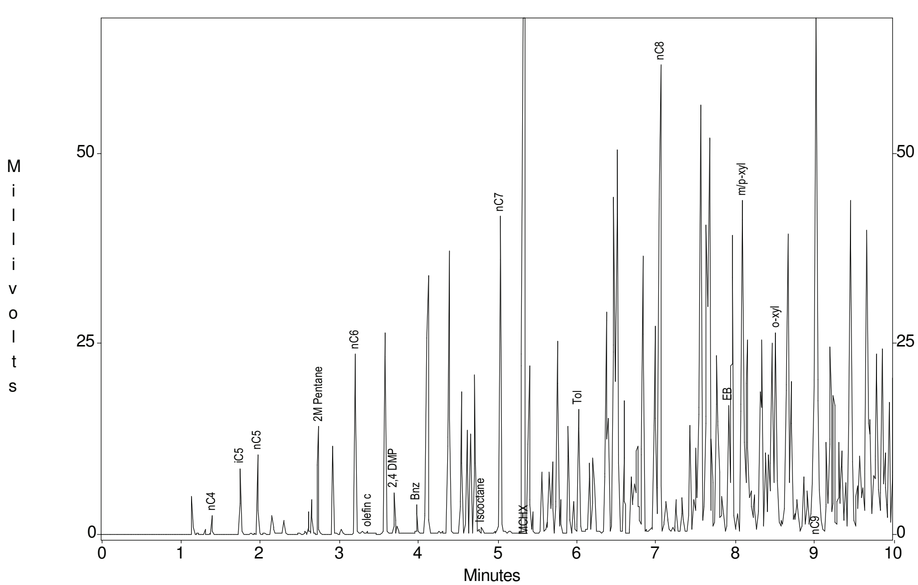
Channel A Results

Peak	Area	Height
nC4	849	1336
iC5	5057	7028
nC5	5278	6470
MTBE	0	0
2M Pentane	11302	12284
nC6	16267	16306
olefin a	0	0
olefin b	0	0
olefin c	343	161
2,4 DMP	3193	3020
Bnz	4078	2898
Isooctane	739	538
nC7	43938	36788
MCHX	134238	90607
Tol	23551	17802
nC8	91164	61309
EB	20398	14109
m/p-xyl	85846	43325
o-xyl	43237	23733
nC9	169139	80946
1,2,4 TMB	71193	34703
nC10	91736	52767
nC11	74044	44815
Naph	24375	7374
nC12	69503	39465
IP13	32531	16036
IP14	31435	19776
nC13	80407	40273
IP15	32851	19061
nC14	88878	46648
IP16	47179	24262
nC15	71287	35574
nC16	54708	28465
IP18	35696	16042
nC17	43673	23795
Pristane	68022	28779
nC18	35405	19450
Phytane	28561	11428
nC19	30165	16208
nC20	22807	13203
nC21	17576	10429
nC22	14563	8641
nC23	12697	7155
nC24	8619	5397
nC25	9894	3846
nC26	5771	3010
nC27	4194	2395
nC28	3148	1744
nC29	3088	1614
nC30	1855	1026
nC31	1447	823
nC32	1002	613
nC33	1212	566
nC34	340	215
nC35	418	249
nC36	406	214
nC37	721	223
nC38	449	155
nC39	738	128
nC40	574	180

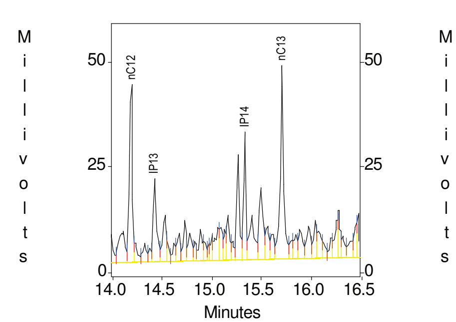
Torkelson Geochemistry, Inc.

Sunoco Philadelphia Refinery, AOI-7
Sample ID : C-167
Acquired : Jan 24, 2012 20:35:48

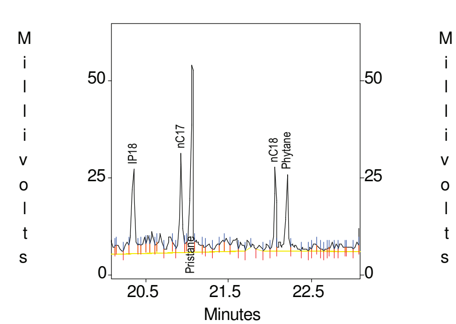
c:\ezchrom\chrom\12005\c-167 -- Channel A



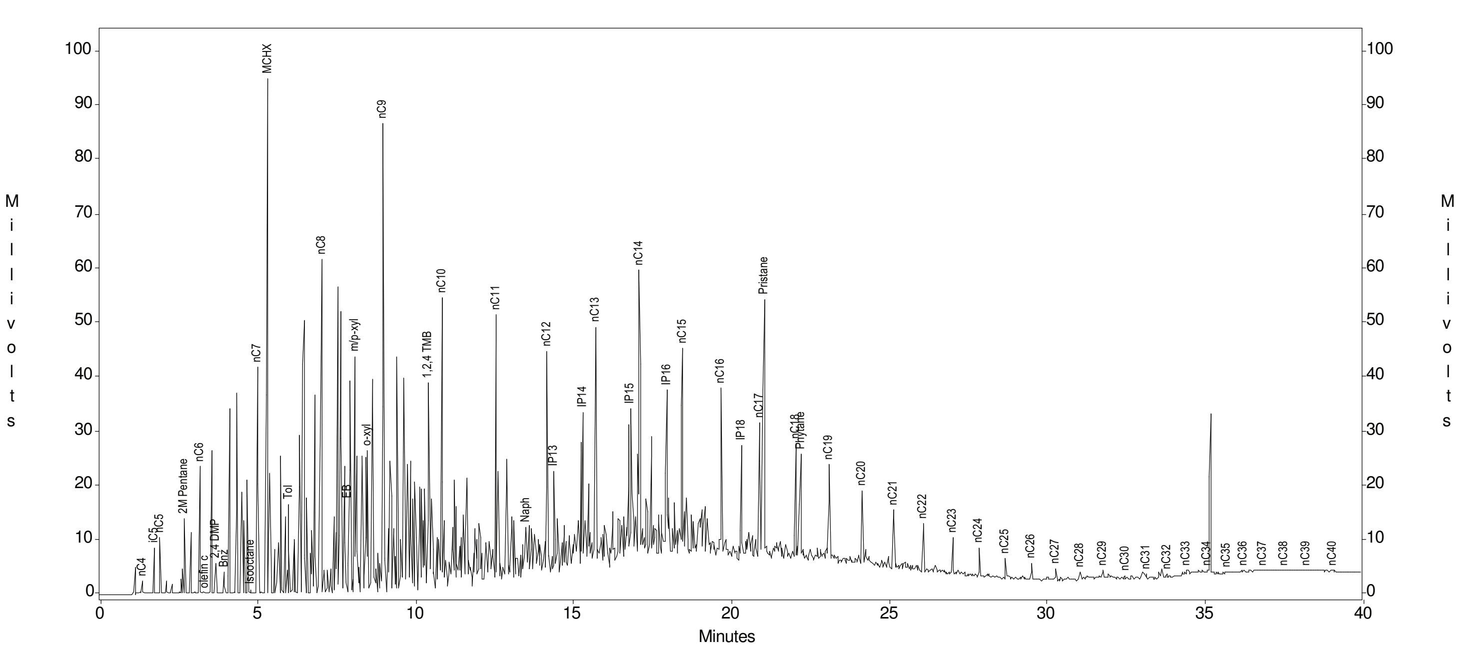
c:\ezchrom\chrom\12005\c-167 -- Channel A



c:\ezchrom\chrom\12005\c-167 -- Channel A



c:\ezchrom\chrom\12005\c-167 -- Channel A



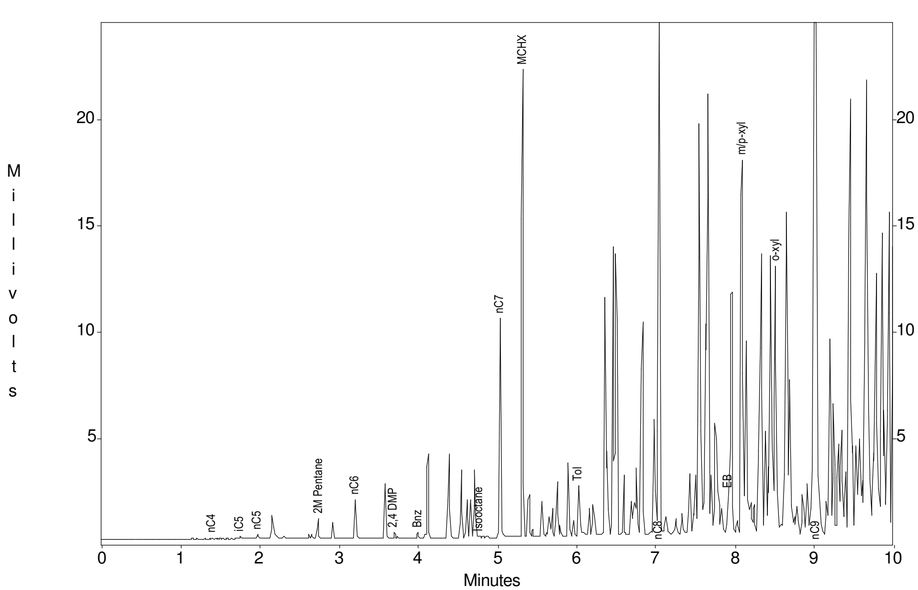
Channel A Results

Peak	Area	Height
nC4	1429	2383
iC5	5768	8508
nC5	7763	10443
MTBE	0	0
2M Pentane	12213	13971
nC6	22266	23604
olefin a	0	0
olefin b	0	0
olefin c	527	258
2,4 DMP	5553	5454
Bnz	5172	3850
Isooctane	970	726
nC7	50183	41546
MCHX	141421	94580
Tol	21026	16318
nC8	58452	61405
EB	24200	16665
m/p-xyl	87198	43453
o-xyl	50381	26099
nC9	181020	86187
1,2,4 TMB	63385	38037
nC10	95686	53057
nC11	84298	49654
Naph	32270	10045
nC12	82140	41917
IP13	46401	19723
IP14	56737	30221
nC13	107923	45829
IP15	56182	30206
nC14	111664	55371
IP16	68162	32922
nC15	89154	40323
nC16	70969	32520
IP18	50309	21653
nC17	51828	25339
Pristane	119819	47886
nC18	40379	21150
Phytane	47725	19418
nC19	30359	17806
nC20	24097	13469
nC21	19130	10953
nC22	15869	9015
nC23	12926	7002
nC24	8568	5214
nC25	10776	3823
nC26	5603	2921
nC27	3964	2156
nC28	2949	1544
nC29	3503	1485
nC30	1536	713
nC31	807	534
nC32	700	456
nC33	1564	475
nC34	254	195
nC35	317	162
nC36	444	203
nC37	312	156
nC38	417	135
nC39	393	88
nC40	347	140

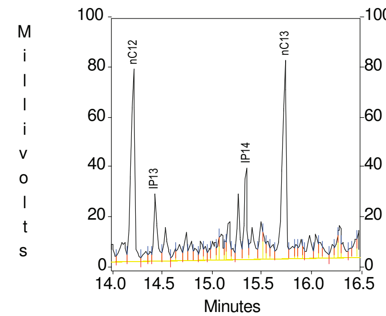
Torkelson Geochemistry, Inc.

Sunoco Philadelphia Refinery, AOI-7
Sample ID : C-168
Acquired : Jan 24, 2012 15:09:04

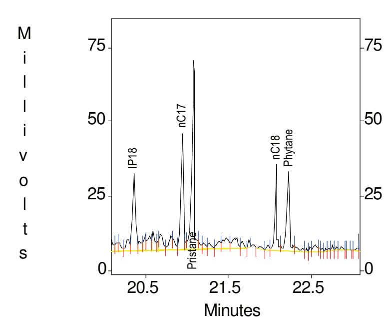
c:\ezchrom\chrom\12005\c-168 -- Channel A



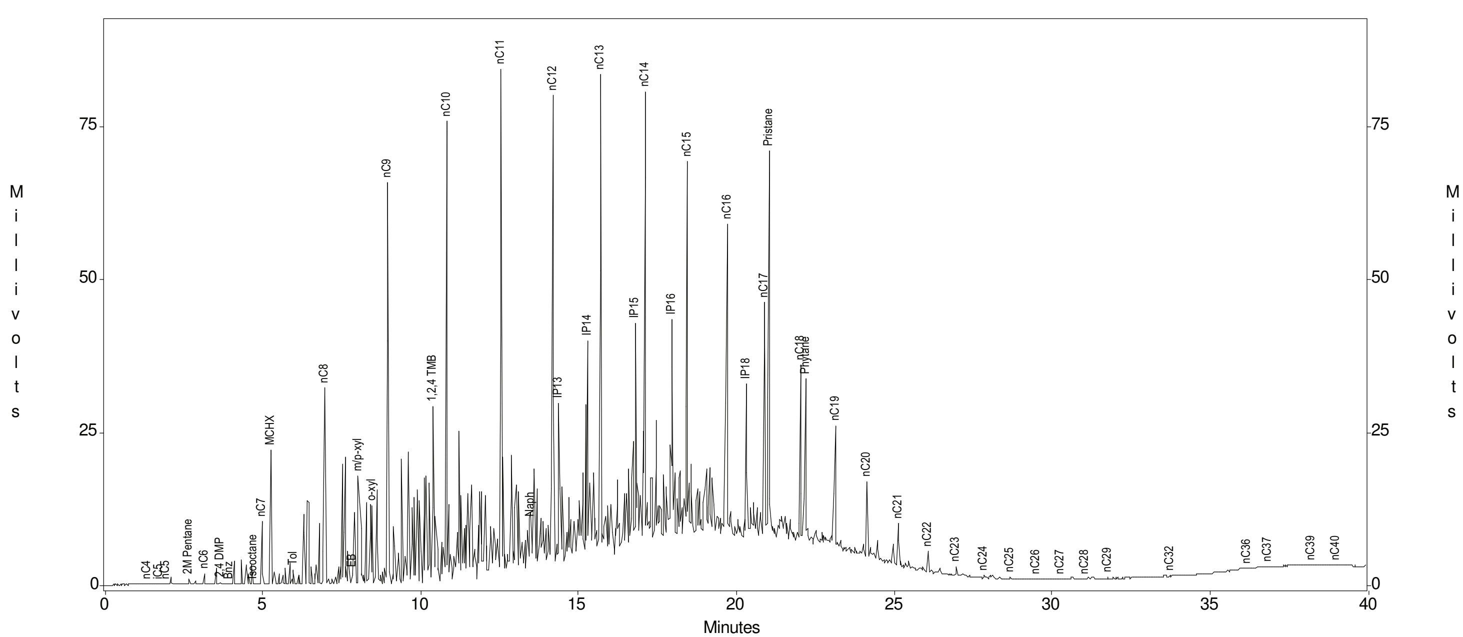
c:\ezchrom\chrom\12005\c-168 -- Channel A



c:\ezchrom\chrom\12005\c-168 -- Channel A



c:\ezchrom\chrom\12005\c-168 -- Channel A



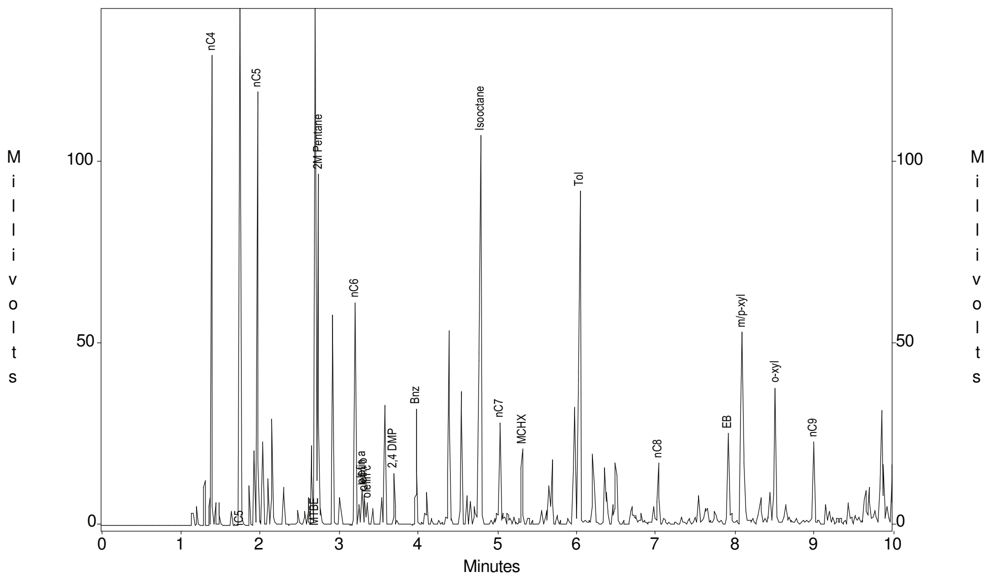
Channel A Results

Peak	Area	Height
nC4	11	12
iC5	115	156
nC5	195	232
MTBE	0	0
2M Pentane	885	953
nC6	1909	1823
olefin a	0	0
olefin b	0	0
olefin c	0	0
2,4 DMP	295	287
Bnz	312	194
Isooctane	76	60
nC7	11974	10315
MCHX	25429	22037
Tol	3858	2337
nC8	40960	31925
EB	2662	1957
m/p-xyl	30680	17628
o-xyl	22332	12633
nC9	118847	65605
1,2,4 TMB	45877	28496
nC10	145999	75009
nC11	173758	82527
Naph	32399	8294
nC12	180165	77417
IP13	57246	27044
IP14	67235	36445
nC13	192895	79816
IP15	72293	38540
nC14	184524	75949
IP16	79240	38208
nC15	153891	63876
nC16	118275	52667
IP18	63620	26141
nC17	86918	39289
Pristane	175971	63916
nC18	59191	28919
Phytane	67345	26693
nC19	33012	19448
nC20	21603	12427
nC21	11921	6957
nC22	5979	3462
nC23	2696	1429
nC24	961	547
nC25	1474	235
nC26	202	109
nC27	306	112
nC28	179	64
nC29	185	85
nC30	0	0
nC31	0	0
nC32	187	69
nC33	0	0
nC34	0	0
nC35	0	0
nC36	41	27
nC37	64	24
nC38	0	0
nC39	61	24
nC40	94	19

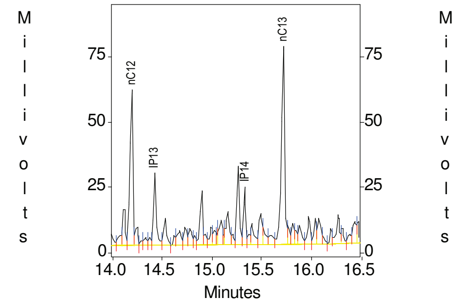
Torkelson Geochemistry, Inc.

Sunoco Philadelphia Refinery, AOI-7
Sample ID : Gas/Dies/Wax std
Acquired : Jan 24, 2012 13:30:21

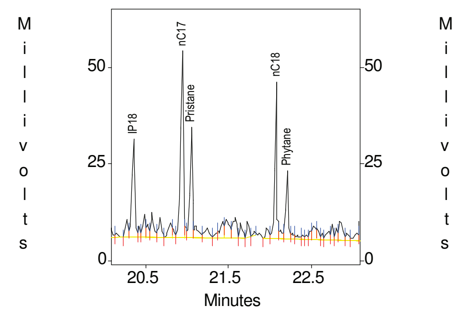
c:\ezchrom\chrom\12005\gadiwax2.2 -- Channel A



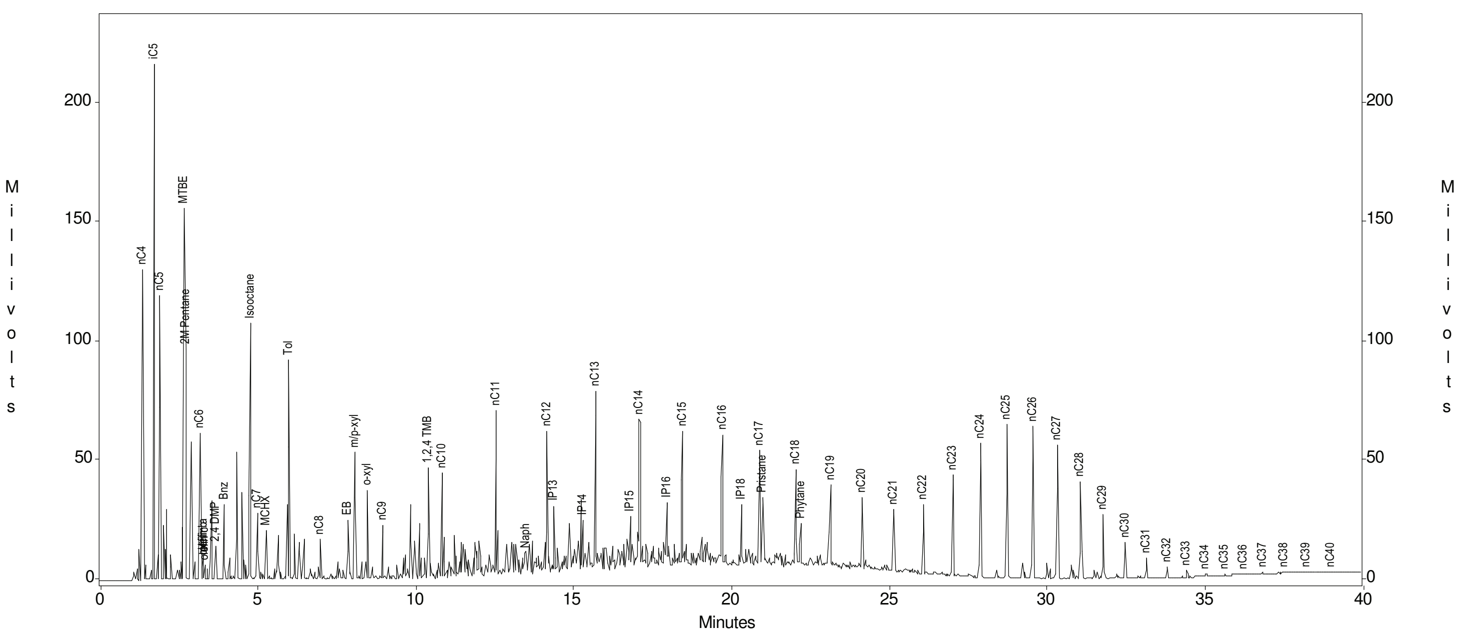
c:\ezchrom\chrom\12005\gadiwax2.2 -- Channel A



c:\ezchrom\chrom\12005\gadiwax2.2 -- Channel A



c:\ezchrom\chrom\12005\gadiwax2.2 -- Channel A



Channel A Results

Peak	Area	Height
nC4	73677	129792
iC5	145823	215819
nC5	85492	119411
MTBE	151834	155860
2M Pentane	85085	96815
nC6	61598	61432
olefin a	10809	10081
olefin b	7874	8007
olefin c	6846	5946
2,4 DMP	14668	14373
Bnz	39340	31842
Isooctane	167239	107228
nC7	35207	28244
MCHX	26058	20919
Tol	150402	91900
nC8	21004	16923
EB	36082	25246
m/p-xyl	134827	53054
o-xyl	58505	37390
nC9	32241	22687
1,2,4 TMB	86691	46650
nC10	71952	43762
nC11	127900	68904
Naph	31375	8295
nC12	119021	59727
IP13	52298	27730
IP14	37044	21964
nC13	160353	75839
IP15	35677	22111
nC14	140349	62687
IP16	61833	26272
nC15	123382	55956
nC16	121923	54574
IP18	54321	25492
nC17	106879	48520
Pristane	63743	28696
nC18	86076	40226
Phytane	37026	17440
nC19	73280	34629
nC20	55905	29936
nC21	47488	25689
nC22	59371	29366
nC23	97609	41933
nC24	153433	55661
nC25	188037	64550
nC26	198010	63488
nC27	155317	56010
nC28	100271	40467
nC29	56747	26733
nC30	26819	14455
nC31	14271	7815
nC32	7519	4349
nC33	4074	2417
nC34	2207	1225
nC35	1243	712
nC36	602	370
nC37	445	207
nC38	745	113
nC39	320	82
nC40	150	56

Torkelson Geochemistry, Inc.				
Density Measurements				
Paar DMA 512 / DMA 60			ASTM Method 4052	
Sample	Density gm/ml	Temp. of Measurement	Job Number	Date
C-147	0.8409	60F	12005	1/31/12
C-148	0.8512	60F	12005	1/31/12
C-150	0.8428	60F	12005	1/31/12
C-151	QNS	60F	12005	1/31/12
C-152	0.8597	60F	12005	1/31/12
C-153	0.8620	60F	12005	1/31/12
C-154	0.8807	60F	12005	1/31/12
C-161	0.8737	60F	12005	1/31/12
C-162	0.8833	60F	12005	1/31/12
C-166	0.8486	60F	12005	1/31/12
C-167	0.8601	60F	12005	1/31/12
C-168	0.8487	60F	12005	1/31/12

Sunoco Refinery - Philadelphia						
TGI Job 12005	AOI-7					
Interpretation of Product Type(s), Proportions and Weathering				Similarities to Other Samples in this Study		
Sample	Product Type(s)	Proportions	Weathering	Quite Similar to	Fairly Similar to	Somewhat Similar to
C-147	Light Crude Oil	100%	Severe		C-148 & C-166	C-152
C-148	Light Crude Oil	100%	Severe		C-147 & C-166	C-152
C-150	Light Crude Oil	100%	Extreme-Severe	Unique		
C-151	Light Crude Oil	100%	Extreme-Severe		C-154 & C-161	C-167
C-152	Light Crude Oil	100%	Severe			C-147, C-148 & C-166
C-153	Light Crude Oil	100%	Extreme	Unique		
C-154	Light Crude Oil	100%	Extreme		C-151 & C-161	C-167
C-161	Light Crude Oil	100%	Extreme		C-154 & C-151	C-157
C-162	Light Crude Oil	100%	Extreme	Unique		
C-166	Light Crude Oil	100%	Severe		C-147 & C-148	C-152
C-167	Light Crude Oil	100%	Extreme			C-151, C-154 & C-161
C-168	Very Light Crude Oil	100%	High-Severe	Unique		

van Genuchten-Mualem Model of LNAPL Distribution and Relative Permeability

Enter Data in Yellow Region

Maximum Monitoring Well LNAPL Thickness (meters)		Gauged January 2012	
		AOI 7 / C-65	
b_o =	0.323	1.060	feet

Soil Characteristic		**(SW)g**
n =	0.328	porosity
N =	1.550	van Genuchten "N"
α =	7.830	van Genuchten "α" [m^{-1}]
S_{wr} =	0.290	irreducible water saturation
S_{orv} =	0.000	residual LNAPL saturation (saturated)
S_{ors} =	0.000	residual LNAPL saturation (vadose)

Fluid Characteristics:		**Lubrication Oil**
ρ_o =	0.9126	LNAPL density (gm/cc)
σ_{aw} =	65.000	air/water (dynes/cm)
σ_{ao} =	31.000	air/oil (dynes/cm)
σ_{ow} =	24.400	oil/water (dynes/cm)

Calculated Parameters		
M =	0.355	van Genuchten "M"
α_{ao} =	14.983	air/LNAPL "α"
α_{ow} =	1.823	LNAPL/water "α"
z_{ao} =	0.028	elevation of air-LNAPL interface
z_{ow} =	-0.295	elevation of LNAPL-water interface
z_{max} =	0.078	maximum free-product elevation
λ =	0.472	pore-size distribution index
Ψ_b =	0.084	B-C displacement pressure head [m]

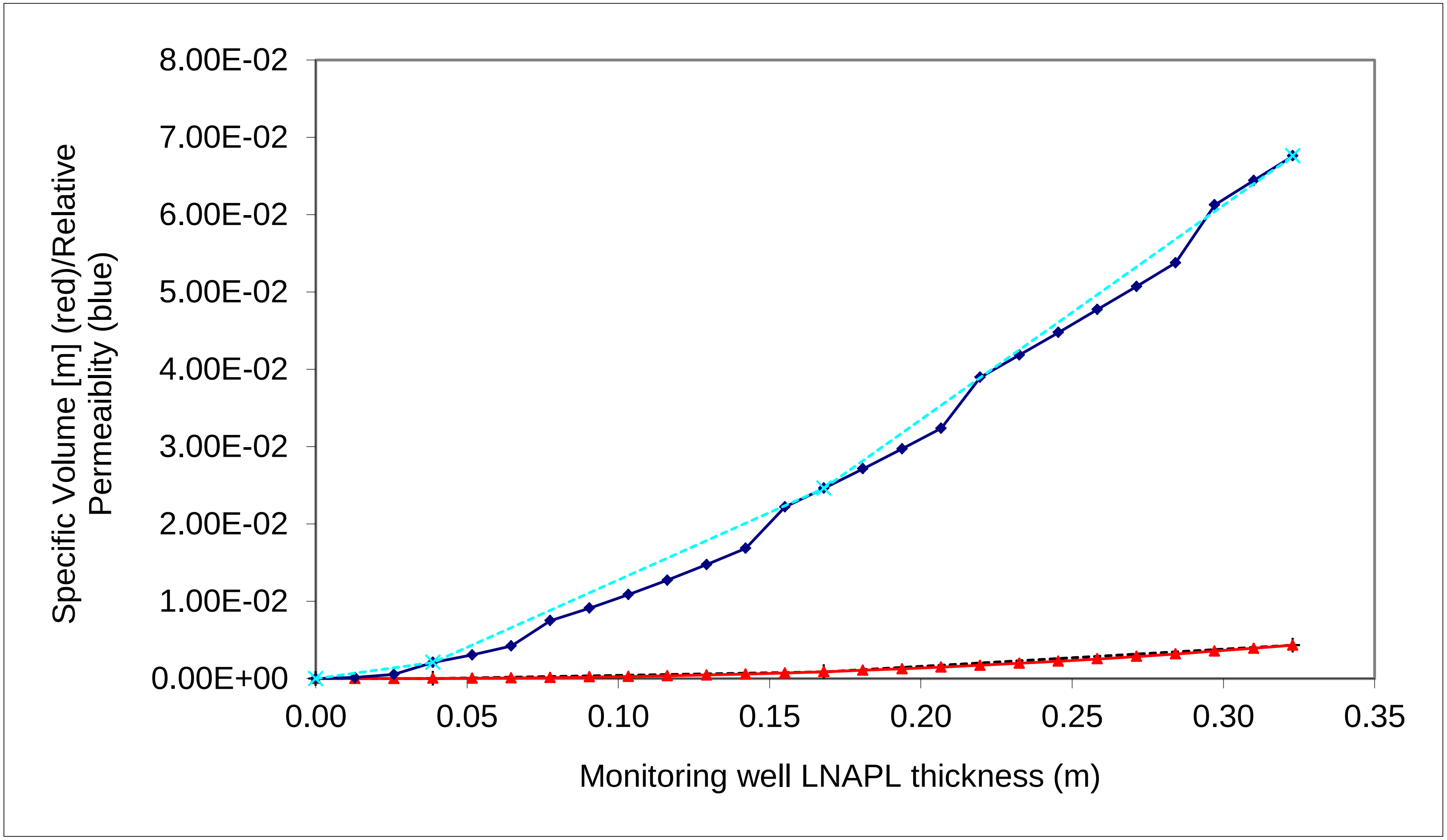
Press Ctrl+Shift+S to calculate sheet

Press Ctrl+Shift+S to calculate sheet

Gauged January 2012

AOI 7 / C-65

Data for curve-fitting segments								
b_o	D_o	k_{ro}	α	β	ξ	η		
0.000	0.000	0.000						
0.039	0.000	0.002	0.0000	0.000516	0.0000	0.053982		
0.168	0.001	0.025	0.0358	0.006724	0.0268	0.174421	1	Eps-Do
0.323	0.004	0.068	0.1277	0.022051	0.0791	0.277231	1	Eps-kro



Monitoring Well LNAPL Thickness b_o (m) =			0.323	Gauged January 2012
D_o =	4.308E-03	k_{ro} =	6.761E-02	AOI 7 / C-65

Press Ctrl+Shift+S to calculate sheet

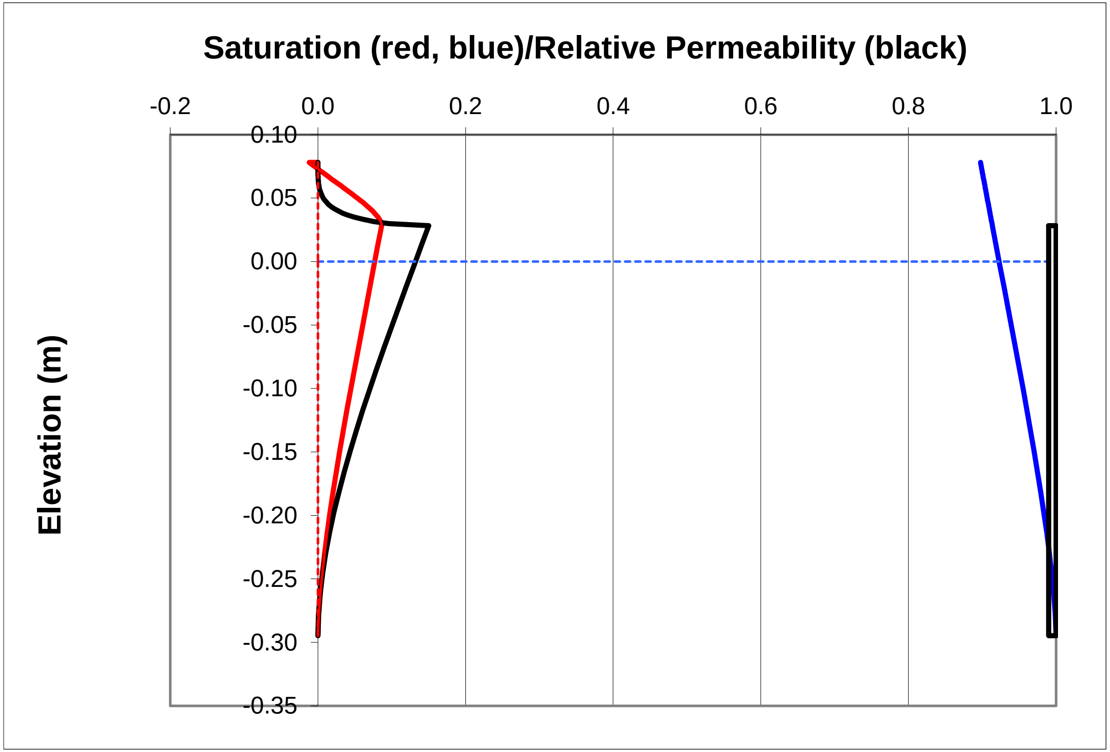


Figure H.02 C-106 LNAPL (vG-M)

van Genuchten-Mualem Model of LNAPL Distribution and Relative Permeability

Enter Data in Yellow Region

Maximum Monitoring Well LNAPL Thickness (meters)		Gauged January 2012	
		AOI 7 / C-106	
b_o =	1.760	0.536	feet

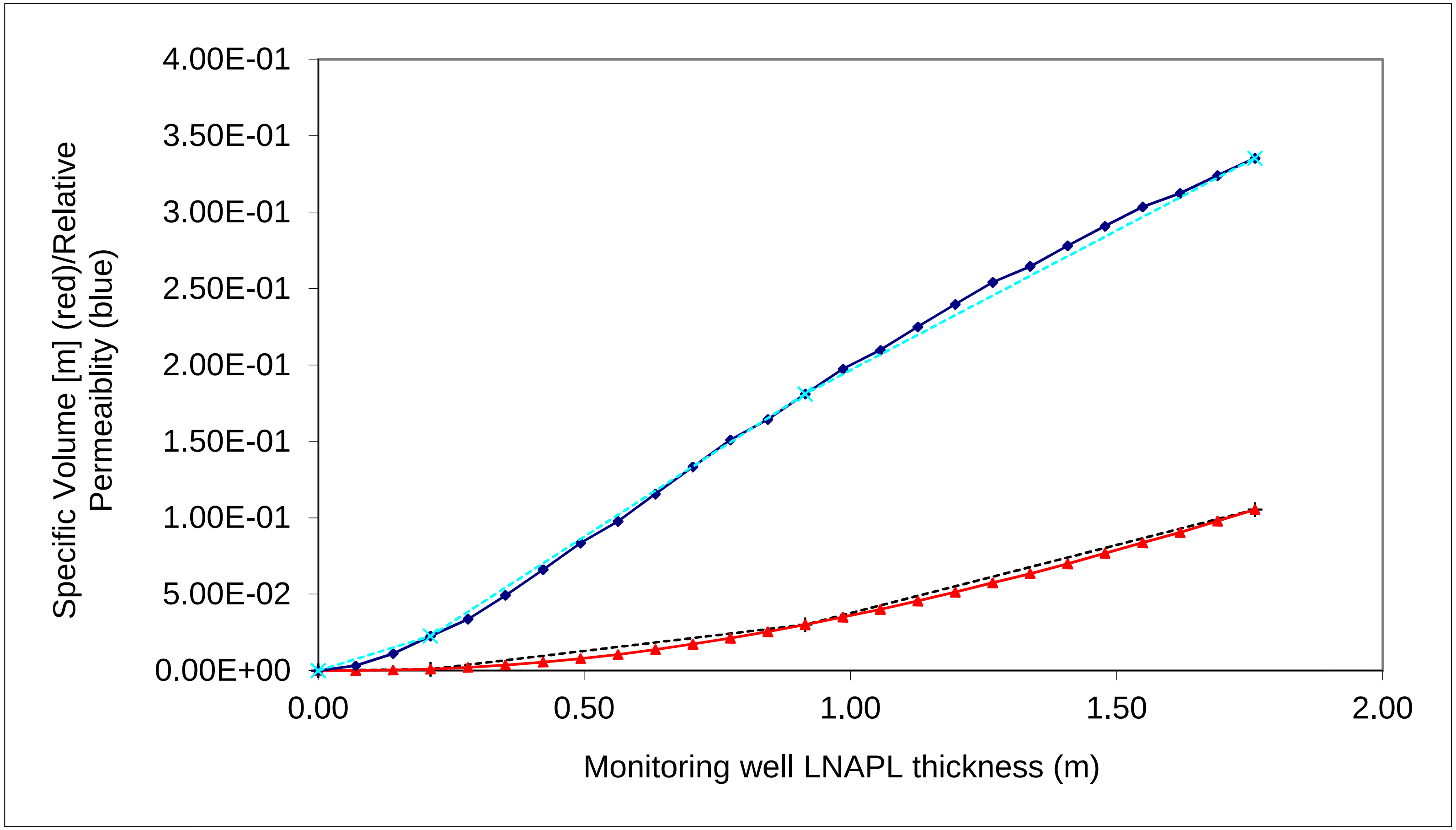
Soil Characteristic		**(SW)g**
n =	0.328	porosity
N =	1.550	van Genuchten "N"
α =	7.830	van Genuchten "α" [m^{-1}]
S_{wr} =	0.290	irreducible water saturation
S_{orv} =	0.000	residual LNAPL saturation (saturated)
S_{ors} =	0.000	residual LNAPL saturation (vadose)

Fluid Characteristics:		**Lubrication Oil**
ρ_o =	0.9306	LNAPL density (gm/cc)
σ_{aw} =	65.000	air/water (dynes/cm)
σ_{ao} =	31.000	air/oil (dynes/cm)
σ_{ow} =	24.400	oil/water (dynes/cm)

Calculated Parameters		
M =	0.355	van Genuchten "M"
α_{ao} =	15.278	air/LNAPL "α"
α_{ow} =	1.448	LNAPL/water "α"
z_{ao} =	0.122	elevation of air-LNAPL interface
z_{ow} =	-1.638	elevation of LNAPL-water interface
z_{max} =	0.312	maximum free-product elevation
λ =	0.472	pore-size distribution index
Ψ_b =	0.084	B-C displacement pressure head [m]

Press Ctrl+Shift+S to calculate sheet

Data for curve-fitting segments			Press Ctrl+Shift+S to calculate sheet					
b_o	D_o	k_{ro}	α	β	ξ	η	Gauged January 2012	
0.000	0.000	0.000					AOI 7 / C-106	
0.211	0.001	0.023	0.0000	0.004752	0.0000	0.106751		
0.915	0.030	0.181	0.1869	0.041297	0.1111	0.225239	1	Eps-Do
1.760	0.105	0.335	0.5779	0.089172	-0.0767	0.182595	1	Eps-kro



Monitoring Well LNAPL Thickness b_o (m) =			1.760	Gauged January 2012
D_o =	1.054E-01	k_{ro} =	3.354E-01	AOI 7 / C-106

Press Ctrl+Shift+S to calculate sheet

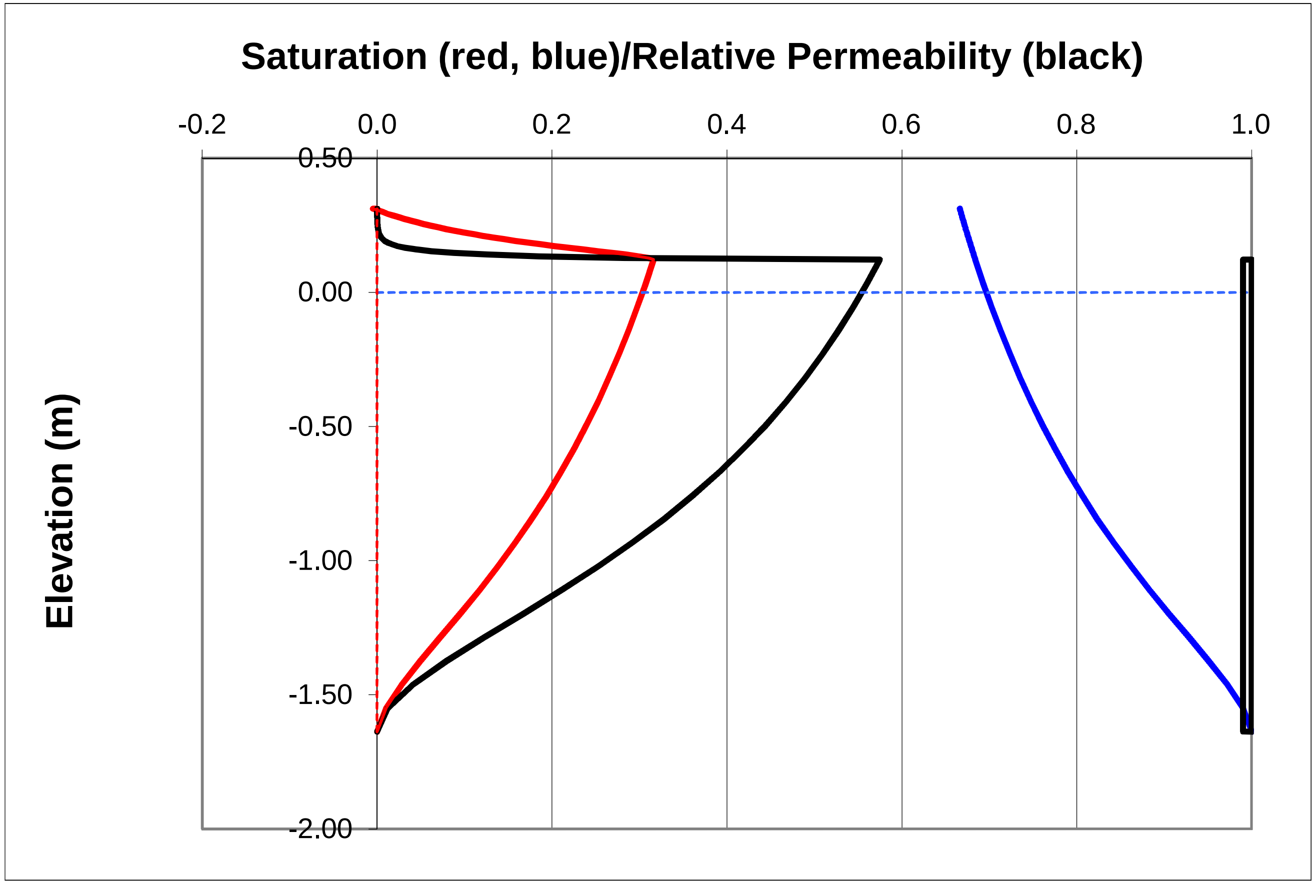


Figure H.03 C-107 LNAPL (vG-M)

van Genuchten-Mualem Model of LNAPL Distribution and Relative Permeability

Enter Data in Yellow Region

Maximum Monitoring Well LNAPL Thickness (meters)		Gauged January 2012	
		AOI 7 / C-107	
b_o =	0.101	0.330	feet

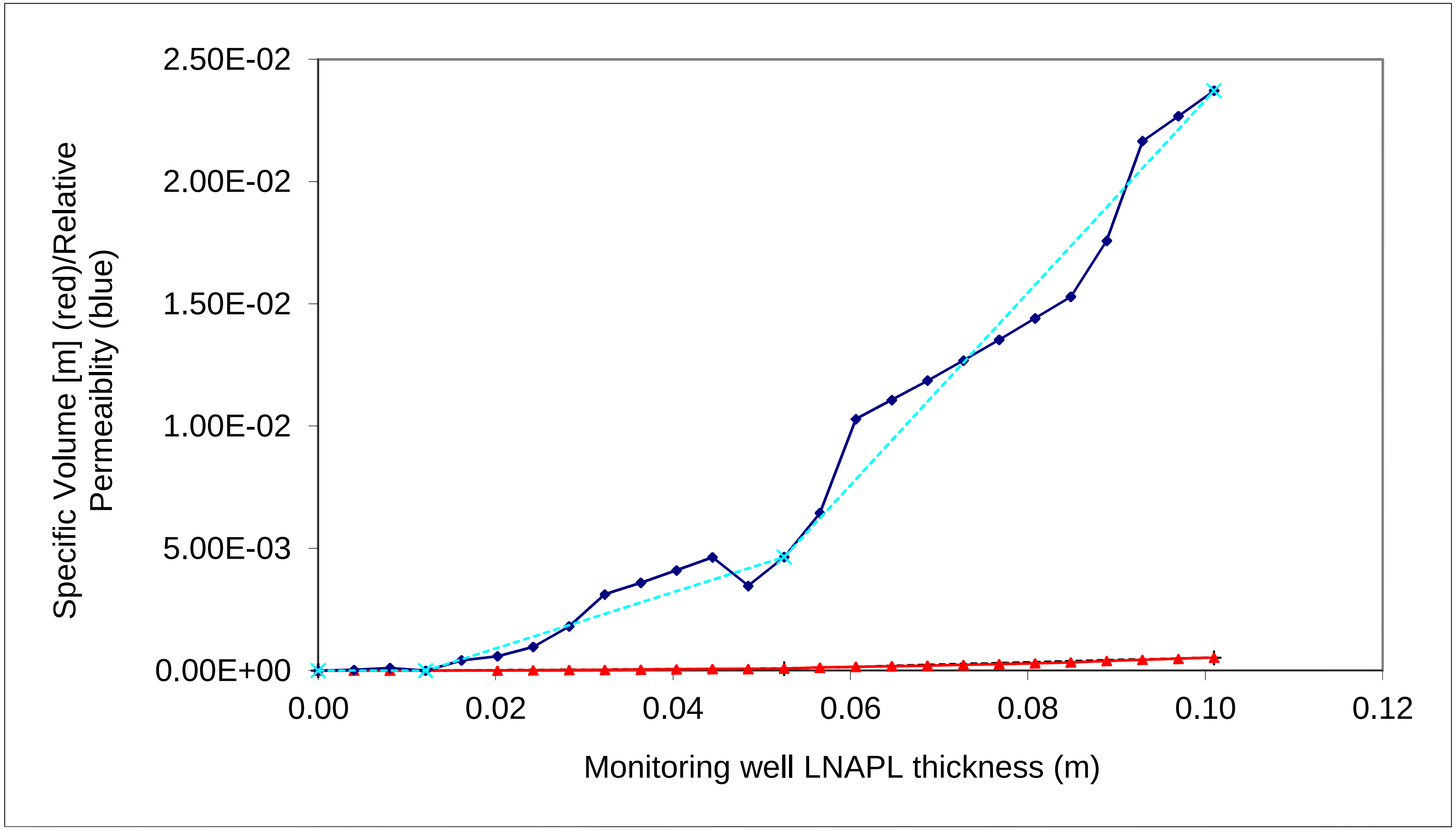
Soil Characteristic		**(GP)s**
n =	0.328	porosity
N =	1.550	van Genuchten "N"
α =	7.830	van Genuchten "α" [m^{-1}]
S_{wr} =	0.290	irreducible water saturation
S_{orv} =	0.000	residual LNAPL saturation (saturated)
S_{ors} =	0.000	residual LNAPL saturation (vadose)

Fluid Characteristics:		**Residual Oil**
ρ_o =	0.8487	LNAPL density (gm/cc)
σ_{aw} =	65.000	air/water (dynes/cm)
σ_{ao} =	32.100	air/oil (dynes/cm)
σ_{ow} =	30.200	oil/water (dynes/cm)

Calculated Parameters		
M =	0.355	van Genuchten "M"
α_{ao} =	13.456	air/LNAPL "α"
α_{ow} =	2.550	LNAPL/water "α"
z_{ao} =	0.015	elevation of air-LNAPL interface
z_{ow} =	-0.086	elevation of LNAPL-water interface
z_{max} =	0.045	maximum free-product elevation
λ =	0.472	pore-size distribution index
Ψ_b =	0.084	B-C displacement pressure head [m]

Press Ctrl+Shift+S to calculate sheet

Data for curve-fitting segments			Press Ctrl+Shift+S to calculate sheet					
b_o	D_o	k_{ro}	α	β	ξ	η	**Gauged January 2012**	
0.000	0.000	0.000					**AOI 7 / C-107**	
0.012	0.000	#VALUE!	#DIV/0!	0.000000	#VALUE!	#VALUE!		
0.053	0.000	0.005	0.0148	0.002266	#VALUE!	#VALUE!	1	Eps-Do
0.101	0.001	0.024	0.0432	0.009213	0.0407	0.393494	1	Eps-kro



Monitoring Well LNAPL Thickness b_o (m) =			0.101	Gauged January 2012
	D_o = 5.321E-04	k_{ro} =	2.372E-02	AOI 7 / C-107

Press Ctrl+Shift+S to calculate sheet

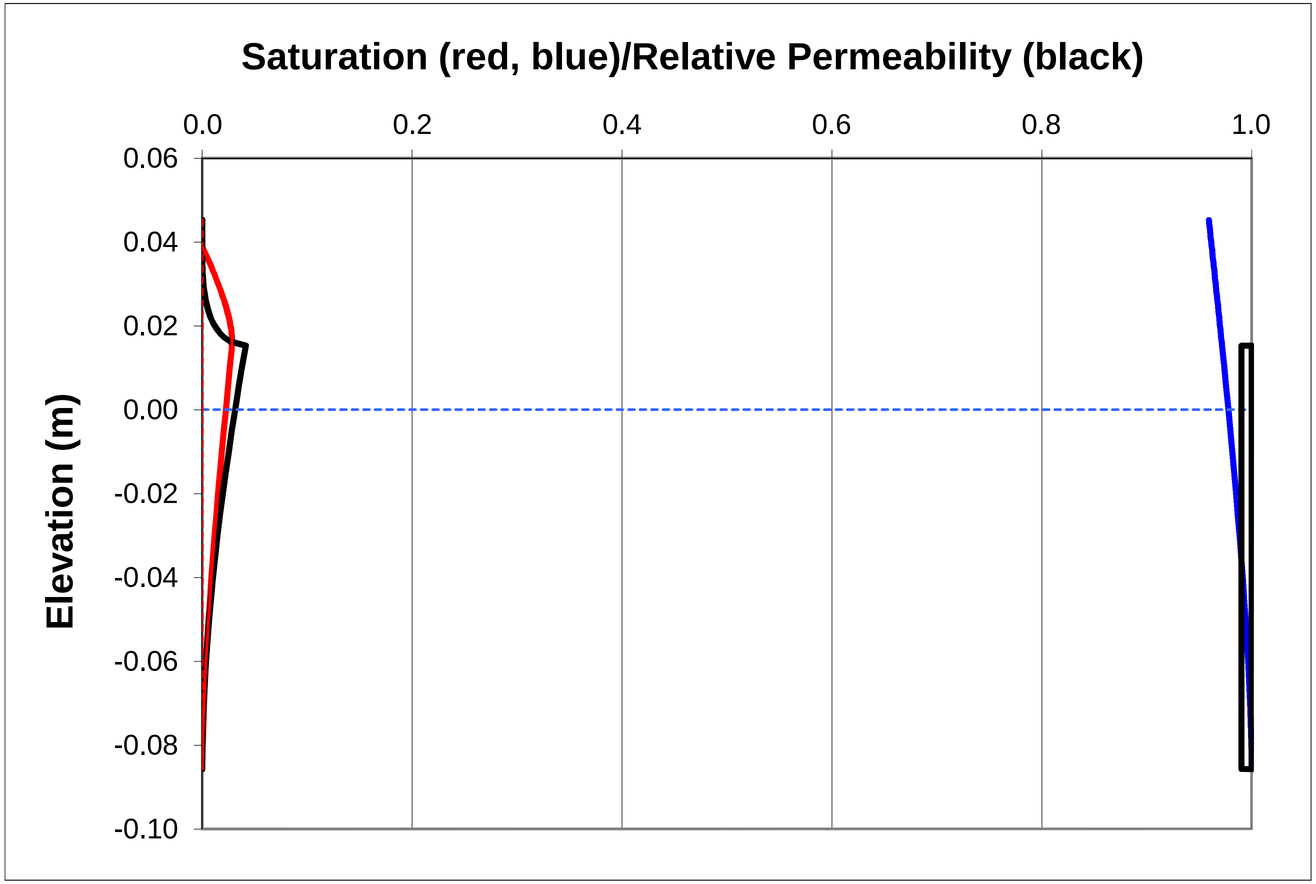


Figure H.04 C-143 LNAPL (vG-M)

van Genuchten-Mualem Model of LNAPL Distribution and Relative Permeability

Enter Data in Yellow Region

Maximum Monitoring Well LNAPL Thickness (meters)		Gauged January 2012	
		AOI 7 / C-143	
b_o =	0.735	2.410	feet

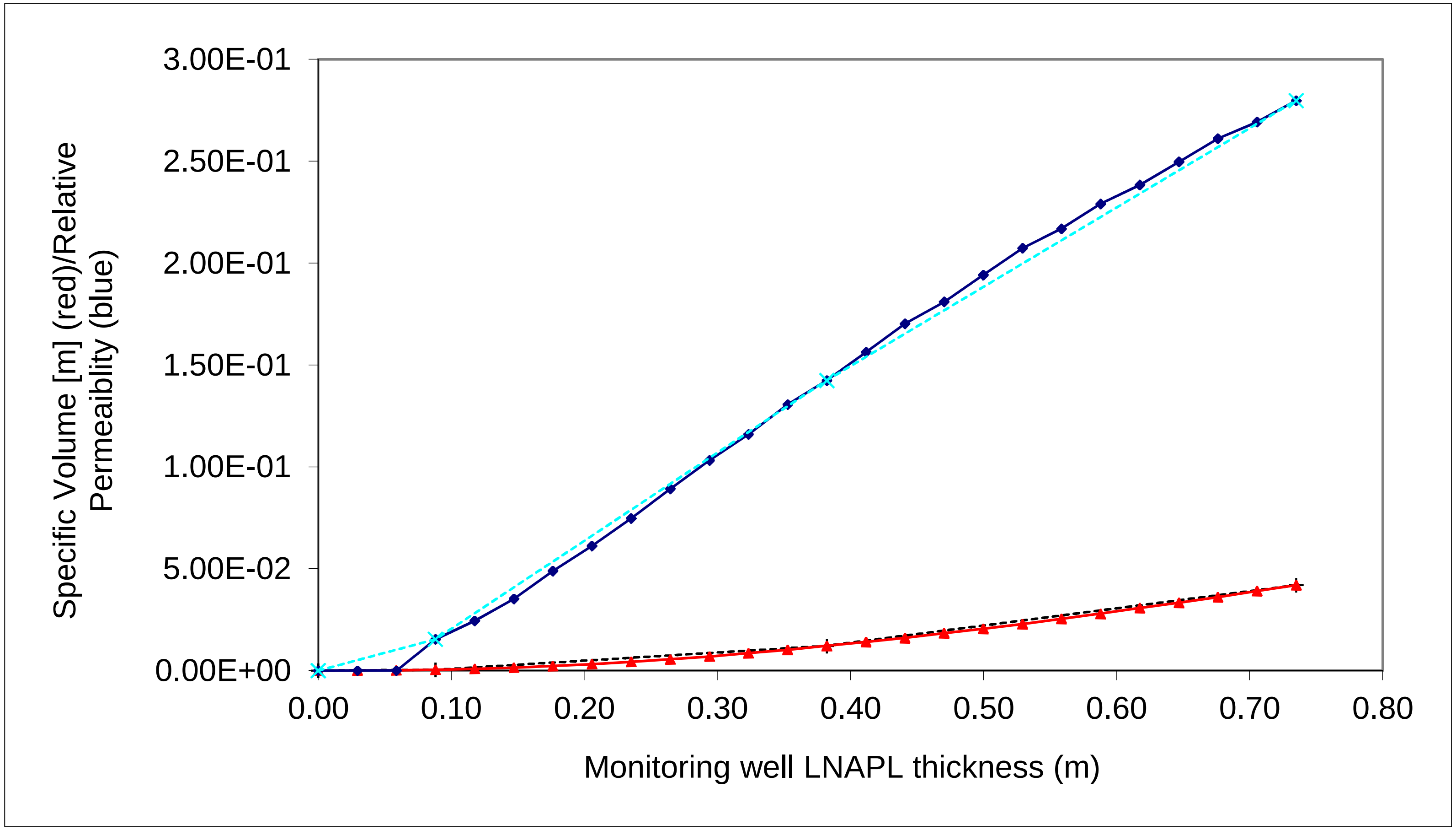
Soil Characteristic		**(SW)g**
n =	0.328	porosity
N =	1.550	van Genuchten "N"
α =	7.830	van Genuchten "α" [m^{-1}]
S_{wr} =	0.290	irreducible water saturation
S_{orv} =	0.000	residual LNAPL saturation (saturated)
S_{ors} =	0.000	residual LNAPL saturation (vadose)

Fluid Characteristics:		**Middle Distillate**
ρ_o =	0.8676	LNAPL density (gm/cc)
σ_{aw} =	65.000	air/water (dynes/cm)
σ_{ao} =	27.300	air/oil (dynes/cm)
σ_{ow} =	24.000	oil/water (dynes/cm)

Calculated Parameters		
M =	0.355	van Genuchten "M"
α_{ao} =	16.175	air/LNAPL "α"
α_{ow} =	2.808	LNAPL/water "α"
z_{ao} =	0.097	elevation of air-LNAPL interface
z_{ow} =	-0.638	elevation of LNAPL-water interface
z_{max} =	0.257	maximum free-product elevation
λ =	0.472	pore-size distribution index
Ψ_b =	0.084	B-C displacement pressure head [m]

Press Ctrl+Shift+S to calculate sheet

Data for curve-fitting segments				Press Ctrl+Shift+S to calculate sheet				
b_o	D_o	k_{ro}	α	β	ξ	η	Gauged January 2012	
0.000	0.000	0.000					AOI 7 / C-143	
0.088	0.000	0.015	0.0000	0.004730	0.0000	0.173826		
0.382	0.012	0.142	0.0777	0.039829	0.0527	0.432181	0.1	Eps-Do
0.735	0.042	0.280	0.2386	0.084424	0.0166	0.389518	0.1	Eps-kro



Monitoring Well LNAPL Thickness b_o (m) =		0.735	Gauged January 2012
D_o = 4.191E-02	$\underline{k}_{ro}$ =	2.798E-01	AOI 7 / C-143

Press Ctrl+Shift+S to calculate sheet

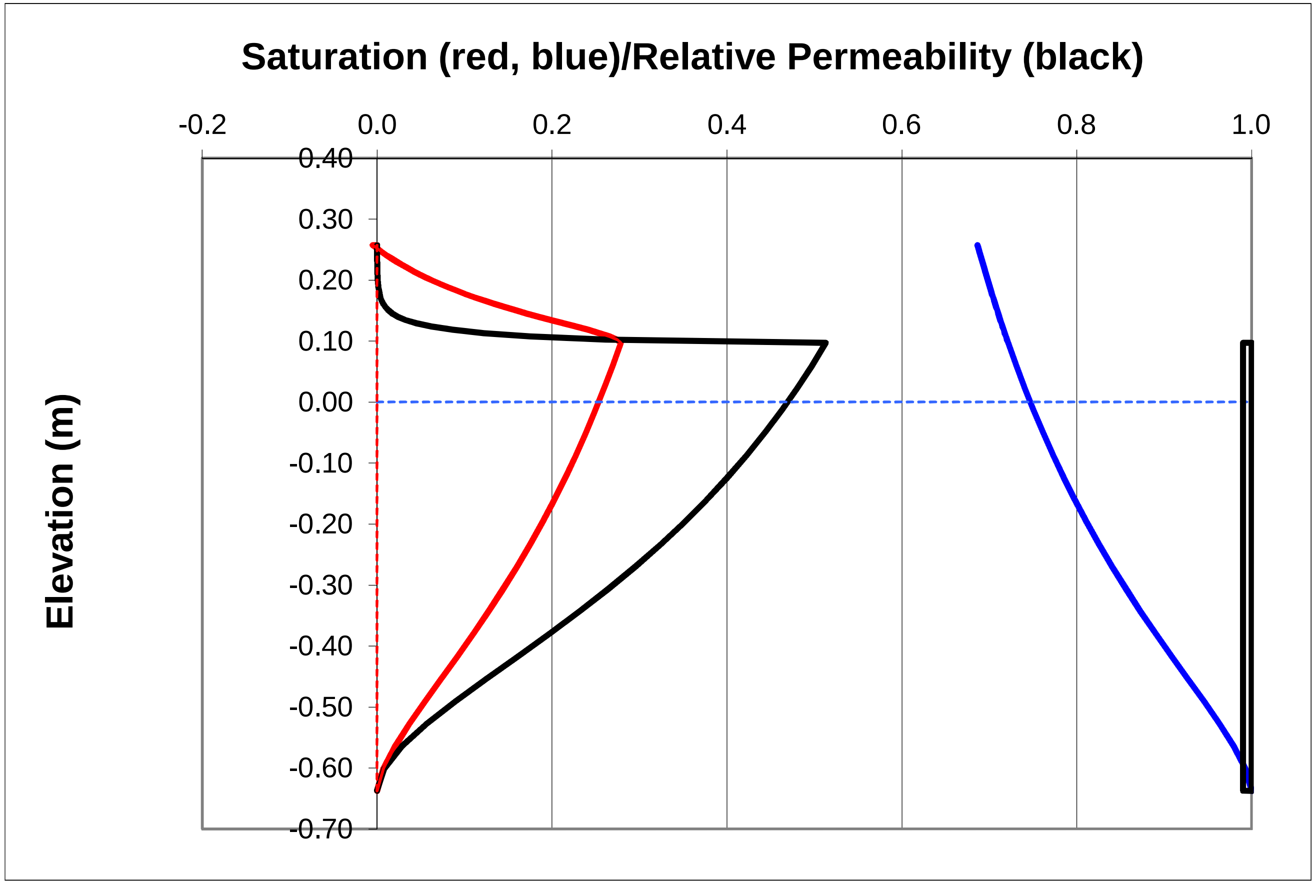


Figure H.05 C-64 LNAPL (vG-M)

van Genuchten-Mualem Model of LNAPL Distribution and Relative Permeability

Enter Data in Yellow Region

Maximum Monitoring Well LNAPL Thickness (meters)		Gauged January 2012	
		AOI 7 / C-64	
b_o =	0.344	1.130	feet

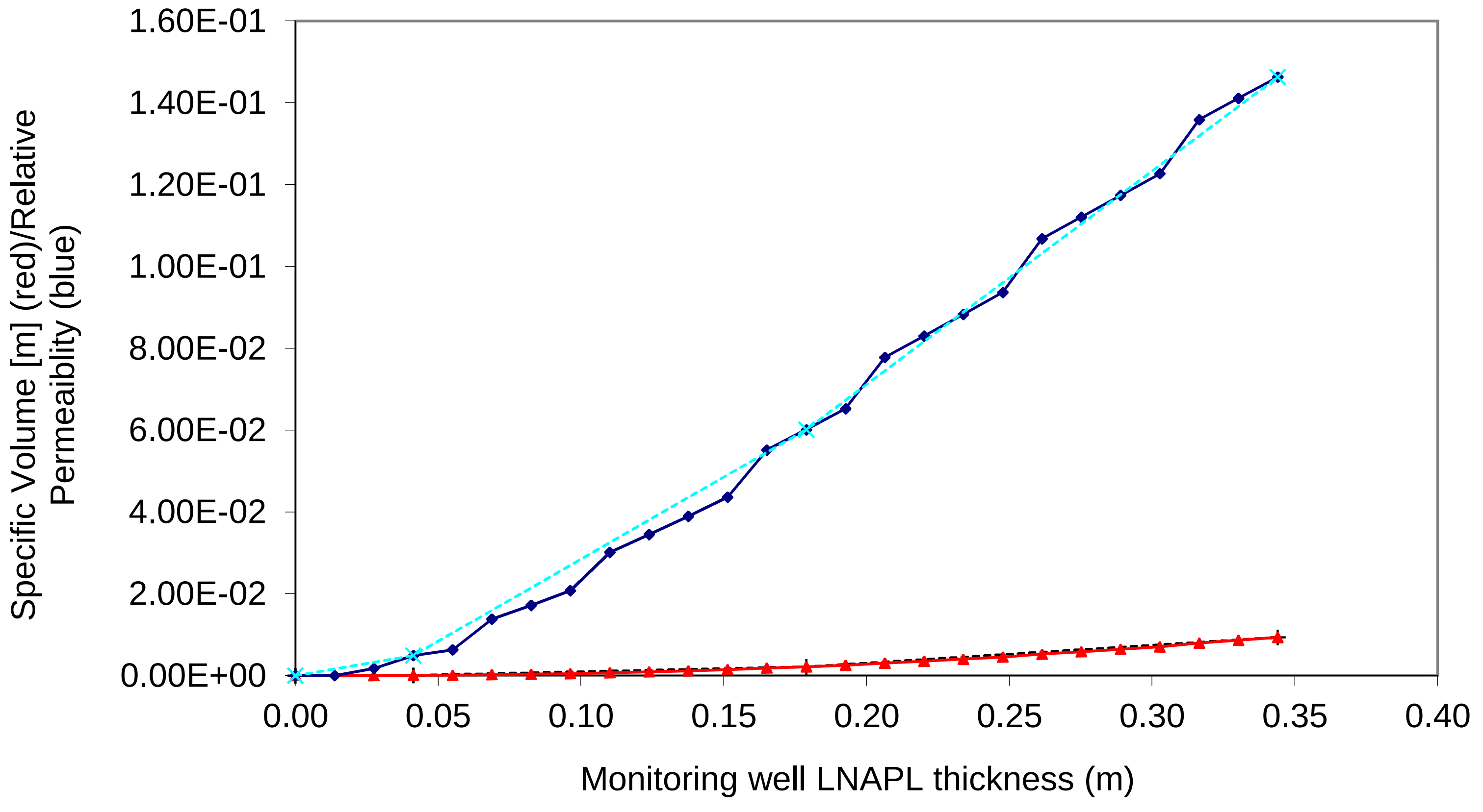
Soil Characteristic		**(SW)g**
n =	0.328	porosity
N =	1.550	van Genuchten "N"
α =	7.830	van Genuchten "α" [m^{-1}]
S_{wr} =	0.290	irreducible water saturation
S_{orv} =	0.000	residual LNAPL saturation (saturated)
S_{ors} =	0.000	residual LNAPL saturation (vadose)

Fluid Characteristics:		**Light Crude**
ρ_o =	0.8807	LNAPL density (gm/cc)
σ_{aw} =	65.000	air/water (dynes/cm)
σ_{ao} =	26.600	air/oil (dynes/cm)
σ_{ow} =	21.900	oil/water (dynes/cm)

Calculated Parameters		
M =	0.355	van Genuchten "M"
α_{ao} =	16.851	air/LNAPL "α"
α_{ow} =	2.772	LNAPL/water "α"
z_{ao} =	0.041	elevation of air-LNAPL interface
z_{ow} =	-0.303	elevation of LNAPL-water interface
z_{max} =	0.111	maximum free-product elevation
λ =	0.472	pore-size distribution index
Ψ_b =	0.084	B-C displacement pressure head [m]

Press Ctrl+Shift+S to calculate sheet

Data for curve-fitting segments			Press Ctrl+Shift+S to calculate sheet					
b_o	D_o	k_{ro}	α	β	ξ	η	Gauged January 2012	
0.000	0.000	0.000					AOI 7 / C-64	
0.041	0.000	0.005	0.0000	0.001401	0.0000	0.119070		
0.179	0.002	0.060	0.0375	0.015290	0.0290	0.401224	1	Eps-Do
0.344	0.009	0.146	0.1293	0.043561	0.0637	0.521793	1	Eps-kro



2/14/2012

Monitoring Well LNAPL Thickness b_o (m) =			0.344	Gauged January 2012
D_o =	9.355E-03	k_{ro} =	1.463E-01	AOI 7 / C-64

Press Ctrl+Shift+S to calculate sheet

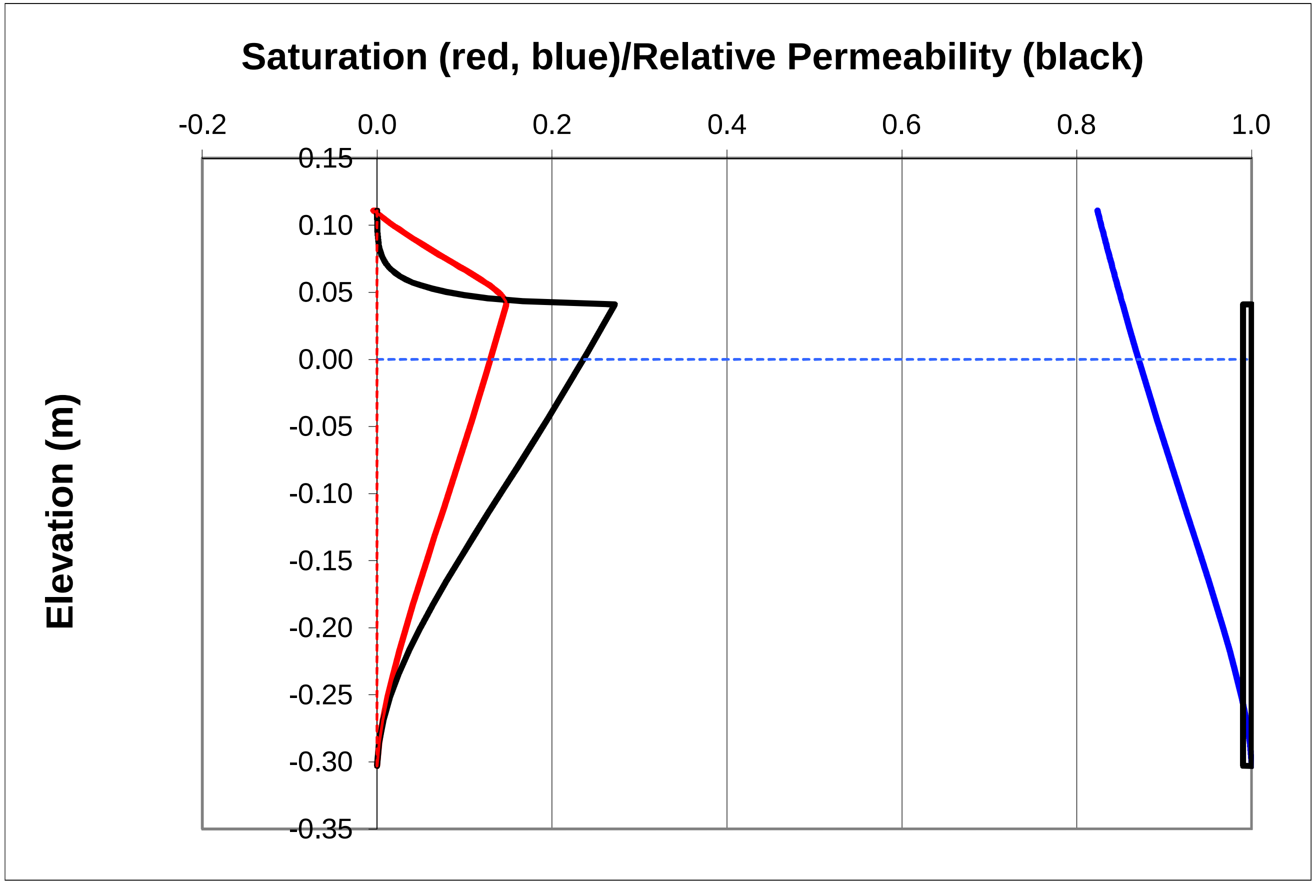


Figure H.06 C-97 LNAPL (vG-M)

van Genuchten-Mualem Model of LNAPL Distribution and Relative Permeability

Enter Data in Yellow Region

Maximum Monitoring Well LNAPL Thickness (meters)		Gauged January 2012	
		AOI 7 / C-97	
b_o =	0.034	0.110	feet

Soil Characteristic		**(SW)g**
n =	0.328	porosity
N =	1.550	van Genuchten "N"
α =	7.830	van Genuchten "α" [m^{-1}]
S_{wr} =	0.290	irreducible water saturation
S_{orv} =	0.000	residual LNAPL saturation (saturated)
S_{ors} =	0.000	residual LNAPL saturation (vadose)

Fluid Characteristics:		**Light Crude**
ρ_o =	0.8428	LNAPL density (gm/cc)
σ_{aw} =	65.000	air/water (dynes/cm)
σ_{ao} =	26.600	air/oil (dynes/cm)
σ_{ow} =	21.900	oil/water (dynes/cm)

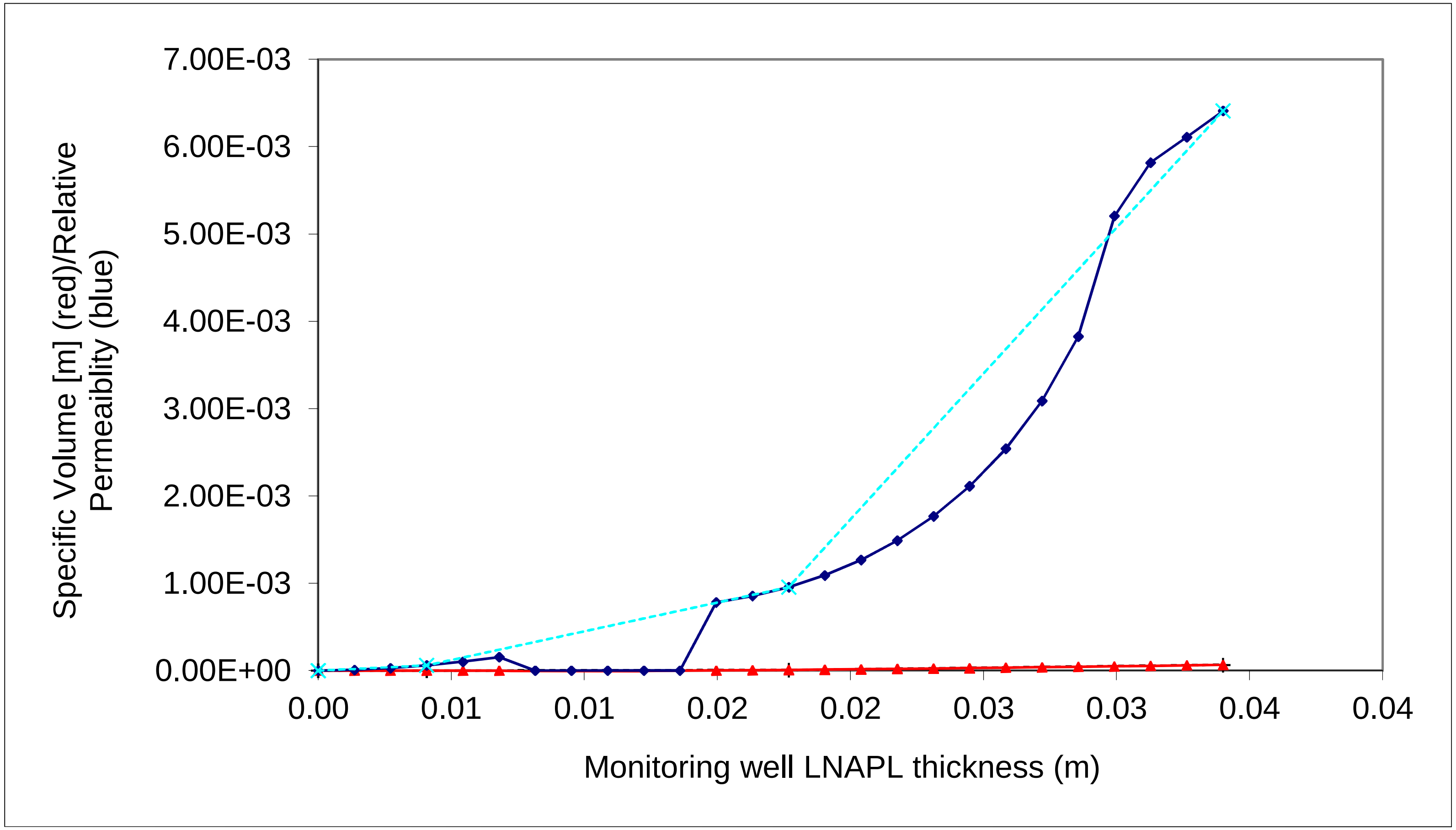
Calculated Parameters		
M =	0.355	van Genuchten "M"
α_{ao} =	16.126	air/LNAPL "α"
α_{ow} =	3.653	LNAPL/water "α"
z_{ao} =	0.005	elevation of air-LNAPL interface
z_{ow} =	-0.029	elevation of LNAPL-water interface
z_{max} =	0.015	maximum free-product elevation
λ =	0.472	pore-size distribution index
Ψ_b =	0.084	B-C displacement pressure head [m]

Press Ctrl+Shift+S to calculate sheet

Data for curve-fitting segments			Press Ctrl+Shift+S to calculate sheet					
b_o	D_o	k_{ro}	α	β	ξ	η		
0.000	0.000	0.000						
0.004	0.000	0.000	0.0000	0.000048	0.0000	0.014507		
0.018	0.000	0.001	0.0037	0.000529	0.0032	0.065887	1	Eps-Do
0.034	0.000	0.006	0.0156	0.003512	0.0148	0.334233	1	Eps-kro

Gauged January 2012

AOI 7 / C-97



2/14/2012

Monitoring Well LNAPL Thickness b_o (m) =			0.034	Gauged January 2012
D_o =	6.471E-05	k_{ro} =	6.410E-03	AOI 7 / C-97

Press Ctrl+Shift+S to calculate sheet

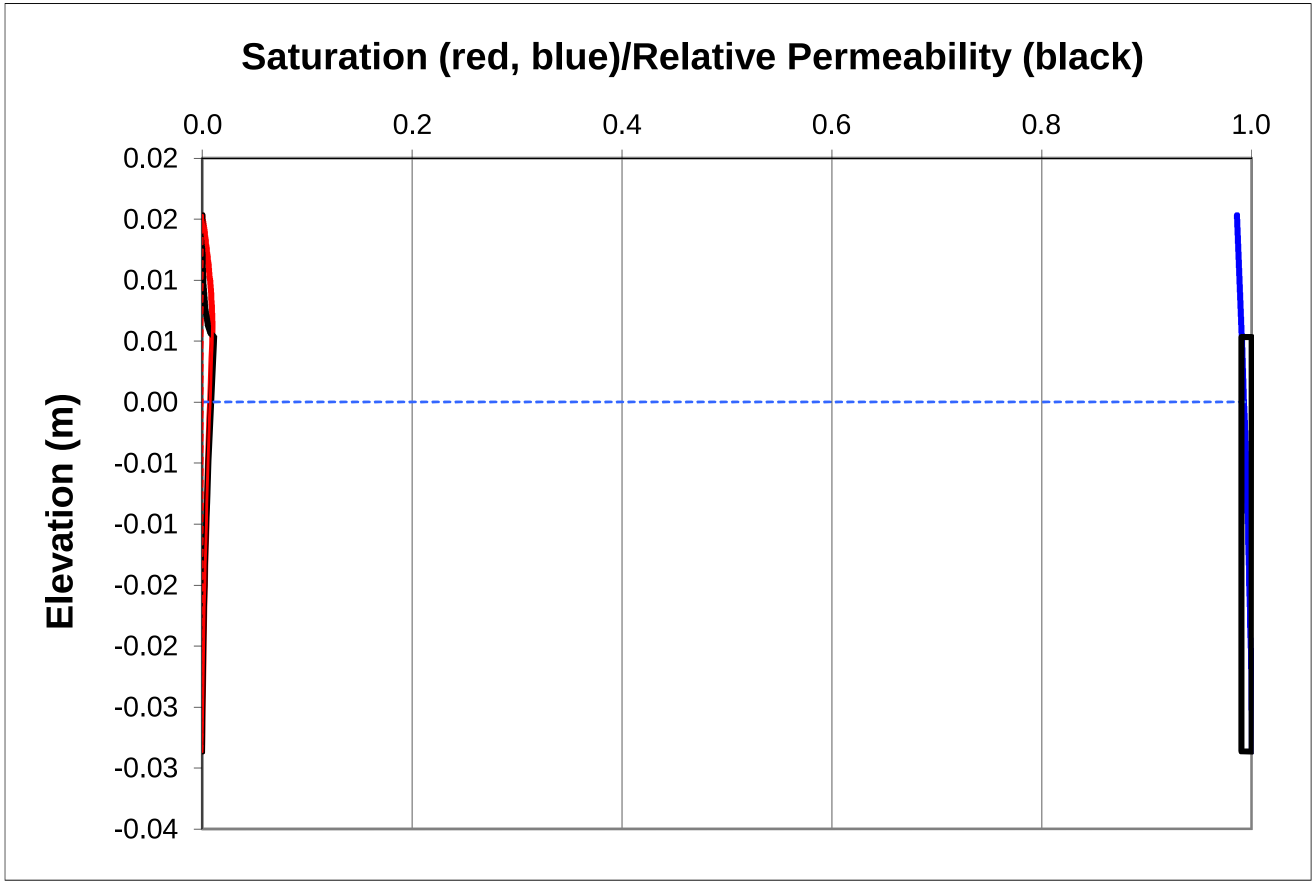


Figure H.07 C-147 LNAPL (vG-M)

van Genuchten-Mualem Model of LNAPL Distribution and Relative Permeability

Enter Data in Yellow Region

Maximum Monitoring Well LNAPL Thickness (meters)		Gauged January 2012	
		AOI 7 / C-147	
b_o =	1.009	3.310	feet

Soil Characteristic		**(SW)g**
n =	0.328	porosity
N =	1.550	van Genuchten "N"
α =	7.830	van Genuchten "α" $[m^{-1}]$
S_{wr} =	0.290	irreducible water saturation
S_{orv} =	0.000	residual LNAPL saturation (saturated)
S_{ors} =	0.000	residual LNAPL saturation (vadose)

Fluid Characteristics:		**Light Crude**
ρ_o =	0.8409	LNAPL density (gm/cc)
σ_{aw} =	65.000	air/water (dynes/cm)
σ_{ao} =	26.600	air/oil (dynes/cm)
σ_{ow} =	21.900	oil/water (dynes/cm)

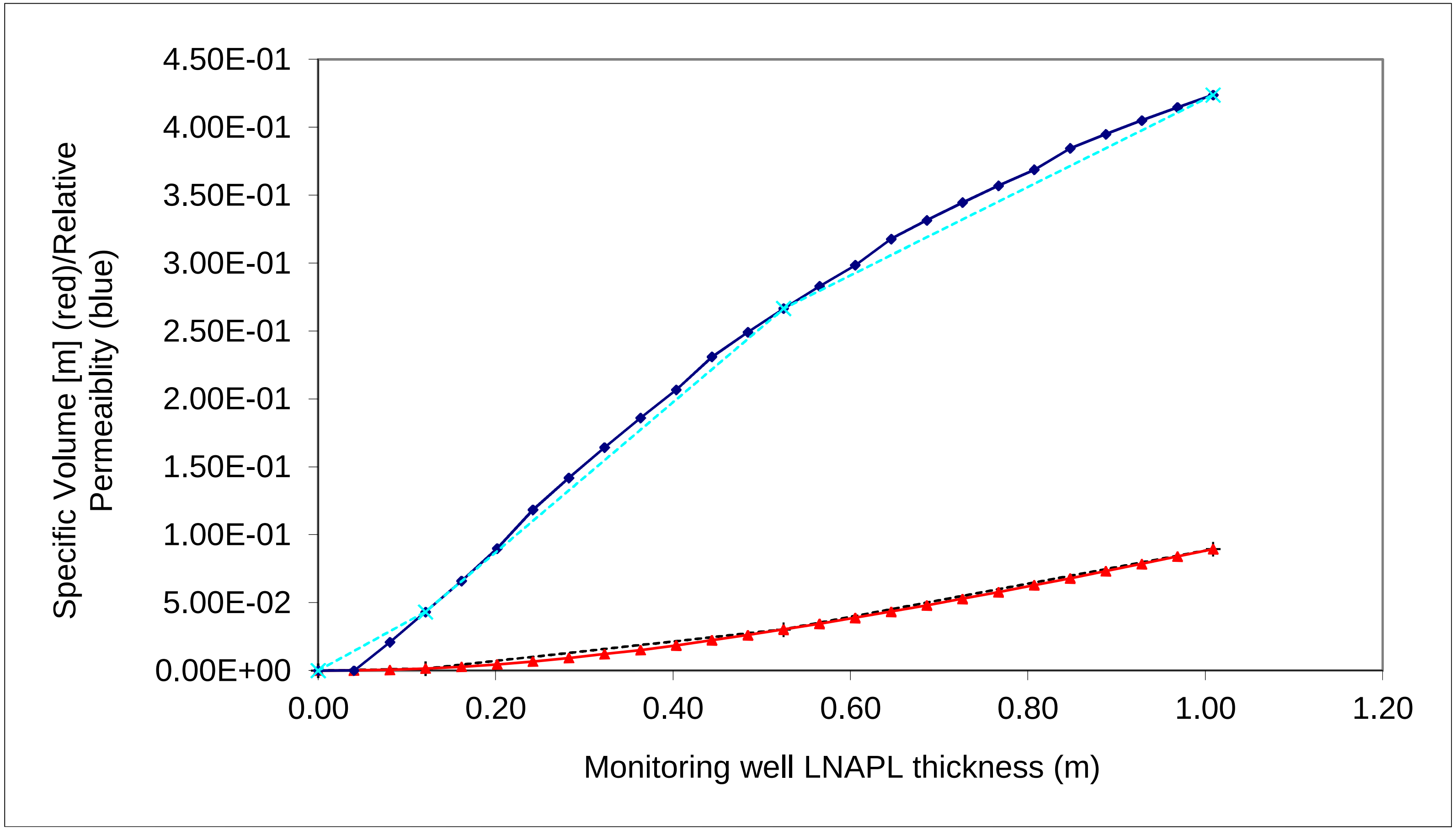
Calculated Parameters		
M =	0.355	van Genuchten "M"
α_{ao} =	16.089	air/LNAPL "α"
α_{ow} =	3.697	LNAPL/water "α"
z_{ao} =	0.161	elevation of air-LNAPL interface
z_{ow} =	-0.848	elevation of LNAPL-water interface
z_{max} =	0.461	maximum free-product elevation
λ =	0.472	pore-size distribution index
Ψ_b =	0.084	B-C displacement pressure head [m]

Press Ctrl+Shift+S to calculate sheet

Data for curve-fitting segments			Press Ctrl+Shift+S to calculate sheet					
b_o	D_o	k_{ro}	α	β	ξ	η		
0.000	0.000	0.000						
0.121	0.001	0.043	0.0000	0.011839	0.0000	0.356779		
0.525	0.030	0.267	0.1010	0.071411	0.0430	0.553362	0.1	Eps-Do
1.009	0.089	0.424	0.2772	0.122254	-0.2959	0.324829	0.1	Eps-kro

Gauged January 2012

AOI 7 / C-147



Monitoring Well LNAPL Thickness b_o (m) =			1.009	Gauged January 2012
	D_o = 8.947E-02	k_{ro} =	4.239E-01	AOI 7 / C-147

Press Ctrl+Shift+S to calculate sheet

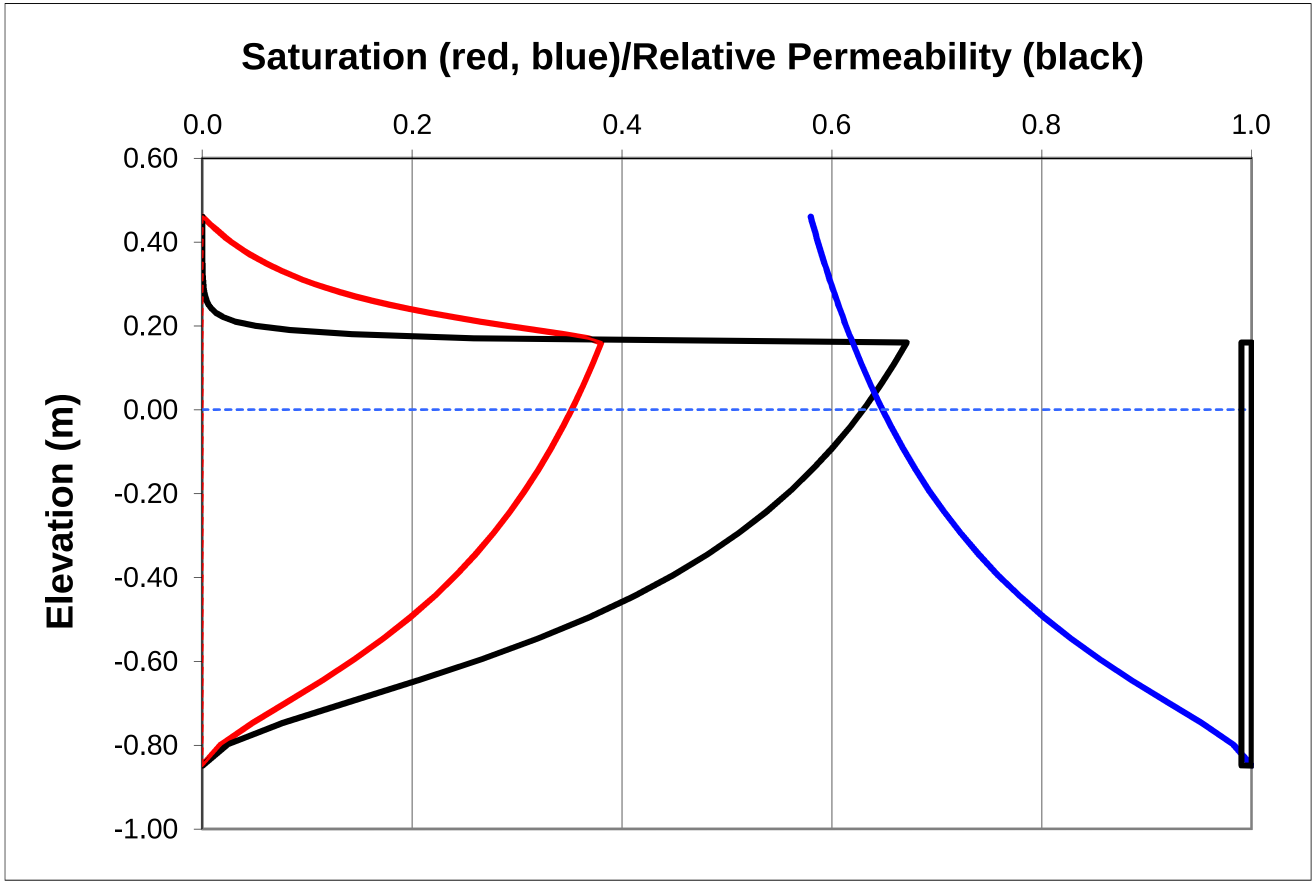


Figure H.08 C-148 LNAPL (vG-M)

van Genuchten-Mualem Model of LNAPL Distribution and Relative Permeability

Enter Data in Yellow Region

Maximum Monitoring Well LNAPL Thickness (meters)		Gauged January 2012	
		AOI 7 / C-148	
b_o =	1.618	5.310	feet

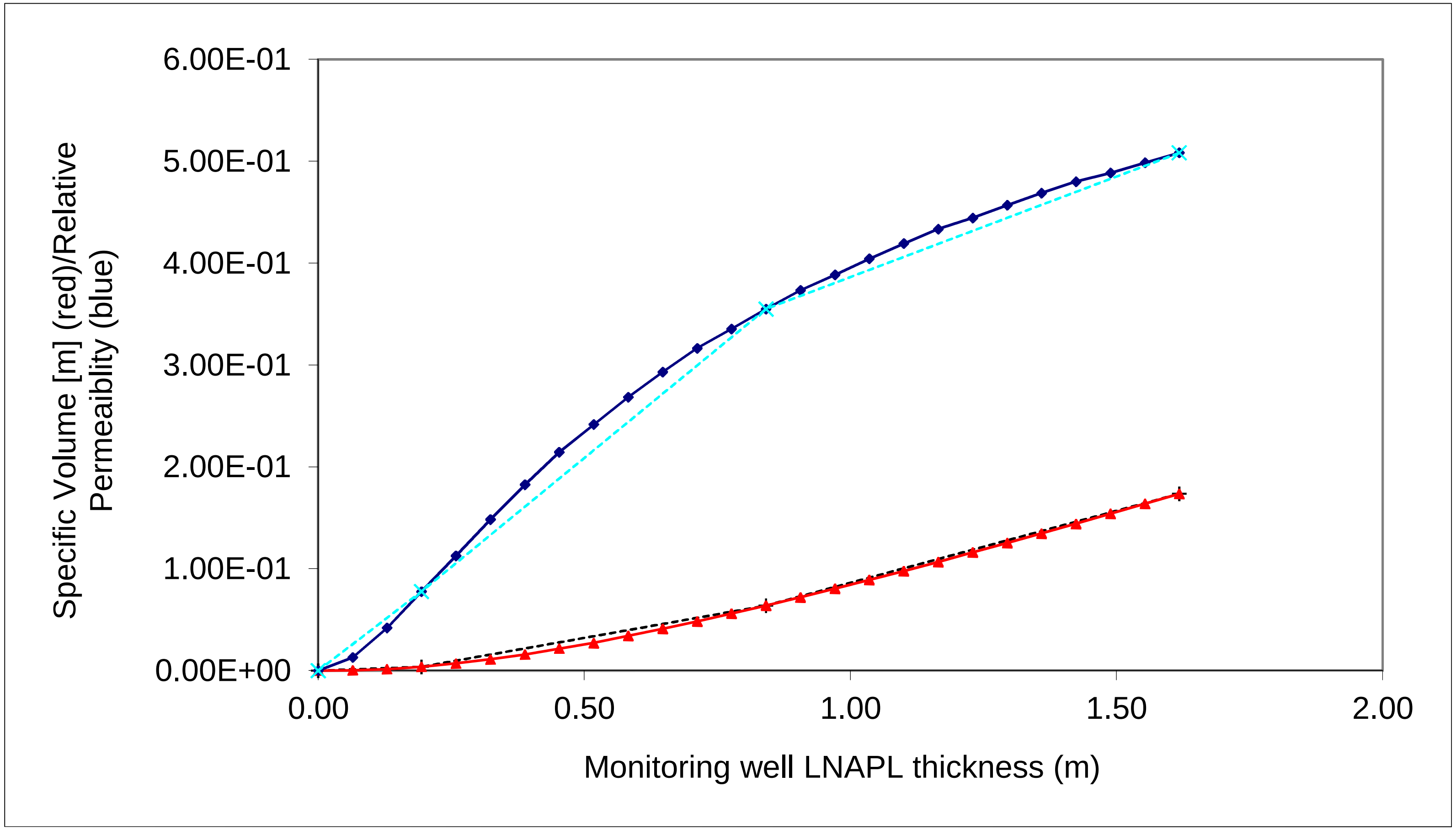
Soil Characteristic		**(SW)g**
n =	0.328	porosity
N =	1.550	van Genuchten "N"
α =	7.830	van Genuchten "α" [m^{-1}]
S_{wr} =	0.290	irreducible water saturation
S_{orv} =	0.000	residual LNAPL saturation (saturated)
S_{ors} =	0.000	residual LNAPL saturation (vadose)

Fluid Characteristics:		**Light Crude**
ρ_o =	0.8512	LNAPL density (gm/cc)
σ_{aw} =	65.000	air/water (dynes/cm)
σ_{ao} =	26.600	air/oil (dynes/cm)
σ_{ow} =	21.900	oil/water (dynes/cm)

Calculated Parameters		
M =	0.355	van Genuchten "M"
α_{ao} =	16.286	air/LNAPL "α"
α_{ow} =	3.458	LNAPL/water "α"
z_{ao} =	0.241	elevation of air-LNAPL interface
z_{ow} =	-1.377	elevation of LNAPL-water interface
z_{max} =	0.681	maximum free-product elevation
λ =	0.472	pore-size distribution index
Ψ_b =	0.084	B-C displacement pressure head [m]

Press Ctrl+Shift+S to calculate sheet

Data for curve-fitting segments				Press Ctrl+Shift+S to calculate sheet				
b_o	D_o	k_{ro}	α	β	ξ	η	**Gauged January 2012**	
0.000	0.000	0.000					**AOI 7 / C-148**	
0.194	0.004	0.078	0.0000	0.019207	0.0000	0.399809		
0.841	0.064	0.355	0.1540	0.092886	0.0130	0.428584	0.1	Eps-Do
1.618	0.174	0.508	0.3895	0.141286	-0.9572	0.197383	0.1	Eps-kro



Monitoring Well LNAPL Thickness b_o (m) =				1.618	Gauged January 2012
	D_o =	1.736E-01	k_{ro} =	5.083E-01	AOI 7 / C-148

Press Ctrl+Shift+S to calculate sheet

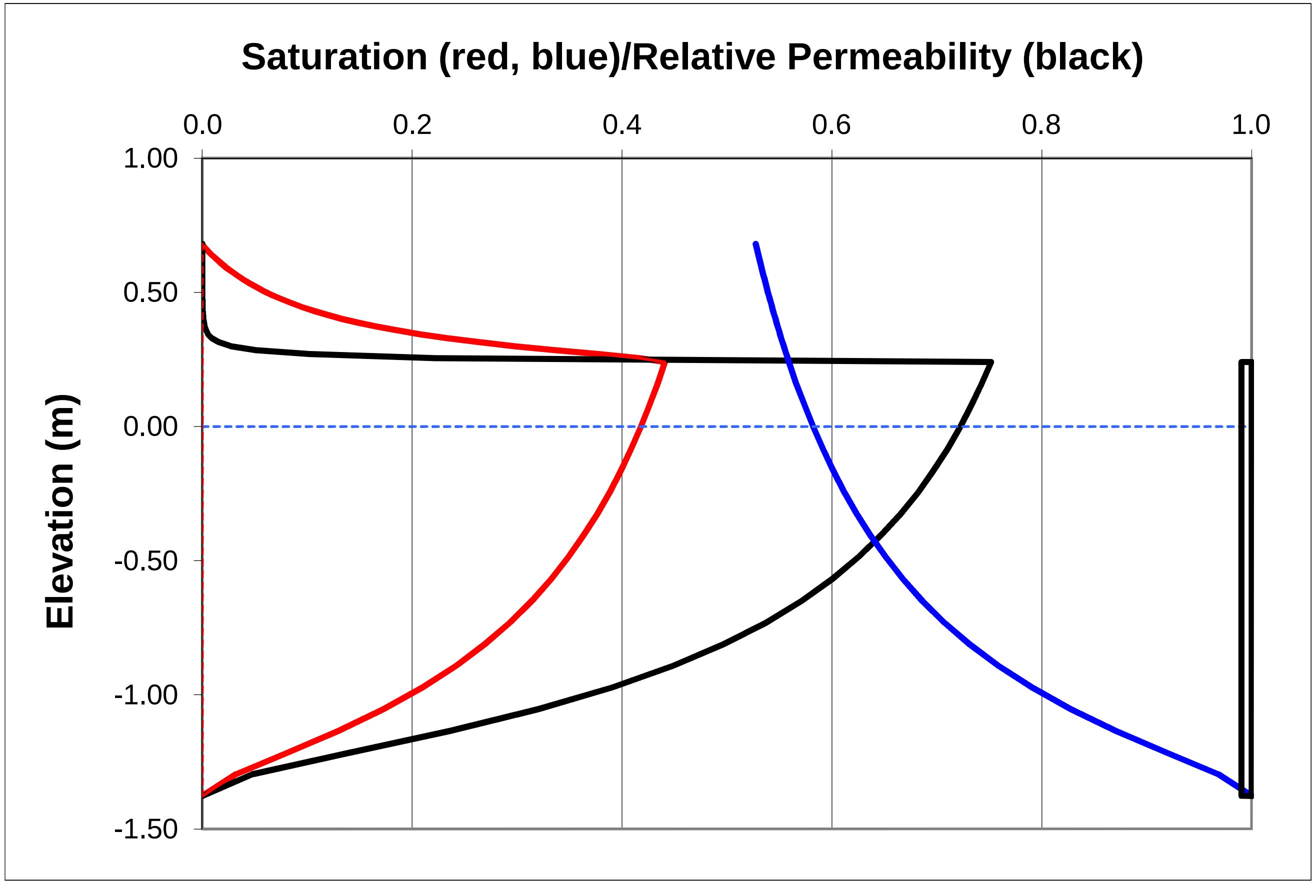


Figure H.09 C-150 LNAPL (vG-M)

van Genuchten-Mualem Model of LNAPL Distribution and Relative Permeability

Enter Data in Yellow Region

Maximum Monitoring Well LNAPL Thickness (meters)		Gauged January 2012	
		AOI 7 / C-150	
b_o =	0.098	0.320	feet

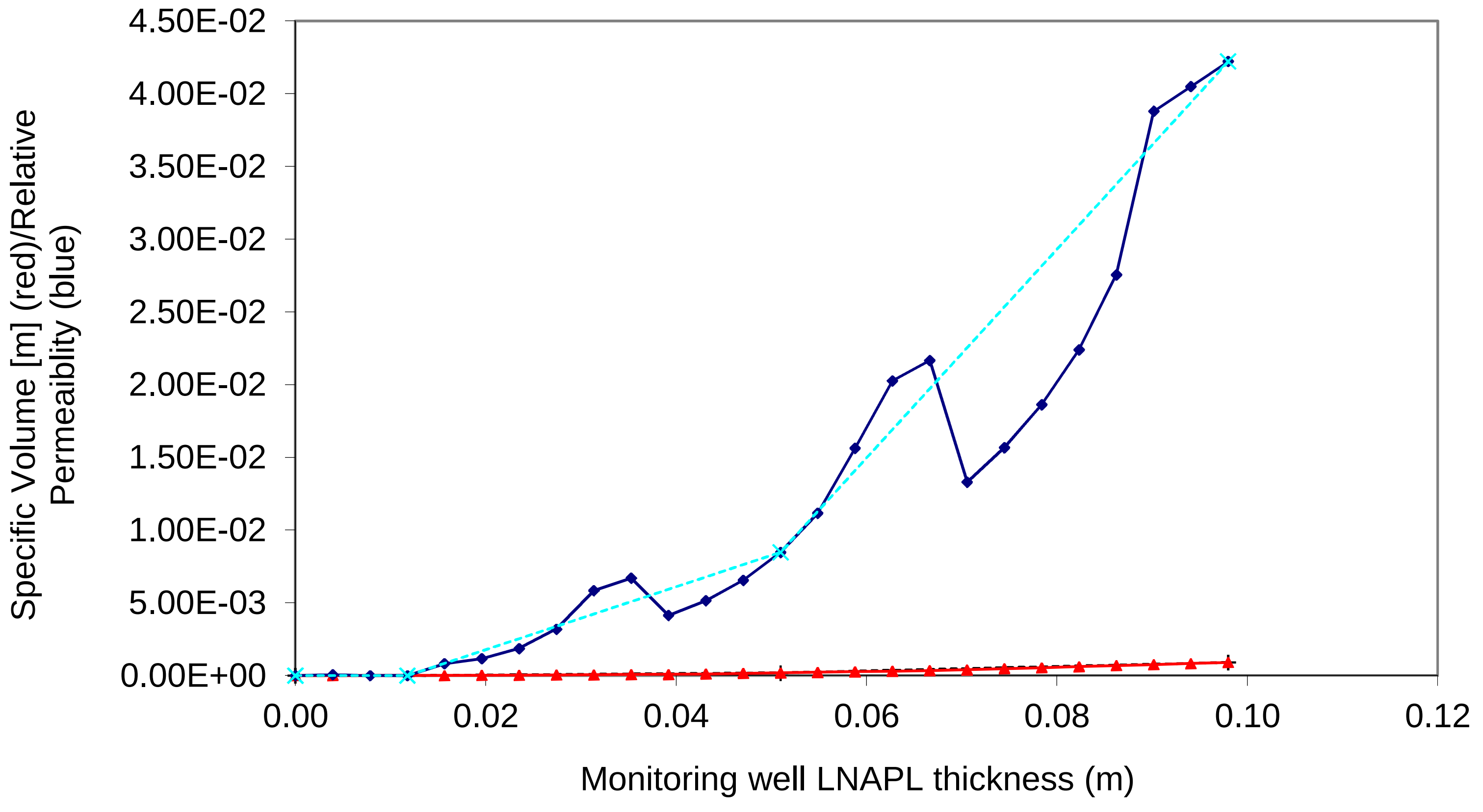
Soil Characteristic		**(SW)g**
n =	0.328	porosity
N =	1.550	van Genuchten "N"
α =	7.830	van Genuchten "α" [m^{-1}]
S_{wr} =	0.290	irreducible water saturation
S_{orv} =	0.000	residual LNAPL saturation (saturated)
S_{ors} =	0.000	residual LNAPL saturation (vadose)

Fluid Characteristics:		**Light Crude**
ρ_o =	0.8428	LNAPL density (gm/cc)
σ_{aw} =	65.000	air/water (dynes/cm)
σ_{ao} =	26.600	air/oil (dynes/cm)
σ_{ow} =	21.900	oil/water (dynes/cm)

Calculated Parameters		
M =	0.355	van Genuchten "M"
α_{ao} =	16.126	air/LNAPL "α"
α_{ow} =	3.653	LNAPL/water "α"
z_{ao} =	0.015	elevation of air-LNAPL interface
z_{ow} =	-0.083	elevation of LNAPL-water interface
z_{max} =	0.045	maximum free-product elevation
λ =	0.472	pore-size distribution index
Ψ_b =	0.084	B-C displacement pressure head [m]

Press Ctrl+Shift+S to calculate sheet

Data for curve-fitting segments			Press Ctrl+Shift+S to calculate sheet					
b_o	D_o	k_{ro}	α	β	ξ	η	**Gauged January 2012**	
0.000	0.000	0.000					**AOI 7 / C-150**	
0.012	0.000	#VALUE!	#DIV/0!	0.000000	#VALUE!	#VALUE!		
0.051	0.000	0.008	0.0128	0.004794	#VALUE!	#VALUE!	1	Eps-Do
0.098	0.001	0.042	0.0390	0.015268	0.0392	0.717525	1	Eps-kro



Monitoring Well LNAPL Thickness b_o (m) =			0.098	Gauged January 2012
	D_o = 9.011E-04	k_{ro} =	4.222E-02	AOI 7 / C-150

Press Ctrl+Shift+S to calculate sheet

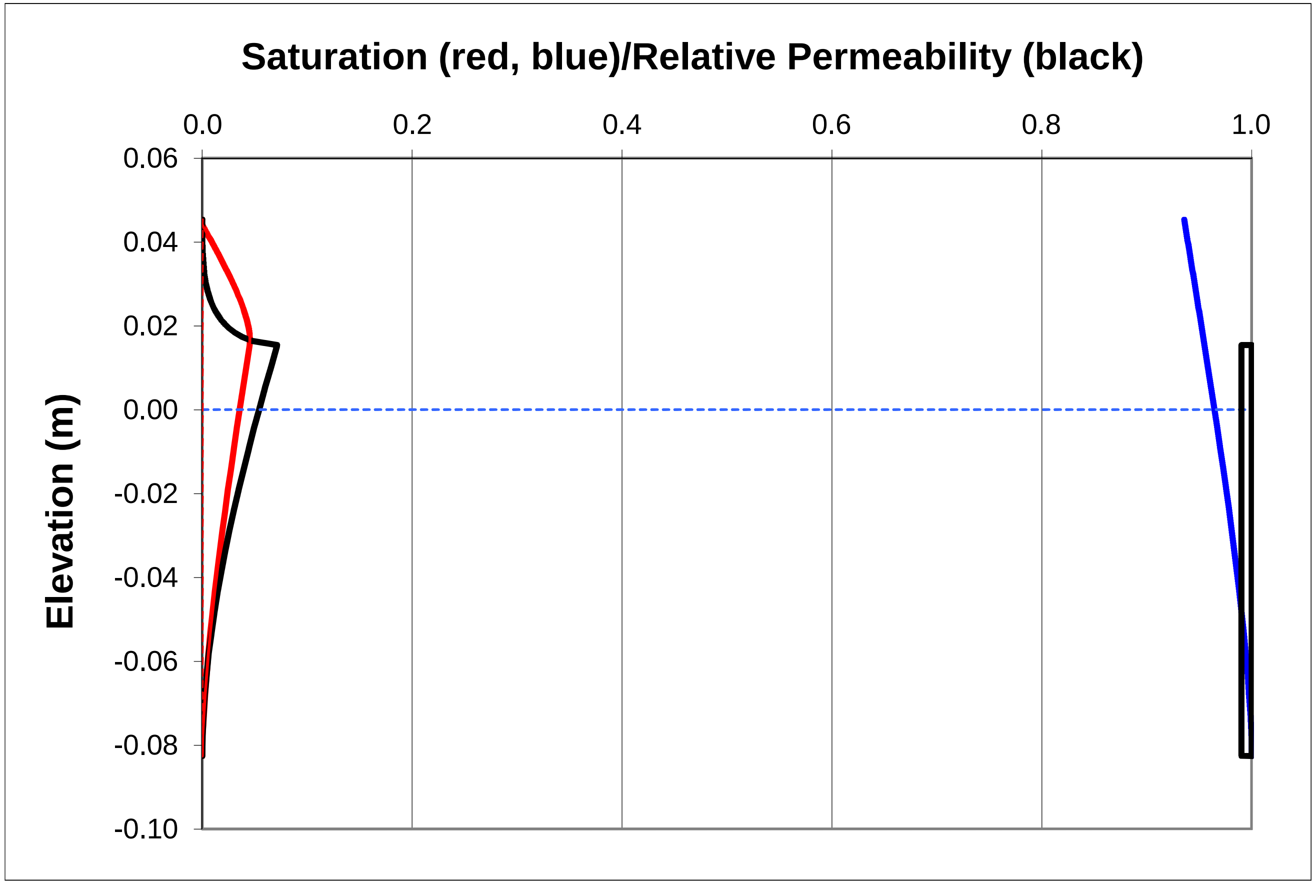


Figure H.10 C-151 LNAPL (vG-M)

van Genuchten-Mualem Model of LNAPL Distribution and Relative Permeability

Enter Data in Yellow Region

Maximum Monitoring Well LNAPL Thickness (meters)		Gauged January 2012	
		AOI 7 / C-151	
b_o =	0.012	0.040	feet

Soil Characteristic		**(SW)g**
n =	0.328	porosity
N =	1.550	van Genuchten "N"
α =	7.830	van Genuchten "α" [m^{-1}]
S_{wr} =	0.290	irreducible water saturation
S_{orv} =	0.000	residual LNAPL saturation (saturated)
S_{ors} =	0.000	residual LNAPL saturation (vadose)

Fluid Characteristics:		**Light Crude**
ρ_o =	0.8597	LNAPL density (gm/cc)
σ_{aw} =	65.000	air/water (dynes/cm)
σ_{ao} =	26.600	air/oil (dynes/cm)
σ_{ow} =	21.900	oil/water (dynes/cm)

Calculated Parameters		
M =	0.355	van Genuchten "M"
α_{ao} =	16.449	air/LNAPL "α"
α_{ow} =	3.261	LNAPL/water "α"
z_{ao} =	0.002	elevation of air-LNAPL interface
z_{ow} =	-0.010	elevation of LNAPL-water interface
z_{max} =	0.012	maximum free-product elevation
λ =	0.472	pore-size distribution index
Ψ_b =	0.084	B-C displacement pressure head [m]

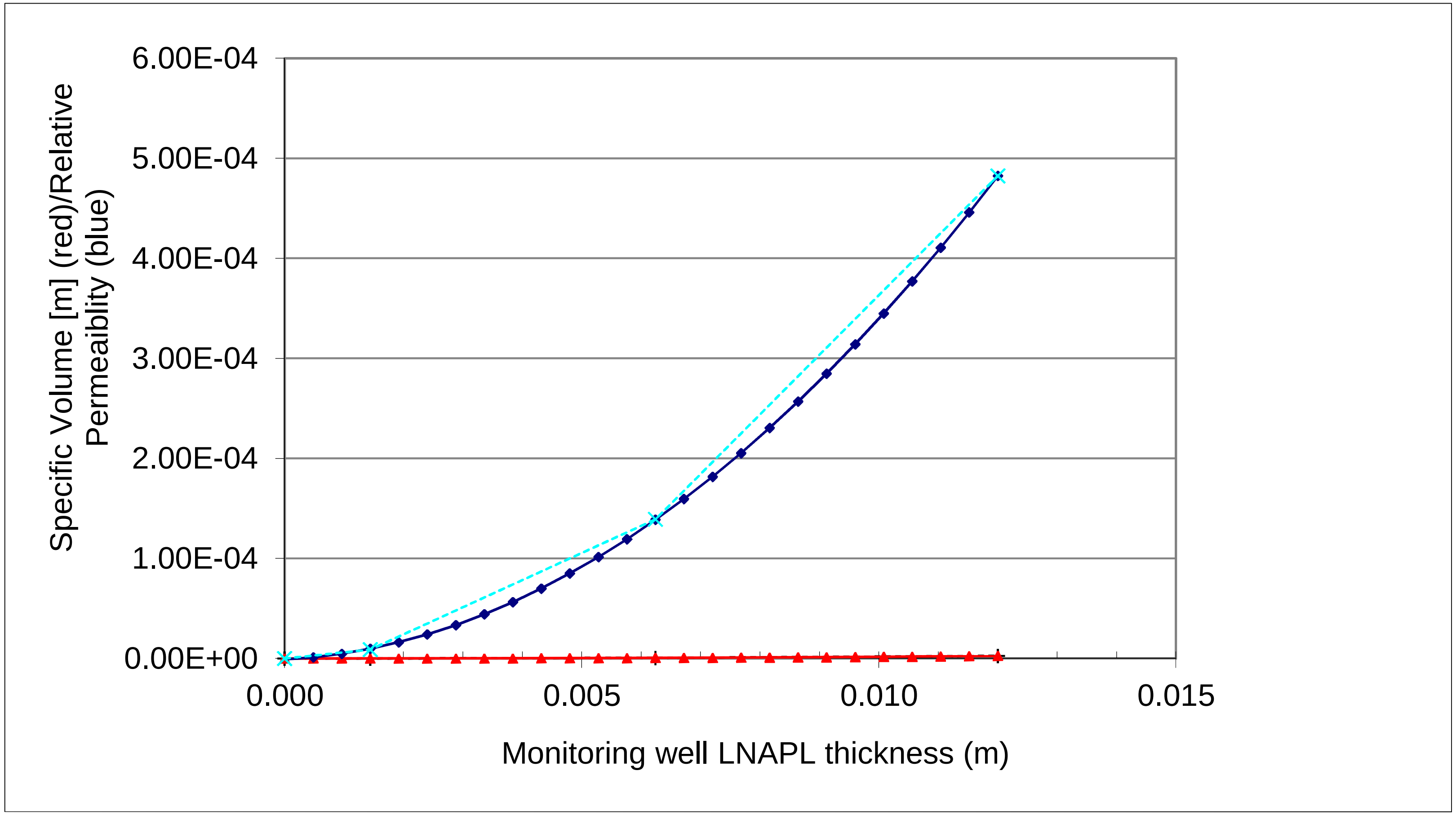
Press Ctrl+Shift+S to calculate sheet

Press Ctrl+Shift+S to calculate sheet

Gauged January 2012

AOI 7 / C-151

Data for curve-fitting segments								
b_o	D_o	k_{ro}	α	β	ξ	η		
0.000E+00	0.000E+00	0.000E+00						
1.440E-03	8.921E-09	8.918E-06	0.0000	0.000006	0.0000	0.006193		
6.240E-03	4.719E-07	1.392E-04	0.0013	0.000096	0.0011	0.027143	0.001	Eps-Do
1.200E-02	2.595E-06	4.824E-04	0.0050	0.000369	0.0039	0.059584	0.001	Eps-kro



Monitoring Well LNAPL Thickness b_o (m) =				0.012	Gauged January 2012
	D_o =	1.277E-05	kro =	4.657E-04	AOI 7 / C-151

Press Ctrl+Shift+S to calculate sheet

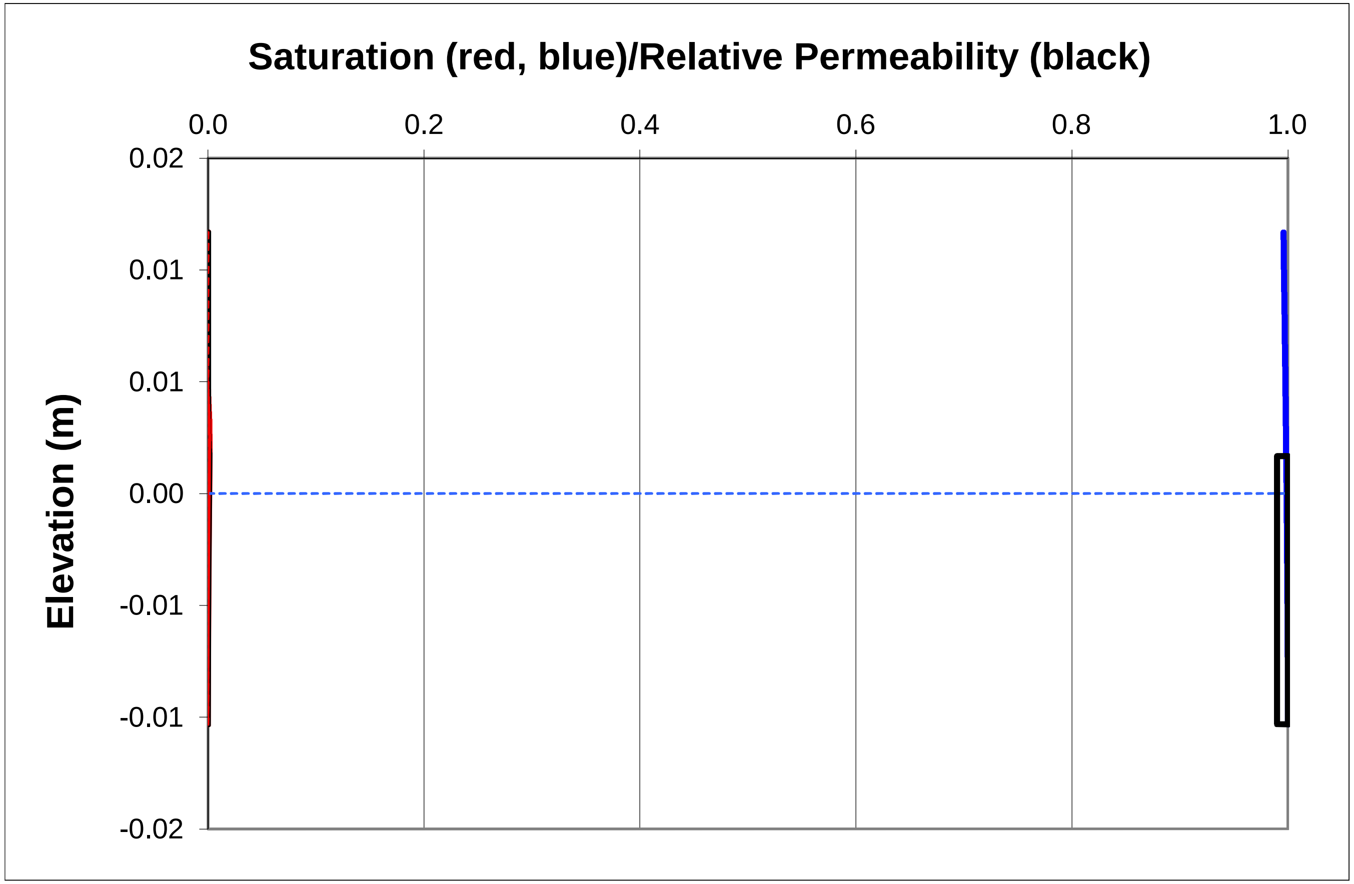


Figure H.11 C-152 LNAPL (vG-M)

van Genuchten-Mualem Model of LNAPL Distribution and Relative Permeability

Enter Data in Yellow Region

Gauged January 2012

AOI 7 / C-152

Maximum Monitoring Well LNAPL Thickness (meters)				
b_o =	0.774	2.540	feet	

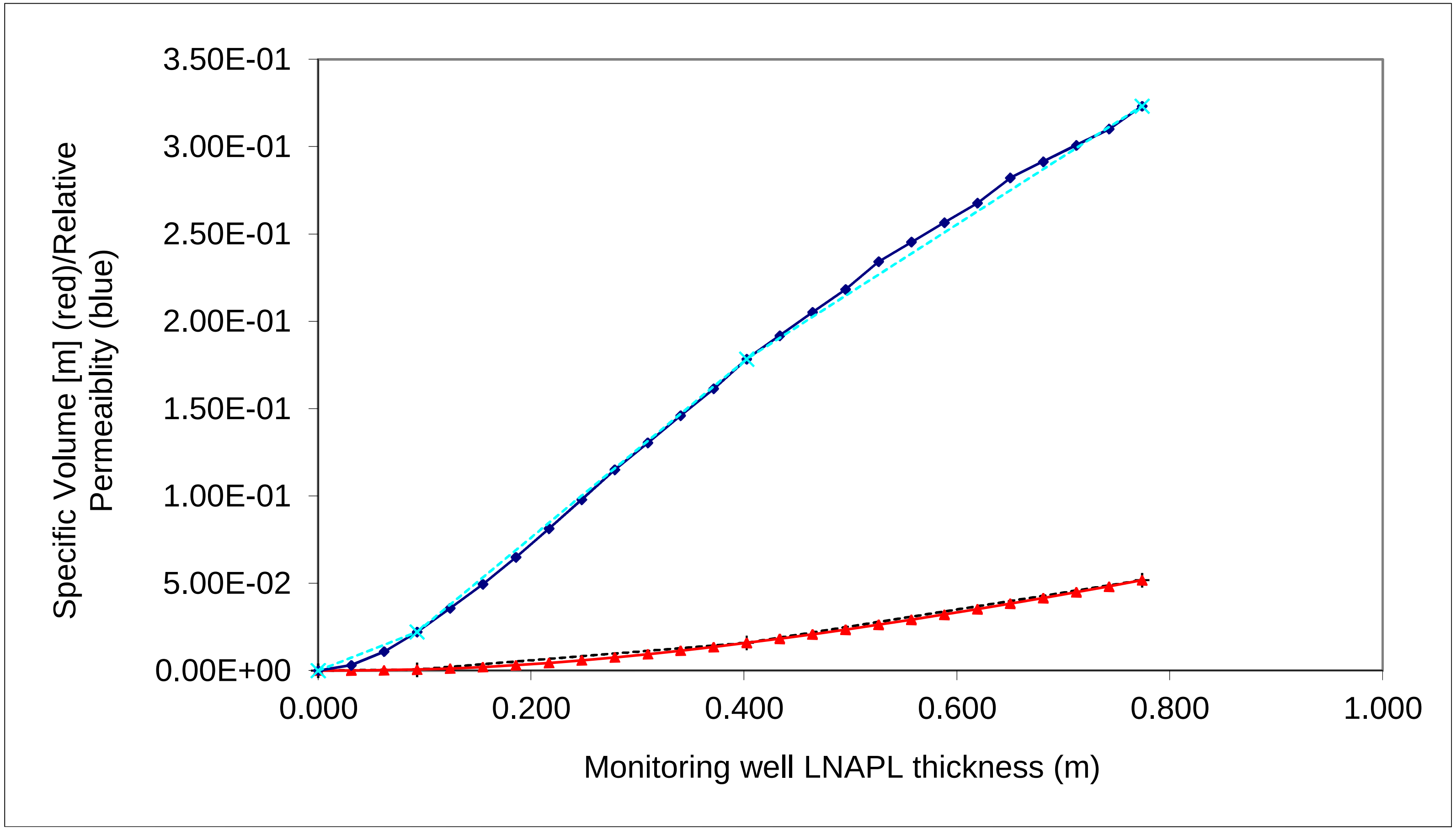
Soil Characteristic		**(SW)g**
n =	0.328	porosity
N =	1.550	van Genuchten "N"
α =	7.830	van Genuchten "α" $[m^{-1}]$
S_{wr} =	0.290	irreducible water saturation
S_{orv} =	0.000	residual LNAPL saturation (saturated)
S_{ors} =	0.000	residual LNAPL saturation (vadose)

Fluid Characteristics:		**Light Crude**
ρ_o =	0.8597	LNAPL density (gm/cc)
σ_{aw} =	65.000	air/water (dynes/cm)
σ_{ao} =	26.600	air/oil (dynes/cm)
σ_{ow} =	21.900	oil/water (dynes/cm)

Calculated Parameters		
M =	0.355	van Genuchten "M"
α_{ao} =	16.449	air/LNAPL "α"
α_{ow} =	3.261	LNAPL/water "α"
z_{ao} =	0.109	elevation of air-LNAPL interface
z_{ow} =	-0.665	elevation of LNAPL-water interface
z_{max} =	0.299	maximum free-product elevation
λ =	0.472	pore-size distribution index
Ψ_b =	0.084	B-C displacement pressure head [m]

Press Ctrl+Shift+S to calculate sheet

Data for curve-fitting segments			Press Ctrl+Shift+S to calculate sheet					
b_o	D_o	k_{ro}	α	β	ξ	η	**Gauged January 2012**	
0.000	0.000	0.000					**AOI 7 / C-152**	
0.093	0.001	0.022	0.0000	0.006337	0.0000	0.237807		
0.402	0.016	0.178	0.0809	0.049298	0.0491	0.504730	0.1	Eps-Do
0.774	0.052	0.323	0.2385	0.096653	-0.0549	0.389957	0.1	Eps-kro



Monitoring Well LNAPL Thickness b_o (m) =				0.774	Gauged January 2012
	D_o =	5.176E-02	k_{ro} =	3.232E-01	AOI 7 / C-152

Press Ctrl+Shift+S to calculate sheet

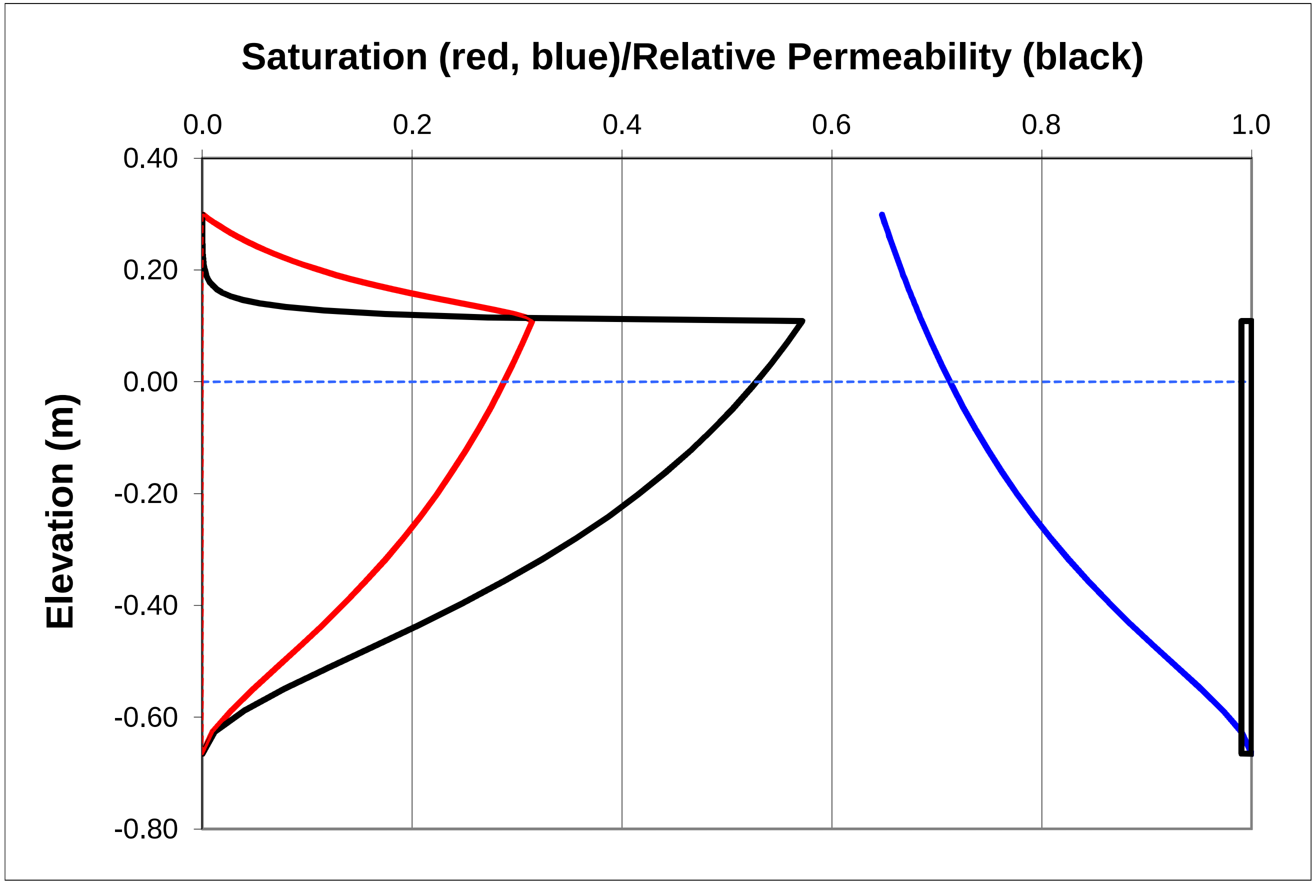


Figure H.12 C-153 LNAPL (vG-M)

van Genuchten-Mualem Model of LNAPL Distribution and Relative Permeability

Enter Data in Yellow Region

Maximum Monitoring Well LNAPL Thickness (meters)

Gauged January 2012

AOI 7 / C-153

b_o =	0.143	0.470	feet

Soil Characteristic — **(SW)g**

n =	0.328	porosity
N =	1.550	van Genuchten "N"
α =	7.830	van Genuchten "α" [m^{-1}]
S_{wr} =	0.290	irreducible water saturation
S_{orv} =	0.000	residual LNAPL saturation (saturated)
S_{ors} =	0.000	residual LNAPL saturation (vadose)

Fluid Characteristics: — **Light Crude**

ρ_o =	0.8620	LNAPL density (gm/cc)
σ_{aw} =	65.000	air/water (dynes/cm)
σ_{ao} =	26.600	air/oil (dynes/cm)
σ_{ow} =	21.900	oil/water (dynes/cm)

Calculated Parameters

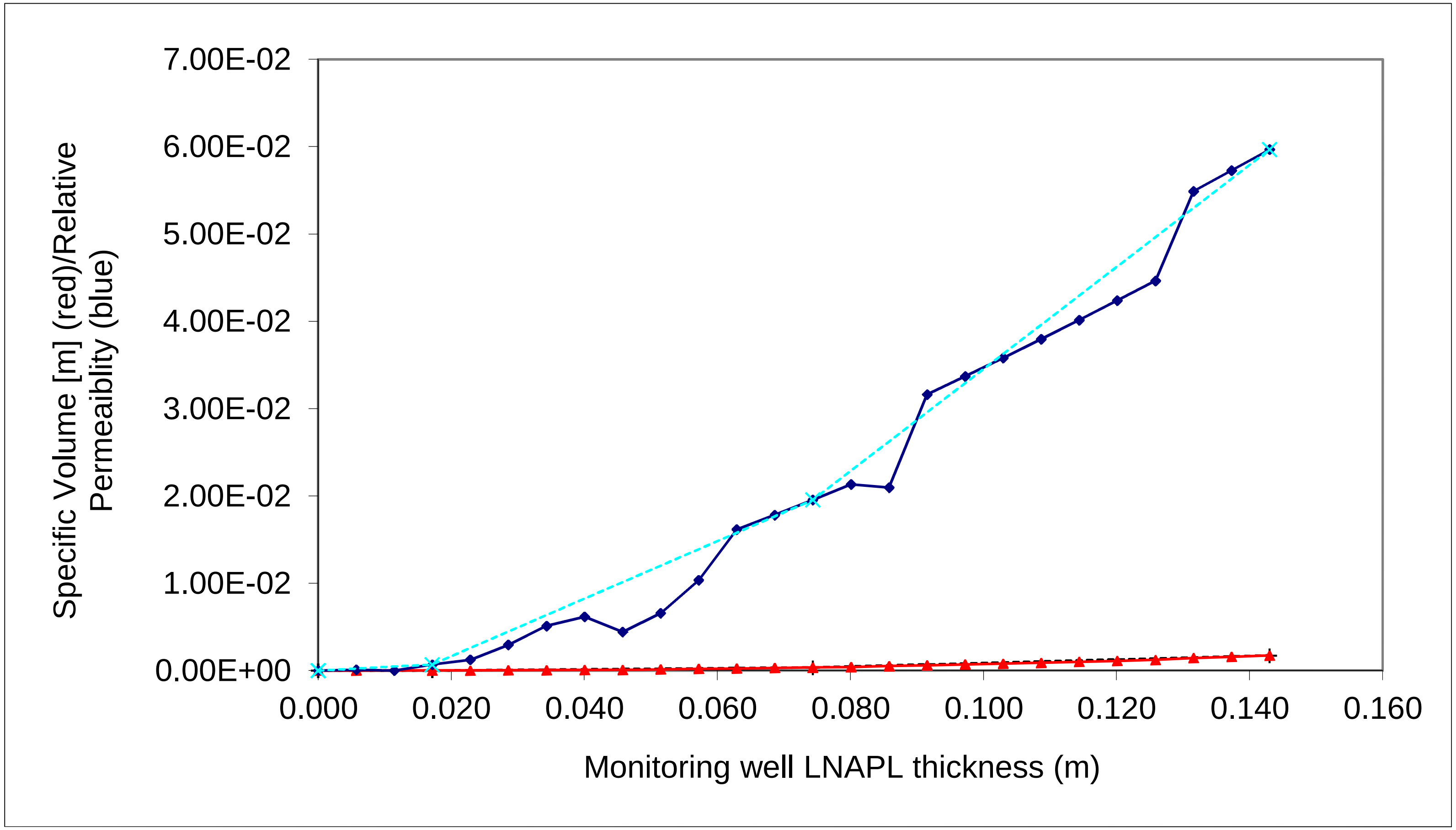
M =	0.355	van Genuchten "M"
α_{ao} =	16.493	air/LNAPL "α"
α_{ow} =	3.207	LNAPL/water "α"
z_{ao} =	0.020	elevation of air-LNAPL interface
z_{ow} =	-0.123	elevation of LNAPL-water interface
z_{max} =	0.060	maximum free-product elevation
λ =	0.472	pore-size distribution index
Ψ_b =	0.084	B-C displacement pressure head [m]

Press Ctrl+Shift+S to calculate sheet

Data for curve-fitting segments			Press Ctrl+Shift+S to calculate sheet					
b_o	D_o	k_{ro}	α	β	ξ	η		
0.000	0.000	0.000						
0.017	0.000	0.001	0.0000	0.000035	0.0000	0.040126		
0.074	0.000	0.020	0.0171	0.006053	0.0151	0.329594	1	Eps-Do
0.143	0.002	0.060	0.0570	0.019998	0.0409	0.584623	1	Eps-kro

Gauged January 2012

AOI 7 / C-153



Monitoring Well LNAPL Thickness b_o (m) =			0.143	Gauged January 2012
	D_o = 1.720E-03	k_{ro} =	5.967E-02	AOI 7 / C-153

Press Ctrl+Shift+S to calculate sheet

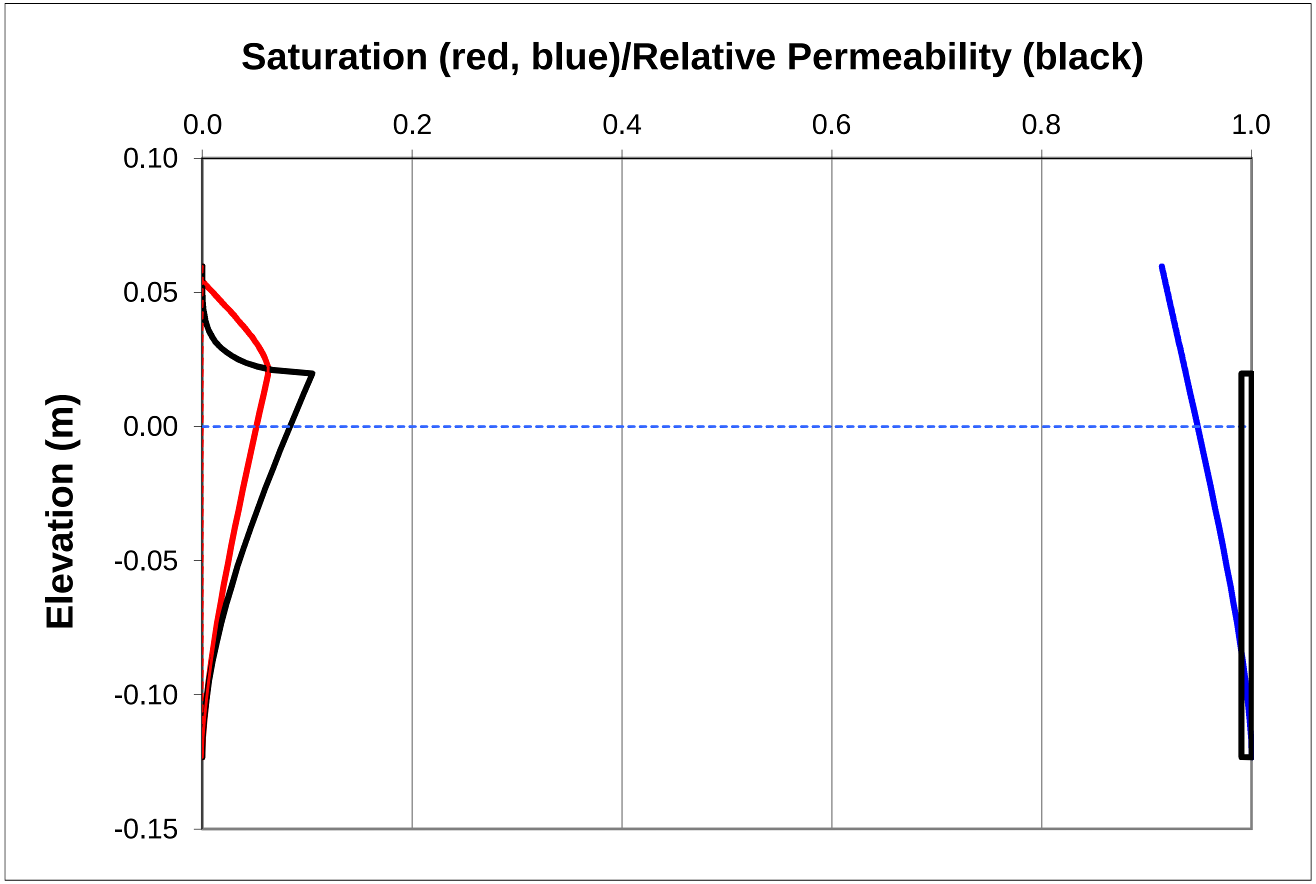


Figure H.13 C-154 LNAPL (vG-M)

van Genuchten-Mualem Model of LNAPL Distribution and Relative Permeability

Enter Data in Yellow Region

Maximum Monitoring Well LNAPL Thickness (meters)		Gauged January 2012	
		AOI 7 / C-154	
b_o =	0.027	0.090	feet

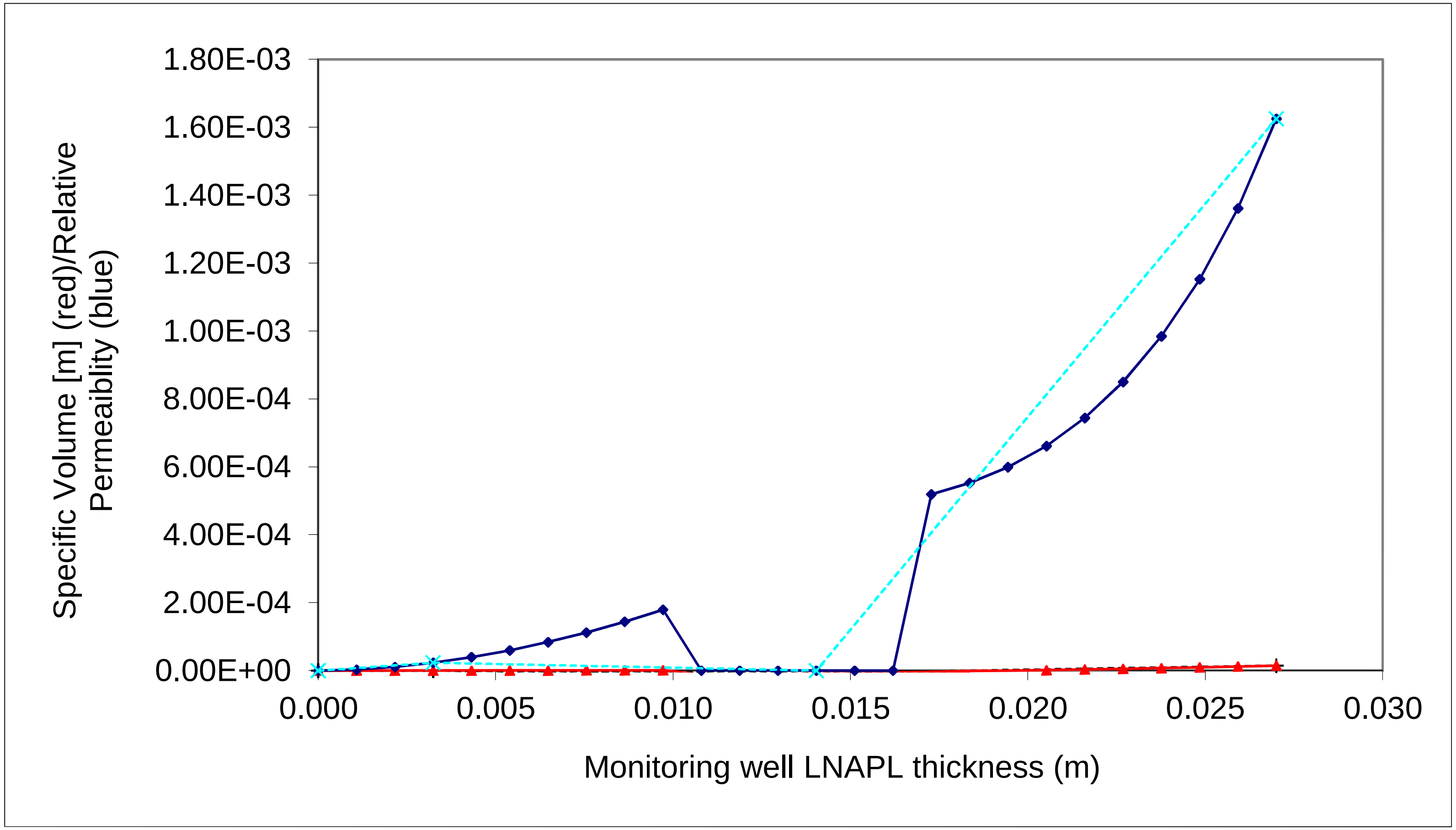
Soil Characteristic		**(SW)g**
n =	0.328	porosity
N =	1.550	van Genuchten "N"
α =	7.830	van Genuchten "α" $[m^{-1}]$
S_{wr} =	0.290	irreducible water saturation
S_{orv} =	0.000	residual LNAPL saturation (saturated)
S_{ors} =	0.000	residual LNAPL saturation (vadose)

Fluid Characteristics:		**Light Crude**
ρ_o =	0.8807	LNAPL density (gm/cc)
σ_{aw} =	65.000	air/water (dynes/cm)
σ_{ao} =	26.600	air/oil (dynes/cm)
σ_{ow} =	21.900	oil/water (dynes/cm)

Calculated Parameters		
M =	0.355	van Genuchten "M"
α_{ao} =	16.851	air/LNAPL "α"
α_{ow} =	2.772	LNAPL/water "α"
z_{ao} =	0.003	elevation of air-LNAPL interface
z_{ow} =	-0.024	elevation of LNAPL-water interface
z_{max} =	0.013	maximum free-product elevation
λ =	0.472	pore-size distribution index
Ψ_b =	0.084	B-C displacement pressure head [m]

Press Ctrl+Shift+S to calculate sheet

Data for curve-fitting segments			Press Ctrl+Shift+S to calculate sheet					
b_o	D_o	k_{ro}	α	β	ξ	η	**Gauged January 2012**	
0.000	0.000	0.000					**AOI 7 / C-154**	
0.003	0.000	0.000	0.0000	0.000022	0.0000	0.007072		
0.014	0.000	#VALUE!	#DIV/0!	0.000000	#VALUE!	#VALUE!	1	Eps-Do
0.027	0.000	0.002	0.0188	0.001773	#VALUE!	#VALUE!	1	Eps-kro



Monitoring Well LNAPL Thickness b_o (m) =				0.027	Gauged January 2012
	D_o =	1.459E-05	k_{ro} =	1.625E-03	AOI 7 / C-154

Press Ctrl+Shift+S to calculate sheet

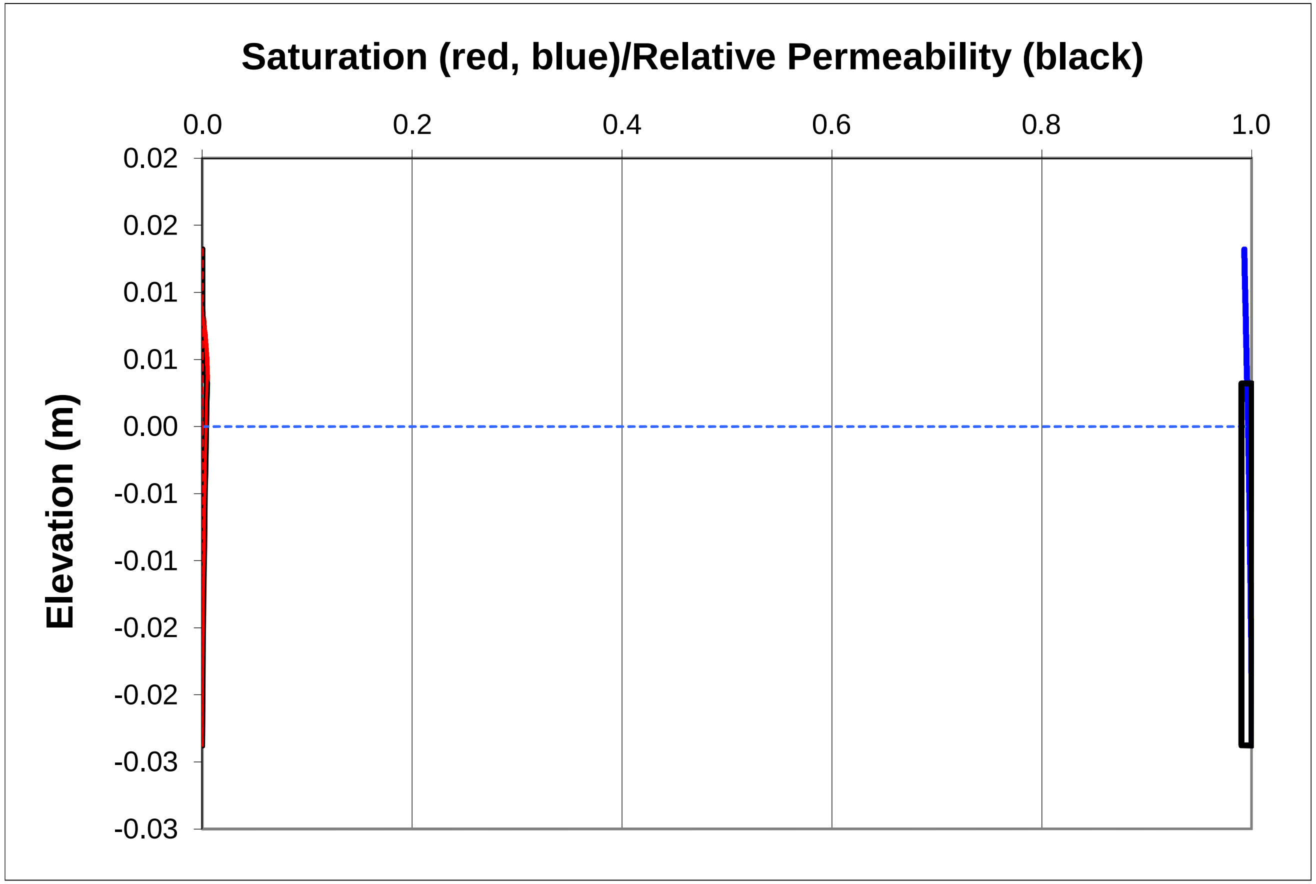


Figure H.14 C-161 LNAPL (vG-M)

van Genuchten-Mualem Model of LNAPL Distribution and Relative Permeability

Enter Data in Yellow Region

Maximum Monitoring Well LNAPL Thickness (meters)		Gauged January 2012	
		AOI 7 / C-161	
b_o =	0.780	0.238	feet

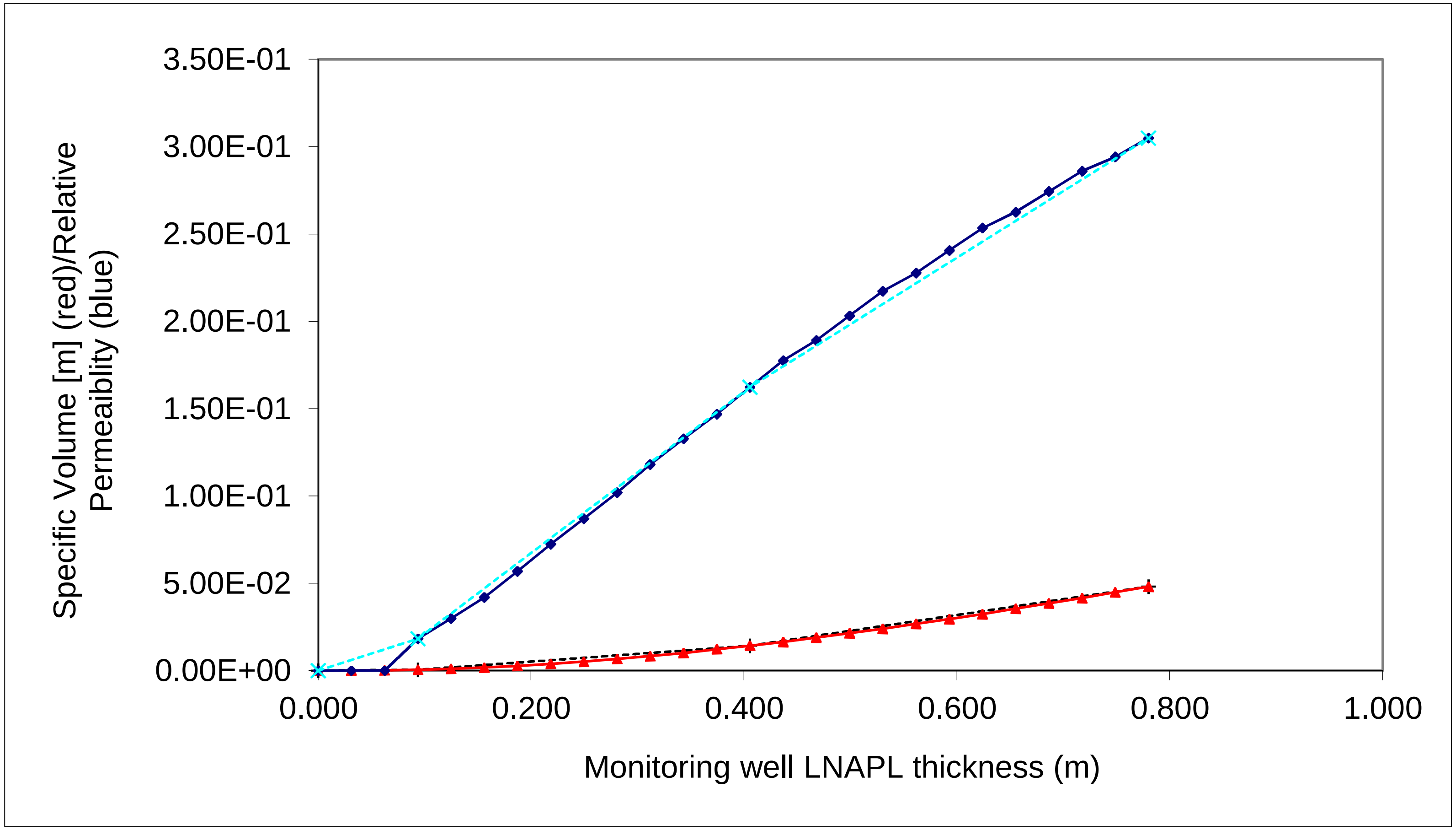
Soil Characteristic		**(SW)g**
n =	0.328	porosity
N =	1.550	van Genuchten "N"
α =	7.830	van Genuchten "α" [m^{-1}]
S_{wr} =	0.290	irreducible water saturation
S_{orv} =	0.000	residual LNAPL saturation (saturated)
S_{ors} =	0.000	residual LNAPL saturation (vadose)

Fluid Characteristics:		**Light Crude**
ρ_o =	0.8737	LNAPL density (gm/cc)
σ_{aw} =	65.000	air/water (dynes/cm)
σ_{ao} =	26.600	air/oil (dynes/cm)
σ_{ow} =	21.900	oil/water (dynes/cm)

Calculated Parameters		
M =	0.355	van Genuchten "M"
α_{ao} =	16.717	air/LNAPL "α"
α_{ow} =	2.935	LNAPL/water "α"
z_{ao} =	0.099	elevation of air-LNAPL interface
z_{ow} =	-0.681	elevation of LNAPL-water interface
z_{max} =	0.269	maximum free-product elevation
λ =	0.472	pore-size distribution index
Ψ_b =	0.084	B-C displacement pressure head [m]

Press Ctrl+Shift+S to calculate sheet

Data for curve-fitting segments				Press Ctrl+Shift+S to calculate sheet				
b_o	D_o	k_{ro}	α	β	ξ	η	**Gauged January 2012**	
0.000	0.000	0.000					**AOI 7 / C-161**	
0.094	0.001	0.018	0.0000	0.005547	0.0000	0.194626		
0.406	0.014	0.162	0.0818	0.044023	0.0541	0.461661	0.1	Eps-Do
0.780	0.048	0.305	0.2481	0.090497	-0.0202	0.381091	0.1	Eps-kro



Monitoring Well LNAPL Thickness b_o (m) =			0.780	Gauged January 2012
	D_o = 4.814E-02	$\underline{k}_{ro}$ =	3.049E-01	AOI 7 / C-161

Press Ctrl+Shift+S to calculate sheet

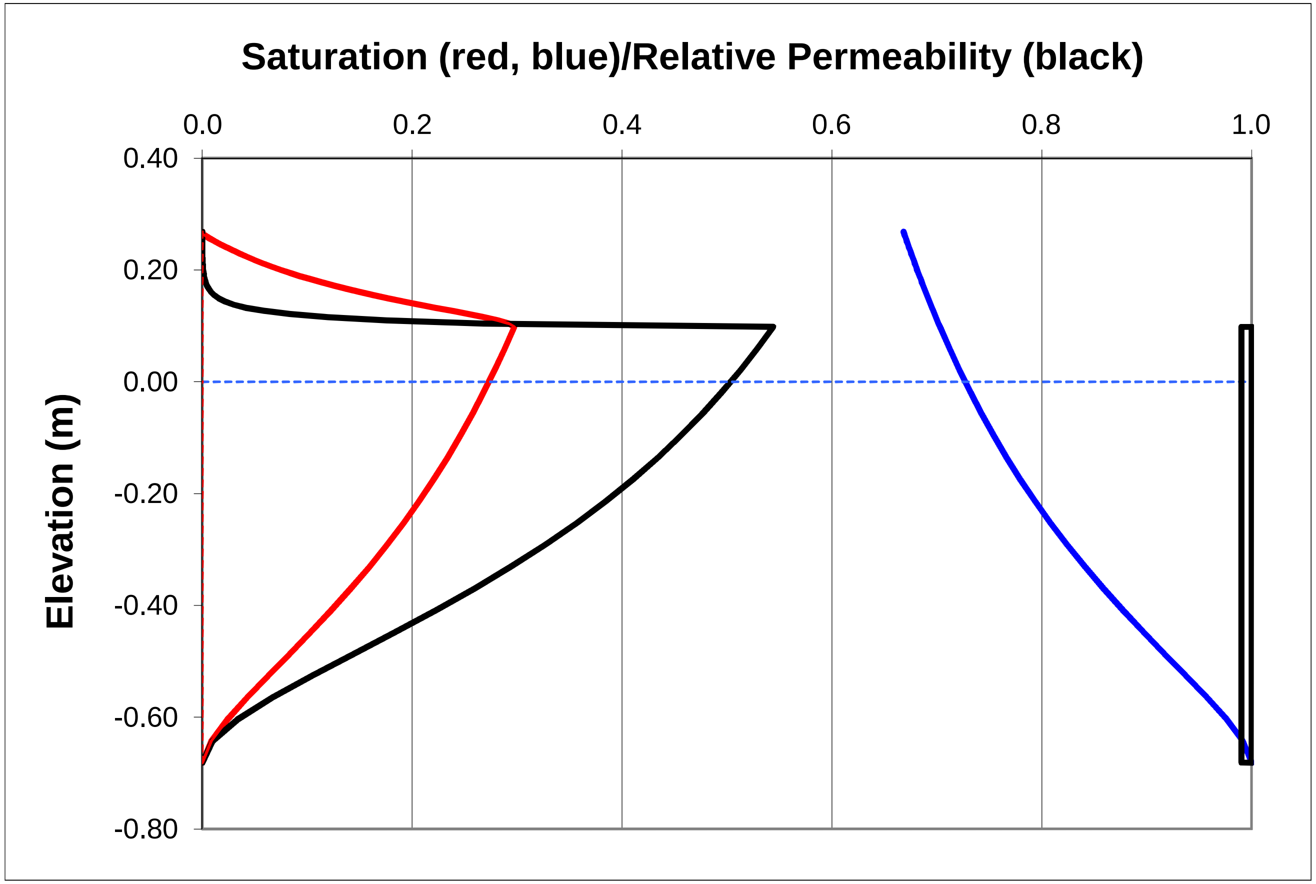


Figure H.15 C-162 LNAPL (vG-M)

van Genuchten-Mualem Model of LNAPL Distribution and Relative Permeability

Enter Data in Yellow Region

Maximum Monitoring Well LNAPL Thickness (meters)		Gauged January 2012	
		AOI 7 / C-162	
b_o =	0.314	1.030	feet

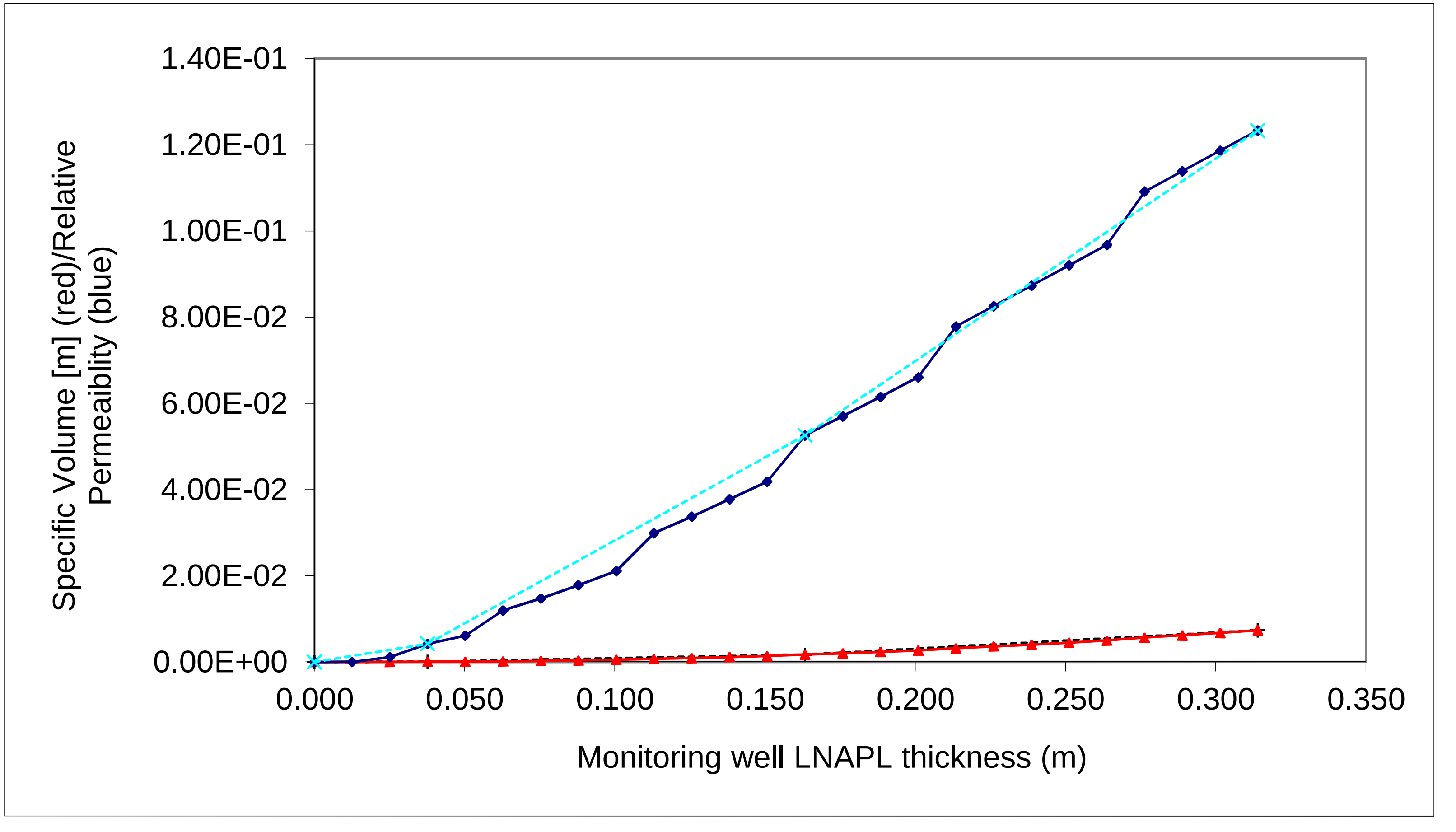
Soil Characteristic		**(SW)g**
n =	0.328	porosity
N =	1.550	van Genuchten "N"
α =	7.830	van Genuchten "α" [m^{-1}]
S_{wr} =	0.290	irreducible water saturation
S_{orv} =	0.000	residual LNAPL saturation (saturated)
S_{ors} =	0.000	residual LNAPL saturation (vadose)

Fluid Characteristics:		**Light Crude**
ρ_o =	0.8833	LNAPL density (gm/cc)
σ_{aw} =	65.000	air/water (dynes/cm)
σ_{ao} =	26.600	air/oil (dynes/cm)
σ_{ow} =	21.900	oil/water (dynes/cm)

Calculated Parameters		
M =	0.355	van Genuchten "M"
α_{ao} =	16.901	air/LNAPL "α"
α_{ow} =	2.712	LNAPL/water "α"
z_{ao} =	0.037	elevation of air-LNAPL interface
z_{ow} =	-0.277	elevation of LNAPL-water interface
z_{max} =	0.097	maximum free-product elevation
λ =	0.472	pore-size distribution index
Ψ_b =	0.084	B-C displacement pressure head [m]

Press Ctrl+Shift+S to calculate sheet

Data for curve-fitting segments			Press Ctrl+Shift+S to calculate sheet					
b_o	D_o	k_{ro}	α	β	ξ	η	Gauged January 2012	
0.000	0.000	0.000					AOI 7 / C-162	
0.038	0.000	0.004	0.0000	0.001162	0.0000	0.111640		
0.163	0.002	0.053	0.0344	0.013160	0.0268	0.385056	1	Eps-Do
0.314	0.007	0.123	0.1181	0.037518	0.0513	0.469582	1	Eps-kro



Monitoring Well LNAPL Thickness b_o (m) =				0.314	Gauged January 2012
	D_o =	7.351E-03	k_{ro} =	1.233E-01	AOI 7 / C-162

Press Ctrl+Shift+S to calculate sheet

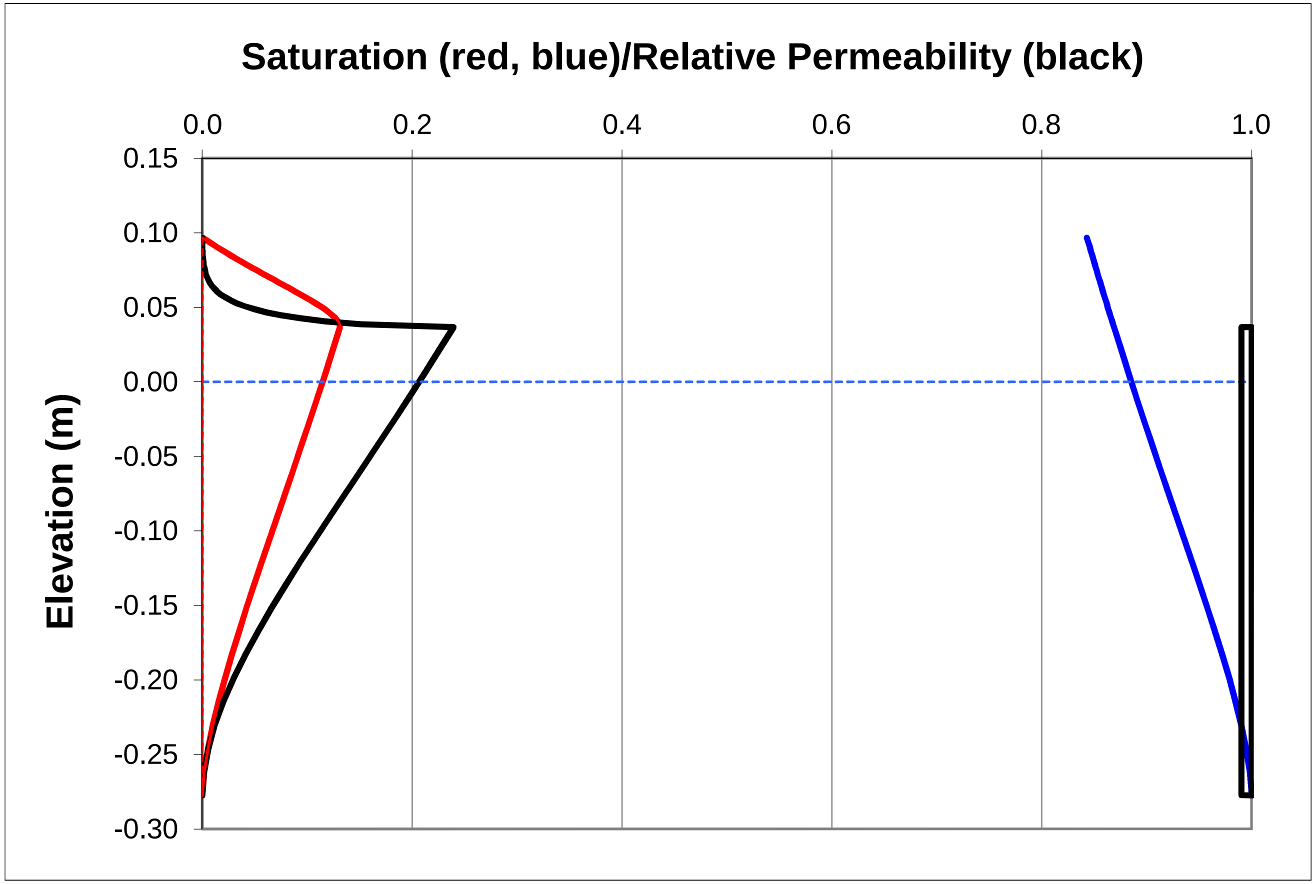


Figure H.16 C-166 LNAPL (vG-M)

van Genuchten-Mualem Model of LNAPL Distribution and Relative Permeability

Enter Data in Yellow Region

Maximum Monitoring Well LNAPL Thickness (meters)		Gauged January 2012 **AOI 7 / C-166**	
b_o =	0.223	0.730	feet

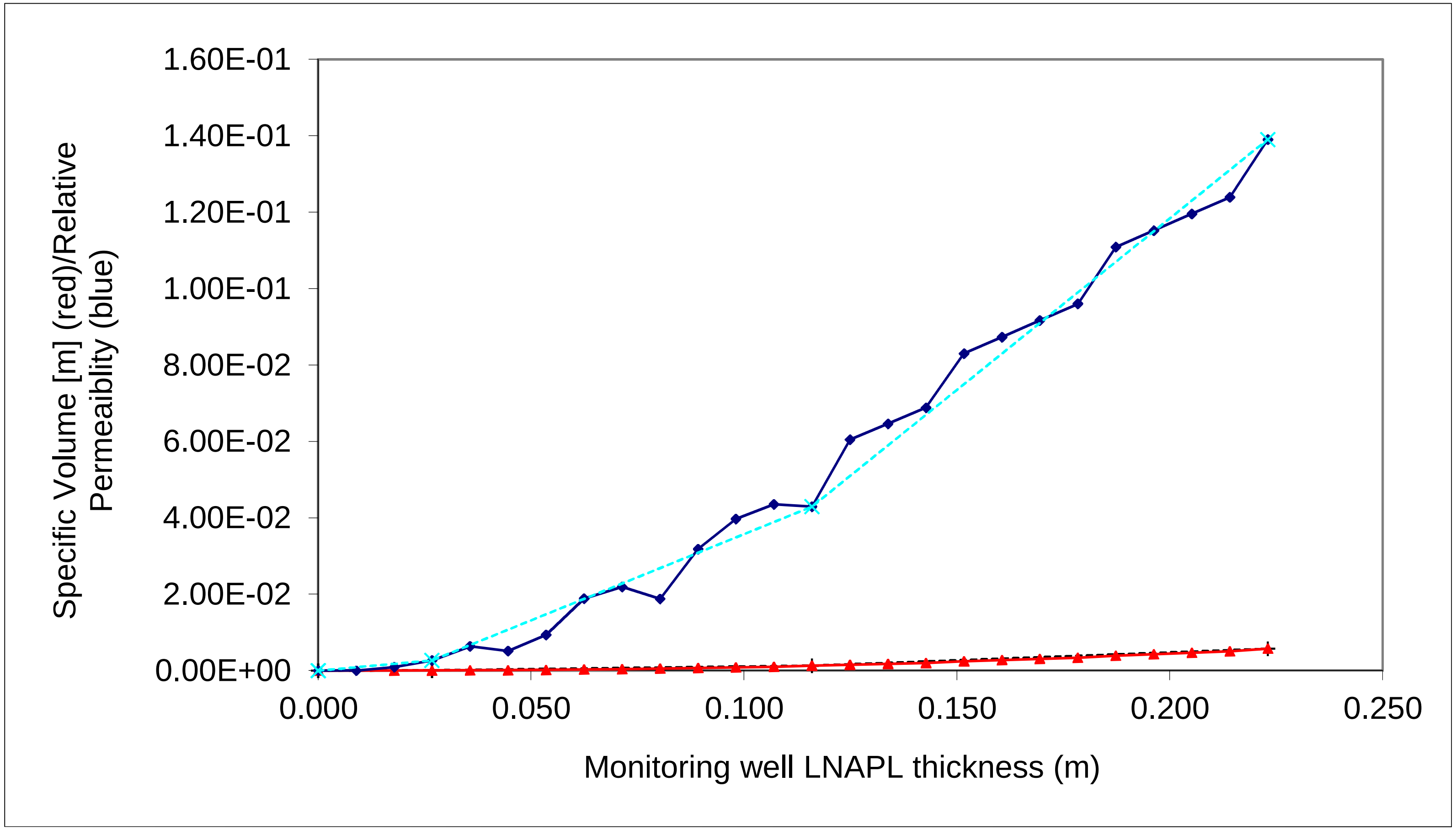
Soil Characteristic		**(SW)g**
n =	0.328	porosity
N =	1.550	van Genuchten "N"
α =	7.830	van Genuchten "α" [m^{-1}]
S_{wr} =	0.290	irreducible water saturation
S_{orv} =	0.000	residual LNAPL saturation (saturated)
S_{ors} =	0.000	residual LNAPL saturation (vadose)

Fluid Characteristics:		**Light Crude**
ρ_o =	0.8486	LNAPL density (gm/cc)
σ_{aw} =	65.000	air/water (dynes/cm)
σ_{ao} =	26.600	air/oil (dynes/cm)
σ_{ow} =	21.900	oil/water (dynes/cm)

Calculated Parameters		
M =	0.355	van Genuchten "M"
α_{ao} =	16.237	air/LNAPL "α"
α_{ow} =	3.518	LNAPL/water "α"
z_{ao} =	0.034	elevation of air-LNAPL interface
z_{ow} =	-0.189	elevation of LNAPL-water interface
z_{max} =	0.104	maximum free-product elevation
λ =	0.472	pore-size distribution index
Ψ_b =	0.084	B-C displacement pressure head [m]

Press Ctrl+Shift+S to calculate sheet

Data for curve-fitting segments			Press Ctrl+Shift+S to calculate sheet					
b_o	D_o	k_{ro}	α	β	ξ	η	**Gauged January 2012**	
0.000	0.000	0.000					**AOI 7 / C-166**	
0.027	0.000	0.003	0.0000	0.001250	0.0000	0.099592		
0.116	0.001	0.043	0.0244	0.014236	0.0209	0.451557	1	Eps-Do
0.223	0.006	0.139	0.0846	0.041519	0.0681	0.897575	1	Eps-kro



Monitoring Well LNAPL Thickness b_o (m) =		0.223		Gauged January 2012
D_o =	5.747E-03	k_{ro} =	1.390E-01	AOI 7 / C-166

Press Ctrl+Shift+S to calculate sheet

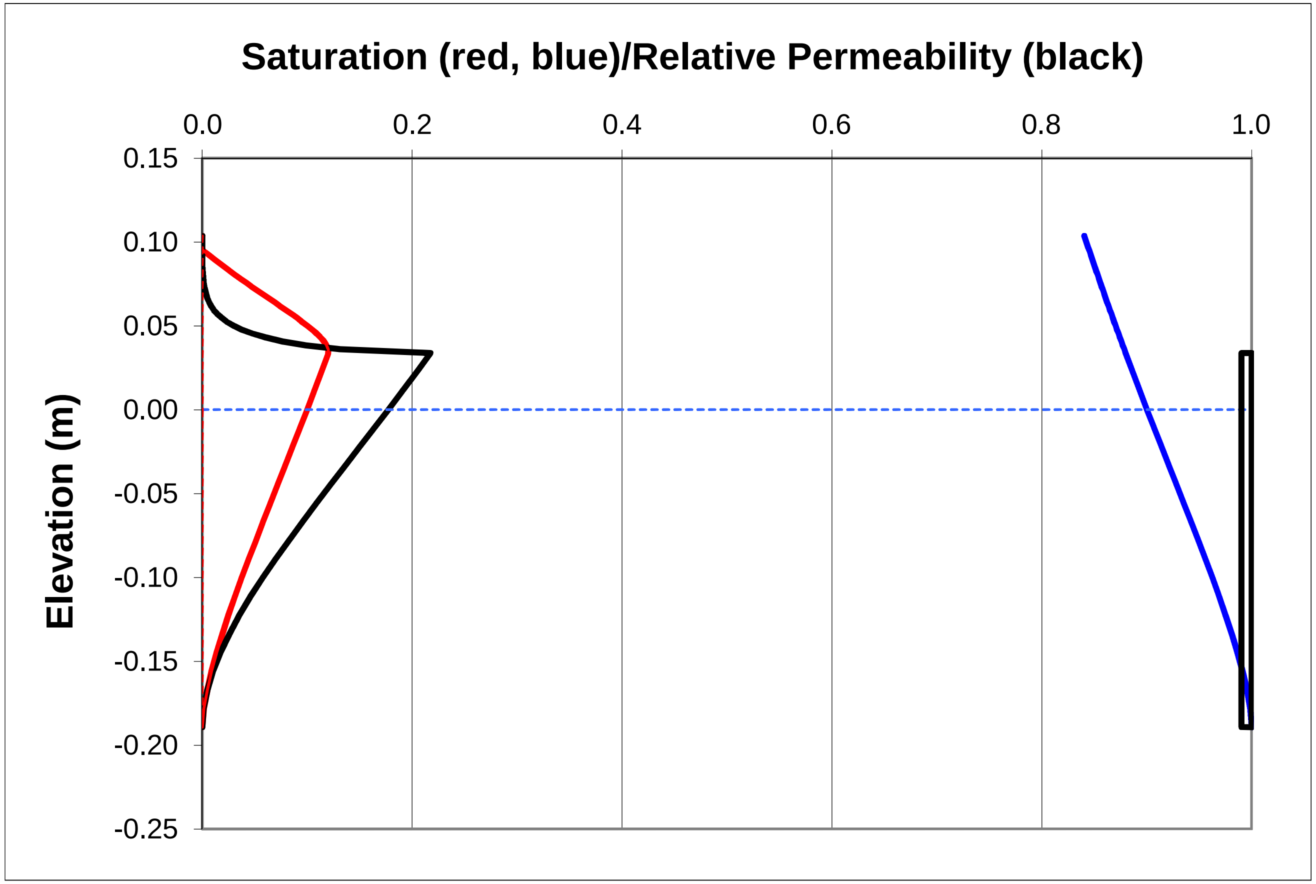


Figure H.17 C-167 LNAPL (vG-M)

van Genuchten-Mualem Model of LNAPL Distribution and Relative Permeability

Enter Data in Yellow Region

Maximum Monitoring Well LNAPL Thickness (meters)		Gauged January 2012	
		AOI 7 / C-167	
b_o =	1.649	5.410	feet

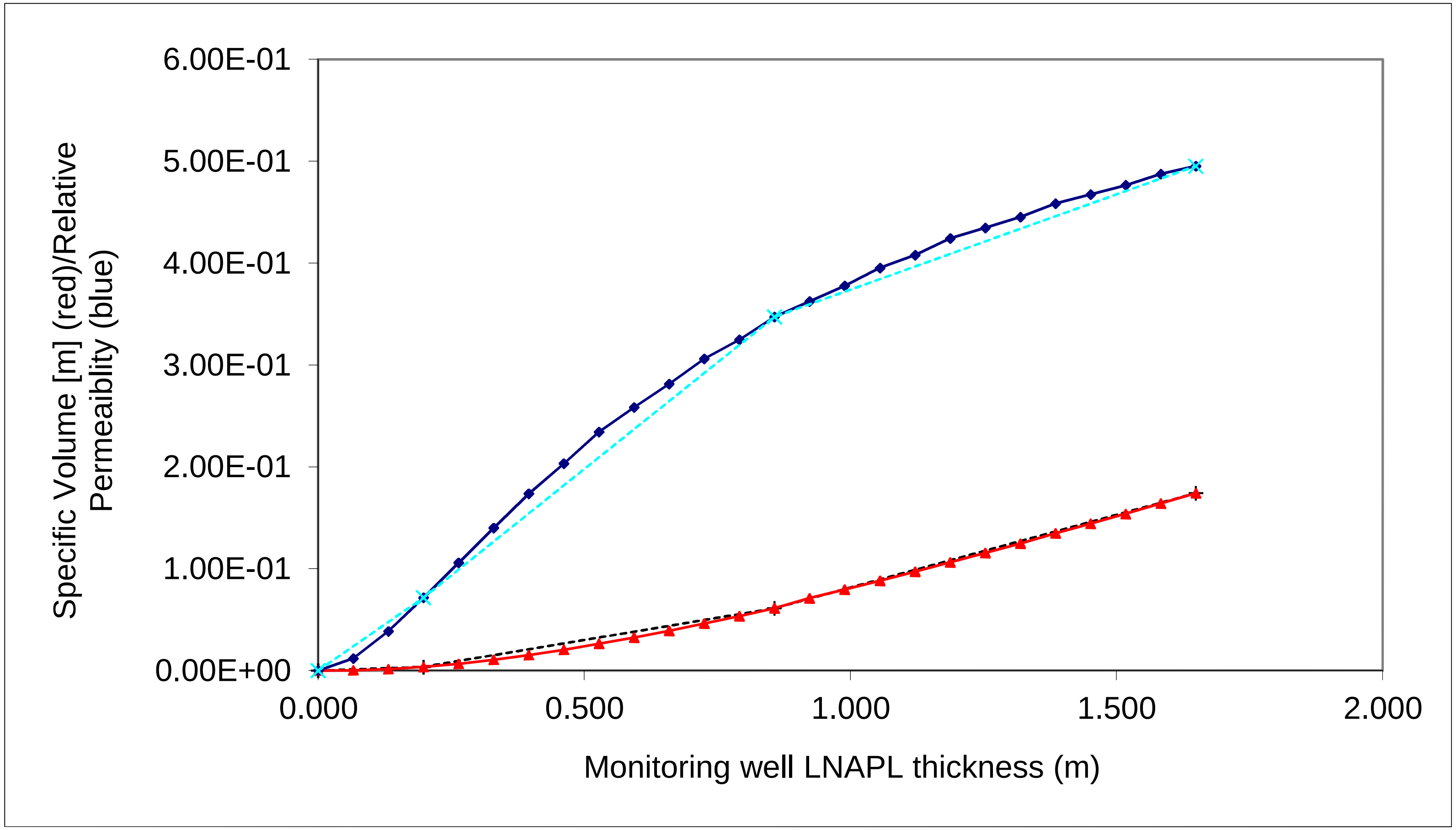
Soil Characteristic		**(SW)g**
n =	0.328	porosity
N =	1.550	van Genuchten "N"
α =	7.830	van Genuchten "α" [m^{-1}]
S_{wr} =	0.290	irreducible water saturation
S_{orv} =	0.000	residual LNAPL saturation (saturated)
S_{ors} =	0.000	residual LNAPL saturation (vadose)

Fluid Characteristics:		**Light Crude**
ρ_o =	0.8601	LNAPL density (gm/cc)
σ_{aw} =	65.000	air/water (dynes/cm)
σ_{ao} =	26.600	air/oil (dynes/cm)
σ_{ow} =	21.900	oil/water (dynes/cm)

Calculated Parameters		
M =	0.355	van Genuchten "M"
α_{ao} =	16.457	air/LNAPL "α"
α_{ow} =	3.251	LNAPL/water "α"
z_{ao} =	0.231	elevation of air-LNAPL interface
z_{ow} =	-1.418	elevation of LNAPL-water interface
z_{max} =	0.641	maximum free-product elevation
λ =	0.472	pore-size distribution index
Ψ_b =	0.084	B-C displacement pressure head [m]

Press Ctrl+Shift+S to calculate sheet

Data for curve-fitting segments			Press Ctrl+Shift+S to calculate sheet					
b_o	D_o	k_{ro}	α	β	ξ	η	Gauged January 2012	
0.000	0.000	0.000					AOI 7 / C-167	
0.198	0.004	0.071	0.0000	0.018016	0.0000	0.361273		
0.857	0.061	0.347	0.1571	0.087389	0.0268	0.417880	0.1	Eps-Do
1.649	0.174	0.495	0.4284	0.142640	-0.9978	0.187097	0.1	Eps-kro



Monitoring Well LNAPL Thickness b_o (m) =			1.649	Gauged January 2012
	D_o = 1.741E-01	$\underline{k}_{ro}$ =	4.952E-01	AOI 7 / C-167

Press Ctrl+Shift+S to calculate sheet

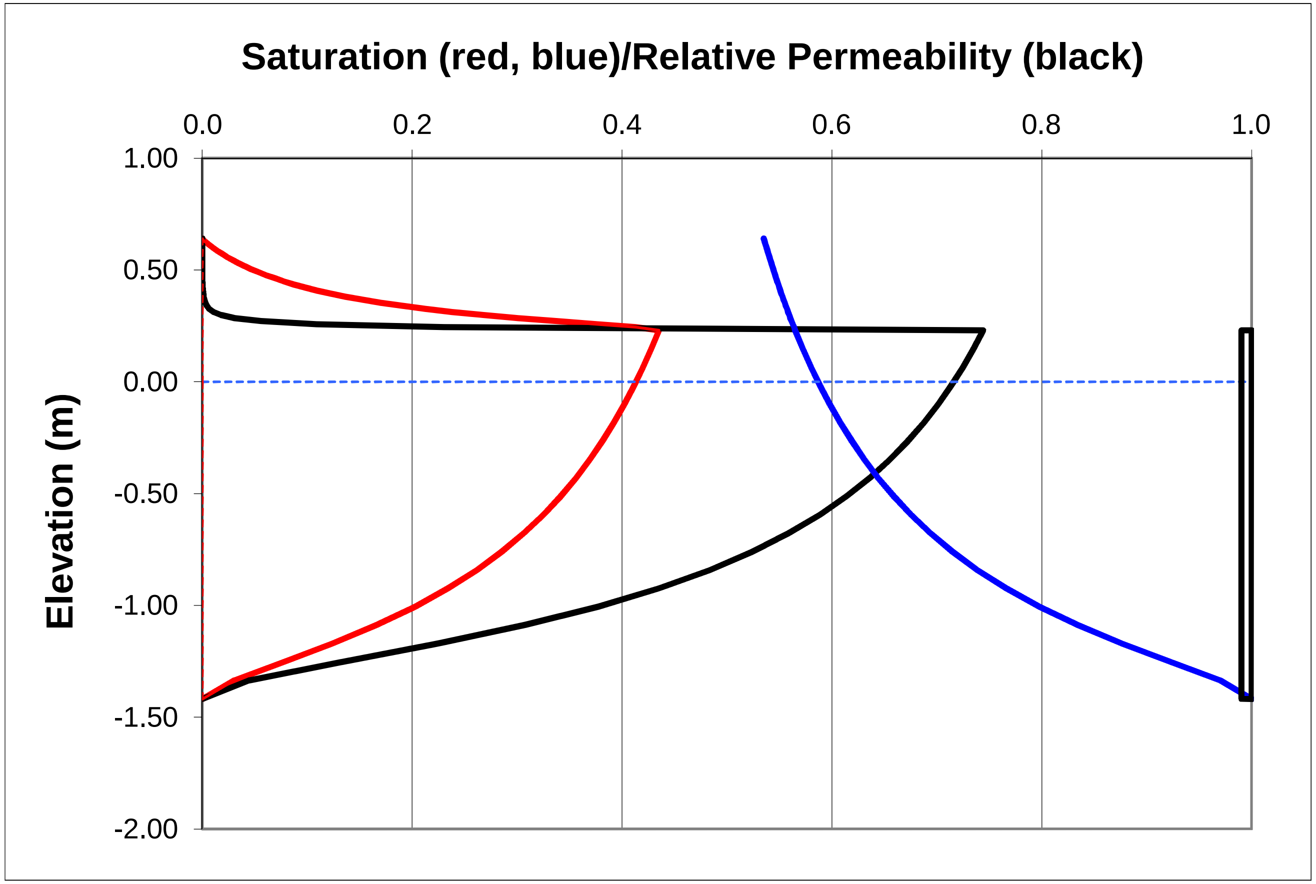


Figure H.18 WP-14 LNAPL (vG-M)

van Genuchten-Mualem Model of LNAPL Distribution and Relative Permeability

Enter Data in Yellow Region

Maximum Monitoring Well LNAPL Thickness (meters)		Gauged January 2012	
		AOI 7 / WP-14	
b_o =	0.323	1.060	feet

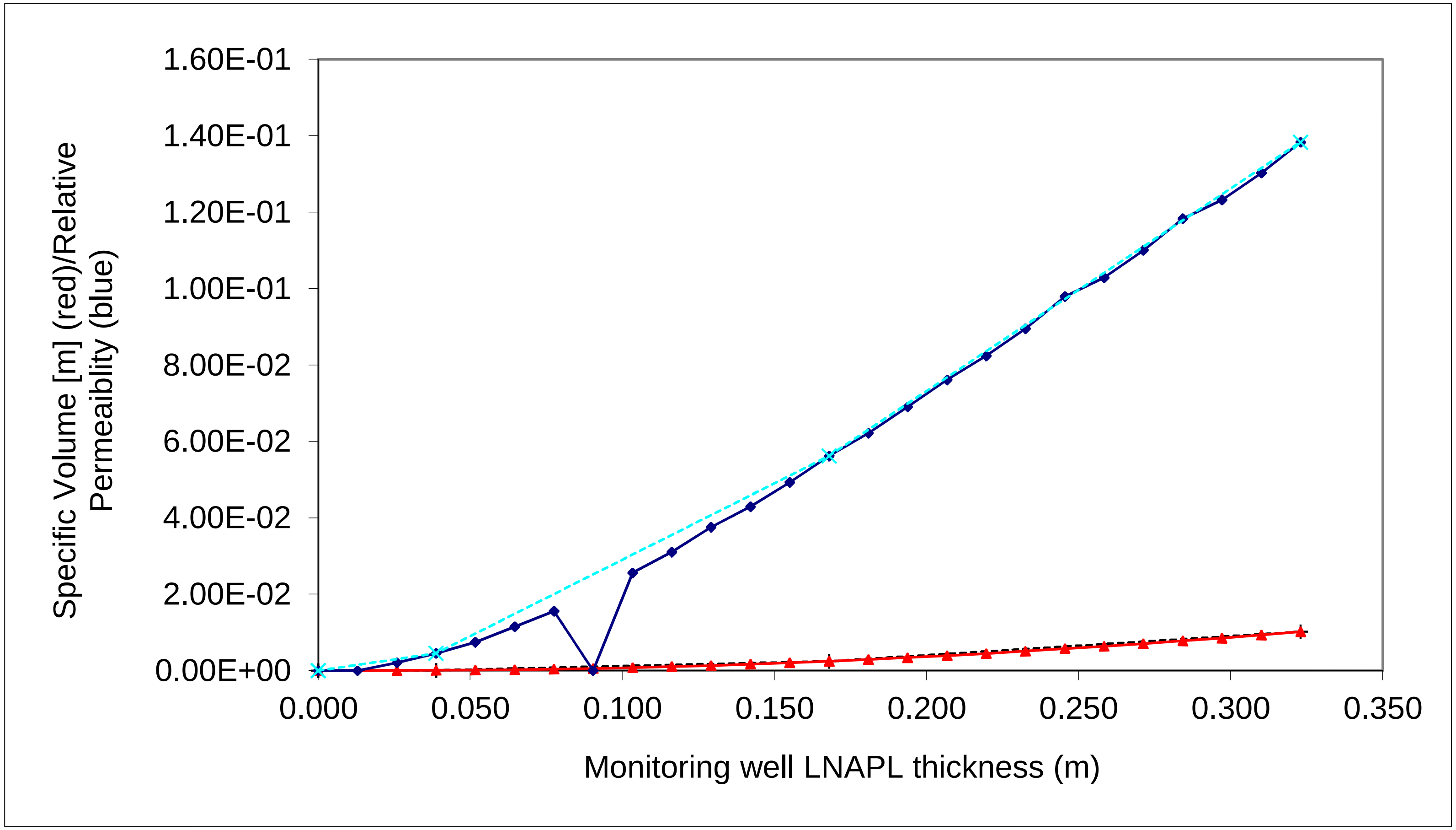
Soil Characteristic		**(SW)g**
n =	0.328	porosity
N =	1.550	van Genuchten "N"
α =	7.830	van Genuchten "α" $[m^{-1}]$
S_{wr} =	0.290	irreducible water saturation
S_{orv} =	0.000	residual LNAPL saturation (saturated)
S_{ors} =	0.000	residual LNAPL saturation (vadose)

Fluid Characteristics:		**Light Crude**
ρ_o =	0.8601	LNAPL density (gm/cc)
σ_{aw} =	65.000	air/water (dynes/cm)
σ_{ao} =	26.600	air/oil (dynes/cm)
σ_{ow} =	21.900	oil/water (dynes/cm)

Calculated Parameters		
M =	0.355	van Genuchten "M"
α_{ao} =	16.457	air/LNAPL "α"
α_{ow} =	3.251	LNAPL/water "α"
z_{ao} =	0.045	elevation of air-LNAPL interface
z_{ow} =	-0.278	elevation of LNAPL-water interface
z_{max} =	0.125	maximum free-product elevation
λ =	0.472	pore-size distribution index
Ψ_b =	0.084	B-C displacement pressure head [m]

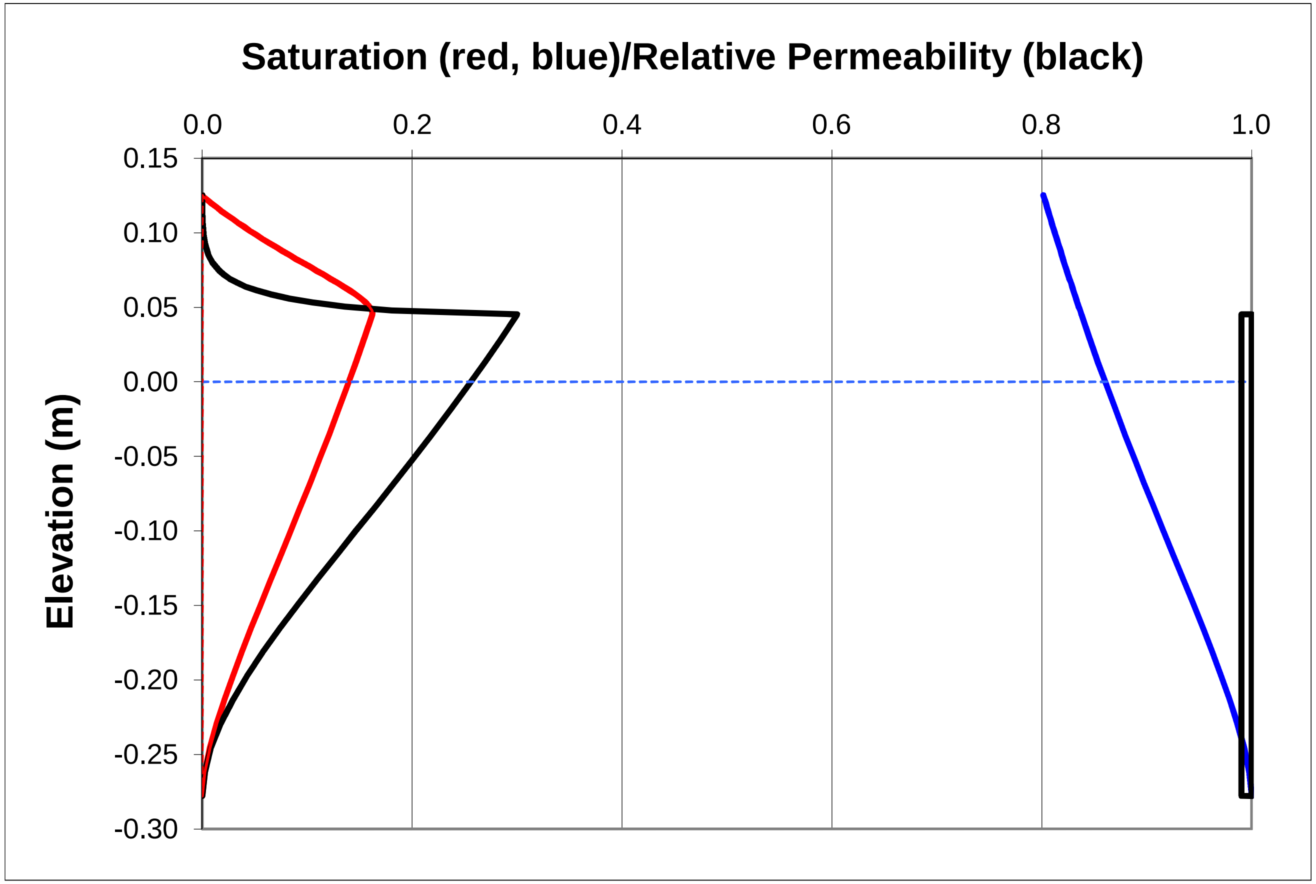
Press Ctrl+Shift+S to calculate sheet

Data for curve-fitting segments				Press Ctrl+Shift+S to calculate sheet				
b_o	D_o	k_{ro}	α	β	ξ	η	**Gauged January 2012**	
0.000	0.000	0.000					**AOI 7 / WP-14**	
0.039	0.000	0.004	0.0000	0.001795	0.0000	0.116036		
0.168	0.002	0.056	0.0349	0.018179	0.0275	0.400227	0.1	Eps-Do
0.323	0.010	0.138	0.1197	0.050112	0.0619	0.529753	0.1	Eps-kro



Monitoring Well LNAPL Thickness b_o (m) =			0.323	Gauged January 2012
D_o =	1.019E-02	k_{ro} =	1.383E-01	AOI 7 / WP-14

Press Ctrl+Shift+S to calculate sheet



APPENDIX I

Development of Site-Specific Standards and Risk Assessment

APPENDIX I
DEVELOPMENT OF SITE-SPECIFIC STANDARDS
AOI 7: SUNOCO PHILADELPHIA REFINERY
PHILADELPHIA, PENNSYLVANIA

Based on the current and future intended non-residential site use, an exposure assessment was conducted for all compounds in surficial soil (0-2 feet bgs) which exceeded the non-residential direct contact statewide health standards in AOI 7. Potential human health exposures for the Refinery are for an industrial worker scenario.

Direct contact exposure pathways to surface soil, groundwater, and LNAPL is for the industrial scenario because of Sunoco's established excavation procedures, PPE requirements and soil handling procedures, as they are described in Appendix K of the 2004 Current Conditions Report (CCR). However, because direct contact to surface soils could occur outside of excavation activities, shallow soil samples were collected in AOI 7 to further evaluate this pathway under a non-residential (on-site worker) scenario.

Based on the recent characterization data collected, concentrations of benzene naphthalene, 1,2,4-trimethylbenzene (1,2,4-TMB), 1,3,5-trimethylbenzene (1,3,5-TMB) and lead were detected above the non-residential soil MSCs in surficial soil (0-2 feet). In accordance with Section IV of the PADEP's Technical Guidance Manual (TGM) (dated June 8, 2002), the COCs listed above were further screened against the EPA Region III Risk-Based Concentrations RBCs (aka, EPA Regional Screening Levels) for industrial soil to potentially reduce the list of compounds carried through the risk assessment. Concentrations of 1,3,5-TMB were below the EPA Region III RBC for industrial soil (10,000 mg/kg) and therefore site-specific criterion for 1,3,5-TMB was not developed. Concentrations of benzene, naphthalene, 1,2,4-TMB and lead were above the EPA Region III RBCs and therefore site-specific criteria were developed, as further described below.

For all compounds that exceed both the non-residential statewide health standards and

EPA Region III RBCs, site-specific standards were calculated using PADEP default intake parameters for an on-site worker and, where appropriate, a risk level of 10^{-4}. The site-specific screening level for benzene was calculated based on inhalation using the calculation provided via email by Samuel Fang, Senior Chemist, of the PADEP. The site specific screening level for 1,2,4-TMB was calculated based on inhalation using the calculation specified in 25 Pa. Code § 250.307(a)(1) and the criteria for naphthalene was calculated based on ingestion using the calculation specified in 25 Pa. Code § 250.306(a). These calculations used the PADEP's default parameters, and an updated target risk level of 1E-4, in consideration of the site-specific conditions (PADEP's default target risk level is 1E-5).

For calculating a site-specific standard for on-site workers exposed to lead, Sunoco used the Society of Environmental Geochemistry and Health (SEGH) model used by PADEP to develop the non-residential MSC. A discussion of the variables used to calculate the lead criteria is provided in the section to follow.

The site-specific standards for these compounds (calculated in Tables I-1 through I-4) are as follows:

Compound	**Calculated Site-Specific Standard (mg/kg)**
Benzene	2,870
Naphthalene	56,780
1,2,4-TMB	560
Lead	1,708

Concentrations of benzene, naphthalene, and 1,2,4-TMB detected in the surface soil samples collected in AOI 7 are below these site-specific standards and, therefore, risk to an on-site worker due to exposure is considered to be within the acceptable ACT 2 range.

The site-specific screening level for lead was calculated based on ingestion as presented in 25 Pa. Code § 250.306(e), Appendix A, Table 7. As described in 25 Pa. Code § 250.306(e), the non-residential soil screening value for lead is based on the method presented in the report 'The Society for Environmental Geochemistry and Health (SEGH) Task Force Approach to the Assessment of Lead in Soil' (Wixson, 1991). The model used by the PADEP and developed by SEGH was also used to calculate the site specific criterion for the refinery. Based on the SEGH model and PADEP's default parameters, PADEP's non-residential direct contact MSC default value for lead in surface soil is 1,000 mg/kg. To develop a site-specific criteria for lead, the values used by PADEP for the target blood lead concentration (T) and geometric mean background blood lead concentration (B) were revised in consideration of site-specific conditions and updated lead data collected by the US Center for Disease Control and Prevention (CDC). Revised values for these parameters are discussed in the following paragraphs.

> <u>Target blood lead concentration (T)</u> – The default target blood lead concentration used by the PADEP to develop the non-residential MSC is 20 ug/dL; however, the Center for Disease Control (CDC) recommends that worker blood lead levels be maintained below 25 ug/dL (NIOSH, 2008) to prevent adverse health effects for most workers from exposure to lead throughout a working lifetime. Based on conversations between representatives of Sunoco and EPA, the target lead blood level identified by the CDC is the level used in the site-specific calculations in Table I-4.

> <u>Geometric mean background blood lead concentration (B)</u> – B is the background blood lead concentration in the target population from sources other than soil and dust. The PADEP's default value for B is 4 ug/dL and, as summarized in PADEPs reference document (Wixson, 1991), is based on data gathered in the United Kingdom from young children. The CDC has monitored blood lead levels in US children and adults since 1976 and, based on the most recent results published by the National Center for Environmental Health of the CDC (NCEH, Page I-3 2005), the mean blood lead concentration for an adult 20 years of age or

older is 1.56 ug/dL. Based on the more recent study by the US CDC, the value used for B in the site specific calculation has been revised to 1.56 ug/dL.

As presented in Table I-4, based on the revised parameters, the derived site-specific standard for lead in soil is 1,708 mg/kg for a refinery worker, and is consistent with the value calculated in the SCRs/RIRs prepared for AOI 9, AOI 5 and AOI 8. One location, BH-10-26, has a concentration of lead above the site specific criteria and will be delineated and remediated as described in the Clean-up Plan.

In addition to calculating the site-specific standards for benzene, naphthalene, 1,2,4-TMB, and lead, the cumulative risk of exposure was also calculated. Lead exposure is dependent on the blood/lead concentration and is not risk based; therefore, lead could not be incorporated into the cumulative risk calculation.

The cumulative hazard index is the combined index for exposure to non-carcinogenic compounds, and should not exceed 1. For AOI 7, the cumulative hazard index for exposure to the non-carcinogenic compounds is 0.55 and is less than the PADEP's requirement of 1.0.

The total cumulative risk is the combined risk of exposure to the concentrations of carcinogenic compounds, which for AOI 7 is benzene. In accordance with the TGM, the total cumulative risk should not exceed 10^{-4}. As presented in Table I-5, the total cumulative risk of exposure to the carcinogenic compounds in AOI 7 is 3.18E-05, and therefore, no remedies are required for AOI 7 to address direct contact to benzene.

Conclusions

Concentrations of benzene, naphthalene, 1,2,4-TMB, and lead detected in surface soil samples collected in AOI 7 were above their respective non-residential soil MSCs and EPA RSLs; and therefore site-specific standards were calculated. Only one location (BH-10-26) had a lead concentration above the site-specific standard, while all other samples were detected below the site-specific screening levels.

Sunoco will delineate the soil concentrations above their MSCs in this area to ensure that soil is below the calculated site-specific standard and locations with detections above the site-specific screening levels will be remediated as described in the Clean-up Plan

References

NCEH. (2005). Third National Report on Human Exposure to Environmental Chemicals. Centers for Disease Control and Prevention, National Center for Environmental Health, Division of Laboratory Sciences. Atlanta, Georgia. NCEH. Pub. No. 05-0570.

NIOSH (2008). Adult Blood Lead Epidemiology and Surveillance (ABLES). http://www.cdc.gov/niosh/topics/ABLES

Wixson, B.G., (1991). The Society of Environmental Geochemistry and Health (SEGH) Task Force Approach to the Assessment of Lead in Soil. Trace Substances in Environmental Health. 11-20.

Table I-1
Derivation of Site-Specific Soil Value
for Benzene[1]
AOI 7 Site Characterization Report
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Parameter	Abbreviation	Assumption	Units	Source
Target Risk[2]	TR	1.00E-04		
Averaging Time for Carcinogens	AT_C	70	yr	25 Pa. Code § 250.307(d)
Transport Factor	TF	13,100	(mg/kg) / (mg/m^3)	25 Pa. Code § 250, Appendix A Table 5
Inhalation Unit Risk	IUR	0.0000078	$(ug/m^3)^{-1}$	25 Pa. Code § 250, Appendix A Table 5
Exposure Time	ET	8	hr/day	25 Pa. Code § 250.307(d)
Exposure Frequency	EF	180	d/yr	25 Pa. Code § 250.307(d)
Exposure Duration	ED	25	yr	25 Pa. Code § 250.307(d)
Conversion Factor	CF	1000	unitless	25 Pa. Code § 250.307(d)

Site-Specific, Non-Residential (Onsite Worker) Screening Value	**2,870**	**mg/kg**
	2,870,000	**ug/kg**

Notes:

1. The site specific screening value was calculated for inhalation based on the calculation specified in 25 Pa. Code 250.307(b)(1)

$$MSC\ (mg/kg) = \frac{TR \times AT_C \times 365\ days/year \times 24\ hr/day \times TF}{IUR \times ET \times EF \times ED \times CF}$$

2. The target risk level was modified from PADEP's default (1E-5) to 1E-4.

Table I-2
Derivation of Site-Specific Soil Value
for Naphthalene[1]
AOI 7 Site Characterization Report
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Parameter	Abbreviation	Assumption	Units	Source
Target Hazard Quotient	THQ	1		25 Pa. Code § 250.306(d)
Oral Reference Dose	RfD_o	0.02	$mg/kg\text{-}day^{-1}$	25 Pa. Code § 250, Appendix A Table 5
Body Weight	BW	70	kg	25 Pa. Code § 250.306(d)
Averaging Time	AT_{NC}	25	yr	25 Pa. Code § 250.306(d)
Absorption	Abs	1	unitless	25 Pa. Code § 250.306(d)
Exposure Frequency	EF	180	d/yr	25 Pa. Code § 250.306(d)
Exposure Duration	ED	25	yr	25 Pa. Code § 250.306(d)
Conversion Factor	CF	1.00E-06	kg/mg	25 Pa. Code § 250.306(d)
Ingestion Rate	IngR	50	mg/day	25 Pa. Code § 250.306(d)

Site-Specific, Non-Residential (Onsite Worker) Screening Value **56,780** **mg/kg**
56,780,000 **ug/kg**

Notes:

1. The site specific screening value was calculated for ingestion based on the calculation specified in 25 Pa. Code 250.306(a)

$$MSC\ (mg/kg) = \frac{THQ \times RFDo \times BW \times AT_{DC} \times 365\ days/year}{Abs \times EF \times ED \times IngR \times CF}$$

Table I-3
Derivation of Site-Specific Soil Value
for 1,2,4-Trimethylbenzene[1]
AOI 7 Site Characterization Report
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Parameter	Abbreviation	Assumption	Units	Source
Target Hazard Quotient	THQ	1	unitless	27 Pa. Code § 250.307(d)
Inhalation Reference Concentration	RfC_i	0.007	mg/kg-day	25 Pa. Code § 250, Appendix A Table 5
Averaging Time for Non-carcinogens	AT_{NC}	25	yr	25 Pa. Code § 250.307(d)
Transport Factor	TF	13,100	(mg/kg) / (mg/m^3)	25 Pa. Code § 250, Appendix A Table 5
Exposure Time	ET	8	hr/day	25 Pa. Code § 250.307(d)
Exposure Frequency	EF	180	d/yr	25 Pa. Code § 250.307(d)
Exposure Duration	ED	25	yr	26 Pa. Code § 250.307(d)

Site-Specific, Non-Residential (Onsite Worker) Screening Value	**560**	**mg/kg**
	560,000	**ug/kg**

Notes:

1. The site specific screening value was calculated for inhalation based on the calculation specified in 25 Pa. Code 250.307(a)(1)

$$\text{MSC (mg/kg)} = \frac{\text{THQ x RfCi x AT}_{NC}\text{ x 365 days/year x 24 hr/day x TF}}{\text{ET x EF x ED}}$$

Table I-4
Derivation of Site-Specific Soil Value
for Lead[1]
AOI 7 Site Characterization Report
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Parameter	Abbreviation	Assumption	Units	Source[2]
Blood lead target concentration	T	25	ug/dL	CDC - ABLES (NIOSH, 2008)
Geometric standard deviation of the blood lead distribution	G	1.4	unitless	25 Pa. Code § 250, Appendix A Table 7
Background blood lead concentration in the population from sources other than soil or dust	B	1.56	ug/dL	NCEH Pub. No. 05-0570 (NCEH, 2005)
Number of standard deviations corresponding to the degree of protection required for the population at risk	n	1.645	unitless	25 Pa. Code § 250, Appendix A Table 7
Response of the blood lead versus soil lead relationship	δ	7.5	ug/dL blood / ug/g soil	25 Pa. Code § 250, Appendix A Table 7

Site-Specific, Non-Residential (Onsite Worker) Screening Value **1,708** **ug/g (mg/kg)**

Notes:

1. The site specific screening value for lead was calculated for ingestion based on the SEGH model as specified by 25 Pa. Code 250.306(e)

$$MSC\ (mg/kg) = \frac{[(T/G^{n}) - B] \times 1000}{\delta}$$

2. Sources for blood lead target level (T) based on conversation between James Oppenheim of Sunoco and Hon Lee of EPA in November 2010.

NIOSH (2008). Adult Blood Lead Epidemiology and Surveillance (ABLES). http://www.cdc.gov/niosh/topics/ABLES

NCEH (2005). Third National Report on Human Exposure to Environmental Chemicals. Centers for Disease Control and Prevention, National Center for Environmental Health, Division of Laboratory Sciences. Atlanta, Georgia. NCEH. Pub. No. 05-0570.

Table I-5
Summary of Site Specific Cumulative Risk Evaluation
AOI 7 Site Characterization Report
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

				Benzene (71-43-2)		Naphthalene (91-20-3)		1,2,4 - Trimethylbenzene (95-63-6)		Lead (7439-92-1)	
Location ID	Sample ID*	Sample Interval	Sample Date	Reported Result (ug/kg)	Calculated Risk	Reported Result (ug/kg)	Calculated Hazard Quotient	Reported Result (ug/kg)	Calculated Hazard Quotient	Reported Result (mg/kg)	Calculated Blood Lead Concentration[4] (ug/dL)
EPA Regional Screening Levels (RSLs) [formerly the Region III RBC[5]]				*5,400*		*18,000*		*260,000*		*800*	
AOI-7	BH-10-05_1.5-2.0	1.5-2	6/9/2010	3	2.52E-09	1,000	1.76E-05	7	1.25E-05	411	8.07
AOI-7	BH-10-06_1.2-1.7	1.2-1.7	6/9/2010	0.7	5.87E-10	3,300	5.81E-05	2	3.59E-06	266	6.18
AOI-7	BH-10-07_1.0-1.5	1-1.5	6/10/2010	ND	--	ND	--	ND	--	305	6.69
AOI-7	BH-10-08_1.5-2.0	1.5-2	6/10/2010	370	3.10E-07	ND	--	210	3.76E-04	444	8.51
AOI-7	BH-10-09_1.2-1.7	1.2-1.7	6/10/2010	2	1.68E-09	4,600	8.10E-05	ND	--	1,230	18.76
AOI-7	BH-10-10_1.5-2.0	1.5-2	6/10/2010	160	1.34E-07	3,300	5.81E-05	890	1.60E-03	725	12.17
AOI-7	BH-10-11_1.5-2.0	1.5-2	6/10/2010	56	4.70E-08	1,500	2.64E-05	430	7.71E-04	184	5.11
AOI-7	BH-10-12_1.5-2.0	1.5-2	6/10/2010	4	3.36E-09	3,800	6.69E-05	6	1.08E-05	414	8.11
AOI-7	BH-10-13_1.5-2.0	1.5-2	6/9/2010	2	1.68E-09	1,000	1.76E-05	ND	--	320	6.89
AOI-7	BH-10-14_1.5-2.0	1.5-2	6/9/2010	260	2.18E-07	4,900	8.63E-05	290	5.20E-04	531	9.64
AOI-7	BH-10-15_1.4-1.9	1.4-1.9	6/9/2010	4	3.36E-09	310	5.46E-06	ND	--	280	6.37
AOI-7	BH-10-16_1.5-2.0	1.5-2	6/9/2010	850	7.13E-07	ND	--	240	4.30E-04	616	10.75
AOI-7	BH-10-17_1.5-2.0	1.5-2	6/9/2010	460	3.86E-07	1,400	2.47E-05	4400	7.89E-03	48	3.34
AOI-7	BH-10-18_1.5-2.0	1.5-2	6/9/2010	0.8	6.71E-10	3,100	5.46E-05	ND	--	478	8.95
AOI-7	BH-10-19_0.5-1.0	0.5-1	6/9/2010	ND	--	ND	--	ND	--	365	7.47
AOI-7	BH-10-20_1.3-1.8	1.3-1.7	6/8/2010	3	2.52E-09	1,200	2.11E-05	ND	--	179	5.05
AOI-7	BH-10-21_1.0-1.5	1-1.5	6/8/2010	ND	--	9,200	1.62E-04	ND	--	869	14.05
AOI-7	BH-10-22_1.5-2.0	1.5-2	6/8/2010	5	4.19E-09	3,700	6.52E-05	ND	--	304	6.68
AOI-7	BH-10-23_1.0-1.5	1-1.5	6/7/2010	19	1.59E-08	110	1.94E-06	ND	--	623	10.84
AOI-7	BH-10-24_1.0-1.5	1-1.5	6/7/2010	94	7.89E-08	1,400	2.47E-05	830	1.49E-03	411	8.07
AOI-7	BH-10-25_1.2-1.7	1.2-1.7	6/7/2010	31,000	2.60E-05	5,500	9.69E-05	200	3.59E-04	79	3.75
AOI-7	BH-10-26_1.5-2.0	1.5-2	6/7/2010	3	2.52E-09	3,300	5.81E-05	ND	--	2,040	**29.33**
AOI-7	BH-10-27_1.5-2.0	1.5-2	6/8/2010	ND	--	21,000	3.70E-04	16000	2.87E-02	393	7.84
AOI-7	BH-10-28_1.5-2.0	1.5-2	6/7/2010	1,600	1.34E-06	30,000	5.28E-04	280,000	5.02E-01	155	4.74
AOI-7	BH-10-29_0.7-1.2	0.7-1.2	6/7/2010	10	8.39E-09	200	3.52E-06	ND	--	395	7.87
AOI-7	BH-10-30_1.5-2.0	1.5-2	6/7/2010	380	3.19E-07	11,000	1.94E-04	240	4.30E-04	250	5.97
AOI-7	BH-10-31_1.5-2.0	1.5-2	6/8/2010	470	3.94E-07	7,300	1.29E-04	1100	1.97E-03	610	10.67
AOI-7	BH-10-32_0.5-1.0	0.5-1	6/8/2010	4	3.36E-09	640	1.13E-05	2	3.59E-06	298	6.60
AOI-7	BH-10-33_1.5-2.0	1.5-2	6/8/2010	ND	--	ND	--	ND	--	43	3.28
AOI-7	BH-10-34_1.0-1.5	1-1.5	6/8/2010	ND	--	ND	--	ND	--	84	3.81
AOI-7	BH-10-35_1.3-1.7	1.3-1.7	6/8/2010	ND	--	ND	--	ND	--	93	3.92
AOI-7	C-129_1-2	1-2	6/2/2010	3	2.52E-09	4,200	7.40E-05	ND	--	252	6.00
AOI-7	C-130_1-2	1-2	6/2/2010	ND	--	ND	--	ND	--	814	13.33
AOI-7	C-131_1-2	1-2	6/3/2010	ND	--	6,500	1.14E-04	ND	--	396	7.88
AOI-7	C-136_1-2	1-2	5/28/2010	7	5.87E-09	550	9.69E-06	ND	--	218	5.56
AOI-7	C-138_1-2	1-2	5/27/2010	12	1.01E-08	110	1.94E-06	14	2.51E-05	103	4.06
AOI-7	C-139_1-2	1-2	6/2/2010	ND	--	ND	--	ND	--	99	4.00
AOI-7	C-140_1-2	1-2	5/26/2010	ND	--	470	8.28E-06	ND	--	99	4.00
AOI-7	C-142_1-2	1-2	6/2/2010	100	8.39E-08	2,000	3.52E-05	180	3.23E-04	1,370	20.58
AOI-7	C-143_1-2	1-2	6/3/2010	2,000	1.68E-06	270	4.76E-06	250	4.48E-04	164	4.85
			Cumulative Total[1]:		**3.18E-05**		**2.41E-03**		**5.47E-01**		

Total Cumulative Risk for Carcinogens[2]: 3.18E-05 < 1 in 10,000

Total Hazard Index for Non-Carcinogens[3]: 0.55 <1

Notes:

ND - Not Detected

BOLD - Indicates locations with concentrations exceeding PADEP's Non-Residential Soil MSC.

[1] Cumulative total of detected concentrations greater than the PADEP Non-Residential Soil MSC.

[2] Total Cumulative Risk is the combined risk of exposure to the detected concentrations of carcinogenic compounds [benzene] and should be less than 1 in 10,000.

[3] Total Hazard Index is the combined hazard quotients of detected concentrations of naphthalene, 1,2,4-TMB, and 1,3,5-TMB and should be less than 1.

[4] Calculated based on site specific parameters provided in Table I-4. The CDC (NIOSH, 2008) recommends that blood lead levels be maintained below 25 ug/dL.

[5] http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/pdf/master_sl_table_run_NOV2011.pdf

*All soil samples collected and analyzed were unsaturated.

APPENDIX J

AOI 7 Workplan

WORK PLAN FOR SITE CHARACTERIZATION
AREA OF INTEREST 7

SUNOCO PHILADELPHIA REFINERY
PHILADELPHIA, PENNSYLVANIA

Sunoco, Inc. (R&M)
3144 Passyunk Avenue
Philadelphia, Pennsylvania

May 26, 2010
2574601

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 Environment Protection (PADEP) and the United States Environmental Protection Agency (EPA). A site characterization work plan for AOIs 2 and 3 was submitted to the PADEP and EPA on March 19, 2010.

This site characterization work plan (work plan) has been prepared specifically for AOI 7, the next AOI to be characterized in accordance with the revised Phase II Corrective Action Schedule which is included as Appendix A. AOI 7, also known as the Girard Point Fuels Processing Area, is located north of Pennypacker Avenue, east of Lanier Avenue, and south and west of the Schuylkill River (Figure 1). AOI 7 encompasses approximately 130 acres and approximately 40 percent of AOI 7 is covered by impervious surfaces. The entire western boundary of AOI 7 is bound by a sheet pile wall. There are a total of five Solid Waste Management Units (SWMUs) located in AOI 7 that were addressed in various stages of investigation as part of the EPA Corrective Action Process. The SWMUs are described in detail in Section 1.2.1 of this work plan.

AOI 7 formerly contained a fluid catalytic cracker (FCC) unit, CO boiler, sulfur plant, East and West Sludge Basin - Resource Conservation and Recovery Act (RCRA) Tank, Hazardous Waste Incinerator, and crude units. Based on the review of historical reports and aerial photographs, early refining units in AOI 7 were built in the 1940s. AOI 7 currently consists of crude units, cracking and alkylation units, hydrodesulfurization units, flares, and above ground storage tanks (ASTs). The ASTs contain primarily naptha crude, waste oil, and cat charge stocks. Eight liquefied petroleum gases (LPG) tanks are located in the south-central portion of this area. A wastewater treatment plant (WWTP) is located along the western portion of AOI 7 adjacent to the Schuylkill River. Four RCRA hazardous waste ASTs are located in the western portion of AOI 7 approximately 150 feet north of the WWTP.

1.1 Objectives

The objective of the proposed activities in this work plan is to characterize current environmental conditions at AOI 7 in accordance with the following: 2003 Consent Order and Agreement (CO&A) between Sunoco and the PADEP, the 2004 CCR, and the PA One Cleanup and Act 2 Program. Below is a list of the general site characterization activities proposed to characterize conditions in AOI 7. These proposed activities are described in detail later in this work plan.

- Review of all available historical environmental reports relating to AOI 7;
- Advance shallow soil borings and collect shallow soil samples from select unpaved areas for laboratory analysis of site compounds of concern (COCs);
- Further characterize AOI 7 SWMUs in accordance with the 2003 CO&A and in context of the PA One Cleanup Program approach to support the closure of the SWMUs by EPA;
- 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 EPA – PA default non-residential permissible exposure levels (PELs), which are based on OSHA PELs for volatilization into indoor air screening;
- 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 the PADEP's recent revisions to the petroleum short list of compounds.

Data collected from the above-listed activities will be evaluated as part of the AOI 7 site characterization process. This data and evaluation will be presented in a Site Characterization/Remedial Investigation Report for AOI 7. This report is anticipated to be submitted to PADEP and EPA by September 30, 2010 in accordance with the revised Phase II Corrective Action Schedule provided as Appendix A to this report.

1.2 Overview of Investigative Framework/Remedial Approach for AOI 7

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 that 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 presented 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 CO&A between PADEP and Sunoco; and
- EPA will issue a letter to Sunoco for each characterized SWMU in AOI 7 for which no further action is required.

The above-bulleted items are still pending.

1.2.1 Overview of RCRA Corrective Action Program Girard Point

A number of RCRA corrective action investigations and RCRA closure investigations were completed in AOI 7 between 1989 and 1999. The reports prepared as part of these RCRA corrective action investigations included:

- 1989 Phase II RCRA Facility Assessment (1989 Phase II RFA);
- 1990 RCRA Facility Investigation Work Plan (1990 RFIWP);
- 1992 RCRA Verification Investigation (1992 RVI);
- 1993 RCRA Facility Investigation (1993 RFI);
- 1998 Phase II RCRA Facility Investigation Work Plan (1998 Phase II RFIWP);
- 1999 Certification of Closure for Girard Point Processing Area Incinerator; and
- 1999 Closure Report for Sludge Storage Basins.

These reports are discussed further in Sections 1.4 and 4.0 below. Based on a review of these reports, five SWMUs were identified in AOI 7 that require further characterization in accordance with the current remedial program. The RCRA reports identify these areas as the northwestern fill area (SWMUs 87, 88, and 89) and storage tank area (SWMUs 90 and 91). These SWMUs are shown in Figures 2 and 3.

The northwestern fill area consists of SWMU 87 (Buried Lead Sludge Area No. 1), SWMU 88 (Buried Lead Sludge Area No. 2), and SWMU 89 (Buried Lead Sludge Area No. 3). All three SWMUs are located adjacent to each other in the northwestern portion of AOI 7 (Figure 3). The Schuylkill River borders these SWMUs to the north and west. The 1990 RFIWP reported that these three SWMUs received cooling tower sludge, leaded tank bottom sludge, and oily tank bottom sludge (add report reference).

One Hazardous Waste Incinerator was formerly located in the in the southwest corner of AOI 7. This incinerator was properly closed in March 1999 and following closure activities, no violations and or releases were reported.

Two hazardous waste sludge basins (388 Tank Basins - East and West) were formerly located in the southwest corner of SWMU 87. The 388 Tank Basins – East and West were properly closed in November 1999. Following closure investigation activities, there was no evidence of a release from the basins.

The storage tank area is located in the southeastern portion of AOI 7 and contains SWMU 90 (Buried Lead Sludge Area No. 4) and SWMU 91 (Buried Lead Sludge Area No. 5). SWMU 90 is located immediately north of SWMU 91 as shown in Figure 3. AOI 3 borders SWMUs 90 and 91 to the east and AOI 6 borders the SWMUs to the south. The 1990 RFIWP reported that leaded sludge from tank bottoms were periodically removed from tanks in this area and were disposed on the ground or in shallow excavations. These SWMUs received waste beginning in the 1960s and up until November 1980. The disposal areas may have also received oily solids, API separator sludge, and spent catalysts (1990 RFIWP).

Historic reports have indicated that SWMUs 87, 88, 89, 90, and 91 have the potential to contain leaded tank bottom materials. Leaded tank bottom materials are distinguished by distinctive rusty-red to black, metallic mostly oxidized scale materials. Leaded tank bottoms also can be found in a matrix of petroleum wax sludge. Sunoco's general procedure to characterize the SWMUs in AOI 7 for the presence of leaded tank bottom materials is described below.

Data collected from shallow soil in SWMU areas as part of the historic RCRA investigations was reviewed to determine additional characterization needs. If shallow soil samples were previously collected from the SWMU areas, and concentrations of lead in these samples did not exceed the current PADEP non-residential soil MSC for lead (450 parts per million (ppm)), then no additional soil samples are proposed to be collected at these areas. If no shallow soil samples were collected from previous soil boring locations, or the shallow soil samples collected exhibited concentrations of lead above the current PADEP MSC, then shallow soil samples will be collected from these historic boring locations. Where shallow soil borings are proposed in this work plan, if materials are encountered in shallow soil within the leaded tank bottom areas matching the physical description of leaded tank bottoms, then Sunoco will perform the following:

- Collect soil samples for total lead;
- If total lead results exceed the PADEP's non-residential soil MSC for lead (450 parts per million), then the samples will be analyzed for lead via a Toxicity Characteristic Leaching Procedure (TCLP), EPA Test Method 1311; and
- Delineated areas that have soils that physically resemble leaded tank bottoms, have concentrations of total lead exceeding 450 parts per million (ppm), and are hazardous for lead based on TCLP analysis, will retain the leaded tank bottom designation.

If no soils are encountered that meet all three of the criteria, then the area will no longer be classified as a leaded tank bottom area. The proposed soil sampling program for the SWMUs are discussed further in Section 2.0 and Appendix C of this work plan.

Sunoco proposes to complete characterization of SWMUs 87, 88, 89, 90, and 91 within the site characterization scope for AOI 7 as described in this work plan. Site characterization and/or remediation of identified leaded tank bottom materials will be completed in accordance with the approach discussed herein, therefore RCRA obligations for all areas within AOI 7 will be satisfied provided that the PADEP and EPA have approved the work completed as documented in the site characterization report and/or a subsequent Cleanup Plan, if necessary. The proposed approach is consistent with the approach used for AOIs 5 and 6 which have been previously characterized and contained suspected leaded tank bottoms. The proposed approach to characterize each SWMU is described in Sections 1.2.2, 1.2.3, 1.2.4, and 1.2.5 below.

1.2.2 SWMU 87 – Buried Lead Sludge Area No. 1

The 1990 RFIWP describes SWMU 87 as buried lead sludge area No.1 located in the western portion of AOI 7 within the northwestern fill area (Figure 3). This area includes process units, crude units, cooling towers, four RCRA hazardous waste ASTs, and storage areas. The 388 Tank Basins were formerly located in the southwest corner of SWMU 87 and were properly closed in November 1999. The southwest corner of SWMU 87 is covered by impervious surface.

Based on results of historical RCRA investigations, a total of three shallow (0.0 to 6.0 feet beneath ground surface) soil samples collected in SWMU 87 (BNA-2, BNA-3, and BNA-5) exceeded the current PADEP soil MSC for lead. These areas and other portions of this SWMU will be further investigated to determine the presence of leaded tank bottoms, delineate leaded tank bottoms if present, and further characterize historical soil exceedance areas.

Sunoco intends to complete a total of six shallow (0 to 2 feet beneath ground surface) soil borings to characterize soil in SWMU 87. These samples will be collected from the locations of former soil borings (BNA-1, BNA-2, BNA-3, BNA-4, BNA-5, and BNA-6) where shallow soil samples were either not previously collected, or exhibited concentrations of lead exceeding the current PADEP MSC. Detailed descriptions of the proposed site characterization activities are described in Sections 2.0 and in Appendix C of this work plan.

1.2.3 SWMU 88 – Buried Lead Sludge Area No. 2

The 1990 RFIWP describes SWMU 88 as buried lead sludge area No.2 located in the northwestern portion of AOI 7 within the northwestern fill area (Figure 3). This area includes cooling towers, process unit areas, and crude unit No. 137. The central portion of SWMU 88 is entirely covered by impervious surface.

Based on results of historical RCRA investigations, a total of five shallow (0.0 to 6.0 feet beneath ground surface) soil samples collected in SWMU 88 (BNA-7, BNA-8, BNA-9, BNA-10, and BNA-11) exceeded the current PADEP soil MSC for lead. These areas and other portions of this SWMU will be further investigated to determine the presence/absence of leaded tank bottoms, delineate leaded tank bottoms if present, and further characterize historical soil exceedance areas.

To characterize shallow soil in SWMU 88, Sunoco intends to complete a total of seven shallow soil borings. These samples will be collected from the locations of former soil borings (BNA-7, BNA-8, BNA-9, BNA-10, and BNA-11) where shallow soil samples were either not previously collected, or exhibited concentrations of lead exceeding the current PADEP MSC. Detailed descriptions of the proposed site characterization activities are described in Section 2.0 and Appendix C of this work plan.

Historical reports reviewed and recent groundwater gauging activities indicate the presence of LNAPL (consisting of lube/residual oil) in monitoring wells C-106, C-107, and C-65 in SWMU 88. A Remedial Action Plan Implementation Report prepared by Dames & Moore in 1993 (1993 RAPIR), delineated the extent of LNAPL by installing a series of well points. These well points have since been destroyed and the presence of LNAPL in SWMU 88 will be further characterized through additional well installation and monitoring activities as described in Section 2.0 and Appendix C of this work plan.

1.2.4 SWMU 89 – Buried Lead Sludge Area No. 3

The 1990 RFIWP describes SWMU 89 as buried lead sludge area No.3 located in the northwestern portion of AOI 7 within the northwestern fill area (Figure 3). This area includes cooling towers, process unit areas, No. 3 separator, unit Nos. 2031 and 433, flares, and above ground pipe racks. Historical reports indicate that a solvent decarbonizer area was located in the southwestern portion of SWMU 89. The majority of SWMU 89 is not covered by impervious surfaces.

Based on results of historical RCRA investigations, one shallow (4.0 to 6.0 feet beneath ground surface) soil sample collected in SWMU 89 (BNA-13) had an exceedance of the current PADEP soil MSC for lead. This area and other portions of SWMU 89 will be further investigated to determine the presence/absence of leaded tank bottoms, delineate leaded tank bottoms if present, and further characterize historical soil exceedance areas.

To characterize shallow soil in SWMU 89, Sunoco intends to complete a total of four shallow soil borings. These samples will be collected from the locations of former soil borings (BNA-12, BNA-13, and BNA-14) where shallow soil samples were either not previously collected, or exhibited concentrations of lead exceeding the current PADEP MSC. Shallow soil samples will also be collected from three proposed shallow monitoring wells and one deep monitoring well in SWMU 89. Detailed descriptions of the proposed site characterization activities are described in Section 2.0 and Appendix C of this work plan.

Historical RCRA reports and recent groundwater gauging activities indicate the presence of LNAPL (consisting of lube/residual oil) in monitoring well C-97 in SWMU 89. The 1993 RAPIR delineated the extent of LNAPL in the vicinity of C-97 by installing well points. The well points have since been destroyed and LNAPL will be further characterized and delineated through additional well installation and monitoring activities as described in Section 2.0 and Appendix C of this work plan.

1.2.5 SWMU 90 – Buried Lead Sludge Area No. 4

The 1990 RFIWP describes SWMU 90 as buried lead sludge area No.4 located in the southeast portion of AOI 7 within the storage tank area (Figure 3). This area includes two storage tanks, four former tank locations within a berm and two former tank locations outside a berm. The majority of SWMU 90 is not covered by impervious surfaces.

Based on results of historical RCRA investigations, three shallow (0.0 to 4.0 feet beneath ground surface) soil samples collected in SWMU 90 (B-90-2, TB-289, and TB-290) had an exceedance of the current PADEP soil MSC for lead. These areas and other portions of SWMU 90 will be further investigated to determine the presence/absence of leaded tank bottoms, delineate leaded tank bottoms if present, and further characterize historical soil exceedance areas.

To characterize shallow soil in SWMU 90, Sunoco intends to complete a total of eight shallow soil borings. These samples will be collected from the locations of former soil borings (B-90-1, B-90-2, B-90-3, B-90-5, B-90-14, B-90-15, TB-289, and TB-290) where shallow soil samples were either not previously collected, or exhibited concentrations of lead exceeding the current PADEP MSC. Detailed descriptions of the proposed site characterization activities are described in Section 2.0 and Appendix C of this work plan.

1.2.6 SWMU 91 – Buried Lead Sludge Area No. 5

The 1990 RFIWP describes SWMU 91 as buried lead sludge area No.5 located in southeast portion of AOI 7 within the storage tank area (Figure 3). This area includes four storage tanks and one former tank location within a bermed area. The northeastern portion of SWMU 90 is covered with impervious surfaces.

Based on the results of historical RCRA investigations, four shallow (0.0 to 4.0 feet below groundsurface) soil samples collected in SWMU 91 (TB-276, TB-277, TB-286, and B-91-19) had an exceedance of the current PADEP soil MSC for lead. These areas and other portions of SWMU 91 will be further investigated to determine the presence/absence of leaded tank bottoms, delineate leaded tank bottoms if present, and further characterize historical soil exceedance areas.

To characterize shallow soil in SWMU 91, Sunoco intends to complete a total of five shallow soil borings in SWMU 91. These samples will be collected from the locations of former soil borings (TB-276, TB-277, TB-286, B-91-19, B-91-1, B-91-8, B-91-18, and B-91-19) where shallow soil samples were either not previously collected, or exhibited concentrations of lead exceeding the current PADEP MSC. Detailed descriptions of the proposed site characterization activities are described in Section 2.0 and Appendix C of this work plan.

1.3 Overview of Existing Remediation Activities in AOI 7

Currently there are no active remediation systems located in AOI 7.

1.4 Work Plan Support Activities

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

<u>AOI 7</u>

- 34 existing groundwater monitoring wells in AOI 7 were surveyed by Langan Engineering and Environmental Services (Langan) in December 2009. 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 7 from January 11 to January 15, 2010. A total of 32 accessible existing wells in AOI 7 were gauged and 28 wells were sampled for site COCs. 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 2 of this work plan.
- Historical aerial photographs with coverage of AOI 7 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 7. 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 7 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.

  Draft Report – Volume II (Appendices) Site Assessment Investigation, Chevron-Gulf Refinery, Philadelphia, PA, Dames and Moore, February 13, 1987.

  Final Report – Permeability Tests, Chevron-Gulf Refinery, Philadelphia, PA, Dames and Moore, September 4, 1987.

  Phase II RCRA Facility Assessment, Chevron USA Inc (Gulf) Facility, Philadelphia, PA, A.T. Kearney, Inc., January 1989.

  EPA Submittal – RCRA Facility Investigation Work Plan, Chevron Refinery, Philadelphia PA, Dames and Moore, April 16, 1990.

  Remedial Action Plan Implementation, Chevron Refinery, Philadelphia, PA, Dames & Moore, September 30, 1993.

RCRA Facility Investigation, Chevron Refinery, Philadelphia, PA, Dames & Moore, November 24, 1993.

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

Phase II Work Plan – RCRA Facility Investigation, Sun Company, Inc (R&M), Philadelphia, PA, Dames and Moore, April 23, 1998.

Certification of Closure for Girard Point Processing Area Incinerator, Sunoco Philadelphia Refinery, Philadelphia, PA, Sunoco Company, Inc., March 4, 1999.

Site Assessment Report: Former Tanks M004/M005, 355 and 174, Sunoco, Inc (R&M) Philadelphia Refinery, Philadelphia, PA, Handex, March 2, 1999.

Closure of Sludge Storage Basins, Sunoco Philadelphia Refinery, Philadelphia, PA, Philip Services (PSC), November 1, 1999.

Above Ground Storage Tank No. 271 Closure Report, Sunoco Philadelphia Refinery, Philadelphia, PA, Secor, July 10, 2002.

Site Characterization Report, AST 271 Area, Girard Point Processing Area, Philadelphia Refinery, Philadelphia, PA, Secor, December 20, 2002.

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

Tank GP 270 Release – Site Characterization Letter Report, Sunoco Inc., Philadelphia Refinery, Philadelphia, PA, Stantec Consulting Corp., November 23, 2009.

Data collected from the above-mentioned historical investigations and reports were compiled and evaluated using the refinery's GIS. Relevant historic features, information and investigation areas are shown in Figure 3. In addition to the historic areas, the data obtained from the January 2010 groundwater gauging and sampling activities are summarized on this figure. The historic data, as well as the

January 2010 groundwater data, were used to modify and refine the proposed site characterization activities, identify data gaps, and further refine the Site Conceptual Model for AOI 7. A summary of the proposed site characterization activities and the objective of each activity are provided in Table 3.

1.4.1 January 2010 Groundwater Gauging and Sampling Results

A total of 32 accessible existing wells in AOI 7 were gauged and 28 wells were sampled for site COCs in January 2010 by Aquaterra. The groundwater gauging data from this event was used to generate inferred groundwater contours as shown in Figure 3.

Four wells (C-65, C-97, C-106, and C-107) in AOI 7 contained measurable LNAPL and therefore groundwater was not sampled from these wells. The results of the groundwater samples collected from monitoring wells in AOI 7 are provided in Table 2 and are illustrated in Figure 3. The results were screened against the PADEP non-residential used aquifer (TDS<2,500) groundwater MSCs (groundwater MSCs). Of the 28 monitoring wells sampled, two wells (C-61 and C-111) had exceedances of benzene's groundwater MSC of 5 micrograms per liter (ug/L). C-61 had a benzene exceedance of 12 ug/L and C-111 had a benzene exceedance of 140 ug/L. No other wells or compounds exceeded the MSCs throughout AOI 7.

Based on the review of historical reports and the January 2010 groundwater gauging and sampling data, the following general statements can be made about geology and hydrogeology in AOI 7:

- Fill/Alluvium, Trenton, Middle/Lower Clay, and Lower Sand units all exist beneath AOI 7;
- The Trenton Gravel may be absent in the southern and eastern portions of AOI 7 and is undifferentiated with Fill/Alluvium;
- Clay is present beneath AOI 7 as a wedge which thickens towards the west and the Schuylkill River. The clay reportedly is approximately 10 feet thick on the east side of AOI 7 and 50 feet thick along its boundary with the Schuylkill River;
- The thickness of the Lower Sand beneath AOI 7 ranges between 10 and 35 feet;

- Depth to bedrock was not clear in any of the historical reports reviewed. Only one monitoring well (MW-65D) was drilled to a depth of 75 feet beneath the ground surface; however, no bedrock was noted on the log;
- Groundwater contours were created using the January 2010 groundwater elevations collected from the Fill/Alluvium and Trenton Gravel wells. As shown in Figure 3, groundwater flow in AOI 7 is generally towards the north and west in the direction of the Schuylkill River. A ground water mound is present in the northwest portion of AOI 7 with flow moving radially away from the mound area. This mounding is likely attributable to the presence of the bulkhead between AOI 7 and the river. Groundwater in the central portion of AOI 7 appears to be relatively flat, however limited monitoring well data exists in this area; and
- Groundwater flow in the Lower Sand unit could not be contoured due to the lack of deep wells in AOI 7.

2.0 PROPOSED SITE CHARACTERIZATION ACTIVITIES

Based on the identified data collection needs for AOI 7, 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

SWMU Area Soil Borings and Sampling

A total of 31 shallow soil borings will be completed to a depth of 2 feet beneath the ground surface in SWMUS 87, 88, 89, 90, and 91. Below is a summary the soil borings to be completed in each SWMU area:

- SWMU 87 – Six shallow soil borings;
- SWMU 88 – Eight shallow soil borings;
- SWMU 89 – Four shallow soil borings;
- SWMU 90 – Eight shallow soil borings; and
- SWMU 91 – Five shallow soil borings.

The locations of the proposed soil borings in the five SWMUs were selected following the rationale described in Section 1.2.1. The soil borings will characterize the potential direct contact to shallow soil exposure pathway, further investigate and determine the presence of leaded tank bottoms, delineate leaded tank bottoms if present, and further characterize historical soil exceedance areas. Soil borings will be advanced with a geoprobe or similar sampling device.

Sample collection criteria for soil samples from within the SWMU areas are further described in Section 1.2.1, Table 2, and Appendix C of this work plan. The proposed boring locations are shown on Figures 2 and 3.

Non-SWMU Area Soil Borings

To characterize the potential direct contact to shallow soil exposure pathway outside of the SWMU areas, shallow soil samples will be collected from 0 to 2 feet beneath the ground surface at each proposed groundwater monitoring well location that is not covered by an impervious surface. Soil boring and sample collection procedures are outlined in Appendix C and the proposed monitoring well/boring locations are depicted on Figures 2 and 3. 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

Fifteen Fill/Alluvium and Trenton Gravel (shallow/intermediate) groundwater monitoring wells are proposed to be installed in AOI 7 as shown on Figures 2 and 3, and are summarized on Table 3. The well borings will be advanced using hollow stem auger drilling methods and screened within the shallow zone (estimated depth of 15 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.

Two deep (Lower Sand) groundwater monitoring wells exist in AOI 7 (C-50D and C-65D). C-50D was installed to a depth of approximately 30 feet beneath the ground surface screening the upper portion of the Lower Sand. C-65D is reported to have been drilled to a depth of 75 feet beneath the ground surface, however the well is damaged and inaccessible A total of five additional deep groundwater monitoring wells are proposed to be installed in AOI 7 as shown on Figures 2 and 3 and summarized on Table 3. The well borings will be advanced using hollow stem auger drilling methods, mud and/or air rotary drilling methods to approximate depths of 90 feet beneath the ground surface (estimated depth to top of bedrock). The purpose of the additional deep wells is to obtain lithologic information beneath AOI 7 and to characterize groundwater quality of the Lower Sand. The wells will be installed and developed in accordance with the procedures in Appendix C.

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 AOI 7, a complete round of groundwater elevation gauging will be performed from all accessible new and existing monitoring wells in AOI 7. 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 AOI 7.

2.3.2 Groundwater Sampling

Coincident with the groundwater gauging activities in the AOI 7, a complete round of groundwater sampling will be conducted including all accessible existing and newly installed monitoring wells that do not contain measurable LNAPL to characterize groundwater quality throughout AOI 7. 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 three wells (C-65, C-106, and C-107) in AOI 7. 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 AOI 7 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 by an Act 2-certified laboratory. The results of the LNAPL characterization analysis will be used to delineate LNAPL plumes and identify product types for remedial evaluation.

2.5 Task 5: Aquifer Testing

As part of historical investigations, aquifer tests have been completed in AOI 7. The hydrogeologic data obtained from 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.

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

There are several potential vapor intrusion receptors (occupied buildings) in AOI 7. All of the buildings are operated by Sunoco and are considered industrial receptors and regulated by OSHA. These potential vapor intrusion receptors are shown in Figure 3. As part of the site characterization, 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. Because the buildings are part of refinery operations, the OSHA permissible exposure limit (PEL)-based limits in the guidance will be used when evaluating site data. The OSHA PEL soil screening values are appropriate because the site and its industrial operations are regulated by OSHA.

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

Fate and transport simulations will be prepared for groundwater in AOI 7 to evaluate potential dissolved-phase migration pathways and potential impacts to receptors, as necessary. Fate and transport modeling will be conducted for COCs in groundwater that exceed their respective MSCs using PADEP approved analytical models (QUICK_DOMENICO.XLS and PENTOXSD). The parameters used in the analyses will consist of site-specific data obtained during previous investigations, values collected during the site characterization activities, and/or default parameters provided in the Act 2 regulations or Technical 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 AOI 7 based on the results of the proposed site characterization activities and the known conditions. This exposure assessment will be based on non-residential current and assumed future site use. If warranted, risk assessment activities will be completed in accordance with Act 2.

2.9 Task 9: Surveying

Sunoco surveyed 34 existing wells in AOI 7 in December 2009 in support of this work plan. Following completion of the proposed soil boring and groundwater monitoring well installation 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 geographic information system (GIS) in accordance with the objectives of the 2003 CO&A and the CCR. This data will be used to modify and refine the Site Conceptual Model for AOI 7 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 AOI 7 will be used to further evaluate subsurface conditions at these areas;
- Soil data collected between 0 and 2 feet beneath the ground surface from within the SWMU areas will further investigate the presence of leaded tank bottoms, delineate leaded tank bottoms if present, and further characterize historical soil exceedance areas;
- Installation, monitoring and sampling of new groundwater monitoring wells will further characterize groundwater quality and flow in shallow, intermediate, and deep zones on AOI 7;
- Further characterize site geology and hydrogeology;
- New and existing LNAPL data in AOI 7 will further characterize LNAPL type, thickness and lateral extent;
- Fate and transport modeling of dissolved phase COCs in groundwater will further characterize the potential for migration of dissolved phase COCs in groundwater in AOI 7; and
- Updated survey data will allow for accurate depiction and evaluation of data points.

2.11 Task 11: Reporting

Following completion of the activities listed above in Tasks 1 through 10, a Site Characterization/Remedial Investigation Report will be prepared for AOI 7 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 May 2010 and will be completed in conjunction with the AOI 2 and 3 work plan site characterization activities. It is anticipated that field activities for AOI 7 will be completed by July 2010. The Site Characterization/Remedial Investigation Report for AOI 7 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 included in this work plan, the PADEP and EPA will be notified prior to implementation of any changes to the work scope.

4.0 REFERENCES

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

Draft Report – Volume II (Appendices) Site Assessment Investigation, Chevron-Gulf Refinery, Philadelphia, PA, Dames and Moore, February 13, 1987.

Final Report – Permeability Tests, Chevron-Gulf Refinery, Philadelphia, PA, Dames and Moore, September 4, 1987.

Phase II RCRA Facility Assessment, Chevron USA Inc (Gulf) Facility, Philadelphia, PA, A.T. Kearney, Inc., January 1989.

EPA Submittal – RCRA Facility Investigation Work Plan, Chevron Refinery, Philadelphia PA, Dames and Moore, April 16, 1990.

Remedial Action Plan Implementation, Chevron Refinery, Philadelphia, PA, Dames & Moore, September 30, 1993.

RCRA Facility Investigation, Chevron Refinery, Philadelphia, PA, Dames & Moore, November 24, 1993.

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

Phase II Work Plan – RCRA Facility Investigation, Sun Company, Inc (R&M), Philadelphia, PA, Dames and Moore, April 23, 1998.

Professional Engineer Certification of Closure for Hazardous Waste Incinerator, Sunoco Philadelphia Refinery, Philadelphia, PA, Philip Services (PSC), February 26, 1999.

Site Assessment Report: Former Tanks M004/M005, 355 and 174, Sunoco, Inc (R&M) Philadelphia Refinery, Philadelphia, PA, Handex, March 2, 1999.

Closure of Sludge Storage Basins, Sunoco Philadelphia Refinery, Philadelphia, PA, Philip Services (PSC), November 1, 1999.

Above Ground Storage Tank No. 271 Closure Report, Sunoco Philadelphia Refinery, Philadelphia, PA, Secor, July 10, 2002.

Site Characterization Report, AST 271 Area, Girard Point Processing Area, Philadelphia Refinery, Philadelphia, PA, Secor, December 20, 2002.

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

Tank GP 270 Release – Site Characterization Letter Report, Sunoco Inc., Philadelphia Refinery, Philadelphia, PA, Stantec Consulting Corp., November 23, 2009.

TABLES

Table 1
Constituents of Concern for Groundwater
AOI 7 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
AOI 7 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 2
Groundwater Analytical Results
AOI 7 Work Plan
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Analysis Name	CAS Number	PADEP Non-Residential Used Aquifer TDS <2,500 mg/L Groundwater MSCs	Location ID	C-108			C-109			C-110			C-111			C-112			C-127		
			Lab ID	5883564			5883576			5883574			5883575			5883578			5883567		
			Sample ID	C-108_011210			C-109_011310			C-110_011310			C-111_011310			C-112_011310			C-127_011310		
			Sample Date	1/12/2010			1/13/2010			1/13/2010			1/13/2010			1/13/2010			1/13/2010		
Volatile Organic Compounds			**Unit**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**
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
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
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
BENZENE	71-43-2	5	ug/l	ND	1	U	ND	1	U	ND	1	U	**140**	1		ND	1	U	ND	1	U
CUMENE	98-82-8	2300	ug/l	ND	2	U	ND	2	U	ND	2	U	60	2		ND	2	U	3	2	
ETHYLBENZENE	100-41-4	700	ug/l	ND	1	U	ND	1	U	ND	1	U	3	1		ND	1	U	ND	1	U
ETHYLENE DIBROMIDE (EDB)	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
METHYL TERTIARY BUTYL ETHER	1634-04-4	20	ug/l	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	5	1	
TOLUENE	108-88-3	1000	ug/l	ND	1	U	ND	1	U	ND	1	U	17	1		ND	1	U	ND	1	U
XYLENE (TOTAL)	1330-20-7	10000	ug/l	2	1		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	**5**	U	ND	**5**	U	ND	**5**	U	ND	**5**	U	ND	**50**	U	ND	**5**	U
FLUORENE	86-73-7	1900	ug/l	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	50	U	ND	5	U
NAPHTHALENE	91-20-3	100	ug/l	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	50	U	ND	5	U
PHENANTHRENE	85-01-8	1100	ug/l	ND	5	U	ND	5	U	ND	5	U	9	5		ND	50	U	ND	5	U
PYRENE	129-00-0	130	ug/l	ND	5	U	8	5		ND	5	U	8	5		ND	50	U	ND	5	U
Metals																					
LEAD (TOTAL)	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

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 2
Groundwater Analytical Results
AOI 7 Work Plan
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Analysis Name	CAS Number	PADEP Non-Residential Used Aquifer TDS <2,500 mg/L Groundwater MSCs	Location ID	C-50			C-50D			C-53A			C-51			C-52			C-54		
			Lab ID	5883572			5883573			5883565			5883566			5883568			5883569		
			Sample ID	C-50_011310			C-50D_011310			C-53A_011210			C-51_011210			C-52_011310			C-54_011310		
			Sample Date	1/13/2010			1/13/2010			1/12/2010			1/12/2010			1/13/2010			1/13/2010		
Volatile Organic Compounds			**Unit**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**
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
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
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
BENZENE	71-43-2	5	ug/l	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U
CUMENE	98-82-8	2300	ug/l	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	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
ETHYLENE DIBROMIDE (EDB)	106-93-4	0.05	ug/l	ND	0.029	U	ND	0.03	U	ND	0.029	U	ND	0.029	U	ND	0.03	U	ND	0.029	U
METHYL TERTIARY BUTYL ETHER	1634-04-4	20	ug/l	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U
TOLUENE	108-88-3	1000	ug/l	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U
XYLENE (TOTAL)	1330-20-7	10000	ug/l	1	1		ND	1	U	1	1		2	1		1	1		2	1	
Semivolatile Organic Compounds																					
CHRYSENE	218-01-9	1.9	ug/l	ND	50	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U
FLUORENE	86-73-7	1900	ug/l	ND	50	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U
NAPHTHALENE	91-20-3	100	ug/l	ND	50	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U
PHENANTHRENE	85-01-8	1100	ug/l	ND	50	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U
PYRENE	129-00-0	130	ug/l	ND	50	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U
Metals																					
LEAD (TOTAL)	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

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 2
Groundwater Analytical Results
AOI 7 Work Plan
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Analysis Name	CAS Number	PADEP Non-Residential Used Aquifer TDS <2,500 mg/L Groundwater MSCs	Location ID	C-57			C-63			C-95			C-96			C-104			C-105		
			Lab ID	5883570			5883563			5883577			5883571			5886108			5886106		
			Sample ID	C-57_011310			C-63_011210			C-95_011310			C-96_011310			C-104_011410			C-105_011410		
			Sample Date	1/13/2010			1/12/2010			1/13/2010			1/13/2010			1/14/2010			1/14/2010		
Volatile Organic Compounds			**Unit**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**
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
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
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
BENZENE	71-43-2	5	ug/l	ND	1	U	3	1		ND	1	U	ND	1	U	ND	1	U	ND	1	U
CUMENE	98-82-8	2300	ug/l	ND	2	U	ND	2	U	18	2		ND	2	U	ND	2	U	ND	2	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
ETHYLENE DIBROMIDE (EDB)	106-93-4	0.05	ug/l	ND	0.029	U	ND	0.029	U	ND	0.03	U	ND	0.029	U	ND	0.03	U	ND	0.029	U
METHYL TERTIARY BUTYL ETHER	1634-04-4	20	ug/l	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U
TOLUENE	108-88-3	1000	ug/l	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U
XYLENE (TOTAL)	1330-20-7	10000	ug/l	ND	1	U	5	1		4	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	**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	6	5		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
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
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
Metals																					
LEAD (TOTAL)	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

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 2
Groundwater Analytical Results
AOI 7 Work Plan
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Analysis Name	CAS Number	PADEP Non-Residential Used Aquifer TDS <2,500 mg/L Groundwater MSCs	Location ID	C-114			C-55			C-56			C-58			C-60			C-61		
			Lab ID	5886101			5886105			5886109			5886102			5886103			5886107		
			Sample ID	C-114_011410			C-55_011410			C-56_011510			C-58_011410			C-60_011410			C-61_011410		
			Sample Date	1/14/2010			1/14/2010			1/15/2010			1/14/2010			1/14/2010			1/14/2010		
Volatile Organic Compounds			**Unit**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**
1,2,4-TRIMETHYLBENZENE	95-63-6	35	ug/l	ND	2	U	ND	2	U	20	2		ND	2	U	ND	2	U	ND	2	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
1,3,5-TRIMETHYLBENZENE	108-67-8	35	ug/l	ND	2	U	ND	2	U	10	2		ND	2	U	ND	2	U	ND	2	U
BENZENE	71-43-2	5	ug/l	1	1		ND	1	U	ND	1	U	ND	1	U	ND	1	U	**12**	1	
CUMENE	98-82-8	2300	ug/l	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U
ETHYLBENZENE	100-41-4	700	ug/l	1	1		ND	1	U	2	1		ND	1	U	ND	1	U	1	1	
ETHYLENE DIBROMIDE (EDB)	106-93-4	0.05	ug/l	ND	0.03	U	ND	0.029	U	ND	0.029	U	ND	0.029	U	ND	0.029	U	ND	0.029	U
METHYL TERTIARY BUTYL ETHER	1634-04-4	20	ug/l	ND	1	U	ND	1	U	ND	1	U	ND	1	U	1	1		ND	1	U
TOLUENE	108-88-3	1000	ug/l	ND	1	U	ND	1	U	1	1		ND	1	U	ND	1	U	ND	1	U
XYLENE (TOTAL)	1330-20-7	10000	ug/l	3	1		ND	1	U	21	1		1	1		ND	1	U	4	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
FLUORENE	86-73-7	1900	ug/l	ND	5	U	ND	5	U	9	5		ND	5	U	ND	5	U	ND	5	U
NAPHTHALENE	91-20-3	100	ug/l	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	11	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
Metals																					
LEAD (TOTAL)	7439-92-1	0.005	mg/l	ND	0.001	U	ND	0.001	U	0.0021	0.001		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 2
Groundwater Analytical Results
AOI 7 Work Plan
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Analysis Name	CAS Number	PADEP Non-Residential Used Aquifer TDS <2,500 mg/L Groundwater MSCs	Location ID	C-62			C-64			C-65			C-98			C-113			C-49		
			Lab ID	5886112			5886110			5886111			5886104			5854746			5854747		
			Sample ID	C-62_011510			C-64_011510			C-65_011510			C-98_011410			C-113_120109			C-49_120109		
			Sample Date	1/15/2010			1/15/2010			1/15/2010			1/14/2010			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**
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
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
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
BENZENE	71-43-2	5	ug/l	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	2	1	
CUMENE	98-82-8	2300	ug/l	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	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
ETHYLENE DIBROMIDE (EDB)	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
METHYL TERTIARY BUTYL ETHER	1634-04-4	20	ug/l	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U
TOLUENE	108-88-3	1000	ug/l	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U
XYLENE (TOTAL)	1330-20-7	10000	ug/l	2	1		ND	1	U	ND	1	U	1	1		ND	1	U	ND	1	U
Semivolatile Organic Compounds																					
CHRYSENE	218-01-9	1.9	ug/l	ND	5	U	ND	5	U	ND	48	U	ND	5	U	ND	5	U	ND	5	U
FLUORENE	86-73-7	1900	ug/l	ND	5	U	ND	5	U	ND	48	U	ND	5	U	ND	5	U	ND	5	U
NAPHTHALENE	91-20-3	100	ug/l	ND	5	U	ND	5	U	ND	48	U	ND	5	U	ND	5	U	ND	5	U
PHENANTHRENE	85-01-8	1100	ug/l	ND	5	U	ND	5	U	ND	48	U	ND	5	U	ND	5	U	ND	5	U
PYRENE	129-00-0	130	ug/l	ND	5	U	ND	5	U	ND	48	U	ND	5	U	ND	5	U	ND	5	U
Metals																					
LEAD (TOTAL)	7439-92-1	0.005	mg/l	ND	0.001	U	ND	0.001	U	0.001	0.001		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 3
Summary of Proposed Site Characterization Activities
AOI 7 Work Plan
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania
"Draft"

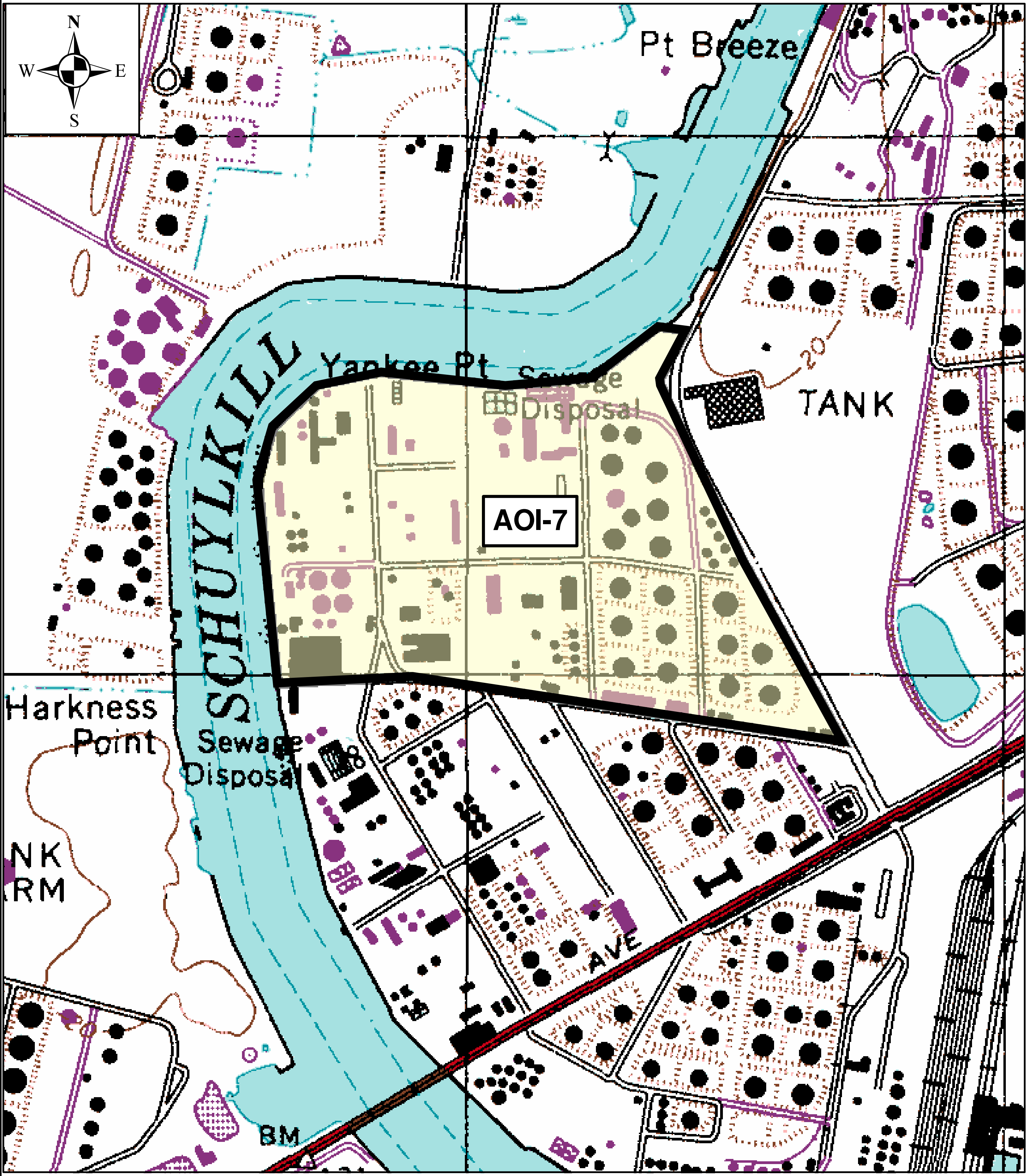
Location ID	Existing	Proposed	Estimated Completion Depth for Proposed Monitoring Wells and Soil Borings[1]	Media	Collection of Soil[2] Sample from 0-2 ft For Site COCs[4]	Observation for Leaded Tank Bottom Materials in Shallow Soil Borings[3]	Collection of Groundwater Sample for Site COCs[4]	LNAPL Data Exists	Objective of Proposed Activity
C-104	X			Groundwater			X		Characterize Shallow/Intermediate Groundwater: SWMU 87 Area/Western AOI 7 Boundary Ecological & Industrial Receptors
C-105	X			Groundwater			X		Characterize Shallow/Intermediate Groundwater: SWMU 87 Area/Western AOI 7 Boundary Ecological & Industrial Receptors
C-106	X			Groundwater			X	X	Characterize Shallow/Intermediate Groundwater: SWMU 88 Area/Western AOI 7 Boundary Ecological & Industrial Receptors, NAPL
C-107	X			Groundwater			X	X	Characterize Shallow/Intermediate Groundwater: SWMU 88 Area/Northwestern AOI 7 Boundary/Industrial Receptors, NAPL
C-108	X			Groundwater			X		Characterize Shallow/Intermediate Groundwater: SWMU 89 Area
C-109	X			Groundwater			X		Characterize Shallow/Intermediate Groundwater: SWMU 90 Area
C-110	X			Groundwater			X		Characterize Shallow/Intermediate Groundwater: SWMU 90 Area/Eastern AOI 7 Boundary
C-111	X			Groundwater			X		Characterize Shallow/Intermediate Groundwater: SWMU 90 Area/Eastern AOI 7 Boundary
C-112	X			Groundwater			X		Characterize Shallow/Intermediate Groundwater: SWMU 91 Area
C-113	X			Groundwater			X		Characterize Shallow/Intermediate Groundwater: SWMU 91 Area/Eastern AOI 7 Boundary
C-114	X			Groundwater			X		Characterize Shallow/Intermediate Groundwater: SWMU 91 Area/Southeastern AOI 7 Boundary/Industrial Receptors
C-127	X			Groundwater			X		Characterize Shallow/Intermediate Groundwater: SWMU 89 Area/Northern AOI 7 Boundary/Ecological Receptors
C-49	X			Groundwater			X		Characterize Shallow/Intermediate Groundwater: SWMU 91 Area/Eastern AOI 7 Boundary
C-50	X			Groundwater			X		Characterize Shallow/Intermediate Groundwater: SWMU 90 Area/Eastern AOI 7 Boundary
C-50D	X			Groundwater			X		Characterize Deep Groundwater: SWMU 90 Area/Eastern AOI 7 Boundary
C-51	X			Groundwater			X		Characterize Shallow/Intermediate Groundwater: Cat Charge Stock Area
C-52	X			Groundwater			X		Characterize Shallow/Intermediate Groundwater: Northern AOI 7 Boundary/Ecological Receptors
C-53A	X			Groundwater			X		Characterize Shallow/Intermediate Groundwater: SWMU 89 Area
C-54	X			Groundwater			X		Characterize Shallow/Intermediate Groundwater: Sulfur Plant Area/Industrial Receptors
C-55	X			Groundwater			X		Characterize Shallow/Intermediate Groundwater: CO Boiler Area/Industrial Receptors
C-56	X			Groundwater			X		Characterize Shallow/Intermediate Groundwater: Liquefied Petroleum Gas AST Area
C-57	X			Groundwater			X		Characterize Shallow/Intermediate Groundwater: Cat Charge Stock Area/Industrial Receptors
C-58	X			Groundwater			X		Characterize Shallow/Intermediate Groundwater: Tank 270 and 271 Area
C-60	X			Groundwater			X		Characterize Shallow/Intermediate Groundwater: M004/M005 Area/Industrial Receptors
C-61	X			Groundwater			X		Characterize Shallow/Intermediate Groundwater: SWMU 87 Area/Western AOI 7 Boundary/Ecological & Industrial Receptors
C-62	X			Groundwater			X		Characterize Shallow/Intermediate Groundwater: SWMU 88 Area/Western AOI 7 Boundary/Ecological & Industrial Receptors
C-63	X			Groundwater			X		Characterize Shallow/Intermediate Groundwater: SWMU 87 Area/Industrial Receptors
C-64	X			Groundwater			X		Characterize Shallow/Intermediate Groundwater: SWMU 89 Area
C-65	X			Groundwater			X	X	Characterize Shallow/Intermediate Groundwater: SWMU 88 Area/Industrial Receptors/NAPL
C-65D	X			Groundwater			X		Characterize Deep Groundwater: SWMU 88 Area/Industrial Receptors
C-95	X			Groundwater			X		Characterize Shallow/Intermediate Groundwater: SWMUs 90 and 91 Area/Eastern AOI 7 Boundary
C-96	X			Groundwater			X		Characterize Shallow/Intermediate Groundwater: Cat Charge Stock Area
C-97	X			Groundwater			X		Characterize Shallow/Intermediate Groundwater: SWMU 89 Area/Ecological Receptors/NAPL
C-98	X			Groundwater			X		Characterize Shallow/Intermediate Groundwater: SWMU 87 Area/Industrial Receptors
C-129		X	15 ft bgs	Soil / Groundwater	X		X		Characterize Soil and Shallow/Intermediate Groundwater: SWMU 87 Area/Industrial Receptors
C-129D		X	90 ft bgs	Soil / Groundwater			X		Characterize Soil and Deep Groundwater: SWMU 87 Area/Industrial Receptors
C-130		X	15 ft bgs	Soil / Groundwater	X		X		Characterize Soil and Shallow/Intermediate Groundwater: Cat Charge Stock Area/Northeast Boundary AOI 7
C-131		X	15 ft bgs	Soil / Groundwater	X		X		Characterize Soil and Shallow/Intermediate Groundwater: SWMU 91 Area/Cat Charge Stock Area
C-132		X	15 ft bgs	Soil / Groundwater	X		X		Characterize Soil and Shallow/Intermediate Groundwater: Southern AOI 7 Boundary/Industrial Receptor
C-133		X	15 ft bgs	Soil / Groundwater	X		X		Characterize Soil and Shallow/Intermediate Groundwater: Tank 270 Area/Liquefied Petroleum Gas Area
C-134		X	15 ft bgs	Soil / Groundwater	X		X		Characterize Soil and Shallow/Intermediate Groundwater: Southern AOI 7 Boundary/ HF Unit Area
C-134D		X	90 ft bgs	Soil / Groundwater			X		Characterize Soil and Deep Groundwater: Southern AOI 7 Boundary/ HF Unit Area
C-135		X	15 ft bgs	Soil / Groundwater	X		X		Characterize Soil and Shallow/Intermediate Groundwater: FCC and HF Unit Area/Industrial Receptors
C-136		X	15 ft bgs	Soil / Groundwater	X		X		Characterize Soil and Shallow/Intermediate Groundwater: Central Portion AOI 7/Sulfur and Cat Unit Area
C-136D		X	90 ft bgs	Soil / Groundwater			X		Characterize Soil and Deep Groundwater: Central Portion AOI 7/Sulfur and Cat Unit Area
C-137		X	15 ft bgs	Soil / Groundwater	X		X		Characterize Soil and Shallow/Intermediate Groundwater: CO Boiler Area/Industrial Receptors

Table 3
Summary of Proposed Site Characterization Activities
AOI 7 Work Plan
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania
"Draft"

Location ID	Existing	Proposed	Estimated Completion Depth for Proposed Monitoring Wells and Soil Borings[1]	Media	Collection of Soil[2] Sample from 0-2 ft For Site COCs[4]	Observation for Leaded Tank Bottom Materials in Shallow Soil Borings[3]	Collection of Groundwater Sample for Site COCs[4]	LNAPL Data Exists	Objective of Proposed Activity
C-138		X	15 ft bgs	Soil / Groundwater	X		X		Characterize Soil and Shallow/Intermediate Groundwater: Maintenance Building Area/M004 and Moo5 Area/Industrial Receptors
C-139		X	15 ft bgs	Soil / Groundwater	X		X		Characterize Soil and Shallow/Intermediate Groundwater: Former AST Area/Industrial Receptors
C-140		X	15 ft bgs	Soil / Groundwater	X		X		Characterize Soil and Shallow/Intermediate Groundwater: Waste Water Treatment Area/Industrial Receptors/Former Haz Waste Incinerator Area
C-140D		X	90 ft bgs	Soil / Groundwater			X		Characterize Soil and Deep Groundwater: Waste Water Treatment Area/Industrial Receptors
C-141		X	15 ft bgs	Soil / Groundwater	X	X	X		Characterize Soil and Shallow/Intermediate Groundwater: SWMU 89 Area/Solvent Decarbonizer Area
C-142		X	15 ft bgs	Soil / Groundwater	X	X	X		Characterize Soil and Shallow/Intermediate Groundwater: SWMU 89 Area/NAPL
C-143		X	15 ft bgs	Soil / Groundwater	X	X	X		Characterize Soil and Shallow/Intermediate Groundwater: SWMU 89 Area/Northern AOI 7 Boundary/NAPL
C-144D		X	90 ft bgs	Soil / Groundwater		X	X		Characterize Soil and Deep Groundwater: SWMU 89 Area/Replacement for C-65D
BH-10-05		X	2 ft bgs	Soil	X	X			Characterize Soil: SWMU 87 Area/Leaded Tank Bottom Investigation
BH-10-06		X	2 ft bgs	Soil	X	X			Characterize Soil: SWMU 87 Area/Leaded Tank Bottom Investigation
BH-10-07		X	2 ft bgs	Soil	X	X			Characterize Soil: SWMU 87 Area/Leaded Tank Bottom Investigation
BH-10-08		X	2 ft bgs	Soil	X	X			Characterize Soil: SWMU 87 Area/Former Lead Exceedance RFI Boring BNA-2/Leaded Tank Bottom Investigation/Former Haz Waste Storage Basin Area
BH-10-09		X	2 ft bgs	Soil	X	X			Characterize Soil: SWMU 87 Area/Former Lead Exceedance RFI Boring BNA-3/Leaded Tank Bottom Investigation
BH-10-10		X	2 ft bgs	Soil	X	X			Characterize Soil: SWMU 87 Area/Former Lead Exceedance RFI Boring BNA-5/Leaded Tank Bottom Investigation
BH-10-11		X	2 ft bgs	Soil	X	X			Characterize Soil: SWMU 88 Area/Leaded Tank Bottom Investigation
BH-10-12		X	2 ft bgs	Soil	X	X			Characterize Soil: SWMU 88 Area/Leaded Tank Bottom Investigation
BH-10-13		X	2 ft bgs	Soil	X	X			Characterize Soil: SWMU 88 Area/Former Lead Exceedance RFI Boring BNA-7/Leaded Tank Bottom Investigation
BH-10-14		X	2 ft bgs	Soil	X	X			Characterize Soil: SWMU 88 Area/Former Lead Exceedance RFI Boring BNA-8/Leaded Tank Bottom Investigation
BH-10-15		X	2 ft bgs	Soil	X	X			Characterize Soil: SWMU 88 Area/Leaded Tank Bottom Investigation
BH-10-16		X	2 ft bgs	Soil	X	X			Characterize Soil: SWMU 88 Area/Leaded Tank Bottom Investigation
BH-10-17		X	2 ft bgs	Soil	X	X			Characterize Soil: SWMU 88 Area/Leaded Tank Bottom Investigation
BH-10-18		X	2 ft bgs	Soil	X	X			Characterize Soil: SWMU 88 Area/Former Lead and Chrysene Exceedance RFI Boring BNA-10/Leaded Tank Bottom Investigation
BH-10-19		X	2 ft bgs	Soil	X	X			Characterize Soil: SWMU 89 Area/Leaded Tank Bottom Investigation
BH-10-20		X	2 ft bgs	Soil	X	X			Characterize Soil: SWMU 89 Area/Leaded Tank Bottom Investigation
BH-10-21		X	2 ft bgs	Soil	X	X			Characterize Soil: SWMU 89 Area/Leaded Tank Bottom Investigation
BH-10-22		X	2 ft bgs	Soil	X	X			Characterize Soil: SWMU 89 Area/Leaded Tank Bottom Investigation
BH-10-23		X	2 ft bgs	Soil	X	X			Characterize Soil: SWMU 90 Area/Former Benzene and Naphthalene Exceedance RFI Boring B-90-1/Leaded Tank Bottom Investigation
BH-10-24		X	2 ft bgs	Soil	X	X			Characterize Soil: SWMU 90 Area/Former Lead Exceedance RFI Boring B-90-2/Leaded Tank Bottom Investigation
BH-10-25		X	2 ft bgs	Soil	X	X			Characterize Soil: SWMU 90 Area/Leaded Tank Bottom Investigation
BH-10-26		X	2 ft bgs	Soil	X	X			Characterize Soil: SWMU 90 Area/Leaded Tank Bottom Investigation
BH-10-27		X	2 ft bgs	Soil	X	X			Characterize Soil: SWMU 90 Area/Former Benzene Exceedance RFI Boring B-90-15/Leaded Tank Bottom Investigation
BH-10-28		X	2 ft bgs	Soil	X	X			Characterize Soil: SWMU 90 Area/Former BTEX Exceedance RFI Boring B-90-13/Leaded Tank Bottom Investigation
BH-10-29		X	2 ft bgs	Soil	X	X			Characterize Soil: SWMU 90 Area/Former Lead Exceedance RFI Boring TB-290/Leaded Tank Bottom Investigation
BH-10-30		X	2 ft bgs	Soil	X	X			Characterize Soil: SWMU 90 Area/Former Benzene Exceedance RFI Boring B-90-5/Leaded Tank Bottom Investigation
BH-10-31		X	2 ft bgs	Soil	X	X			Characterize Soil: SWMU 91 Area/Former Benzene Exceedance RFI Boring B-91-1/Leaded Tank Bottom Investigation
BH-10-32		X	2 ft bgs	Soil	X	X			Characterize Soil: SWMU 91 Area/Former Lead Exceedance RFI Boring TB-277/Leaded Tank Bottom Investigation
BH-10-33		X	2 ft bgs	Soil	X	X			Characterize Soil: SWMU 91 Area/Former Lead Exceedance RFI Boring TB-276/Leaded Tank Bottom Investigation
BH-10-34		X	2 ft bgs	Soil	X	X			Characterize Soil: SWMU 91 Area/Leaded Tank Bottom Investigation
BH-10-35		X	2 ft bgs	Soil	X	X			Characterize Soil: SWMU 91 Area/Former Lead Exceedance RFI Boring TB-286/Leaded Tank Bottom Investigation

Notes:
1. Final depth of well and screen placement to be determined by geologist based on field observation while completing the boring.
2. 0-2' soil samples will be collected from where impervious surfaces are not present.
3. If leaded tank bottoms are observed sample in accordance with Section 1.2.1 and Appendix C of work plan.
4. Analysis of COCs listed in Table 1 of the Work Plan.
5. 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
RFI = RCRA Facility Investigation Report, Chevron Refinery, PA, prepared by Dames and Moore, November 24, 1993.
SWMU = Solid Waste Management Unit

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-7
AOI-7 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 7 Workplan\Figure 1- Site Location Map - AOI7.mxd

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
- Bulkhead

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

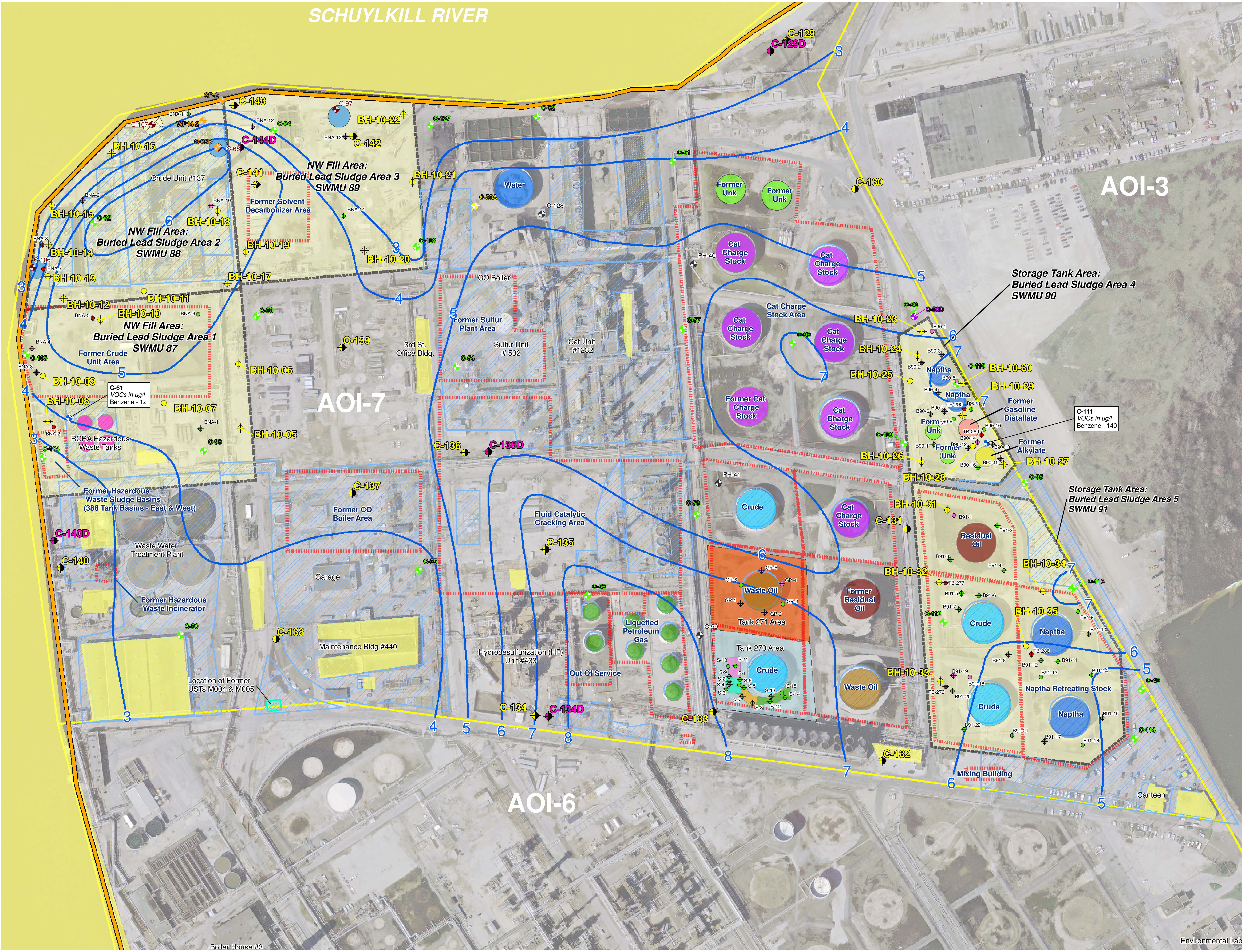
Figure 2 - Summary of Proposed Site Characterization Activities AOI 7
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

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

0 70 140 280 Feet

SCALE: 1" = 140'
DATE: April 26, 2010
DRN. BY: MH/DW
CKD. BY: DW
JOB#: 2574601

Q:\data6\2574601\ArcGIS\MapDocuments\AOI 7 Workplan\AOI-7 Proposed Locations_042610.mxd



Legend

Existing, Historic Investigation, and Historic Use Areas

- Bulkhead
- Industrial/Ecological Receptors
- Impervious Surfaces
- AOIs
- Solid Waste Management Unit (SWMU)
- Historic Use Areas
- Former Underground Storage Tanks M004 & M005
- Tank 271 Investigation Area

Tank 270 Investigation Area

- Tank 270 Investigation Area
- Area 1
- Area 2
- Area 3
- Area 4

Historic Tank Use/Content

- Alkylate
- Cat Charge Stock
- Crude Oil
- Gasoline Distallate
- Liquefied Petroleum Gas (LPG)
- Naptha
- Residual Fuel Oil
- Unknown
- Waste Oil
- RCRA Hazardous Waste Tanks
- Water

Historic RCRA Soil Borings

- Does Not Exceed PADEP Soil MSCs
- VOCs Exceed PADEP Soil MSCs
- Lead Exceeds PADEP Soil MSCs

January 2010 Groundwater Data

- Fill/Alluvium/Trenton Gravel Monitoring Well with Exceedance of PADEP MSCs
- Lower Sand Monitoring Well with No Exceedance of PADEP MSCs
- Shallow Monitoring Well with No Exceedances of PADEP MSCs
- Wells with LNAPL
- Wells Not Sampled
- Abandoned/Unable to Locate
- January 2010 Groundwater Elevation Contour (ft amsl)

NAPL Plumes - January 2010

- Lube Oil
- Residual Oil

Proposed Site Characterization Activities

- Proposed Deep Lower Sand Monitoring Well
- Proposed Shallow Fill/Alluvium/Trenton Gravel Monitoring Well
- Proposed Shallow Soil Boring

Notes:
1. 2005 aerial photography provided by the Delaware Valley Regional Planning Commission (DVRPC).
2. Wells C-63 and C-50D were not used the generation of the groundwater contours.

Figure 3: Historical Investigation Areas and Proposed Site Characterization Activities for AOI-7
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: April 26, 2010
DRN. BY: MH/DW
CKD. BY: DW
JOB#: 2574601

Q:\data6\2574601\ArcGIS\MapDocuments\AOI 7 Workplan\AOI-7 Summary Figure_042610.mxd

APPENDIX A

Revised Phase II Corrective Action Activities Schedule

Appendix A

Revised Phase II Corrective Action Activities

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

Timescale: 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2 — Qtr 1, Qtr 2, Qtr 3, Qtr 4

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

Task | Progress | Summary | External Tasks | Deadline
Split | Milestone | Project Summary | External Milestone

APPENDIX B

Historical Aerial Photograph Review Summary

APPENDIX B

HISTORICAL AERIAL PHOTOGRAPH REVIEW SUMMARY
AOI 7 WORK PLAN FOR SITE CHARACTERIZATION
SUNOCO PHILADELPHIA REFINERY
PHILADELPHIA, PENNSYLVANIA

AOI 7 Historical Aerial Photographs

Available historical aerial photographs with coverage of AOI 7 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 the eastern portion of the site primarily as undeveloped land. Land disturbance is visible in the northern and central portions of the site. Several above ground tanks (ASTs) and small building structures are visible in the west-central portion of the site. Undeveloped, but disturbed land is visible along the western portion of the site bordering the Schuylkill River.

- The 1945 aerial photograph depicts an increased density of building structures throughout AOI 7. Five ASTs, currently know today as the cat charge stock area are visible in the south eastern portion of the site. Much of the land throughout AOI 7 has been regarded and disturbed. What appears to be a two large pits or basins are located in the northwest corner of the AOI 7. . .

- The 1959 and 1965 aerial photographs depict major expansion throughout most of AOI 7. The cat charge stock and storage tank areas are visible in the eastern portion of AOI 7. These two aerials depict similar features as what exists today.

- The 1965 and 1970 aerial photographs were of poor quality. What appear to be small impoundment areas are visible in the northern portion of AOI 7. The large pit or basin areas once located in the northwestern portion of AOI 7 appear to have been re-graded and developed over with small buildings. All other features are similar to the 1959 and 1969 aerial photographs.

- The 1975 aerial photograph depicts the waste water treatment plant located in the western portion of AOI 7. Additional small building structures are present throughout AOI 7. Additional small impoundment areas are visible in the northern portion of AOI 7. Increases of what appears to be overhead pipe racks are visible throughout AOI 7.

- 1980, 1985, and 1990 aerial photographs depict similar site features as depicted on the 1975 aerial photograph.

- The 1995 to 2005 aerial photographs depict the removal of several large ASTs which were once located in the southeastern portion of the site. Additional smaller ASTs have also been removed in the central portions of AOI 7. Several small building structures once located in the central and western portion of AOI 7 appear to have been removed.

APPENDIX C

Field Procedures

APPENDIX C
FIELD PROCEDURES
AOI 7 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 are required to be worn. Based on site conditions, 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 are all likely hazards to be encountered on-site. Additional hazards are mentioned in the 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), and air monitoring instruments (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 can be performed with various equipment including: a dedicated bailer for hand bailing low volumes of water; a surface mounted electric centrifugal pump with dedicated polyethylene tubing; and/or 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 measurable free product.

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) Use a 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. Collection of Ground Water Samples. 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 AOI 7:

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 in SWMUs 87, 88, 89, 90, and 91 in AOI 7:

1) Borehole Advancement

During soil sampling activities at SWMUs 87, 88, 89, 90, and 91, 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 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 must have 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: direct sample or 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 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) Field Procedures:

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.

Q:\data6\2574601\Office Data\Reports\Workplans\AOI 7 Work Plan\Appendices\Appendix C\Appendix C_Field Procedures_032410.doc