

**Fourth Quarter 2013 and Calendar Year
2013 Summary Progress Report for the
Former Defense Supply Center
Philadelphia Facility
Philadelphia, PA**

February 15, 2014

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for the Former Defense Supply Center
Philadelphia Facility
Philadelphia, PA**

LNAPL recovery operations for
the Former DSCP facility and the
Former Passyunk Homes area.

Prepared for:
Pennsylvania Department of
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1. Executive Summary

This Fourth Quarter 2013 and Calendar Year (CY) 2013 Summary Progress Report (Progress Report) for the Former Defense Supply Center Philadelphia (DSCP) Site presents remediation system operations and maintenance (O&M) data, Site-wide liquid level and groundwater elevation gauging data, Site-wide groundwater sampling data, and a description of potential activities for the First Quarter of CY 2014. The activities described herein were conducted as required by the Administrative Order (Order), dated December 10, 1999 between the Commonwealth of Pennsylvania, Department of Environmental Protection (PADEP) and the Department of the Army and DSCP (collectively the Defense Logistics Agency, or DLA) by ARCADIS U.S., Inc. (ARCADIS).

This report includes a summary of Order-required remediation activities completed during CY 2013. As approved by the PADEP via electronic mail (e-mail) on December 11, 2013, this summary is hereby provided in lieu of a stand-alone annual report for the Former DSCP Site. Additionally, the PADEP has approved a regulatory due date for this Progress Report of February 15, 2014.

The Order requires that remediation be conducted as needed to remove as much petroleum Light Non-Aqueous Phase Liquid (LNAPL) as is practicable from beneath the Former DSCP property, including Quartermaster Plaza, and the following contiguous properties: the CSX railroad right of way, the Steen property, and the Former Passyunk Homes property (currently the Philadelphia Housing Authority [PHA] property and the Siena Place property). Collectively, these properties are defined in the Administrative Order as the "Affected Area", and the Affected Area is the "Site" as defined under the Pennsylvania Land Recycling and Environmental Remediation Standards Act (Land Recycling Act or Act 2).

During the Fourth Quarter of 2013, vapor phase petroleum hydrocarbon mass and LNAPL recovery continued via vacuum enhanced skimming (VES). A total of 3,489 gallons was recovered. O&M data were used to optimize VES system performance, specifically to enhance the rate of vapor and liquid phase petroleum hydrocarbon recovery. To track the removal of petroleum hydrocarbon mass via the VES system, analytical results of influent summa canister TO-15 samples were evaluated.

Additional activities designed to enhance the conceptual Site model (CSM) and/or operation and control of the Site's remediation systems were also conducted. These

included a liquid level gauging event and a groundwater sampling event, inclusive of all accessible Site groundwater monitoring and recovery wells.

As discussed in previous reports, LNAPL recovery at the Former DSCP Site was initially very robust, and had been following a decreasing trend from 1999 to 2005 as groundwater elevations began to rise in the vicinity of the Site and the availability of easily recoverable LNAPL decreased. The 2005 addition of a VES system, which combined petroleum hydrocarbon vapor recovery with LNAPL recovery, temporarily halted this trend. By the end of 2006, the rate of LNAPL recovery again began to define a generally decreasing trend which continued until the Fourth Quarter 2011, when optimization efforts began (for a complete history, see Appendix F). As a result of the remediation system optimization efforts, the mass of petroleum hydrocarbons recovered as vapor since the Fourth Quarter of 2011 is now more than five times greater than the amount recovered since the start-up of the VES system in 2005 (e.g., 53,402 gallons from the Fourth Quarter 2011 to date versus 10,038 gallons from 2005 through the Third Quarter 2011). During the Fourth Quarter of 2013, 143 gallons of LNAPL were recovered by the fixed-skimming system and an additional 3,346 gallons of LNAPL (as vapor) was recovered by the VES system, for a total recovery of 3,489 gallons for the quarter. The new cumulative recovery of LNAPL as of December 31, 2013 is now 1,021,754 gallons.

This Progress Report documents the state of the Site remediation optimization and Act 2 path-to-closure work conducted during CY 2013. The Order-required LNAPL remediation work described herein was implemented with the goal of improving the rate of LNAPL remediation via existing Site remediation equipment. This goal has been achieved despite naturally occurring constraints such as elevated groundwater levels and the resulting submerged LNAPL beneath the water table aquifer in portions of the Site.

Site remediation activities are in support of, in addition to LNAPL-specific cleanup goals specified in the Order, the eventual establishment of Site aquifer-specific cleanup goals under the Act 2 Program. These Act 2 goals include a Site Specific Standard (SSS) pathway elimination approach for LNAPL and specific petroleum hydrocarbon Short List Constituents of Concern (COC) in the shallow aquifer zone. Regarding the deep aquifer, pursuit of a background standard approach as defined under Act 2 or attainment of a Non-Use Aquifer Determination (NUAD) are potentially viable options. Data reported in this and prior reports since October 2011 continue to support pursuit of these potential Act 2 endpoints. It is believed that the synchronization of aquifer sampling and monitoring activities from nearby facilities, and the sharing and

evaluation of data, will be essential to the establishment of these Act 2 Site aquifer-specific cleanup goals. Limited available Site characterization and remediation data from the adjacent former Sun Oil Company (Sunoco) refinery have been reviewed, but additional information is necessary, specifically regarding the current nature of remediation activities, groundwater flow, and petroleum hydrocarbon contaminant transport within the aquifer systems beneath the refinery. This information would specifically support the deep aquifer NUAD approach suggested above.

In addition to the summary of CY 2013 works completed, this report also presents activities tentatively (based upon availability of funds) planned for the First Quarter of CY 2014. These activities will support continued refinement of the DLA's remediation strategy under the Order and provide a foundation for continued voluntary Site path-to-closure activities under Act 2.

2. Introduction

The Former Defense Supply Center Philadelphia (DSCP) property was closed under the 1993 Base Realignment and Closure (BRAC) program. In 2001, the US Army transferred the air and surface rights to the Philadelphia Authority for Industrial Development (PAID) for commercial development. A shopping center, known as Quartermaster Plaza, was constructed in 2004 on the northwestern portion of the Former DSCP property. It currently contains approximately 18 retail stores and 4 restaurants.

Between 2002 and 2008, residences at the former Passyunk Homes complex were razed, and a new Philadelphia Housing Authority (PHA) office and maintenance building was constructed in the southern portion of the Site (south of Interstate 76 [I-76], the Schuylkill Expressway) and on the northern portion of the Former Passyunk Homes property. The Former Passyunk Homes property was purchased by Penrose Park Associates and is being redeveloped for residential housing. This growing housing development and neighborhood is called Siena Place. The former Sunoco refinery boundary is located approximately 100 feet from the western edge of the Site, across a section of I-76 and west of the CSX Railroad, (as shown on Figures 1 through 3). The refinery is now jointly owned and operated by the Carlyle Group and Energy Transfer Partners L.P.

Petroleum hydrocarbon constituents and Light Non-Aqueous Phase Liquid (LNAPL) have been observed and are currently found in the shallow (i.e., water table) aquifer at the Site. The area impacted by LNAPL has been investigated by the former Sunoco

refinery, the Former DSCP, and the Defense Energy Support Center (DESC). Remediation began in 1996 using skimmer pumps installed to remove the petroleum LNAPL from the shallow aquifer, and a full-scale vacuum enhanced skimming (VES) System has been in operation since 2005.

This Progress Report is submitted in accordance with the terms in the Order dated December 10, 1999. It provides Site remedial progress and environmental monitoring results from the Fourth Quarter (October, November, and December) of 2013 and suggests possible activities for the first quarter of CY 2014 and beyond. This Progress Report also summarizes the Site remediation and environmental monitoring activities conducted during the First through Fourth Quarters of CY 2013 as well as the key results and findings from these activities.

Included in this Progress Report are the following Fourth Quarter-specific data:

- Monthly photo-ionization detector (PID), smoke tube, and lower explosive limit (LEL) meter monitoring data for two sanitary sewer manholes on the Packer Avenue Sewer (MH-C and MH-G, as shown in Figures 1-3), and three additional sanitary sewer locations selected by the Defense Logistics Agency (DLA) and the United States Army Corps of Engineers (USACE) (19th and Moyamensing East, 19th and Moyamensing West, Pollock and Moyamensing, and 19th Street [near the cut through]);
- Site-wide groundwater elevation and LNAPL thickness gauging data from a liquid level measurement event conducted on December 3-5, 2013;
- Laboratory analytical and field parameter data from the groundwater sampling event conducted from December 4, 2013 through December 17, 2013. The event included the collection of groundwater samples via low flow sampling methods from all accessible Site groundwater monitoring and recovery wells. Samples were submitted for laboratory analysis for the Pennsylvania Department of Environmental Protection (PADEP) *Short List of Petroleum Products for Leaded Gasoline, Aviation Gasoline and Jet Fuel*;
- Remediation operation and maintenance (O&M) data from the Site's fixed and modular LNAPL skimming units and VES System; and
- Data from Site remediation system optimization testing activities conducted during the quarter.

3. Vapor Measurements from the Packer Avenue Sewer

Two Packer Avenue sewer manholes (MH-C and MH-G), as seen in Figures 1-3, were monitored monthly with a PID, smoke tubes, and LEL meter. As previously reported, the intent of the monitoring was to evaluate the vacuum effect on the Packer Avenue sewer system imparted by the Sewer Vapor Extraction system located on the former Sunoco refinery. The Sewer Vapor Extraction System is managed and maintained by the operators of the former Sunoco refinery. The purpose of the Sewer Vapor Extraction system is to prevent a buildup of gasses (e.g., methane [CH₄] and petroleum hydrocarbon vapors) in the sewer system. Vapor measurements were collected on October 21, November 5, and December 30, 2013 and are shown in Table 1.

Smoke tubes were used to determine if air was moving into or out of the sewer manhole covers at the time of the monitoring event. The results of smoke tube testing indicated that air was flowing out of the manholes during all testing events with the exception of MC-G, where airflow was into the sewer during the October 21 and November 5 events, then out of the sewer during the December 30 event. During the November 5 event, the 19th Street location (near the cut through) showed neutral airflow, while airflow during the other two events was out of the sewer. Following smoke tube testing, a PID equipped with a 10.6 electron-volt (eV) lamp, and a MSA Passport LEL/Oxygen (O₂) meter were used to monitor and gather measurements from ports in the two sewer manhole covers. Readings ranged from 0.0 parts per million (ppm) to 22.2 ppm and 0% LEL to 46% LEL. Readings above 100 ppm are reported to the PADEP, former Sunoco refinery, the DLA, and the USACE Baltimore and Philadelphia District offices.

At the request of the USACE, readings were also collected at the following sanitary sewer manholes, each of which measured 0.0% LEL and 0.0 ppm: 19th and Moyamensing East, 19th and Moyamensing West, and Pollock and Moyamensing. At the Pollock and Moyamensing location, airflow indications were not available because of the absence of manhole openings.

These observations are in line with previously reported sanitary sewer observations since October 2011.

4. Liquid Level Gauging and Groundwater Sampling

Site-wide liquid level gauging and groundwater sampling events were conducted during the Third and Fourth quarters of 2013. Like previous gauging events, and as

required by the Order, all accessible wells within the Site's monitoring and recovery well network work included in these events. The comprehensive groundwater sampling events also included the entire Site monitoring and recovery well network, except for those wells not accessible at the time of the events (details provided below).

The data from these two events has provided the most comprehensive view to date of the distribution of dissolved-phase petroleum hydrocarbon impacts in the aquifer systems beneath the Site. Additionally, this information has been added to the Site's database, which includes laboratory analytical results from five partial groundwater sampling events conducted from 2010 to 2011, and two comprehensive groundwater sampling events during the Third and Fourth Quarters of 2012. The partial events included only about one third (approximately 40 wells) of the Site's monitoring well network. Through completion of the two most recent Site-wide groundwater sampling events in 2013, and through incorporation of this data, spatial and temporal petroleum hydrocarbon contaminant distribution trends have become apparent. Details are provided below. The intent of this data collection and integration is ultimately to provide remediation performance feedback and to serve as a basis for eventual attainment demonstration under the Act 2 program.

4.1 Liquid Level Gauging – Fourth Quarter 2013

The VES system and pneumatic skimming system recovery wells were deactivated on November 29, 2013 and November 26, 2013, respectively, such that on December 3-5, 2013, liquid level gauging data from the Site's monitoring and recovery well network could be collected. Table 2 contains the gauging event data. Hydrographs for Site monitoring wells selected previously for long term groundwater elevation trend monitoring have been updated accordingly. These hydrographs are included as Appendix A (for MW-29, MW-32, MW-36, PH-14, PH-15, PH-18, and PH-20). With the exception of abandoned wells PH-15 and MW-35, the hydrographs show groundwater elevations during the Fourth Quarter of 2013 gauging event to have been towards the upper limit of the elevations recorded since 2001. Over time, these oscillating elevations show an amplitude of approximately two feet, and are generally concomitant as indicated by similar trends on the hydrographs for MW-29, MW-32, MW-36, PH-14, PH-18 and PH-20. These hydrograph patterns therefore may be Site-wide in extent, and are likely affected by seasonal changes, precipitation, and leaking sewers. Future evaluations may include a comparison of hydrograph data to local precipitation data.

The groundwater levels measured during the Fourth Quarter of 2013 continue to be well above (i.e., by approximately two feet) the drought -indicative groundwater

elevations reported from late 2001 to the beginning of 2003. The data continue to support the underlying Site-wide trend towards higher groundwater elevations since the start of Site LNAPL remediation activities in the 1990s. Including the Fourth Quarter elevation data, the hydrographs also suggest that this trend towards generally higher Site groundwater elevations may be stabilizing as the elevations recorded from 2009 to present have been more similar than those obtained previously (i.e., after the 2001 to 2003 drought).

The gauging event included the monitoring and recovery wells on the Former DSCP property, the Former Passyunk Homes property (i.e., around the PHA building and Siena Place Homes property), the CSX property, and the P. Agnes property. Access to the Steen property was denied by the Steen property owner prior to the December 2013 gauging event. Access issues are currently being negotiated between the USACE and the property owner. Therefore, the shallow and deep aquifer zone monitoring wells present on the Steen property were not gauged and have not been included in the potentiometric surface maps described below. Access to these wells was available during the Third Quarter 2012 gauging event. The potentiometric maps provided in previous quarterly progress reports presented these data.

Groundwater elevations used to prepare the hydrographs (Appendix A) and the potentiometric surface maps shown as Figures 1 and 2 were determined by subtracting the depth to water from the elevation of the surveyed measuring point (the top of the inner well casing). In cases where LNAPL was measured in a well, the groundwater elevations were corrected by multiplying the apparent LNAPL thickness by a specific gravity of 0.77, and adding this value to the groundwater elevation. This value, used in previous calculations, is an average of the range of specific gravity values provided in the *Fourth Quarter of 1999 Progress Report* by IT Corp (specifically Appendix D of that report).

Corrected groundwater elevation data was used to create a potentiometric surface map for the shallow aquifer zone beneath the Site (Figure 1). A few Site wells are screened in areas where the presence of near-surface silty clay units and/or the presence of extensive paved areas of the Site appear to impede infiltration of precipitation, creating isolated perched zones and sinks. Additionally, based on the continued observance of isolated potentiometric high points at discrete well locations, some wells appear to be influenced by other infiltration sources, such as leakage from the numerous sanitary and storm sewer laterals that underlie the Site. Regardless of the source, and as found during prior gauging events, anomalous elevation heads were measured in the wells listed below (i.e., with respect to levels measured in the

majority of surrounding shallow aquifer zone wells). The monitoring wells excluded from the shallow aquifer zone potentiometric map include PH-RW-D, PH-RW-H, PH-RW-I, PH-RW-A, PH-RW-S, PH-RW-Q, PH-MW-56, PH-MW-57, PH-PH-6, PH-MW-37 (on the Siena Place Homes property), CSX-MW-1, CSX-MW-4 (on the CSX property), and DSCP-MW-59, DSCP-MW-1A, DSCP-MW-33, DSCP-MW-2 (on the Former DSCP property).

Based on water level measurements and well construction details, several well screens were found to be submerged at the time of the gauging event. Groundwater elevations for wells with submerged screens have been excluded from the shallow aquifer/water table potentiometric surface map. These wells include DSCP-MW-5, DSCP-MW-11, DSCP-MW-14, DSCP-MW-34, EPH-MWS-5, PH-MWS-4, and PH-RW-N. Exclusion of these wells, and the wells described above, do not materially affect the interpretation of the potentiometric surface for the gauging event.

As described above, the access agreement to the Steen property has lapsed. Access to the monitoring wells was denied by the Steen property owner; therefore the monitoring wells present on the Steen property were not gauged and have not been included in the contours shown in Figure 1 or Figure 2. All contours in this area have been inferred. Additionally, the access agreement to the Southeastern Pennsylvania Transportation Authority (SEPTA) property had lapsed at the time of the event, and access to the SEPTA property was denied for gauging and sampling. SEPTA access is current as of January 2014. Monitoring wells present on the SEPTA property were not gauged and have not been included in the contours shown in Figures 1 and 2.

Figure 1 shows the shallow aquifer groundwater gradient in the northern portion of the Site to be oriented in a largely north-northwesterly to south-southeasterly direction, starting near DSCP-MW-20 at an elevation of 4.42 feet (ft) above mean sea level (AMSL) to EPH-PH-5 at 0.40 ft AMSL. A separate and distinct potentiometric high with a largely opposing gradient is noticeable in the southeastern portion of the Site. The high point is located at EPH-PH-7 at 3.21 ft AMSL, and the potentiometric surface slopes to the northeast.

Like the potentiometric surface beneath the northern half of the Site, and as seen in multiple previous potentiometric surface maps derived from Site gauging event data, the potentiometric surface beneath the southern portion of the Site indicates that groundwater flow is in a roughly southerly direction from the PHA building to the southern portion of Siena Place Homes. In the midsection of the Site, a trough-like depression is oriented east-west in the shallow aquifer potentiometric surface. This

feature, which has also been regularly observed during prior quarterly gauging events, is most pronounced near the BJ's retail building and in an area extending southwest from the VES system building to the former PHA property.

Gauging data from the Site's eleven deep aquifer zone wells were used to create a deep aquifer zone potentiometric surface map, as shown on Figure 2. Previous deep aquifer zone potentiometric maps indicated a gradient oriented south to southeast, a direction generally concordant with the dip azimuth of the deep aquifer zone's hydrostratigraphic units. Figure 2 shows a slightly different potentiometric pattern with a gradient oriented in a more southern direction. The absence of Steen property monitoring well gauging data affects the visual presentation of the potentiometric surface data.

Vertical gradients (i.e., head potentials) between the shallow and deep aquifer zone for the Fourth Quarter 2013 well gauging events are shown on Table 3. Gradients were calculated using measured groundwater elevations for wells within nested shallow and deep aquifer zone pairs. Well pairs included:

- CSX-DW-4 and DSCP-MW-7;
- DSCP-DW-1 and DSCP-MW-23A;
- DSCP-DW-13 and DSCP-MW-11;
- DSCP-DW-6 and DSCP-MW-2B;
- PH-DW-10 and PH-MWS-1;
- PH-DW-11 and PH-PH-22;
- PH-DW-2 and PH-MWS-15;
- DSCP-MW-20D and DSCP-MW-20; and
- PH-DW-3 and EPH-PH-5.

With the exception of one location, vertical gradients during the Fourth Quarter of 2013 well gauging event were found to be indicative of a broad downward groundwater flow potential throughout the general midsection of the Site. Monitoring wells PH-DW-10 and PH-MWS-1 comprised the only well pair to exhibit an upward gradient during the Fourth Quarter 2013 gauging event. This well pair is located within the western portion of Site. The wells with downward potentials are generally located near or directly below the Site's primary LNAPL and constituent of concern (COC) impact areas. These wells are generally coincident with the approximate reported extent of a "breach" in the base of the Site's shallow aquifer zone. This "breach" is described in

prior reports as a geologic feature that allows a vertical hydraulic connection between the shallow aquifer units and the underlying Cretaceous aquifer units¹. The concept of the “breach” is supported by data obtained from original well construction logs and direct-push/direct-sensing logs that show a thinning or absence of confining clay layers in some areas of the Site. Characteristics of the “breach,” including its lateral extent and the vertical hydraulic conductivity observed within it, are similar to characteristics of other features in nearby coastal plain areas that have been interpreted as paleochannels. Additional discussion on COC data collected to help further evaluate aquifer features such as the previously reported “breach” is presented in subsequent sections of this report.

Corrected groundwater elevation data were used to prepare an apparent LNAPL thickness map (Figure 3). The apparent LNAPL thickness contours are approximate and do not necessarily indicate consistent in-situ LNAPL saturation, volume, mobility or recoverability. However, the measurements are useful as a metric, to be used in context with other metrics such as constituent concentrations, to evaluate the progress of remediation through time. Measured LNAPL thickness is influenced spatially by various factors including; 1) the heterogeneous nature of the LNAPL (i.e., both type and degree of weathering – a range of light, middle and heavy end distillates were identified via historic LNAPL fingerprinting data), 2) hydrogeologic characteristics (e.g. stratigraphic soil types over the screened interval of a given well and characteristics of a well), 3) well construction (screen type and interval, sand pack design), and 4) temporal changes (e.g., groundwater level fluctuations).

As shown on Figure 3, the distribution of LNAPL appears to be constrained within an elongated area, following an east-west trend. This distribution has been seen in previous gauging events and appears to roughly coincide with the recurring east-west “trough” in the shallow potentiometric surface (Figure 1).

While the horizontal extent of LNAPL shown is similar to past gauging event data, there are notable changes. Compared to the levels seen in 2012, LNAPL levels have decreased in certain areas of the Site, especially in the southeast portion on the PHA property where many wells showed LNAPL thicknesses of <0.25 ft. The exact mechanism for this change is not known; however the reduction in thickness may be related to the focused vacuum and skimming approach to remediation system O&M

¹ As defined by Ron Sloto, USGS, in meetings on September 17, 2010 and January 19, 2012.

that has been applied to date. Compared to the Third Quarter of 2013, the general trends of LNAPL distribution remain largely the same, suggesting that the LNAPL body at the Site is becoming stable and is not laterally mobile. While small LNAPL thickness increases and decreases in individual wells are observed, these superficial changes in thickness may be related seasonal fluctuations in groundwater elevation, and to the focused vacuum and skimming approach to the remediation system O&M that has been applied to date.

Due to access issues with Steen and SEPTA, data from wells on these properties were not obtained in the Fourth Quarter of 2013. However, the absence of LNAPL measurements from Steen property shallow aquifer zone wells does not appear to have materially affected the interpreted extent of Site LNAPL (i.e., with respect to previous Site LNAPL inferred thickness maps). No data from the groundwater/LNAPL gauging event conducted at the Sunoco refinery and adjacent Philadelphia Gas Works (PGW) property were available for the preparation of these figures.

4.2 Site Wide Groundwater Sampling Event– Fourth Quarter 2013

A groundwater sampling event was conducted at the Site from December 4, 2013 through December 17, 2013. The event was the second Site wide groundwater sampling event of CY 2013, following a Site wide event in the Third Quarter of 2013, and included nearly all of the wells within the Site's monitoring and recovery well network. The event included all accessible monitoring and recovery wells on the Former DSCP property, the Former Passyunk Homes property (the new PHA building and the Siena Place Homes), the CSX property, and the P. Agnes property. Access to the Steen property was not available during this event due to access agreement issues.

Like the Third Quarter 2013 groundwater sampling events, the Fourth Quarter 2013 event included collection of samples for laboratory analysis of previously defined Short List COC² from all accessible monitoring and recovery wells. Data will be used with historic sampling data and future Site-wide sampling data to: 1) evaluate remedial performance, 2) determine the stability of Site LNAPL, and 3) present data in support of an Act 2 Site-Specific Standard (SSS) closure approach for Site LNAPL.

² PADEP Short List for Petroleum Products- Leaded Gasoline, Aviation Gasoline, and Jet Fuel

The recovery wells connected to the VES System on the Former DSCP property and the Former Passyunk Homes property were deactivated on November 29, 2013 and the recovery wells connected to the pneumatic system were deactivated on November 26, 2013. Site recovery wells were reactivated on December 17, 2013 following completion of groundwater gauging and sampling activities.

After liquid level data were collected, accessible wells were sampled via low flow sampling techniques by QED bladder pumps. Groundwater sampling was conducted from the middle of the saturated screened interval of each groundwater monitoring well. During pre-sampling well purging, pH, conductivity, temperature, dissolved oxygen, and turbidity readings were measured at regular intervals to ensure water quality parameters had stabilized prior to sampling. Groundwater sampling logs are included in Appendix B. For LNAPL-bearing wells, sample collection was accomplished using procedures designed to obtain representative groundwater samples free of LNAPL. These procedures are outlined in previous quarterly progress reports.

The language in the Order requires that remediation be conducted as needed to remove as much petroleum LNAPL as is practicable from beneath the Former DSCP property. The following COC from the PADEP *Short List of Petroleum Products for Leaded Gasoline, Aviation Gasoline and Jet Fuel* were selected for analysis based on the reported approximate composition of LNAPL at the Site. The Short List of Petroleum Products includes:

- Benzene
- Toluene
- Ethyl Benzene
- Xylenes (Total)
- Cumene (Isopropylbenzene)
- Napthalene
- Trimethyl benzene, 1,2,4- (Trimethyl benzene, 1,3,4-)
- Trimethyl benzene, 1,3,5-
- Dichloroethane, 1,2-
- Dibromoethane, 1,2-
- Lead (dissolved)

Due to Site history of arsenic detections and impacted soils (Risk Assessment), dissolved arsenic was also analyzed. Groundwater samples were analyzed for methyl tertiary-butyl ether (MTBE). To evaluate potential MTBE distribution and degradation,

samples were also analyzed for tertiary butyl alcohol (TBA), a known daughter product of anaerobic degradation of MTBE.

Samples from 141 wells were analyzed using EPA 8260B for Volatile Organic Compounds (VOCs), EPA 8011 for Semi-Volatile Organic Compounds (SVOCs), and EPA 6020 for dissolved lead and arsenic. Analytical data packages are located in Appendix C. Tabulated analytical results are presented in Tables 4a and 4b. Results were compared to the PADEP Groundwater Medium Specific Concentrations (MSCs) for Non-Residential Used Aquifers with Total Dissolved Solids (TDS) less than or equal to (\leq) 2,500 milligrams per liter (mg/L). Analytical results that exceed the Non-Residential Used Aquifer (TDS <2,500 mg/L) Groundwater MSCs are bolded and highlighted in yellow. If the detection limit for a reported result exceeded the MSC and the result was a non-detect, the result was highlighted grey. These standards have been selected for comparison purposes only and are not intended to be the target cleanup goals for Site groundwater. A Site Specific Standard or Background Standard approach to Site groundwater cleanup may be pursued as previously discussed with PADEP (e.g. meetings held on October 27, 2011, January 19, 2012 and March 13, 2012). For the deep aquifer zone, as discussed during the March 6, 2013 PADEP meeting, either a background standard approach or an area-wide Non-Use Aquifer Determination (NUAD) will be pursued.

Table 4a shows analytical results of the Site VOC COC, including MTBE and TBA, compared to the MSCs. Table 4a also shows the sum of all VOC COC. The results are shown on Figure 4 through Figure 13. Each figure shows a well location based on the total VOC COC concentration only for the respective aquifer zone. The figures are organized to summarize differing concentration ranges for both the shallow and deep aquifers, as follows:

- Figure 4 shows total VOC results for COC in the shallow/intermediate aquifer that are greater than 10,000 micrograms per liter (ug/L);
- Figure 5 shows total VOC results for COC for the shallow/intermediate aquifer that are between 3,000 ug/L and 10,000 ug/L;
- Figure 6 shows total VOC results for COC for the shallow/intermediate aquifer that are between 1,000 ug/L and 3,000 ug/L;
- Figure 7 shows total VOC results for COC for the shallow/intermediate aquifer that are between 100 ug/L and 1,000 ug/L;
- Figure 8 shows total VOC results for COC for the shallow/intermediate aquifer that are between 1 ug/L and 100 ug/L;

- Figure 9 shows total VOC results for COC for the shallow/intermediate aquifer that are less than 1 ug/L;
- Figure 10 shows total VOC results for COC in the deep aquifer that are greater than 1,000 ug/L; and
- Figure 11 shows total VOC results for COC in the deep aquifer that are less than 1,000 ug/L.
- Figure 12 shows MTBE and TBA results for the shallow/intermediate aquifer
- Figure 13 shows MTBE and TBA results for the deep aquifer

Site metals concentration in the groundwater for the shallow and intermediate aquifer zones are shown in Figures 14 and 15 while Site metals concentrations in the deep aquifer are shown in Figure 16. Each of these figures show the data compared to the Non-Residential Used Aquifer (TDS <2,500 mg/L) Groundwater MSC. Arsenic and lead are the two diagnostic metals detected in groundwater at the Site that reportedly may have an association with the Order-defined petroleum hydrocarbon impacts. Tabulated metals values are given in Table 4b.

4.2.1 Site Wide Groundwater Sampling Event Observations – Shallow and Deep Aquifer Zone

Volatile Organic Compound Constituents of Concern

A total of 16 shallow and intermediate wells yielded results where total VOC COC exceeded 10,000 ug/L (shown in blue on Figures 4-11, detail Figure 4). Most of these wells are clustered within the central portion of the Site, including the VES well network on the PHA property and the general vicinity of the VES building. Four wells on the Former DSCP property have total VOC COC greater than 10,000 ug/L, and twelve do on the PHA property. The northernmost of all the wells with VOC COC >10000 ug/L is DSCP-MW-3A, and the southernmost well is PH-MWS-2A. Within the wells with high total VOCs, benzene is generally the COC with the highest concentration. Total VOC concentrations range from 10,193 ug/L in PH-MW-43 to 37,797 ug/L in DSCP-MW-65, and benzene concentrations range from 5,130 ug/L in PH-MW-43 to 31,100 ug/L in PH-IW-10.

Overall, the highest reported groundwater VOC COC concentration data points generally cluster in the center of the Site and occupy an area with an elongated east to west axis, with points of lower VOC COC concentration surrounding the area. This spatial distribution of the high VOC wells coincides with the “breach” in the shallow aquifer zone potentiometric surface and measured LNAPL distribution.

While locations of high VOC COC and locations of greatest measured LNAPL thickness both lie in the “breach” in the center of the Site, a complete correlation between LNAPL thickness and groundwater VOC COC concentration was not observed. Areas of high measured LNAPL thickness, such as near DSCP-RW-9 [1.03 ft.], do not necessarily contain total VOC COC levels greater than 10,000 ug/L. This may be an indication of the spatially variable composition of the Site’s LNAPL, as previously reported, and specifically may indicate the presence of heavier or more weathered LNAPL in the vicinity of these wells. Through volatilization and in-situ biodegradation, the Site’s VES system and naturally occurring indigenous microbes weather LNAPL via removal of the VOC COC components. Therefore, declining COC concentration trends and the continued observation of discordant LNAPL and VOC COC distributions are to be expected.

Surrounding the central area of total VOC COC results greater than 10,000 ug/L are the wells with greater than 1,000 but less than 10,000 ug/L VOC COC, shown in yellow on Figures 4-11. Figures 5 and 6 show results between 1,000 ug/L and 10,000 ug/L. A total of 35 shallow and intermediate wells yielded total VOC COC results in this category. For these wells, benzene is typically the COC with the highest concentration, with a maximum of 8,620 ug/L at DSCP-MW-14.

Wells with VOC COC concentrations less than 1,000 ug/L are generally found toward the edges of the Site, and are shown in green on Figures 4-11. A total of 78 shallow and intermediate wells were placed in this category. At 32 of these locations, benzene still exceeds the Non-Residential Used Aquifer (TDS <2,500 mg/L) Groundwater MSC.

Two wells reaching the deep aquifer showed total VOC COC concentrations of more than 1,000 ug/L: PH-DW-11 on the PHA property along the western portion of the Site, and PH-DW-3 on the southern portion of the Site, as shown in yellow on Figure 10. PH-DW-11 yielded a total VOC COC concentration of 5,454 ug/L, and a benzene concentration of 4,970 ug/L. PH-DW-3 yielded 5,859 ug/L total VOC COC, and 5,410 ug/L benzene. The remaining nine deep wells, shown on Figure 11, had total VOC COC concentrations less than 1,000 ug/L. Of these, two wells exceeded the Non-Residential Used Aquifer (TDS<2,500 mg/L) Groundwater MSC for benzene, and four exceeded the MSC for MTBE.

MTBE and TBA

Figures 12 and 13 show MTBE and TBA results in the shallow/intermediate and deep aquifer zones. During the Fourth Quarter 2013 event, 18 MTBE detections were

observed, including 8 of which were above the Non-Residential Used Aquifer (TDS <2,500 mg/L) Groundwater MSC. Observations regarding MTBE results include:

- 10 shallow/intermediate wells are shown with MTBE detections, and 4 exceed the MSC, with a maximum detection of 67.1 ug/L at DSCP-IW-12. Of the detections that exceed the MSC, one is located in the center of the Site near areas of measurable LNAPL. One is located towards the western boundary of the Site on the PHA property, and two others are located further north along the western boundary, on the northern DSCP and CSX properties.
- 8 deep wells are shown with MTBE detections, and 4 exceed the MSC, with a maximum detection of 42.1 ug/L at CSX-DW-5. The wells that show MTBE detections that exceed the MSC are found along the western boundary of the Site. Three are located to the north, on the northern DSCP and CSX properties, and one is located on PHA property.

The Fourth Quarter 2013 event included samples that were also analyzed for TBA, a daughter product derived from the biodegradation, or a precursor chemical compound in the manufacturing, of MTBE. While TBA is not a PADEP regulated compound, it was sampled to aid in understanding of the COC interacting with groundwater redox zones and flux of groundwater and COC within the Site's aquifer systems. TBA was not sampled and analyzed in sampling events prior to the Third Quarter of 2013, but as TBA data are collected from future events, trends in MTBE migration and degradation may become apparent. In the Fourth Quarter 2013 event, 51 wells showed TBA detections. Results are shown on Figures 12 and 13.

Figures 12-13 show the following observations:

- 44 shallow/intermediate wells showed TBA detections, maximum 4,390 ug/L in PH-MW-43. PH-MW-43 is located towards the western boundary of the Site on the PHA property.
- 7 deep wells showed TBA detections, maximum 309 ug/L in PH-DW-3. PH-DW-3 is located towards the southern edge of the Site.
- 5 wells in the shallow/intermediate zones show MTBE detections but not TBA detections. These wells include CSX-IW-5, DSCP-MW-1, DSCP IW-1, DSCP-IW-13, and DSCP-MW-44A. These wells are located in the central to

northwestern portions of the Site.

- 2 wells in the deep zone show MTBE detections but not TBA detections. These wells include DSCP-MW-20D and PH-DW-10. DSCP-MW-20D is located within the northwestern portion of the Site, up-gradient of the “breach.” PH-DW-10 is located in the central portion of the Site along the western boundary, on the PHA property.

Dissolved Metals

Table 4b and Figures 14-16 show dissolved metals results for dissolved arsenic and lead in the shallow and deep aquifer. Dissolved lead concentrations are represented by larger circles, while arsenic is represented by small circles. Detections that exceed the Non-Residential Used Aquifer (TDS<2500 mg/L) Groundwater MSCs are highlighted in blue. The metals results for arsenic and lead in both the shallow and deep aquifers showed detections exceeding MSC levels in the same areas of high VOCs, where measureable LNAPL is located. In addition, results from several shallow and deep wells on the CSX property to the west of the Site showed levels of arsenic and lead that exceeded the MSCs.

Specific observations include:

- 96 shallow/intermediate wells are shown with arsenic detections, maximum 186 ug/L at DSCP-RW-5/MW-25. 51 of these detections exceed the PADEP MSC.
- Shallow/intermediate arsenic impacts are observed throughout the Site, with the highest impact centered on the area of measureable LNAPL.
- 7 deep wells are shown with arsenic detections, maximum 6.5 ug/L at both CSX-DW-5 and DSCP-DW-12. All of these detections were below the PADEP MSC.
- 20 shallow/intermediate wells are shown with lead detections, maximum 175 ug/L at DSCP-RW-5/MW-25. 6 of these detections exceed the PADEP MSC.
- All but one of the shallow/intermediate wells with lead exceedances are located along the western portion of the Site, near and on the CSX property.

One well, DSCP-MW-34, is located on the eastern portion of the Site.

- One lead detection was reported for the deep aquifer zone, in DSCP-MW-20D, at a concentration of 14.8 ug/L. This detection exceeds the PADEP MSC.

4.3 Historical Site-Wide Groundwater Sampling Event Data Observations

Historical VOC COC data tables were compiled from Site-wide groundwater sampling events dating as far back as 1994. These tables are given in Appendix D, and may be read in conjunction with Figures 4-13, which show the most recent groundwater sampling data. The color coding used in these figures (blue for VOCs >10,000 ug/L, green for 1,000-10,000, and yellow for <1,000) has been applied to the well IDs in the historic data table for reference.

Wells with total VOCs >10,000 ug/L during the most recent sampling event have historically shown high levels of VOCs, including benzene and MTBE (where data available). The well with the highest total VOCs during the Fourth Quarter of 2013, DSCP-MW-65, was installed in January 2014, and also showed high VOC levels during the Third Quarter of 2013 when the well was first sampled. This well is located in the central portion of the Site. The well with the highest benzene level for the most recent event, PH-IW-10, has shown benzene levels of over 15,000 ug/L since 2007, with a maximum level of 36,100 ug/L during the Third Quarter of 2013. This well is located on the western edge of the PHA property.

Recent results from the Third and Fourth Quarters of 2013 compared to historic data show a few wells with increasing trends in VOC COC. These wells include PH-PH-17, PH-PH-19, PH-RW-E, and PH-RW-V. These wells are located within the southern portion of the Site, and are not currently connected to the VES system.

Comparison of recent and historical data also shows decreasing trends in some wells. Decreasing trends were noted in 21 wells, including CSX-MW-5, DSCP-MW-5, DSCP-MW-14, DSCP-MW-30, DSCP-MW-4A, DSCP-RW-4, EPH-MW-39, PH-DW-3, PH-MWS-2A, PH-MWS-3, PH-MW-42, PH-MW-55, PH-MW-60, PH-PH-1, PH-PH-14, PH-PH-20, PH-PH-21, PH-RW-A, PH-RW-B, PH-RW-D, and PH-RW-G. Trends in these well locations will continue to be monitored through the addition of future sampling results to the historical data table.

During the Third Quarter of 2013, DSCP-MW-29 was noted as showing a two order of magnitude decrease in VOC COC, from 8,600 ug/L and 8,389 ug/L in 2012 to 45.2

ug/L in the Third Quarter of 2013. This result was considered anomalous, and was flagged for comparison with future sampling results. During the Fourth Quarter of 2013, DSCP-MW-29 showed a VOC COC result of 8,846 ug/L, similar to the 2012 data. This increase back to historic levels indicates that the low VOC COC result obtained in the Third Quarter of 2013 was not representative of the current conditions at this location.

Similarly, CSX-MW-2 showed a large increase in VOC COC during the Third Quarter of 2013, from no reported detections in 2012 to 6,585 ug/L during the Third Quarter of 2013. However, during the Fourth Quarter of 2013, CSX-MW-2 yielded a result of 12.4 ug/L, indicating that the high levels observed during the Third Quarter of 2013 were not representative of current conditions.

Though TBA data is only available since the Third Quarter of 2013, it has been included in the historical data table, along with MTBE, so that with the addition of data from future sampling events, trends in TBA and MTBE concentrations may be observed. Based on the Third and Fourth Quarter of 2013 data, Site locations with MTBE and TBA detections remain largely consistent, and include the central portion of the Site on the Former DSCP property, the western portion of the Site on PHA property, and the northwestern portion of the Site on CSX property. The following specific observations were noted:

- As reported in the Third Quarter of 2013 progress report, three shallow/intermediate wells showed MTBE detections but not TBA detections. Two of these wells, including CSX-IW-5 and DSCP-IW-1, showed similar results in the Fourth Quarter of 2013. These two wells are located on the western and northwestern portions of the Site.
- In the Fourth Quarter, DSCP-MW-1, DSCP-IW-13, and DSCP-MW-44A also showed MTBE detections but not TBA detections. These wells are located in the central portion of the Site.

For deep wells, DSCP-MW-20D and PH-DW-10 showed MTBE detections but not TBA detections during both the Third and Fourth Quarters of 2013. These wells are located within the northwestern portion of the Site. The historical data table in Appendix D will be used as a database, and data from future groundwater sampling events will be added. This information will be used along with remediation O&M data to better define

contaminant concentration and LNAPL thickness trends and to focus future Site remedial efforts.

Though metal concentration data have not been included in the historical data table in Appendix D, several observations were made comparing the Third Quarter of 2013 metals data to that of the Fourth Quarter of 2013:

- Generally, regions with arsenic and lead detections remained consistent from the Third Quarter to the Fourth Quarter of 2013. Arsenic impacts were observed throughout the Site, with the highest impact centered on the area of measureable LNAPL. Lead impacts were observed towards the western portion of the Site.
- The well with the maximum lead detection during the Fourth Quarter of 2013, DSCP-RW-5/MW-25 at 175 ug/L, showed no lead detection during the Third Quarter. This result has been marked, and will be compared with metal concentration data from future events to determine if the result accurately represents concentration trends near the well location.
- During the Fourth Quarter of 2013, one deep well, DSCP-MW-20D, showed a lead detection (14.8 ug/L) that exceeded the PADEP MSC, while no deep wells showed lead exceedances during the Third Quarter of 2013. This well, along with other deep wells, will be monitored for lead detections in future events.

5. Liquid Levels and the Packer Avenue Sewer

During the Fourth Quarter of 2013 and CY 2013, and consistent with previous observations, measureable LNAPL was not observed in the monitoring wells located south of the Packer Avenue sewer. Appendix E contains figures depicting the elevation of the LNAPL, groundwater, and the bottom of the sewer. Groundwater elevations in the wells in close proximity to the Packer Avenue sewer were higher than the bottom of the sewer.

6. VES System Operation and Maintenance

Remediation began at the Site in 1996 utilizing in-well skimmer pumps for removal of LNAPL. In March 1999, operation of an expanded LNAPL skimming system commenced. The expanded system included two separate fixed pneumatic LNAPL

skimming systems at the Former DSCP property and the Former Passyunk Homes property (the PHA property). The current VES System, which began operations in March 2005, was installed to enhance LNAPL recovery rates by inducing a pressure (i.e., vacuum) gradient that can help draw additional LNAPL to the recovery wells without depressing the groundwater table. The VES system also removes hydrocarbon mass via vapor phase recovery which can be expressed as LNAPL using a vapor mass to LNAPL volume conversion factor. For a complete history of Site remedial operations, please see Appendix F – Site History. This history reveals how the more recently adopted dynamic approach to O&M has allowed remediation efforts to evolve based on the needs of the system so that recovery is more effective. Below is a description of the performance of the mobile and VES systems and related remediation O&M observations during the Fourth Quarter of 2013.

6.1 Fixed Skimming System – Fourth Quarter 2013

The fixed LNAPL skimmer pumps are connected to a totalizer installed in each recovery well vault. Recovery well totalizers are used only to estimate the LNAPL recovered from each well during skimmer pump operation. This is because as a function of normal skimmer pump operation, some air passes through the totalizers along with the LNAPL, and/or totalizers can occasionally become stuck as a function of regular operation, resulting in inaccurate estimation of the quantity of LNAPL recovered at each well. The more accurate measurement of the volume of LNAPL recovered by skimming is obtained from tank charts that correlate storage tank volume and the depth of LNAPL measured in a given Site LNAPL storage tank (where the total volume of LNAPL recovered is monitored continuously and recorded weekly, at a minimum). This tank chart data is obtained via a volume-measuring probe installed in each of the Site's two LNAPL aboveground storage tanks (ASTs).

The fixed system LNAPL skimmer pumps located on the Former Passyunk Homes property (the current PHA property) are connected to a 5,200-gallon AST and the fixed system LNAPL skimmer pumps located on the Former DSCP property are connected to a 10,000-gallon AST. Tables 5 and 6 detail the estimated quantity of LNAPL recovered from each of the fixed system recovery wells, in addition to the total and cumulative LNAPL recovered by each fixed system based on the tank charts mentioned above. Table 5 contains the LNAPL recovered for the Former DSCP system and Table 6 contains the LNAPL recovered for the Former Passyunk Homes system.

During the Fourth Quarter 2013, Former DSCP area fixed skimming system recovery wells did not recover any LNAPL according to the totalizers in the recovery well vaults (as shown in Table 5). However, as discussed above, recovery well totalizers are not the most accurate method of recording the amount of LNAPL recovered. It is suspected that one or more of the totalizers were stuck and therefore did not record the amount of LNAPL being recovered during the Fourth Quarter 2013. Based on volume-measuring probe data and resultant tank chart readings the AST on the Former DSCP property received approximately 143 gallons of LNAPL during the quarter. This results in a total approximate volume of LNAPL recovered by the Former DSCP area fixed system of 508,068 gallons through the end of the Fourth Quarter 2013.

In October of 2013 a belt broke on the PHA skimming system air compressor and as a result, LNAPL skimming operations on the PHA property stopped. As a temporary fix, while a replacement belt was ordered, a mobile system was stationed on the PHA property and connected to recovery wells RW-A and PH-20, focusing skimming efforts strictly on these two wells. The LNAPL recovered from these wells were plumbed into the AST on the PHA property. While the air compressor was repaired, the controller from the mobile skimming system is being utilized as the PHA skimming system as an optimization test discussed in greater detail below.

During the Fourth Quarter of 2013, and according to the totalizers in each recovery well vault (as shown on Table 6), the Former Passyunk Homes property fixed skimming system recovered 93 gallons from RW-A and 87 gallons from PH-20. However, as of the end of the Fourth Quarter 2013, no measureable LNAPL has collected in the AST. This indicates that the skimming system lines still have not filled with a sufficient quantity of LNAPL to accumulate in the AST. The underground piping for this system has a capacity of approximately 500 gallons, which must fill prior to any LNAPL entering the AST. Approximately 167,558 gallons of LNAPL have been recovered by the Former Passyunk Homes fixed skimming system since it was started in March 1999. This total remains unchanged as of the end of the Fourth Quarter 2013.

Both fixed skimming systems were shut down for the quarterly groundwater gauging and sampling event from November 26, 2013 to December 17, 2013. With the exception of this event, the skimmer systems operated continuously during the quarter. Neither AST used for storing LNAPL was pumped out during this quarter. System O&M, pump cycling frequency and pump intakes were adjusted as necessary. Adjustments were made to optimize LNAPL recovery while maintaining enough LNAPL thickness in the wells to prevent pumping groundwater along with the recovered LNAPL.

As discussed in previous quarterly reports, the low LNAPL recovery by skimmer pump from 2006 to date is most likely the result of the following factors:

- The majority of the LNAPL that was recoverable by skimmer pump has been removed;
- A reduction in the regional pumping rates in the shallow aquifer over the years in the vicinity of the Site has resulted in higher groundwater elevations. As a result, much of the remaining LNAPL/ petroleum hydrocarbon mass at the Site is now most likely trapped below the water table. This change in the regional aquifer effectively reduced the amount of mobile LNAPL available for recovery by skimmer pump. The resulting increase in the groundwater level has also submerged the screened interval in some recovery wells thereby cutting off the recovery well from any mobile LNAPL and or hydrocarbon vapor that may be present adjacent to the well; and
- As evidenced by recent activities related to aquifer testing on the Site, there is likely some fouling in the screens and sand packs of the Site's wells, especially those that have been actively used for LNAPL and vapor recovery for several years. Fouling can occur due to biological activity (biofouling) or from extended periods of vapor recovery in LNAPL wells. In the case of vapor recovery, the lighter fraction of the LNAPL is volatilized, leaving behind the less volatile, heavier, and more viscous fraction. Fouling can reduce soil porosity in the formation adjacent to the recovery well, reducing the rate of recovery over time.

Site subsurface conditions, such as relatively high groundwater elevations, have decreased the effectiveness of the skimming. Because of the generally lower ability to recover LNAPL by skimmer pump, ARCADIS has been conducting optimization testing activities on the vapor recovery portion of the VES system as discussed in Section 6.3 below. Additionally, ARCADIS has also been conducting optimization of the operational strategy of the fixed skimmer systems including:

- Keeping skimmer pumps off in recovery wells that exhibit less than 0.3 ft of free LNAPL to prevent water from being pumped into the ASTs, and to reduce the amount of labor expended on tasks that do not yield significant LNAPL recovery. These recovery wells are checked periodically and the skimmers are turned on only when supervised to pump out accumulated LNAPL but not to pump water into the ASTs;

- Removing skimmer pumps from recovery wells that do not exhibit recoverable LNAPL to reduce costs associated with maintaining pumps in wells where no LNAPL is being recovered. These pumps are kept onsite and will be re-deployed when recoverable LNAPL is measured in these recovery wells;
- Operating sets of fixed skimming (recovery) wells at higher vacuum levels (i.e. between 20 and 30 inches of water (iw) for extended periods of time, then periodically stopping the vacuum and using the skimmer pumps to pump out the LNAPL that has accumulated. This strategy, often referred to as “pulsing” the smear zone, is a dynamic approach to LNAPL recovery which can help mobilize LNAPL in the smear zone not otherwise effected by a more static VES strategy. Periodically stopping the vacuum in this strategy is necessary in some of the wells as the effectiveness of the skimmer pumps may be decreased by these higher vacuums. This pulsing of the aquifer is done by focusing LNAPL skimming at the VES wells being utilized in rotating groups, discussed in more detail in Section 6.3 below.
- Conducting an optimization test using the RW-A and PH-20 skimmers with a pump controller removed from one of the mobile systems. This strategy operates the skimmer on a timed schedule (three events per day, five minutes per event) in place of continuous operation, to allow the LNAPL to recover in the well between periods of pump operation. By allowing the LNAPL in wells to recover, the LNAPL in the well is not cut off from the surrounding LNAPL in the formation, and as a result of surface tension, more LNAPL can be drawn into the well. This strategy may have the added benefit of pumping less water into the storage tank. By adjusting the controller frequency, the pump is controlled to only pump when LNAPL is present. This test commenced in the Third Quarter of 2013, continued into the Fourth Quarter of 2013 and is ongoing. While the well totalizers are not an accurate way to calculate LNAPL recovery and the tank chart for the AST on the PHA property still shows no accumulation, this focused method is showing material is being moved due to the in well totalizers showing greater amounts than had been seen in the past few quarters. The results of this ongoing optimization test will be provided in future quarterly reports.

This optimized fixed-skimming system operational strategy appears to have contributed to a significant increase in the amount of LNAPL recovered by skimming

from the Third Quarter of 2012 through the Fourth Quarter of 2013. LNAPL recovery tables are provided in Appendix G.

6.2 Modular Skimming System – Fourth Quarter 2013

A modular LNAPL recovery system is currently also operating on the Former DSCP property, at well DSCP-MW-3A (installed October 25, 2004). The LNAPL recovery data for this modular system is included in Table 7. A graph showing the total LNAPL recovery per quarter over time by the modular systems is included in Appendix G. No LNAPL was recovered by the modular system at DSCP-MW-3A during this quarter.

As discussed above, the ongoing optimization efforts involve testing the Site's LNAPL skimming methodology. The operational methodology being applied to the fixed skimming systems is also being applied to the modular skimming unit currently installed at DSCP-MW-3A. DSCP-MW-3A is operating on a pump controller that allows the unit to pump LNAPL on a timed frequency of twice per day for 5 minutes.

LNAPL recovery by the modular skimming system at DSCP-MW-3A remains low as there is not much apparent recoverable LNAPL in this location. It is, however, the only location where recoverable LNAPL exists in a well that is not already connected to the fixed skimming systems and where a modular system can be safely deployed. The low level of effort afforded by the use of the modular skimming system is the main reason why skimming has continued at this location. Evaluation of the feasibility of deploying modular units at other locations of the Site is ongoing.

6.3 VES System Operation and Optimization Fourth Quarter 2013

As part of system improvement activities in 2004, the VES system was installed to enhance the recovery rate of the existing LNAPL skimming systems. As originally designed, the VES system allows the placement of vacuum on selected recovery wells to create a pressure (vacuum) gradient. Ideally, this gradient helps draw additional LNAPL to the recovery well. However, the applied vacuum also removes hydrocarbon mass via vapor phase recovery which can be expressed as gallons of LNAPL using a conversion factor. Additional details on the calculations were provided in previous quarterly reports and are discussed in Appendix F – Site History.

The well field optimization testing that commenced in the Fourth Quarter 2011 determined that the application of focused VES system-generated vacuum on a selected subset of recovery wells increased the overall rate and quantity of petroleum

hydrocarbon mass recovery from the VES system. This focused vacuum strategy, as opposed to the equal application of VES vacuum to all Site recovery wells, has been continued through the Fourth Quarter 2013 with some minor changes to the subset of wells being used for continuous VES operation. Appendix H shows which VES system wells were operated during this quarter.

The subsets of the VES system wells in Appendix H have been grouped into primary, secondary and tertiary subsets of wells. In the current remedial strategy, only the primary recovery wells are utilized for continuous focused vacuum extraction due to consistent mass recovery yielded by these wells. These primary wells are only shut off briefly to periodically pump out the LNAPL that accumulates by skimmer pump. The secondary wells, which do not consistently yield as much mass recovery as the primary wells, are operated (in addition to the primary wells) in rotating groups of 3 to 5 wells. This strategy of periodically operating groups of secondary wells is done to generate a pulsing effect in portions of the plume, increasing the overall mass recovery of both LNAPL and extracted vapor. The VES system was operated during the Fourth Quarter of 2013 using the primary wells, secondary group 1 and tertiary wells RW-E and RW-W at an applied vacuum of between 10 to 33 iw. The remainder of the recovery wells were not used due to lower potential mass recovery rates, but the wells are checked periodically to determine if they should be added to the secondary well rotation. Wells may be added to increase mass recovery on a temporary basis or if LNAPL is consistently present in these wells.

Monitoring of CH₄ (with and without carbon filter), LEL, carbon dioxide (CO₂), and O₂ were recorded periodically during the quarter. Mass recovery was calculated using PID data collected at the VES system manifold. However, high CH₄ results tend to negatively skew the PID data collected at the VES system manifold, therefore PID data was calibrated using TO-15 summa canister air sample data. The petroleum hydrocarbon mass recovery calculations for the focused VES system are based on a weighted average of the compounds detected in the TO-15 manifold combined influent vapor samples. These samples are collected twice-monthly, when possible, to allow better accuracy of the mass recovery calculations. During the Fourth Quarter 2013, five of these samples were collected. The average molecular weights from the results of the TO-15 samples of the combined influent were calculated in grams per mole (g/mol) as follows:

- October 9, 2013 – 88.52 g/mol
- October 28, 2013 – 88.90 g/mol
- November 6, 2013 – 89.55 g/mol

- November 26, 2013 – 90.17 g/mol
- December 20, 2013 – 89.23 g/ mol

The TO-15 summa canister vapor sample results can be found in Appendix I. Mass recovery calculations are presented in Appendix J.

During the Fourth Quarter 2013, the VES system operated in optimized/focused-vacuum mode yielding an average mass recovery of 9.9 pounds/hour (lbs/hr). This represents a decrease from the mass recovery rate observed during the Third Quarter 2013 and is a function of the revised remedial strategy discussed above (i.e., application of focused vacuum over a greater number and varying combinations of recovery wells). The overall mass recovered for the Fourth Quarter 2013 was actually higher than the previous quarter due to greater up time. Additionally, mass recovery remains higher utilizing the focused vacuum remedial strategy than it was prior to optimization.

During the Fourth Quarter 2013, the average CH₄ (with carbon filter) was 5.4%, up from 4.1% in the previous quarter. The average CO₂ was 7.4%, up from 5.3% in the previous quarter, and the average O₂ was 9.6%, down from the 11.8% in the previous quarter. These changes are the result of modifications to the recovery wells being used for focused vacuum extraction during the reporting period (i.e., the primary and secondary groups of recovery wells).

Both thermal oxidizers (TX100 & TX200) can operate; however, only TX200 was used during the Fourth Quarter 2013. One thermal oxidizer was adequate to treat the vapor from the VES system during this time period. The second oxidizer, TX100 was maintained on standby in the event of a problem with TX200.

The overall VOC recovery rate for the VES system from October 1, 2013 through December 31, 2013 was 20,247 pounds which correlates to approximately 3,346 gallons of LNAPL. This is calculated using the mean density of the compounds detected in the laboratory analytical results of the summa canister samples collected from the influent vapor stream at the VES system manifold. This mean density is calculated based on a weighted average of the molecular weights of the compounds detected. This conversion factor was calculated as follows during the Fourth Quarter 2013:

- 5.90 pounds (lbs)/gallon on October 9, 2013
- 5.97 lbs/gallon on October 28, 2013

- 5.91 lbs/gallon on November 6, 2013
- 5.93 lbs/gallon on November 28, 2013
- 5.91 lbs/gallon on December 20, 2013

A graph showing the cumulative mass recovery of the VES system per quarter is included in Appendix G. As shown on this graph, the mass recovered by the optimized VES system since the Fourth Quarter of 2011 is more than five times the total mass recovered by the VES system since its start-up in 2005 through the Fourth Quarter of 2011. In the Fourth Quarter of 2013, VES mass recovery was lower than the all-time high in the Second Quarter of 2012 (when vacuum truck testing combined with lower groundwater levels lead to a spike in the mass recovery in that quarter). The mass recovery by VES was however higher in the Fourth Quarter of 2013 than the previous quarter. As mentioned above, these changes are the result of modifications to the recovery wells being used for focused vacuum extraction during the reporting period (i.e., the primary and secondary groups of recovery wells) as well as lower flow rates from the well field. It is anticipated that the optimization efforts will maintain these higher mass recovery levels from the VES system.

6.4 Methane and Carbon Dioxide Forensic Techniques

In addition to mass recovered as VOCs, the VES system also contributes to the in-situ degradation of hydrocarbon mass by way of aerobic microbial degradation. The effect of aerobic microbial degradation can be estimated using the concentration of CO₂ entering the VES system. As discussed in previous quarterly reports, the calculation of the aerobic microbial degradation had been based on a conservative estimate of 10% of the CO₂ recovered being attributed directly to in-situ aerobic degradation of VOCs. In order to determine a more accurate “weighting” factor to convert CO₂ and CH₄ to pounds of hydrocarbon mass degraded in situ, carbon isotopic analysis of the CO₂ and CH₄ from the headspace of recovery wells, as well as the VES-extracted soil vapor, commenced in the Third and Fourth Quarters of 2013. The analysis of the carbon isotopes present in these samples can be used to determine the portion of CO₂ and CH₄ attributed to degradation of a fossil fuel compared to the portion derived from more modern sources (such as human activities and the decay of peat in soils).

In the Third and Fourth Quarters of 2013, samples for isotopic analysis of soil vapor were collected from the following locations:

- CH₄ in RW-A headspace on August 21, 2013;
- CH₄ in RW-5 headspace on September 23, 2013;

- CH₄ from the VES combined influent on October 19, 2013;
- CO₂ from the VES combined influent on October 28, 2013;
- CO₂ from RW-A headspace on November 6, 2013; and
- CO₂ from RW-5 headspace on November 6, 2013.

Analytical results of these samples as well as calculated results of the percent contribution from Petroleum Hydrocarbon Degradation are provided below and in Appendix K. The amount of the carbon 14 (¹⁴C) isotope, expressed as percent modern carbon (pMC), in the CH₄ and CO₂ is used to determine the “age” of the CH₄, and CO₂, similar to age dating of organic material from archeological sites (i.e. CH₄ or CO₂ derived from degradation of petroleum hydrocarbons will have zero ¹⁴C, while CH₄ or CO₂ derived from anthropogenic sources such as landfills may be up to 100 pMC). The analytical results of the CH₄ in these samples indicate that the carbon present in the CH₄ had a ¹⁴C value ranging from 1.1 to 7.1 pMC. Additionally, the analytical results of the CO₂ in these samples indicate that the carbon present in the CO₂ had a ¹⁴C value ranging from 6.0 to 18.1 pMC. The low values of ¹⁴C in these samples indicate that both the CH₄ and CO₂ are primarily derived from degradation of petroleum hydrocarbons (i.e. anaerobic degradation of the LNAPL plume).

These analytical results suggest that the relatively high levels of CH₄ present in the formation and extracted by the VES system are in large part the result of years of anaerobic LNAPL biodegradation. This process is occurring naturally, and is independent of the VES system operation. However, the CO₂ present in the formation and extracted soil vapor is increasingly being derived from aerobic in-situ biodegradation, which can be directly attributed to the operation of the VES system (i.e., as the VES system withdraws CO₂, CH₄ and VOC laden soil gas, the concurrent infiltration of atmospheric air supplies oxygen to the subsurface).

As discussed previously, the calculation of the aerobic microbial degradation had been based on a conservative estimate of 10% of the CO₂ recovered being attributed directly to in-situ aerobic degradation of VOCs. The isotopic analytical result of CO₂ in the soil vapor of the VES system combined influent conducted during the Fourth Quarter 2013 yielded a value of 16 pMC. This demonstrates that 16% of the CO₂ recovered by the VES system is derived from modern or anthropogenic sources (i.e. not related to in-situ degradation of the VOCs). To determine how much of the remaining 84% of the CO₂ is then directly attributed to in-situ degradation of the VOCs, the percent derived from degradation of peat and organics in soil must be considered. As described in the Technical Memorandum included in Appendix K, the amount of ¹⁴C in CO₂ derived

from the degradation of peat is approximately 74 pMC. The percent contribution from petroleum hydrocarbon degradation is then expressed as:

$$100 - \frac{100 \times 16 \text{ pMC (sample result)}}{74 \text{ pMC (contribution from peat)}} = 78\% \text{ (from petroleum hydrocarbons)}$$

The results of this analysis therefore demonstrates that the percent of the carbon dioxide recovered that may be directly attributed to the VES system operation is approximately 78%; much greater than the 10% that had been conservatively assumed in previous reports.

This assessment represents only one data point from the CO₂ in the combined VES system influent, so to refine these results, routine isotopic analysis of the CO₂ in the combined influent is planned to be conducted starting in the First Quarter of 2014. Updated results will be provided in the First Quarter 2014 Report, including a table which will track the total mass degraded in-situ by aerobic degradation based on updated isotopic analysis data during that quarter. However, if the results of this one isotopic sample of CO₂ from the VES system influent in the Fourth Quarter 2013 were applied to the entire quarter, a total of 74,451 lbs of VOCs were degraded in-situ as measured by CO₂ recovered. This yields another 12,536 gallons of LNAPL removed in the Fourth Quarter 2013 by in-situ degradation (calculations are found in Appendix J – Mass Recovery Table). This total is not being added to the total mass recovery by the VES system at this time, but will be tracked in a separate table beginning in 2014.

7. Investigation Derived Waste

The approach to management of investigation derived waste (IDW) was outlined in the Draft Waste Management Plan (WMP; PARS, 2012) submitted to USACE on August 21, 2012. The WMP was developed to be a “living” document, such that IDW from each phase of work would be addressed in an addendum to the WMP.

IDW removed from the Site during the Fourth Quarter of 2013 consisted of the following:

- Approximately 5000 gallons liquid waste from sampling and O&M activities, removed on October 22, 2013
- Approximately 1700 gallons liquid waste from sampling and O&M activities, removed on December 16, 2013

All waste manifests are included in Appendix L.

8. Annual Summary Report for the Calendar Year 2013

This section of the Fourth Quarter 2013 Progress Report is a summary of the activities conducted during CY 2013, as required by the terms in the PADEP Administrative Order dated December 10, 1999. Like the Fourth Quarter 2012 Progress and 2012 Annual Summary Report, the summary of CY 2013 activities has been appended to the Fourth Quarter 2013 Progress Report in place of a separate submittal. PADEP's acceptance of this combined submittal was provided by the email exchange between Richard Bell (DLA) and David Burke (PADEP) on December 11, 2013. For more detailed information, please refer to the individual quarterly progress reports that have been prepared for CY 2013. This section summarizes progress petroleum hydrocarbon LNAPL remediation at the Site for CY 2013, which as discussed above, encompasses the LNAPL vapor enhanced skimming and vapor extraction being conducted on the Former DSCP property and the Former Passyunk Homes property. A summary of Site history can be found in Appendix F.

8.1 Vapor Measurements from the Packer Avenue Sewer – CY 2013

Two Packer Avenue sewer manholes (MH-C and MH-G), as seen in Figures 1-3, were monitored monthly with a PID, smoke tubes, and an explosimeter throughout CY 2013. No readings in excess of 100 parts per million (ppm) were observed during CY 2013.

Below is a summary of readings collected during CY 2013:

Fourth Quarter 2013 and Calendar Year 2013
 Summary Progress Report for the Former
 Defense Supply Center Philadelphia Facility
 Philadelphia, PA

January 11, 2013	MH-C	MC-G	July 22, 2013	MH-C	MC-G
LEL (%)	2.0%	0.0%	LEL (%)		LEL (%)
PID (ppm)	2.8	1.6	PID (ppm)		PID (ppm)
Air Flow	IN	IN	Air Flow		Air Flow
February 13, 2013			August 6, 2013		
LEL (%)	0.0%	0.0%	LEL (%)		LEL (%)
PID (ppm)	3.1	1.9	PID (ppm)		PID (ppm)
Air Flow	OUT	IN	Air Flow		Air Flow
March 27, 2013			September 26, 2013		
LEL (%)	6.0%	0.0%	LEL (%)		LEL (%)
PID (ppm)	3.7	1.5	PID (ppm)		PID (ppm)
Air Flow	OUT	IN	Air Flow		Air Flow
April 29, 2013			October 21, 2013		
LEL (%)	0.0%	2.0%	LEL (%)		LEL (%)
PID (ppm)	0.0	3.3	PID (ppm)		PID (ppm)
Air Flow	IN	IN	Air Flow		Air Flow
May 13, 2013			November 5, 2013		
LEL (%)	0.0%	12.0%	LEL (%)		LEL (%)
PID (ppm)	0.0	0.0	PID (ppm)		PID (ppm)
Air Flow	IN	IN	Air Flow		Air Flow
June 4, 2013			December 30, 2013		
LEL (%)	0.0%	2.0%	LEL (%)		LEL (%)
PID (ppm)	0.0	24.3	PID (ppm)		PID (ppm)
Air Flow	IN	OUT	Air Flow		Air Flow

At the request of the USACE, readings were also collected on a periodic basis during CY 2013 at the following additional manholes: 19th and Moyamensing East, 19th and Moyamensing West, Pollock and Moyamensing, and 19th Street (near the cut through). All LEL readings were 0.0% and all PID readings were 0.0 ppm during the checks of these manholes, and no odors other than normal sewer gas odors were observed. These observations are in line with previously reported observations since October 2011.

8.2 Quarterly Liquid Level Gauging

Quarterly measurements of the depth to groundwater and LNAPL, if present, were obtained from the Site recovery and monitoring wells during the CY 2013. These gauging events were conducted to evaluate groundwater flow directions as well as apparent LNAPL thickness in wells. The Fourth Quarter 2013 measurements are discussed in Section 4.1 of this report. Results of the remaining measurements can be found in the previously submitted quarterly progress reports.

8.3 Quarterly Site-Wide Groundwater Sampling

Site-wide groundwater sampling events were conducted during the Third and Fourth Quarters of 2013. Analytical data from these events were collected to evaluate the concentrations and distribution of COC across the Site. During the Third and Fourth Quarters of 2013, samples were analyzed for VOC COC (including MTBE and TBA) and metals. During the Third Quarter of 2013, select samples were also analyzed for geochemical parameters. Sampling results for the Fourth Quarter of 2013 are discussed in Section 4.2 of this report. Results of the Third Quarter 2013 event are provided in the Third Quarter 2013 progress report.

Beginning in the Third Quarter of 2013, a historical data table was developed to compare recent analytical results to those from sampling events dating as far back as 1994. The most recent table, including results from the Fourth Quarter of 2013, is provided in Appendix D. Results from future sampling events will be added to this data table, in order to establish increasing or decreasing trends in COC concentrations.

8.4 Aquifer Testing- Second Quarter 2013 Pump Test

The First Quarter 2013 report outlined the installation of monitoring well DSCP-MW-65, for the purpose of conducting an aquifer test to estimate hydraulic conductivity, yield, and pumping well efficiency within the Site's shallow aquifer zone. Well DSCP-MW-65 was constructed on January 14, 2013. Additional construction details are provided in the First Quarter of 2013 progress report. MW-65 and the surrounding recovery and shallow aquifer zone monitoring wells used for the collection of pumping test data collectively lie within the "breach."

Groundwater levels at DSCP-MW-65 and 4 observation wells (MW-31, RW-1A, Prepack-02 and MW-32) were measured, and levels were corrected for background changes in water levels, including those due to changes in barometric pressure.

Average calculated aquifer transmissivity and storativity values based on the 24-hour pumping test are 4,300 ft²/day and 0.05, respectively. Further details are provided in the Second Quarter of 2013 progress report.

8.5 Direct-Push- Third Quarter of 2013

As was introduced and discussed in the Third and Fourth Quarter of 2012 Progress Reports, additional subsurface direct-sensing work was conducted using Geoprobe direct push technology equipped with Electrical Conductivity (EC), Membrane Interface Probe (MIP), Hydraulic Profiling Tool (HPT), and an integration of these sensing techniques called MiHPT. Investigative work was completed between July 29, 2013 and August 6, 2013, and between August 20, 2013 and August 23, 2013. Data collected during this work will be used to update the Site-wide conceptual Site model (CSM), for support of future Site remediation and Act 2 path-to-closure activities.

8.6 VES System Operation and Maintenance

A summary of the quarterly LNAPL recovery operations of the various systems in CY 2013 are included in Appendix G. Table 1 of Appendix G contains a list of LNAPL recovery throughout 2013 and the following sections summarize this period of recovery. Figures 1 through 4 of Appendix G present the quarterly totals of LNAPL removed along with a running total of the LNAPL removed from the Former DSCP system, the Former Passyunk Homes system, the mobile systems and LNAPL recovered as vapor from the VES system, respectively.

8.6.1 Fixed Skimming System

As discussed in greater detail in Section 6, recovery well totalizers are only used to estimate the LNAPL recovered from each well for skimmer pump optimization. The total LNAPL recovered is obtained via readings from a volume-measuring probe installed in each of the Site's two recovered LNAPL ASTs.

Appendix G, Figures 1 and 2 illustrate the Former Passyunk Homes and Former DSCP system LNAPL recovery by quarter.

8.6.2 Fixed Skimming System Quarterly Results CY 2013

A total of 4,378 gallons of LNAPL was recovered by the Former DSCP area fixed skimming system. The LNAPL recovered per quarter is broken down as follows:

- First Quarter of 2013: 2,074 gallons LNAPL recovered
- Second Quarter of 2013: 1,678 gallons LNAPL recovered
- Third Quarter of 2013: 483 gallons LNAPL recovered
- Fourth Quarter of 2013: 143 gallons LNAPL recovered

No LNAPL was recovered from the Former PHA are fixed skimming system during the CY 2013.

8.6.3 Modular Skimming System – Quarterly Results CY 2013

A total of 67 gallons of LNAPL was recovered by the modular skimming system installed at DSCP-MW-3A during CY 2013. The LNAPL recovered per quarter is broken down as follows:

- First Quarter of 2013: 17 gallons LNAPL recovered
- Second Quarter of 2013: 33 gallons LNAPL recovered
- Third Quarter of 2013: 17 gallons LNAPL recovered
- Fourth Quarter of 2013: no LNAPL recovered

8.6.4 Summary of VES System Operation and Optimization CY 2013

Monitoring of CH₄ (with and without carbon filter), LEL, CO₂, and O₂ were recorded periodically during the year. Mass recovery was calculated using PID data collected at the VES system manifold. However, high CH₄ results tends to negatively skew the PID data collected at the VES system manifold, therefore PID data was calibrated using TO-15 summa canister air sample data. The petroleum hydrocarbon mass recovery calculations for the focused VES system are based on a weighted average of the compounds detected in the TO-15 manifold combined influent vapor samples discussed in greater detail in Section 6.3. The TO-15 summa canister vapor sample results for CY 2013 can be found in appendices for each quarterly report previously submitted as well as Appendix I for this report for the Fourth Quarter 2013. Mass tracking calculations for CY 2013 are presented in Appendix J.

During CY 2013, the VES system operated in optimized/focused-vacuum mode yielding an average mass recovery of 10.4 lbs/hour, a substantial increase in mass recovery when compared to the recovery rate prior to system optimization testing. For comparison, the VES system averaged approximately 4.17 lbs/hour in the Third Quarter 2011 (prior to optimization testing). During CY 2013, the average CH₄ (with carbon filter) was 4.2%, the average CO₂ was 5.6%, and the average O₂ was 11.6%.

The overall VOC recovery rate for the VES system from for CY 2013 was 100,148 lbs, which correlates to approximately 16,988 gallons of LNAPL. This number is calculated using the mean density of the compounds detected in the laboratory analytical results of the summa canister samples collected from the influent vapor stream at the VES system manifold. The analytical results as well as the calculations supporting the conversion factor are presented in the individual quarterly reports for CY 2013; however, it ranged from 5.89 to 5.98 lbs VOCs per gallon of LNAPL. The mass recovery per quarter by the VES system as VOC vapor for CY 2013 is broken down as follows:

- First Quarter 2013: 4,101 gallons of LNAPL
- Second Quarter 2013: 7,204 gallons of LNAPL
- Third Quarter 2013: 2,337 gallons of LNAPL
- Fourth Quarter 2013: 3,346 gallons of LNAPL

The new cumulative total LNAPL recovered as vapor by the VES system since system start up in 2005 through the end of the CY 2013 is now 53,402 gallons. The cumulative LNAPL recovered to date by at the Site is discussed in Section 9.0 below.

9. Summary

The total LNAPL recovered from the start of LNAPL recovery operations in 1996 through the Third Quarter 2013 was 1,018,265 gallons. During the Fourth Quarter of 2013, an additional 3,346 gallons of LNAPL was recovered by the VES system, 143 gallons were recovered by the DSCP fixed skimming system and no gallons were recovered by the modular (mobile) skimming system, yielding a total of 3,489 gallons of LNAPL for the quarter. The total LNAPL recovered from 1996 through the Fourth Quarter of 2013 was 1,021,754 gallons. The following table illustrates the LNAPL recovered in gallons during the Third and Fourth Quarters of 2013, along with an annual summary.

Recovery System	Current Quarter (Q4) LNAPL Recovered (Gallons)	Previous Quarter (Q3) LNAPL Recovered (Gallons)	Change in LNAPL Recovered (Gallons)	CY 2013 (Q1-Q4) LNAPL Recovered (Gallons)
Former DSCP Fixed System	143	483	-340	4,378
Modular Units	0	17	-17	67
Passyunk Homes System	0	0	0	0
VES System	3,346	2,337	1,009	16,988
Total	3,489	2,837	669	21,433

The total cumulative LNAPL recovery through the end of the Fourth Quarter of 2013 is shown below. Total cumulative data shown is the sum of the recovery from the Fourth Quarter 2011 through the Fourth Quarter of 2013, added to the total cumulative LNAPL recovered as previously reported by Tetra Tech (TtEC) in the Third Quarter of 2011 Progress Report. The cumulative recovery of LNAPL since the start of LNAPL recovery operations in 1996 through the end of the end of the Fourth Quarter 2013 is now 1,021,754 gallons.

System	System Description	Dates	Gallons
Army Corps of Engineers	This value has been reported by the United States Army Corps of Engineers as the total removed during their initial recovery efforts at the Former DSCP.	1996 – 1999	153,350
Former Internal Combustion Engine	An internal combustion engine was used to perform a pilot test of vacuum enhanced skimming. This number represents the calculated volume of LNAPL removed as vapors from this event.	2002 – 2003	2,840
Former DSCP System	This value represents the volume of LNAPL removed utilizing the recovery system on the Former DSCP Property. See Section 6.1 for system details.	1999 - Current	508,068
Former Passyunk Homes System	This value represents the volume of product removed utilizing the recovery system on the Former Passyunk Homes Property. See Section 6.1 for system details.	1999 – Current	167,558
Mobile Units	This value represents the total volume of product removed utilizing the mobile recovery systems. See Section 6.2 for system details.	1999 – Current	136,427
VES System	The calculated volume of LNAPL removed as vapors from the existing VES system. See sections 6.3 and 6.4	2005 – Current	53,402
VTE Testing	Estimated amount of liquid LNAPL Recovered during VTE testing.	June 2012	110
TOTAL			1,021,754 Gallons

The results of remediation O&M and optimization testing conducted to date are summarized as follows:

- The majority of the mobile LNAPL (or LNAPL available for recovery) has been removed from the Site. However, petroleum mass is still available for recovery in the vapor phase. By increasing the vacuum on the VES system recovery wells, an increase of mass recovery has been observed. Optimization testing also showed that some VES system recovery wells will not produce high mass recovery rates in the vapor phase, most likely due to submerged well screens or fouling issues.
- Optimization testing also showed that a “pulsing” operational strategy can increase recovery of LNAPL in the liquid phase by the skimmer pumps. To achieve the benefit of a pulsing remediation strategy and maintain high mass recovery, a strategy of operating a primary group of wells and rotating groups of secondary wells has been employed.
- An optimization test using a pump controller similar to those employed on the mobile units is being tested on recovery well RW-A and PH-20, and is thus far yielding promising results. The controller may allow the skimmer to pump more LNAPL over time by not pumping all of the LNAPL out of the well (and thereby not cutting off the well from the LNAPL in the formation). This strategy also should prevent the skimmers from pumping water into the storage tanks as the pump frequency can be set such the pump only operates when its intake is fully immersed in LNAPL.
- This optimized operational strategy for the fixed skimming systems, appears to have contributed to a significant increase in the amount of LNAPL recovered by skimming from the Third Quarter 2012 through the Fourth Quarter 2013. However, even with this increase in the LNAPL recovery by skimming, it is likely that a greater volume of mass can be recovered in the vapor phase than by skimming with the current groundwater elevation.
- The VES optimization efforts applied to the VES system have been successful. The mass recovered by the optimized VES system since the Fourth Quarter 2011 is more than five times the total mass recovered by the VES system since its start-up in 2005 through the Fourth Quarter 2011.
- In the Fourth Quarter of 2013, VES mass recovery remained significantly higher than the average observed mass recovery prior to commencement of optimization efforts in the Fourth Quarter of 2011.

- In general, the high levels of CO₂ in the vapor stream of the VES system during the optimization testing indicate that in-situ degradation of petroleum hydrocarbon is actively occurring in the shallow aquifer. However, the presence of CH₄ and lack of O₂ in the vapor stream indicate that this process is largely anaerobic and that aerobic degradation (the faster of the two processes) is O₂ limited. As a result, the testing suggests that the Former DSCP Site may be amenable to a future bioventing / air injection strategy which can accelerate the process of in-situ degradation by providing O₂ to the subsurface.
- The optimization testing has suggested that a bioventing / air injection strategy would be best utilized in the fringes of the impacted area, and where the LNAPL is less degraded. The results of the LNAPL fingerprinting analysis suggests that the areas of the Site near RW-A and RW-2 are potential locations where bioventing may be implemented in the future.
- As discussed in previous quarterly reports, isotopic analysis of the carbon in the CO₂ and CH₄ can be conducted to determine the portion of CO₂ and CH₄ attributed to degradation of a fossil fuel as opposed to modern sources. Isotopic analysis of CO₂ and CH₄ commenced in the Third Quarter 2013 for the purposes of providing a more accurate “weighting” factor to convert CO₂ and CH₄ to pounds of hydrocarbon mass degraded in situ. The analytical results of these samples indicate that the majority of the CH₄ and CO₂ is from a fossil fuel source (i.e. the LNAPL plume) and not from modern landfill or organic material. Additional samples of both CO₂ and CH₄ from other wells onsite and the VES system influent will be continue to be presented in future quarterly reports as more data becomes available, and will be used to track the amount of LNAPL degraded in-situ by the VES system.

The evaluation of these optimization testing activities is ongoing into the First Quarter 2014; the results of the testing will be provided to PADEP in the quarterly reports.

10. Future Activities

The following are a list of projected tentative activities planned or are under consideration for the First Quarter of 2014. These include:

- Integration of direct push data with existing conceptual Site model hydrostratigraphic data, particularly for further definition of the “breach” and description of its effect on groundwater flow and COC and LNAPL distribution;
- Conducting a groundwater gauging and sampling event in February 2014.
- Completion of an evaluation of the existing groundwater models using the information gleaned from the investigative work above to conduct an evaluation of potential changes in the remedial strategy to recover mass from the Site.
- Continuation of groundwater sampling analytical data compilation to ultimately use a trend analysis statistical approach to support well field optimization and LNAPL stability determination

Finally, and as discussed with the PADEP during the meetings held on January 19, 2012 and March 13, 2012, the overall goal of the ongoing optimization testing and related activities described above is to improve LNAPL remediation at the Former DSCP Site. As lessons are learned, data will continue to be applied and remediation O&M procedures modified as feasible using existing Site remediation infrastructure.