Stantec

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November 29, 2021
File: 213402602

VIA OnBase Electronic Forms Upload

Attention: Lisa Strobridge, P.G.
Pennsylvania Department of Environmental Protection
2 East Main Street
Norristown, Pennsylvania 19401

Dear Ms. Strobridge,

Reference: Response to Public Comments
Remedial Investigation Report Addendum,
Area of Interest 4
Sitewide PADEP Facility ID No. 780190
AOI 4 eFACTS PF No. 770318
Former Philadelphia Refinery
3144 Passyunk Avenue
City of Philadelphia
Philadelphia County

1.0 INTRODUCTION

On September 30, 2021, Evergreen submitted a Remedial Investigation Report Addendum (RIR Addendum) for Area of Interest (AOI) 4 for the former Philadelphia Refinery (facility). As outlined in Evergreen's 2019 Public Involvement Plan for the Act 2 Remediation Process at the former Sunoco Philadelphia Refinery, Evergreen accepted public comments for a 30-day period following the submission of the RIR Addendum. The purpose of this letter is to provide the comments received from the public and Evergreen's responses to these comments for PADEP consideration of the RIR Addendum. This response letter amends the previously submitted RIR Addendum and completes the submission. This response letter and attachments will be posted to Evergreen's website upon submission to the PADEP in the posted location of the RIR Addendum.

2.0 RESPONSE TO PUBLIC COMMENTS

This section presents the comments received from the public via email (phillyrefinerycleanup@ghd.com), the website (https://phillyrefinerycleanup.info/), and United States Postal Service mail (PO Box 7275, Wilmington, Delaware 19803). Evergreen received two sets of comments for AOI 4, one directly from the Clean Air Council (CAC) and one from an individual via email (**Attachment A**). The set of emailed comments did not include technical comments in reference to the RIR Addendum but is included in **Attachment A** for completeness. Note that the document received from CAC included both comments to reports for AOIs 4 and 9, but only the comments pertaining to AOI 4 are addressed in this document.

Comments received were technical in nature when considered in full; therefore, the responses provided herein are also technical and not “plain language” so that the comments could adequately be addressed and evaluated by PADEP as part of the RIR Addendum review. CAC also submitted comments regarding Evergreen’s work investigating perfluoroalkyl and polyfluoroalkyl substances (PFAS). Evergreen will address these comments separately as they do not pertain to the RIR Addendum. Evergreen did also check for comment submissions following the closure of the formal 30-day comment period ending October 30, and no additional public comments have been received since that date. Note that previously published Evergreen documents referenced in this letter have not been included as attachments but can be found on the website (https://phillyrefinerycleanup.info/).

Comment 1a, Soil in AOI-4

Evergreen does not address problems identified in the delineation of soil contamination identified in the Department’s technical deficiency letter in June 2021.

Response to Comment 1a

The technical deficiency letter issued by Pennsylvania Department of Environmental Protection (PADEP) in June 2021, was for the Public Comment Remedial Investigation Report (RIR), specifically requesting more detailed responses/explanations. This was not a technical deficiency for delineation of lead in soil. In its August 28, 2021 response to PADEP comments on the March 2021 Public Comment RIR, Philadelphia Refinery Operations, a series of Evergreen Resources Group, LLC (Evergreen) responded to Comment #3 referenced by the Clean Air Council (CAC) by providing sitewide maps, tables, and a narrative to discuss delineation of lead distribution. The focus of that discussion included 1) demonstration that exceedances of the site-specific standard (SSS) are delineated, 2) description of the data relating to the statewide soil to groundwater medium-specific concentration (MSC) at the site boundaries, and 3) description of the data relating to the statewide direct contact MSCs at the site boundary. Evergreen refers the commenter to that discussion for sitewide lead in surface soil. In the AOI 4 RIR Addendum, although only new data collected since the submission of the RIR was included in tabular form (Table 2-11), a presentation of all shallow lead soil data compared to all three relevant criteria was included as Figure 4-8 and was discussed in Section 4.4. It is additionally worth noting that disapproval for the 2017 AOI 4 RIR was not for reasons of soil characterization or delineation. Evergreen presented additional data in the AOI 4 RIR Addendum that were not required for remedial investigation purposes but were collected for use in future Act 2 reports.

The CAC expresses that the rationale for the soil samples collected following the submission of the RIR is not clear quoting the section summarizing the constituents of concern presented in the conceptual site model section of the report (Section 4.3.2). The CAC is referred to Section 2.11 for a detailed explanation of the samples collected for lead in surface soil and Section 2.4 for further details regarding the soil samples collected as part of the geophysical confirmation drilling program. The rationale for the surface soil sample collected for lead bears further explanation as there appears to be a misunderstanding regarding the purpose. The CAC recognizes additional sampling presented in this report to delineate to 1,000 milligrams per kilogram (mg/kg) ahead of a potential regulatory change but states that "Evergreen is not doing this for past sampling events discussed in previous reports.". It is in fact Evergreen's intention to delineate all exceedances of 1,000 mg/kg of lead in surface soil near the property boundary. In AOI 4, many of these exceedances were removed from the site in the Interim Remedial Action described in Section 2.12, a remedial action performed by Evergreen to remediate an area of lead above the current SSS. Only one sample location, at S-408, remained that had not been delineated near the property boundary. An additional sample, AOI4-BH-21-01, was collected for this purpose.

The CAC may be referring to the fact that Evergreen has not tightly delineated to a value lower than the current SSS within the property boundary. This is true; however, Evergreen is not required to do so. Delineation to the current selected standard has been achieved. The intention of additional sampling was to collect more data near the property boundary to evaluate conditions closer to potential offsite receptors.

Comment 1b, Soil in AOI-4

It would be premature to approve the report because there is an unresolved question of the appropriateness of a site-specific standard for lead in surface soil**.**

Response to Comment 1b

Evergreen acknowledges that a change to the numeric SSS for lead in soil will likely be necessary following potential changes to the MSCs. However, PADEP has not yet promulgated a rulemaking establishing revised standards and default input values. Further, PADEP has made clear by its publication of the notice titled "Calculation of Soil Lead Medium-Specific Concentrations; Advance Notice of Proposed Rulemaking" on October 30, 2021 in the Pennsylvania Bulletin (https://www.pacodeandbulletin.gov/Display/pabull?file=/secure/pabulletin/data/vol51/51-44/1798.html), decisions around the calculation of the state's default standards for lead in soil have yet to be determined. The notice solicits comment from the public regarding input values and calculation methods. It would be premature for Evergreen to select an alternate standard for the former Philadelphia Refinery but has done some additional evaluation in the interim. Evergreen agrees that a likely outcome is that the United States Environmental Protection Agency (USEPA) Adult Lead Model with a target blood lead level of 5 micrograms per deciliter (ug/dL) would be used. As CAC pointed out, this would result in a concentration near 1,100 mg/kg. This is the reason why Evergreen, in good faith, performed additional soil sampling at the property boundary to the current non-residential direct contact MSC of 1,000 mg/kg which is lower than the current selected standard and near to an anticipated future standard. CAC states "It would be unreasonable for the Department to approve the report where it is based on the premise that a SSS of 2,240 mg/kg applies, especially where the Department has stated that it intends to revise the lead standard in the future, without providing details.". The PADEP has provided details regarding its current thought process around the future lead standards in the October 30, 2021 Pennsylvania Bulletin notice.

Comment 3a, Water Table in AOI-4

Evergreen should install monitoring wells to the east and southeast of S-369 in the northeast corner of AOI-4, as directed by the Department.

Response to Comment 3a

The focus of Evergreen's AOI 4 RIR Addendum was to address the deficiency noted by the PADEP in the June 21, 2017 RIR disapproval letter. The deficiency was issued for delineation at the AOI 4 southeast property boundary. In a June 29, 2017 comment letter, the PADEP recommended delineation to the east and southeast of well S-369, located in the northeast AOI 4 corner, to inform the sitewide fate and transport assessment. Evergreen provided rationale supporting characterization of the groundwater flow pattern in that area in a response letter dated August 30, 2017. Offsite data from a former Ryder truck rental facility were used in conjunction with refinery and former Defense Supply Center Philadelphia (DSCP) data to demonstrate that the convergent groundwater flow pattern documented in the AOI 4 RIR has persisted and is driven by the prevalence of a leaky section of the Lower Schuylkill East Side Intercepting Sewer (intercepting sewer). This pattern is anticipated to date back to the mid-1960s when the intercepting sewer project was completed. It is noted that there is no remediation system operating near well S-259 and that the area of depressed groundwater is presumed to be created by leakage into the nearby intercepting sewer.

It is important to note that Evergreen's reports place emphasis on leakage into and out of the intercepting sewer under 26th Street, not the Packer Avenue sewer. The 2001 United States Geological Survey (USGS) report objective was to understand the Packer Avenue sewer's potential role in influencing past groundwater flow conditions and contaminant transport potential proximal to an offsite hydrocarbon plume near the former DSCP facility. The modeler assumed that Layer 7 (lower sand unit) simulated potentiometric surfaces would approximate the water-table surface under pumping conditions because the Potomac-Raritan-Magothy (PRM) aquitard(s) are missing in the area. This was not a direct measure of flow direction in the water table but a modeled prediction of past conditions driven by groundwater withdrawals from the lower aquifer. Evergreen's mapping of recent water-table conditions is based on field-measured water levels in wells.

As a part of the AOI 4 RIR Addendum and in preparation for the sitewide fate and transport assessment, Evergreen collected forensics data and compound specific isotope analysis (CSIA) data to explore petroleum source potential in proximity to well S-369 and the offsite ARCO property. This data was primarily collected to further address the potential need for offsite delineation in the area. The CSIA data for benzene indicates that the S-369 benzene is unrelated to the other well samples and is likely from a different source or mixture of sources than the benzene sampled from wells ARCO-3 and ARCO-1D. The multivariate analysis (MVA) models were performed to explore potential source similarities/dissimilarities in the molecular structure of the chemistry dataset. However, note that benzene, toluene, and MTBE have excluded variables in the MVA models due to their higher diffusivity potentials than other hydrocarbons in the volatile organic compound (VOC) range. In chemometrics terms, these parameters were excluded from the MVAs due to their low Diagnostic Power (DP) relative to other VOC range parameters. Exclusions of more soluble MTBE, benzene, and toluene from the MVA models facilitated the chemometric study of the dominant aspect of the sample fingerprint - with higher DP in context VOC range chemistry. CSIA overcomes DP limitations by being independent of concentration effects; consequently, CSIA was employed to evaluate the source-related questions of MTBE, benzene, and toluene occurrences. Therefore, potential source origins and biodegradation dynamics of benzene, toluene, and MTBE were explored in a CSIA focused investigation.

Vertical hydraulic head potentials between water-bearing units along 26th Street were evaluated by

Evergreen in the 2016 AOI 1 RIR (Figure 5-8) and the 2017 AOI 4 RIR (Figure 5-8). These data indicate that under current conditions there is the potential for leakage and/or upwelling of groundwater from the lower PRM aquifer into the water table where the aquitard is thin to absent. The area of upward flow potential is constrained to the intercepting sewer corridor, and the mechanism presumed to drive the pattern is exfiltration of groundwater into the intercepting sewer. Again, the reference to the 2001 USGS study findings is irrelevant to the concepts discussed in the Evergreen RIR because a different sewer is being discussed (intercepting sewer and not the Packer Avenue sewer) for a different time period (recent groundwater conditions versus past scenarios when pumping of the lower sand unit of the PRM in south Philadelphia was significant and resulted in the downward vertical gradients documented in the 2001 study). A similar modeling study is not needed to substantiate Evergreen's finding of convergent groundwater flow along the intercepting sewer near well S-369 because the pattern is supported by actual field observations from wells and has been found to persist.

Other comments pertaining to the water table include the potential for mounding in AOI 4 and the extent of data presented in each RIR Addendum figure. In review of the figures, Evergreen found that Figures 4-1c and 4-1d were missing well S-369 data. Those figures have been revised and attached to these comment responses. Note that the inclusion of well S-369 data does not substantially change the flow pattern or conclusions presented. The differences in data extent are due to the available well gauging data for each event. Two events were performed specifically to inform the Penrose area of AOI 4 (November 2018 and December 2020). Note that Evergreen does not have access to routinely gauge offsite wells owned by others for the former DSCP facility; however, an effort is made by both parties to share well gauging data and to coordinate synoptic gauging events when possible. The topography in AOI 4 is inherently flat and thus the water table is characterized by a subtle and subdued pattern with shallow gradients. A small contour interval was used in the AOI 4 RIR Addendum figures to evaluate the conditions and can give the perception that gradients are larger than what they are. The April 2021 data for wells S-104 and S-96 are called out as examples and are found to be within the reasonable range of historic data.

Comment 3b, Water Table in AOI-4

Evergreen and the Department have not addressed the longstanding question of the direction of the flow of contaminants east of AOI-4, which was raised previously in connection with the investigation of the Defense Supply Center Philadelphia.

Response to Comment 3b

Evergreen's RIRs for the former Philadelphia Refinery areas along 26th Street including AOI 4 have focused on characterization of the nature and extent of contamination from petroleum releases during past operation of the refinery under Sunoco and earlier ownership. In Evergreen’s opinion the characterizations included in the RIRs demonstrate sufficient delineation of those contamination sources and an adequate understanding of the current conditions supporting the pattern of groundwater flow and future potential for contaminant transport. Evergreen's groundwater model is calibrated to these data and will predict the flow and future extent of petroleum contaminants in groundwater. The area east of AOI 4 will be included in the assessment. Evergreen continues to assess contamination sources along the 26th Street corridor where comingling of onsite and offsite groundwater contaminant plumes is supported by multiple lines of evidence and a complex mixture of petroleum is present. Note that the 1998 IST study (referenced and linked in

Clean Air Council correspondence) was commissioned to understand the source of non-aqueous phase liquid (NAPL) beneath the former DSCP property and not necessarily to understand the flow pattern of dissolved groundwater contaminants mixing in the area.

Comment 3c, Water Table in AOI-4

Evergreen has not established that the additional five monitoring wells to the southeast of the Penrose Avenue remediation system are sufficient to address off-site migration.

Response to Comment 3c

Evergreen's AOI 4 RIR Addendum explained in detail the progression of offsite subsurface characterization along the southeastern boundary which was the cause for the primary RIR disapproval. The initial five wells were installed in the inferred downgradient direction of groundwater flow from the characterized plume and constructed to intersect the water table and shallow depositional sequence impacted by petroleum onsite. Two wells were installed south of Penrose Avenue so that the Penrose Avenue sewer potential effects on groundwater could be evaluated. Initial rounds of groundwater sampling from these wells indicated that delineation could not be demonstrated and that several different sources were involved. A second round of onsite and offsite characterization work was later completed in this area using a high-resolution geophysical scanning tool so that additional wells could be optimally placed to target zones of contamination recognized on the imagery. An additional 10 wells were installed as an outcome of this work, nine of which were installed offsite. The 10 additional wells were constructed to characterize the impacts identified in the scans and from observations of soil core during drilling. Where co-located with existing wells, new wells were installed with submerged screens to characterize vertical gradient potential between water-table aquifer deposits (Pleistocene alluvium and PRM upper sand unit). In general, characterization of the offsite area of Penrose Avenue south of AOI 4 included best practices in accordance with PADEP guidance followed by application of one of the most technologically advanced methods available in the industry to find light non-aqueous phase (LNAPL) and contaminants in the subsurface.

Much of Evergreen's AOI 4 RIR Addendum documents the extensive effort put forth to understand the pattern and sources of contamination in the area of the southeastern AOI 4 boundary with Penrose Avenue. Figure 4-4 was developed to further what was documented in the RIR by extending the benzene concentration data through the offsite area and using maximum concentration data from the time period that would provide the highest resolution and conservative scenario through which to evaluate the nature and extent of petroleum contamination. Trend plots were provided in the AOI 4 RIR for individual wells in AOI 4 source areas to inform decisions on dissolved benzene and MTBE concentrations through time. These were not included in the addendum because of limited data availability in the offsite area; however, these will be updated in support of the sitewide fate and transport assessment as additional samples are collected. A petroleum forensics characterization, CSIA study, wastewater tracer study, and pumping mechanisms were included to provide multiple lines of evidence supporting a complex mixture of offsite contamination where sources outside of AOI 4 are impacting groundwater. The benzene shown in Figure 4-4 is a representation of all benzene sources characterized and does not imply that benzene has migrated beyond the sewer from an AOI 4 source. Evergreen's data supports that offsite sources which may include former retail stations and a sewer "hotspot" are impacting groundwater in AOI 4, with migration of the most soluble compounds benzene, MTBE, and toluene into AOI 4 by way of past Penrose Remediation System well pumping.

Comment 3d, Water Table in AOI-4

Evergreen’s Qualitative Fate and Transport analysis is flawed.

Response to Comment 3d

Evergreen's AOI 4 RIR Addendum included an update to the RIR's qualitative fate and transport assessment that used benzene concentrations in groundwater as a proxy for the maximum extent of petroleum hydrocarbon contamination in the area of the RIR deficiency. The nature and extent of contamination was evaluated in detail to inform whether delineation under Act 2 was sufficient to proceed with the sitewide fate and transport assessment. What Evergreen has found is that many of the wells support sufficient delineation of benzene in the offsite area, and where it can be interpreted that benzene concentrations are too elevated for delineation, the forensics MVA model groupings and CSIA data indicate mixed sources are present. In the case of benzene, the CSIA data support that there are offsite source(s) not related to AOI 4 benzene (e.g., source identified by wells S-375, S-377, and S-378) and/or offsite source(s) of benzene that are represented in AOI 4 by biodegraded versions of the same source indicated to have migrated onto the tank farm (e.g., source identified by well S-376 with biodegraded versions identified by wells S-223 and S-240). Evergreen postulated that Penrose Avenue Remediation System pumping was the mechanism that introduced offsite benzene into AOI 4 to mix with existing benzene from AOI 4 sources.

Regarding well construction, it is important to consider the reality of the area's Coastal Plain geologic framework. The deposits mapped throughout the facility and vicinity are not isotropic and homogeneous, and contaminant transport tends to follow discrete pathways that are driven by gradients and permeability. The geophysical scan tool of electrical resistivity imaging was used for delineation support so that the best possible locations to find contaminants could be targeted for additional well installations and media sampling. For example, review of the well log for S-448 in the RIR Addendum Appendix C (CD-14/S-448) indicates that well's screen was installed to discretely intersect the depth interval with the greatest field-observed contamination impacts based on the photoionization detector and visual observations. This was also the depth interval suggested for targeted groundwater sampling at CD-14/S-448 because of an electrical anomaly indicated on the resistivity image for line PBF-14 (RIR Addendum Appendix N).

For a discussion of the differences between MVA model groupings and CSIA as lines of information to inform AOI 4 delineation, please review the response to Comment 3a. Significant NAPL contamination and NAPL migration are no longer recognized just within the boundary of AOI 4. Only well S-241 had an estimated value of NAPL transmissivity (August 2018) that was in excess of industry recognized criterion for pore-scale mobility (RIR Addendum Appendix F), and this well is located in an area of AOI 4 impacted by a petroleum release after Sunoco ownership. Groundwater data support that the offsite contaminant mass of VOCs is significant and comparable to what is recognized in AOI 4 near the southeastern boundary. MTBE has no recognized AOI 4 source near the southeastern boundary. While the MTBE concentrations were significant in the Penrose Avenue Remediation System recovery wells, they are not clearly indicative of an AOI 4 point source (for example EPA/600/R-04/179 discusses MTBE concentrations expected in gasoline spills, and MTBE concentrations documented in the AOI 1 RIR for Belmont Terminal and the former Philadelphia Refinery Tank Farm No. 1 groundwater are more suggestive of what to expect for MTBE point sources in the former refinery) and were not observed until the wells began pumping as supported by trend plots provided in RIR Addendum Appendix T. Well S-449 has no documented local pathway for contaminant migration into the lower aquifer from AOI 4 sources, and CSIA data exploring AOI 4 source potential for MTBE indicate it is dissimilar to the former refinery wells sampled.

Evergreen's forthcoming sitewide fate and transport assessment will require some knowledge of contaminant degradation for calibration and defensibility of the transport models. Knowledge of natural source zone depletion and contaminant attenuation are important to inform Act 2 cleanup goals and remedial strategies. In Evergreen's opinion, the biodegradation lines of data provided in the RIR Addendum are significant and play a supporting role in Act 2 decisions.

Comment 5a, Deep Aquifer in AOI-4

The Department should not allow Evergreen to continue attempting to fragment the remedial investigation by diverting an analysis of the fate and transport of contaminants into a Remedial Investigation Report due at the end of the year.

Response to Comment 5a

With regard to comments previously submitted by CAC, Evergreen refers CAC to the August 28, 2021 response submitted to PADEP's June 29, 2021 Letter of Technical Deficiency for the Public Involvement RIR, specifically to the response submitted for Comment #2. This response provides a detailed discussion of impacts in the lower aquifer for all the AOIs. In the AOI 4 RIR Addendum, the distribution of impacts in the lower aquifer is shown on Figure 4-7b and was discussed in Sections 4.3.1, 4.6, and 4.7.

In Comment 5a, the CAC continues to express concern regarding the separation of the Sitewide Fate and Transport RIR from the individual AOI RIRs. Evergreen has previously responded to this concern in the August 28, 2021 response stating "This arrangement was agreed to by PADEP and EPA, and it was formalized in the 2003, 2012, and 2020 consent order and agreements. Given the size and complexity of the site, the remediator and the regulatory agencies believed it was impractical to compile all site characterization work into a single RIR. The agencies would also be unable to satisfactorily review the information in the 90-day statutory period." Evergreen adds that it understands that the current method can be viewed as "fragmentation" of the reporting process. It is not intended to be such. Further, by grouping the fate and transport reporting on a sitewide basis, this effort is more wholistic than including fate and transport in each individual AOI RIR, not less. Previous modeled analyses of contaminant transport that were conducted on an AOI by AOI basis, including the one for the lower aquifer, AOI 11, were restricted and did not consider the complex groundwater flow patterns that do not conform to AOI boundaries. In order to use more rigorous modeling tools including the USGS Modular Finite-Difference Groundwater Flow Model (MODFLOW) to model groundwater flow on a sitewide basis and Modular Three-Dimensional Multispecies Transport Model (MT3DMS) to use the MODFLOW model to wholistically simulate contaminant transport, Evergreen requested that the quantitative fate and transport portion of the project be combined into a single Sitewide Fate and Transport RIR. It is feasible, practical, and more accurate to combine this task and perform it on a sitewide basis.

One of CAC's main reasons for concern regarding the division of the RIRs seems to be in relation to previous approvals and how they relate to the Sitewide Fate and Transport RIR. The AOI RIR approval letters that PADEP has issued to date, with the exception of the letter for AOI 10, contain statements that Evergreen will complete a separate report containing a fate and transport analysis to satisfy Act 2 requirements (Title 25 Pa. Code Section 250.408). The Sitewide Fate and Transport RIR is still part of the remedial investigation process. In other words, the remedial investigation process for all AOIs is not considered complete until the Sitewide Fate and Transport RIR is approved. It is worth noting that only after the RIR stage has been completed will PADEP allow Evergreen to move forward with the submission of other reports that will address risk at the site and present options for cleanup.

Comment 7a, Vapor Intrusion in AOI-4

Evergreen should analyze preferential pathways for vapor intrusion on- and off-site for AOI-4 before applying proximity distances or screening values.

Response to Comment 7a

Evergreen agrees that additional evaluation of preferential pathways is needed and that the evaluation that presented data with reference to proximity distances does not tell the full story of potentially complete pathways for vapor intrusion. The presentation of the currently known information regarding proximity distances, as was presented in the AOI 4 RIR Addendum, does not preclude a preferential pathway evaluation or other further evaluation. It is only intended to use currently available information and put it into context of the potential for vapor intrusion.

The Vapor Intrusion (VI) Guidance does require the evaluation of "planned future inhabited buildings" and specifies that this evaluation, along with other potentially complete pathways for vapor intrusion, is required in the Final Report (Page IV-1). A complete pathway evaluation is not required at the remedial investigation report stage. As specified in the VI Guidance, Evergreen will need to demonstrate that risk is mitigated to an acceptable level to demonstrate attainment of an Act 2 Standard in the Final Report. This is one of PADEP's mechanisms for assuring that future buildings will have proper mitigation measures. Additionally, this assessment will include a complete VI evaluation for offsite receptors including an evaluation of potential preferential pathways. It is anticipated that the preferential pathway evaluation will be focused on offsite receptors as potential onsite sources are anticipated to be mitigated through engineering controls.

Comment 7b, Vapor Intrusion in AOI-4

Evergreen should take additional soil samples before applying screening values to the buildings on AOI-4, in accordance with the Vapor Intrusion Guidance.

Response to Comment 7b

The Conceptual Master Plan C for Future Redevelopment published by Hilco in 2020 is, as the name suggests, highly conceptual. The project is years away from issuing drawings for construction. The remediator cannot accurately perform VI assessment on planned buildings at this stage as specifics such as location, size, and construction are not yet known. In addition, location of buildings relative to depth of groundwater impacts and soil impacts must be taken into consideration. This cannot yet be done until final grades are established. These are major factors in Evergreen's plans to submit Cleanup Plans (including VI evaluation) on a phased basis that aligns with Hilco's development plans. Evergreen will coordinate with Hilco at the Cleanup Plan phase to incorporate appropriate mitigation measures for planned future inhabited buildings when the plans are beyond the conceptual phase. The CAC questions the applicability of Hilco's July 15, 2020 Soil Management Plan that states Hilco intends to install vapor mitigation measures on newly constructed buildings or conduct sampling to demonstrate that controls are not necessary. It is worth noting that the Soil Management Plan is a part of the binding First Amendment to the Consent Order and Agreement executed by Hilco, Evergreen, and the PADEP. Evergreen is indeed the responsible party for impacts prior to 2013, but Hilco has committed to actively participating in the process by performing mitigation and/or sampling to support their redevelopment efforts. Evergreen and Hilco intend to work together at this phase of the project to mitigate potential vapor intrusion issues in new structures. Additionally, as noted in the response to Comment 7a, a complete pathway evaluation is required at a later stage of the Act 2 process, not at the remedial investigation stage.

Regards,

Stantec Consulting Services, Inc

Kachel

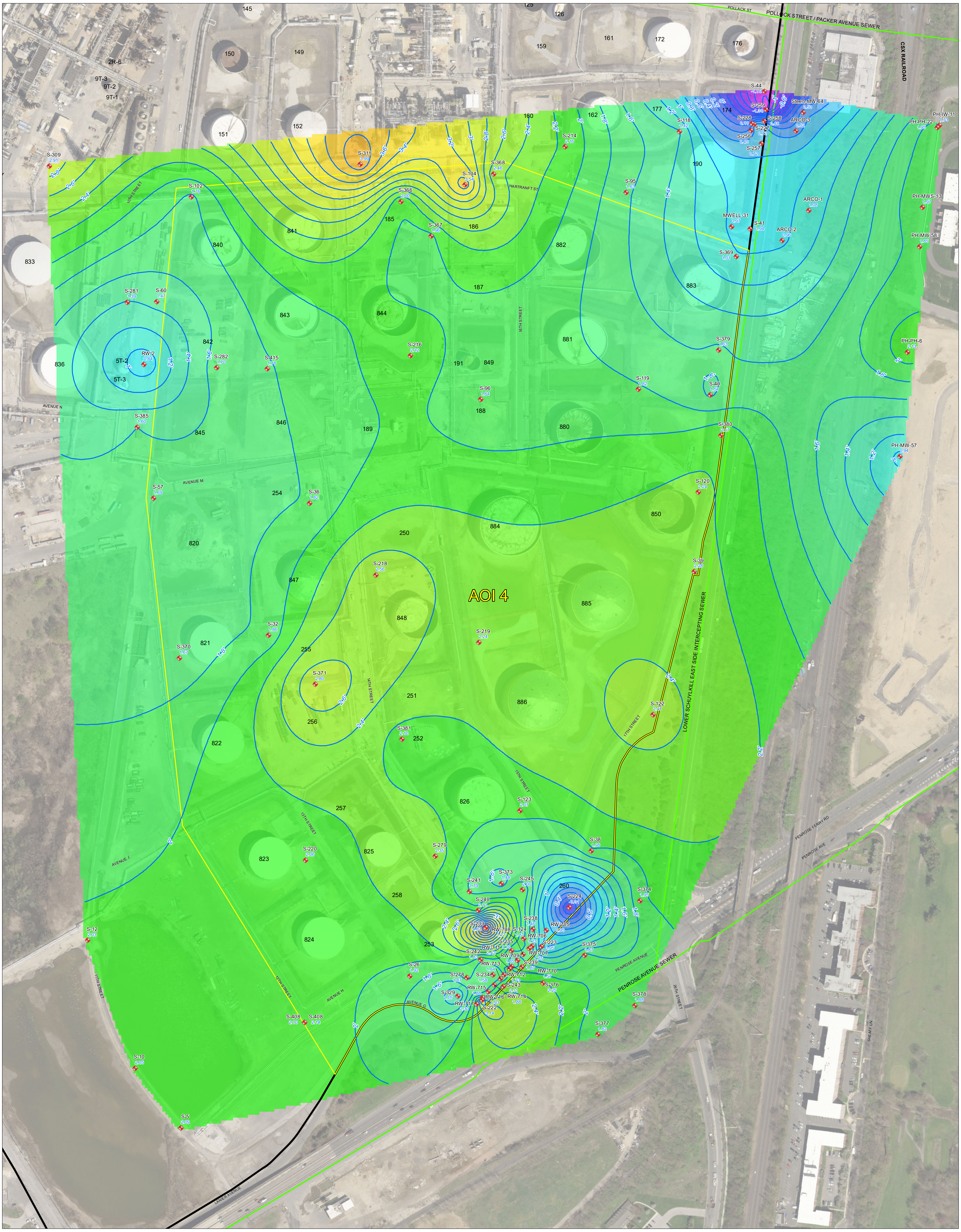
Andrew Klingbeil, P.G.
Associate Geologist

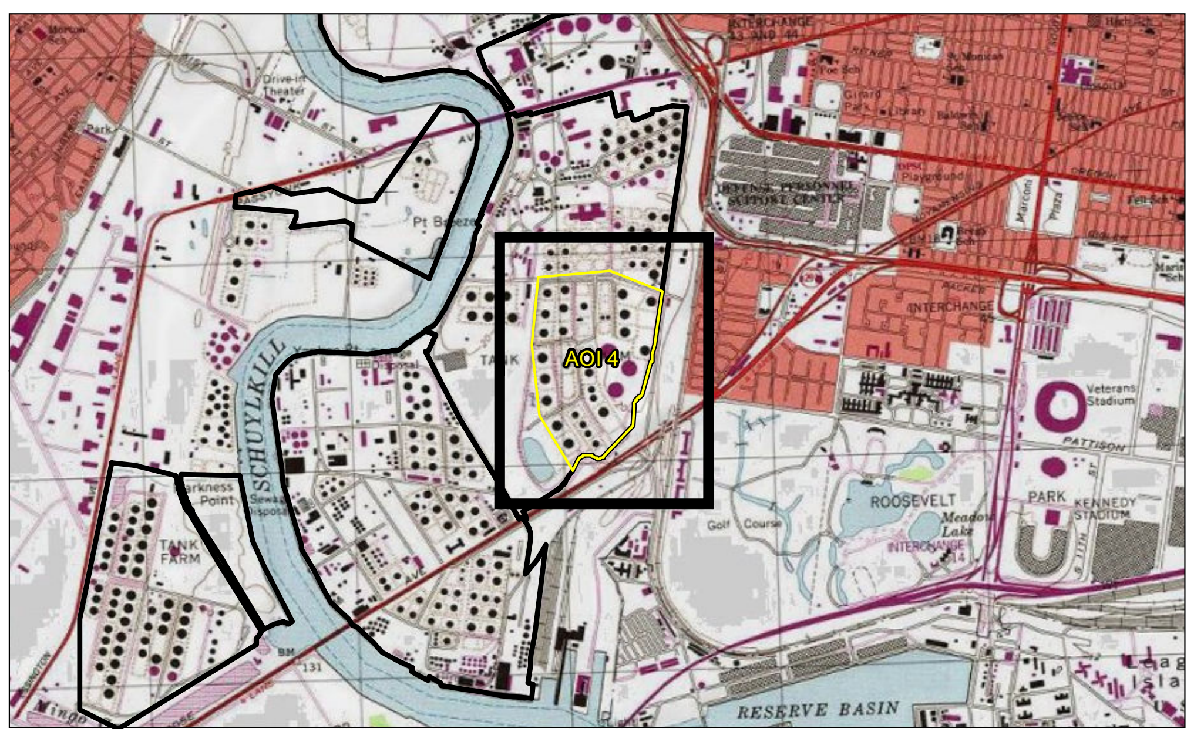
Jenny Kachel, P.G.
Geologist

Enclosures: Figure 4-1b – Unconfined Aquifer Elevation, June 2019
Figure 4-1c – Unconfined Aquifer Elevation, October 2019
Figure 4-1e – Unconfined Aquifer Elevation, April 2021
Attachment A – Public Comments

c. Tiffani Doerr (Evergreen)
Scott Cullinan (Evergreen)
Kevin Bilash (USEPA)
Patrick O'Neill (City of Philadelphia)
Jennifer Menges (Stantec)

FIGURES





LEGEND

⌖	MONITORING WELL SCREENED IN UNCONFINED AQUIFER, UTILIZED FOR JUNE 2019 ELEVATION SURFACE
—	WATER-TABLE ELEVATION CONTOUR (FEET NAVD 88)
—	APPROXIMATE LOCATION OF PHILADELPHIA WATER DEPARTMENT SEWER
☐	AREA OF INTEREST (AOI) 4 BOUNDARY
☐	FORMER PHILADELPHIA REFINERY
-0.31	CORRECTED GROUNDWATER ELEVATION (FT NAVD88)
30	TANK ID

JUNE 2019 WATER-TABLE ELEVATION FT NAVD88

🟧	4.4 to 4.6	🟩	1.4 to 1.6
🟧	4.2 to 4.4	🟩	1.2 to 1.4
🟧	4.0 to 4.2	🟦	1.0 to 1.2
🟨	3.8 to 4.0	🟦	0.8 to 1.0
🟨	3.6 to 3.8	🟦	0.6 to 0.8
🟨	3.4 to 3.6	🟦	0.4 to 0.6
🟨	3.2 to 3.4	🟦	0.2 to 0.4
🟨	3.0 to 3.2	🟦	0 to 0.2
🟩	2.8 to 3.0	🟦	-0.2 to 0
🟩	2.6 to 2.8	🟪	-0.4 to -0.2
🟩	2.4 to 2.6	🟪	-0.6 to -0.4
🟩	2.2 to 2.4	🟪	-0.8 to -0.6
🟩	2.0 to 2.2	🟪	-1.0 to -0.8
🟩	1.8 to 2.0	🟪	-1.2 to -1.0
🟩	1.6 to 1.8	🟪	-1.4 to -1.2

0 160 320 Feet
1:1,920 (At original document size of 22x34)

N

Notes

1. Coordinate System: NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet
   North American Vertical Datum of 1988 (NAVD 88)
2. Sources: Stantec
3. Depth to groundwater and LNAPL, where present, were measured in each well to the nearest one-hundredth of a foot using an interface probe.
4. FT NAVD88 = feet referenced to the North American Vertical Datum of 1988
5. Groundwater elevation data was interpolated using point kriging with a linear variogram model in Surfer to produce a surface model. The model is interpreted to be a reasonable approximation of the unconfined aquifer elevation within the limits of the available well data.
6. Aerial & Topo Copyright:© 2013 National Geographic Society, i-cubed
   PEMA Philadelphia County 2018 Aerial Imagery

Figure No.

4-1b

Title

UNCONFINED AQUIFER ELEVATION, JUNE 2019

Client/Project

PHILADELPHIA REFINERY OPERATIONS, A SERIES OF
EVERGREEN RESOURCES GROUP, LLC
FORMER PHILADELPHIA REFINERY
3144 PASSYUNK AVENUE, PHILADELPHIA, PA 19145

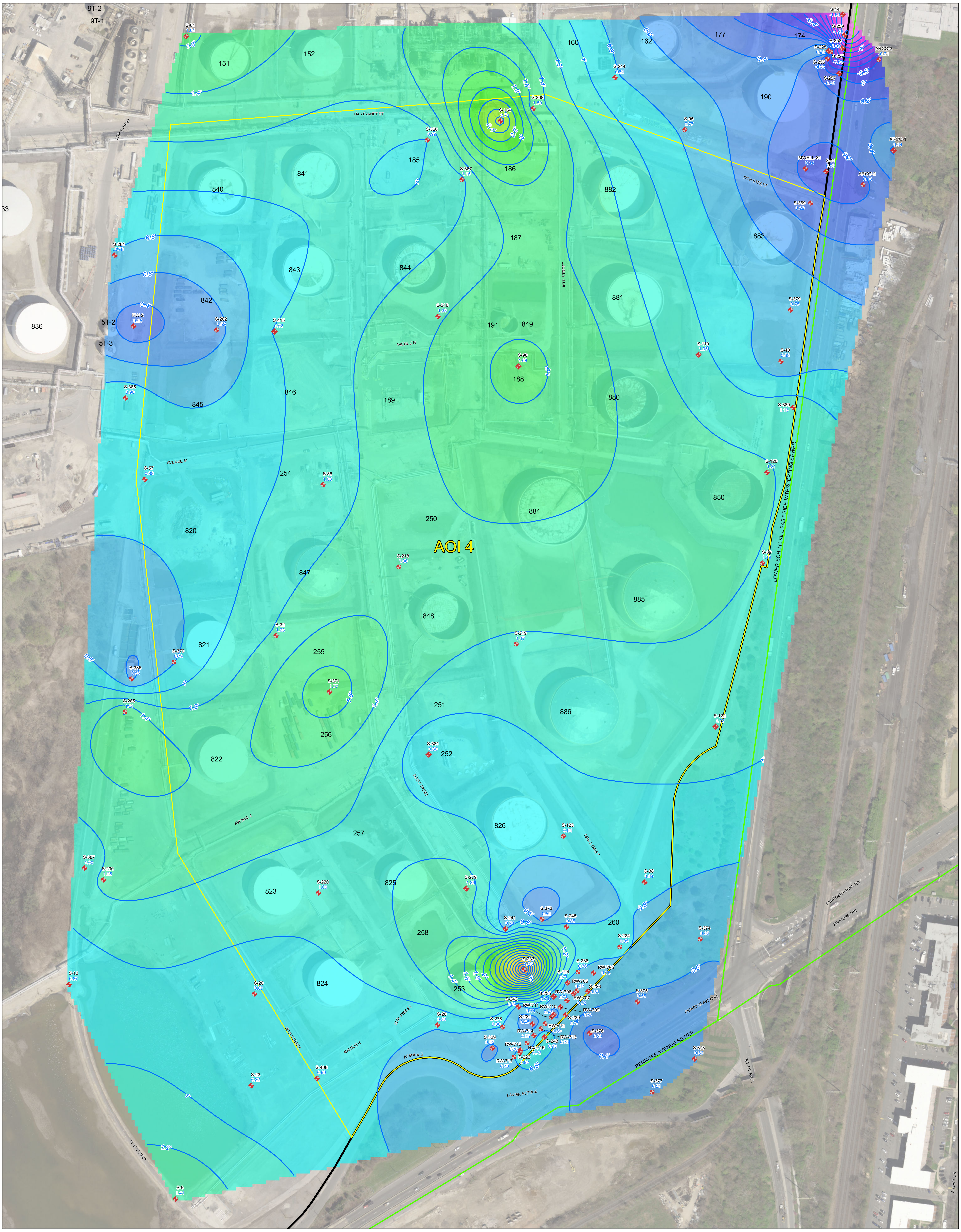
Project Location

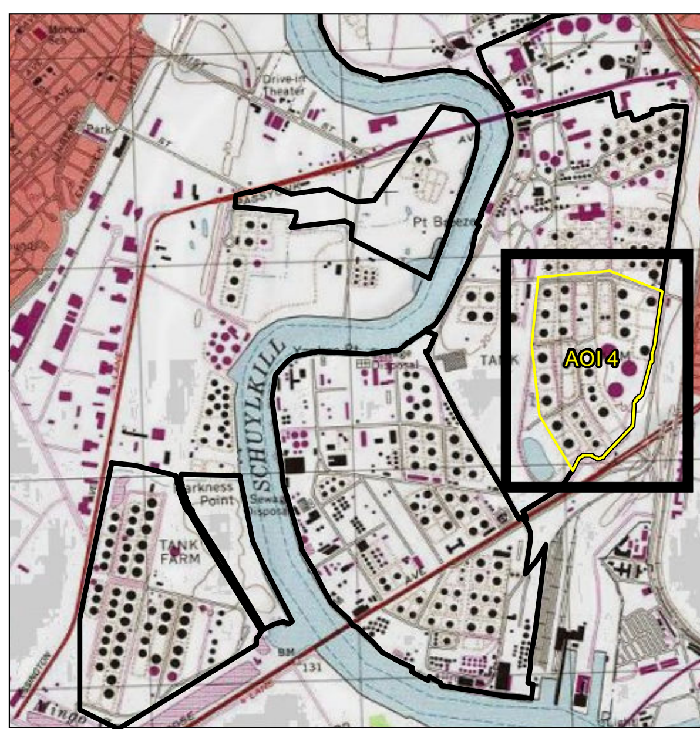
City of Philadelphia,
Philadelphia County,
Pennsylvania

213402602
Prepared by GWC on 9/20/2021 Technical
Review by AJH on 11/12/2021
Independent Review by JKK on 11/12/2021

Stantec

EVERGREEN





LEGEND

- ⌖ MONITORING WELL SCREENED IN UNCONFINED AQUIFER, UTILIZED FOR OCTOBER 2019 ELEVATION SURFACE
- — WATER-TABLE ELEVATION CONTOUR (FEET NAVD 88)
- — APPROXIMATE LOCATION OF PHILADELPHIA WATER DEPARTMENT SEWER
- ☐ AREA OF INTEREST (AOI) 4 BOUNDARY
- ☐ FORMER PHILADELPHIA REFINERY
- 2.73 CORRECTED GROUNDWATER ELEVATION (FT NAVD88)
- 30 TANK ID

OCTOBER 2019 WATER-TABLE ELEVATION FT NAVD88

4.2 to 4.4	2.0 to 2.2	-0.2 to 0
4.0 to 4.2	1.8 to 2.0	-0.4 to -0.2
3.8 to 4.0	1.6 to 1.8	-0.6 to -0.4
3.6 to 3.8	1.4 to 1.6	-0.8 to -0.6
3.4 to 3.6	1.2 to 1.4	-1.0 to -0.8
3.2 to 3.4	1.0 to 1.2	-1.2 to -1.0
3.0 to 3.2	0.8 to 1.0	-1.4 to -1.2
2.8 to 3.0	0.6 to 0.8	-1.6 to -1.4
2.6 to 2.8	0.4 to 0.6	-1.8 to -1.6
2.4 to 2.6	0.2 to 0.4	-2.0 to -1.8
2.2 to 2.4	0 to 0.2	

0 140 280 Feet

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N

Figure No.

4-1c

Title

UNCONFINED AQUIFER ELEVATION, OCTOBER 2019

Client/Project

PHILADELPHIA REFINERY OPERATIONS, A SERIES OF
EVERGREEN RESOURCES GROUP, LLC
FORMER PHILADELPHIA REFINERY
3144 PASSYUNK AVENUE, PHILADELPHIA, PA 19145

Project Location

City of Philadelphia,
Philadelphia County,
Pennsylvania

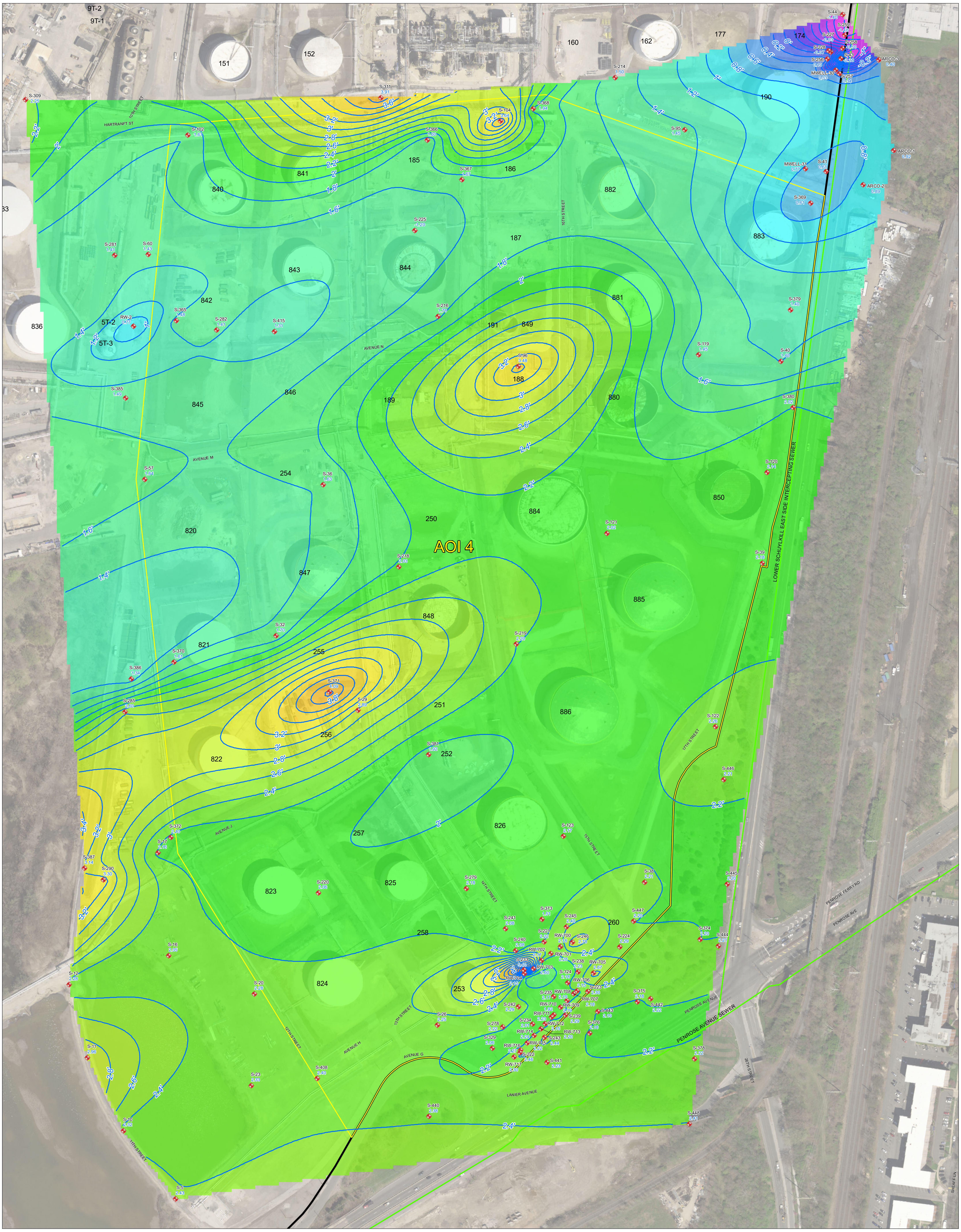
213402602
Prepared by GWC on 9/20/2021 Technical
Review by AJH on 11/12/2021
Independent Review by JKK on 11/12/2021

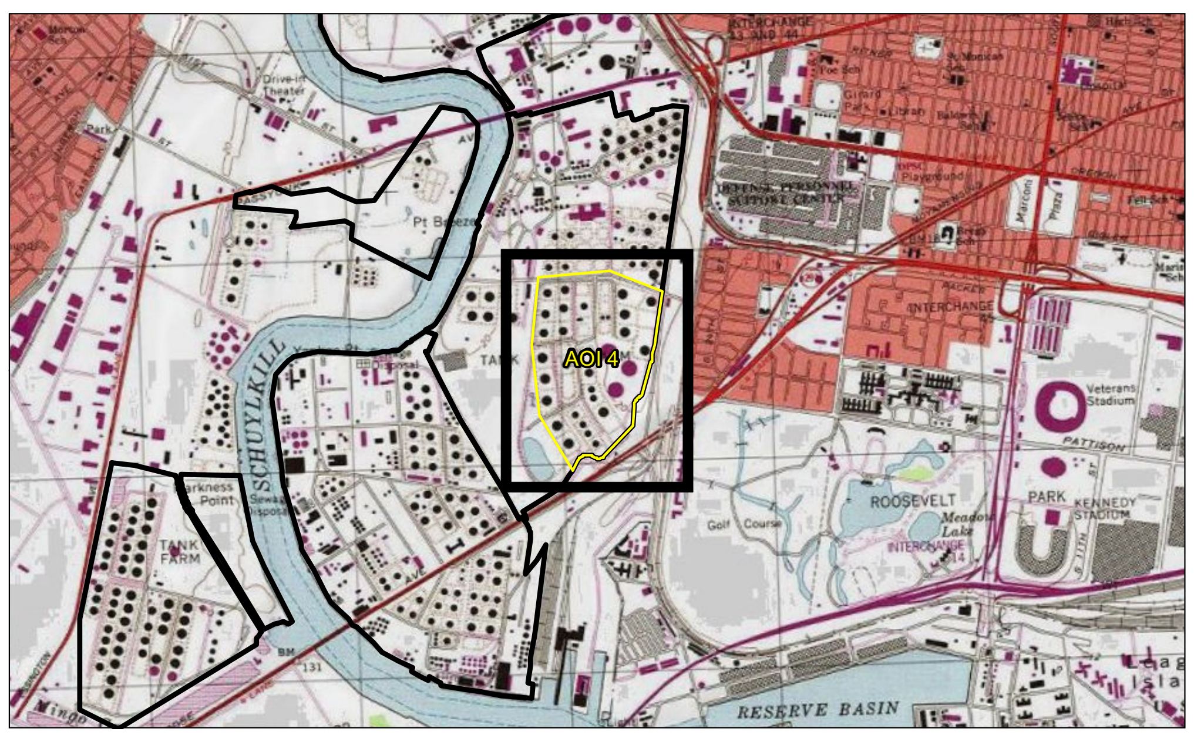
Stantec

EVERGREEN

Notes

1. Coordinate System: NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet North American Vertical Datum of 1988 (NAVD 88)
2. Sources: Stantec
3. Depth to groundwater and LNAPL, where present, were measured in each well to the nearest one-hundredth of a foot using an interface probe.
4. FT NAVD88 = feet referenced to the North American Vertical Datum of 1988
5. Groundwater elevation data was interpolated using point kriging with a linear variogram model in Surfer to produce a surface model. The model is interpreted to be a reasonable approximation of the unconfined aquifer elevation within the limits of the available well data.
6. Aerial & Topo Copyright:© 2013 National Geographic Society, i-cubed PEMA Philadelphia County 2018 Aerial Imagery





LEGEND

⌖	MONITORING WELL SCREENED IN UNCONFINED AQUIFER, UTILIZED FOR APRIL 2021 ELEVATION SURFACE
—	WATER-TABLE ELEVATION CONTOUR (FEET NAVD 88)
—	APPROXIMATE LOCATION OF PHILADELPHIA WATER DEPARTMENT SEWER
☐	AREA OF INTEREST (AOI) 4 BOUNDARY
☐	FORMER PHILADELPHIA REFINERY
2.44	CORRECTED GROUNDWATER ELEVATION (FT NAVD88)
30	TANK ID

APRIL 2021 WATER-TABLE ELEVATION FT NAVD88

🟧	4.8 to 5.0	🟨	3.0 to 3.2	🟩	1.2 to 1.4	🟪	-0.6 to -0.4
🟧	4.6 to 4.8	🟨	2.8 to 3.0	🟦	1.0 to 1.2	🟪	-0.8 to -0.6
🟧	4.4 to 4.6	🟩	2.6 to 2.8	🟦	0.8 to 1.0	🟪	-1.0 to -0.8
🟧	4.2 to 4.4	🟩	2.4 to 2.6	🟦	0.6 to 0.8	🟪	-1.2 to -1
🟧	4.0 to 4.2	🟩	2.2 to 2.4	🟦	0.4 to 0.6	🟪	-1.4 to -1.2
🟧	3.8 to 4.0	🟩	2.0 to 2.2	🟦	0.2 to 0.4	🟪	-1.6 to -1.4
🟨	3.6 to 3.8	🟩	1.8 to 2.0	🟦	0 to 0.2	🟪	-1.8 to -1.6
🟨	3.4 to 3.6	🟩	1.6 to 1.8	🟦	-0.2 to 0	🟪	-2.0 to -1.8
🟨	3.2 to 3.4	🟩	1.4 to 1.6	🟪	-0.4 to -0.2		

0 140 280 Feet

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N

Figure No.

4-1e

Title

UNCONFINED AQUIFER ELEVATION, APRIL 2021

Client/Project

PHILADELPHIA REFINERY OPERATIONS, A SERIES OF
EVERGREEN RESOURCES GROUP, LLC
FORMER PHILADELPHIA REFINERY
3144 PASSYUNK AVENUE, PHILADELPHIA, PA 19145

Project Location

City of Philadelphia,
Philadelphia County,
Pennsylvania

213402602
Prepared by GWC on 8/16/2021 Technical
Review by AJH on 11/19/2021
Independent Review by JKK on 11/19/2021

Stantec

EVERGREEN

Notes

1. Coordinate System: NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet North American Vertical Datum of 1988 (NAVD 88)
2. Sources: Stantec
3. Depth to groundwater and LNAPL, where present, were measured in each well to the nearest one-hundredth of a foot using an interface probe.
4. FT NAVD88 = feet referenced to the North American Vertical Datum of 1988
5. Groundwater elevation data was interpolated using point kriging with a linear variogram model in Surfer to produce a surface model. The model is interpreted to be a reasonable approximation of the unconfined aquifer elevation within the limits of the available well data.
6. Aerial & Topo Copyright:© 2013 National Geographic Society, i-cubed PEMA Philadelphia County 2018 Aerial Imagery

ATTACHMENT A

Public Comments

CLEAN AIR COUNCIL

Evergreen Resources Management Operations
a series of Evergreen Resources Group, LLC
On behalf of Sunoco, Inc. (R&M), now known as Sunoco (R&M), LLC

Pennsylvania Department of Environmental Protection

Site Characterization/Remedial Investigation Reports/Risk Assessments
Philadelphia Refinery Complex
3144 Passyunk Avenue, Philadelphia, Pennsylvania

Remedial Investigation Report Addendum AOI-4
Remedial Investigation Report Addendum AOI-9

October 30, 2021

Written Comments by Clean Air Council

Via email: phillyrefinerycleanup@ghd.com

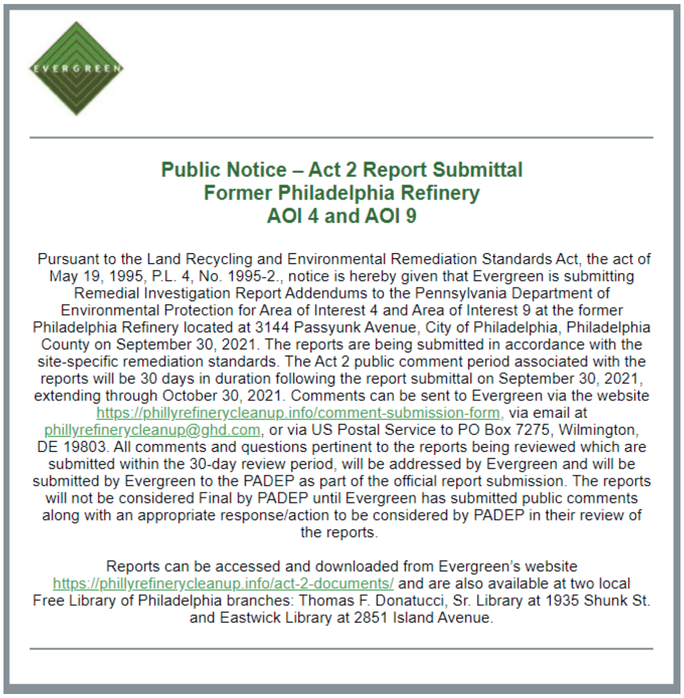
Clean Air Council ("the Council") appreciates the opportunity to provide comments on Evergreen Resources Management Operations' ("Evergreen's") Site Characterization Reports and Remedial Investigation Reports for Area of Interest 4 ("AOI-4") and Area of Interest 9 ("AOI-9") at the former Philadelphia refinery. The reports were prepared by Evergreen on behalf of Sunoco, Inc. (R&M), now known as Sunoco (R&M), LLC ("Sunoco"). Sunoco is the party legally responsible for contamination prior to its sale of the property in 2012.

The Council is a non-profit environmental organization headquartered at 135 South 19th Street, Suite 300, Philadelphia, Pennsylvania, 19103. For 50 years, the Council has worked to improve air quality across Pennsylvania. The Council has members throughout the Commonwealth who support its mission to protect everyone's right to breathe clean air, including members in Allegheny County.

Evergreen submitted the reports to the Pennsylvania Department of Environmental Protection ("the Department") under Act 2 of 1995. *See* Evergreen, Act 2 Documents. The reports were submitted pursuant to the Consent Order and Agreement (2003) and the Consent Order and Agreement (2012). These two reports are being submitted pursuant to a revised Consent Order. *See* First Amendment to Consent Order and Agreement (June 26, 2020), page 5 of 77 (setting deadline of reports by September 30, 2021).

The comments are submitted in response to this notice:

celebrating 50 years
Philadelphia 135 S. 19th Street | Suite 300 | Philadelphia, PA 19103 | 215-567-4004 | Fax 215-567-5791 www.cleanair.org
Harrisburg 107 N. Front Street | Suite 113 | Harrisburg, PA 17101 | 717-230-8806 | Fax 717-230-8808 www.facebook.com/cleanaircouncil
Wilmington Community Service Building | 100 W. 10th Sreet | Suite 106 | Wilmington, DE 19801 | 302-691-0112 www.twitter.com/cleanaircouncil



Public Notice – Act 2 Report Submittal
Former Philadelphia Refinery
AOI 4 and AOI 9

Pursuant to the Land Recycling and Environmental Remediation Standards Act, the act of May 19, 1995, P.L. 4, No. 1995-2., notice is hereby given that Evergreen is submitting Remedial Investigation Report Addendums to the Pennsylvania Department of Environmental Protection for Area of Interest 4 and Area of Interest 9 at the former Philadelphia Refinery located at 3144 Passyunk Avenue, City of Philadelphia, Philadelphia County on September 30, 2021. The reports are being submitted in accordance with the site-specific remediation standards. The Act 2 public comment period associated with the reports will be 30 days in duration following the report submittal on September 30, 2021, extending through October 30, 2021. Comments can be sent to Evergreen via the website https://phillyrefinerycleanup.info/comment-submission-form, via email at phillyrefinerycleanup@ghd.com, or via US Postal Service to PO Box 7275, Wilmington, DE 19803. All comments and questions pertinent to the reports being reviewed which are submitted within the 30-day review period, will be addressed by Evergreen and will be submitted by Evergreen to the PADEP as part of the official report submission. The reports will not be considered Final by PADEP until Evergreen has submitted public comments along with an appropriate response/action to be considered by PADEP in their review of the reports.

Reports can be accessed and downloaded from Evergreen's website https://phillyrefinerycleanup.info/act-2-documents/ and are also available at two local Free Library of Philadelphia branches: Thomas F. Donatucci, Sr. Library at 1935 Shunk St. and Eastwick Library at 2851 Island Avenue.

All documents cited in these comments are hyperlinked or attached. The yellow or orange highlighting in the quoted and snipped passages was added to direct attention to relevant text.

Index to Comments

1. **Soil in AOI-4**

    a. Evergreen does not address problems identified in the delineation of soil contamination identified in the Department's technical deficiency letter in June 2021.

    b. It would be premature to approve the report because there is an unresolved question of the appropriateness of a site-specific standard for lead in surface soil.

2. **Soil in AOI-9**

    a. Evergreen does not address problems identified in the delineation of soil contamination identified in the Department's technical deficiency letter in June 2021.

    b. It would be premature to approve the report because there is an unresolved question of the appropriateness of a site-specific standard for lead in surface soil.

3. **Water Table in AOI-4**

    a. Evergreen should install monitoring wells to the east and southeast of S-369 in the northeast corner of AOI-4, as directed by the Department.

    b. Evergreen and the Department have not addressed the longstanding question of the direction of the flow of contaminants east of AOI-4, which was raised previously in connection with the investigation of the Defense Supply Center Philadelphia.

    c. Evergreen has not established that the additional five monitoring wells to the southeast of the Penrose Avenue remediation system are sufficient to address off-site migration.

    d. Evergreen's Qualitative Fate and Transport analysis is flawed.

4. **Water Table in AOI-9**

    a. Evergreen should provide a more thorough analysis of the potential for off-site migration of benzene and MTBE.

    b. Evergreen's Qualitative Fate and Transport analysis is flawed.

5. **Deep Aquifer in AOI-4**

a. The Department should not allow Evergreen to continue attempting to fragment the remedial investigation by diverting an analysis of the fate and transport of contaminants into a Remedial Investigation Report due at the end of the year.

6. Deep Aquifer in AOI-9

a. The Department should not allow Evergreen to continue attempting to fragment the remedial investigation by diverting an analysis of the fate and transport of contaminants into a Remedial Investigation Report due at the end of the year.

7. Vapor Intrusion in AOI-4

a. Evergreen should analyze preferential pathways for vapor intrusion on- and off-site for AOI-9 before applying proximity distances or screening values.

b. Evergreen should take into account the location of planned buildings in AOI-4 in its vapor intrusion analysis.

8. Vapor Intrusion in AOI-9

a. Evergreen should analyze preferential pathways for vapor intrusion on- and off-site for AOI-9 before applying proximity distances or screening values.

b. Evergreen should take additional soil samples before applying screening values to the buildings on AOI-9, in accordance with the Vapor Intrusion Guidance.

9. PFAS

a. The Department should not allow Evergreen to divert a PFAS investigation into a separate investigation outside the Act 2 process and public comment process.

b. With respect to effluent sampling, the PFAS investigation performed by Evergreen in AOI-4 and AOI-9 is insufficient.

c. With respect to deep aquifer sampling, the PFAS investigation performed by Evergreen in AOI-4 and AOI-9 is insufficient.

d. The Department should require Evergreen to conduct sampling PFAS in the water table (upper aquifer), which it has not done.

Table of Attachments

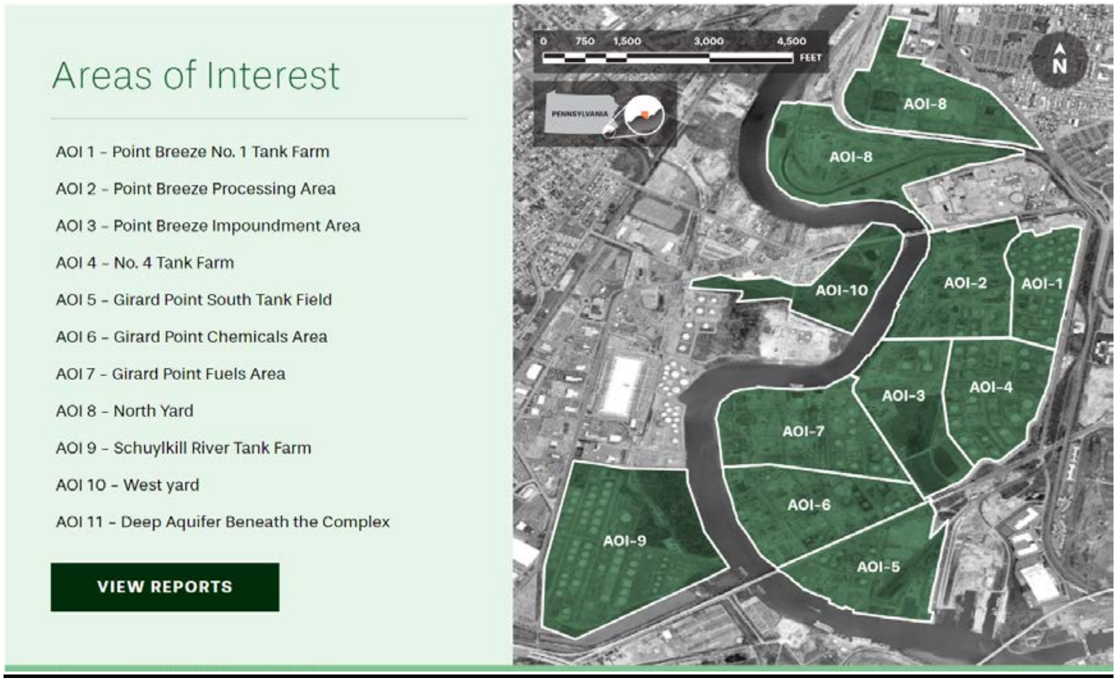
Attachment 1 --	Comments of Clean Air Council dated January 14, 2021
Attachment 2 --	PA Department of Environmental Protection, Letter of Technical Deficiency dated June 29, 2021
Attachment 3 --	PA Department of Environmental Protection, Memorandum Relating to Letter of Technical Deficiency dated June 29, 2021
Attachment 4 --	U.S. Geological Survey, U.S. DOI, Simulation of Ground-Water Flow in the Potomac-Raritan-Magothy Aquifer System Near the Defense Supply Center Philadelphia, and the Point Breeze Refinery, Southern Philadelphia County, Pennsylvania, 2001 https://pubs.usgs.gov/wri/2001/4218/wri20014218.pdf
Attachment 5 --	PA Department of Environmental Protection, Cleanup of the Philadelphia Refinery Report to the City of Philadelphia Refinery Advisory Group Environmental and Academic Committee Meeting, Aug. 27 2019
Attachment 6 --	PA Department of Environmental Protection, Land Recycling Program Technical Guidance Manual, Appendix A (Groundwater Monitoring Guidance)
Attachment 7 --	PA Department of Environmental Protection, Land Recycling Program Technical Guidance Manual, Section IV: Vapor Intrusion

Table of Relevant Reports

Area of Interest	Title	Date
AOI-4 No. 4 Tank Farm	2013 Report (disapproved) 2017 Report (part 1) 2017 Report (part 2) (disapproved) 2021 Report (new): Philadelphia Refinery AOI_4_RIR_Addendum_09-30-2021_Part_1 (part 1) Philadelphia Refinery AOI_4_RIR_Addendum_09-30-2021_Part_2 (part 2) Philadelphia Refinery AOI_4_RIR_Addendum_09-30-2021_Part_3 (part 3)	November 16, 2013 March 24, 2017 September 30, 2021
AOI-9 Schuylkill River Tank Farm	2015 Report (part 1) 2015 Report (part 2) (disapproved) 2017 Report Addendum (part 1) 2017 Report Addendum (part 2) (disapproved) 2021 Report (new): 2020 Philadelphia Refinery_AOI_9_Second_RIR_Addendum_09-30-2021	December 31, 2015 February 8, 2017 September 30, 2021
AOI-11 Deep Aquifer Beneath Complex	2011 Report (part 1) 2011 Report (part 2) 2013 Report (part 1) 2013 Report (part 2) (disapproved)	September 12, 2011 June 21, 2013
Site-Wide Reports	2015 Human Health Risk Assessment Report	February 25, 2015

(Lead in Surface Soils)	(approved)	
Sampling for PFAS (Effluent from Remediation Systems)	System Effluent PFAS Sampling Summary – 03-22-2021 (“March 2021 report”)	March 22, 2021
Sampling for PFAS (Deep Aquifer)	PFAS Lower Aquifer Sampling Summary – 09-30-2021 (“September 2021 report”)	September 30, 2021

Areas of Interest



Areas of Interest

AOI 1 – Point Breeze No. 1 Tank Farm

AOI 2 – Point Breeze Processing Area

AOI 3 – Point Breeze Impoundment Area

AOI 4 – No. 4 Tank Farm

AOI 5 – Girard Point South Tank Field

AOI 6 – Girard Point Chemicals Area

AOI 7 – Girard Point Fuels Area

AOI 8 – North Yard

AOI 9 – Schuylkill River Tank Farm

AOI 10 – West yard

AOI 11 – Deep Aquifer Beneath the Complex

Source: Evergreen, Home - PRLR

Summary of Comments

The Council is providing comments on two addendum reports -- one for Area of Interest 4 (AOI-4) and another for Area of Interest 9 (AOI-9). It would be premature to approve the two reports, which are deficient for a number of reasons set forth in detail below. The Department should disapprove the reports.

The Council incorporates by reference its comments submitted on previous reports for AOI-4 and AOI-9 in January 2021. *See* Attachment 1 -- Comments of Clean Air Council dated January 14, 2021. In particular, the Council directs the attention of Evergreen and the Department to the following comments:

1. Comment #7 (Evergreen Has Not Sufficiently Delineated the Nature and Extent of Contamination in the Deep Aquifer and the Unconfined Aquifer (Water Table)),

2. Comment #11 (Evergreen May Not Fragment the Remedial Investigation Reports by Diverting its Deficiencies Into a Future Fate and Transport Remedial Investigation Report),

3. Comment #12 (Evergreen Fails to Sufficiently Delineate Exceedances of the Soil-to-Groundwater Numeric Value and the Direct Contact Numeric Value for All Constituents of Concern), and

4. Comment #13 (The Department Should Disapprove Evergreen's Proposed Site-Specific Standard of 2240 mg/kg for Lead in Surface Soils).

In addition to fragmenting the remedial investigation of the deep aquifer (through the diversion of work to a separate Fate and Transport Remedial Investigation Report due on December 31, 2021), Evergreen presents a new form of fragmentation of the reports. The Department cannot reasonably approve these new reports without consolidating them with previous reports for which the Department issued a letter of technical deficiency in June 2021.

With respect to soil, Evergreen repeats errors in previous reports, skewing the delineation toward a site-specific standard of 2240 mg/kg for lead that is not justified.

With respect to the water table, Evergreen has not properly delineated off-site migration from AOI-4 and AOI-9, or contamination within these areas of interest. With respect to the deep aquifer, Evergreen has not corrected flaws identified in previous reports for AOI-4 and AOI-9.

With respect to soil vapor intrusion, Evergreen erroneously inverts the sequence of events in an investigation, skipping the pathway step and admitting that it is incomplete, leaving it for another day. In addition, its sampling is insufficient and does not take into consideration planned buildings on the property.

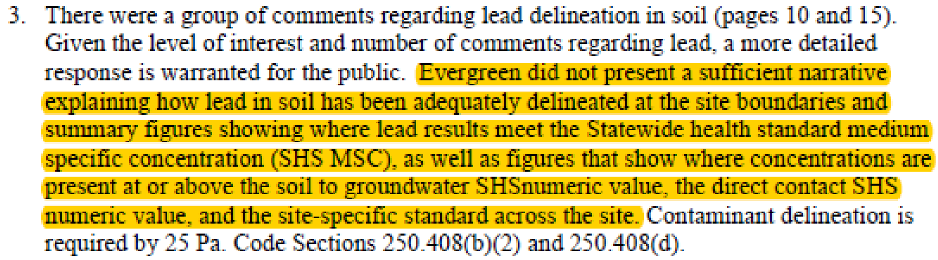
With respect to PFAS, Evergreen erroneously attempts to divert the investigation into an investigation outside Act 2 and the public comment process. Its sampling was unduly restrictive, being limited to places of assumed firefighting activities and not recognizing that PFAS contaminants may migrate for considerable distances. The Department should require more sampling in both AOI-4 and AOI-9, including sampling of the water table and sampling for groundwater migrating into Mingo Basin and ultimately the Schuylkill River.

Comments

1. Soil in AOI-4.

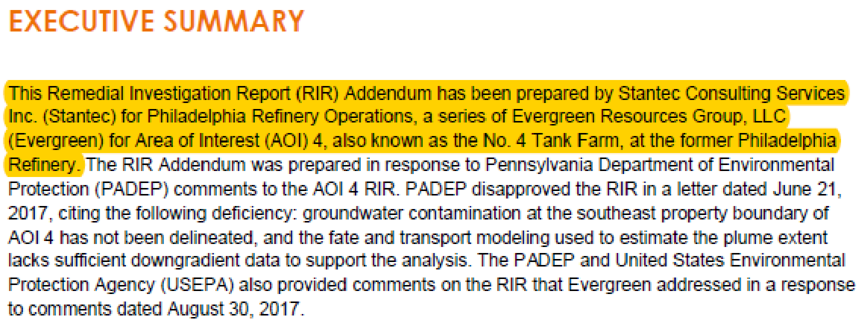
a. Evergreen does not address problems identified in the delineation of soil contamination identified in the Department's technical deficiency letter in June 2021.

In a letter of technical deficiency issued this summer for past remedial investigation reports, the Department notified Evergreen that it had failed to provide a sufficient narrative explaining how lead has been adequately delineated:



3. There were a group of comments regarding lead delineation in soil (pages 10 and 15). Given the level of interest and number of comments regarding lead, a more detailed response is warranted for the public. Evergreen did not present a sufficient narrative explaining how lead in soil has been adequately delineated at the site boundaries and summary figures showing where lead results meet the Statewide health standard medium specific concentration (SHS MSC), as well as figures that show where concentrations are present at or above the soil to groundwater SHSnumeric value, the direct contact SHS numeric value, and the site-specific standard across the site. Contaminant delineation is required by 25 Pa. Code Sections 250.408(b)(2) and 250.408(d).

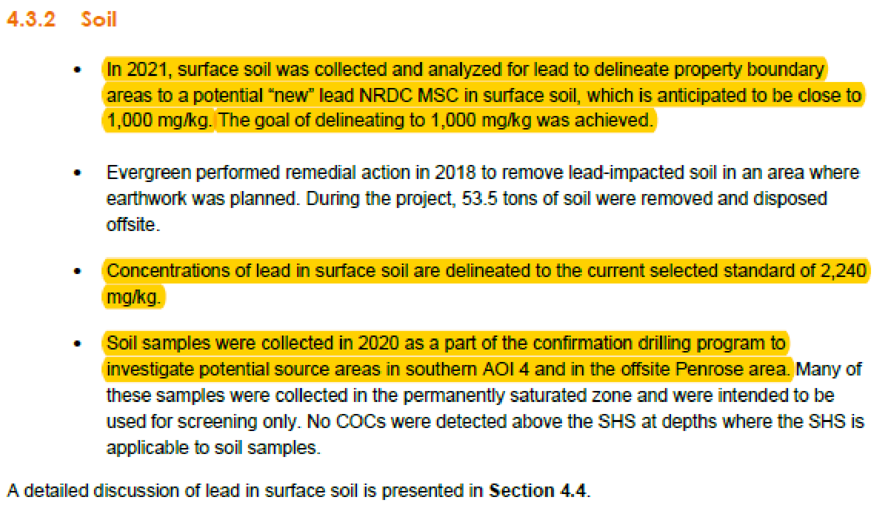
See Attachment 2 -- PA Department of Environmental Protection, Letter of Technical Deficiency dated June 29, 2021, Item #3. The present report purports to be an addendum of a past report for AOI-4 that was disapproved in 2017:



EXECUTIVE SUMMARY

This Remedial Investigation Report (RIR) Addendum has been prepared by Stantec Consulting Services Inc. (Stantec) for Philadelphia Refinery Operations, a series of Evergreen Resources Group, LLC (Evergreen) for Area of Interest (AOI) 4, also known as the No. 4 Tank Farm, at the former Philadelphia Refinery. The RIR Addendum was prepared in response to Pennsylvania Department of Environmental Protection (PADEP) comments to the AOI 4 RIR. PADEP disapproved the RIR in a letter dated June 21, 2017, citing the following deficiency: groundwater contamination at the southeast property boundary of AOI 4 has not been delineated, and the fate and transport modeling used to estimate the plume extent lacks sufficient downgradient data to support the analysis. The PADEP and United States Environmental Protection Agency (USEPA) also provided comments on the RIR that Evergreen addressed in a response to comments dated August 30, 2017.

Id., page 1. The AOI-4 Addendum Report does not attempt to address this technical deficiency identified by the Department in June 2021. Rather, it simply discusses soil sampling in 2020 and 2021:



4.3.2 Soil

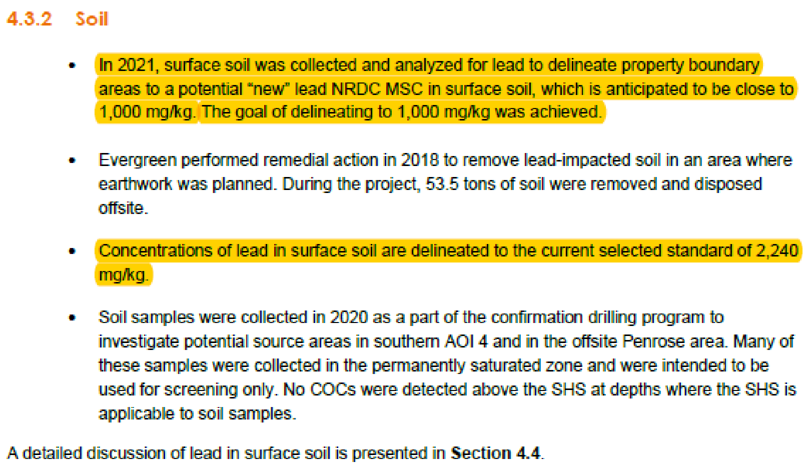
- In 2021, surface soil was collected and analyzed for lead to delineate property boundary areas to a potential "new" lead NRDC MSC in surface soil, which is anticipated to be close to 1,000 mg/kg. The goal of delineating to 1,000 mg/kg was achieved.
- Evergreen performed remedial action in 2018 to remove lead-impacted soil in an area where earthwork was planned. During the project, 53.5 tons of soil were removed and disposed offsite.
- Concentrations of lead in surface soil are delineated to the current selected standard of 2,240 mg/kg.
- Soil samples were collected in 2020 as a part of the confirmation drilling program to investigate potential source areas in southern AOI 4 and in the offsite Penrose area. Many of these samples were collected in the permanently saturated zone and were intended to be used for screening only. No COCs were detected above the SHS at depths where the SHS is applicable to soil samples.

A detailed discussion of lead in surface soil is presented in **Section 4.4**.

Addendum Report (AOI-4), page 34. Evergreen does not establish how it made the decisions regarding the choice of these samples in these locations for these chemicals, and how this all relates to past reports. Nor does Evergreen discuss deficiencies in soil sampling in the past reports and address how those deficiencies will be corrected.

The public cannot evaluate the sufficiency of the soil investigation in the AOI-4 Addendum Report without connecting it to the previous report disapproved in 2017 and a letter of technical deficiency issued in June 2021. Stated differently, to approve the AOI-4 Addendum Report would be to fragment the remedial investigation of soil contamination.

According to the quoted material above, Evergreen purports to be delineating lead contamination based on surface soil samples in 2020 and 2021 according to "a potential “new” lead NRDC MSC in surface soil, which is anticipated to be close to 1,000 mg/kg":



4.3.2 Soil

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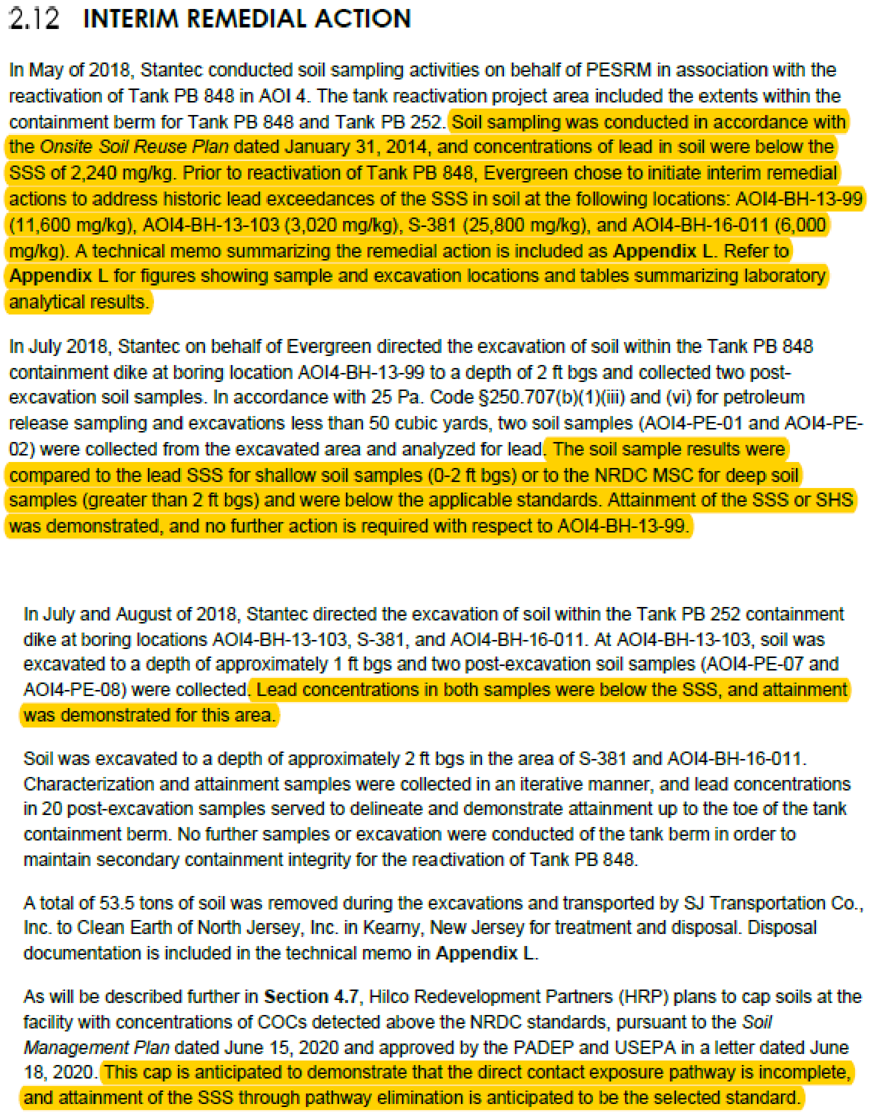
A detailed discussion of lead in surface soil is presented in **Section 4.4**.

See 2021 Addendum Report (AOI-4), Section 4.3.2 (Contaminants of Concern), page. Evergreen is doing this because the Department decided not to proceed with a proposed statewide health standard of 2500 mg/kg for lead. *See id.*, Section 4.4 (Lead in Surface Soil), Figure 4-8. Evergreen is not doing this for past sampling events discussed in previous reports.

A similar flaw extends to Evergreen's discussion of an interim remedial action in connection with the reactivation of Tank PB 848, which is based on the premise that a site-specific standard of 2240 mg/kg would apply:



2.12 INTERIM REMEDIAL ACTION

In May of 2018, Stantec conducted soil sampling activities on behalf of PESRM in association with the reactivation of Tank PB 848 in AOI 4. The tank reactivation project area included the extents within the containment berm for Tank PB 848 and Tank PB 252. Soil sampling was conducted in accordance with the *Onsite Soil Reuse Plan* dated January 31, 2014, and concentrations of lead in soil were below the SSS of 2,240 mg/kg. Prior to reactivation of Tank PB 848, Evergreen chose to initiate interim remedial actions to address historic lead exceedances of the SSS in soil at the following locations: AOI4-BH-13-99 (11,600 mg/kg), AOI4-BH-13-103 (3,020 mg/kg), S-381 (25,800 mg/kg), and AOI4-BH-16-011 (6,000 mg/kg). A technical memo summarizing the remedial action is included as **Appendix L**. Refer to **Appendix L** for figures showing sample and excavation locations and tables summarizing laboratory analytical results.

In July 2018, Stantec on behalf of Evergreen directed the excavation of soil within the Tank PB 848 containment dike at boring location AOI4-BH-13-99 to a depth of 2 ft bgs and collected two post-excavation soil samples. In accordance with 25 Pa. Code §250.707(b)(1)(iii) and (vi) for petroleum release sampling and excavations less than 50 cubic yards, two soil samples (AOI4-PE-01 and AOI4-PE-02) were collected from the excavated area and analyzed for lead. The soil sample results were compared to the lead SSS for shallow soil samples (0-2 ft bgs) or to the NRDC MSC for deep soil samples (greater than 2 ft bgs) and were below the applicable standards. Attainment of the SSS or SHS was demonstrated, and no further action is required with respect to AOI4-BH-13-99.

In July and August of 2018, Stantec directed the excavation of soil within the Tank PB 252 containment dike at boring locations AOI4-BH-13-103, S-381, and AOI4-BH-16-011. At AOI4-BH-13-103, soil was excavated to a depth of approximately 1 ft bgs and two post-excavation soil samples (AOI4-PE-07 and AOI4-PE-08) were collected. Lead concentrations in both samples were below the SSS, and attainment was demonstrated for this area.

Soil was excavated to a depth of approximately 2 ft bgs in the area of S-381 and AOI4-BH-16-011. Characterization and attainment samples were collected in an iterative manner, and lead concentrations in 20 post-excavation samples served to delineate and demonstrate attainment up to the toe of the tank containment berm. No further samples or excavation were conducted of the tank berm in order to maintain secondary containment integrity for the reactivation of Tank PB 848.

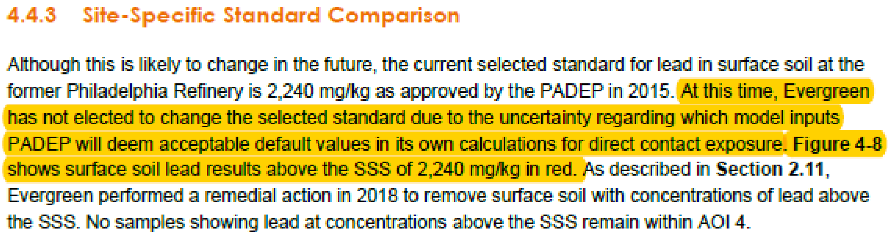
A total of 53.5 tons of soil was removed during the excavations and transported by SJ Transportation Co., Inc. to Clean Earth of North Jersey, Inc. in Kearny, New Jersey for treatment and disposal. Disposal documentation is included in the technical memo in **Appendix L**.

As will be described further in **Section 4.7**, Hilco Redevelopment Partners (HRP) plans to cap soils at the facility with concentrations of COCs detected above the NRDC standards, pursuant to the *Soil Management Plan* dated June 15, 2020 and approved by the PADEP and USEPA in a letter dated June 18, 2020. This cap is anticipated to demonstrate that the direct contact exposure pathway is incomplete, and attainment of the SSS through pathway elimination is anticipated to be the selected standard.

See id., Section 2.12 (Interim Remedial Action), pages 18-19.

b. It would be premature to approve the report because there is an unresolved question of the appropriateness of a site-specific standard for lead in surface soil.

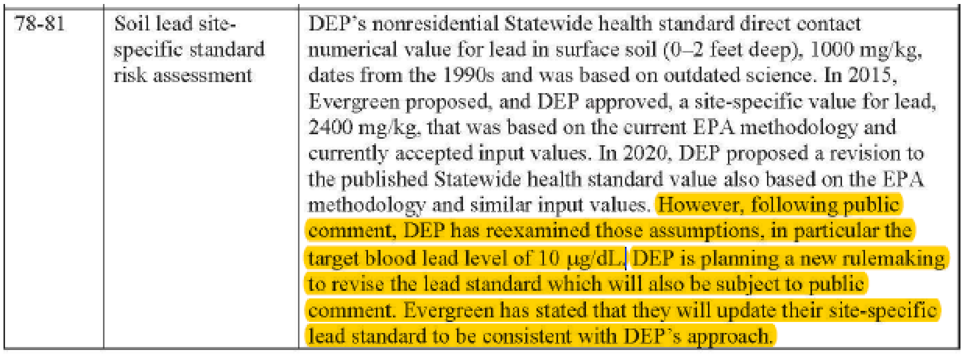
As it has done in successive reports, Evergreen continues to rely on the site-specific standard of 2240 mg/kg, despite the Department's withdrawal of the proposed statewide health standard of 2500 mg/kg. (Both standards were based on the premise that the target blood lead level should be 10 ug/dL, rather than 5 ug/dL). Evergreen alleges "uncertainty regarding which model inputs PADEP will deem acceptable default values in its own calculations for direct contact exposure”:



4.4.3 Site-Specific Standard Comparison

Although this is likely to change in the future, the current selected standard for lead in surface soil at the former Philadelphia Refinery is 2,240 mg/kg as approved by the PADEP in 2015. At this time, Evergreen has not elected to change the selected standard due to the uncertainty regarding which model inputs PADEP will deem acceptable default values in its own calculations for direct contact exposure. **Figure 4-8** shows surface soil lead results above the SSS of 2,240 mg/kg in red. As described in **Section 2.11**, Evergreen performed a remedial action in 2018 to remove surface soil with concentrations of lead above the SSS. No samples showing lead at concentrations above the SSS remain within AOI 4.

Addendum Report (AOI-4), Section 4.4.3 Site-Specific Standard Comparison, page 35. In its Memo relating to its Letter of Technical Deficiency, the Department states that it intends to introduce a new rulemaking to address the lead standard:



78-81	Soil lead site-specific standard risk assessment	DEP’s nonresidential Statewide health standard direct contact numerical value for lead in surface soil (0–2 feet deep), 1000 mg/kg, dates from the 1990s and was based on outdated science. In 2015, Evergreen proposed, and DEP approved, a site-specific value for lead, 2400 mg/kg, that was based on the current EPA methodology and currently accepted input values. In 2020, DEP proposed a revision to the published Statewide health standard value also based on the EPA methodology and similar input values. However, following public comment, DEP has reexamined those assumptions, in particular the target blood lead level of 10 μg/dL. DEP is planning a new rulemaking to revise the lead standard which will also be subject to public comment. Evergreen has stated that they will update their site-specific lead standard to be consistent with DEP’s approach.

See Attachment 3 -- PA Department of Environmental Protection, Memorandum Relating to Letter of Technical Deficiency dated June 29, 2021, page 9. However, the Department has said nothing about what it contemplates for a statewide health standard or for a site-specific standard for this project.

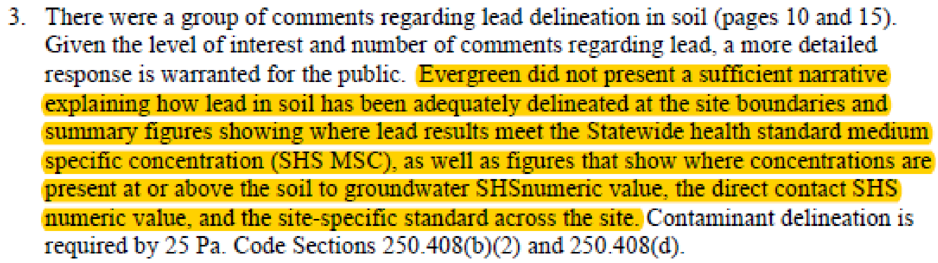
The arithmetic is not complicated. A site-specific standard calculated under EPA’s Adult Lead Model with a target blood lead level of 5 ug/dL would be no greater than 1100, considering the other assumptions made by the Department when it drafted the Act 2 rulemaking that it later withdrew. The Department should explain how there could be any other result.

It would be unreasonable for the Department to approve the report where it is based on the premise that a site-specific standard of 2240 mg/kg applies, especially where the Department has stated that it intends to revise the lead standard in the future, without providing details.

2. **Soil in AOI-9.**

a. Evergreen does not address problems identified in the delineation of soil contamination identified in the Department's technical deficiency letter in June 2021.

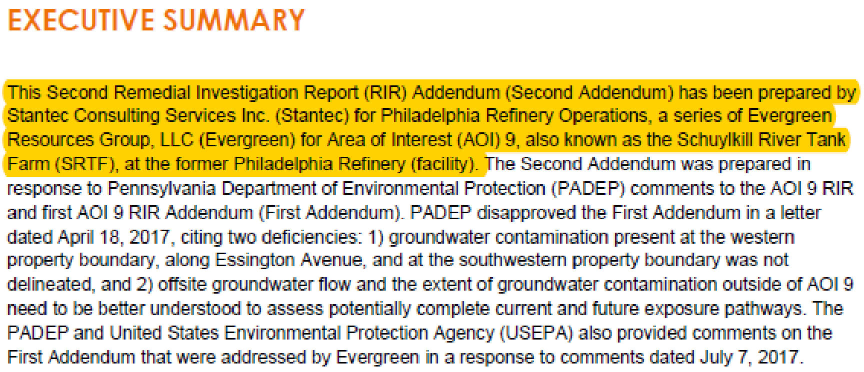
In a letter of technical deficiency issued this summer for past remedial investigation reports, the Department notified Evergreen that it had failed to provide a sufficient narrative explaining how lead has been adequately delineated:



3. There were a group of comments regarding lead delineation in soil (pages 10 and 15). Given the level of interest and number of comments regarding lead, a more detailed response is warranted for the public. Evergreen did not present a sufficient narrative explaining how lead in soil has been adequately delineated at the site boundaries and summary figures showing where lead results meet the Statewide health standard medium specific concentration (SHS MSC), as well as figures that show where concentrations are present at or above the soil to groundwater SHSnumeric value, the direct contact SHS numeric value, and the site-specific standard across the site. Contaminant delineation is required by 25 Pa. Code Sections 250.408(b)(2) and 250.408(d).

See Attachment 2 -- Letter of Technical Deficiency dated June 29, 2021, Item #3.

The present report purports to be an addendum of a past report for AOI-9 that was disapproved in 2017:

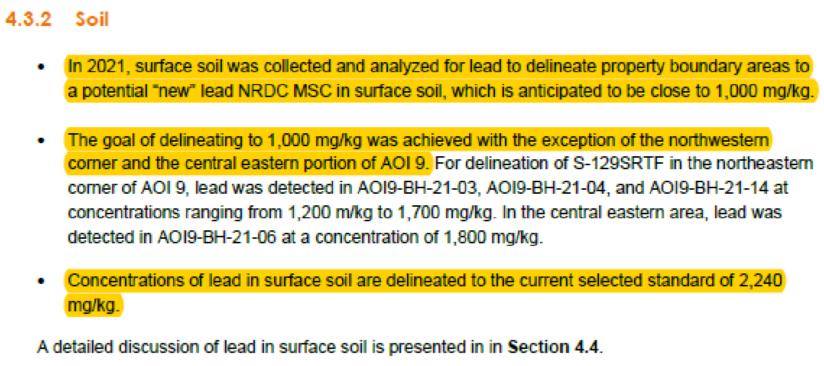


EXECUTIVE SUMMARY

This Second Remedial Investigation Report (RIR) Addendum (Second Addendum) has been prepared by Stantec Consulting Services Inc. (Stantec) for Philadelphia Refinery Operations, a series of Evergreen Resources Group, LLC (Evergreen) for Area of Interest (AOI) 9, also known as the Schuylkill River Tank Farm (SRTF), at the former Philadelphia Refinery (facility). The Second Addendum was prepared in response to Pennsylvania Department of Environmental Protection (PADEP) comments to the AOI 9 RIR and first AOI 9 RIR Addendum (First Addendum). PADEP disapproved the First Addendum in a letter dated April 18, 2017, citing two deficiencies: 1) groundwater contamination present at the western property boundary, along Essington Avenue, and at the southwestern property boundary was not delineated, and 2) offsite groundwater flow and the extent of groundwater contamination outside of AOI 9 need to be better understood to assess potentially complete current and future exposure pathways. The PADEP and United States Environmental Protection Agency (USEPA) also provided comments on the First Addendum that were addressed by Evergreen in a response to comments dated July 7, 2017.

See 2021 Addendum Report (AOI-9), page 1.

The AOI-9 Addendum Report does not attempt to address the technical deficiency identified by the Department in June 2021. Rather, it simply discusses soil sampling in 2020 and 2021:



4.3.2 Soil

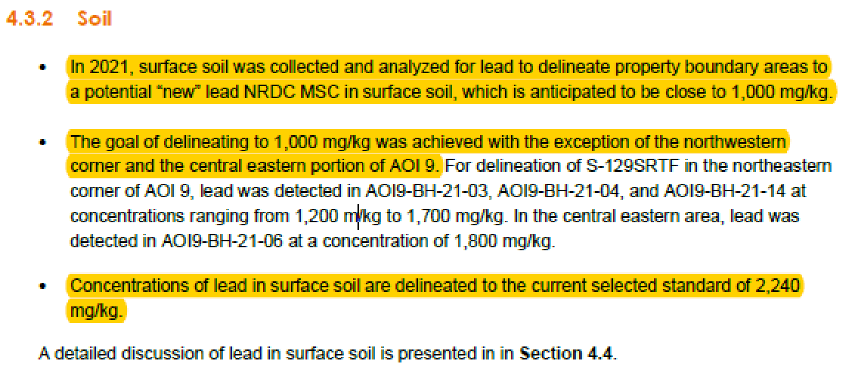
- In 2021, surface soil was collected and analyzed for lead to delineate property boundary areas to a potential "new" lead NRDC MSC in surface soil, which is anticipated to be close to 1,000 mg/kg.
- The goal of delineating to 1,000 mg/kg was achieved with the exception of the northwestern corner and the central eastern portion of AOI 9. For delineation of S-129SRTF in the northeastern corner of AOI 9, lead was detected in AOI9-BH-21-03, AOI9-BH-21-04, and AOI9-BH-21-14 at concentrations ranging from 1,200 m/kg to 1,700 mg/kg. In the central eastern area, lead was detected in AOI9-BH-21-06 at a concentration of 1,800 mg/kg.
- Concentrations of lead in surface soil are delineated to the current selected standard of 2,240 mg/kg.

A detailed discussion of lead in surface soil is presented in in **Section 4.4**.

See 2021 Addendum Report (AOI-9), page 34. Evergreen does not establish how it made the decisions regarding the choice of these samples in these locations for these chemicals, and how this all relates to past reports. Nor does Evergreen discuss deficiencies in soil sampling in the past reports and address how those deficiencies will be corrected.

The public cannot evaluate the sufficiency of the soil investigation in the AOI-9 Addendum Report without connecting it to the previous report disapproved in 2017 and a letter of technical deficiency issued in June 2021. Stated differently, to approve the AOI-9 Addendum Report would be to fragment the remedial investigation of soil contamination.

According to the quoted material above, Evergreen purports to be delineating lead contamination based on surface soil samples in 2020 and 2021 according to "a potential "new" lead NRDC MSC in surface soil, which is anticipated to be close to 1,000 mg/kg":



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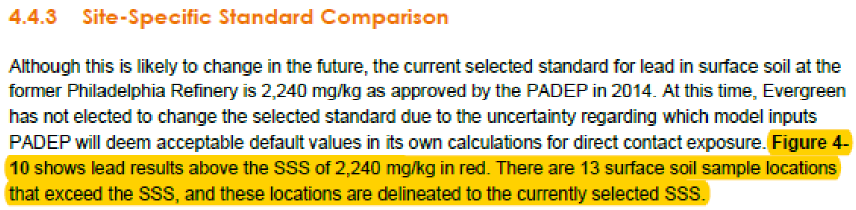
- Concentrations of lead in surface soil are delineated to the current selected standard of 2,240 mg/kg.

A detailed discussion of lead in surface soil is presented in in **Section 4.4**.

See 2021 Addendum Report (AOI-9), Section 4.3.2 (Contaminants of Concern), page 29. Evergreen is doing this because the Department decided not to proceed with a proposed statewide health standard of 2500 mg/kg for lead. But Evergreen is only doing this for samples in 2021. *See id.*, Section 4.4 (Lead in Surface Soil), Figure 4-8. Evergreen is not doing this for past sampling events discussed in previous reports.

b. It would be premature to approve the report because there is an unresolved question of the appropriateness of a site-specific standard for lead in surface soil.

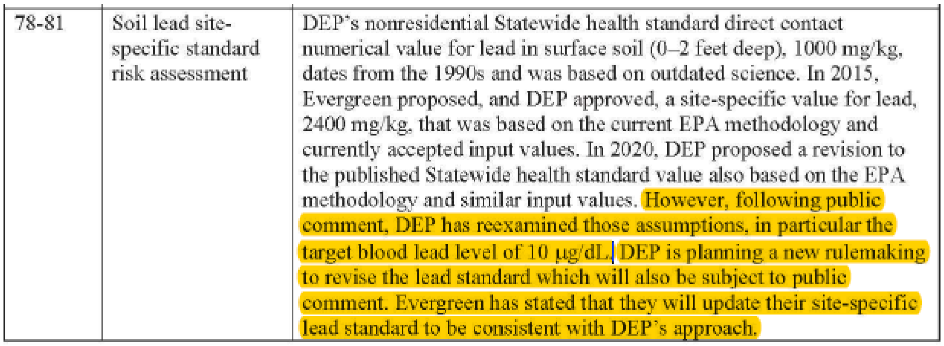
As it has done in successive reports, Evergreen continues to assume that the site-specific standard of 2240 mg/kg will continue to apply, despite the Department's withdrawal of the proposed statewide health standard of 2500 mg/kg. (Both standards were based on the premise that the target blood lead level should be 10 ug/dL, rather than 5 ug/dL). This is clear from the following statement:



4.4.3 Site-Specific Standard Comparison

Although this is likely to change in the future, the current selected standard for lead in surface soil at the former Philadelphia Refinery is 2,240 mg/kg as approved by the PADEP in 2014. At this time, Evergreen has not elected to change the selected standard due to the uncertainty regarding which model inputs PADEP will deem acceptable default values in its own calculations for direct contact exposure. Figure 4-10 shows lead results above the SSS of 2,240 mg/kg in red. There are 13 surface soil sample locations that exceed the SSS, and these locations are delineated to the currently selected SSS.

See 2021 Addendum Report (AOI-9), Section 4.4.3 (Site-Specific Standard Comparison), page 31. In its Memorandum in support of the technical deficiency letter, the Department states that it intends to introduce a new rulemaking to address the lead standard:



78-81	Soil lead site-specific standard risk assessment	DEP's nonresidential Statewide health standard direct contact numerical value for lead in surface soil (0–2 feet deep), 1000 mg/kg, dates from the 1990s and was based on outdated science. In 2015, Evergreen proposed, and DEP approved, a site-specific value for lead, 2400 mg/kg, that was based on the current EPA methodology and currently accepted input values. In 2020, DEP proposed a revision to the published Statewide health standard value also based on the EPA methodology and similar input values. However, following public comment, DEP has reexamined those assumptions, in particular the target blood lead level of 10 µg/dL. DEP is planning a new rulemaking to revise the lead standard which will also be subject to public comment. Evergreen has stated that they will update their site-specific lead standard to be consistent with DEP's approach.

See Attachment 3 -- Memorandum Relating to Letter of Technical Deficiency dated June 29, 2021, page 9. However, the Department has said nothing about what it contemplates for a statewide health standard or for a site-specific standard for this project.

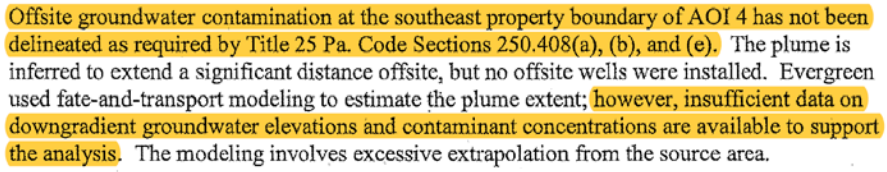
The arithmetic is not complicated. A site-specific standard calculated under EPA's Adult Lead Model with a target blood lead level of 5 ug/dL would be no greater than 1100 mg/kg, considering the other assumptions made by the Department when it drafted the Act 2 rulemaking that it later withdrew. The Department should explain how there could be any other result.

It would be unreasonable for the Department to approve the report where it is based on the premise that a site-specific standard of 2240 mg/kg applies, especially where the Department has stated that it intends to revise the lead standard in the future, without providing details.

3. Water Table in AOI-4.

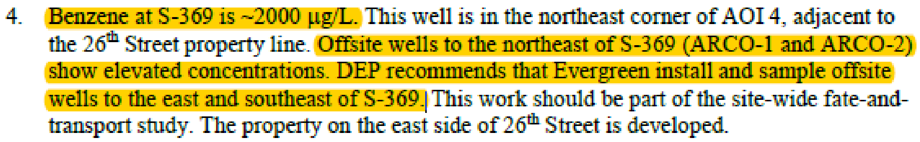
a. Evergreen should install monitoring wells to the east and southeast of S-369 in the northeast corner of AOI-4, as directed by the Department.

In disapproving the report for AOI-4, the Department noted that Evergreen had not properly delineated off-site groundwater contamination:



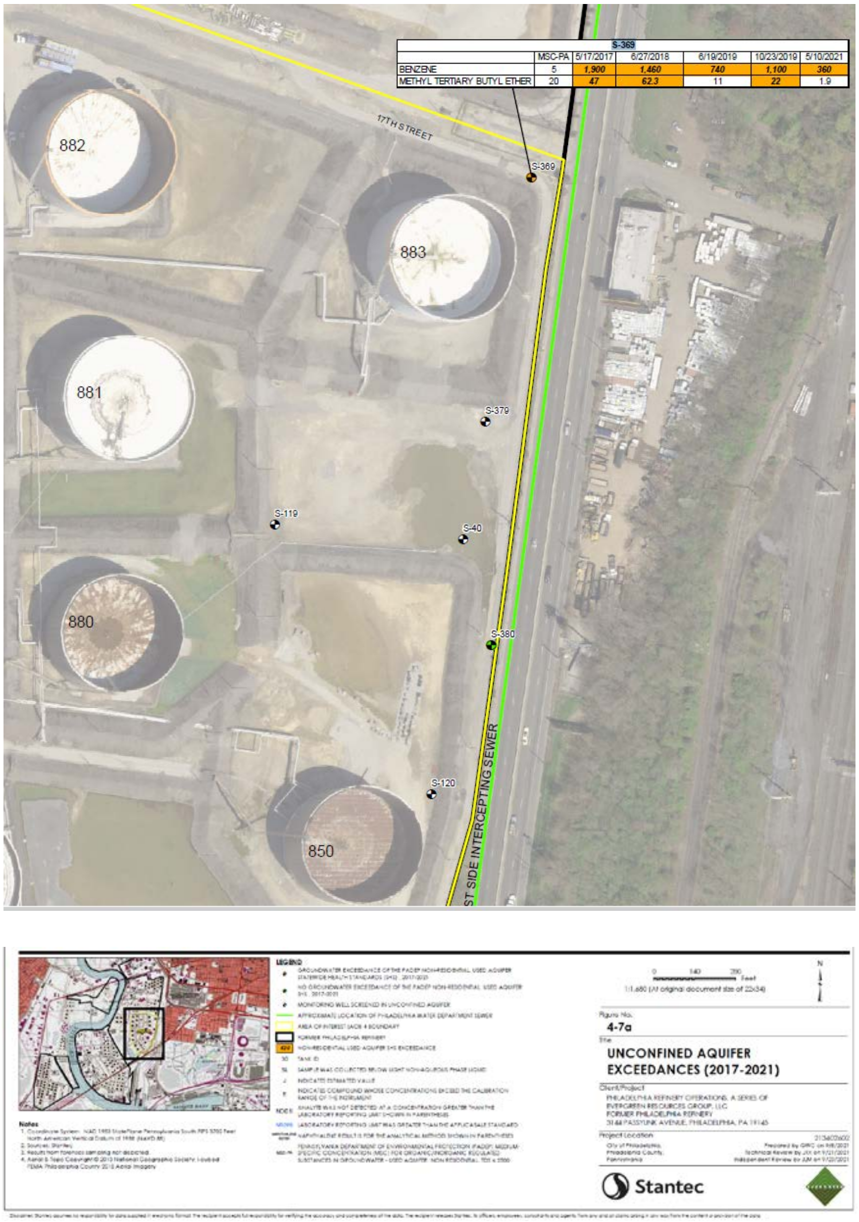
> Offsite groundwater contamination at the southeast property boundary of AOI 4 has not been delineated as required by Title 25 Pa. Code Sections 250.408(a), (b), and (e). The plume is inferred to extend a significant distance offsite, but no offsite wells were installed. Evergreen used fate-and-transport modeling to estimate the plume extent; however, insufficient data on downgradient groundwater elevations and contaminant concentrations are available to support the analysis. The modeling involves excessive extrapolation from the source area.

See AOI-4 PADEP Letter_RIR_20170621, page 1 (highlighting added for emphasis). To be more precise, in the comments the Department stated that Evergreen should install off-site wells to the east and southeast of S-369:



> 4. Benzene at S-369 is ~2000 µg/L. This well is in the northeast corner of AOI 4, adjacent to the 26th Street property line. Offsite wells to the northeast of S-369 (ARCO-1 and ARCO-2) show elevated concentrations. DEP recommends that Evergreen install and sample offsite wells to the east and southeast of S-369. This work should be part of the site-wide fate-and-transport study. The property on the east side of 26th Street is developed.

See AOI-4 PADEP Comments_RIR_20170629, page 1, Comment 4 (highlighting added for emphasis). According to Evergreen's report, S-369 is in the northeast corner of AOI-4:

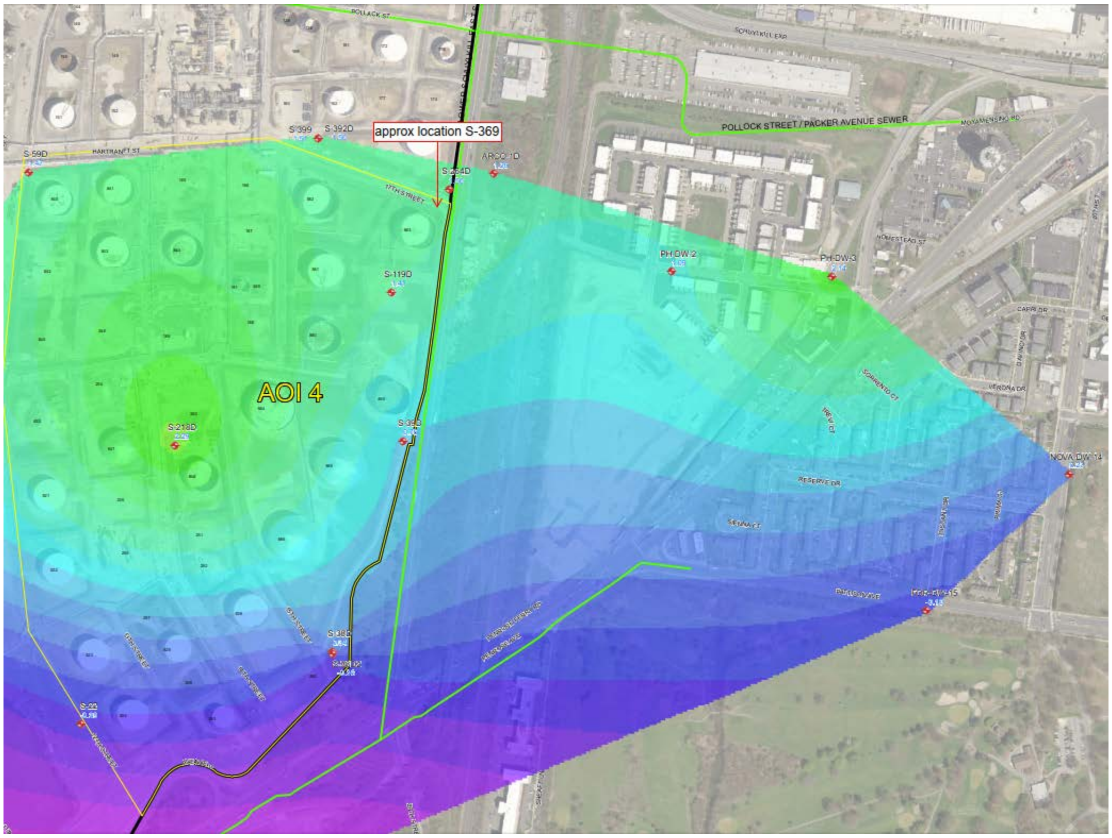


S-369						
	MSC-PA	5/17/2017	6/27/2018	6/19/2019	10/23/2019	5/10/2021
BENZENE	5	1,900	1,460	740	1,100	360
METHYL TERTIARY BUTYL ETHER	20	47	62.3	11	22	1.9

See id., Figure 4-7a, Unconfined Aquifer Exceedances (2017-2021)

But Evergreen disregarded the Department's request. It has not installed an off-site unconfined well anywhere near S-369. Instead, it has focused unconfined aquifer evaluations on the southernmost boundary of AOI-4 near the Penrose Avenue remedial system.

Sunoco has access to deep aquifer wells to the east and southeast of S-369 where similarly placed shallow aquifer wells could be positioned. Figure 4-2a of the 2021 Addendum Report illustrates the access and recent gaging of lower aquifer wells positioned off-site and east and southeast of S-369:

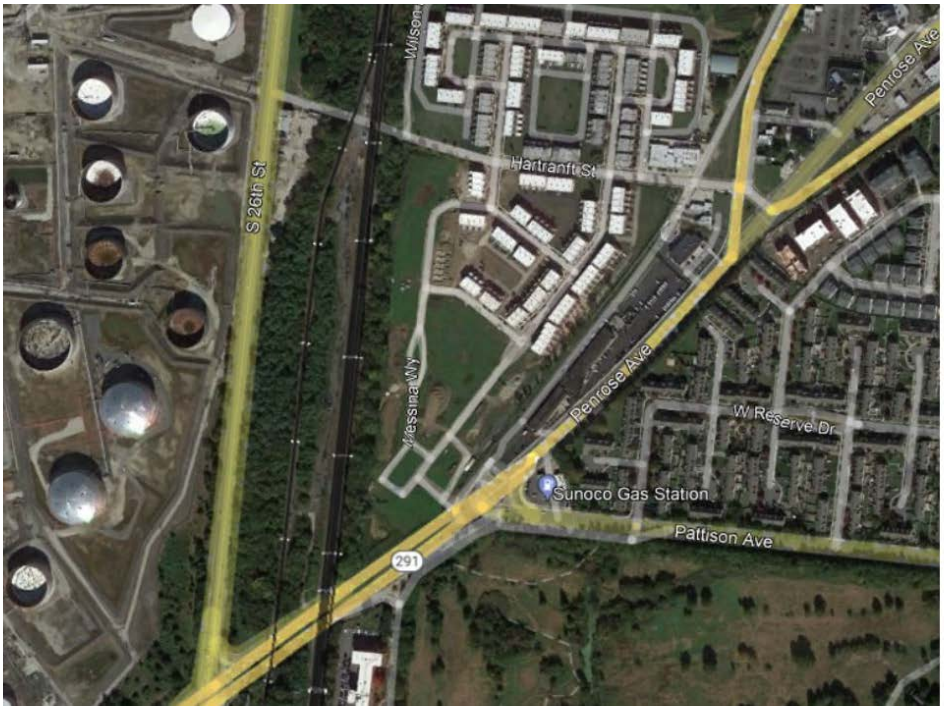


See 2021 Addendum Report (AOI-4), Figure 4-2a - Lower Aquifer Elevation June 2019 (pdf page 161 of 307).

In addition to positioning shallow wells next to off-site deep wells pictured above in Figure 4-2a (ARCO 1D, PH-DW-2, PH-DW-3, NOVA-DW-14 and FDR-DW-15), Sunoco has access to unconfined wells to the east (PH-MW-57, PH-MWS-15, PH-MW-56, ARCO 2) as demonstrated in the 2016 remedial investigation report for AOI-1:

See Philadelphia Refinery_AOI 1 RIR_8-5-16_Part1, page 110, Figure 5-5 (May 2015 Water Table Elevation - Including Synoptic DSCP Gauging Data).

The following 2021 aerial view of the area east of AOI-4 shows many options for placing off-site unconfined wells:

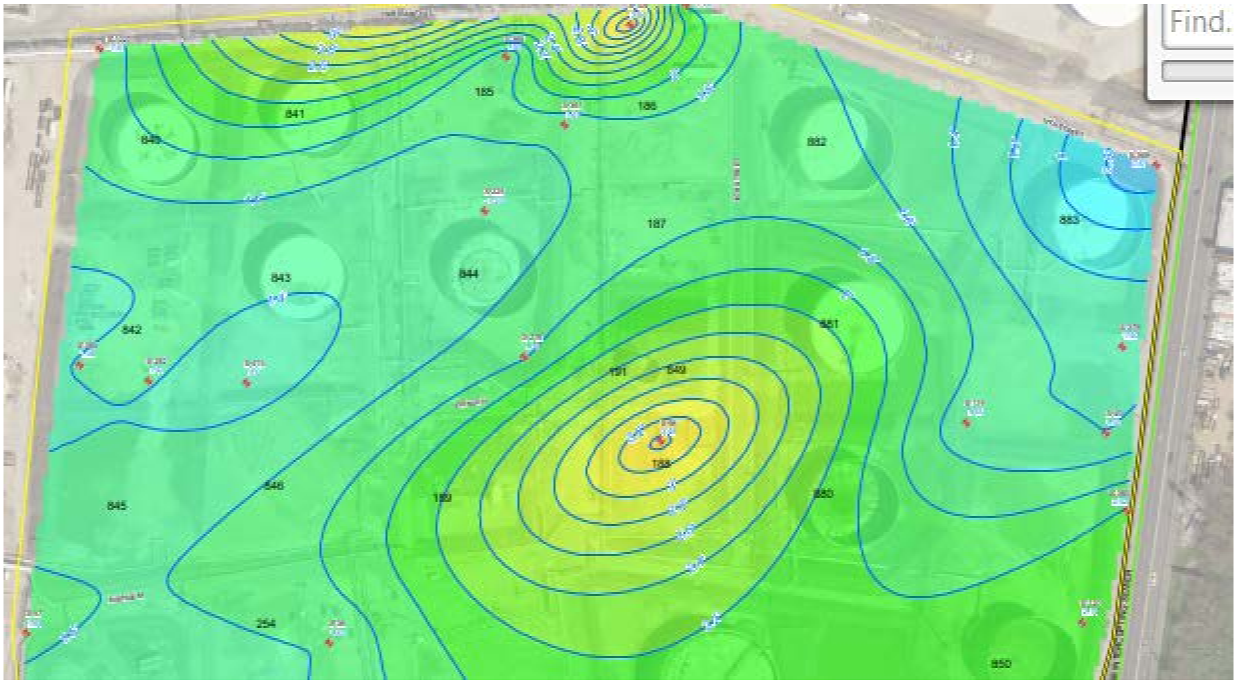


See Google Earth aerial view east of S-369 and AOI-4 (October 2021). Sunoco could locate monitoring wells between South 26th St and the railroad, which separate AOI-4 from the residentially developed lands to the east. Open space on the residentially developed area may afford additional well placement options. Without off-site monitoring wells to the east and southeast, the extent of contamination cannot be delineated.

The mapping of the shallow groundwater elevations in the vicinity of S-369 as presented in Figures 4-1a through 4-1e of the 2021 addendum report is based on gaging events in November 2018, June 2019, October 2019, December 2020 and April of 2021. But two of the five events exclude the S-369 area and four of the five exclude groundwater contouring in areas off-site to the east and southeast of S-369.

Conversely, Sunoco maps the lower aquifer flow using similar dates and includes the gaging of on- and off-site wells with mapping groundwater elevations in areas beyond the AOI-4 boundary. The Department should require Sunoco's groundwater elevation and contamination mapping of the unconfined aquifer to be made robust.

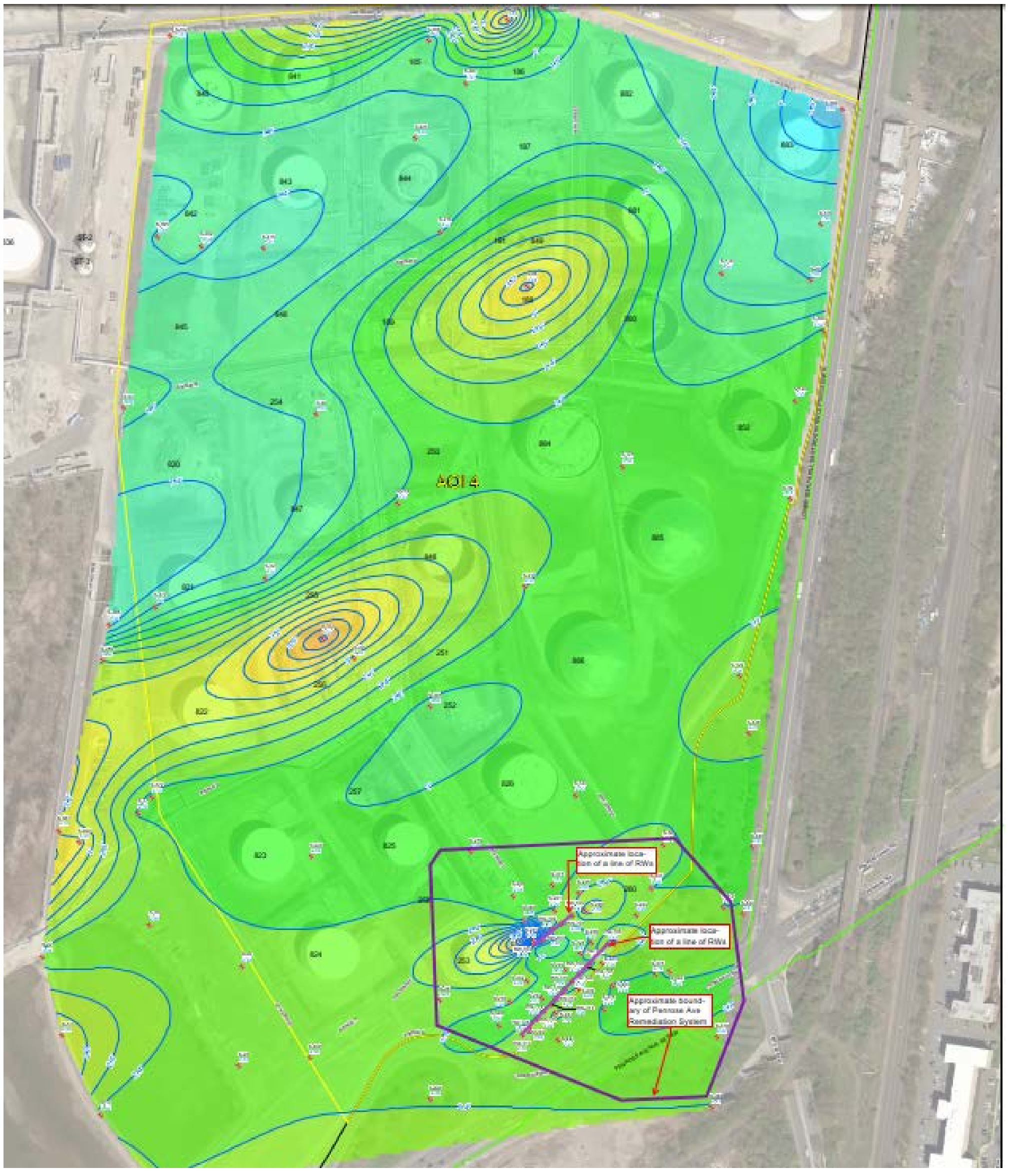
Furthermore, the Sunoco groundwater elevation mapping of the shallow water table shown on Figures 4-1a through 4-1e illustrate unexplained contours that may influence flow direction and contamination delineations on-site. An example is shown below in the snip of the northern portion of Figure 4-1e, showing a groundwater mound centering on shallow on-site wells (S-104 and S-96).



See 2021 Addendum Report (AOI-4), Figure 4-1e (Unconfined Aquifer Elevation April 2021).

Cross referencing Figure 4-1e with the location of the Penrose remediation system and extraction points, it appears that potential groundwater mounds centering on shallow monitoring wells (S-104, S-96, S-371) are not explained. Perhaps remedial systems, perching conditions, well construction or other factors can be attributed to the contours surrounding these wells taking a mounding shape. But this should be analyzed.

Such overlays may also help to explain the shapes of other areas contoured on Sunoco Figures 4-1a through 4-1e (perhaps with mounded, drawdown, convergence around sewers, or other unexplained shapes). An example of an overlay for the Penrose remediation system is shown below superimposed on Figure 4-1e:



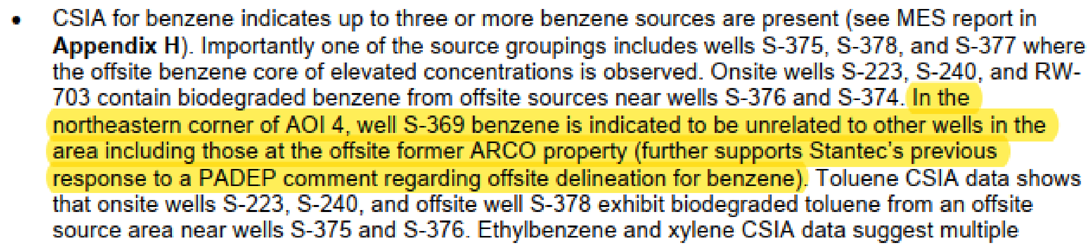
See id., Figure 4-1e - Unconfined Aquifer Elevation April 2021, with Penrose Ave Remediation system polygon, line and point features superimposed. Other areas of AOI-4 and adjoining boundaries should be overlain similarly.

On the shallow water table elevation maps, Sunoco should overlay collector sewers that convey to the main interceptor sewers, and overlay remediation system boundaries as polygons, and extraction and injection line or point features. This information is important for analyzing and interpreting groundwater elevations and the extent of contamination.

In Sunoco's consultant's August 30, 2017 response to Comment 4 from the Department's June 29, 2017 Report, the reason offered for not adding unconfined wells to the east and southeast of S-369 is that the sewer along 26th Street is serving as a sink and that furthermore the direction of flow in this area is from the east. *See* Letter from Stantec Consulting Services, Inc., to C. David Brown, Pennsylvania Department of Environmental Protection, page 2.

Sunoco's consultant supports (in part) the assertion that the sewer is acting as a sink by presenting a contour map of the unconfined aquifer for June/July 2008. However, that map and a similar one included in the current report (Figure 4-1b for June 2019) show that the contours in the northeast portion of AOI-4 are primarily governed by a cone of depression centered on S-259 to the north in AOI-1. While the 2016 report for AOI-1 makes no mention of a remediation system operating here, it is clear that there is a groundwater sink in this area. This sink may indeed be a breach in the sewer located north of AOI-4, but that does not change the probability that the high concentrations of benzene detected in S-369 are migrating off AOI-4.

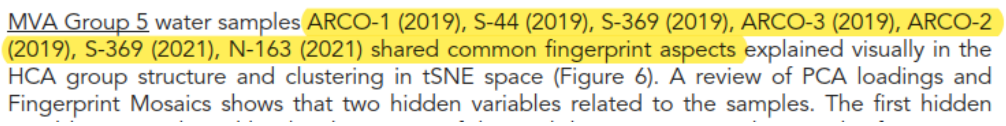
Nearby (to the east) well ARCO-1 was sampled during this reporting period and does have elevated benzene present. Sunoco's consultant suggests that S-369 is unrelated to the ARCO wells to the east:



- CSIA for benzene indicates up to three or more benzene sources are present (see MES report in **Appendix H**). Importantly one of the source groupings includes wells S-375, S-378, and S-377 where the offsite benzene core of elevated concentrations is observed. Onsite wells S-223, S-240, and RW-703 contain biodegraded benzene from offsite sources near wells S-376 and S-374. In the northeastern corner of AOI 4, well S-369 benzene is indicated to be unrelated to other wells in the area including those at the offsite former ARCO property (further supports Stantec's previous response to a PADEP comment regarding offsite delineation for benzene). Toluene CSIA data shows that onsite wells S-223, S-240, and offsite well S-378 exhibit biodegraded toluene from an offsite source area near wells S-375 and S-376. Ethylbenzene and xylene CSIA data suggest multiple

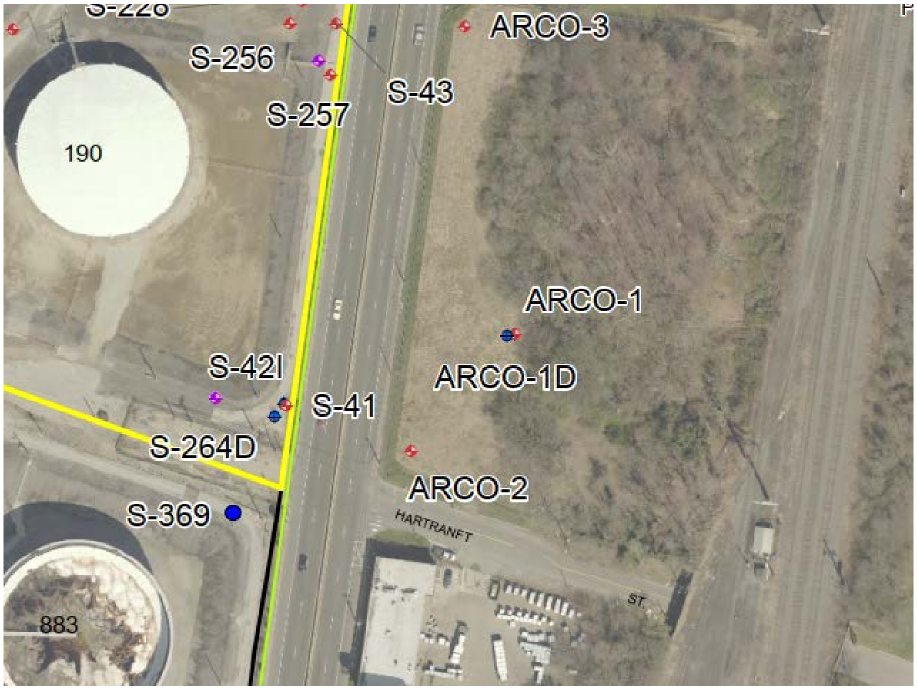
See 2021 Addendum Report (AOI-4), pdf page 45 of 307.

However, in the Multi-Variant Analysis performed by ChemQuants, the report states:



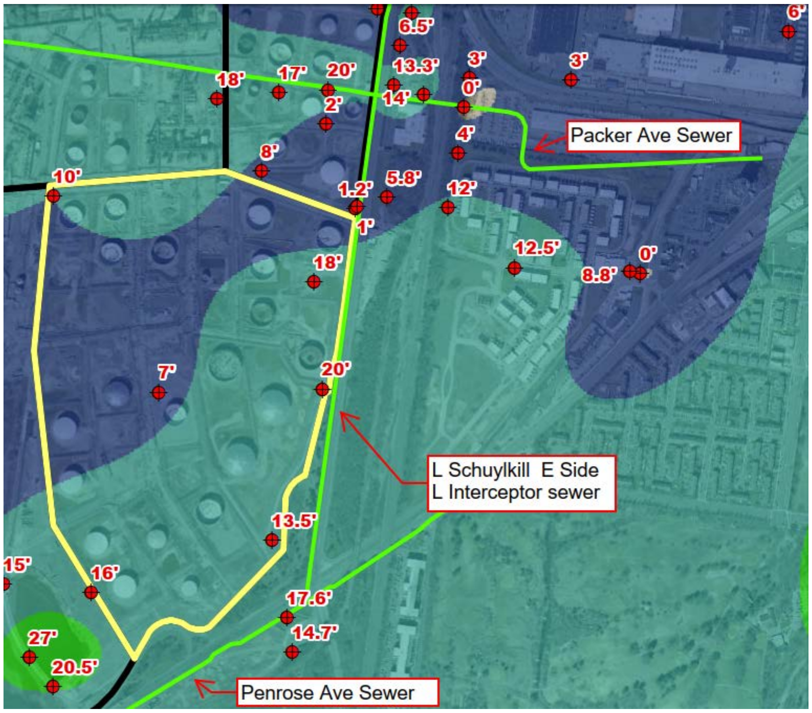
MVA Group 5 water samples ARCO-1 (2019), S-44 (2019), S-369 (2019), ARCO-3 (2019), ARCO-2 (2019), S-369 (2021), N-163 (2021) shared common fingerprint aspects explained visually in the HCA group structure and clustering in tSNE space (Figure 6). A review of PCA loadings and Fingerprint Mosaics shows that two hidden variables related to the samples. The first hidden

See 2021 Addendum Report (AOI-4), part 3, pdf page 823 of 1779. That report links S-369 to the ARCO wells to the east, which are shown below in Figure 6-3 of the 2016 RIR for AOI-1:



See Philadelphia Refinery_AOI 1 RIR_8-5-16_Part1, pdf page 116 of 261 (Figure 6-3 - Estimated LNAPL Extent In AOI-1 And Vicinity).

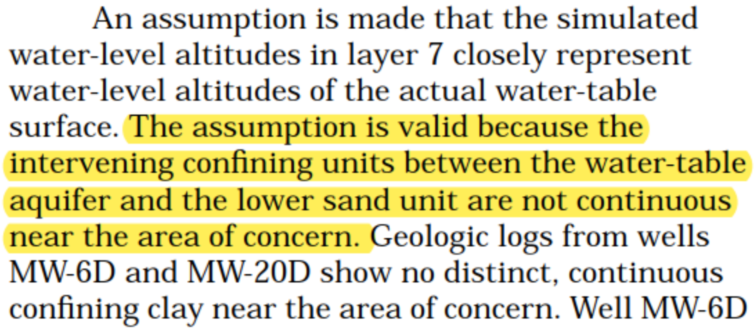
The area surrounding S-369 and the aforementioned sink also has a thin to absent middle clay, as demonstrated by the isopach mapping of the middle clay unit Figure 4-14 of the 2021 addendum report:



See 2021 Addendum Report (AOI-4), pdf page 177 of 307, Figure 4-14 (Isopach Map of the Middle Clay United Aquitard). Sunoco has not provided an assessment of the vertical downward gradients and their influence on the unconfined aquifer groundwater flow in this location. An alternative explanation may be the sink is being influenced by vertical downward gradients.

In fact, when evaluating the impacts of the Packer Avenue sewer on hydrocarbon plume migration in the vicinity of the Defense Facility Supply and Sunoco sites, this sewer was not shown to be a barrier (see USGS, 2001, modeling of the Defense Supply Center Philadelphia / Point Breeze Refinery Area by the U.S. Geological Survey). The USGS conclusions of 2001 were supported by a Modflow model, which demonstrated contaminated groundwater flow was unimpeded by the sewer. The model also showed downward vertical gradients. A similar evaluation of other sewers effects on the migration of contamination would be critical to understanding groundwater flow and substantiate Sunoco's assertion of groundwater flow converging on the sewer in the vicinity of S-369.

Sunoco's consultant further asserted in the August 30, 2017 comment response letter that the groundwater in the area of S-369 is flowing from the east to the west, but did not provide sufficient on- or off-site groundwater gaging to support this. 2001 modeling of the Defense Supply Center Philadelphia / Point Breeze Refinery Area by the U.S. Geological Survey supports a <u>southeast flow direction</u> in a modeled area. That report states as follows:



> An assumption is made that the simulated water-level altitudes in layer 7 closely represent water-level altitudes of the actual water-table surface. The assumption is valid because the intervening confining units between the water-table aquifer and the lower sand unit are not continuous near the area of concern. Geologic logs from wells MW-6D and MW-20D show no distinct, continuous confining clay near the area of concern. Well MW-6D

See Attachment 4 -- U.S. Geological Survey, U.S. DOI, Simulation of Ground-Water Flow in the Potomac-Raritan-Magothy Aquifer System Near the Defense Supply Center Philadelphia, and the Point Breeze Refinery, Southern Philadelphia County, Pennsylvania, at page 51, (2001) https://pubs.usgs.gov/wri/2001/4218/wri20014218.pdf [hereinafter "USGS 2001 Flow Report"] (highlighting added for emphasis).

The report goes on to state that from 1947 through 1995, a hydrocarbon plume could have been migrating to the southeast, unimpeded by the sewer:

Because historical ground-water-flow directions were predominately to the southeast, the Packer Avenue sewer would have been a barrier to hydrocarbon plume migration to the southeast from 1900 to 1947. Subsequent to 1947 through 1995 the hydrocarbon plume could have been migrating to the southeast, unimpeded by the sewer. Also, the simulated hydrographs on figure 47 show the consistent lower head in layer 7 (compared to layer 1) at cells 16,30 and 17,30, which indicates downward vertical ground-water-flow gradients.

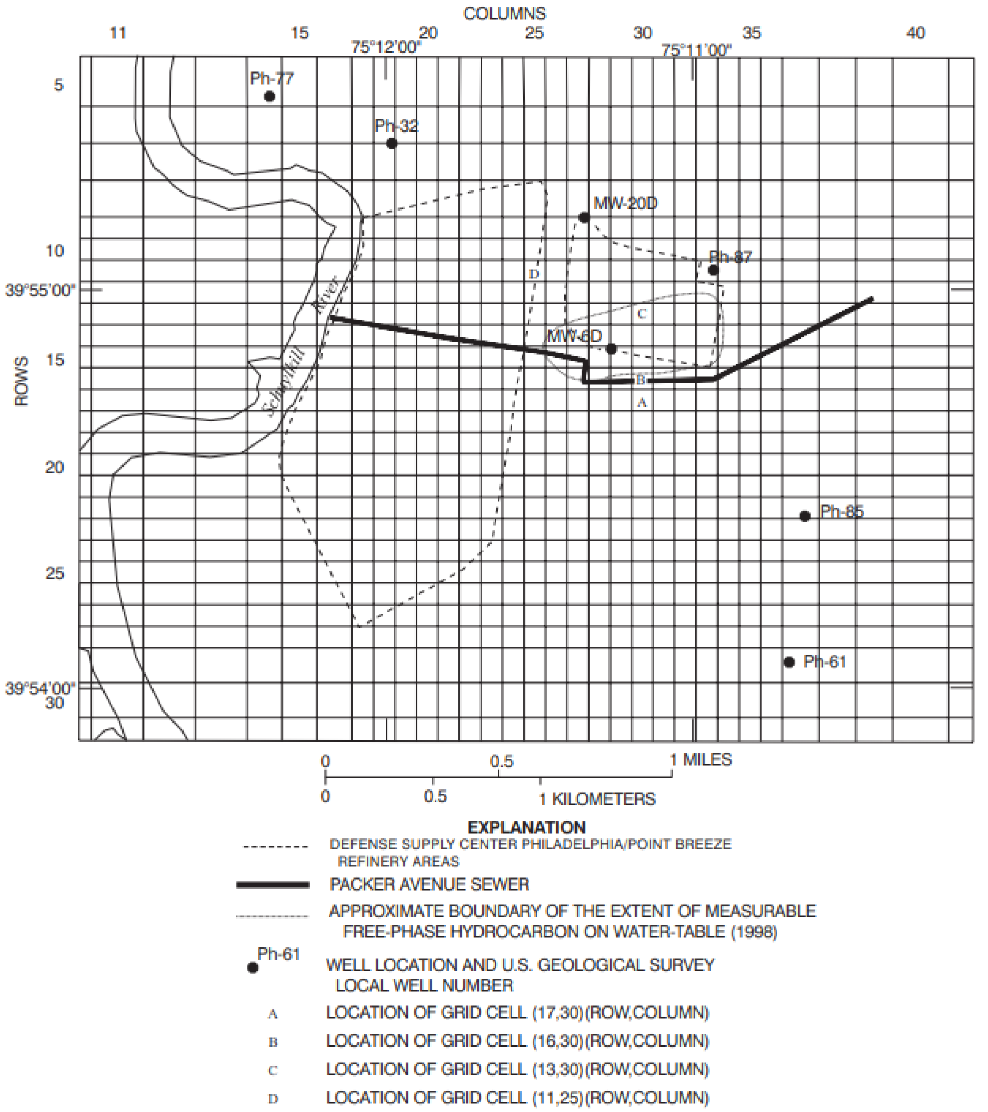
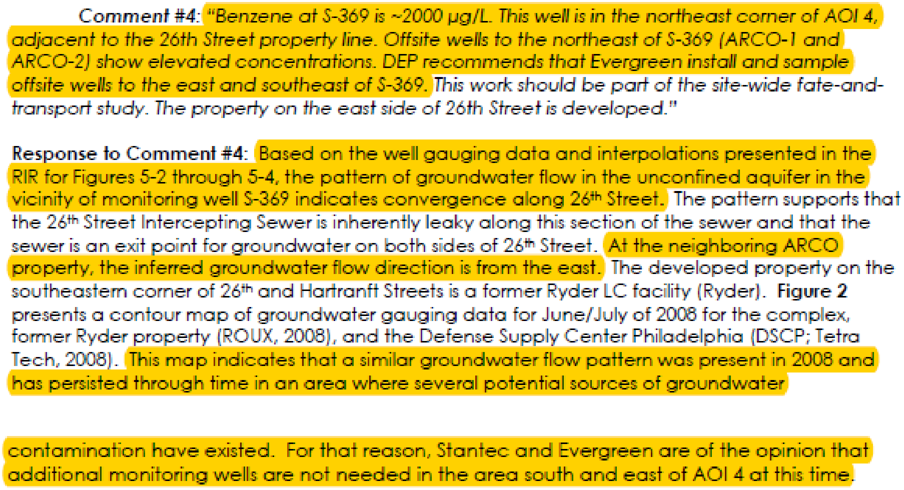


Figure 39. The Defense Supply Center Philadelphia/Point Breeze Refinery area showing selected observation wells, selected grid cell locations, and the Packer Avenue sewer.

See id. at 53.

Sunoco inferred groundwater flow direction is from the east at the ARCO (aka Defense Supply Center) property, which conflicts with the USGS 2001 Flow Report.



Comment #4: "Benzene at S-369 is ~2000 µg/L. This well is in the northeast corner of AOI 4, adjacent to the 26th Street property line. Offsite wells to the northeast of S-369 (ARCO-1 and ARCO-2) show elevated concentrations. DEP recommends that Evergreen install and sample offsite wells to the east and southeast of S-369. This work should be part of the site-wide fate-and-transport study. The property on the east side of 26th Street is developed."

Response to Comment #4: Based on the well gauging data and interpolations presented in the RIR for Figures 5-2 through 5-4, the pattern of groundwater flow in the unconfined aquifer in the vicinity of monitoring well S-369 indicates convergence along 26th Street. The pattern supports that the 26th Street Intercepting Sewer is inherently leaky along this section of the sewer and that the sewer is an exit point for groundwater on both sides of 26th Street. At the neighboring ARCO property, the inferred groundwater flow direction is from the east. The developed property on the southeastern corner of 26th and Hartranft Streets is a former Ryder LC facility (Ryder). **Figure 2** presents a contour map of groundwater gauging data for June/July of 2008 for the complex, former Ryder property (ROUX, 2008), and the Defense Supply Center Philadelphia (DSCP; Tetra Tech, 2008). This map indicates that a similar groundwater flow pattern was present in 2008 and has persisted through time in an area where several potential sources of groundwater

contamination have existed. For that reason, Stantec and Evergreen are of the opinion that additional monitoring wells are not needed in the area south and east of AOI 4 at this time.

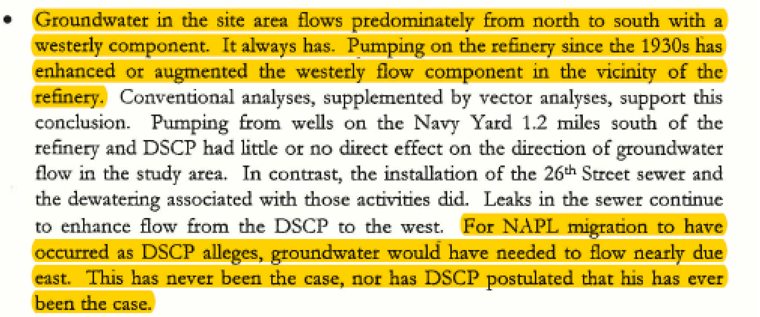
See AOI-4 Evergreen Response_RIR_20170830, pages 2-3 (highlighting added for emphasis).

b. Evergreen and the Department have not addressed the longstanding question of the direction of the flow of contaminants east of AOI-4, which was raised previously in connection with the investigation of the Defense Supply Center Philadelphia.

This is important because the direction of flow of contamination in the groundwater has not been established. The Defense Supply Center Philadelphia has attributed it to Sunoco, and Sunoco has denied this.

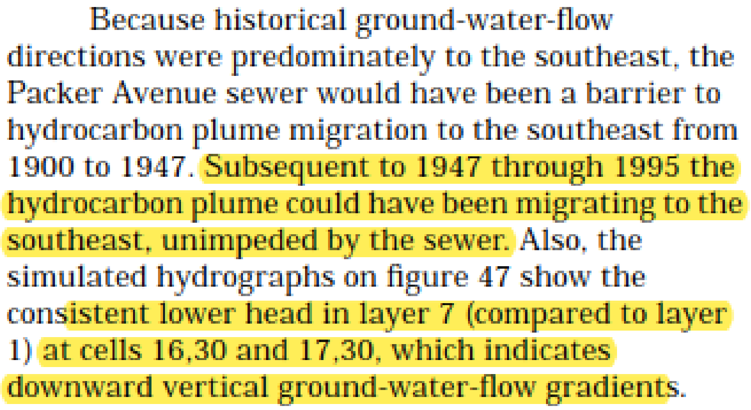
In a report in 1998, Integrated Science & Technology (a consultant to Sunoco) prepared a remedial investigation report relating to the Defense Supply Center Philadelphia, located to the east of 26th Street. This was done in connection with a remedial investigation for a facility to be closed under the 1993 Base Realignment and Closure Program. Sunoco's consultant concluded that "the refinery is not the source of the NAPL plume beneath the DSCP site." IST (1998). Non-Aqueous Phase Liquid (NAPL) Source Study at Defense Supply Center Philadelphia V1 (March 1998) (392 pages), Section 9 (Summary and Conclusions, page 9-3) [hereinafter "IST Report"]. This conclusion was based on five questionable premises.

The first premise was that contamination would have to flow nearly due east from the refinery, given the general nature of groundwater flow in the area:



- Groundwater in the site area flows predominately from north to south with a westerly component. It always has. Pumping on the refinery since the 1930s has enhanced or augmented the westerly flow component in the vicinity of the refinery. Conventional analyses, supplemented by vector analyses, support this conclusion. Pumping from wells on the Navy Yard 1.2 miles south of the refinery and DSCP had little or no direct effect on the direction of groundwater flow in the study area. In contrast, the installation of the 26th Street sewer and the dewatering associated with those activities did. Leaks in the sewer continue to enhance flow from the DSCP to the west. For NAPL migration to have occurred as DSCP alleges, groundwater would have needed to flow nearly due east. This has never been the case, nor has DSCP postulated that his has ever been the case.

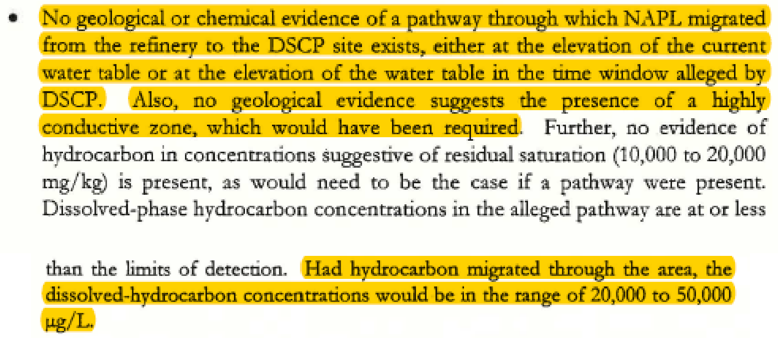
Id., page 9-2. This premise is questionable because page 53 of the USGS 2001 Flow Report suggests that shallow groundwater flows unimpeded by the sewer and to the southeast in the modeled area including AOI-4. Furthermore, the report cites clays separating the shallow from the lower aquifer in this area are discontinuous and cites downward gradients. *See* USGS Flow Report at 45. While the sewers drain by gravity towards the Schuylkill, the downward gradients could have a significant impact on the shallow groundwater flow resulting in flow away from as opposed to towards the Schuylkill:



Because historical ground-water-flow directions were predominately to the southeast, the Packer Avenue sewer would have been a barrier to hydrocarbon plume migration to the southeast from 1900 to 1947. Subsequent to 1947 through 1995 the hydrocarbon plume could have been migrating to the southeast, unimpeded by the sewer. Also, the simulated hydrographs on figure 47 show the consistent lower head in layer 7 (compared to layer 1) at cells 16,30 and 17,30, which indicates downward vertical ground-water-flow gradients.

USGS Flow Report at 45.

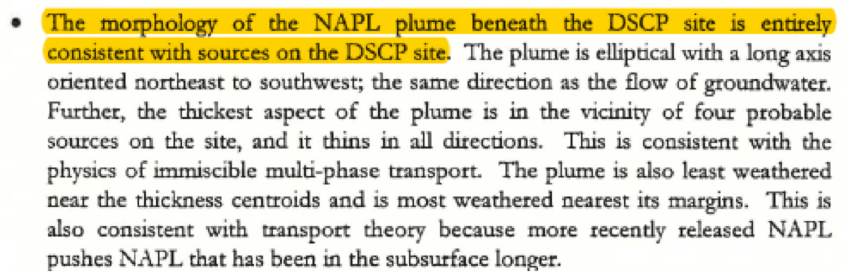
The second premise was that there was no evidence of a highly conductive zone that would have been required:



- No geological or chemical evidence of a pathway through which NAPL migrated from the refinery to the DSCP site exists, either at the elevation of the current water table or at the elevation of the water table in the time window alleged by DSCP. Also, no geological evidence suggests the presence of a highly conductive zone, which would have been required. Further, no evidence of hydrocarbon in concentrations suggestive of residual saturation (10,000 to 20,000 mg/kg) is present, as would need to be the case if a pathway were present. Dissolved-phase hydrocarbon concentrations in the alleged pathway are at or less than the limits of detection. Had hydrocarbon migrated through the area, the dissolved-hydrocarbon concentrations would be in the range of 20,000 to 50,000 µg/L.

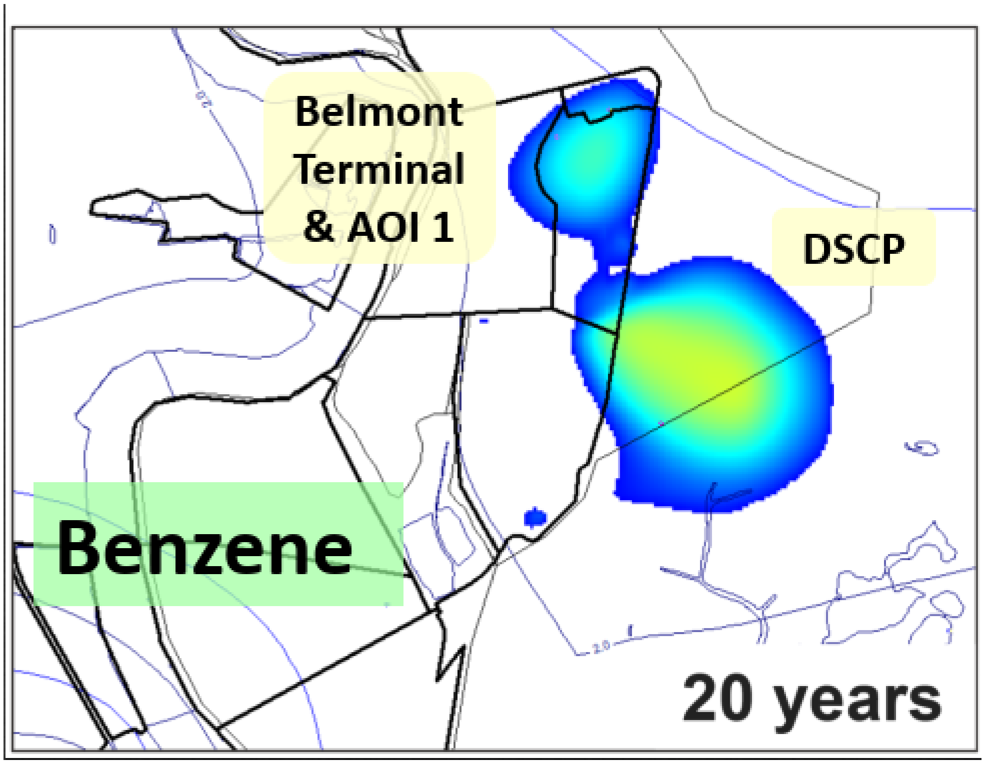
IST Report, page 9-2 to 9-3. This premise is questionable because the 2001 USGS Flow Report cites the surficial aquifer to have a hydraulic conductivity in the horizontal direction of 5.5 ft/day. *See* Table 2, page 20. And while this is not highly conductive, it is nonetheless conductive. The USGS Report also cites the clays separating the shallow from the lower aquifer in this area are discontinuous and similarly conductive in the vertical direction. 2001 USGS Flow Report at 6, 21. Thus the effects of downward gradients would impart influence on the contamination concentration.

The third premise was that the morphology of the plume on the Defense Supply Center Philadelphia site was consistent with sources on that site:



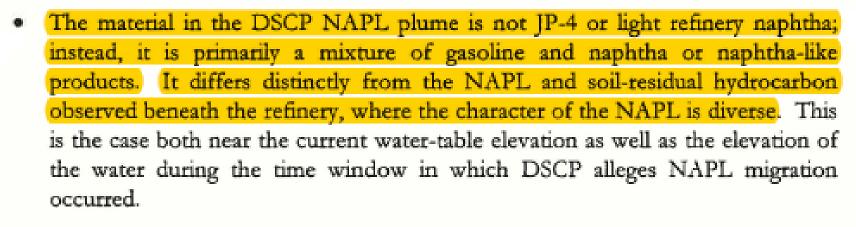
- The morphology of the NAPL plume beneath the DSCP site is entirely consistent with sources on the DSCP site. The plume is elliptical with a long axis oriented northeast to southwest; the same direction as the flow of groundwater. Further, the thickest aspect of the plume is in the vicinity of four probable sources on the site, and it thins in all directions. This is consistent with the physics of immiscible multi-phase transport. The plume is also least weathered near the thickness centroids and is most weathered nearest its margins. This is also consistent with transport theory because more recently released NAPL pushes NAPL that has been in the subsurface longer.

IST Report, page 9-3. This premise is questionable because in 2019, the Department's modeling showed a modeled plume that is trending northwest to southeast. This trend supports the modeling from the 2001 USGS Flow Report and suggests the plume morphology is consistent with sources from AOI-1 and AOI-4:



Attachment 5 -- PA Department of Environmental Protection, Cleanup of the Philadelphia Refinery Report to the City of Philadelphia Refinery Advisory Group Environmental and Academic Committee Meeting, August 27, 2019, slide 29.

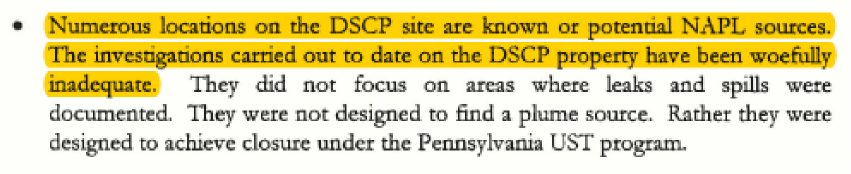
The fourth premise was that the plume was primarily a mixture of gasoline and naphtha or naphtha-like products, and not JP-4 or light refinery naphtha:



- The material in the DSCP NAPL plume is not JP-4 or light refinery naphtha; instead, it is primarily a mixture of gasoline and naphtha or naphtha-like products. It differs distinctly from the NAPL and soil-residual hydrocarbon observed beneath the refinery, where the character of the NAPL is diverse. This is the case both near the current water-table elevation as well as the elevation of the water during the time window in which DSCP alleges NAPL migration occurred.

Id., page 9-3. This premise is not relevant to whether the contamination at S-369 is migrating off-site, because benzene and other aromatic hydrocarbons are constituents of all these refined petroleum products. The fact that petroleum product sources were found at the DSCP does not imply that benzene contamination detected east of AOI-4 is not related to the contamination present at S-369.

The fifth premise was that numerous locations on that site were known or potential NAPL sources:



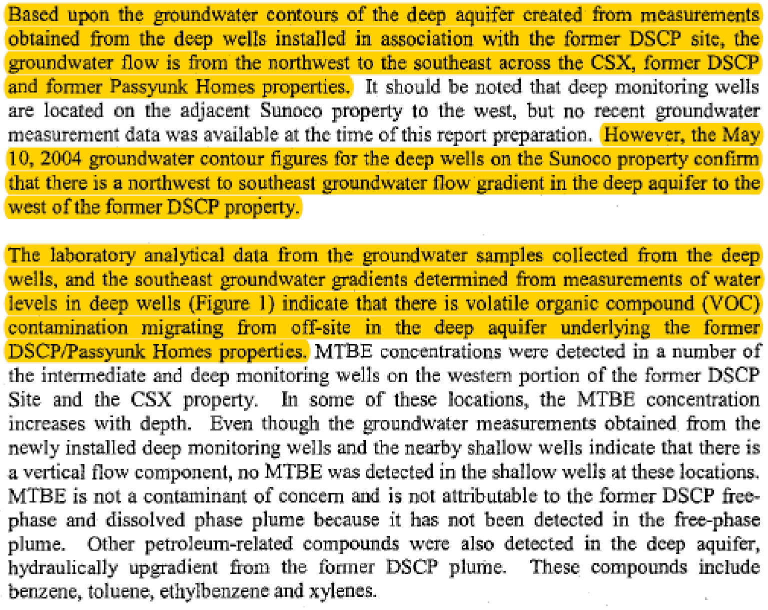
- Numerous locations on the DSCP site are known or potential NAPL sources. The investigations carried out to date on the DSCP property have been woefully inadequate. They did not focus on areas where leaks and spills were documented. They were not designed to find a plume source. Rather they were designed to achieve closure under the Pennsylvania UST program.

Id., page 9-3. As with the previous premise, this is not relevant because the fact that petroleum product sources were not adequately delineated at the DSCP does not imply that benzene contamination detected east of AOI-4 is not related to the contamination present at S-369.

Sunoco's consultant also prepared the following documents, which do not expressly address the question of the direction of the migration of groundwater between the aquifer under the refinery and the aquifer under the Defense Supply Center Philadelphia:

1. IST (1998). Non-Aqueous Phase Liquid (NAPL) Source Study at Defense Supply Center Philadelphia V2.pdf (544 pages) (boring logs going back to at least 1984)
2. IST (1998). Non-Aqueous Phase Liquid (NAPL) Source Study at Defense Supply Center Philadelphia V3.pdf (181 pages) (documents relating to hydraulic conductivity)
3. IST (1998). Non-Aqueous Phase Liquid (NAPL) Source Study at Defense Supply Center Philadelphia V4.pdf (3112 pages) (laboratory reports)
4. IST (2008). December 2007 Summary. Unpublished study (54 pages) (Appendix A contains subsurface logs).

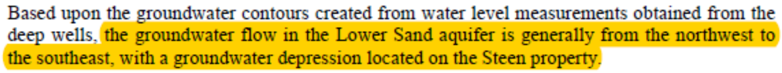
Tetra Tech (a consultant for the Defense Energy Support Center) drew the opposite conclusions of Sunoco in a report that concluded that VOC contamination was migrating from an off-site source onto the DSCP site and former Passyunk Homes properties:



Based upon the groundwater contours of the deep aquifer created from measurements obtained from the deep wells installed in association with the former DSCP site, the groundwater flow is from the northwest to the southeast across the CSX, former DSCP and former Passyunk Homes properties. It should be noted that deep monitoring wells are located on the adjacent Sunoco property to the west, but no recent groundwater measurement data was available at the time of this report preparation. However, the May 10, 2004 groundwater contour figures for the deep wells on the Sunoco property confirm that there is a northwest to southeast groundwater flow gradient in the deep aquifer to the west of the former DSCP property.

The laboratory analytical data from the groundwater samples collected from the deep wells, and the southeast groundwater gradients determined from measurements of water levels in deep wells (Figure 1) indicate that there is volatile organic compound (VOC) contamination migrating from off-site in the deep aquifer underlying the former DSCP/Passyunk Homes properties. MTBE concentrations were detected in a number of the intermediate and deep monitoring wells on the western portion of the former DSCP Site and the CSX property. In some of these locations, the MTBE concentration increases with depth. Even though the groundwater measurements obtained from the newly installed deep monitoring wells and the nearby shallow wells indicate that there is a vertical flow component, no MTBE was detected in the shallow wells at these locations. MTBE is not a contaminant of concern and is not attributable to the former DSCP free-phase and dissolved phase plume because it has not been detected in the free-phase plume. Other petroleum-related compounds were also detected in the deep aquifer, hydraulically upgradient from the former DSCP plume. These compounds include benzene, toluene, ethylbenzene and xylenes.

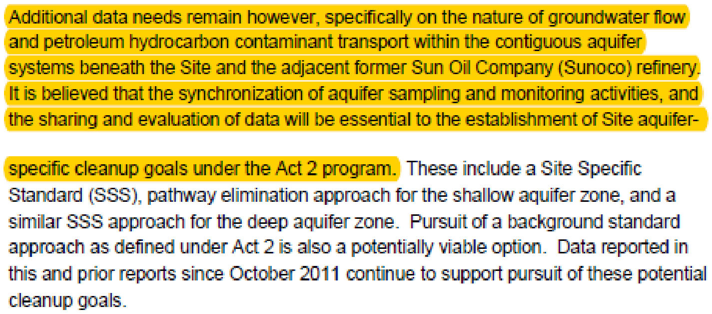
See Tetra Tech (2005). Intermediate and Deep Well Installation and Sampling Report for the Former DSCP (July 30, 2005) (269 pages), Section 7.0 (Conclusion), page 16. It drew a similar conclusion in another report two years later:



Based upon the groundwater contours created from water level measurements obtained from the deep wells, the groundwater flow in the Lower Sand aquifer is generally from the northwest to the southeast, with a groundwater depression located on the Steen property.

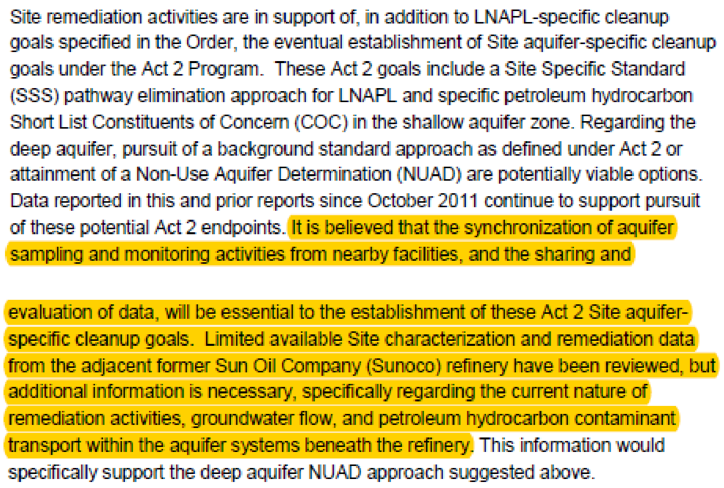
Tetra Tech (2007). 2006-2007 Intermediate and Deep Well Installation and Sampling Report for the Former DSCP (July 24, 2005) (209 pages)

Later reports prepared by a consultant for the defense facility (technically, for the United States Army Engineer District, Philadelphia) concerning O&M for the facility indicated that additional information relating to the nature of this groundwater flow was necessary:

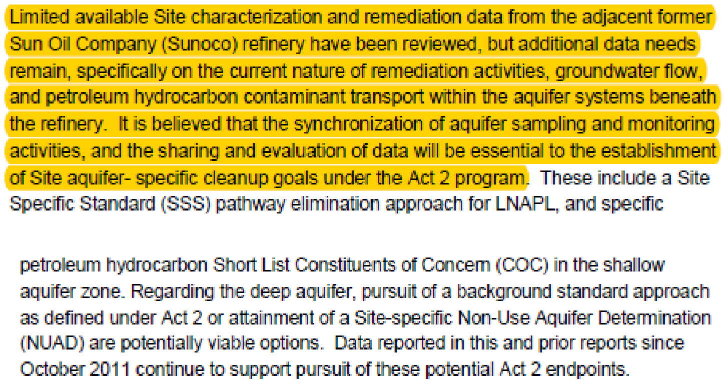


Additional data needs remain however, specifically on the nature of groundwater flow and petroleum hydrocarbon contaminant transport within the contiguous aquifer systems beneath the Site and the adjacent former Sun Oil Company (Sunoco) refinery. It is believed that the synchronization of aquifer sampling and monitoring activities, and the sharing and evaluation of data will be essential to the establishment of Site aquifer-specific cleanup goals under the Act 2 program. These include a Site Specific Standard (SSS), pathway elimination approach for the shallow aquifer zone, and a similar SSS approach for the deep aquifer zone. Pursuit of a background standard approach as defined under Act 2 is also a potentially viable option. Data reported in this and prior reports since October 2011 continue to support pursuit of these potential cleanup goals.

ARCADIS (2013). Second Quarter 2013 Report for the Former Defense Supply Center Philadelphia Facility, Philadelphia, PA (July 31, 2013) (33 pages), Executive Summary, pages 2-3. Similar statements were made in reports submitted the following year:


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.

ARCADIS (2014a). Fourth Quarter 2013 and Calendar Year 2013 Summary Progress Report for the Former DSCP (February 15, 2014) (46 pages), Executive Summary, pages 2-3.


Limited available Site characterization and remediation data from the adjacent former Sun Oil Company (Sunoco) refinery have been reviewed, but additional data needs remain, specifically on the current nature of remediation activities, groundwater flow, and petroleum hydrocarbon contaminant transport within the aquifer systems beneath the refinery. It is believed that the synchronization of aquifer sampling and monitoring activities, and the sharing and evaluation of data will be essential to the establishment of Site aquifer- specific cleanup goals under the Act 2 program. These 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 Site-specific 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.

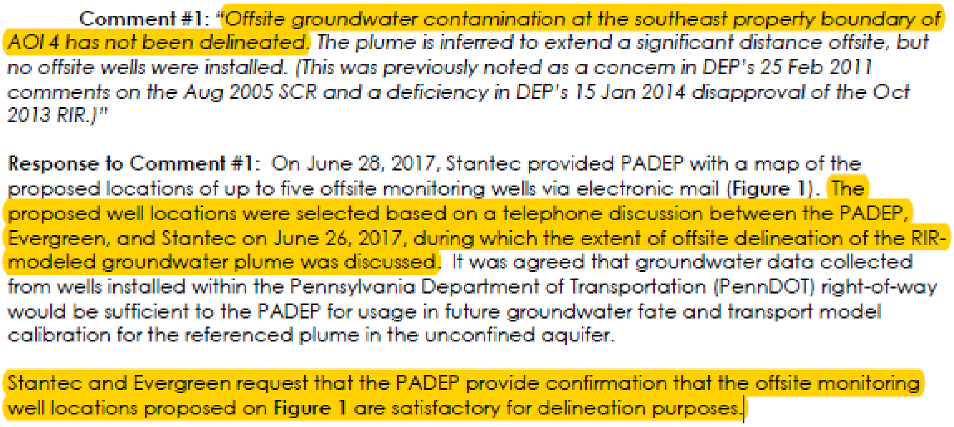
ARCADIS (2014b). Second Quarter 2014 Progress Report for the Former Defense Supply Center Philadelphia Facility, Philadelphia, PA (July 31, 2014) (45 pages), Executive Summary, pages 2-3.

Questions regarding the interaction of the aquifer underneath the refinery and the aquifer underneath the Defense Supply Center Philadelphia have not been resolved. It would be premature for the Department to approve the 2021 addenda report without addressing this question.

c. Evergreen has not established that the additional five monitoring wells to the southeast of the Penrose Avenue remediation system are sufficient to address off-site migration.

Ultimately, Evergreen did install five monitoring wells off-site near AOI-4, but they are all located to the southeast of the Penrose Avenue remediation system and not near S-369 in the northeast corner of AOI-4. Evergreen has not provided a sufficient explanation for its decision to install that number of monitoring wells in those locations in the manner that they were installed.

All that is stated about the choice of those wells is that there was a telephone discussion between Evergreen and the Department, followed up by a request to approve those five locations:



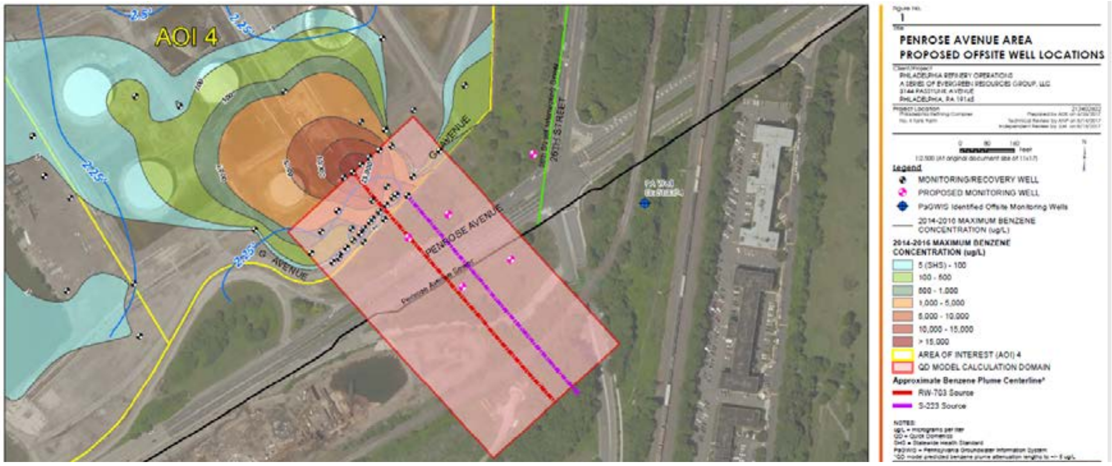
Comment #1: "Offsite groundwater contamination at the southeast property boundary of AOI 4 has not been delineated. The plume is inferred to extend a significant distance offsite, but no offsite wells were installed. (This was previously noted as a concern in DEP's 25 Feb 2011 comments on the Aug 2005 SCR and a deficiency in DEP's 15 Jan 2014 disapproval of the Oct 2013 RIR.)"

Response to Comment #1: On June 28, 2017, Stantec provided PADEP with a map of the proposed locations of up to five offsite monitoring wells via electronic mail (**Figure 1**). The proposed well locations were selected based on a telephone discussion between the PADEP, Evergreen, and Stantec on June 26, 2017, during which the extent of offsite delineation of the RIR-modeled groundwater plume was discussed. It was agreed that groundwater data collected from wells installed within the Pennsylvania Department of Transportation (PennDOT) right-of-way would be sufficient to the PADEP for usage in future groundwater fate and transport model calibration for the referenced plume in the unconfined aquifer.

Stantec and Evergreen request that the PADEP provide confirmation that the offsite monitoring well locations proposed on **Figure 1** are satisfactory for delineation purposes.

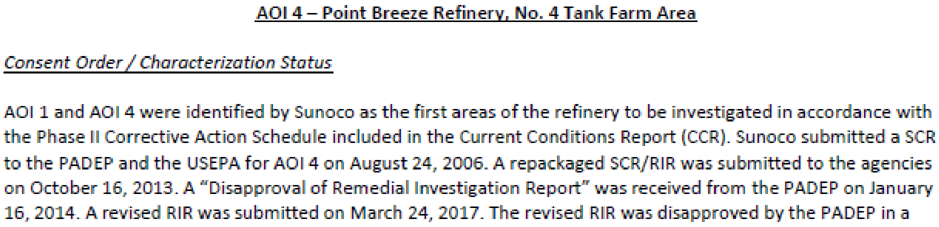
See AOI-4 Evergreen Response_RIR_20170830, page 1 (highlighting added for emphasis).

The proposed locations are set forth in the following Figure:



See id., Figure 1 -- Penrose Avenue Area Proposed Offsite Well Locations (pdf page 58 of 63).

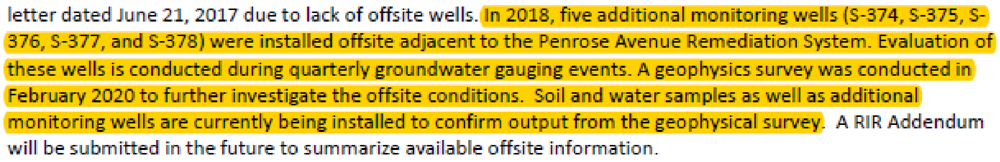
A groundwater remediation report states that the five wells were installed in 2018:



AOI 4 – Point Breeze Refinery, No. 4 Tank Farm Area

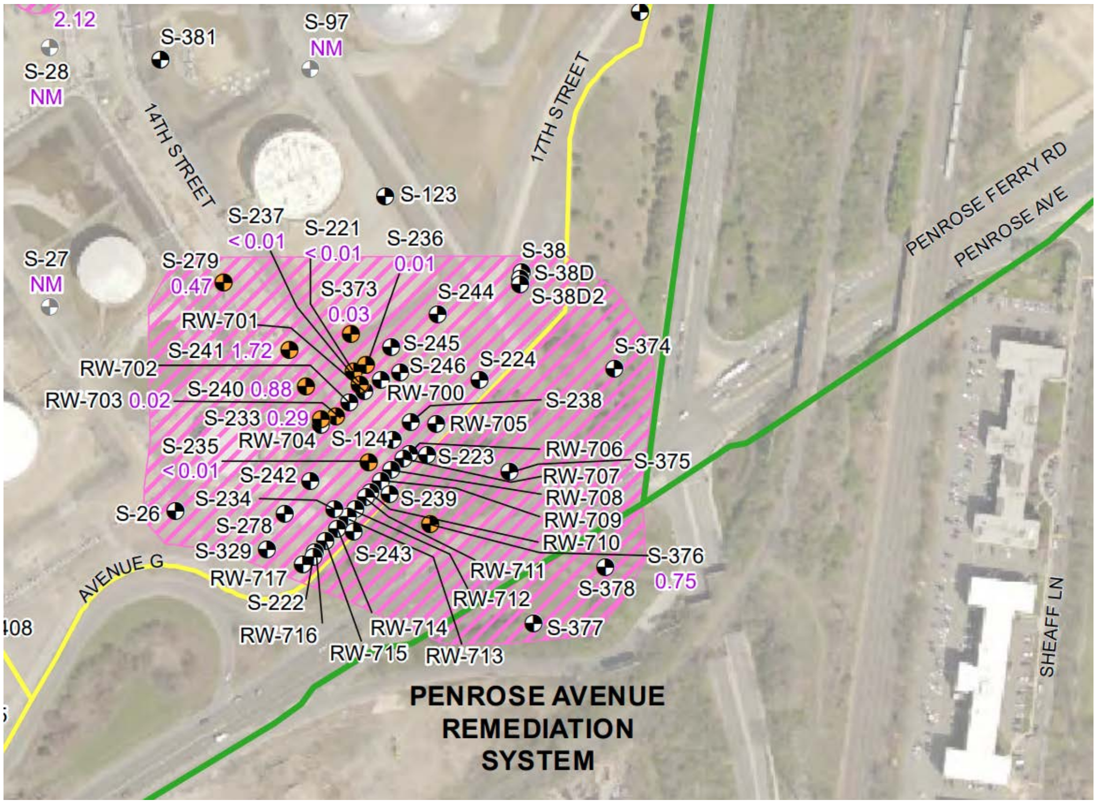
Consent Order / Characterization Status

AOI 1 and AOI 4 were identified by Sunoco as the first areas of the refinery to be investigated in accordance with the Phase II Corrective Action Schedule included in the Current Conditions Report (CCR). Sunoco submitted a SCR to the PADEP and the USEPA for AOI 4 on August 24, 2006. A repackaged SCR/RIR was submitted to the agencies on October 16, 2013. A "Disapproval of Remedial Investigation Report" was received from the PADEP on January 16, 2014. A revised RIR was submitted on March 24, 2017. The revised RIR was disapproved by the PADEP in a



letter dated June 21, 2017 due to lack of offsite wells. In 2018, five additional monitoring wells (S-374, S-375, S-376, S-377, and S-378) were installed offsite adjacent to the Penrose Avenue Remediation System. Evaluation of these wells is conducted during quarterly groundwater gauging events. A geophysics survey was conducted in February 2020 to further investigate the offsite conditions. Soil and water samples as well as additional monitoring wells are currently being installed to confirm output from the geophysical survey. A RIR Addendum will be submitted in the future to summarize available offsite information.

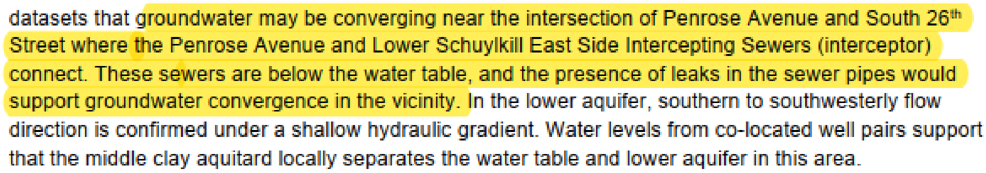
Philadelphia Refinery Remediation Program Groundwater Remediation Status Report, First Half 2020 (July 31, 2020), pages 4-5 (highlighting added for emphasis), https://phillyrefinerycleanup.info/wp-content/uploads/2020/11/2020-First-Half-Philadelphia-Remed-Status-Report.pdf. Again, this says nothing about the criteria used for making the decisions about installing that number of monitoring wells in those locations in the manner that they were installed. The following are the locations of the five additional monitoring wells:



See id., Figure 3. The previous report says nothing about the criteria used for making the decisions about installing that number of monitoring wells in those locations in the manner that they were installed. *See* Philadelphia Refinery Remediation Program Groundwater Remediation Status Report, Second Half 2019 (January 30, 2020), https://phillyrefinerycleanup.info/wp-content/uploads/2020/03/2019-Second-Half-Philadelphia-Remed-Status-Report.pdf.

Based on a review of the guidance documents, Evergreen has not established that the number, placement, and manner of installation of wells is sufficient to address off-site migration even near the Penrose Avenue Remediation System.

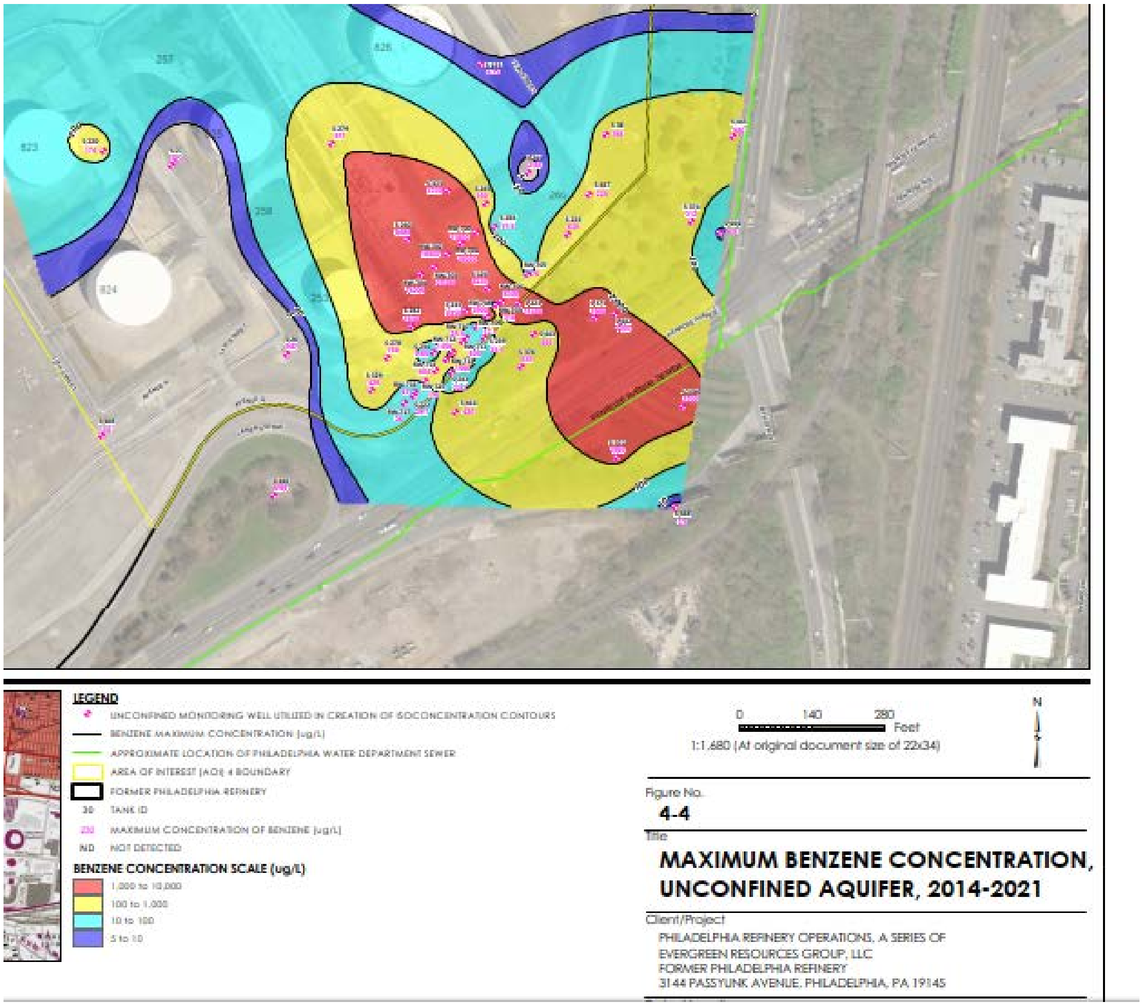
When evaluating the impacts of the Packer Avenue sewer on hydrocarbon plume migration in the vicinity of the Defense Facility Supply and Sunoco sites, this sewer was not shown to be a barrier (USGS, 2001). USGS conclusions were supported by a Modflow model, which demonstrated contaminated groundwater flow was unimpeded by the sewer. The model also showed downward vertical gradients. A similar evaluation would be necessary to support Sunoco’s statement in the 2021 Addendum to the AOI-4 Report:



> datasets that groundwater may be converging near the intersection of Penrose Avenue and South 26th Street where the Penrose Avenue and Lower Schuylkill East Side Intercepting Sewers (interceptor) connect. These sewers are below the water table, and the presence of leaks in the sewer pipes would support groundwater convergence in the vicinity. In the lower aquifer, southern to southwesterly flow direction is confirmed under a shallow hydraulic gradient. Water levels from co-located well pairs support that the middle clay aquitard locally separates the water table and lower aquifer in this area.

See 2021 AOI-4 Report, page 8 (highlighting added for emphasis).

The effects of Penrose Avenue and Lower Schuylkill East Side Intercepting sewers on the migration of contamination would be critical to understanding groundwater flow and support Sunoco’s placement of monitoring wells. In fact, the contamination mapping shows benzene to be migrating beyond the sewer as shown below in Figure 4-4:



See 2021 Addendum Report (AOI-4), pdf page 166 of 307, Figure 4-4 (Maximum Benzene Concentration Unconfined Aquifer, 2014-202).

Just because Evergreen installed more than three monitoring wells off-site does not make this sufficient. In fact, the guidance document states that knowledge of the vertical component of flow is best accomplished through pairs of shallow and deep wells:

> Using the groundwater levels from piezometers or wells at the site, the groundwater flow direction and hydraulic gradient can be determined. ***At least three monitoring points are needed to determine the horizontal flow direction and hydraulic gradient***; however, at some sites, knowledge of the vertical component of flow may be important. ***This is best accomplished by using well pairs of "shallow" and "deep" piezometers or short-screened wells***.

See Attachment 6 -- PA Department of Environmental Protection, Technical Guidance Manual, Appendix A (Groundwater Monitoring Guidance), page A-17 (bold italics added for emphasis).

As for the number of wells, the guidance document cites a number of considerations that are relevant -- none of which were discussed by Evergreen in the reports:

> ***The number of wells needed depends on site-specific factors***. In general, the spacing of background or upgradient wells should be adequate to account for any spatial variability in the groundwater quality. ***Downgradient wells should be positioned to adequately monitor the activity and any other variability of the groundwater quality***. Compliance wells should be considered downgradient wells and positioned as close to the downgradient boundary of the site. ***The estimate of the separation distance will depend on the extent and type of activity, the geology, and the potential contaminants*** (see also Section C.4 on the Areal Placement of Wells).

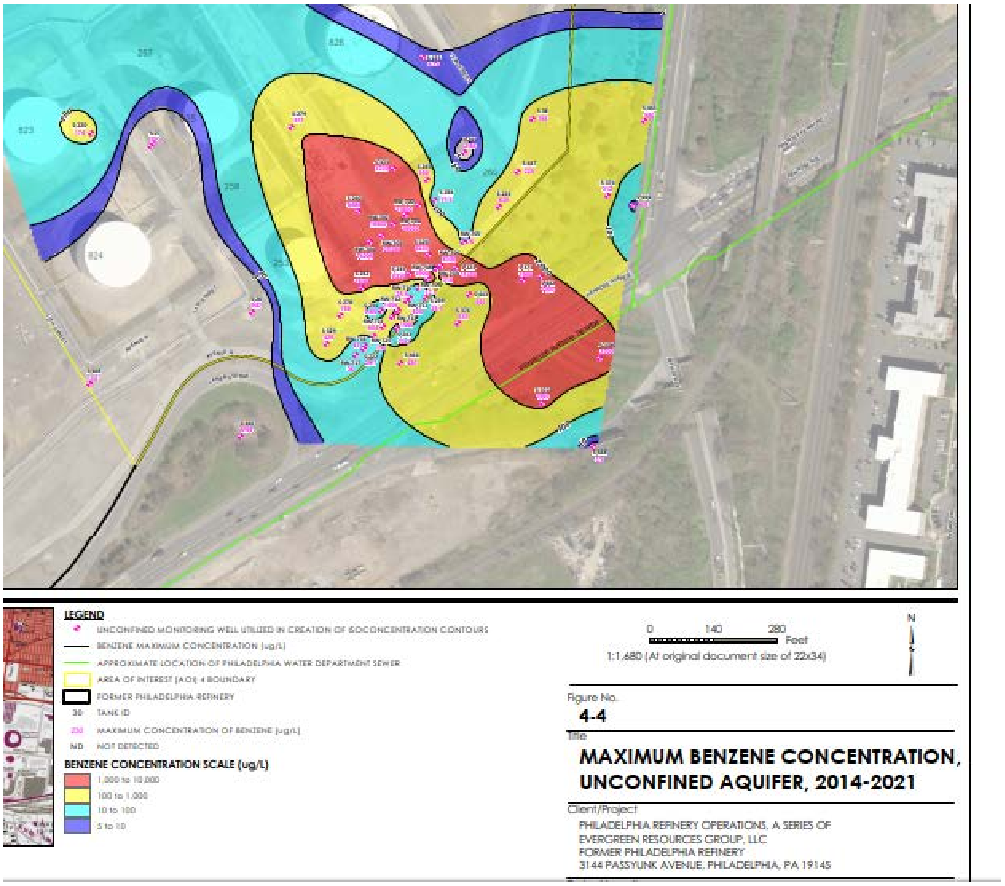
See id., page A-26 (bold italics added for emphasis).

Disregarding the guidance document, Evergreen fails to thoroughly display the contamination data on its isoconcentration maps as well:

> ***Isoconcentration maps can be useful in plume interpretation and for placement of groundwater recovery wells***. Also, the remediator should keep in mind the relationship of the flow lines with the activity's location or potential sources of contamination.

See id., page A-23 (bold italics added for emphasis). The Council already pointed out the importance of isoconcentration maps in its comments in January 2021 on the past twenty remedial investigation reports. *See* Attachment 1 -- Comments of Clean Air Council dated January 14, 2021, Comment 7(E), pages 66-72.

Sunoco's Figure 4-4 maximum benzene concentration unconfined aquifer 2014 - 2021 groups the highest benzene concentrations onto a single map. Mapping isoconcentration in this manner does not illustrate how the contamination plume has changed in time over the period 2014 through 2021.



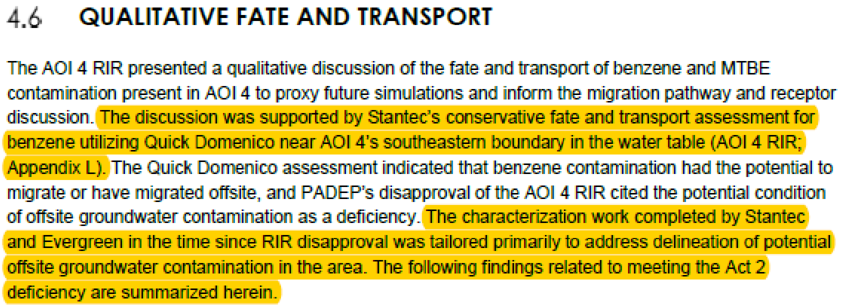
See 2021 Addendum Report (AOI-4), pdf page 166 of 307, Figure 4-4 (Maximum Benzene Concentration Unconfined Aquifer, 2014-2021).

Using progression mapping of maximum benzene contamination measured in individual years 2014, 2015, 2016, 2017, 2018, 2019, 2020 and 2021 would provide time-specific plume changes through time. The sole maximum benzene concentration mapping of contamination fails to demonstrate plume changes, which is critical to placing monitoring wells.

The five new wells were installed in 2018 and therefore there should now be at least three years' worth of data to provide progression mapping that includes these new points of observation. In prior years, it would also be helpful to see the plume concentration progression, even though the additional off-site wells did not exist in that time. In addition to showing the maximum as it did, Sunoco should prepare isoconcentration progression maps showing conditions in the individual years and use these data to assess the adequacy of the newly placed monitoring wells.

d. Evergreen’s Qualitative Fate and Transport analysis is flawed.

In its Qualitative Fate and Transport analysis, Evergreen purports to address the flaws in its previously disapproved First Addendum report:

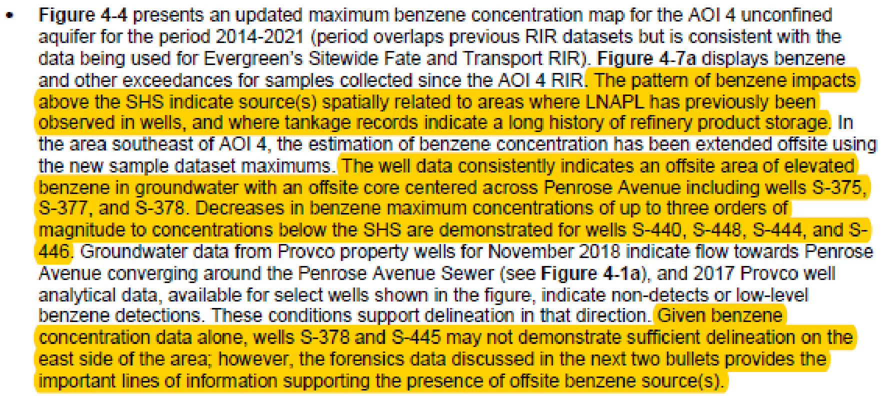


4.6 QUALITATIVE FATE AND TRANSPORT

The AOI 4 RIR presented a qualitative discussion of the fate and transport of benzene and MTBE contamination present in AOI 4 to proxy future simulations and inform the migration pathway and receptor discussion. The discussion was supported by Stantec’s conservative fate and transport assessment for benzene utilizing Quick Domenico near AOI 4’s southeastern boundary in the water table (AOI 4 RIR; Appendix L). The Quick Domenico assessment indicated that benzene contamination had the potential to migrate or have migrated offsite, and PADEP’s disapproval of the AOI 4 RIR cited the potential condition of offsite groundwater contamination as a deficiency. The characterization work completed by Stantec and Evergreen in the time since RIR disapproval was tailored primarily to address delineation of potential offsite groundwater contamination in the area. The following findings related to meeting the Act 2 deficiency are summarized herein.

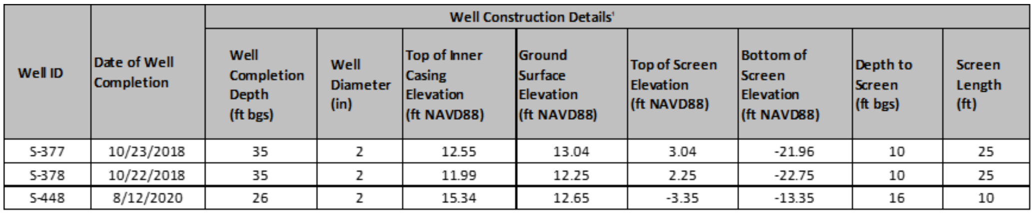
See 2021 Addendum Report (AOI-4), Section 4.6, page 37 (Qualitative Fate and Transport), page 33 (highlighting added for emphasis). But the additional work is not sufficient to cure the deficiencies in the remedial investigation.

Evergreen erroneously asserts that the newly installed wells have adequately delineated the extent of benzene contamination south of AOI-4:



- **Figure 4-4** presents an updated maximum benzene concentration map for the AOI 4 unconfined aquifer for the period 2014-2021 (period overlaps previous RIR datasets but is consistent with the data being used for Evergreen’s Sitewide Fate and Transport RIR). **Figure 4-7a** displays benzene and other exceedances for samples collected since the AOI 4 RIR. The pattern of benzene impacts above the SHS indicate source(s) spatially related to areas where LNAPL has previously been observed in wells, and where tankage records indicate a long history of refinery product storage. In the area southeast of AOI 4, the estimation of benzene concentration has been extended offsite using the new sample dataset maximums. The well data consistently indicates an offsite area of elevated benzene in groundwater with an offsite core centered across Penrose Avenue including wells S-375, S-377, and S-378. Decreases in benzene maximum concentrations of up to three orders of magnitude to concentrations below the SHS are demonstrated for wells S-440, S-448, S-444, and S-446. Groundwater data from Provco property wells for November 2018 indicate flow towards Penrose Avenue converging around the Penrose Avenue Sewer (see **Figure 4-1a**), and 2017 Provco well analytical data, available for select wells shown in the figure, indicate non-detects or low-level benzene detections. These conditions support delineation in that direction. Given benzene concentration data alone, wells S-378 and S-445 may not demonstrate sufficient delineation on the east side of the area; however, the forensics data discussed in the next two bullets provides the important lines of information supporting the presence of offsite benzene source(s).

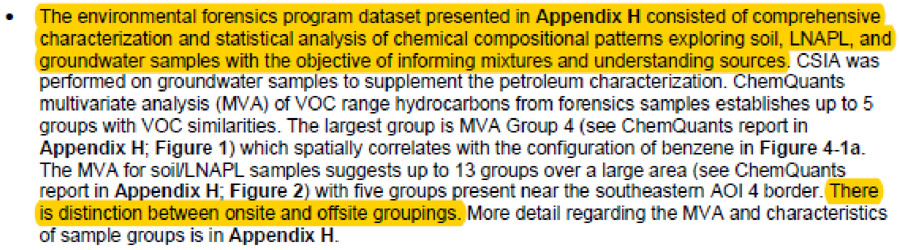
See id., Section 4.6.3 (Petroleum Distribution in Soil and Groundwater), page 39 (highlighting added for emphasis). This is flawed because the S-44X-series wells were installed not for delineation but for the high-resolution site characterization geophysics work, and were screened at different intervals than the S-37X-series wells installed for delineation purposes. For example, while downgradient wells S-377 and S-378 were installed with a 25-foot screens roughly spanning 3 to -22 feet above mean sea level (amsl), the farther downgradient well, S-448 was installed with a 10-foot screen from -3.35 to -13.35 amsl:



Well ID	Date of Well Completion	Well Construction Details[1]							
		Well Completion Depth (ft bgs)	Well Diameter (in)	Top of Inner Casing Elevation (ft NAVD88)	Ground Surface Elevation (ft NAVD88)	Top of Screen Elevation (ft NAVD88)	Bottom of Screen Elevation (ft NAVD88)	Depth to Screen (ft bgs)	Screen Length (ft)
S-377	10/23/2018	35	2	12.55	13.04	3.04	-21.96	10	25
S-378	10/22/2018	35	2	11.99	12.25	2.25	-22.75	10	25
S-448	8/12/2020	26	2	15.34	12.65	-3.35	-13.35	16	10

It is possible that the S-448 screened interval did not intercept the benzene plume because it may be screened at the wrong interval.

Evergreen erroneously downplays the possibility of downgradient migration of contamination from the AOI-4 Penrose area by describing the presence of additional sources of contamination south and east of AOI-4:

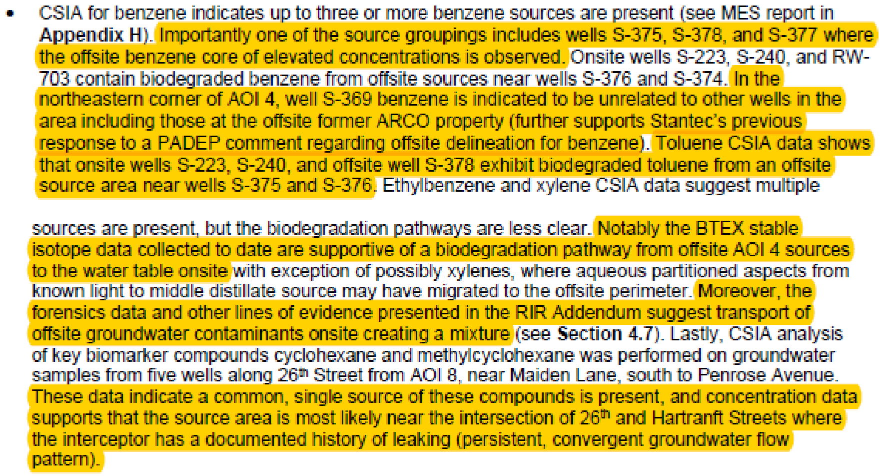


- The environmental forensics program dataset presented in **Appendix H** consisted of comprehensive characterization and statistical analysis of chemical compositional patterns exploring soil, LNAPL, and groundwater samples with the objective of informing mixtures and understanding sources. CSIA was performed on groundwater samples to supplement the petroleum characterization. ChemQuants multivariate analysis (MVA) of VOC range hydrocarbons from forensics samples establishes up to 5 groups with VOC similarities. The largest group is MVA Group 4 (see ChemQuants report in **Appendix H**; **Figure 1**) which spatially correlates with the configuration of benzene in **Figure 4-1a**. The MVA for soil/LNAPL samples suggests up to 13 groups over a large area (see ChemQuants report in **Appendix H**; **Figure 2**) with five groups present near the southeastern AOI 4 border. There is distinction between onsite and offsite groupings. More detail regarding the MVA and characteristics of sample groups is in **Appendix H**.

See 2021 Addendum Report (AOI-4), page 39 (highlighting added for emphasis). This is flawed because as noted above for the S-369 contamination area, Compound-Specific Isotope Analysis (CSIA) evaluation conclusions do not always match the Multi-Variant Analysis conclusions. While these fingerprinting evaluations might provide insight about plume sources and extent of biodegradation, they are not clear cut and they are subject to interpretation.

Additionally, the presence of additional sources does not negate the need to more fully delineate the extent of contamination south of Penrose. There is significant NAPL contamination just within the boundary of AOI-4 that is migrating off-site. The mass of benzene and other aromatics is likely to be much higher than the mass of contamination introduced to the environment from these alternate sources.

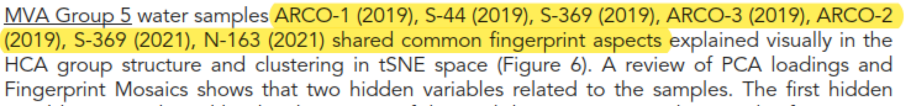
Evergreen erroneously asserts that the S-369 benzene is not related to the off-site contamination at or near the former AROC property:



- CSIA for benzene indicates up to three or more benzene sources are present (see MES report in **Appendix H**). Importantly one of the source groupings includes wells S-375, S-378, and S-377 where the offsite benzene core of elevated concentrations is observed. Onsite wells S-223, S-240, and RW-703 contain biodegraded benzene from offsite sources near wells S-376 and S-374. In the northeastern corner of AOI 4, well S-369 benzene is indicated to be unrelated to other wells in the area including those at the offsite former ARCO property (further supports Stantec's previous response to a PADEP comment regarding offsite delineation for benzene). Toluene CSIA data shows that onsite wells S-223, S-240, and offsite well S-378 exhibit biodegraded toluene from an offsite source area near wells S-375 and S-376. Ethylbenzene and xylene CSIA data suggest multiple

sources are present, but the biodegradation pathways are less clear. Notably the BTEX stable isotope data collected to date are supportive of a biodegradation pathway from offsite AOI 4 sources to the water table onsite with exception of possibly xylenes, where aqueous partitioned aspects from known light to middle distillate source may have migrated to the offsite perimeter. Moreover, the forensics data and other lines of evidence presented in the RIR Addendum suggest transport of offsite groundwater contaminants onsite creating a mixture (see **Section 4.7**). Lastly, CSIA analysis of key biomarker compounds cyclohexane and methylcyclohexane was performed on groundwater samples from five wells along 26th Street from AOI 8, near Maiden Lane, south to Penrose Avenue. These data indicate a common, single source of these compounds is present, and concentration data supports that the source area is most likely near the intersection of 26th and Hartranft Streets where the interceptor has a documented history of leaking (persistent, convergent groundwater flow pattern).

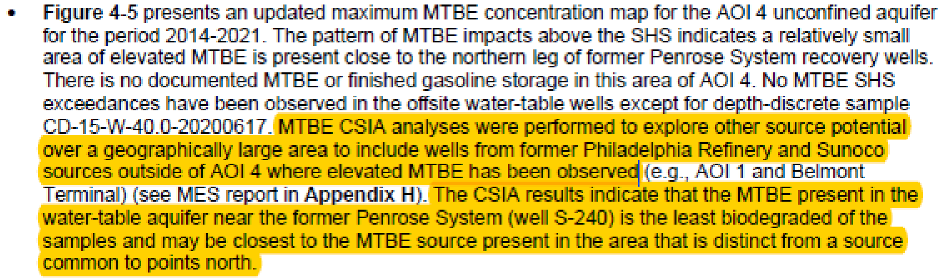
See id., pages 39-40 (highlighting added for emphasis). In addition to reasons discussed above, this is flawed because the MVA analysis indicates that the contamination in the areas is related.



MVA Group 5 water samples ARCO-1 (2019), S-44 (2019), S-369 (2019), ARCO-3 (2019), ARCO-2 (2019), S-369 (2021), N-163 (2021) shared common fingerprint aspects explained visually in the HCA group structure and clustering in tSNE space (Figure 6). A review of PCA loadings and Fingerprint Mosaics shows that two hidden variables related to the samples. The first hidden

See 2021 Addendum Report (AOI-4), part 3, pdf page 823 of 1779 (highlighting added for emphasis).

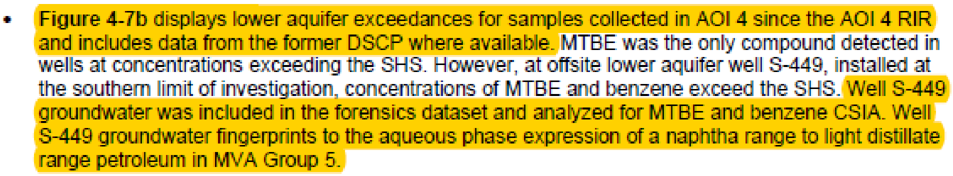
Evergreen erroneously suggests that the MTBE problem is a problem associated with an off-site source:



- **Figure 4-5** presents an updated maximum MTBE concentration map for the AOI 4 unconfined aquifer for the period 2014-2021. The pattern of MTBE impacts above the SHS indicates a relatively small area of elevated MTBE is present close to the northern leg of former Penrose System recovery wells. There is no documented MTBE or finished gasoline storage in this area of AOI 4. No MTBE SHS exceedances have been observed in the offsite water-table wells except for depth-discrete sample CD-15-W-40.0-20200617. MTBE CSIA analyses were performed to explore other source potential over a geographically large area to include wells from former Philadelphia Refinery and Sunoco sources outside of AOI 4 where elevated MTBE has been observed (e.g., AOI 1 and Belmont Terminal) (see MES report in **Appendix H**). The CSIA results indicate that the MTBE present in the water-table aquifer near the former Penrose System (well S-240) is the least biodegraded of the samples and may be closest to the MTBE source present in the area that is distinct from a source common to points north.

See id., part 1, page 40 (highlighting added for emphasis). This is not persuasive, given the high concentrations of MTBE sampled in this area suggest an on-site point source (concentrations ranging from 20 ppb to 5000 ppb).

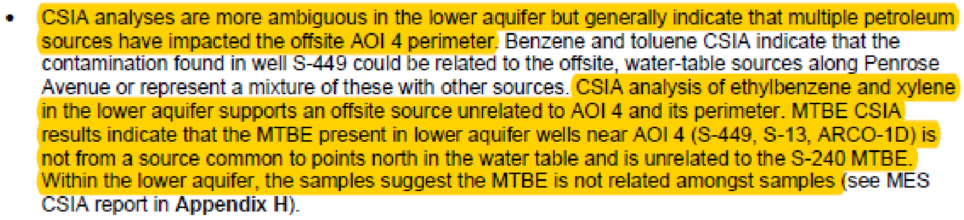
Again, Evergreen erroneously suggests that the MTBE problem is a problem associated with an off-site source:



- **Figure 4-7b** displays lower aquifer exceedances for samples collected in AOI 4 since the AOI 4 RIR and includes data from the former DSCP where available. MTBE was the only compound detected in wells at concentrations exceeding the SHS. However, at offsite lower aquifer well S-449, installed at the southern limit of investigation, concentrations of MTBE and benzene exceed the SHS. Well S-449 groundwater was included in the forensics dataset and analyzed for MTBE and benzene CSIA. Well S-449 groundwater fingerprints to the aqueous phase expression of a naphtha range to light distillate range petroleum in MVA Group 5.

See id., page 40 (highlighting added for emphasis). This is flawed because the existence of some contamination from an off-site source in S-449 does not mean there is not a problem with contamination of benzene coming from AOI-4.

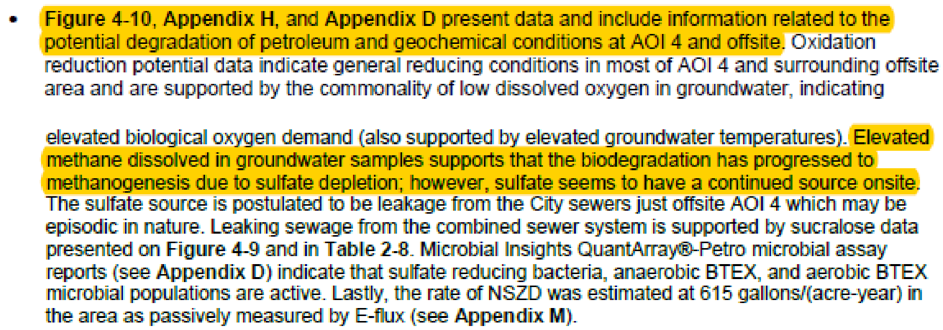
Again, Evergreen erroneously suggests that the MTBE problem is a problem associated with an off-site source:



- CSIA analyses are more ambiguous in the lower aquifer but generally indicate that multiple petroleum sources have impacted the offsite AOI 4 perimeter. Benzene and toluene CSIA indicate that the contamination found in well S-449 could be related to the offsite, water-table sources along Penrose Avenue or represent a mixture of these with other sources. CSIA analysis of ethylbenzene and xylene in the lower aquifer supports an offsite source unrelated to AOI 4 and its perimeter. MTBE CSIA results indicate that the MTBE present in lower aquifer wells near AOI 4 (S-449, S-13, ARCO-1D) is not from a source common to points north in the water table and is unrelated to the S-240 MTBE. Within the lower aquifer, the samples suggest the MTBE is not related amongst samples (see MES CSIA report in **Appendix H**).

See id., page 40 (highlighting added for emphasis). This is flawed because the existence of some contamination from an off-site source in S-449 does not mean there is no MTBE contamination coming from AOI-4, especially considering the high concentration in the vicinity of RW-701 and RW-702.

Evergreen makes the unremarkable assertion that some biodegradation is occurring in groundwater:



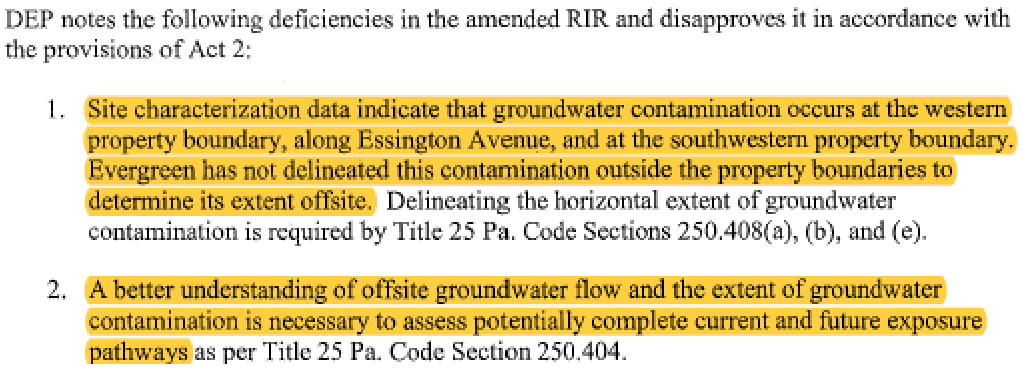
- **Figure 4-10**, **Appendix H**, and **Appendix D** present data and include information related to the potential degradation of petroleum and geochemical conditions at AOI 4 and offsite. Oxidation reduction potential data indicate general reducing conditions in most of AOI 4 and surrounding offsite area and are supported by the commonality of low dissolved oxygen in groundwater, indicating elevated biological oxygen demand (also supported by elevated groundwater temperatures). Elevated methane dissolved in groundwater samples supports that the biodegradation has progressed to methanogenesis due to sulfate depletion; however, sulfate seems to have a continued source onsite. The sulfate source is postulated to be leakage from the City sewers just offsite AOI 4 which may be episodic in nature. Leaking sewage from the combined sewer system is supported by sucralose data presented on **Figure 4-9** and in **Table 2-8**. Microbial Insights QuantArray®-Petro microbial assay reports (see **Appendix D**) indicate that sulfate reducing bacteria, anaerobic BTEX, and aerobic BTEX microbial populations are active. Lastly, the rate of NSZD was estimated at 615 gallons/(acre-year) in the area as passively measured by E-flux (see **Appendix M**).

See id., pages 40-41 (highlighting added for emphasis). With the closure of a refinery after 150 years, some biodegradation is not unexpected. Evergreen does not assert that this means it has no further responsibility.

4. Water Table in AOI-9.

a. Evergreen should provide a more thorough analysis of the potential for off-site migration of benzene and MTBE.

In disapproving the report for AOI-9, the Department noted that Evergreen had not properly delineated off-site groundwater contamination:

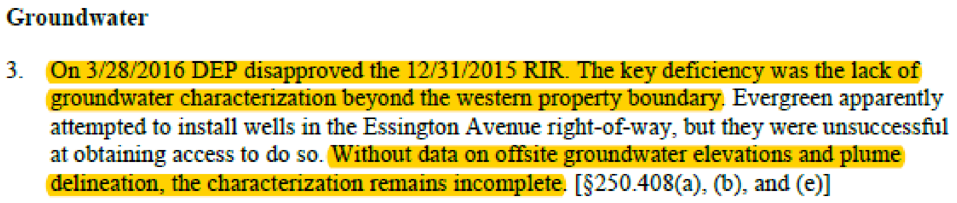


DEP notes the following deficiencies in the amended RIR and disapproves it in accordance with the provisions of Act 2:

1. Site characterization data indicate that groundwater contamination occurs at the western property boundary, along Essington Avenue, and at the southwestern property boundary. Evergreen has not delineated this contamination outside the property boundaries to determine its extent offsite. Delineating the horizontal extent of groundwater contamination is required by Title 25 Pa. Code Sections 250.408(a), (b), and (e).

2. A better understanding of offsite groundwater flow and the extent of groundwater contamination is necessary to assess potentially complete current and future exposure pathways as per Title 25 Pa. Code Section 250.404.

See AOI-9_PADEP Letter_RIR Addendum_20170418, page 1 (highlighting added for emphasis). To be more precise, in the comments the Department stated that Evergreen should install off-site wells:

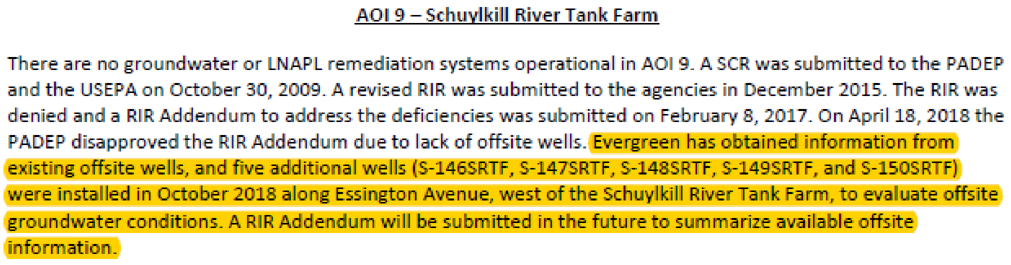


Groundwater

3. On 3/28/2016 DEP disapproved the 12/31/2015 RIR. The key deficiency was the lack of groundwater characterization beyond the western property boundary. Evergreen apparently attempted to install wells in the Essington Avenue right-of-way, but they were unsuccessful at obtaining access to do so. Without data on offsite groundwater elevations and plume delineation, the characterization remains incomplete. [§250.408(a), (b), and (e)]

See AOI-9_PADEP Comments_RIR Addendum_20170418, page 1, Comment 3 (highlighting added for emphasis).

A groundwater remediation report states that the five wells were installed in 2018:



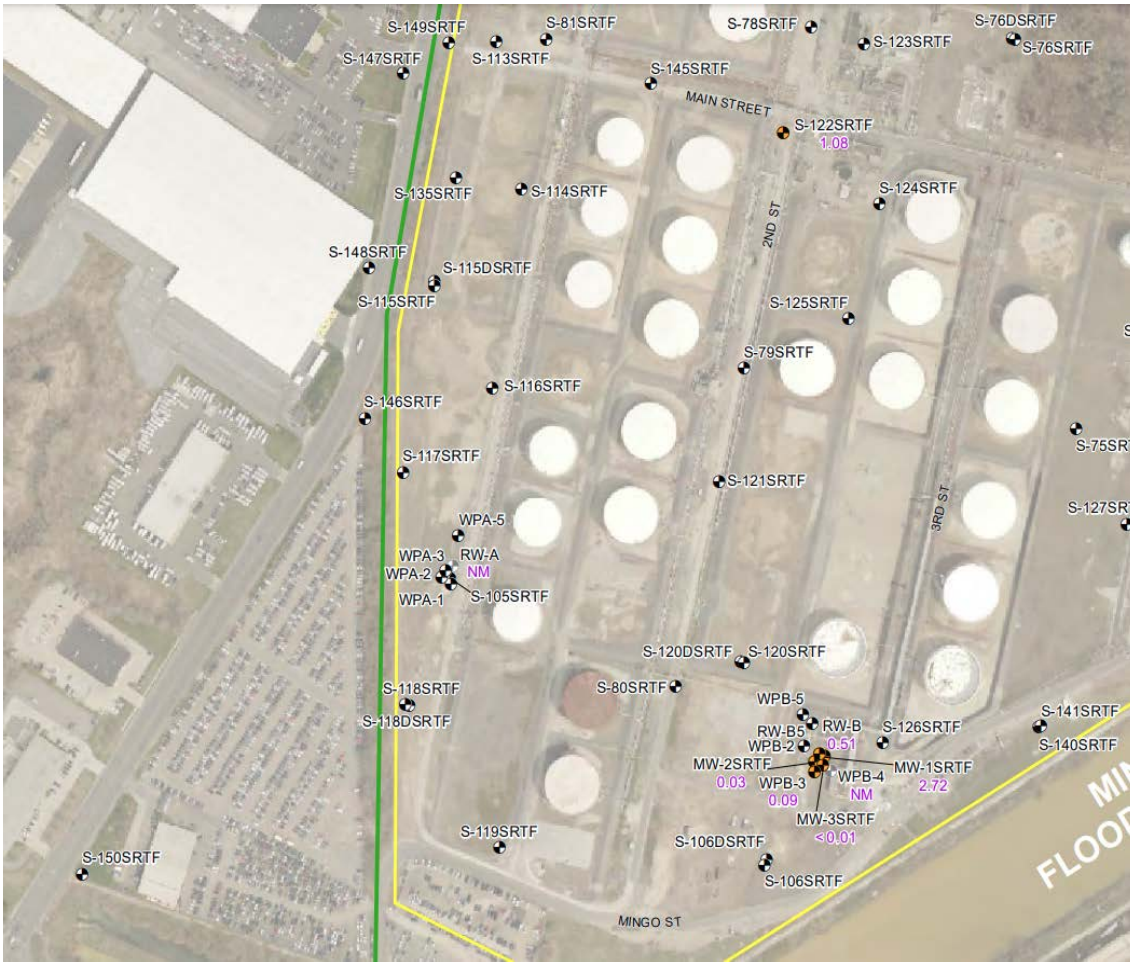
AOI 9 – Schuylkill River Tank Farm

There are no groundwater or LNAPL remediation systems operational in AOI 9. A SCR was submitted to the PADEP and the USEPA on October 30, 2009. A revised RIR was submitted to the agencies in December 2015. The RIR was denied and a RIR Addendum to address the deficiencies was submitted on February 8, 2017. On April 18, 2018 the PADEP disapproved the RIR Addendum due to lack of offsite wells. Evergreen has obtained information from existing offsite wells, and five additional wells (S-146SRTF, S-147SRTF, S-148SRTF, S-149SRTF, and S-150SRTF) were installed in October 2018 along Essington Avenue, west of the Schuylkill River Tank Farm, to evaluate offsite groundwater conditions. A RIR Addendum will be submitted in the future to summarize available offsite information.

Philadelphia Refinery Remediation Program Groundwater Remediation Status Report, First Half 2020 (July 31, 2020), page 8 (highlighting added for emphasis), https://phillyrefinerycleanup.info/wp-content/uploads/2020/11/2020-First-Half-Philadelphia-

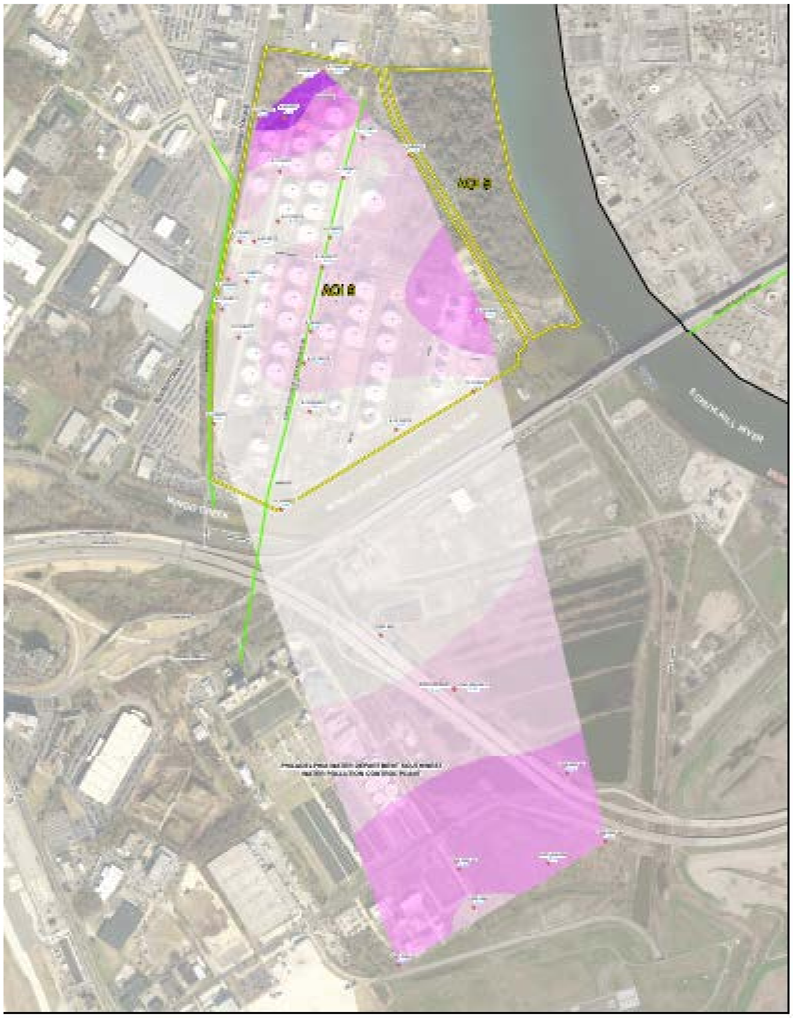
Remed-Status-Report.pdf. Again, this says nothing about the criteria used for making the decisions about installing that number of monitoring wells in those locations in the manner that they were installed. The following are the locations of the five additional monitoring wells:

The locations of the five additional wells (S-146SRTF, S-147SRTF, S-148SRTF, S-149SRTF, and S-150SRTF) are set forth in Figure 2 (Site Plan):



See 2021 Addendum Report (AOI-9), Figure 2 -- Site Plan, page 13.

The mapping of the shallow groundwater elevations west of the AOI-9 as presented in the 2021 RIR Figures 4-2a focused attention on the influence of Mingo Creek and areas south of AOI-9, but not towards the west:



See id., Figure 4-2a (Unconfined Aquifer Elevation June 2018). Figure 4-2a illustrates groundwater elevations approximately 3,000 feet from the southern boundary of AOI-9. But on the western boundary, the farthest extent of groundwater gaging was a mere 100 feet beyond the boundary after the four newly installed unconfined aquifer wells were available. Sunoco should treat the mapping of groundwater at the western boundary as it has for the southern boundary.

Sunoco maps the lower aquifer flow similar to its mapping the unconfined condition south of AOI-9 as illustrated by Figures 4-3a, 4-3b and 4-3e, Lower Aquifer Elevation June 2018, February 2019, August 2021, respectively:

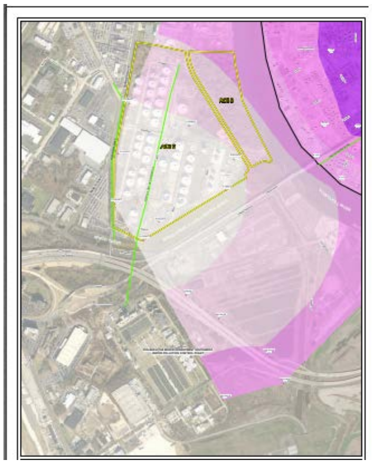


Figure 4-3a

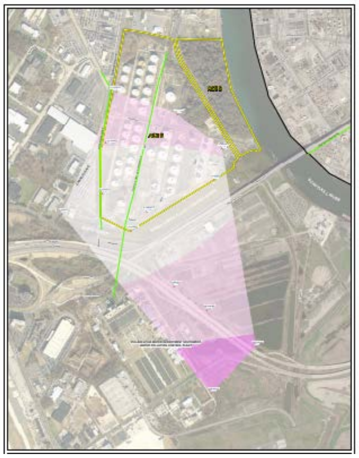


Figure 4-3b

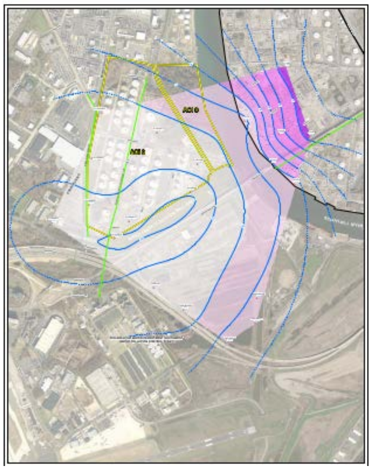
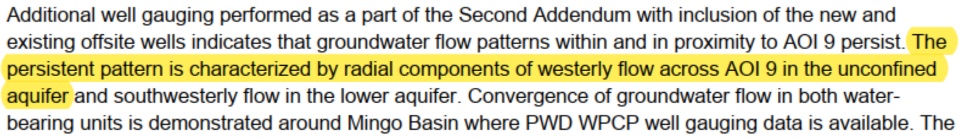


Figure 4-3e

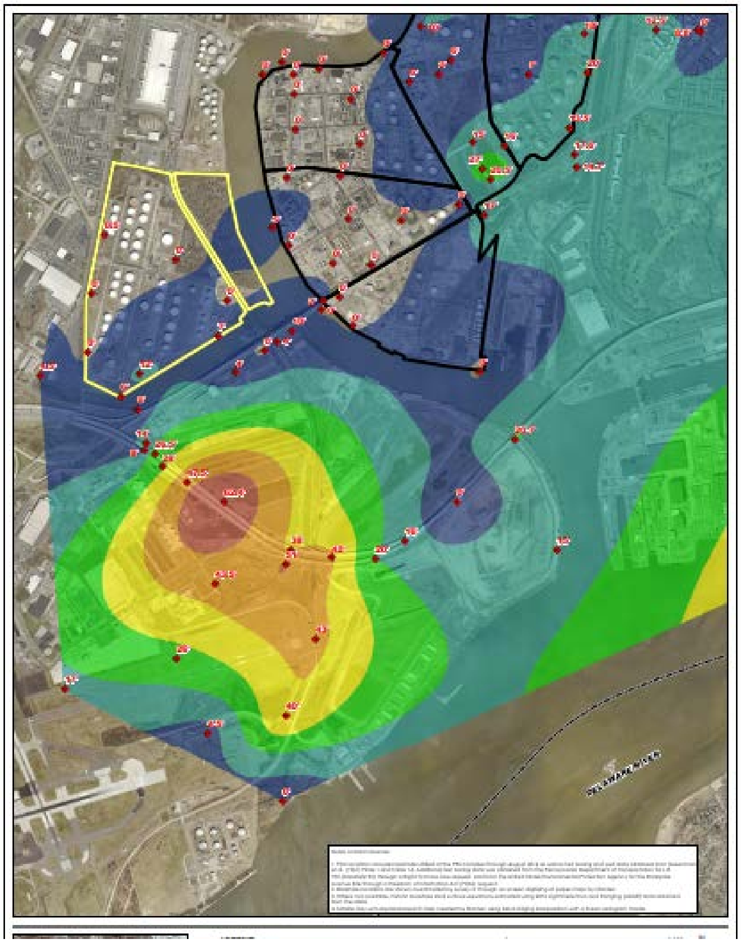
See id.

Evergreen recognizes that there is a westerly groundwater flow component:


Additional well gauging performed as a part of the Second Addendum with inclusion of the new and existing offsite wells indicates that groundwater flow patterns within and in proximity to AOI 9 persist. The persistent pattern is characterized by radial components of westerly flow across AOI 9 in the unconfined aquifer and southwesterly flow in the lower aquifer. Convergence of groundwater flow in both water-bearing units is demonstrated around Mingo Basin where PWD WPCP well gauging data is available. The

See id., pdf page 7, Executive Summary. The Department should require Sunoco's groundwater elevation and contamination mapping of the unconfined aquifer on the western AOI-9 boundary to be made robust.

The western boundary of AOI-9 is shown to have no middle clay as demonstrated by the isopach mapping of the middle clay unit Figure 4-14:



See *id.*, pdf page 137 of 2130, Figure 4-14 (Isopach Map of the Middle Clay Unit Aquitard).

Sunoco has not provided an assessment of the vertical downward gradients and their influence on the unconfined aquifer groundwater flow in this location.

Just because Evergreen installed more than three monitoring wells does not make its investigation sufficient. In fact, the guidance document states that knowledge of the vertical component of flow is best accomplished through pairs of shallow and deep wells:

> Using the groundwater levels from piezometers or wells at the site, the groundwater flow direction and hydraulic gradient can be determined. ***At least three monitoring points are needed to determine the horizontal flow direction and hydraulic gradient***; however, at some sites, knowledge of the vertical component of flow may be important. ***This is best accomplished by using well pairs of "shallow" and "deep" piezometers or short-screened wells***.

See Attachment 6 -- PA Department of Environmental Protection, Technical Guidance Manual, Appendix A (Groundwater Monitoring Guidance), page A-17 (bold italics added for emphasis).

As for the number of wells, the guidance document cites a number of considerations that are relevant -- none of which were discussed by Evergreen in the reports:

> ***The number of wells needed depends on site-specific factors***. In general, the spacing of background or upgradient wells should be adequate to account for any spatial variability in the groundwater quality. ***Downgradient wells should be positioned to adequately monitor the activity and any other variability of the groundwater quality***. Compliance wells should be considered downgradient wells and positioned as close to the downgradient boundary of the site. ***The estimate of the separation distance will depend on the extent and type of activity, the geology, and the potential contaminants*** (see also Section C.4 on the Areal Placement of Wells).

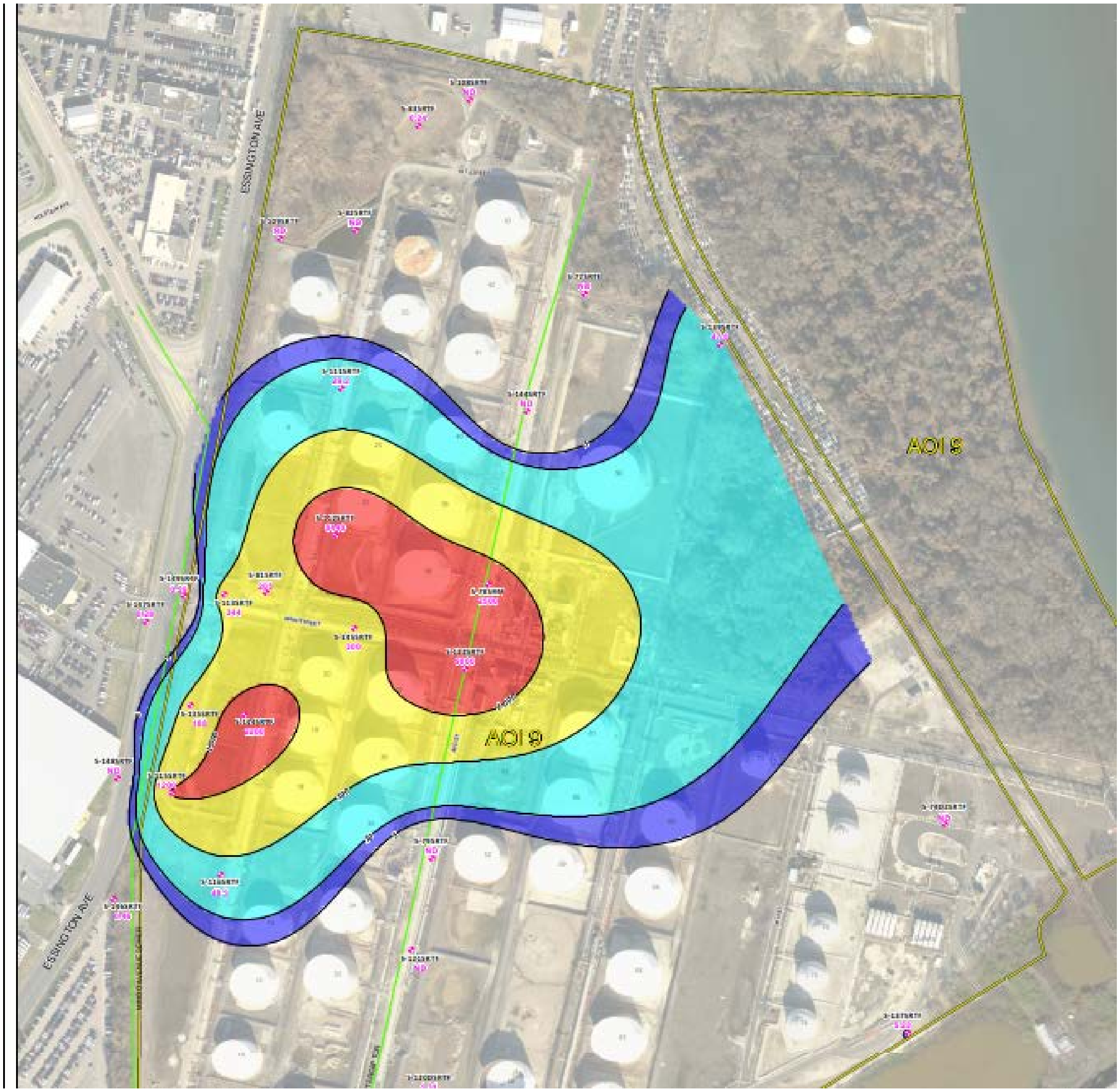
See id., page A-26 (bold italics added for emphasis).

Disregarding the guidance document, Evergreen fails to thoroughly display the contamination data on its isoconcentration maps as well:

> ***Isoconcentration maps can be useful in plume interpretation and for placement of groundwater recovery wells***. Also, the remediator should keep in mind the relationship of the flow lines with the activity's location or potential sources of contamination.

See id., page A-23 (bold italics added for emphasis). The Council already pointed out the importance of isoconcentration maps in its comments in January 2021 on the past twenty remedial investigation reports. *See* Attachment 1 -- Comments of Clean Air Council dated January 14, 2021, Comment 7(E), pages 66-72.

Evergreen's Figure 4-5 maximum benzene concentration unconfined aquifer 2014 - 2021 groups the highest benzene concentrations onto a single map. But mapping isoconcentration in this manner does not illustrate how the contamination plume has changed in time over the period 2014 through 2021:



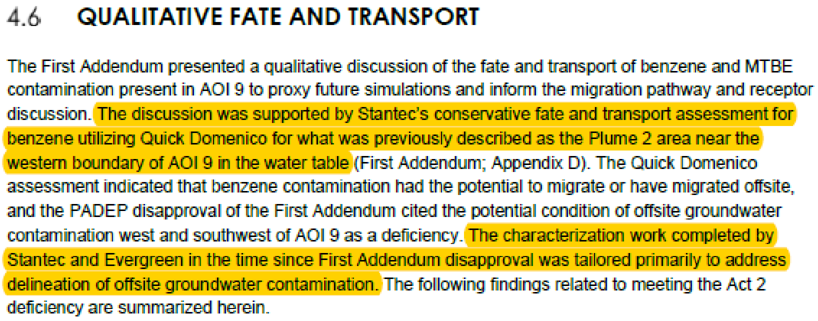
See 2021 Addendum Report (AOI-9), Figure 4-5 Maximum Benzene Concentration Unconfined Aquifer, 2014-2021 (pdf page 127 of 307).

Using progression mapping of maximum benzene contamination measured in individual years 2014, 2015, 2016, 2017, 2018, 2019, 2020 and 2021 would provide time-specific plume changes through time. The sole maximum benzene concentration mapping of contamination fails to demonstrate plume changes, which is critical to placing monitoring wells.

Four of the five new wells were installed in 2018 and therefore there should be at least three years' worth of data to provide progression mapping that includes these new points of observation. In prior years, it would also be helpful to see the plume concentration progression, even though the additional off-site wells did not exist in that time. In addition to showing the maximum as it did, Sunoco should prepare isoconcentration progression maps showing conditions in the individual years and use these data to assess the adequacy of the newly placed monitoring wells.

b. Evergreen's Qualitative Fate and Transport analysis is flawed.

In its Qualitative Fate and Transport analysis, Evergreen purports to address the flaws in its previously disapproved First Addendum report:

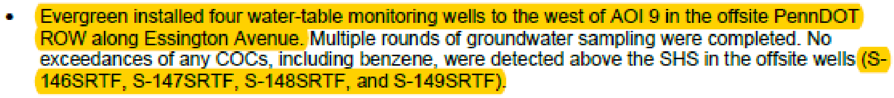


4.6 **QUALITATIVE FATE AND TRANSPORT**

The First Addendum presented a qualitative discussion of the fate and transport of benzene and MTBE contamination present in AOI 9 to proxy future simulations and inform the migration pathway and receptor discussion. The discussion was supported by Stantec's conservative fate and transport assessment for benzene utilizing Quick Domenico for what was previously described as the Plume 2 area near the western boundary of AOI 9 in the water table (First Addendum; Appendix D). The Quick Domenico assessment indicated that benzene contamination had the potential to migrate or have migrated offsite, and the PADEP disapproval of the First Addendum cited the potential condition of offsite groundwater contamination west and southwest of AOI 9 as a deficiency. The characterization work completed by Stantec and Evergreen in the time since First Addendum disapproval was tailored primarily to address delineation of offsite groundwater contamination. The following findings related to meeting the Act 2 deficiency are summarized herein.

See 2021 Addendum Report (AOI-9), Section 4.6 (Qualitative Fate and Transport), page 33 (highlighting added for emphasis). But in fact the additional work is not sufficient to cure the deficiencies in the remedial investigation.

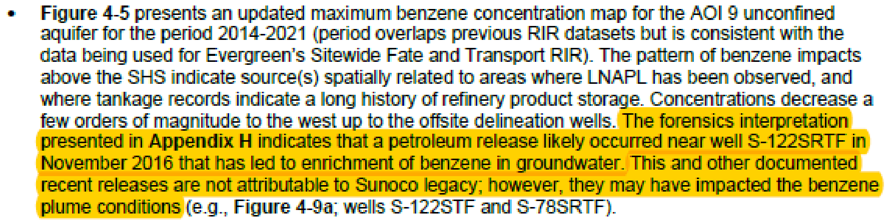
As noted above, Evergreen asserts that it has installed four monitoring wells for the water table off-site and west of AOI-9:



- Evergreen installed four water-table monitoring wells to the west of AOI 9 in the offsite PennDOT ROW along Essington Avenue. Multiple rounds of groundwater sampling were completed. No exceedances of any COCs, including benzene, were detected above the SHS in the offsite wells (S-146SRTF, S-147SRTF, S-148SRTF, and S-149SRTF).

See id., page 33 (highlighting added for emphasis). As discussed above, this is flawed because Evergreen has not established that the number, placement, and manner of installation of wells is sufficient to address off-site migration.

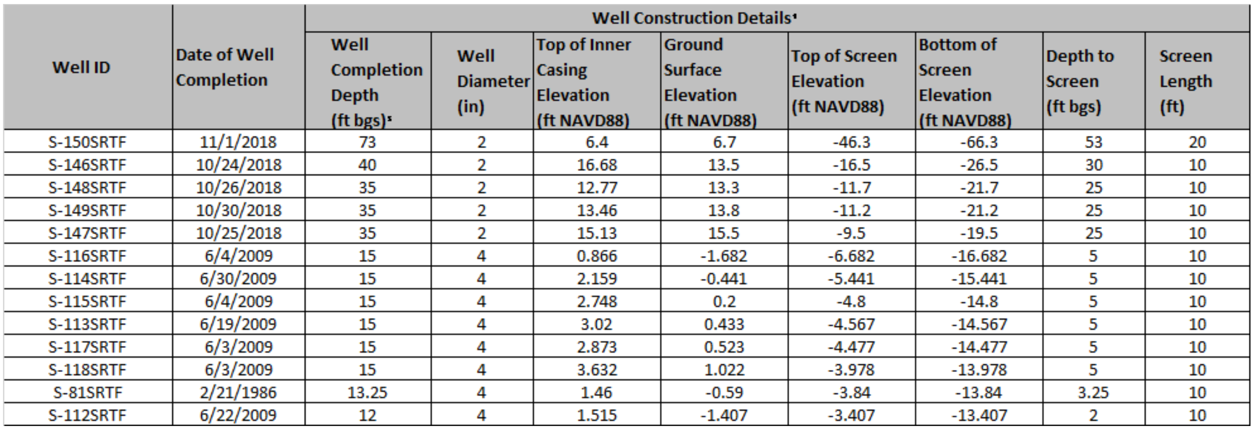
Evergreen erroneously offers a figure presenting an updated maximum benzene concentration map for the water table relating to AOI-9:



- **Figure 4-5** presents an updated maximum benzene concentration map for the AOI 9 unconfined aquifer for the period 2014-2021 (period overlaps previous RIR datasets but is consistent with the data being used for Evergreen's Sitewide Fate and Transport RIR). The pattern of benzene impacts above the SHS indicate source(s) spatially related to areas where LNAPL has been observed, and where tankage records indicate a long history of refinery product storage. Concentrations decrease a few orders of magnitude to the west up to the offsite delineation wells. The forensics interpretation presented in **Appendix H** indicates that a petroleum release likely occurred near well S-122SRTF in November 2016 that has led to enrichment of benzene in groundwater. This and other documented recent releases are not attributable to Sunoco legacy; however, they may have impacted the benzene plume conditions (e.g., **Figure 4-9a**; wells S-122STF and S-78SRTF).

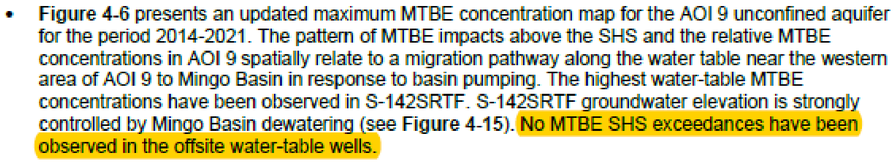
See id., page 33, citing Figure 4-5 (Maximum Benzene Concentration, Unconfined Aquifer, 2014-2021) (highlighting added for emphasis). In addition to reasons discussed above, this is flawed because it does not delineate the contamination. The western perimeter of the shaded regions (shaded in purple) still demonstrates exceedances of the groundwater standard of 5 ug/L. This simply replicates the error of installing only four monitoring wells off-site at the locations and the manner chosen by Evergreen, without any meaningful substantiation for these decisions.

Furthermore, the new off-site wells are not screened at depths that would further delineate the plume. The contaminated on-site wells in AOI-9 (e.g. S-113SRTF, S-114SRTF, S-115SRTF, S-116SRTF, S-117SRTF, S-118SRTF, S-81SRTF, and S-112SRTF) all have the top of their ten-foot screens located at approximate depths of -3.4 to -6.7 feet above mean sea level (amsl). However, the four new unconfined aquifer wells (S-146SRTF through S-146SRTF) all have the tops of their ten-foot screens at approximate depths of -9.5 to -16.5 feet amsl. Therefore, the new wells are monitoring a completely different portion of the aquifer. Therefore, comparisons to the on-site concentrations are not warranted and it is not accurate to say the plume has been delineated.



Well ID	Date of Well Completion	Well Construction Details							
		Well Completion Depth (ft bgs)	Well Diameter (in)	Top of Inner Casing Elevation (ft NAVD88)	Ground Surface Elevation (ft NAVD88)	Top of Screen Elevation (ft NAVD88)	Bottom of Screen Elevation (ft NAVD88)	Depth to Screen (ft bgs)	Screen Length (ft)
S-150SRTF	11/1/2018	73	2	6.4	6.7	-46.3	-66.3	53	20
S-146SRTF	10/24/2018	40	2	16.68	13.5	-16.5	-26.5	30	10
S-148SRTF	10/26/2018	35	2	12.77	13.3	-11.7	-21.7	25	10
S-149SRTF	10/30/2018	35	2	13.46	13.8	-11.2	-21.2	25	10
S-147SRTF	10/25/2018	35	2	15.13	15.5	-9.5	-19.5	25	10
S-116SRTF	6/4/2009	15	4	0.866	-1.682	-6.682	-16.682	5	10
S-114SRTF	6/30/2009	15	4	2.159	-0.441	-5.441	-15.441	5	10
S-115SRTF	6/4/2009	15	4	2.748	0.2	-4.8	-14.8	5	10
S-113SRTF	6/19/2009	15	4	3.02	0.433	-4.567	-14.567	5	10
S-117SRTF	6/3/2009	15	4	2.873	0.523	-4.477	-14.477	5	10
S-118SRTF	6/3/2009	15	4	3.632	1.022	-3.978	-13.978	5	10
S-81SRTF	2/21/1986	13.25	4	1.46	-0.59	-3.84	-13.84	3.25	10
S-112SRTF	6/22/2009	12	4	1.515	-1.407	-3.407	-13.407	2	10

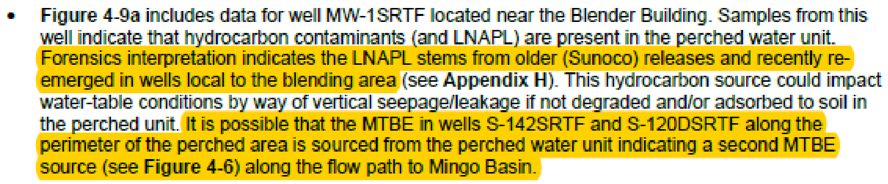
Evergreen offers a similar figure presenting an updated maximum MTBE concentration map for the water table relating to AOI-9:



- **Figure 4-6** presents an updated maximum MTBE concentration map for the AOI 9 unconfined aquifer for the period 2014-2021. The pattern of MTBE impacts above the SHS and the relative MTBE concentrations in AOI 9 spatially relate to a migration pathway along the water table near the western area of AOI 9 to Mingo Basin in response to basin pumping. The highest water-table MTBE concentrations have been observed in S-142SRTF. S-142SRTF groundwater elevation is strongly controlled by Mingo Basin dewatering (see **Figure 4-15**). No MTBE SHS exceedances have been observed in the offsite water-table wells.

See 2021 Addendum Report (AOI-9), page 33(highlighting added for emphasis). Again, this is flawed because this simply reflects the groundwater monitoring network previously developed by Evergreen.

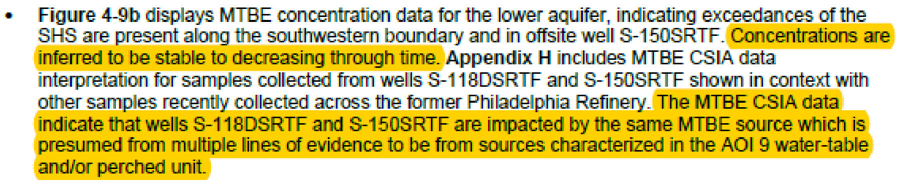
Evergreen makes assertions regarding a source of MTBE in AOI-9:



- **Figure 4-9a** includes data for well MW-1SRTF located near the Blender Building. Samples from this well indicate that hydrocarbon contaminants (and LNAPL) are present in the perched water unit. Forensics interpretation indicates the LNAPL stems from older (Sunoco) releases and recently re-emerged in wells local to the blending area (see **Appendix H**). This hydrocarbon source could impact water-table conditions by way of vertical seepage/leakage if not degraded and/or adsorbed to soil in the perched unit. It is possible that the MTBE in wells S-142SRTF and S-120DSRTF along the perimeter of the perched area is sourced from the perched water unit indicating a second MTBE source (see **Figure 4-6**) along the flow path to Mingo Basin.

See id., page 34 (highlighting added for emphasis). It appears that Evergreen is pointing to a possible second source within AOI-9.

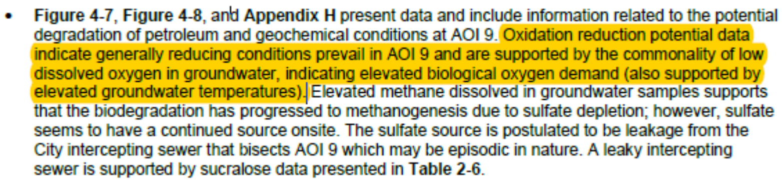
With respect to the deep aquifer, Evergreen states that well S-150SRTF (the only off-site well installed some distance from the property) and S-118DSRTF (located within the perimeter of AOI-9) are presumed to be from sources characterized in the AOI-9 water table and/or the perched unit:



- **Figure 4-9b** displays MTBE concentration data for the lower aquifer, indicating exceedances of the SHS are present along the southwestern boundary and in offsite well S-150SRTF. Concentrations are inferred to be stable to decreasing through time. **Appendix H** includes MTBE CSIA data interpretation for samples collected from wells S-118DSRTF and S-150SRTF shown in context with other samples recently collected across the former Philadelphia Refinery. The MTBE CSIA data indicate that wells S-118DSRTF and S-150SRTF are impacted by the same MTBE source which is presumed from multiple lines of evidence to be from sources characterized in the AOI 9 water-table and/or perched unit.

See id., page 34 (highlighting added for emphasis). Again, it appears that Evergreen is pointing to a possible second source within AOI-9.

Evergreen makes the unremarkable suggestion that some biodegradation is occurring in groundwater:



- **Figure 4-7**, **Figure 4-8**, and **Appendix H** present data and include information related to the potential degradation of petroleum and geochemical conditions at AOI 9. Oxidation reduction potential data indicate generally reducing conditions prevail in AOI 9 and are supported by the commonality of low dissolved oxygen in groundwater, indicating elevated biological oxygen demand (also supported by elevated groundwater temperatures). Elevated methane dissolved in groundwater samples supports that the biodegradation has progressed to methanogenesis due to sulfate depletion; however, sulfate seems to have a continued source onsite. The sulfate source is postulated to be leakage from the City intercepting sewer that bisects AOI 9 which may be episodic in nature. A leaky intercepting sewer is supported by sucralose data presented in **Table 2-6**.

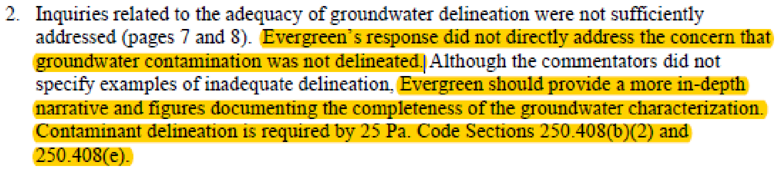
See id., page 34 (highlighting added for emphasis). With the closure of a refinery after 150 years, some biodegradation is not unexpected. Evergreen does not assert that this means it has no further responsibility.

5. Deep Aquifer in AOI-4.

a. The Department should not allow Evergreen to continue attempting to fragment the remedial investigation by diverting an analysis of the fate and transport of contaminants into a Remedial Investigation Report due at the end of the year.

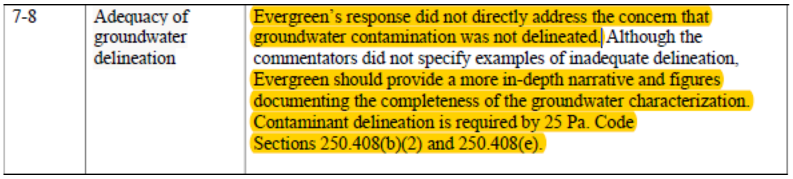
In its comments on previous reports for AOI-4 and AOI-9, the Council identified a number of flaws in Evergreen's investigation of the deep aquifer. The Council incorporates by reference its comments on the investigation of the deep aquifer. *See* Attachment 1 -- Comments of Clean Air Council dated January 14, 2021, Comment #7, pages 47-86. These comments were not adequately addressed by Evergreen in its Public Comment Remedial Investigation Report. *See* Former Refinery Public Comment RIR Report_03-31-2021 (March 31, 2021).

Several months later, the Department issued a letter of technical deficiency and supporting memorandum, noting that Evergreen had not sufficiently



2. Inquiries related to the adequacy of groundwater delineation were not sufficiently addressed (pages 7 and 8). Evergreen's response did not directly address the concern that groundwater contamination was not delineated. Although the commentators did not specify examples of inadequate delineation, Evergreen should provide a more in-depth narrative and figures documenting the completeness of the groundwater characterization. Contaminant delineation is required by 25 Pa. Code Sections 250.408(b)(2) and 250.408(e).

Attachment 2 -- Letter of Technical Deficiency dated June 29, 2021, page 2.[1]



7-8	Adequacy of groundwater delineation	Evergreen's response did not directly address the concern that groundwater contamination was not delineated. Although the commentators did not specify examples of inadequate delineation, Evergreen should provide a more in-depth narrative and figures documenting the completeness of the groundwater characterization. Contaminant delineation is required by 25 Pa. Code Sections 250.408(b)(2) and 250.408(e).

Attachment 3 -- Memorandum Regarding Letter of Technical Deficiency dated June 29, 2021, page 4.

In reviewing the present reports, it is important to note that Evergreen has already attempted to fragment the remedial investigation by diverting its investigation of the deep aquifer into a Fate and Transport Remedial Investigation Report due on December 31, 2021. The reports for AOI-11 that were disapproved years ago included a fate and transport analysis. Now Evergreen is attempting to take out the fate and transport analysis to segment the reports and make them easier to approve and harder to challenge. A fate and transport analysis is a part of a remedial investigation, and not separate from it.

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[1] While the Department asserts that "commenters did not specify examples of inadequate delineation," that is not the responsibility of commenters, who do not have access to the property. Commenters are not required to identify a contaminated sample of soil or groundwater that Evergreen has not identified. It is sufficient for comments to identify flaws in the methodology of Evergreen, which merit revisions of its work.

Now there is another potential for fragmentation of the remedial investigation reports. The Department is in the position of reviewing two addendum reports for AOI-4 and AOI-9 several months after issuing technical deficiency letters for reports that had been reopened for public comment in January 2021. The Department cannot reasonably approve either of these reports pending the deficiencies in the underlying reports to which these reports are to be added.

Stated differently, the Department should require Evergreen to consolidate its work for these two addenda reports with the other pending reports for AOI-4 and AOI-9, and it should include a Fate and Transport analysis all in one comprehensive report.

6. **Deep Aquifer in AOI-9.**

a. The Department should not allow Evergreen to continue attempting to fragment the remedial investigation by diverting an analysis of the fate and transport of contaminants into a Remedial Investigation Report due at the end of the year.

As discussed above in connection with AOI-4, the Department should not approve these fragmented reports, but should require Evergreen to consolidate them and include a Fate and Transport analysis in one comprehensive report.

7. **Vapor intrusion in AOI-4**

The Department should require Evergreen to revise its vapor intrusion investigation for AOI-4, which is significantly flawed.

In its report for AOI-4, Evergreen includes a section relating to testing for vapor intrusion. *See* 2021 Addendum Report (AOI-4), Section 3.0 (Updated Vapor Intrusion Assessment), pages 27-28. The following is the diagram of past locations of samples:

See id., Appendix G, Figure 1. This sampling included only one outdoor and one indoor air sample taken from AOI-4 (at 15 Pump House). *See id.* The indoor sample found several contaminants of concern, including benzene, ethylbenzene, naphthalene, toluene, 1,2,4-TMB, m,p-xylenes, and o-xylenes. *See id.*, at 17, Table 2-12. The concentrations of benzene, naphthalene, and 1,2,4-TMB were in excess of the Site Specific Standard Vapor Intrusion Screening Values. *See id.*, Table 2-12.

Evergreen also notes that it tested well samples for exceedance of the non-residential statewide health standard vapor intrusion screening values for groundwater in AOI-4, and marked these exceedances on a figure it notes also identifies potential preferential pathways for vapor intrusion:

See 2021 Addendum Report (AOI-4), page 27; Appendix G, Figure 3-1 (Vapor Intrusion Assessment).

a. Evergreen should analyze preferential pathways for vapor intrusion on- and off-site for AOI-9 before applying proximity distances or screening values.

Evergreen erroneously reverses the sequence of a proper vapor intrusion analysis, performing a screening before it has even completed a pathway analysis, and leaving the pathway analysis for another day. This contravenes the Department's guidance document. If the Department were to approve the report, it would enable Evergreen to avoid action to remedy vapor intrusion in future buildings in AOI-4 that are already anticipated.

Under Act 2, a remediator must address the vapor intrusion exposure pathway when a site has occupied buildings or future plans include inhabited buildings. *See* 25 Pa. Code 250.404 ("The person shall summarize [exposure] pathways for current land use and any probable future land use separately in the site-specific remedial investigation report."); 25 Pa. Code § 250.312(a) ("The final report must include, as appropriate, an assessment that addresses the vapor intrusion exposure pathway").

The Vapor Intrusion Guidance says that "[a]n assessment of external preferential pathways, significant foundation openings, and the presence of SPL [separate phase liquid] needs to be performed prior to screening as these are conditions that can limit the use of screening values." *See* Attachment 7 -- PA Department of Environmental Protection, Land Recycling Program Technical Guidance Manual, Section IV: Vapor Intrusion ("Vapor Intrusion Guidance"), page IV-39. Preferential pathways should also be examined before proximity distances are applied (or, at the very least, have to be examined in tandem with proximity distances), because when preferential pathways are present, the relevant proximity distances are those between sources of vapor and the pathways, rather than between sources of vapor and buildings themselves. *See id.* at IV-14--IV-23; Figure IV-6, page IV-44.[2]

But Evergreen's order of analysis is entirely reversed. Evergreen's analysis begins with a comparison of indoor air sampling to screening values. *See* 2021 Addendum Report (AOI-4), Section 3.1, pages 27-28 (Onsite Air Sampling Results). Then it examines proximity distances between locations of groundwater exceedances and off-site receptors. *See id.*, Section 3.2, pages 28-29 (Groundwater to Vapor Intrusion Screening). Then it concedes that it has not completed a preferential pathway analysis (which it claims it will do in a later Act 2 deliverable), even though it is aware that some utility lines are near areas with exceedances of the non-residential groundwater statewide health standard vapor intrusion screening values (SVGW-NR). *See id.*, Section 3.2.4, page 29 (Assessment of Preferential Pathways).

Evergreen has already identified a number of utility lines that may serve as preferential pathways throughout AOI-4, including in areas likely to have further development. *See id.*, Figure 3-1 (inlaid above). An approval of the report would undermine the Department's ability to require Evergreen to perform a proper analysis of the vapor intrusion pathway. It would be

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[2] Additionally, when Evergreen does a final analysis of proximity distances, it should prove, rather than assume, that the soil in AOI-4 is "acceptable soil" under the Vapor Intrusion Guidance, especially since it admits there is fill in AOI-4. *See* 2021 Addendum Report (AOI-4), page 28.

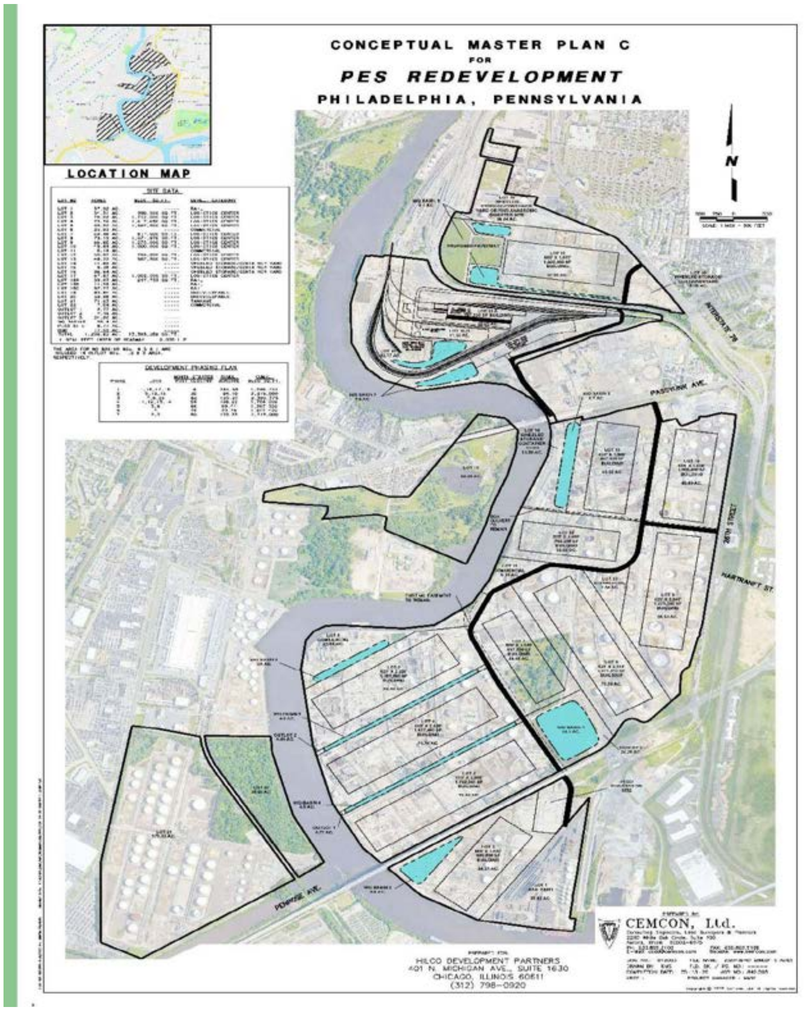
inappropriate to allow Evergreen to apply screening values and proximity distances before analysing preferential pathways.

b. Evergreen should take into account the location of planned buildings in AOI-4 in its vapor intrusion analysis.

Evergreen's responsibility for the vapor intrusion investigation extends to areas where future buildings are planned. *See* Vapor Intrusion Guidance, page IV-1 ("VI must be addressed for existing inhabited buildings and undeveloped areas of the property where inhabited buildings are planned to be constructed in the future."). This reflects regulatory requirements. *See* 25 Pa. Code 250.404 ("The person shall summarize [exposure] pathways for current land use *and any probable future land use* separately in the site-specific remedial investigation report.") (emphasis added).

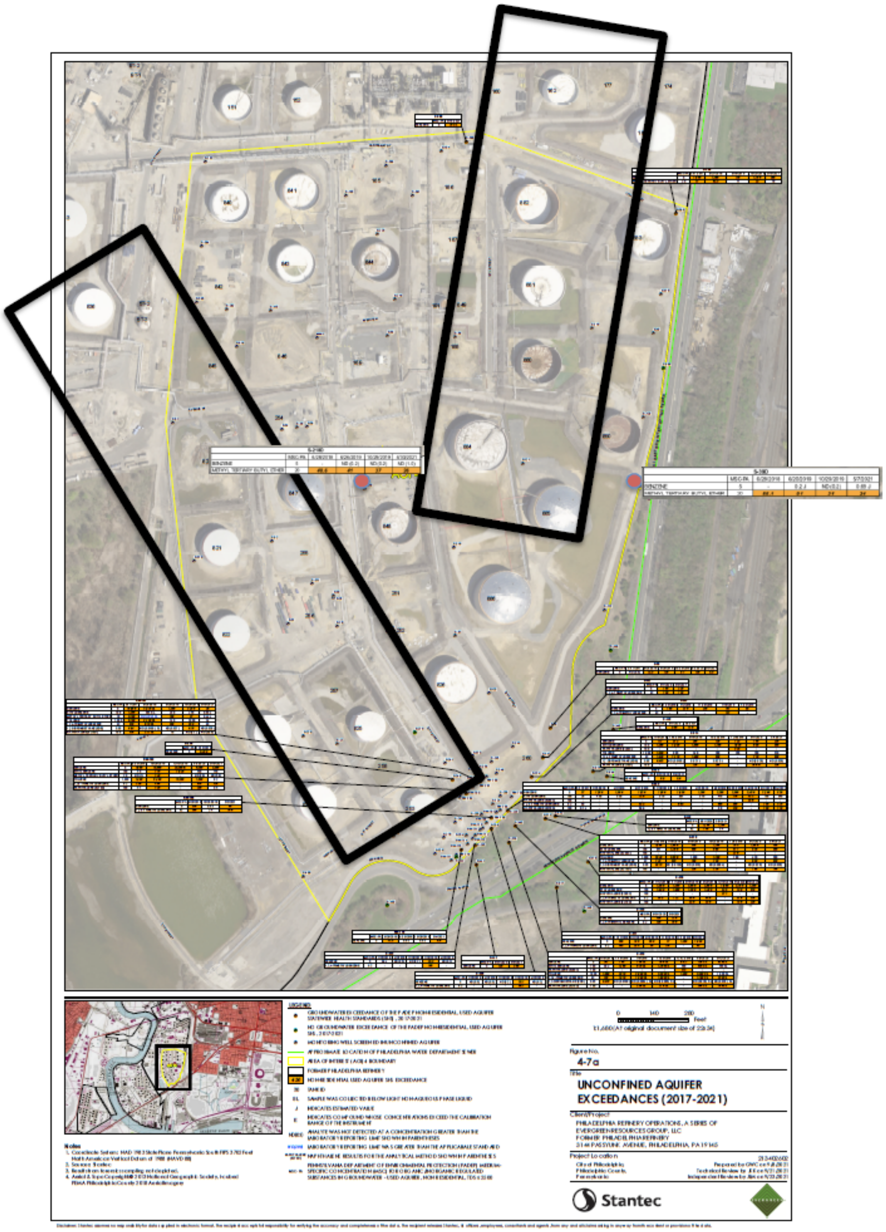
The Vapor Intrusion Guidance recommends a number of methods for testing near-source soil gas, sub-slab soil, and indoor air quality to screen for possible vapor intrusion. *See* Vapor Intrusion Guidance, at page IV-28--IV-29. It also specifically "recommends a minimum of two sample locations per building for sub-slab soil gas, and indoor air sampling and at least two near-source soil gas sample locations at the source." *Id.* It is therefore appropriate to require near-source soil gas sampling where buildings are planned, even if they have not yet been constructed.

According to its 2020 Master Plan for redevelopment, Hilco plans to construct buildings over much of AOI-4:



See Cemcon, Ltd., Conceptual Master Plan C for Future Redevelopment, located in Philadelphia Refinery Legacy Remediation Act 2 Program Information Session (August 27, 2020), page 10.

To represent these proposed buildings in Evergreen's map of groundwater exceedances in AOI-4, the Council has inserted black rectangles into the following figure showing groundwater exceedances:



See 2021 Addendum Report (AOI-4), Appendix G, Figure 4-7a (Unconfined Aquifer Exceedances).

Evergreen's analysis of groundwater to vapor intrusion screening does not address the anticipated existence of these buildings on the property. The only mention of the future use of the site Evergreen makes is where it appears to defer this indefinitely in the future. *See id.*, Section 3.2 (Groundwater to Vapor Intrusion Screening), pages 28-29. The Department should reject the suggestion that an intention by Hilco to install a remediation measure for vapor intrusion in the future is a substitute for Evergreen delineating the vapor intrusion problem now. *See id.*, page 28 ("As outlined in their Soil Management Plan dated June 15, 2020, HRP intends to install vapor mitigation measures on newly constructed buildings or conduct sampling to demonstrate that controls are not necessary"). Evergreen is the party responsible for this remediation, and it should therefore properly delineate exposure pathways itself, rather than deferring this to the future.

It is Evergreen's responsibility to properly investigate the existing contamination on the site. *See* 2012 Consent Order and Buyer-Seller Agreement, paragraphs L, 4. This responsibility should include a *full* examination of possible vapor intrusion, including in future buildings that are planned. *See* Vapor Intrusion Guidance, at page IV-1 ("VI must be addressed for existing inhabited buildings and undeveloped areas of the property where inhabited buildings are planned to be constructed in the future."). This reflects regulatory requirements. *See* 25 Pa. Code 250.404 ("The person shall summarize [exposure] pathways for current land use *and any probable future land use* separately in the site-specific remedial investigation report.") (emphasis added).

The Vapor Intrusion Guidance recommends a number of methods for testing near-source soil gas, sub-slab soil, and indoor air quality to screen for possible vapor intrusion. *See* Vapor Intrusion Guidance, at page IV-28--IV-29. It also specifically "recommends a minimum of two sample locations per building for sub-slab soil gas, and indoor air sampling and at least two near-source soil gas sample locations at the source." *Id.*

But Evergreen has only performed indoor air sampling in a building it acknowledges is likely to be demolished. To properly address the vapor intrusion pathway, it should take multiple samples of soil gas near each potential source of vapor intrusion in AOI-4 (e.g., known dissolved groundwater exceedances and pockets of SPL) and at the locations of planned buildings.

First, Evergreen should fully identify all possible preferential pathways of vapor intrusion, rather than defer this indefinitely to the future.

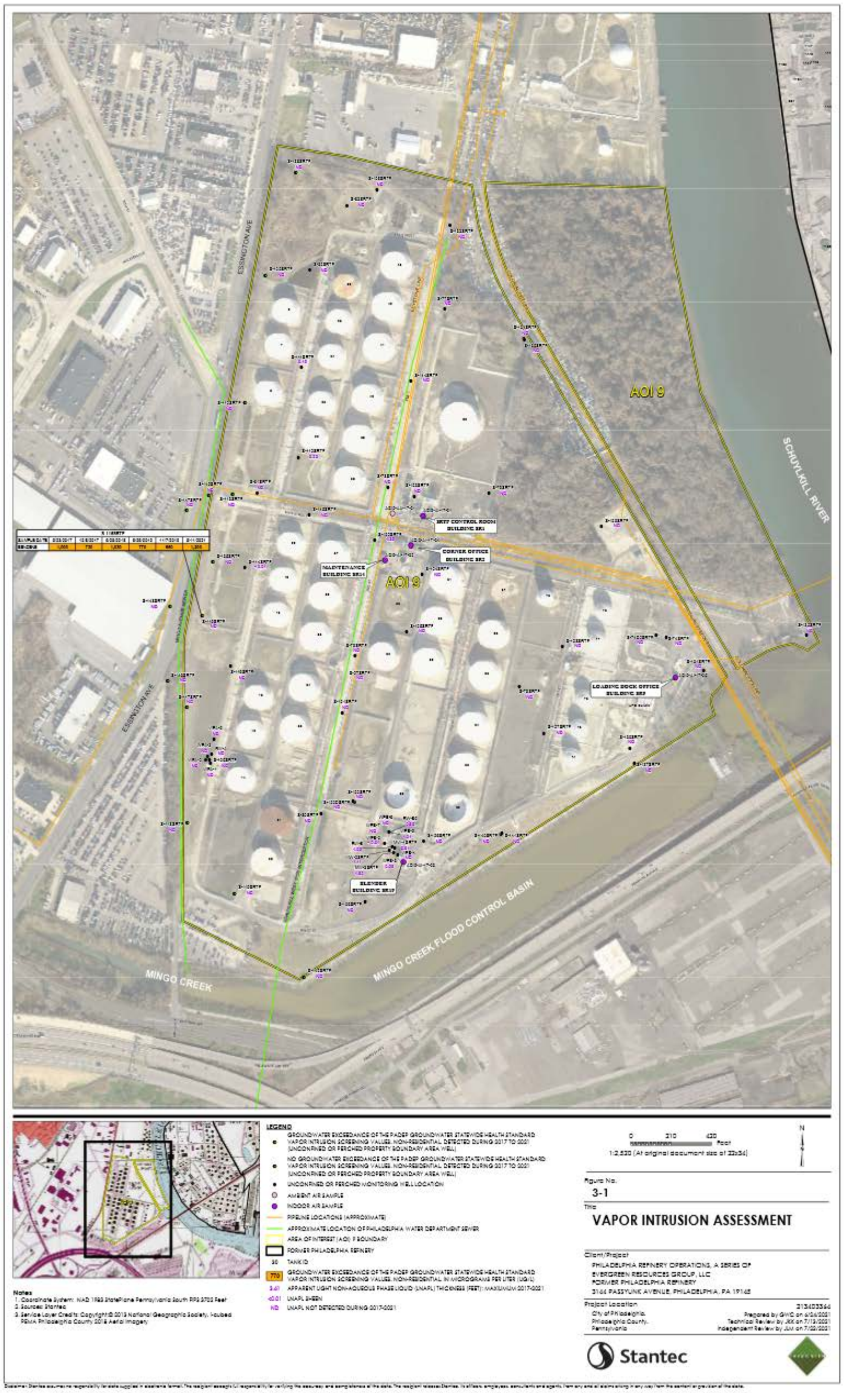
8. Vapor Intrusion in AOI-9

As in the case with AOI-4, the Department should require Evergreen to revise its vapor intrusion investigation for AOI-9, which is significantly flawed.

a. Evergreen should analyze preferential pathways for vapor intrusion on- and off-site for AOI-9 before applying proximity distances or screening values.

Again, Evergreen erroneously reverses the sequence of the vapor intrusion analysis. *See* AOI-9 Report, Section 3.1, pages 22-23 (Onsite Air Sampling Results). It recognizes that preferential pathways exist under AOI-9, including some utility lines that exit the property line. But it has not performed a full preferential pathway analysis, which it attempts to defer indefinitely into the future. *See id.*, Section 3.4, page 24 (Assessment of Preferential Pathways). At the same time, it prematurely claims to use horizontal proximity distances to rule out vapor intrusion from groundwater to off-site buildings. *See id.*, Section 3.2, pages 23-24 (Groundwater to Vapor Intrusion Screening).

On the following map, Evergreen notes the location of possible preferential pathways in AOI-9 (that it notes is incomplete):



See 2021 Addendum Report (AOI-9), Figure 3-1 (Vapor Intrusion Assessment). This Figure demonstrates that utility lines exit AOI-9 in multiple locations, providing possible pathways for vapor intrusion off-site. Both the orange and green lines shown could act as preferential pathways, and many leave the site.

As noted above with respect to AOI-4, the Vapor Intrusion Guidance states that "[a]n assessment of external preferential pathways, significant foundation openings, and the presence of SPL [separate phase liquid] needs to be performed prior to screening as these are conditions that can limit the use of screening values." Vapor Intrusion Guidance at IV-39. Therefore, Evergreen should complete a preferential pathway analysis before it applies screening values or proximity distances to address the vapor intrusion pathway, on-site or off-site.

It would be unreasonable for the Department to approve the current reports, which prematurely purport to rule out off-site vapor migration despite the lack of a complete analysis of preferential pathways, while pushing off a complete analysis of preferential pathways into the future. That would be tantamount to whipsawing the Department.

b. Evergreen should take additional soil samples before applying screening values to the buildings on AOI-9, in accordance with the Vapor Intrusion Guidance.

Hilco's Conceptual Master Plan (inlaid above) does not propose the construction of new buildings on AOI-9, and Hilco does not anticipate cut and fill activities on AOI-9 in its June 2020 Soil Management Plan. *See* HRP Philadelphia Holdings, LLC, Final Soil Management Plan, (June 15, 2020), Figure 2, page 19.

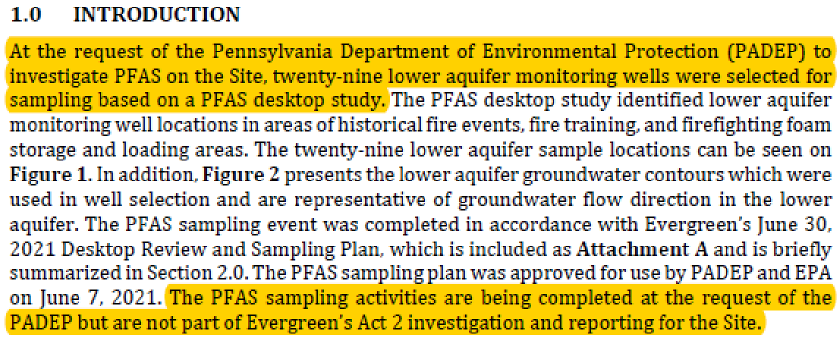
Evergreen has already analyzed some indoor air samples from the buildings in AOI-9. *See* AOI-9 Report, pages 21-22. According to the report, these samples found multiple instances of naphthalene in concentrations above the EPA's Regional Screening Values. *Id.* But Evergreen has not established that this is sufficient. The Department's guidance "recommends a minimum of two sample locations per building for sub-slab soil gas, and indoor air sampling and at least two near-source soil gas sample locations at the source." Vapor Intrusion Guidance, at IV-29. The exact number of samples needed to address vapor intrusion is determined based on a number of factors. Because indoor air sampling has already suggested potential vapor intrusion, Evergreen should perform soil-vapor testing near each building, both sub-slab and near-source, as the Guidance suggests.

9. PFAS

There is no discussion of PFAS chemicals in the remedial investigation reports for AOI-4 or AOI-9. Apparently, Evergreen has decided to divert the investigation of PFAS contamination into a separate investigation outside of the public comment process. This is inappropriate. In addition, the investigation of PFAS contaminants in the two reports in March 2021 and September 2021 is insufficient.

a. The Department should not allow Evergreen to divert a PFAS investigation into a separate investigation outside the Act 2 process and public comment process.

In response to comments from the public, Evergreen has prepared two reports relating to a remedial investigation for PFAS contaminants. *See* System Effluent PFAS Sampling Summary – 03-22-2021 ("March 2021 report"); *see also* PFAS Lower Aquifer Sampling Summary – 09-30-2021 ("September 2021 report"), *available at* https://phillyrefinerycleanup.info/pfas/. Nevertheless, Evergreen considers the PFAS investigation to be outside the scope of the Act 2 investigation:



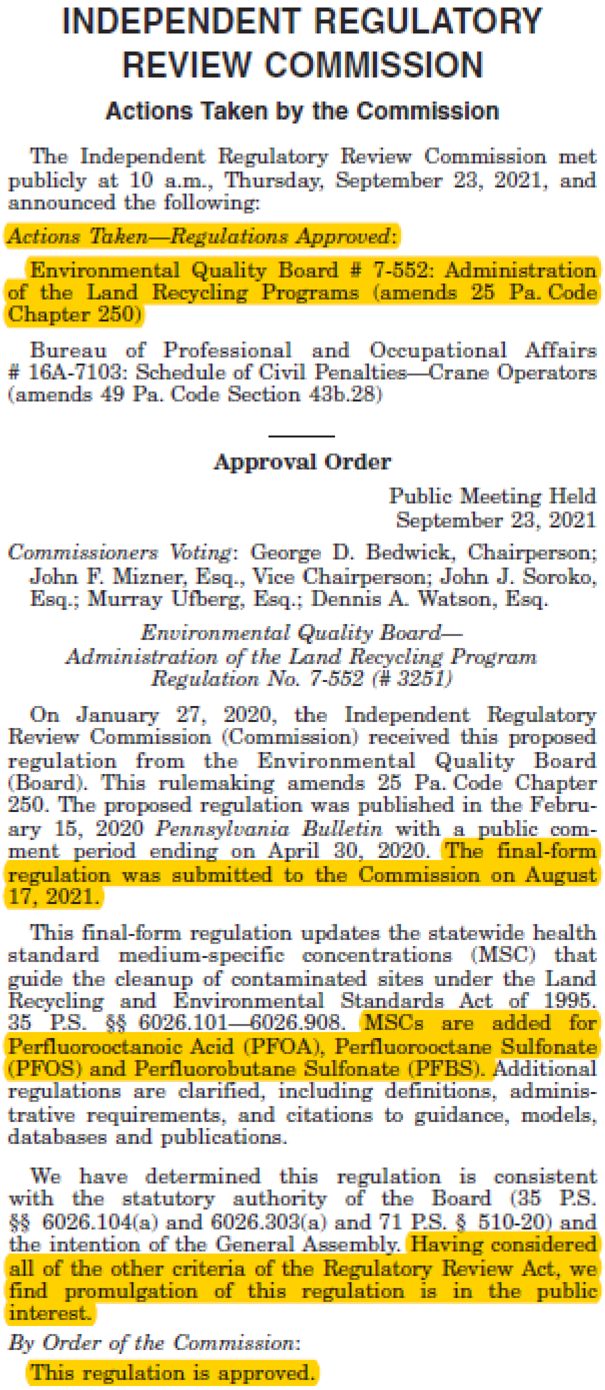
1.0 INTRODUCTION

At the request of the Pennsylvania Department of Environmental Protection (PADEP) to investigate PFAS on the Site, twenty-nine lower aquifer monitoring wells were selected for sampling based on a PFAS desktop study. The PFAS desktop study identified lower aquifer monitoring well locations in areas of historical fire events, fire training, and firefighting foam storage and loading areas. The twenty-nine lower aquifer sample locations can be seen on **Figure 1**. In addition, **Figure 2** presents the lower aquifer groundwater contours which were used in well selection and are representative of groundwater flow direction in the lower aquifer. The PFAS sampling event was completed in accordance with Evergreen's June 30, 2021 Desktop Review and Sampling Plan, which is included as **Attachment A** and is briefly summarized in Section 2.0. The PFAS sampling plan was approved for use by PADEP and EPA on June 7, 2021. The PFAS sampling activities are being completed at the request of the PADEP but are not part of Evergreen's Act 2 investigation and reporting for the Site.

See September 2021 report, pdf page 2, Sandborn Head Memorandum dated September 30, 2021 (highlighting added for emphasis).

In response to these comments, the Department should explain whether it will allow Evergreen to undertake this investigation outside the scope of the Act 2 investigation (and the public comment process), or whether this investigation will be incorporated into the Act 2 investigation. The Council incorporates by reference its comments on PFAS contamination that it made with respect to previous reports for AOI-4 and AOI-9. *See* Attachment 1 -- Comments of Clean Air Council dated January 14, 2021, Comment #15, pages 165-167.

If Evergreen's attempted diversion of a PFAS investigation into an investigation outside the Act 2 investigation and the public comment process is based on the premise that the PFAS chemicals are not "regulated substances" under the Act 2 regulations, the Department should explain how the PFAS investigation will be managed after the pending final-form rulemaking is published. The final-form rulemaking for remediation standards was submitted to the Independent Regulatory Review Commission on August 17, 2021. The Commission issued an order approving it this month:



INDEPENDENT REGULATORY REVIEW COMMISSION

Actions Taken by the Commission

The Independent Regulatory Review Commission met publicly at 10 a.m., Thursday, September 23, 2021, and announced the following:

Actions Taken—Regulations Approved:

Environmental Quality Board # 7-552: Administration of the Land Recycling Programs (amends 25 Pa. Code Chapter 250)

Bureau of Professional and Occupational Affairs # 16A-7103: Schedule of Civil Penalties—Crane Operators (amends 49 Pa. Code Section 43b.28)

Approval Order

Public Meeting Held
September 23, 2021

Commissioners Voting: George D. Bedwick, Chairperson; John F. Mizner, Esq., Vice Chairperson; John J. Soroko, Esq.; Murray Ufberg, Esq.; Dennis A. Watson, Esq.

Environmental Quality Board—
Administration of the Land Recycling Program
Regulation No. 7-552 (# 3251)

On January 27, 2020, the Independent Regulatory Review Commission (Commission) received this proposed regulation from the Environmental Quality Board (Board). This rulemaking amends 25 Pa. Code Chapter 250. The proposed regulation was published in the February 15, 2020 *Pennsylvania Bulletin* with a public comment period ending on April 30, 2020. The final-form regulation was submitted to the Commission on August 17, 2021.

This final-form regulation updates the statewide health standard medium-specific concentrations (MSC) that guide the cleanup of contaminated sites under the Land Recycling and Environmental Standards Act of 1995. 35 P.S. §§ 6026.101—6026.908. MSCs are added for Perfluorooctanoic Acid (PFOA), Perfluorooctane Sulfonate (PFOS) and Perfluorobutane Sulfonate (PFBS). Additional regulations are clarified, including definitions, administrative requirements, and citations to guidance, models, databases and publications.

We have determined this regulation is consistent with the statutory authority of the Board (35 P.S. §§ 6026.104(a) and 6026.303(a) and 71 P.S. § 510-20) and the intention of the General Assembly. Having considered all of the other criteria of the Regulatory Review Act, we find promulgation of this regulation is in the public interest.

By Order of the Commission:

This regulation is approved.

See 51 Pa. B. 6494 (October 9, 2021), http://www.pacodeandbulletin.gov/secure/pabulletin/data/vol51/51-41/51-41.pdf (highlighting added for emphasis).

As noted in the notice above, the final-form rulemaking will add three PFAS contaminants (PFOA, PFOS, and PFBS) to the list of regulated substances subject to Act 2 standards. *See* Preamble to Final-Form Rulemaking, pdf page 1 ("this rulemaking adds MSCs for three new contaminants, namely Perfluorooctanoic Acid (PFOA), Perfluorooctane Sulfonate (PFOS) and Perfluorobutane Sulfonate (PFBS)"); *see also* Final Appendix A, Tables 1-7, pdf pages 14 (Medium-Specific Concentrations for Organic Regulated Substances in Groundwater), 26 (Direct Contact Numeric Values), 45 (Soil to Groundwater Numeric Values), 65 (Physical and Toxicological Properties).[3]

Additionally, the Environmental Protection Agency intends to propose adding PFAS compounds (including PFOA and PFOS) to the list of hazardous substances under CERCLA. *See* U.S. EPA, PFAS Strategic Roadmap: EPA's Commitment to Action 2021-2024 (released October 2021), page 17 https://www.epa.gov/system/files/documents/2021-10/pfas-roadmap_final-508.pdf. A proposed rule is expected in early 2022. *See id.* Apart from the pending final-form rulemaking in Pennsylvania, Act 2 programs are required to address "regulated substances" which will include PFAS compounds upon EPA's "hazardous substances" designation.

The Department should not allow Evergreen to shift the PFAS investigation to an investigation outside the Act 2 process and public comment process.

b. With respect to effluent sampling, the PFAS investigation performed by Evergreen in AOI-4 and AOI-9 is insufficient.

According to the March 2021 report, Evergreen chose to sample effluent locations where there were discharges to the on-site industrial wastewater treatment plant or directly to the Philadelphia Water Department sewer system:

> Samples were collected from the treatment systems that currently discharge treated groundwater to the former refinery's onsite industrial wastewater treatment plant or directly to the Philadelphia Water Department (PWD) sewer system (currently Maiden Lane only).

March 2021 report, page 1. But Evergreen did not conduct sampling for contamination in the Penrose Avenue sewer system in AOI-4, even though that system is permitted for discharge to the Philadelphia Water Department. *See* Groundwater Remediation Status Report (First Half 2020), page 5, https://phillyrefinerycleanup.info/wp-content/uploads/2020/11/2020-First-Half-Philadelphia-Remed-Status-Report.pdf. Nor did it conduct sampling for contamination of effluent in AOI-9, even though it is a source of stormwater discharge to the Mingo Creek basin and the Southwest Water Pollution Control Plant:

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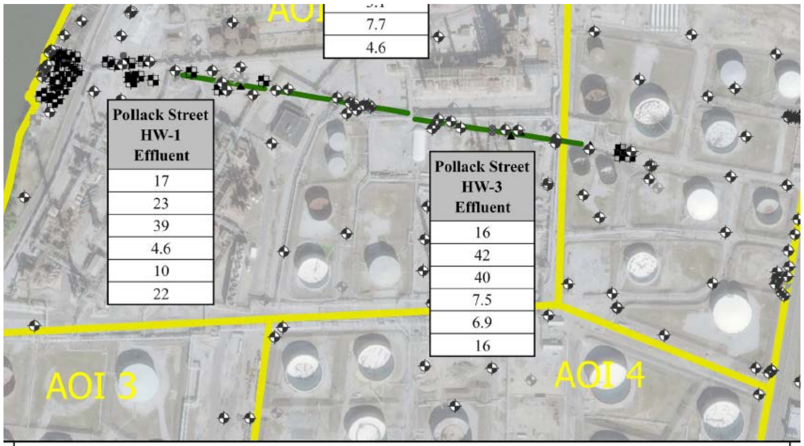
[3] Materials were downloaded from the Environmental Quality Board's website on October 27, 2021. *See* https://www.dep.pa.gov/PublicParticipation/EnvironmentalQuality/Pages/2021-Meetings.aspx (June 15, 2021 meeting materials).



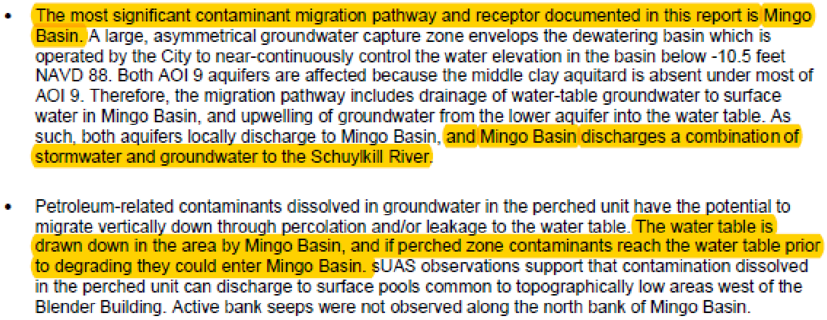
PFAS SAMPLING RESULTS - 17 FEBRUARY, 2021

FORMER PHILADELPHIA REFINERY
REMEDIATION SYSTEMS
PHILADELPHIA, PENNSYLVANIA

March 2021 report, Figure 1, pdf page 4 of 117.

The Department should require more sampling, including on-site sampling prior to discharge to the Mingo Creek basin and the Philadelphia Water Department Southwest Water Pollution Control Plant.

Evergreen admits that the Mingo Basin is the most significant contamination pathway discussed in the AOI-9 Report, and that Mingo Basin in turn flows into the Schuylkill River:



- The most significant contaminant migration pathway and receptor documented in this report is Mingo Basin. A large, asymmetrical groundwater capture zone envelops the dewatering basin which is operated by the City to near-continuously control the water elevation in the basin below -10.5 feet NAVD 88. Both AOI 9 aquifers are affected because the middle clay aquitard is absent under most of AOI 9. Therefore, the migration pathway includes drainage of water-table groundwater to surface water in Mingo Basin, and upwelling of groundwater from the lower aquifer into the water table. As such, both aquifers locally discharge to Mingo Basin, and Mingo Basin discharges a combination of stormwater and groundwater to the Schuylkill River.

- Petroleum-related contaminants dissolved in groundwater in the perched unit have the potential to migrate vertically down through percolation and/or leakage to the water table. The water table is drawn down in the area by Mingo Basin, and if perched zone contaminants reach the water table prior to degrading they could enter Mingo Basin. sUAS observations support that contamination dissolved in the perched unit can discharge to surface pools common to topographically low areas west of the Blender Building. Active bank seeps were not observed along the north bank of Mingo Basin.

See 2021 Addendum Report (AOI-9), pdf page 40 of 246. Stated differently, the effluent from the refinery (stormwater, groundwater) going into the Mingo Basin is not significantly different from the effluent that Evergreen did sample in other areas of interest in the March 2021 report.

The Department should require Evergreen to expand its sampling for PFAS in AOI-4 and AOI-9 to include effluent sampling in those areas of interest.

c. With respect to deep aquifer sampling, the PFAS investigation performed by Evergreen in AOI-4 and AOI-9 is insufficient.

According to the second sampling report in September 2021, Evergreen chose locations for sampling in the lower aquifer based on areas of historical fire events and related activities:

> The PFAS desktop study identified lower aquifer monitoring well locations in areas of historical fire events, fire training, and firefighting foam storage and loading areas.

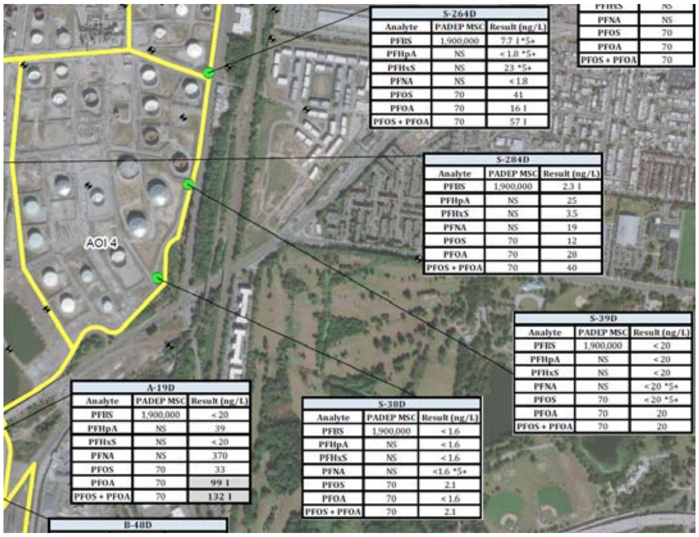
See PFAS Lower Aquifer Sampling Summary – 09-30-2021, page 2. This sampling approach is too limiting, given the propensity of PFAS contaminants to migrate for distances. PFAS contaminants persist for long periods of time. *See* U.S. Environmental Protection Agency, Technical Fact Sheet – Perfluorooctane Sulfonate (PFOS) and Perfluorooctanoic Acid (PFOA) (November 2017), https://www.epa.gov/sites/production/files/2017-12/documents/ffrrofactsheet_contaminants_pfos_pfoa_11-20-17_508_0.pdf. Once they migrate into groundwater they can spread for distances away from the entry point. Performing sampling at only the assumed locations of historical firefighting activities is unduly limiting.

Additionally, the use of fire fighting foams introduces many varieties of polyfluorinated PFAS compounds. Polyfluorinated compounds can be naturally transformed to perfluorinated PFAS compounds such as PFOA and PFOS after migrating, creating new PFOA and PFOS plumes away from the original release location. Since it is known that firefighting foams were used in large quantities at the refineries, a more extensive sampling program should be undertaken throughout the unconfined and deep aquifers, and not just in the locations sampled.

In the case of AOI-4, Evergreen conducted sampling for PFAS contaminants in only two monitoring wells at the eastern edge of the property (S-38D and S-39D):

See September 2021 Report, pdf page 10 of 107, Figure 3 (Potential Areas Where Firefighting Foam May Have Been Previously Used at the Former Philadelphia Refinery).

The report states that the results were below the Department's proposed Medium-Specific Concentrations:



PFHxS	NS
PFNA	NS
PFOS	70
PFOA	70
PFOS + PFOA	70

S-264D

Analyte	PADEP MSC	Result (ng/L)
PFBS	1,900,000	7.7 I *5+
PFHpA	NS	< 1.8 *5+
PFHxS	NS	23 *5+
PFNA	NS	< 1.8
PFOS	70	41
PFOA	70	16 I
PFOS + PFOA	70	57 I

S-284D

Analyte	PADEP MSC	Result (ng/L)
PFBS	1,900,000	2.3 I
PFHpA	NS	25
PFHxS	NS	3.5
PFNA	NS	19
PFOS	70	12
PFOA	70	28
PFOS + PFOA	70	40

S-39D

Analyte	PADEP MSC	Result (ng/L)
PFBS	1,900,000	< 20
PFHpA	NS	< 20
PFHxS	NS	< 20
PFNA	NS	< 20 *5+
PFOS	70	< 20 *5+
PFOA	70	20
PFOS + PFOA	70	20

A-19D

Analyte	PADEP MSC	Result (ng/L)
PFBS	1,900,000	< 20
PFHpA	NS	39
PFHxS	NS	< 20
PFNA	NS	370
PFOS	70	33
PFOA	70	99 I
PFOS + PFOA	70	132 I

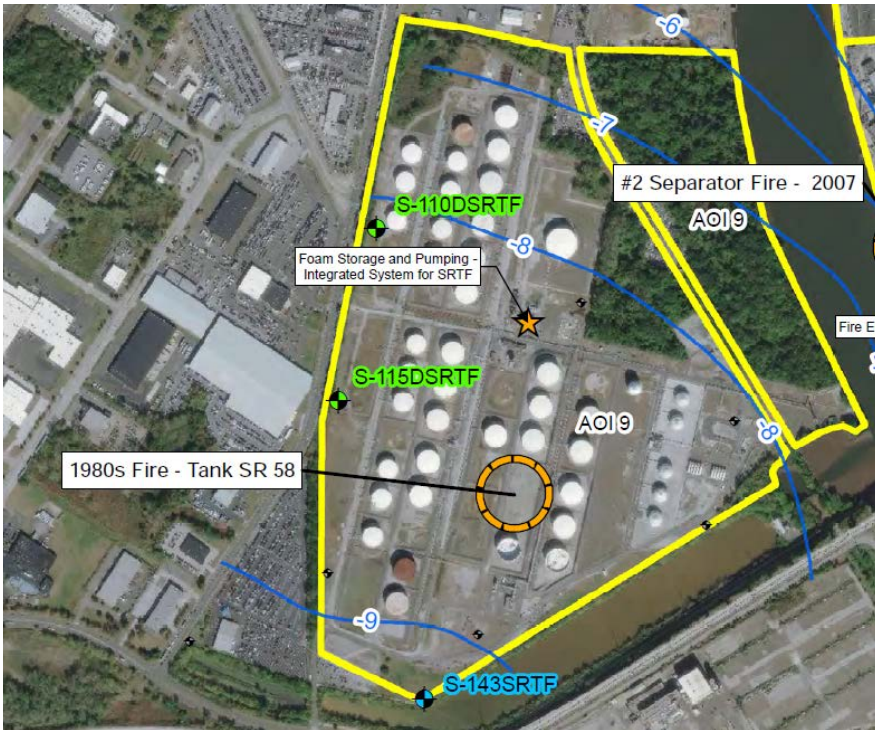
S-38D

Analyte	PADEP MSC	Result (ng/L)
PFBS	1,900,000	< 1.6
PFHpA	NS	< 1.6
PFHxS	NS	< 1.6
PFNA	NS	<1.6 *5+
PFOS	70	2.1
PFOA	70	< 1.6
PFOS + PFOA	70	2.1

B-48D

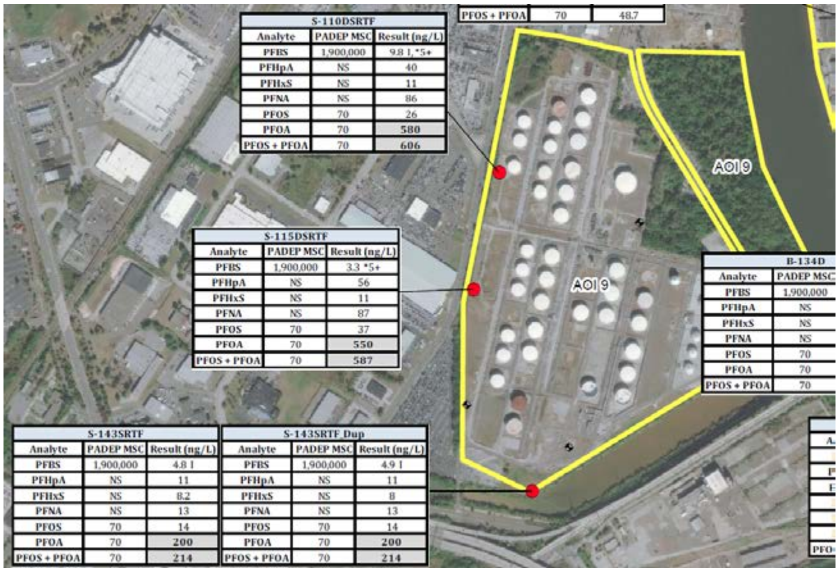
See id., pdf page 11 of 107, Figure 4 (July 2021 Lower Aquifer PFAS Groundwater Results in Data Boxes).

In the case of AOI-9, Evergreen conducted sampling at only three lower aquifer locations at the edge of the property (S-110,S-115, S-143):



See id., pdf page 10 of 107, Figure 3 (Potential Areas Where Firefighting Foam May Have Been Previously Used at the Former Philadelphia Refinery).

For the three samples in AOI-9, all three locations show elevated values of PFAS contaminants several times higher than the Department's proposed Medium-Specific Concentrations:



PFOS + PFOA	70	48.7

S-110DSRTF		
Analyte	PADEP MSC	Result (ng/L)
PFBS	1,900,000	9.8 J,*5+
PFHpA	NS	40
PFHxS	NS	11
PFNA	NS	86
PFOS	70	26
PFOA	70	580
PFOS + PFOA	70	606

S-115DSRTF		
Analyte	PADEP MSC	Result (ng/L)
PFBS	1,900,000	3.3 *5+
PFHpA	NS	56
PFHxS	NS	11
PFNA	NS	87
PFOS	70	37
PFOA	70	550
PFOS + PFOA	70	587

B-134D	
Analyte	PADEP MSC
PFBS	1,900,000
PFHpA	NS
PFHxS	NS
PFNA	NS
PFOS	70
PFOA	70
PFOS + PFOA	70

S-143SRTF		
Analyte	PADEP MSC	Result (ng/L)
PFBS	1,900,000	4.8 J
PFHpA	NS	11
PFHxS	NS	8.2
PFNA	NS	13
PFOS	70	14
PFOA	70	200
PFOS + PFOA	70	214

S-143SRTF_Dup		
Analyte	PADEP MSC	Result (ng/L)
PFBS	1,900,000	4.9 J
PFHpA	NS	11
PFHxS	NS	8
PFNA	NS	13
PFOS	70	14
PFOA	70	200
PFOS + PFOA	70	214

See id., pdf page 11 of 107, Figure 4 (July 2021 Lower Aquifer PFAS Groundwater Results in Data Boxes). Concentrations of 580 ng/L, 550 ng/L, and 200 ng/L for PFOA in S-110DSRTF, S-115DSRTF, and S-143SRTF are several times the proposed Medium-Specific Concentration of 70 ng/L, and concentrations of 606 ng/L, 587 ng/L, and 214 ng/L for PFOA + PFOA in the same samples are several times the proposed Medium-Specific Concentration of 70 ng/L.

In the case of both AOI-4 and AOI-9, Evergreen should be doing more sampling based on the flow of groundwater in the lower aquifer, and not just based on the assumed locations of historical fires.

The two PFAS reports that Evergreen has prepared do not provide a justification for the lack of testing in locations that are adjacent or downgradient of the locations of historical fires, or other locations into which groundwater might flow. Therefore, they do not sufficiently delineate the nature and extent of PFAS contamination.

d. The Department should require Evergreen to conduct sampling PFAS in the water table (upper aquifer), which it has not done.

Although Evergreen took some samples of the deep aquifer, it did not conduct any sampling of the water table. The March 2021 report relates to effluent from treatment systems and the September 2021 report relates to the deep aquifer. There is no reason for Evergreen to ignore the water table when conducting sampling for PFAS. The Department should require Evergreen to include the water table.

Evergreen's sampling approach for PFAS is too limiting. The Department should require Evergreen to perform sampling based on broader considerations that consider the propensity of PFAS contaminants to migrate in groundwater and the flow of groundwater to Mingo Basin, and it should be conducting sampling in the water table.

Thank you for your consideration of the comments of the Council.

____
Joseph Otis Minott
Executive Director and Chief Counsel

Christopher D. Ahlers
Staff Attorney

Joseph A. Ingrao
Legal Fellow

Nily Dan, Ph.D (Chemical Engineering)
Engineering Volunteer
Consultant

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cdbrown@pa.gov (Department of Environmental Protection)
jdula@pa.gov
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pennsylvania
DEPARTMENT OF ENVIRONMENTAL
PROTECTION

June 29, 2021

Ms. Tiffani L. Doerr, PG
Evergreen Resource Management Operations
2 Righter Parkway, Suite 120
Wilmington, DE 19083

Re: Letter of Technical Deficiency
Public Involvement Remedial Investigation Report
eFACTS PF No. 780190
PESRM - Evergreen
3144 Passyunk Avenue
City of Philadelphia
Philadelphia County

Dear Ms. Doerr:

The Department of Environmental Protection (DEP) has received and reviewed the March 31, 2021 document titled "Public Comment Remedial Investigation Report" (report), received on March 31, 2021 for the property referenced above. The report was prepared by Sanborn Head and Associates, Inc. and submitted to DEP in accordance with the Land Recycling and Environmental Remediation Standards Act (Act 2), and it constitutes a Remedial Investigation Report as defined in Chapter 3.

The subject report consists of public comments and responses by the remediator, Evergreen Resources Management Operations, concerning various Act 2 remedial investigation and risk assessment reports submitted between 2011 and 2017.

The procedures and regulations set forth in Act 2 must be followed in order for your site to qualify for the liability protection provided by the Act. Upon initial review, DEP finds the submission is technically deficient and the following items are needed to complete your submission:

1. There were multiple public inquiries regarding potential impacts to drinking water supplies, including a question about drinking water intake portals downstream from the site (pages 5, 31, 28-31 42-43, and 76). Evergreen's response indicated that Pennsylvania Groundwater Information System (PaGWIS) and eMapPA were evaluated for identification of potable supply wells within a one-mile radius of the site. Inquiries with DEP's Safe Drinking Water Program and New Jersey Department of Environmental Protection (NJDEP) are also needed. On page 29, Evergreen states "The groundwater beneath the site is not allowed to be used for any potable (human consumption) or industrial use…" Evergreen should include reference to the source material to support this statement.

The response on pages 30-31 includes reference to two USGS reports without summarizing the findings, details on how these reports were used to develop the site conceptual model, or how they will be used in the fate and transport model.

The response on page 31, 43, and 76 should be moved to Section 2 of the report, and "low probability for potable water supply wells in the area," "not expected to impact local drinking water supplies," and "concentrations found in the deep aquifer do not indicate a potential risk to communities in New Jersey…" should be qualified with documentation.

Exposure pathway evaluation is a requirement of 25 Pa. Code Section 250.404.

2. Inquiries related to the adequacy of groundwater delineation were not sufficiently addressed (pages 7 and 8). Evergreen's response did not directly address the concern that groundwater contamination was not delineated. Although the commentators did not specify examples of inadequate delineation, Evergreen should provide a more in-depth narrative and figures documenting the completeness of the groundwater characterization. Contaminant delineation is required by 25 Pa. Code Sections 250.408(b)(2) and 250.408(e).

3. There were a group of comments regarding lead delineation in soil (pages 10 and 15). Given the level of interest and number of comments regarding lead, a more detailed response is warranted for the public. Evergreen did not present a sufficient narrative explaining how lead in soil has been adequately delineated at the site boundaries and summary figures showing where lead results meet the Statewide health standard medium specific concentration (SHS MSC), as well as figures that show where concentrations are present at or above the soil to groundwater SHSnumeric value, the direct contact SHS numeric value, and the site-specific standard across the site. Contaminant delineation is required by 25 Pa. Code Sections 250.408(b)(2) and 250.408(d).

4. Comments regarding benzene concentrations near the Verizon South District Work Center (SDWC) property and Maiden Lane and concern about potential offsite migration were included on pages 15 and 16. These questions were specific to the adequacy of the delineation of groundwater contamination in this area of the site. Evergreen's response did not adequately explain and document (with figures and tables) that the extent of the benzene plume was determined in the remedial investigation. Contaminant delineation is required by 25 Pa. Code Sections 250.408(b)(2) and 250.408(e).

5. Comments were also received regarding benzene concentrations at the property boundary (pages 27 and 43). One commentator contended that benzene groundwater contamination beyond the fence line had not been mapped. Evergreen did not document in their response that the extent of benzene contamination in groundwater at and beyond the property boundary has been determined in the remedial investigations. This

documentation should include an expanded narrative and maps. Contaminant delineation is required by 25 Pa. Code Sections 250.408(b)(2) and 250.408(e).

6. A question regarding the condition of land along the waterfront following ship fires was included on page 77. Evergreen's response stated waterfront investigations are presented in remedial investigation reports for Areas of Interest (AOIs) 2, 3, 5, 6, 7, 8, 9, and 10. Evergreen did not provide a detailed summary with specific information to answer the question. Soil characterization is required by 25 Pa. Code Sections 250.408(b)(2) and 250.408(d).

Please address the above summarized technical deficiencies within 60 days. If the deficiencies noted above are corrected and a report resubmitted to DEP within 60 days, it will not be necessary to resubmit report review fees, resend the municipal notice, or republish the public notice. Please include a copy of this correspondence with any resubmission to confirm to DEP staff that an administrative completeness check is not necessary. If the corrected report is resubmitted later than 60 days from the date of this letter, the resubmitted report will need to include the appropriate fees and proofs of municipal and public notices.

We look forward to assisting you in the remediation of this property and encourage you to contact us throughout this process. If you have any questions or need further information regarding this matter, please contact Lisa Strobridge by email at lstrobridg@pa.gov or by telephone at 484.250.5796.

Any person aggrieved by this action may appeal the action to the Environmental Hearing Board (Board), pursuant to Section 4 of the Environmental Hearing Board Act, 35 P.S. § 7514, and the Administrative Agency Law, 2 Pa.C.S. Chapter 5A. The Board's address is:

Environmental Hearing Board
Rachel Carson State Office Building, Second Floor
400 Market Street
P.O. Box 8457
Harrisburg, PA 17105-8457

TDD users may contact the Environmental Hearing Board through the Pennsylvania Relay Service, 800.654.5984.

Appeals must be filed with the Board within 30 days of receipt of notice of this action unless the appropriate statute provides a different time. This paragraph does not, in and of itself, create any right of appeal beyond that permitted by applicable statutes and decisional law.

A Notice of Appeal form and the Board's rules of practice and procedure may be obtained online at http://ehb.courtapps.com or by contacting the Secretary to the Board at 717.787.3483. The Notice of Appeal form and the Board's rules are also available in braille and on audiotape from the Secretary to the Board.

IMPORTANT LEGAL RIGHTS ARE AT STAKE. YOU SHOULD SHOW THIS DOCUMENT TO A LAWYER AT ONCE. IF YOU CANNOT AFFORD A LAWYER, YOU MAY QUALIFY FOR FREE PRO BONO REPRESENTATION. CALL THE SECRETARY TO THE BOARD AT 717.787.3483 FOR MORE INFORMATION. YOU DO NOT NEED A LAWYER TO FILE A NOTICE OF APPEAL WITH THE BOARD.

IF YOU WANT TO CHALLENGE THIS ACTION, YOUR APPEAL MUST BE FILED WITH AND RECEIVED BY THE BOARD WITHIN 30 DAYS OF RECEIPT OF NOTICE OF THIS ACTION.

Sincerely,

Ragesh R Patel

Ragesh R. Patel
Regional Manager
Environmental Cleanup and Brownfields

cc:
- Ms. Costello (Sanborn, Head & Associates, Inc.)
- Philadelphia Department of Health
- City of Philadelphia
- Mr. Brown, P.G.
- Ms. Strobridge, PG
- Mr. Glass, Esq.
- Mr. Bilash, U.S. EPA
- Ms. Bass

pennsylvania
DEPARTMENT OF ENVIRONMENTAL
PROTECTION

MEMO

TO Ragesh R. Patel
Regional Manager
Environmental Cleanup and Brownfields

FROM Lisa Strobridge, P.G. Lisa Strobridge
Professional Geologist

THROUGH C. David Brown, P.G
Professional Geologist Manager

DATE June 29, 2021

RE ECB – Land Recycling Program
Act 2 Technical Memo Summary
Public Involvement Remedial Investigation Report
eFACTS PF No. 780190
PESRM - Evergreen
3144 Passyunk Avenue
City of Philadelphia
Philadelphia County

Property Owner:
Hilco Redevelopment Partners
99 Summer Street, Suite 1110, Boston, MA 02110

Remediator:
Evergreen Resource Management Operations
2 Righter Parkway, Suite 120
Wilmington, DE 19083

Site Address:
3144 Passyunk Ave
Philadelphia, PA 19145

Act 2 Standard(s) Sought: site-specific standard for soil and groundwater

Property Size: ~1300 acres

Project Site History: Petroleum refining began at the Philadelphia Refinery circa 1870. The facility consisted of two refineries, Point Breeze operated by Atlantic Petroleum Corporation (formerly ARCO) and Girard Point by Chevron (formerly Gulf). Sunoco purchased these two refineries in 1988 and 1994 and consolidated them into a single facility. In 2012 Sunoco sold the refinery to the Carlyle Group and entered a joint venture to operate it as Philadelphia Energy Solutions (PES). Sunoco, Inc. is now a subsidiary of Energy Transfer Partners, L.P., and Evergreen is a Sunoco affiliate that is responsible for legacy environmental remediation. In 2020 PES was acquired by Hilco Redevelopment Partners (HRP).

The Philadelphia Refinery processed up to 330,000 barrels a day of crude oil. It produced gasoline, diesel, jet fuel, kerosene, home heating oil, and other petroleum liquids. The facility consisted of multiple process units, above-ground storage tanks, pipelines, as well as truck, railcar, and barge transfer equipment. The facility has been divided into eleven areas of interest (AOI 1–11) for purposes of characterizing contamination. The first ten are geographical areas of the facility, and AOI 11 represents the deep groundwater aquifer.

Site Cleanup History: An initial NIR was submitted October 16, 2006; it was revised with updated information on November 17, 2014 and December 14, 2016. The facility entered into a consent order and agreement with DEP's Clean Water Program in December 1993; the agreement was succeeded by another in December 2003 which terminated in December 2013. The facility is currently subject to a DEP buyer–seller agreement which became effective September 8, 2012 and was amended June 26, 2020. The site entered into the One Cleanup Program with DEP and EPA on November 8, 2011.

The City of Philadelphia requested a public involvement plan in a letter dated November 3, 2006. Sunoco held an initial public meeting on September 19, 2007. Sunoco began submitting Act 2 remedial investigation reports in 2011; multiple Act 2 reports were submitted by Sunoco and Evergreen through 2017. In 2018 DEP determined that Evergreen had not fulfilled the public participation requirements of Act 2 for the reports that had been submitted and reviewed. In a meeting on November 27, 2018 with Evergreen, the City, and EPA, and in subsequent communications and meetings, DEP directed Evergreen to rectify the lack of public involvement for the 2011–2017 reports and ensure that public involvement requirements were satisfied for all future reporting.

Since 2019 Evergreen has reinvigorated the public participation program for the project. Public outreach has included: a website posting all Act 2 reports and related documents, plain language summaries of reports, an informational mailer sent to surrounding addresses by U.S. Mail, placing documents in two neighborhood libraries, creating an email distribution list, soliciting comments and questions on the website and through other means, meeting with community groups, and hosting public information and question-and-answer sessions. Evergreen held a public meeting on August 27, 2020 which initiated a public comment period for the 2011–2017 reports. The period lasted over 120 days and closed with another public meeting on January 14, 2021. The comment/response remedial investigation report reviewed here is the compilation of the questions and comments received during (and before) that period.

The comment/response RIR encompasses the corrective public participation for all of the following previously submitted Act 2 reports.

Area	PF ID	Report Type	Report Date	Decision Letter	Status
Site-wide	780190	RAR	2/26/2015	5/6/2015	approved
AOI 1	778374	RIR	8/16/2016	11/1/2016	approved
AOI 2	778376	RIR	7/25/2017	10/18/2017	approved
AOI 3	778377	RIR	3/22/2017	6/14/2017	approved
AOI 4	770318	RIR	10/18/2013	1/15/2014	disapproved
		RIR	3/27/2017	6/21/2017	disapproved
AOI 5	748141	RIR	12/15/2011	3/15/2012	disapproved
		RIR	2/10/2017	5/2/2017	approved
AOI 6	769099	RIR	9/5/2013	11/27/2013	disapproved
		RIR	11/28/17	2/26/2018	approved
AOI 7	750870	RIR	3/1/2012	n/a	no decision
		RIR	9/20/2013	12/18/2013	disapproved
		RIR	6/12/2017	8/30/2017	approved
AOI 8	749898	RIR	2/6/2012	n/a	no decision
		RIR	12/27/2017	3/22/2018	approved
AOI 9	778379	RIR	12/31/2015	3/28/2016	disapproved
		RIR	2/8/2017	4/18/2017	disapproved
AOI 10	720775	RIR	8/10/2011	1/6/2012	approved
		RAR	8/19/2016	11/10/2016	approved
AOI 11	745291	RIR	9/12/2011	n/a	no decision
		FR	6/28/2013	9/26/2013	disapproved

PF ID: eFACTS primary facility identification number
AOI: area of interest
RIR: remedial investigation report
RAR: risk assessment report
FR: final report

Review Findings: This technical memo summarizes DEP’s review of the March 31, 2021 Public Comment Remedial Investigation Report. Overall, the report captured the comments that were received as part of public review process including public meetings and online submittals, and it provides responses to each of the questions and comments. Evergreen separated their responses into two sections: one for comments related to past Act 2 reports and the other for additional comments not specific to Act 2 reports. Many of the questions and comments pertained to issues that will be addressed in future reports (groundwater fate and transport, risk assessments, cleanup plans), that relate to environmental issues outside of the Act 2 cleanup (such as air quality), or involve HRP’s redevelopment plans. Many questions simply sought further information, and Evergreen provided appropriate responses. DEP examined the questions and comments from the above categories that were not specific to Act 2 reports, but this Act 2 Technical Memo Summary focuses on questions and comments specific to Act 2 reports.

Response Deficiencies

Page Number	**Public Comment**	**DEP Assessment**
5, 28-31, 42-43, 76	Multiple inquiries are present regarding potential impacts to drinking water supplies, including a question about drinking water intake portals downstream from the site.	Evergreen's response indicated that Pennsylvania Groundwater Information System **(**PaGWIS**)** and eMapPA were evaluated for identification of potable supply wells within a one-mile radius of the site. Inquiries with DEP's Safe Drinking Water Program and New Jersey Department of Environmental Protection (NJDEP) are also needed. On page 29, Evergreen states "The groundwater beneath the site is not allowed to be used for any potable (human consumption) or industrial use…" Evergreen should include reference to the source material to support this statement. The response on page 30-31 includes reference to two USGS reports without summarizing the findings, details on how these reports were used to develop the site conceptual model, or how they will be used in the fate and transport model. In addition, the response on page 31, 43, and 76 should be moved to Section 2 of the report, and "low probability for potable water supply wells in the area," "not expected to impact local drinking water supplies," and "concentrations found in the deep aquifer do not indicate a potential risk to communities in New Jersey…" should be qualified with documentation. Exposure pathway evaluation is a requirement of 25 Pa. Code Section 250.404.
7-8	Adequacy of groundwater delineation	Evergreen's response did not directly address the concern that groundwater contamination was not delineated. Although the commentators did not specify examples of inadequate delineation, Evergreen should provide a more in-depth narrative and figures documenting the completeness of the groundwater characterization. Contaminant delineation is required by 25 Pa. Code Sections 250.408(b)(2) and 250.408(e).
10 and 15	Group of comments regarding lead delineation	Given the level of interest and number of comments regarding lead, a more detailed response is warranted for the public. Evergreen did not present a sufficient narrative explaining how lead in soil has been adequately delineated at the site boundaries and summary figures showing where lead results meet the Statewide health standard medium specific concentrations (SHS MSC), as well as figures that show where

		concentrations are present at or above the soil to groundwater SHS MSC, the direct contact SHS MSC, and the site-specific standard across the site. Contaminant delineation is required by 25 Pa. Code Sections 250.408(b)(2) and 250.408(d).
15-16	Group of comments regarding benzene concentrations near Verizon SDWC property and Maiden Lane and concern about potential offsite migration.	These questions were specific to the adequacy of the delineation of groundwater contamination in this area of the site. Evergreen's response did not adequately explain and document (with figures and tables) that the extent of the benzene plume was determined in the remedial investigation. Contaminant delineation is required by 25 Pa. Code Sections 250.408(b)(2) and 250.408(e).
27, 43	Comments regarding benzene near property boundary.	Comments were also received regarding benzene concentrations at the property boundary (pages 27 and 43). One commentator contended that benzene groundwater contamination beyond the fence line had not been mapped. Evergreen did not document in their response that the extent of benzene contamination in groundwater at and beyond the property boundary has been determined in the remedial investigations. This documentation should include an expanded narrative and maps. Contaminant delineation is required by 25 Pa. Code Sections 250.408(b)(2) and 250.408(e).
40 and 77	Questions about condition of land along the waterfront following ship fires.	Evergreen's response stated waterfront investigations are presented in remedial investigation reports for Areas of Interest (AOIs) 2, 3, 5, 6, 7, 8, 9, and 10. Evergreen did not provide a detailed summary with specific information to answer the question. Clarification regarding how the waterfront was or is planned to be evaluated is requested. This question and response should also be moved to Section 2. Soil characterization is required by 25 Pa. Code Sections 250.408(b)(2) and 250.408(d).

Review Comments

In addition to the above deficiencies, DEP is requesting the following responses to comments be re-evaluated to provide more clarity and transparency in future reporting:

Page Number	**Public Comment**	**DEP Assessment**
General	n/a	DEP requests that the future re-submittal include a numbering system for each comment.
General	Multiple	The responses generally lacked specificity. Including excerpts or citations from past reports, figures, and/or tables would result in additional transparency and clarity when responding to questions.
General	A public comment was received regarding Evergreen's use of sheet piling and a bulkhead to minimize contaminant migration to the Schuylkill River.	A response to this comment was not included in the report. We suggest that Evergreen provide a summary of the location of the sheet piling and bulkhead, a summary of groundwater flow in the area, a brief discussion of contaminant concentrations along the groundwater flow path in the vicinity of these structures, and the basis for these structures mitigating impact to the Schuylkill River. DEP recognizes that this information will be more fully described in a future cleanup plan.
1	n/a	It is incorrectly stated that Evergreen "successfully held a Public Information Session on Aug. 27, 2021". The meeting was Aug. 27, 2020.
9	Group of comments regarding sampling other metals in addition to lead.	Evergreen's response identifies the 1992 Resource Conservation and Recovery Act (RCRA) Facility Investigation as the basis for ongoing evaluation of lead as this was the only metal identified as a contaminant of concern (COC) following that investigation. The 1992 report evaluated metals in a portion of the refinery complex, and not across the property. The areas evaluated in 1992 include: Solid Waste Management Unit (SWMU)-1 West Yard (AOI-10), SWMU-2 North Yard (a portion of AOI-8), and SWMU-3 Stormwater Impoundment Basin/Guard Basin (portion of AOI-3 and AOI-4). We suggest providing additional details that explain inorganic sampling across other areas of the refinery.
15-16	Group of comments regarding benzene concentrations near Verizon SDWC property and Maiden Lane and concern about potential offsite migration.	The response would benefit from further explanation of the relationship between the Refinery and Verizon SDWC properties. The basis for the background standard selection for the Verizon property, groundwater flow patterns between the two sites, discussion of light non-aqueous phase liquid (LNAPL) and dissolved impacts between Verizon SDWC and the horizontal recovery well, and the observations following the installation of the horizontal well operation also should be summarized. .

23-24	Comments regarding the tide gate	Evergreen's response clarified that the tide gate was not installed to address tidal changes associated with climate change, but rather as an interim remedial measure to mitigate LNAPL in the sewer. The response should be expanded to address the specific questions asked, including the height that the tide gate is built to accommodate and reference to the historical report(s) that contain tide gate information.
30	Questions regarding vertical migration of contaminants	These are good examples of the lack of specificity with the response provided. Details regarding frequency of sampling, comments on and/or examples of plume expansion/shrinking based on analytical results, and references to specific cross sections would provide concrete support to ambiguous statements.
31	A comment identified the difference between a benzene graphic presented in the August 2020 meeting and a similar graphic presented historically.	Additional explanation with graphics presented side by side would be useful for clarity and transparency of explanation.
39	A request for historical reports referenced in the 2004 Current Conditions Report was made.	The response indicated the 2004 Current Conditions Report is not an Act 2 report, nor are the documents referenced in that report, and that some of the reports are included on the website. Evergreen and DEP communicated with the commentor regarding this comment via email exchanges on 11/18/2020 and 12/8/2020.DEP would also like to let the public know that DEP files can be reviewed by submitting a file review request located at http://www.depgreenport.state.pa.us/InformalFileReviewRequest/
44-45	Questions regarding PFAS sampling.	DEP has asked Evergreen to perform further investigation of PFAS. DEP recommends that the PFAS sampling results be posted on website for public review.
50	Question about public meetings.	The response can be updated to include all meetings completed.,
64-70	Multiple questions regarding remediation conducted to date and proposed remediation.	Consider creating a brief plain language summary of remediation conducted to date at each AOI for public consumption. This would help clarify the interim remedial actions completed to date that were summarized in the RIs, as well as serve as a precursor to future Cleanup Plan submittals.

67	Request to make water discharge permits public.	Response indicated that the PWD discharge permits would be posted to the website. A review of the website on 5/30/2021 did not locate the permits.
74	Question regarding selected standards for public park portion of the site.	Clarification is requested to include proposed future use of this portion of the site and selected standards consistent with Act 2.
75	Comment regarding classification as voluntary cleanup.	It is suggested that the response also acknowledge cleanup obligations under RCRA (not voluntary) that are being completed through the One Cleanup Program.
78-81	Soil lead site-specific standard risk assessment	Commentators noted concerns with Evergreen's site-specific standard for lead in soil in the 2015 risk assessment report approved by DEP. These comments pertain to an Act 2 report and should be included in Section 2.

<u>DEP Responses</u>
DEP previously provided responses for certain questions that were cited by Evergreen (e.g., pages 54–55, 59, 62, and 63). Some additional information is provided in response to certain questions and comments below.

Page Number	Public Comment	DEP Assessment
11	Fragmenting remedial investigation reports	The commentator is concerned with Evergreen breaking its remedial investigation reporting into multiple documents. This arrangement was agreed to by DEP and EPA, and it was formalized in the 2003, 2012, and 2020 consent order and agreements. Given the size and complexity of the site, the remediator and the regulatory agencies believed it was impractical to compile all site characterization work into a single RIR. The agencies would also be unable to satisfactorily review the information in the 90-day statutory period.
12-14	Age of site characterization data	Commentators noted that much of the soil and groundwater data was collected many years ago and should be updated. Given the size and complexity of the site, it is understandable that investigations would elapse over many years; the same is true of many large Act 2 sites. DEP's Technical Guidance Manual recognizes that older site characterization data is valid in many cases if the site conditions are understood and stable (Section II.A.4.b.). Evergreen is responsible for environmental conditions up to 2012, and DEP is satisfied that the age of the sampling prior to the time of PES's ownership are appropriate. Evergreen and HRP will both be performing a substantial amount of

		additional soil sampling as part of the process unit decommissioning, aboveground storage tank closures, and surface regrading. In addition, Evergreen will continue to periodically monitor groundwater, and they will be responsible for performing groundwater attainment sampling prior to submitting the final report.
78-81	Soil lead site-specific standard risk assessment	DEP's nonresidential Statewide health standard direct contact numerical value for lead in surface soil (0–2 feet deep), 1000 mg/kg, dates from the 1990s and was based on outdated science. In 2015, Evergreen proposed, and DEP approved, a site-specific value for lead, 2400 mg/kg, that was based on the current EPA methodology and currently accepted input values. In 2020, DEP proposed a revision to the published Statewide health standard value also based on the EPA methodology and similar input values. However, following public comment, DEP has reexamined those assumptions, in particular the target blood lead level of 10 μg/dL. DEP is planning a new rulemaking to revise the lead standard which will also be subject to public comment. Evergreen has stated that they will update their site-specific lead standard to be consistent with DEP's approach.

DEP Final Action Approval/Disapproval Letter: Issuance of a technical deficiency letter is recommended for the Public Comment Remedial Investigation Report based on the above. On 6/24/2021, DEP informed Evergreen that a technical deficiency was going to be issued for this report and explained that most of the deficiencies were related to incomplete/insufficient comment responses and additional information needed for lead delineation. It was decided that DEP would share the technical memo and following review of the decision letter and technical memo, Evergreen would determine if a meeting with DEP is warranted to review the deficiencies.

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Site Contact: Tiffani Doerr, P.G. **Phone:** 302-477-1305

Site Consultant: Colleen Costello, Senior VP, Sanborn, Head & Associates, Inc.
Phone: 610-984-1712

CLEAN AIR COUNCIL

Evergreen Resources Management Operations
a series of Evergreen Resources Group, LLC
On behalf of Sunoco, Inc. (R&M), now known as Sunoco (R&M), LLC

Pennsylvania Department of Environmental Protection

Site Characterization/Remedial Investigation Reports/Risk Assessments
Philadelphia Refinery Complex
3144 Passyunk Avenue, Philadelphia, Pennsylvania

Written Comments by Clean Air Council

Clean Air Council ("the Council") appreciates the opportunity to provide comments on Evergreen Resources Management Operations' ("Evergreen's") Site Characterization Reports and Remedial Investigation Reports regarding contamination at the former Philadelphia refinery. The reports were prepared by Evergreen on behalf of Sunoco, Inc. (R&M), now known as Sunoco (R&M), LLC ("Sunoco"). Sunoco is the party legally responsible for contamination prior to its sale of the property in 2012.

The Council is a non-profit environmental organization headquartered at 135 South 19th Street, Suite 300, Philadelphia, Pennsylvania, 19103. For 50 years, the Council has worked to improve air quality across Pennsylvania. The Council has members throughout the Commonwealth who support its mission to protect everyone's right to breathe clean air, including members in Allegheny County. The Council has approximately 35,000 activist members.

Evergreen submitted the reports to the Pennsylvania Department of Environmental Protection ("the Department") under Act 2 of 1995. *See* Evergreen, Act 2 Documents. The reports were submitted pursuant to the Consent Order and Agreement (2003) and the Consent Order and Agreement (2012). There are 19 remedial investigation reports and 2 risk assessments, listed in the Table of Reports on page 4. The comments also address work under the corrective action provisions of the Resource Conservation and Recovery Act ("RCRA"). Evergreen submitted reports relating to this work to EPA pursuant to the Settlement Agreement (2012). The work under Act 2 and RCRA are under the One Cleanup Program. Evergreen, Site History.

All documents cited in these comments are hyperlinked or attached.

celebrating 50 years
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Index to Comments

Procedure and Process

1. The Council Appreciates the Proactive Revision of the Public Involvement Plan and the Reopening of the Public Comment Period For 19 Remedial Investigation Reports and 2 Risk Assessments.
2. Evergreen Should Not Characterize This Remediation Project as a Voluntary Cleanup.
3. Evergreen Should Make Available on its Website All Historical Reports Referenced in Appendix A of the 2004 Current Conditions Report.
4. Evergreen Has Not Sufficiently Answered Questions From the Public on its Q&A Webpage.

Content of Reports

5. Evergreen's Conceptual Site Model is Fundamentally Flawed, Necessitating Substantially Revised Reports for Public Comment Before Submission to the Department.
6. Evergreen Should Revise the Reports to Reflect Up-To-Date Material (Including Data and Analyses From Groundwater Monitoring Status Reports).
7. Evergreen Has Not Sufficiently Delineated the Nature and Extent of Contamination in the Deep Aquifer and the Unconfined Aquifer (Water Table).
8. Evergreen Fails to Properly Delineate the Contamination of Arsenic, Manganese, and Other Inorganics (Metals) in the Unconfined Aquifer and the Deep Aquifer.
9. Evergreen Fails to Demonstrate that the Sheet Pile Wall and Bulkhead Provide Sufficient Protection Against the Migration of Contamination to the Schuylkill River.
10. The Remedial Investigation Reports are Deficient Because They Fail to Address the Impacts of Climate Change -- Including Sea Level Rise and Storm Surges.
11. Evergreen May Not Fragment the Remedial Investigation Reports by Diverting its Deficiencies Into a Future Fate and Transport Remedial Investigation Report.
12. Evergreen Fails to Sufficiently Delineate Exceedances of the Soil-to-Groundwater Numeric Value and the Direct Contact Numeric Value for All Constituents of Concern.
13. The Department Should Disapprove Evergreen's Proposed Site-Specific Standard of 2240 mg/kg for Lead in Surface Soils.

<u>Table of Attachments</u>

Attachment 1 -- Letter from Evergreen dated February 11, 2014.

Attachment 2 -- DEP Letter dated November 8, 2011

Attachment 3 -- Evergreen’s Q&A (downloaded December 30, 2020)

Attachment 4 -- Comments of Clean Air Council on Proposed Act 2 Rulemaking, dated April 30, 2020

Attachment 5 -- Comments of Clean Air Council, Attachments 1-26

Attachment 6 -- Comments of Clean Air Council, Attachments 27-30

Attachment 7 -- Comments of Clean Air Council, Attachments 31-33

Attachment 8 -- Comments of Clean Air Council, Attachments 34-53

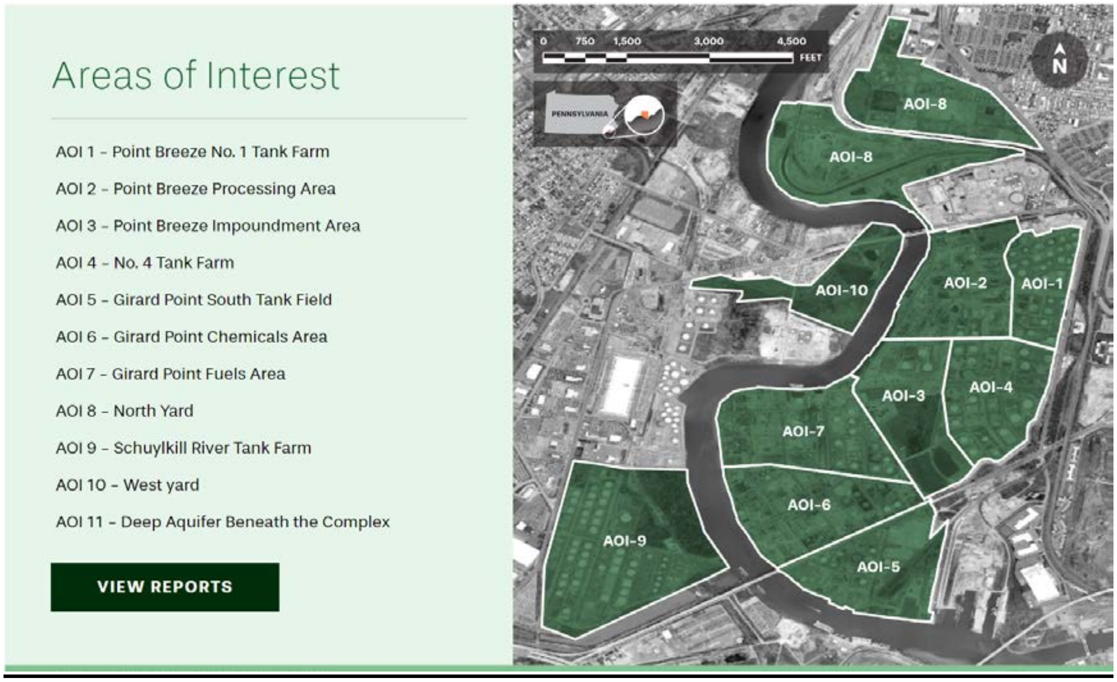
Table of Reports

(Remedial Investigation Reports and Risk Assessments)

Area of Interest	Title	Date
AOI-1 Point Breeze No. 1 Tank Farm	2016 Report (part 1) 2016 Report (part 2) (approved)	August 5, 2016
AOI-2 Point Breeze Processing Area	2017 Report (part 1) 2017 Report (part 2) (approved)	July 20, 2017
AOI 3 Point Breeze Impoundment Area	2017 Report (part 1) 2017 Report (part 2) (approved)	March 20, 2017
AOI-4 No. 4 Tank Farm	2013 Report (disapproved) 2017 Report (part 1) 2017 Report (part 2) (disapproved)	November 16, 2013 March 24, 2017
AOI-5 Girard Point South Tank Field	2011 Report/Cleanup Plan (disapproved) 2017 Report (part 1) 2017 Report (part 2) (approved)	December 13, 2011 January 16, 2017
AOI-6 Girard Point Chemicals Area	2013 Report (part 1) 2013 Report (part 2) (disapproved) 2017 Report (part 1) 2017 Report (part 2) (approved)	September 3, 2013 November 21, 2017

AOI-7 Girard Point Fuels Area	2012 Report (disapproved) 2013 Addendum to Report (disapproved) 2017 Report (part 1) 2017 Report (part 2) (approved)	February 29, 2012 September 19, 2013 June 9, 2017
AOI-8 North Yard	2012 Report (part 1) 2012 Report (part 2) (approved) 2017 Report (part 1) 2017 Report (part 2) (approved)	January 31, 2012 December 21, 2017
AOI-9 Schuylkill River Tank Farm	2015 Report (part 1) 2015 Report (part 2) (disapproved) 2017 Report Addendum (part 1) 2017 Report Addendum (part 2) (disapproved)	December 31, 2015 February 8, 2017
AOI-10 West Yard	2011 Report (approved) 2016 Ecological Risk Assessment (approved)	June 29, 2011 September 16, 2016
AOI-11 Deep Aquifer Beneath Complex	2011 Report (part 1) 2011 Report (part 2) 2013 Report (part 1) 2013 Report (part 2) (disapproved)	September 12, 2011 June 21, 2013
Site-Wide Reports (Lead in Surface Soils)	2015 Human Health Risk Assessment Report (approved)	February 25, 2015

Areas of Interest



Areas of Interest

- AOI 1 – Point Breeze No. 1 Tank Farm
- AOI 2 – Point Breeze Processing Area
- AOI 3 – Point Breeze Impoundment Area
- AOI 4 – No. 4 Tank Farm
- AOI 5 – Girard Point South Tank Field
- AOI 6 – Girard Point Chemicals Area
- AOI 7 – Girard Point Fuels Area
- AOI 8 – North Yard
- AOI 9 – Schuylkill River Tank Farm
- AOI 10 – West yard
- AOI 11 – Deep Aquifer Beneath the Complex

Source: Evergreen, Home - PRLR

Summary of Comments

The Council is providing comments on Evergreen's remedial investigation reports on the nature and extent of contamination in the soil and groundwater at the former Philadelphia refinery.

Throughout these comments, the Council will be referring to Evergreen as the author of the reports, but it should be made clear that it is Sunoco, Inc. (R&M), now known as Sunoco (R&M), LLC ("Sunoco") that is the party legally responsible for the contamination prior to its sale of the property in 2012. Evergreen has prepared these reports as an agent, consultant, and corporate affiliate of Sunoco. Evergreen was formed in 2013 to manage Sunoco's environmental liabilities. *See* Attachment 1 -- Letter from Evergreen dated February 11, 2014. Under applicable environmental laws, a private agreement does not nullify statutory obligations.

In the interest of avoiding confusion, the Council may at times generally refer to the reports as Evergreen reports, despite the fact that some of them were prepared by Sunoco before Evergreen was formed. This is consistent with the spirit of that relationship structured by Sunoco, the responsible party. With respect to individual reports, the Council will refer to Evergreen or Sunoco, as appropriate based on the context.

In terms of procedure and process, these comments provide a history of the lack of public involvement in the preparation of the reports, with an eye toward making sure that the public is involved in the future.

The Council wishes to clarify that this remediation project is not a "voluntary cleanup," because it is being done pursuant to a series of consent orders dating back to at least 2003. The fact that an order is a labelled a "consent order" does not make it voluntary.

The Council asks that Evergreen make available all relevant historical reports on its website, and make changes to the website to make it more accessible.

The Council is also commenting collectively on Evergreen's answers to questions on the Q&A section of its website, which presumably reflects Evergreen's most recent thoughts on the remedial investigation.

As for the content of the remedial investigation reports, Evergreen's Conceptual Site model is fundamentally flawed due to insufficient analysis and synthesis of information relating to the soil and groundwater investigation. To properly revise the reports, Evergreen would have to dramatically change its approach, with the result that it would change the nature of the reports and the characterization of contamination. Accordingly, the public should be given another opportunity for public comment before the submission of revised reports to the Department.

Because the public is commenting on reports that are all at least three years old, Evergreen should revise them and synthesize them with other information, data and analysis from other sources, including groundwater remediation status reports. The public should not be put into the position of commenting on reports that may be stale.

Evergreen has not delineated the nature and extent of contamination in the deep aquifer and the unconfined aquifer (water table). It has not completely delineated contamination of the aquifer that provides a source of water supply in New Jersey.

Evergreen has failed to delineate contamination for metals in groundwater, paring down its list of Constituents of Concern over time and discontinuing sampling for chemicals such as arsenic and manganese, without sufficient explanation.

Although Evergreen cites the existence of an 8400-foot sheet pile wall as a buffer against the migration of contamination toward the adjacent Schuylkill River, Evergreen provides no meaningful discussion of the protectiveness of this wall, making circular assertion that "groundwater behind the sheet pile wall can discharge no faster to the Schuylkill River than the sheet pile wall permits."

Evergreen fails to consider the impacts of climate change (including sea level rise and storm surges) on the soil and groundwater contamination. This is material and significant because the Schuylkill River is expected to experience a sea level rise of 2 feet by 2050, and there is widespread lead contamination in surface soil (0-2 feet) on the site.

It would be inappropriate and unfair for Evergreen to fragment these remedial investigation reports by diverting a discussion of the deficiencies in these reports into yet another remedial investigation report to be made available later in 2021. The public cannot submit complete comments now in the absence of a promised Fate and Transport Analysis. Moreover, if the current reports are approved Evergreen will argue that material in the current reports may not be reopened in a public comment period on that carved-out report later this year. The material is interrelated.

Throughout the reports, Evergreen marginalizes the soil-to-groundwater numeric value (typically, the more stringent of numeric values under Act 2) in favor of a less stringent direct contact numeric value and an even less stringent proposed site-specific standard for lead. The problem is most notable in the case of lead, but it is common to other contaminants as well.

Evergreen should abandon its proposed site-specific standard of 2240 mg/kg for lead in surface soils (0-2 feet). This was based on a target blood lead level of 10 ug/dL in a human fetus, which is two times the level that the Centers for Disease Prevention and Control was using for case management for children exposed to lead even at the time when Evergreen made this proposal. On its website, Evergreen has committed to changing this proposal if the Department changes its target blood lead level. Because the Department has done this in a pending Act 2 rulemaking, Evergreen should abandon its proposal.

Because the reports define exceedances (that is, concentrations above an applicable standard) in terms of that flawed proposed standard, the reports do not provide a complete and accurate picture of the lead contamination and its significance in the context of appropriate standards.

Finally, Evergreen should prepare a work plan and revise the reports to include Per- and Polyfluoroalkyl Substances (PFAS) as a constituent of concern. Other states have required this in remedial investigations, and the Department recently proposed to add Medium-Specific Concentrations for three PFAS chemicals in the Act 2 regulations.

Data overload is not a substitute for analysis and synthesis. This comment period concerns a large number of documents -- 19 remedial investigation reports and two risk assessments. Evergreen has collected a large amount of data from soil samples and groundwater samples. Similar efforts to gather data were made by other consultants before Evergreen was formed. The number of pages and the amount of data do not cure the analytical flaws in the reports.

Sometimes, deficiencies in reports may be easily cured. That is not the case here. The flaws in these reports are so widespread that substantial revisions are necessary. Evergreen should revise its reports to address these comments, and it should schedule another public comment period before any revised reports are submitted to the Department.

Comments

1. The Council Appreciates the Proactive Revision of the Public Involvement Plan and the Reopening of the Public Comment Period For 19 Remedial Investigation Reports and 2 Risk Assessments.

The Council appreciates the opportunity to provide these comments on remedial investigation reports and risk assessments prepared by Evergreen on behalf of Sunoco. Evergreen provided this comment period in response to concerns that the public involvement requirements and objectives of Act 2 had not been met. In this comment, the Council sets forth its best understanding of what happened and why. The Council hopes that this will help decision makers avoid a similar situation in the future.

This is not meant to be a meaningless exercise in checking boxes--but instead should reflect a serious obligation of the local government, the public and especially impacted neighbors.

A. Consistent with Act 2, the Public Involvement Plan should include measures to involve the public in the development and review of reports, include a proactive community information and consultation program.

There are two important public involvement provisions in Act 2 that apply to this remedial investigation and cleanup. First, a responsible party utilizing a site-specific standard:

> (n) Notice and review provisions.--***Persons utilizing the site-specific standard shall comply with the following requirements for notifying the public and the department of planned remediation activities***:
>
> (1)(i) A notice of intent to remediate a site shall be submitted to the department which provides, to the extent known, a brief description of the location of the site, a listing of the contaminant or contaminants involved and the proposed remediation measures. The department shall publish an acknowledgment noting receipt of the notice of intent in the Pennsylvania Bulletin. At the same time a notice of intent to remediate a site is submitted to the department, a copy of the notice shall be provided to the municipality in which the site is located, and a summary of the notice of intent shall be published in a newspaper of general circulation serving the area in which the site is located.
>
> (ii) The notices required by this paragraph shall include a 30-day public and municipal comment period during which the municipality can request to be involved in the development of the remediation and reuse plans for the site. ***If requested by the***

> ***municipality, the person undertaking the remediation shall develop and implement a public involvement program plan which meets the requirements of subsection (o).*** Persons undertaking the remediation are encouraged to develop a proactive approach to working with the municipality in developing and implementing remediation and reuse plans.
>
> (2) ***The following notice and review provisions apply each time a remedial investigation report, risk assessment report, cleanup plan and final report demonstrating compliance with the site-specific standard is submitted to the department***:
>
> (i) When the report or plan is submitted to the department, a notice of its submission shall be provided to the municipality in which the site is located, and a notice summarizing the findings and recommendations of the report or plan shall be published in a newspaper of general circulation serving the area in which the site is located. ***If the municipality requested to be involved in the development of the remediation and reuse plans, the reports and plans shall also include the comments submitted by the municipality, the public and the responses from the persons preparing the reports and plans***.
>
> (ii) The department shall review the report or plan within no more than 90 days of its receipt or notify the person submitting the report of deficiencies. If the department does not respond with deficiencies within 90 days, the report shall be deemed approved.
>
> (3) If the remedial investigation report, risk assessment report and cleanup plan are submitted at the same time to the department, the department shall notify persons of any deficiencies in 90 days. If the department does not respond with deficiencies within 90 days, the reports are deemed approved.

See Act 2, §304(n) (emphasis added), 35 P.S. §6026.304(n) (same, unofficial statute).

Because Sunoco intended to use a site-specific standard, the law required Sunoco to provide notice in the first instance. *See* Act 2, §304(n)(2)(i) (requiring "a notice summarizing the findings and recommendations of the report or plan shall be published in a newspaper of general circulation serving the area in which the site is located"), 35 P.S. §6026.304(n)(2)(i) (same, in unofficial statute), 25 Pa. Code 250.6. In addition, because the City of Philadelphia requested to be involved in the development of the remediation and reuse plans, Sunoco was required to prepare a Public Involvement Plan and include in its reports to the Department comments received from the public.

Second, if the municipality requests to be involved in the remediation and reuse plans for the site, the responsible party must develop a public involvement plan that involves the public in the cleanup and use of the property:

> (o) Community involvement.--***Persons using site-specific standards are required to develop a public involvement plan which involves the public in the cleanup and use of the property*** if the municipality requests to be involved in the remediation and reuse plans for the site.

See Act 2, §304(o) (emphasis added), 35 P.S. §6026.304(o) (same, in unofficial statute). The statute requires the plan to include measures to involve the public in the development and review of a remedial investigation report as well as a risk assessment report:

> The plan ***shall propose measures*** to ***involve the public*** in the ***development and review*** of the ***remedial investigation report, risk assessment report***, cleanup plan and final report.

Id. (bold italics added for emphasis). Therefore, these requirements extend not only to the 20 remedial investigation reports, but also to the Human Health Risk Assessment for lead (a risk assessment report).

Finally, the state provides a list of techniques that may be included in these measures, including a "proactive community information and consultation program":

> Depending on the site involved, ***measures may include techniques such as*** developing a ***proactive community information and consultation program*** that includes door step notice of activities related to remediation, public meetings and roundtable discussions, convenient locations where documents related to a remediation can be made available to the public and designating a single contact person to whom community residents can ask questions; the formation of a community-based group which is used to solicit suggestions and comments on the various reports required by this section; and, if needed, the retention of trained, independent third parties to facilitate meetings and discussions and perform mediation services.

Id. The word "proactive" is important for unraveling what happened with public participation in the case of the former refinery. Although not strictly required by the language of the statute, a proactive program would be one calculated to make sure that the community is actively participating in a project and submitting comments on reports where there is evidence that it is not.

B. While the 2007 plan contemplated only the sharing of information about the project, the 2019 plan now contemplates a nested public comment period for reports.

After a Notice of Intent to Remediate was submitted in 2006, the City of Philadelphia requested that Sunoco develop a Public Involvement Plan. *See* Evergreen, Public Involvement. In response, Sunoco prepared a plan in 2007, several years before the 2012 transaction. *See* Sunoco, Public Involvement Plan (2007). The notice provisions are set forth as follows:

> The Act 2 Report submittals will include the appropriate municipal and public notice requirements in accordance with the provisions of Act 2. Notices will be published in the Pennsylvania Bulletin and a summary of the notice will appear in at least one local newspaper. As part of the Public Involvement Plan, ***Sunoco intends to hold an initial public meeting and subsequent meetings on an as-needed basis upon request of the City of Philadelphia to give status updates of the project***. EPA will complete additional public involvement through activities, such as notices under Corrective Action Program and by updating its online Fact Sheet for the refinery.

Id. (bold italics added for emphasis). The plan also contemplated making documents available and scheduling an initial public information session. *Id.* But it does not speak in terms of receiving comments on proposed reports, or even in terms of public comment periods. It does not even use the term "comment" at all. Rather, it only contemplates sharing information about the project.

Evergreen has attempted to address this deficiency in a second Public Involvement Plan prepared in 2019, several years after the 2012 transaction. This second plan uses the word "comment" repeatedly, and it explains how future reports will be made available for a nested public comment period between Evergreen and the public, before the reports are submitted to the Department:

> All future Act 2 report submittals will have public notices as per above including the newspaper notices and correspondence. ***The notices will be sent/published prior to submittal of the reports, and will include a 30-day public comment period per Act 2 guidelines***. Reports will be posted to the website and library branches prior to initiation of the 30-day comment period. Upon conclusion of the 30-day public comment period, the ability to comment on the reports via the website will be closed, and no further comments accepted. ***Evergreen will summarize and respond to comments received during the 30-day comment period and will submit them in document form to PADEP, USEPA, and the City of Philadelphia***.

See Evergreen, Public Involvement Plan (June 19, 2019). This is a "proactive" way of addressing the requirements of Act 2. *See* Act 2, §304(n) ("[i]f the municipality requested to be involved in the development of the remediation and reuse plans, the reports and plans shall also include the comments submitted by the municipality, the public and the responses from the persons preparing the reports and plans"), 35 P.S. §6026.304(n) (same, in unofficial statute).

C. The 2011 Work Plan incorporated only "aspects of public involvement."

Prior to the 2012 transaction, Sunoco prepared a work plan to address contamination under the 2003 consent order. Attaching the Public Involvement Plan discussed above, it spoke in terms of holding meetings and giving updates on the project:

> 4 Public Involvement
>
> The Public Involvement Plan is provided in Appendix E. ***This plan incorporates aspects of public involvement under both PADEP's Act 2 program and EPA's RCRA Corrective Action program***. The Act 2 report submittals will include the appropriate municipal and public notice requirements in accordance with the provisions of Act 2. Notices will be published in the Pennsylvania Bulletin and a summary of the notice will appear in four local newspapers, including the Philadelphia Daily News, South Philly Review, Philadelphia Inquirer and, Philadelphia Globe Times. As part of the public involvement plan, ***Sunoco intends to hold an initial public meeting in the city of Philadelphia to present the strategy and give status updates of the project at the CAP meeting on an annual basis***.
>
> EPA will complete its own public involvement through notices under the Corrective Action Program and by updating its online Fact Sheet for the refinery.

See Sunoco, Interim Activities Workplan (2011), Section 4.4, page 13. But Sunoco should have done more. While the work plan stated that the plan "incorporates aspects of public involvement" under the law, it does not specifically offer comment periods on individual reports.

D. Newspaper notices did not provide meaningful notice of an opportunity for public comment.

Based on a sampling of Sunoco's newspaper notices for AOI-5, it is clear that they do not provide sufficient information to inform people of the availability of a public comment period. The following three notices did not acknowledge the opportunity for public comment, they did not invite public comment, and they did not provide any contact information for people who might have been inclined to submit comments if they had been aware that they had such an opportunity. The notices did not even use the word "comment."

In 2011, Sunoco apparently published the following notice in the newspaper:

> Notification of Receipt of Site Characterization/Remedial Investigation Report/Cleanup Plan
>
> ***Notice is hereby given that Sunoco Inc. (R&M) (Sunoco) is in the process of submitting a Site Characterization/ Remedial Investigation Report/Cleanup Plan to the Pennsylvania Department of Environmental Protection (PADEP),*** Southeast Regional Office for Area of Interest 5 (AOI 5) located at the Sunoco Philadelphia Refinery, Philadelphia, Pennsylvania. ***Sunoco has indicated in the report that site characterization activities have been completed at AOI 5*** in accordance with the Land Recycling and Environmental Remediation Standards Act and the 2004 Memorandum of Agreement between the PADEP and U.S. Environmental Protection Agency (EPA) (a.k.a., the PA One Cleanup Program). ***This notice is made under the provision of the Land Recycling and Environmental Remediation Standards Act, the Act of May 19, 1995, P.L. #4, No. 2.***

See Sunoco, Copy of Notice of Publication (November 14, 2011). The notice merely stated that Sunoco is in the process of submitting a report, that it believes site characterization activities have been completed, and that the notice is being made under Act 2.

In 2015, Evergreen apparently published the following notice in the newspaper:

> Notification of Submittal of a Remedial Investigation Report
>
> ***Notice is hereby given that Evergreen Resources Group LLC (Remediator), is in the process of submitting a Remedial Investigation Report to the Pennsylvania Department of Environmental Protection***, Southeast Regional Office for Area of Interest 5 located at the Philadelphia Energy Solutions Refining and Marketing LLC Facility, Philadelphia County, Philadelphia, PA. The report is being submitted in accordance with the site-specific remediation standards established under the Land Recycling and Environmental Remediation Standards Act. ***This notice is made under the provision of the Land Recycling and Environmental Remediation Standards Act, the Act of May 19, 1995, P.L. #4, No. 2.***

See Evergreen, Copy of Notice of Publication (March 19, 2015). This is like the first notice.

In 2017, Evergreen apparently published the following notice in the newspaper:

> Notification of Submittal of a Remedial Investigation Report
>
> ***Notice is hereby given that Evergreen Resources Group LLC (Remediator), is in the process of submitting a Remedial Investigation Report to the Pennsylvania Department of Environmental Protection,*** Southeast Regional Office for Area of Interest 5 located at the Philadelphia Energy Solutions Refining and Marketing LLC Refining Complex, Philadelphia County, Philadelphia, PA. The report is being submitted in accordance with the site-specific remediation standards established under the Land Recycling and Environmental Remediation Standards Act. ***This notice is made under the provision of the Land Recycling and Environmental Remediation Standards Act, the Act of May 19, 1995, P.L. #4, No. 2***.

See Evergreen, Copy of Notice of Publication (February 3, 2017). This notice is like the first and second notices.

The notices were not proactive. They merely asserted that Sunoco and Evergreen were in the process of submitting a report to the Department. Based on that limited information, a reasonable person would not understand that there was an opportunity for public comment.

E. Sunoco narrowly construed public participation requirements as only requiring it to "inform" the public about the project.

Sunoco submitted two reports relating to these three notices (the second report relates to the second and third notices). In these reports Sunoco did not refer to the public comment process and it did not attach any public comments -- implying that it received none in response to the vague newspaper notices above.

In a 2011 report, Sunoco indicated it would be giving status updates to the community on an annual basis. Apparently, this meant only that it would inform the community about what it would be doing:

> 12.0 COMMUNITY RELATION ACTIVITIES
>
> A Community Relation Plan (CRP) that includes ***public involvement with local residents to inform them of the anticipated investigations and remediation activities*** was completed as part of the NIR submittal in 2006. The purpose of this CRP is to provide a mechanism for the community, government officials, and other interested or affected citizens ***to be***

> ***informed of on-site activities related to the investigation activities at the Site***. This plan ***incorporates aspects of public involvement under both PADEP's Act 2 program and EPA's RCRA Corrective Action program.*** This report and future Act 2 reports will include the ***appropriate municipal and public notices*** in accordance with the provisions of Act 2. Notices will be published in the Pennsylvania Bulletin and a summary of the notice will appear in a local newspaper. As part of the CRP, Sunoco intends to hold an initial public meeting in the city of Philadelphia ***to present the strategy and give status updates of the project at the CAP meeting on an annual basis***.
>
> A copy of the NIR and the Act 2 report notifications for this SCR/RIR are included in Appendix A.

See 2011 Report (AOI-5), Section 12.0, page 47. In two places in the paragraph above, Sunoco makes it clear that the purpose of the plan is to "inform" the public. It states that the plan incorporates "aspects of public involvement" under the law (see the discussion on that in the Council's comment above), and it does not mention the ability to submit comments on reports. The attachments to the report do not include any public comments, implying that none were received in response to the vague newspaper notices. *See also* 2011 Report (AOI-5), part 2, including Appendix A.

In the 2017 report, Evergreen made very similar statements, again framing the process in terms of informing the public of what it would be doing, and ignoring the role of public comment.

> 10.0 COMMUNITY RELATION ACTIVITIES
>
> A Community Relation Plan (CRP) that includes public involvement with local residents ***to inform them of the anticipated investigations and remediation activities*** was completed as part of the original NIR submittal in 2006. A revised NIR was submitted in 2014. The purpose of the CRP is to provide a mechanism for the community, government officials, and other interested or affected citizens ***to be informed of on-site activities*** related to the remediation
> program at the Site. ***This plan incorporates aspects of public involvement under both PADEP's Act 2 program and EPA's RCRA Corrective Action program***. Sunoco held an initial public meeting ***to present the strategy and give a status update of the project***. As part of the CRP, ***Sunoco has presented updates*** on the remediation program to the Community Action Plan (CAP) ***on an as requested basis***. The CAP meets on a monthly basis and

> includes members of the community, local officials and PES employees.
>
> This report and future Act 2 reports will include the ***appropriate municipal and public notices*** in accordance with the provisions of Act 2. Notices will be published in the Pennsylvania Bulletin and a summary of the notice will appear in a local newspaper. A copy of the original NIR, the
> 2014 NIR and the Act 2 report notifications for this RIR are included in Appendix A.

See 2017 Report (AOI-5), Section 10.0, page 63. The attachments to the report do not include any public comments, implying that none were received in response to the vague newspaper notices. *See* 2017 Report (AOI-5), part 2.

F. The Department did not address public involvement requirements in its responses to the reports.

In its review of the submitted reports for AOI-5, the Department does not question whether the public involvement requirements were met. *See* 2012 Disapproval Letter (AOI-5), 2012 Comments (AOI-5); *see also* 2017 Approval Letter (AOI-5), 2017 Comments (AOI-5), 2017 Memorandum (AOI-5). Rather, it limits its comments to the technical aspects of the reports. The same is true for comments and memoranda for the other reports. *See* Evergreen, Act 2 Documents.

In conclusion, Sunoco did not draft notices sufficient to inform the community of the opportunity to provide public comments, or of the existence of a public comment period. This did not comply with the public involvement provisions of Act 2. It is not enough to simply make a large number of documents available and inform the public what one is doing. It is important to be "proactive," as allowed by the law.

In its 2019 Public Involvement Plan, Evergreen has taken a positive step by structuring public involvement around subsequent public comment periods. Still, this is something that should have been done a long time ago. Public comment is a fundamental aspect of public involvement. Without it, a Public Involvement Plan cannot be meaningful.

Of course, public comment is not sufficient to give meaning to the public involvement requirements of Act 2. Ultimately, it is important that the opportunities for public comment and public involvement are meaningful. To make them meaningful, Evergreen should by doing other things to facilitate public understanding of its work, as it has recently done its website. The Council makes additional recommendations for making public involvement more meaningful, with respect to the posting of documents on Evergreen's website. *See* Comment #3, below.

2. Evergreen Should Not Characterize This Remediation Project as a Voluntary Cleanup.

Perhaps unintentionally, Evergreen has provided the public impression that this is a voluntary cleanup, rather than an involuntary one. This is an incorrect impression because the remedial investigation and cleanup are being done pursuant to a series of consent orders dating back to 2003 -- nearly twenty years. (There was also a consent order in 1993). The fact that a cleanup is done pursuant to a consent order does not make it voluntary.

On its website, Evergreen makes two errors -- (1) equating the Voluntary Cleanup Program with Act 2, and (2) giving the impression that its work is being done under the Voluntary Cleanup Program because the work is being done under the One Cleanup Program:

> The PADEP and USEPA signed an agreement entitled "One Cleanup Program Memorandum of Agreement (MOA or One-Cleanup Program)" in 2004, ***which clarifies how sites remediated under Pennsylvania's Voluntary Cleanup Program (Act 2) may also satisfy RCRA corrective action requirements*** through characterization and attainment of remediation standards established under the Pennsylvania Land Recycling and Environmental Remediation Standards Act (statutory name for Act 2). ***In November 2011, the facility was entered into the One Cleanup Program with the USEPA Region III and PADEP***, though both agencies had substantial involvement in the progress of the environmental activity at the complex prior to that time. In November 2011, Sunoco submitted a revised Work Plan for Sitewide Approach under the One Cleanup Program (Work Plan for Sitewide Approach).

See Evergreen, Site History (visited December 26, 2020) (emphasis added).

A. Act 2 applies to all cleanups, whether voluntary or involuntary.

Evergreen has conflated the Voluntary Cleanup Program with Act 2. These two things are not synonymous. Act 2 is a state law that applies not only to voluntary cleanups, but also to those required by a number of state environmental laws:

> Section 106. Scope.
>
> (a) ***Remediation standards***.--The environmental remediation standards established under this act ***shall be used whenever site remediation is voluntarily conducted or is required under*** the act of June 22, 1937 (P.L.1987, No.394), known as The Clean Streams Law, the act of January 8, 1960 (1959 P.L.2119, No.787), known as the Air Pollution Control Act, ***the act of July***

> ***7, 1980 (P.L.380, No.97), known as the Solid Waste Management Act***, the act of July 13, 1988 (P.L.525, No.93), referred to as the Infectious and Chemotherapeutic Waste Law, ***the act of October 18, 1988 (P.L.756, No.108), known as the Hazardous Sites Cleanup Act, and the act of July 6, 1989 (P.L.169, No.32), known as the Storage Tank and Spill Prevention Act, to be eligible for cleanup liability protection under Chapter 5***. In addition, the remediation standards established under this act shall be considered as applicable, relevant and appropriate requirements for this Commonwealth under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (Public Law 96-510, 42 U.S.C. § 9601 et seq.) and the Hazardous Sites Cleanup Act.

See Act 2, §106(a) (emphasis added), 35 P.S. §6026.106(a) (same, in unofficial statute).

B. This is not a voluntary cleanup under the 2003 consent order with the Department of Environmental Protection.

In reality, the remedial investigation is required by a series of consent orders dating back to at least December 17, 2003. *See* 2003 Consent Order and Agreement, pages 4-7, Sections 3-4 (setting forth corrective action requirements, including Phase One and Phase Two requirements). That consent order did not use the word "voluntary." *See generally id.* Rather, the agreement was executed so that the Department would not bring a lawsuit against Sunoco for noncompliance with the law:

> After full and complete negotiation of all matters set forth in this CO&A and upon mutual exchange of covenants contained herein, ***the parties desiring to avoid litigation and intending to be legally bound, it is hereby ORDERED by the Department and AGREED to by Sunoco as follows***:
>
> 1. ***Authority***. This CO&A is an Order of the Department authorized ***and issued pursuant to Sections 5 and 316 of the Clean Streams Law, 35 P.S. §§ 691.5, 691.316***; and Section 1917-A of the Administrative Code, supra.

Id., page 3 (bold italics added for emphasis). (As noted earlier, Act 2 applies to cleanups required under the statute highlighted above).

It is true that DEP did not assess civil penalties because the responsible party had undertaken considerable work to date:

> Civil Penalties. The Department recognizes that Sunoco began operations at a portion of the Philadelphia Refinery and Belmont

> Terminal in 1988, and began operations at another portion in 1994, ***and that Sunoco has undertaken considerable work to address contamination at these facilities***, and that contamination was present at the facilities for decades prior to Sunoco's operations. Accordingly, no Civil Penalties are assessed to Sunoco except as provided in Paragraph 13 (Stipulated Penalties).

See id. at Section 12, page 7 (bold italics added for emphasis). But that did not make the work required by the consent order "voluntary."

C. This is not a voluntary cleanup under the One Cleanup Program.

In the original notice of intent to remediate on October 12, 2006, Sunoco does not refer to a "Voluntary Cleanup Program," and it does not make a request for this to be considered a voluntary cleanup. *See* Sunoco, Initial Notice of Intent to Remediate (October 2006). Rather, it merely expressed an intent for the work to be done under the One Cleanup Program. *See id.* ("[t]his NIR is being submitted with the intent to enter the Sunoco Philadelphia Refinery into the One Cleanup Program with PaDEP and the USEPA."). It stated that the work was to be done under the 2003 consent order:

> This NIR covers remediation being done as part of the 2003 Consent Order and Agreement (CO&A) at Point Breeze, Girard Point and Schuylkill River Tank Farm.

Id. at 1. Subsequent notices of intent to remediate did not suggest this was a voluntary cleanup. *See* Evergreen, Update of Notice of Intent to Remediate (November 2014); *see also* Evergreen, Update of Notice of Intent to Remediate (December 2016).

In response to the original notice of intent to remediate, the Department and EPA never agreed that this was a voluntary cleanup. Rather, they only agreed to Sunoco's participation in the One Cleanup Program. *See* Attachment 2 -- Letter dated November 8, 2011 ("[t]he EPA agrees to your participation in the One Cleanup Program per your wish to select this option within the NIR.").

The One Cleanup Program is simply an administrative agreement between the Department and the Environmental Protection Agency to cooperate with respect to their oversight of a cleanup subject to both state law (Act 2) and federal law:

> **One Cleanup Program**
>
> In 2004, Pennsylvania DEP and the U.S. Environmental Protection Agency signed an historic Memorandum of Agreement (MOA) that ***outlines a procedure where sites remediated according to Pennsylvania's Land Recycling Program may also satisfy requirements for three key federal laws***: the Resource

> Conservation and Recovery Act (RCRA), the Comprehensive Environmental Response Compensation Liability Act (CERCLA or Superfund) and the Toxic Substances Control Act (TSCA).
>
> By opting into this program, a remediator/facility can be provided with a "one-stop shop" for state and federal standards guiding the cleanup of brownfield sites. ***Sites owners or operators subject to RCRA Corrective Action may be able to satisfy federal RCRA obligations and[1] obtain liability relief under Pennsylvania's Act 2 program***.

See DEP, One Cleanup Program (bold italics added for emphasis); *see also* One Cleanup Program Memorandum of Agreement (April 21, 2004).

It may be the case that the Department has indiscriminately conflated the terms "Voluntary Cleanup Program" with the term "Act 2." Currently, its website does this. *See* DEP, Land Recycling Program (last visited December 26, 2020) ("Pennsylvania's Land Recycling Program (Voluntary Cleanup Program) was established by a series of legislation enacted in 1995").

But any error by the Department does not make this a voluntary cleanup.

D. This is not a voluntary cleanup under the 2012 consent order with the Department of Environmental Protection.

Nothing in the August 14, 2012 consent order with the Department makes this a voluntary cleanup. *See* 2012 Consent Order and Agreement, page 6, Section 4(a) ("Seller's Obligations. Seller shall: a. Attain and demonstrate compliance with the Site-Specific Standard for all Pre-Existing Contamination in accordance with the Department-approved Plans and Act 2, by December 2020 ….". This legal agreement setting a deadline for attainment of a remediation standard does not use the word "voluntary." Again, the Department ordered the responsible party to comply with the terms of the document:

> After full and complete negotiation of all matters set forth in this Agreement, and upon mutual exchange of the covenants contained herein, ***the Parties intending to be legally bound, it is hereby ORDERED by the Department and AGREED TO by Seller and Buyer as follows***:
>
> 1. Authority. This Agreement is an Order of the Department authorized and ***issued pursuant to*** the environmental laws of the Commonwealth listed in Paragraph A, particularly ***Sections 5, 316, 402 and 610 of the Clean Streams Law***, 35 P.S. §§ 691.5,

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[1] The word "and" is in bold in the original.

> 691.316, 691.402 and 691.610; ***Sections 4 and 602 of the Solid Waste Act***, 35 P.S. §§ 6018.4 and 6018.602; ***Sections 107 and 1309 of the Storage Tank Act***, 35 P.S. §§ 6021.107 and 6021.1309; and 71 P.S. § 510-17.

See id., pages 4-5 (bold italics added for emphasis). (As noted earlier, Act 2 applies to cleanups required under the three statutes highlighted above).

As in the case of the 2003 consent order, this did not make this a voluntary cleanup.

E. This is not a voluntary cleanup under the 2012 prospective purchaser agreement with the Environmental Protection Agency.

Nothing in the prospective purchaser agreement with the Environmental Protection Agency makes this a voluntary cleanup. While that agreement contemplated a settlement and covenant not to sue, that arrangement was with the prospective purchasers, and not with Sunoco:

> The Parties agree to undertake all actions required of each of them by the terms and conditions of this Settlement Agreement. ***The purpose of this Settlement Agreement as it pertains to the Parties, is to settle and resolve***, subject only to reservations and limitations contained in Sections VIII (Certification), IX (Covenant Not to Sue), X (Reservation of Rights), and XI (Settling Respondents' Covenant Not to Sue), ***the potential liability of the Settling Respondents for the Existing Contamination at the Property which would otherwise result from PES R&M LLC becoming the owner and/or operator of the Property***.

See 2012 Settlement Agreement and Covenant Not to Sue, page 4, paragraph 5 (bold italics added for emphasis). The Settling Respondents were Philadelphia Energy Solutions LLC and Philadelphia Energy Solutions Refining and Marketing LLC -- not Sunoco. *See id.*, page 1.

Nevertheless, the agreement contained provisions applicable to Sunoco, to ensure that it would meet its corrective action requirements under federal law:

> ***Sunoco agrees to undertake all actions required by Section XVII (Obligations by Sunoco)*** of this Settlement Agreement. ***The purpose of this Settlement Agreement as it pertains to Sunoco is to provide assurances that Sunoco will implement its corrective action obligations under RCRA at the Property***. Furthermore, Sunoco agrees that the actions to be undertaken pursuant to the terms and conditions of this Settlement Agreement are in its benefit.

See id., page 4, paragraph 5 (bold italics added for emphasis). Under the agreement, Sunoco was *required* to do a number of things for assurances of financial responsibility for its corrective action obligations. *See id.,* paragraphs 27-33, pages 57-71. This was not voluntary.

True, the Settlement Agreement states that Sunoco had entered into the Voluntary Cleanup Program on October 12, 2006. *See id.*, paragraph 17, page 10 ("Sunoco voluntarily entered into the Act 2 Program on October 12, 2006. PADEP and EPA are addressing the Site under the One Cleanup Program Memorandum of Agreement ("MOA") signed by PADEP and EPA in 2004."). But this simply repeats the error made by the Department in characterizing Act 2 as a Voluntary Cleanup Program.

F. This is not a voluntary cleanup under the 2020 First Amendment to Consent Order and Agreement.

Finally, nothing in the 2020 consent order makes this a voluntary cleanup. *See* 2020 First Amendment to Consent Order and Agreement. Amending the 2012 consent order to acknowledge Hilco's new ownership of the owner/operator (Philadelphia Energy Solutions Refining and Marketing LLC), it sets forth a new timeline for the submission of remedial investigation reports and cleanup reports. *See id.,* pages 4-5 (requiring attainment with cleanup standards by December 31, 2030).

Accordingly, Evergreen should not characterize this as a voluntary cleanup.

3. **Evergreen Should Make Available on its Website All Historical Reports Referenced in Appendix A of the 2004 Current Conditions Report**.

Evergreen has prepared a website that is helpful for locating the available remedial investigation reports, and it is neatly organized according to Area of Interest. *See* Evergreen, Act 2 Documents. Linked from this webpage, Evergreen has created a webpage for groundwater monitoring reports for 2015-present, which is also clear and well-organized. *See* Evergreen, Semi-Annual Remediation Status Reports.

However, Evergreen's webpage for historical reports is unorganized and incomplete. *See* Evergreen, Referenced Historical Reports ("Referenced Historic Reports"). It is helpful that this webpage is also linked from the webpage for the Act 2 Reports. However, the documents are listed in alphabetical order according to the title of the saved document. Without point headings or some other outline, this webpage is difficult to navigate. Evergreen should reorganize this webpage according to some criterion that would help the public to better understand the project (by Area of Interest, chronological order, etc.).

Finally, Evergreen should post all the historical reports set forth in Appendix A of the 2004 Current Conditions Report on its webpage. *See* 2004 Current Conditions Report and Comprehensive Remedial Plan (all Areas of Interest), pdf pages 150-153. It appears that Evergreen has already posted a number of these reports on its webpage. In addition, at the request of the Council, Evergreen recently posted 15 of the remaining reports from Appendix A at the top of that webpage. The Council appreciates Evergreen doing this.

The Council made that request because it was looking for documentation relating to the sheet pile wall, which provides the last line of defense against the migration of contaminated groundwater to the Schuylkill River. (*See* Comment #9, below). The documents recently posted by Evergreen do not provide any more detail on the sheet pile wall, beyond the minimal detail provided in Evergreen's reports. Posting all the historical reports would help the public gather documents relating to this issue as well as other issues regarding the remedial investigation.

Finally, the Council requests that Evergreen make available on its website geological logs and detailed well construction information for all the monitoring well and remedial well network. This would help the public in providing a detailed review and comments to the remedial investigations. *See* Comment #7, below.

The Council requests that Evergreen make the documents word-searchable before posting them. Many of the documents posted on the website are word-searchable, but many are not. Depending on the length of the document, it may take as much as half an hour for a user to make a document word-searchable.

4. **Evergreen Has Not Sufficiently Answered Questions From the Public on its Q&A Webpage.**

Evergreen has dedicated a webpage to address comments from the public on an ongoing basis. *See* Evergreen, Q & A. In theory, this is a good practice. However, a number of Evergreen's responses did not answer the question or inappropriately deferred answers to a future report. Evergreen will be submitting the Q&A to the Department. *See id.* ("The questions and comments below have been generated from website comment forms, emails, and public meeting comments. These will be updated periodically and will be included in the Public Comment Remedial Investigation Report to be submitted to the agencies upon completion of the public comment period."). Therefore, the Council is commenting directly on the Q&A, which are separately attached and numbered to facilitate a discussion regarding them. *See* Attachment 3 -- Evergreen's Q&A (downloaded on December 30, 2020).

As a preliminary matter, it would be helpful if Evergreen were to organize the Q&A on its website according to some numbering system, to make it easier for the public to track. (This is why the Council downloaded all the Q&A on December 30, 2020 and assigned numbers to them). Also, additional Q&A were added since that time. Without some sort of tracking system, it is very difficult to even identify changes to the webpage.

A. Public involvement
Q&A 58

In response to a question why it took so long to engage the public in the preparation of the remedial investigation reports, Evergreen merely describes the notifications that were made. But it does not answer the question:

> [Q&A 58]
>
> Why did it take 10+ years, and an almost-catastrophic explosion, for Evergreen to come back and engage the public?
>
> Since Atlantic/Sunoco purchased the refinery, there have been 21 Act 2 reports submitted and, ***at the time of each submission (as well as at the time of each of three Notices of Intent to Remediate (NIR) submitted for the property), a letter was sent to the City of Philadelphia and notices appeared in a local newspaper informing the public of each submittal and their opportunity to comment on the submittals***. In August 2018, DEP requested that Evergreen revisit the previous public involvement plan with the City of Philadelphia. After a meeting with DEP, EPA and City officials in November 2018, Evergreen began developing the www.phillyrefinerycleanup.info website in preparation for a public meeting. The fire at PES' facility occurred after this effort was underway, in June of 2019. At that time, Evergreen suggested

> opening the website prior to announcing a date for a legacy remediation public meeting to allow the agencies to share the website in order to aid in answering questions that were being posed about Sunoco's legacy remediation program. The June 2019 fire at the PES facility does not relate to Evergreen's Act 2 submittals or public involvement plan.

See id., Q&A 58. In the present comments, the Council is setting forth its own answer to the question. *See* Comment #1, above.

B. Proposed site-specific standard for lead
Q&A 12, 36, 43, 44, 70, 72, 90, 91, 94, 95, 98, 99, 100, 101, 102, 103

In the past, Evergreen took the position that its proposed site-specific standard was appropriate because it asserted that a target blood level of 10 ug/dL was appropriate. *See* Attachment 3 -- Q&A 70 ("Evergreen derived a site-specific direct contact numeric value in their 2015 risk assessment based on a target blood lead level of 10 mg/dL.").[2] But in response to two recent questions, Evergreen has stated that "[i]f the PADEP changes their assumptions related to lead, such as permissible blood lead levels, Evergreen will update the SSS accordingly." *Id.*, Q&A 100, 102.

In December 2020, the Department decided to change its assumption regarding a target blood lead level. In the pending rulemaking, it is now proposing a direct contact numeric value based on a target blood lead level of 5 ug/dL:

> Decisions Based on Workgroup Analysis
>
> - ***Use a Target Blood Lead Level of 5 ug/dL***
> - Use a Probability of Exceeding the Target Blood Lead Level of 5%
> - Use all environmental media inputs
> - Resulting lead values in Table 4A:
>   - o Non-residential direct contact value = 1,100 mg/kg
>   - o Residential direct contact value = 150 mg/kg
>
> (Both rounded to two significant figures)

DEP, Overview of Chapter 250 Draft-Final Rulemaking, page 9 (slide presentation, December 16, 2020) (bold italics added for emphasis); *see also* DEP, Draft Chapter 250 Rulemaking Table 4A (December 16, 2020) (striking "2,500" and inserting "1,100" for proposed direct contact

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[2] In this Q&A there is a typographical error with respect to the units. Evergreen assumed a target blood lead level of 10 ug/dL, not 10 mg/dL. The error is not material to the analysis.

numeric value); *cf.* 50 Pa. B. 1011, 1072, Table 4A (February 15, 2020) (initially proposing direct contact numeric value of 2,500 mg/kg).[3]

Evergreen should follow through with its responses and abandon its proposed site-specific standard of 2240 mg/kg.

The Council will address the proposed site-specific standard in more detail in Comment #13, below. The Council is also attaching its comments on the proposed Act 2 Rulemaking, explaining why the Department should use a target blood lead level of 5 ug/dL, rather than 10 ug/dL. *See* Attachments 4-8 -- Comments of Clean Air Council, dated April 30, 2020. The reasoning set forth in the Council's comments to the Department is also applicable to Evergreen's proposed site-specific standard.

C. Fate and Transport Remedial Investigation Report
Q&A 7, 10, 12, 13, 14, 16, 17, 18, 19, 20, 21, 22, 23, 26, 30, 31, 32, 66, 75, 84, 94, 99)

The Technical Guidance Manual recognizes that a fate and transport analysis is a part of a remedial investigation. *See* Comment #11, below. However, Evergreen asserts that it is necessary to have all of the present remedial investigation reports approved before it completes a fate and transport model:

> [Q&A 23]
>
> How much more information do you need to complete the fate and transport model?
>
> We believe we have sufficient information to complete the model. ***However, we need to have agreeance on that from DEP prior to submittal. In other words, all of the Remedial Investigation Reports must be approved first (meaning, that DEP feels we have sufficiently defined the contamination so that a model can be accurate and complete).*** Once the RIR Addendums for AOI's 4 and 9 are submitted and approved, the fate and transport model will be finalized and submitted to PADEP for approval.

See Attachment 3 -- Q&A 23 (bold italics added for emphasis). But Evergreen makes this assertion only because Evergreen persuaded the Department to allow this. *See e.g.*, 2017 Approval Letter (AOI-5) ("Evergreen will complete separate Act 2 reporting to satisfy additional remedial investigation requirements for a fate-and-transport analysis (Title 25 Pa.

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[3] The December 2020 materials are available on the Department's webpage for the meeting of the Cleanup Standards Scientific Advisory Board. *See* DEP, December 16, 2020 – Cleanup Standards Scientific Advisory Board Meeting (virtual meeting via WebEx).

Code Section 250.408(a)”). (Similar statements are made in the Department’s approval letters for AOI-1, AOI-2, AOI-3, AOI-4, AOI-6, AOI-7, and AOI-9).

Moreover, the legal authority cited in the Department’s letter does not compel the conclusion that a remedial investigation report should be fragmented in the manner sought by Evergreen. It merely sets forth requirements for a remedial investigation where a site-specific standard is sought. *See* 25 Pa. Code Section 250.408(a). In fact, that section refers to a “site characterization” and a “report” in the singular, not in the plural. *See id.*

Apparently, Evergreen assumes that the remedial investigation report for AOI-11 was disapproved only because of a flawed fate and transport analysis. Indeed, Evergreen draws the erroneous conclusion that the reports for AOI-11 were approvable apart from the fate and transport analysis:

> [Q&A 12]
>
> 1)We are concerned about lead in surface soil. The standard Evergreen has proposed does not address the risk.
> ***2) Evergreen has not obtained approval from DEP for remedial investigation reports for several of the more contaminated areas of interest. Including the aquifer.***
> 3) The work done so far does not consider the impacts of climate change, rising sea level and worsening storms. Note: for the purpose of response, this comment was split into three topics by Evergreen.
>
> ….
>
> 2)DEP did not approve two of the RIRs – AOI-4 and AOI-9 – based on the need for additional offsite characterization, not a level of contamination over other AOIs. ***The characterization portion of the AOI-11 report was sufficient for approval; however, the fate and transport portion of the AOI-11 reports was not, which is why the report was not approved***. Data has been collected from the lower aquifer wells as part of the other AOI remedial investigations since 2013 and reported in the Remedial Investigation Report submitted since 2013.
>
> ….

See Attachment 3 -- Evergreen’s Q&A 12.

> [Q&A 75]

> ***Can you comment on why AOI11 deep groundwater report has not yet been approved?"***
>
> ***There were both an AOI 11 Remedial Investigation Report and a Final Report that were submitted. Both were disapproved solely for the fate and transport analysis that was included in the reports. The remedial investigation portion of those reports were good***. Note that before we started a site wide model concept, each of the AOI reports had separate individual models completed, but we have since updated that approach because the only disapproval points for those reports were based on the fate and transport, In subsequent talks with PADEP, we decided that the next phase of reporting for AOI 11 would be in the site-wide Fate and Transport RI report. Also note that AOI 11 has been monitored continually and data reported in other AOI RIRs.

See id., Q&A 75.

Evergreen goes even further, making the flawed assertion that conditions are protective of human health both onsite and offsite:

> [Q&A 26]
>
> ***There has been some concern that because of the aquifer under the water, pollutants from the refinery may impact drinking water in downstream New Jersey. Do you think this was ever a concern?*** If yes, will it continue to be one even as the refinery shuts down?
>
> Evergreen's role is to evaluate and remediate groundwater conditions created based on use of the facility up through 2013. Based on extensive data collected over the last 20+ years, and groundwater modeling performed to date, it is highly unlikely that those groundwater impacts affect drinking water quality in New Jersey. As part of the Act 2 process, Sunoco and Evergreen have performed several preliminary risk assessments, including accounting for the projection of dissolved contaminant migration in groundwater. ***All assessments to date have shown that conditions with respect to groundwater beneath the facility are protective of human health both onsite and offsite***. Evergreen is working on a complete groundwater fate and transport analysis, which projects where and how far contaminants will travel and at what concentrations, as well as other reports that will provide additional and more detailed analysis.

See id., Q&A 26.

The Council submits that this is not the case. For reasons set forth throughout the Council's comments, there are a number of flaws in the reports' discussion of the deep aquifer, including Evergreen's insufficient characterization of the relationship between the unconfined aquifer and the deep aquifer. Contrary to Evergreen's assertions, it is not true that "[t]he characterization portion of the AOI-11 report was sufficient for approval," or that "[t]he remedial investigation portion of those reports were good." The whole thing was a remedial investigation report and the report for the remedial investigation was disapproved.

Despite its assertions to the contrary, Evergreen actually acknowledges that its characterization of the relationship between the unconfined aquifer and the deep aquifer is flawed, when it promises "pressure gradients" and mapping of the clay layer in a future Fate and Transport Remedial Investigation Report:

> [Q&A 19]
>
> When will Evergreen conduct the fate and transport analysis for the lower aquifer? ***There is no aquitard between upper and lower aquifer across most of the site. Won't the heavily contaminated shallow aquifer gradually leach contaminants into the lower aquifer?*** (a critical drinking water source for New Jersey)
>
> The fate and transport analysis for the lower aquifer will be performed once the Remedial Investigation Reports for AOI 4 and AOI 9 have been approved. ***There are areas beneath the Site where connections exist between the lower aquifer and water table aquifer are less extensive than the areas where we have that important clay layer present***. The cross section shown during the August 27th Public Information Session was just one example from the site model that straddles the Schuylkill River where the aquitard is interpreted to be missing. ***Other cross sections show the continuity of that clay layer***. Even where the aquitard is missing, it does not necessarily mean that water and contaminants will move down into the deeper aquifer. ***That potential has to do with pressure gradients that the model can simulate. The fate and transport model will simulate future scenarios based upon current conditions***.
>
> ***It is noted that the fate and transport analysis will include mapping of the middle clay unit aquitard***. Water quality in the lower aquifer is monitored through routine sampling of groundwater from approximately 80 wells, and to date significant contamination has not been observed in the lower aquifer beneath the Site. Considering the aging and degrading petroleum sources

> in the water table from historic Sunoco sources, we do not expect groundwater hydrocarbon plumes to expand under current groundwater conditions.

See id., Q&A 19.

But Evergreen cannot have it both ways. It asserts that the future report is dependent on the present reports, at the same time that it asserts that the present reports are dependent upon the future report. Stated differently, all that Evergreen does is validate the notion that the material is interrelated, and Evergreen wants to break it apart. Moreover, in promising "pressure gradients" and mapping of the middle clay unit aquitard in a future remedial investigation report, Evergreen appears to be offering new data and information not present in the current reports. Accordingly, they are really one report and Evergreen is trying to break it apart.

Evergreen incorrectly assumes that the present remedial investigation reports reflect current conditions:

> [Q&A 13]
>
> Why is there no mention of climate change in discussion of the Water-table aquifer? ***These levels could change by multiple feet in the next few decades.***
>
> One of Evergreen's primary objectives through the remedial investigations under Act 2 was to characterize the facility's geologic framework and the water-bearing units it supports. Potential flow pathways for contaminant transport could be evaluated in this manner using recent groundwater observations from hundreds of wells at the facility. ***Evergreen's groundwater model is calibrated and validated to these recent groundwater data to provide defensible fate and transport simulations that are based on current conditions***. A sensitivity analysis was performed on the groundwater model to evaluate the impact of changes to inputs on performance and increase confidence in its ability to make predictions.
>
> Evergreen recognizes that climate changes are predicted that could alter local hydrologic conditions near the facility, such as higher water levels in the water-table aquifer or higher tides in the Schuylkill River. An assessment of climate change from available, published resources and the potential implications to Evergreen's groundwater model will be included in the upcoming Fate and Transport RIR.

See id., Q&A 13. As discussed in Comment #6 above, the public is commenting on remedial investigation reports that are all at least three years old, and Evergreen has not integrated the data, information, and analysis of its recent groundwater remediation status reports into these remedial investigation reports.

Now we know that Evergreen could have done the fate and transport analysis for the present public comment period, but it chose not to do so. In response to a question from a commenter, it admits that its groundwater flow model is complete:

> [Q&A 17]
>
> What is the status of your groundwater and aquifer modeling for all pollutants?
>
> ***The groundwater flow model has been completed but cannot be finalized and submitted until all Remedial Investigation Reports are approved as data collected for these reports are used as the basis for the groundwater flow model***. Groundwater contaminant fate and transport model efforts will be conducted subsequent to approval of the Remedial Investigation Reports ***since the fate and transport modeling is dependent upon the information in the Remedial Investigation Reports*** and the groundwater flow model.

See id., Q&A 17. There is no apparent reason why Evergreen would need nearly a year after the end of this public comment period to prepare a report.

In fact, the public has every reason to fear being sandbagged by fragmenting the remedial investigation reports in this manner. If the current reports are approved, that could freeze data, information, and analysis and make it difficult for the public to make future comments on a fate and transport model that depend on these reports. Evergreen makes this clear in a response to a question from a commenter, when it states that reports do not get updated once approved:

> [Q&A 67]
>
> ***Many of the finalized online reports reflect reviews done between 2011 to 2016 with no updates. How can I learn what happened next?*** Is there a person to contact with specific, referenced questions, which would be onerous for a Zoom conference?
>
> ***RIR reports do not get updated once approved***. Once RIRs are completed and approved, other report types are submitted with additional information, activities, and updates in the Act 2 process. Evergreen has multiple reports planned for 2021 and will provide a draft schedule on the website of upcoming reports.

> We have also provided copies of the semi-annual update reports on the website, which are not Act 2 submittals, but provide a routine update on remediation activities at the facility. You can ask questions in writing via email or live during the next Zoom meeting. In addition, Evergreen is currently planning smaller group meetings in the future which may make communication easier.

See id., Q&A 67 (bold italics added for emphasis).

Hypothetically, there could be circumstances that might compel a remedial investigation report to be finalized as a condition for preparing another report. For example, this might be the scenario for a cleanup plan. But that is not what is contemplated by Evergreen. It does not attempt to characterize it as a risk assessment, which Evergreen characterizes as separate from the present reports:

> [Q&A 94]
>
> It may have been more effective if this presentation was made available a week ago and we could have spent these two hours asking pertinent questions, ***such as: 1. what are the critical paths for considering the risks of lead and benzene to the adjacent communities;*** 2. how are increased climate-change risks being assessed; 3. how is ground and surface water run off being considered in the plans; 4. how is Hilco assessing the additional risks of (what looks like will be) hard scape pavement of 85-90% of the site?
>
> 1-Pathways and routes of exposure are discussed in the RIRs and they will be presented in more detail in the Risk Assessment Report. ***The Risk Assessment Report will be submitted after the public comments on the Remedial Investigation Reports, and after completion of the Public Comment RIR and the Fate and Transport RIR***.
>
> ….

See id., Q&A 94 (bold italics added for emphasis). Rather, Evergreen simply contemplates diverting material that should be in the current remedial investigation reports into another remedial investigation report to be made available later this year, under the name “Fate and Transport Remedial Investigation Report.”

Stated differently, that future remedial investigation report is simply the long-awaited remedial investigation report for AOI-11, following the disapproval of the report for AOI-11 over seven years ago. The subject matter of the AOI-11 report was shifted into the individual reports for the other individual Areas of Interest, and now Evergreen is attempting to shift them out into a standalone report again. Evergreen may not launder the deficiencies and fragment the remedial investigation reports in this manner.

The Council will address this in more detail in Comment #11, below.

D. Water quality and compliance with permit requirements
Q&A 82, 85)

Two commenters posed questions regarding the quality of water discharged from remediation systems and Evergreen's compliance with permit requirements. In response, Evergreen did not answer these questions. Evergreen should answer the questions.

In response to Question 83, Evergreen summarizes the nature of the process of sampling, but it does not answer the question regarding the quality of the water discharged from the remediation system:

> [Q&A 83]
>
> ***What is the quality of the water discharged from the Pollock St well system into the Schuylkill?***
>
> Groundwater collected from the Pollack St well system is not discharged directly to the Schuylkill River. Groundwater discharged from any remediation system is either processed through the facility's wastewater treatment plant which operates under a National Pollutant Discharge Elimination System (NPDES) permit held by PES ***or discharged to the Philadelphia Water Department (PWD) sewer system via a Groundwater Discharge Permit held by Evergreen***. ***Evergreen samples groundwater discharge to the PWD sewer per the permit requirements*** and the discharge from the facility's wastewater treatment plant is sampled by PES in accordance with their NPDES Permit.

See Attachment 3 -- Q&A 83. To be sure, Evergreen has a permit for an indirect discharge and the property owner Philadelphia Energy Solutions Refining and Marketing LLC (now owned by Hilco) has a permit for a direct discharge to the Schuylkill River. But this is a legal distinction that avoids the question posed about water quality. Certainly, Evergreen has the ability to obtain information regarding the quality of water discharged to the Schuylkill River, even though it is not a direct discharger.

In response to Question 85, Evergreen acknowledges that there are monthly discharge monitoring requirements, but does not answer the question whether permit requirements have been met:

> [Q&A 85]
>
> Is there a permit for the discharge of water from the wastewater treatment system to the PWD, who is the permit holder, ***and have the permit requirements been met?***
>
> Evergreen has a permit for any contaminated water that we discharge to PWD, and Evergreen is the permittee. ***The permit has monthly discharge monitoring requirements that need to be achieved to meet the requirements of the permit***. Some of the discharge from Evergreen's systems go directly to the PES wastewater treatment plant. PES had a NPDES permit to operate their wastewater treatment plant, which is permitted through the PADEP, which is different from a PWD permit. Hilco Redevelopment Partners (HRP) will now be running the waste water treatment plant and will be permittee for the NPDES permit.

See id., Q&A 85.

Evergreen should properly answer the two questions.

E. Air quality and soil vapor intrusion
Q&A 10

One commenter posed a question about soil vapor intrusion and whether sampling for air quality would be done in residential areas nearby. Applying circular reasoning, Evergreen asserts that sampling is not warranted because there is no known contamination:

> [Q&A 10]
>
> Air quality measurements were made within existing buildings, ***but no air quality data was collected in surrounding neighborhoods or onsite at contaminated locations***.
>
> Evergreen must investigate air quality stemming from subsurface contamination only, not from refinery operations above ground. As documented in the Remedial Investigation Reports, air samples were collected from inside site buildings, and from outdoor air locations both as background and above areas of known LNAPL plumes. ***There are no known residential areas where the contaminated groundwater has migrated from the facility to beneath those areas, which would possibly warrant sampling***. Also, future movement of contaminant plumes over time will be part of future site activities, including fate and transport modeling

> and evaluation of any potential risk associated with the migration of offsite plumes as part of a vapor intrusion assessment.

See id., Q&A 10. Of course, the only way one would have knowledge of contamination would be through sampling. Not having taken samples, Evergreen says it has no knowledge of contamination that would justify taking samples. And Evergreen will not have knowledge of contamination if it does not take samples. Evergreen should provide a better answer than this.

The last sentence of the response is not adequate because it is a vague reference to future fate and transport modeling that would avoid the question posed and would fragment this remedial investigation. Evergreen admits it has taken air samples from buildings onsite, and it has not relied solely on future fate and transport modeling in place of taking those samples. It should provide an explanation why air sampling in neighboring residential areas should be treated differently.

F. Delineation of nature and extent of lead contamination
Q&A 103

One commenter posed a question how Evergreen could have delineated the extent of lead contamination, having used an inappropriate site-specific standard. In response, Evergreen states that it compared the concentrations of soil samples to both the soil-to-groundwater numeric value and the site-specific standard, in the context of its tables attached to the reports:

> [Q&A 103]
>
> Since Evergreen used an inappropriate standard as a basis for its remedial investigation reports, ***how does it justify that it has correctly defined the extent of lead contamination?***
>
> As noted in response to other questions concerning the lead, the calculation of the site-specific standard was appropriate in accordance with the Act 2 regulations and recommendations from the USEPA and the PADEP. As part of the remedial investigations, ***the lead data was compared to the Act 2 SHS MSC, which is 450 ppm, based on the soil to groundwater pathway, to define the extent of lead contamination. This comparison is shown on the figures/tables in the RI Reports and in the 8/27/20 Public Information Session, so the extend [sic] of lead has been delineated to 450 ppm at the Site. Data was also compared to the site-specific standard.***

See id., Q&A 103. This is misleading because the soil-to-groundwater numeric value and the site-specific standard do not receive the same consideration in terms of Evergreen’s synthesis and narration of the data.

When Evergreen asserts that “the lead data was compared to the Act 2 SHS MSC, which is 450 ppm, based on the soil to groundwater pathway, to define the extent of lead contamination,” it is merely pointing out that it dropped a column in a spreadsheet to set forth both the soil-to-groundwater numeric value and the site-specific standard. This does not mean that this received any meaningful analysis in the narrative text of the reports -- which it did not.

Moreover, the following illustration from the 2017 report for AOI-5 demonstrates that Evergreen’s assertion is simply incorrect. The spreadsheet of data only includes a column for the site-specific standard (2240 mg/kg), and there is no column for the soil-to-groundwater numeric value (450 mg/kg) or the direct contact numeric value (1000 mg/kg):

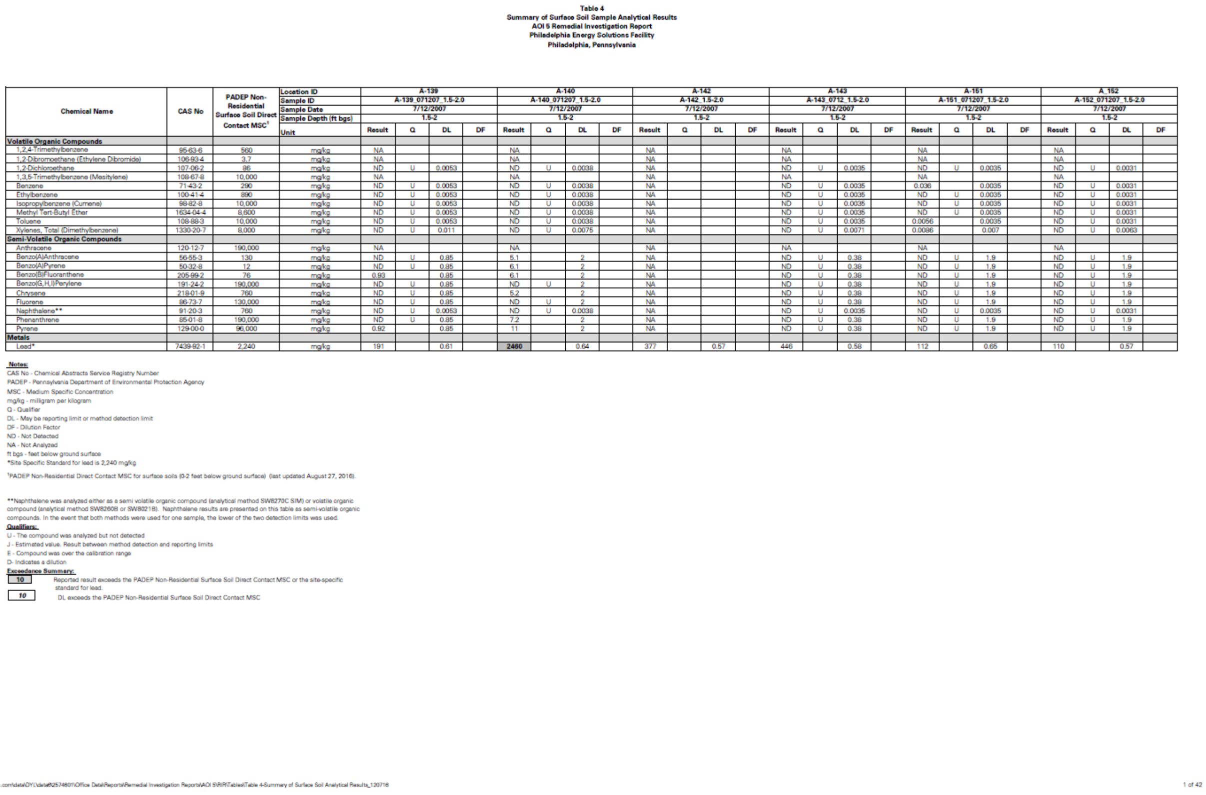


Table 4
Summary of Surface Soil Sample Analytical Results
AOI 5 Remedial Investigation Report
Philadelphia Energy Solutions Facility
Philadelphia, Pennsylvania

Chemical Name	CAS No	PADEP Non-Residential Surface Soil Direct Contact MSC[1]	Location ID	A-139				A-140				A-142			
			Sample ID	A-139_071207_1.5-2.0				A-140_071207_1.5-2.0				A-142_1.5-2.0			
			Sample Date	7/12/2007				7/12/2007				7/12/2007			
			Sample Depth (ft bgs)	1.5-2				1.5-2				1.5-2			
			Unit	Result	Q	DL	DF	Result	Q	DL	DF	Result	Q	DL	DF
Volatile Organic Compounds															
1,2,4-Trimethylbenzene	95-63-6	560	mg/kg	NA				NA				NA			
1,2-Dibromoethane (Ethylene Dibromide)	106-93-4	3.7	mg/kg	NA				NA				NA			
1,2-Dichloroethane	107-06-2	86	mg/kg	ND	U	0.0053		ND	U	0.0038		NA			
1,3,5-Trimethylbenzene (Mesitylene)	108-67-8	10,000	mg/kg	NA				NA				NA			
Benzene	71-43-2	290	mg/kg	ND	U	0.0053		ND	U	0.0038		NA			
Ethylbenzene	100-41-4	890	mg/kg	ND	U	0.0053		ND	U	0.0038		NA			
Isopropylbenzene (Cumene)	98-82-8	10,000	mg/kg	ND	U	0.0053		ND	U	0.0038		NA			
Methyl Tert-Butyl Ether	1634-04-4	8,600	mg/kg	ND	U	0.0053		ND	U	0.0038		NA			
Toluene	108-88-3	10,000	mg/kg	ND	U	0.0053		ND	U	0.0038		NA			
Xylenes, Total (Dimethylbenzene)	1330-20-7	8,000	mg/kg	ND	U	0.011		ND	U	0.0075		NA			
Semi-Volatile Organic Compounds															
Anthracene	120-12-7	190,000	mg/kg	NA				NA				NA			
Benzo(A)Anthracene	56-55-3	130	mg/kg	ND	U	0.85		5.1		2		NA			
Benzo(A)Pyrene	50-32-8	12	mg/kg	ND	U	0.85		6.1		2		NA			
Benzo(B)Fluoranthene	205-99-2	76	mg/kg	0.93		0.85		6.1		2		NA			
Benzo(G,H,I)Perylene	191-24-2	190,000	mg/kg	ND	U	0.85		ND	U	2		NA			
Chrysene	218-01-9	760	mg/kg	ND	U	0.85		5.2		2		NA			
Fluorene	86-73-7	130,000	mg/kg	ND	U	0.85		ND	U	2		NA			
Naphthalene**	91-20-3	760	mg/kg	ND	U	0.0053		ND	U	0.0038		NA			
Phenanthrene	85-01-8	190,000	mg/kg	ND	U	0.85		7.2		2		NA			
Pyrene	129-00-0	96,000	mg/kg	0.92		0.85		11		2		NA			
Metals															
Lead*	7439-92-1	2,240	mg/kg	191		0.61		**2460**		0.64		377		0.57	

Chemical Name	Location ID	A-143				A-151				A_152			
	Sample ID	A-143_0712_1.5-2.0				A-151_071207_1.5-2.0				A-152_071207_1.5-2.0			
	Sample Date	7/12/2007				7/12/2007				7/12/2007			
	Sample Depth (ft bgs)	1.5-2				1.5-2				1.5-2			
	Unit	Result	Q	DL	DF	Result	Q	DL	DF	Result	Q	DL	DF
Volatile Organic Compounds													
1,2,4-Trimethylbenzene	mg/kg	NA				NA				NA			
1,2-Dibromoethane (Ethylene Dibromide)	mg/kg	NA				NA				NA			
1,2-Dichloroethane	mg/kg	ND	U	0.0035		ND	U	0.0035		ND	U	0.0031	
1,3,5-Trimethylbenzene (Mesitylene)	mg/kg	NA				NA				NA			
Benzene	mg/kg	ND	U	0.0035		0.036		0.0035		ND	U	0.0031	
Ethylbenzene	mg/kg	ND	U	0.0035		ND	U	0.0035		ND	U	0.0031	
Isopropylbenzene (Cumene)	mg/kg	ND	U	0.0035		ND	U	0.0035		ND	U	0.0031	
Methyl Tert-Butyl Ether	mg/kg	ND	U	0.0035		ND	U	0.0035		ND	U	0.0031	
Toluene	mg/kg	ND	U	0.0035		0.0056		0.0035		ND	U	0.0031	
Xylenes, Total (Dimethylbenzene)	mg/kg	ND	U	0.0071		0.0086		0.007		ND	U	0.0063	
Semi-Volatile Organic Compounds													
Anthracene	mg/kg	NA				NA				NA			
Benzo(A)Anthracene	mg/kg	ND	U	0.38		ND	U	1.9		ND	U	1.9	
Benzo(A)Pyrene	mg/kg	ND	U	0.38		ND	U	1.9		ND	U	1.9	
Benzo(B)Fluoranthene	mg/kg	ND	U	0.38		ND	U	1.9		ND	U	1.9	
Benzo(G,H,I)Perylene	mg/kg	ND	U	0.38		ND	U	1.9		ND	U	1.9	
Chrysene	mg/kg	ND	U	0.38		ND	U	1.9		ND	U	1.9	
Fluorene	mg/kg	ND	U	0.38		ND	U	1.9		ND	U	1.9	
Naphthalene**	mg/kg	ND	U	0.0035		ND	U	0.0035		ND	U	0.0031	
Phenanthrene	mg/kg	ND	U	0.38		ND	U	1.9		ND	U	1.9	
Pyrene	mg/kg	ND	U	0.38		ND	U	1.9		ND	U	1.9	
Metals													
Lead*	mg/kg	446		0.58		112		0.65		110		0.57	

Notes:
CAS No - Chemical Abstracts Service Registry Number
PADEP - Pennsylvania Department of Environmental Protection Agency
MSC - Medium Specific Concentration
mg/kg - milligram per kilogram
Q - Qualifier
DL - May be reporting limit or method detection limit
DF - Dilution Factor
ND - Not Detected
NA - Not Analyzed
ft bgs - feet below ground surface
*Site Specific Standard for lead is 2,240 mg/kg

[1] PADEP Non-Residential Direct Contact MSC for surface soils (0-2 feet below ground surface) (last updated August 27, 2016).

**Naphthalene was analyzed either as a semi volatile organic compound (analytical method SW8270C SIM) or volatile organic compound (analytical method SW8260B or SW8021B). Naphthalene results are presented on this table as semi-volatile organic compounds. In the event that both methods were used for one sample, the lower of the two detection limits was used.

Qualifiers:
U - The compound was analyzed but not detected
J - Estimated value. Result between method detection and reporting limits
E - Compound was over the calibration range
D- Indicates a dilution

Exceedance Summary:
10 Reported result exceeds the PADEP Non-Residential Surface Soil Direct Contact MSC or the site-specific standard for lead.
10 DL exceeds the PADEP Non-Residential Surface Soil Direct Contact MSC

1 of 42

See 2017 Report (AOI-5), Table 4 (Summary of Surface Soil Sample Analytical Results), pdf pages 86-127. This means that Evergreen disregarded the lower soil-to-groundwater numeric value (450 mg/kg) when it delineated the contamination.

This is not just a matter of one spreadsheet. In just this one report, there are 42 of these spreadsheets for lead in surface soil. There are nine other areas of interest in which lead samples were taken, and some of them have two reports, and not just one report. Evergreen should explain why it made the assertion in the Q&A that it compared the concentrations of soil samples with the two numeric values. The Council addresses this in more detail in Comment #12, below.

Evergreen should also explain why merely inserting a column listing the two numeric values would be sufficient to delineate the contamination with respect to those values. Again, what is important is that there be meaningful public participation in this process. *See* Comment #1, above. When Evergreen simply points to long data tables, that does not provide a meaningful public understanding. It needs to do analysis and synthesis, and it needs to explain things better.

G. <u>Pre-2012 and post-2012 contamination</u>
Q&A 56, 87 (duplicate)

One commenter posed the question about dividing contamination into pre-2012 contamination and post-2012 contamination, to allocate responsibility following the 2012 sale by Sunoco to the current owner Philadelphia Energy Solutions Refining and Marketing LLC. (The latter continues to be the owner/operator in 2021, as a subsidiary of Hilco).

In response, Evergreen acknowledged that there has been post-2012 contamination and that in some instances responsibility has been divided between Sunoco and the owner:

> [Q&A 56, 87]
>
> ***How is it determined what ground pollution is from 2012 and before…and what is from 2012 to the present?***
>
> When the facility was sold to PES in 2012, Sunoco had a good understanding of the nature and extent of contamination at the facility. It was assumed that any known contamination at the time of the sale was Sunoco's responsibility to cleanup. After the sale of the property, if changes in the contaminant profile on-site occurred, or known spills happened, the resulting cleanup became PES' responsibility. ***In some instances, new contamination co-exists with old contamination, and the responsibility is shared***.

See Attachment 3 -- Q&A 56, 87. Evergreen should provide a more detailed explanation regarding post-2012 contamination and how it is shared.

This is important for several reasons. First, to the extent there has been post-2012 contamination (e.g., contamination resulting from releases due to the fire in June 2019), that would tend to avoid review in Evergreen's reports, unless there has been an overlap of contamination or data. If that is the case, the public would like to know where it could obtain information about such post-2012 contamination.

Second, this concern is even greater for releases of hazardous substances during the past three years. The remedial investigation reports are at least three years old and they would not reflect releases in the past three years.

5. Evergreen's Conceptual Site Model is Fundamentally Flawed, Necessitating Substantially Revised Reports for Public Comment Before Submission to the Department.

In the reports, Evergreen has set forth a Conceptual Site Model (CSM) that reflects its view of geologic conditions and the contamination of the soil and groundwater. The "model" literally takes the form of a narrative text that has evolved over time, through the following documents: (1) 2003 Consent Order, (2) 2003 Phase I Remedial Plan, (3) 2004 Current Conditions Report, and (4) reports for the individual Areas of Interest. As developed and revised by Evergreen, this model is flawed in a number of ways, set out more fully in Comments #6, 7, 8, 9, 10, 11, 12, 13, 14, and 15.

The Conceptual Site Model is at least three years old, with the last report being submitted in 2017. While Evergreen has prepared groundwater remediation status reports since that time, Evergreen has not synthesized material from those reports with the remedial investigation reports that are the subject of this comment period. *See* Comment # 6, below. Evergreen should bring the information and analysis up-to-date.

The model does not appropriately characterize geologic conditions (including the relationship between the unconfined aquifer (water table) and the deep aquifer). Evergreen's inadequately attempts to address concerns regarding the potential pathway of migration of contamination by way of the deep aquifer to water supplies in New Jersey. *See* Comment # 7, below.

Evergreen does not analyze the apparent Light Non-Aqueous Phase Liquids in combination with groundwater flow direction data and exceedances for Semi-Volatile and Volatile Organic Compounds and metals in the deep aquifer. Evergreen has not provided a meaningful analysis and synthesis of shallow and deep aquifer monitoring data.

The model does not provide a complete delineation of metals in the deep aquifer. With respect to the investigation of AOI-11, Evergreen sampled for a wider range of metals including arsenic and manganese before 2013. But since that time, it has scaled back this effort in the reports for the other Areas of Interest, without providing a meaningful explanation. *See* Comment # 8, below.

Evergreen provides no meaningful analysis regarding the sheet pile wall -- the last line of defense against the migration of contaminated groundwater, which tends to flow toward the Schuylkill River, as admitted by Evergreen. This is an 8400-foot wall along the perimeter of AOI-5, AOI-6, AOI-7, and AOI-2. Repetitive statements about it being protective are conclusory and circular. *See* Comment # 9, below.

Evergreen does not consider climate change in delineating contamination for a site that has a high water table and neighbors the Schuylkill River, which is anticipated to experience sea level rise of two feet by 2050. This is significant given the widespread lead contamination in the surface soils (0-2 feet) throughout the site. *See* Comment # 10, below.

To address numerous deficiencies in the reports, Evergreen has attempted to divert them into a Fate and Transport Remedial Investigation Report to be prepared later in 2021. *See* Comment # 11, below. This would put the public into the awkward position of commenting on only part of a remedial investigation, with an important part missing. These parts are interrelated. In addition, if the current reports were to be approved, an objection would inevitably be made that the scope of future public comments should exclude material relating to the current reports. This would result in fragmentation of the remedial investigation reports and it would be fundamentally unfair to the public.

Evergreen skips important steps in delineating soil contamination according to numeric values of the Act 2 regulations. Areas of the site have a high water table (at times, it is less than ten feet from the surface of the soil). Where the soil buffer distance for a particular contaminant is less than the depth of the water table, Evergreen should have characterized exceedances of the more stringent soil-to-groundwater numeric value (450 mg/kg, for lead), rather than the less stringent direct contact numeric value (1000 mg/kg, for lead). *See* Comment # 12, below. Where Evergreen has referred to the soil-to-groundwater numeric value, it has marginalized its significance, relegating it to data in long tables and not providing a proper focus in the narrative text. In some instances, the reports have erroneously ignored the soil-to-groundwater numeric value altogether.

The model mistakenly relies on a proposed site-specific standard for lead in residential soils of 2240 mg/kg, calculated in 2015 based on an assumed target blood level of 10 ug/dL. Even at that time, that value was contradicted by the Centers for Disease Control and Prevention, which used a reference value of 5 ug/dL for case management for children exposed to lead. *See* Comment # 13, below. Last month, the Department changed its mind regarding a proposed direct contact numeric value of 2500 mg/kg for lead, which had been calculated assuming a target blood level of 10 ug/dL. *See* Comment # 4, above. Because the Department is now assuming a target blood lead level of 5 ug/dL in support of a proposed direct contact numeric value of 1100 mg/kg, Evergreen should abandon the proposed site-specific standard.

The flaws in this approach have a significant impact on the nature and characterization of lead in the surface soils. *See* Comment # 14, below. This is especially the case for AOI-5 and AOI-9 -- two of the more heavily contaminated areas of the site.

When revising the reports, Evergreen should prepare and submit a work plan to include Per- and Polyfluoroalkyl Substances (PFAS) as a Constituent of Concern in this remedial investigation. *See* Comment # 15, below. These substances are associated with the use of foams provided for firefighting. There is a history of catastrophic fires at the refinery -- including a terrible fire that resulted in the deaths of eight firefighters in 1975. PFAS has been the subject of remedial investigations in other states. In a pending rulemaking, the Department has proposed to establish Medium-Specific Concentrations for three PFAS chemicals.

To properly address these flaws, Evergreen will have to make significant revisions that will change the reports in a material way. Therefore, the public should be allowed an opportunity to comment on them again before submission to the Department. No prejudice to Evergreen will result from this. It currently has a ten-year timetable to come into attainment with applicable remediation standards. *See* 2020 First Amendment to Consent Order and Agreement, page 5 of 77. The last report was submitted over three years ago. Evergreen has not yet corrected deficiencies in a report relating to the deep aquifer that was disapproved by the Department in 2013 -- over seven years ago.

Under the revised consent order, Evergreen must provide a public comment period on the current reports by March 23, 2021. *See* 2020 First Amendment to Consent Order and Agreement, page 5 of 77. But the consent order is silent as to when Evergreen must submit the reports once it has received public comments. *See id.* Therefore, Evergreen has time to address the flaws in the model and the Department can require another public comment period before the submission of those revised reports.

6. Evergreen Should Revise the Reports to Reflect Up-To-Date Material (Including Data and Analyses From Groundwater Monitoring Status Reports).

While the Council appreciates the reopening of the public comment period for the reports, the public is now in the awkward position of providing comments on reports containing information, data, and analyses that may be out-of-date. The most recent report was submitted for AOI-8 in December 2017 -- over three years ago. *See* Evergreen, Act 2 Documents. In order for this public comment process to be meaningful, Evergreen should revise the reports to reflect more recent information, data, and analyses. It should also make the revised reports available for public comment again before submission to the Department.

The Department recognizes that a remedial investigation should address recent data that are representative of soil and groundwater conditions. According to its guidance document, soil data that are over two years old may be used in a site characterization only if conditions are not reasonably expected to change:

> Historical data (i.e., data more than two years old) can be used during site characterization ***if there is no reasonable expectation that the site conditions associated with the release being investigated have changed*** (e.g., changes in property use resulting in changes in exposure).

DEP, Technical Guidance Manual, Section II(A)(4)(b)(i), page II-13 (bold italics added for emphasis). The Department makes a similar statement regarding groundwater data for a site characterization:

> Remediators can use historic data for identifying trends at sites ***that are not reasonably expected to have changes in site conditions associated with the release being investigated*** (e.g., natural attenuation or degradation).

Id., Section II(A)(4)(b)(ii), page II-15 (bold italics added for emphasis).

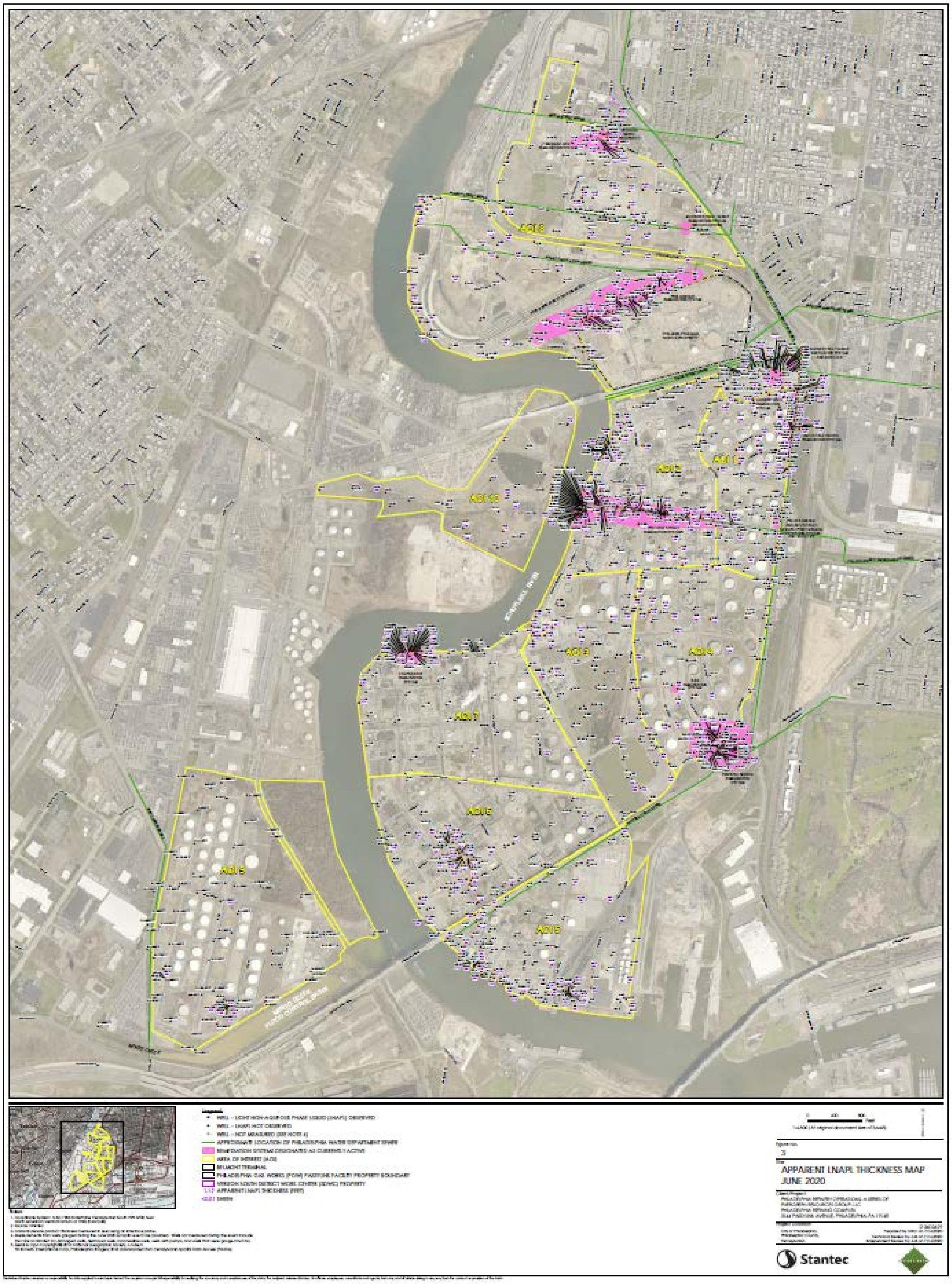
Because the last Evergreen report was submitted over three years ago, all the data underlying the reports are now considered “historical data,” which should be used only if there is no reasonable expectation that the site conditions associated with the release being investigated have changed.

Presumably, Evergreen has the means to address this problem. Evergreen should synthesize the material from the groundwater remediation status reports prepared every six months since 2015. *See generally* Evergreen, Semi-Annual Remediation Status Reports. Those reports contain more recent data on groundwater. It would be a challenge for the public to undertake an analysis of those reports and synthesize them with the remedial investigation reports. This is something that Evergreen can and should do.

Those reports alone would not bring data and information up to date, as the ostensible purpose of them was different. But Evergreen will have gathered other information, data, and analyses relevant to the reports subject to this comment period. (In fact, we know that this is the case because Evergreen is attempting to divert a fate and transport analysis into another remedial investigation report later this year).

The groundwater remediation status reports identify wells that had not been installed when earlier reports were prepared. The 2013 report for AOI-11 does not reflect at least 15 additional deep wells that were apparently constructed since that time. *See* 2013 Report (AOI-11), Figures 5 and 6; *see also* Semi-Annual Remediation Status Report (Second Half 2019), Table 2 (Sitewide Fourth Quarter 2019 Gauging Data) (identifying 58 wells in the lower aquifer). They also provide more recent data on groundwater data in the deep aquifer.

In addition, those reports provide a more precise delineation of Light Non-Aqueous Phase Liquids in shallow wells. Figure 3 in a recent groundwater remediation status report not only shows the presence of additional wells installed since 2017, but also demonstrates the apparent thickness of Light Non-Aqueous Phase Liquids:



See Semi-Annual Remediation Status Report (First Half 2020), Figure 3 (Apparent LNAPL Thickness Map), pdf page 14 of 52. These liquids were present in shallow wells S-414 (thickness of 1.50 feet), S-382 (thickness of 0.92 feet) and S-283 (thickness of 0.54 feet). In contrast, the remedial investigation report for AOI-3 shows no Light Non-Aqueous Phase Liquids in these shallow wells. *See* 2017 Report (AOI-3), Section 5.7 (LNAPL Characterization Results), pages 33-35, Figure 16 (Figure 16: Apparent LNAPL Thickness and Type), pdf page 173 of 760.

Evergreen should have synthesized and integrated material from those reports and done a similar analysis for all Areas of Interest.

Certainly, the data exist for doing this. In the tables in the groundwater remediation status reports there are columns setting forth the thickness of LNAPL. *See e.g.*, Semi-Annual Remediation Status Report (First Half 2020), Table 1 (First Quarter 2020 Gauging Data), Table 2 (Sitewide Annual 2020 Gauging Data), Table 3 (Comparison of Gauging Data for Select Wells). These data are not necessarily included in the remedial investigation reports.

Consistent with the Technical Guidance Manual, Evergreen should revise the reports so that the public is not commenting on reports containing historical data that are more than three years old. (It would not be a satisfactory response to this comment for Evergreen to simply assert that it has checked the groundwater remediation status reports and that it does not feel the need to revise the remedial investigation reports).

7. Evergreen Has Not Sufficiently Delineated the Nature and Extent of Contamination in the Deep Aquifer and the Unconfined Aquifer (Water Table).

There are fundamental flaws in Evergreen's analysis regarding the nature and extent of contamination in the deep aquifer and unconfined aquifer (water table), as well as in its analysis regarding the relationship between these aquifers.

A. Evergreen has not substantiated its assertion that significant contamination has not been observed in the lower aquifer.

In an answer to a question on its website, Evergreen makes the following statement:

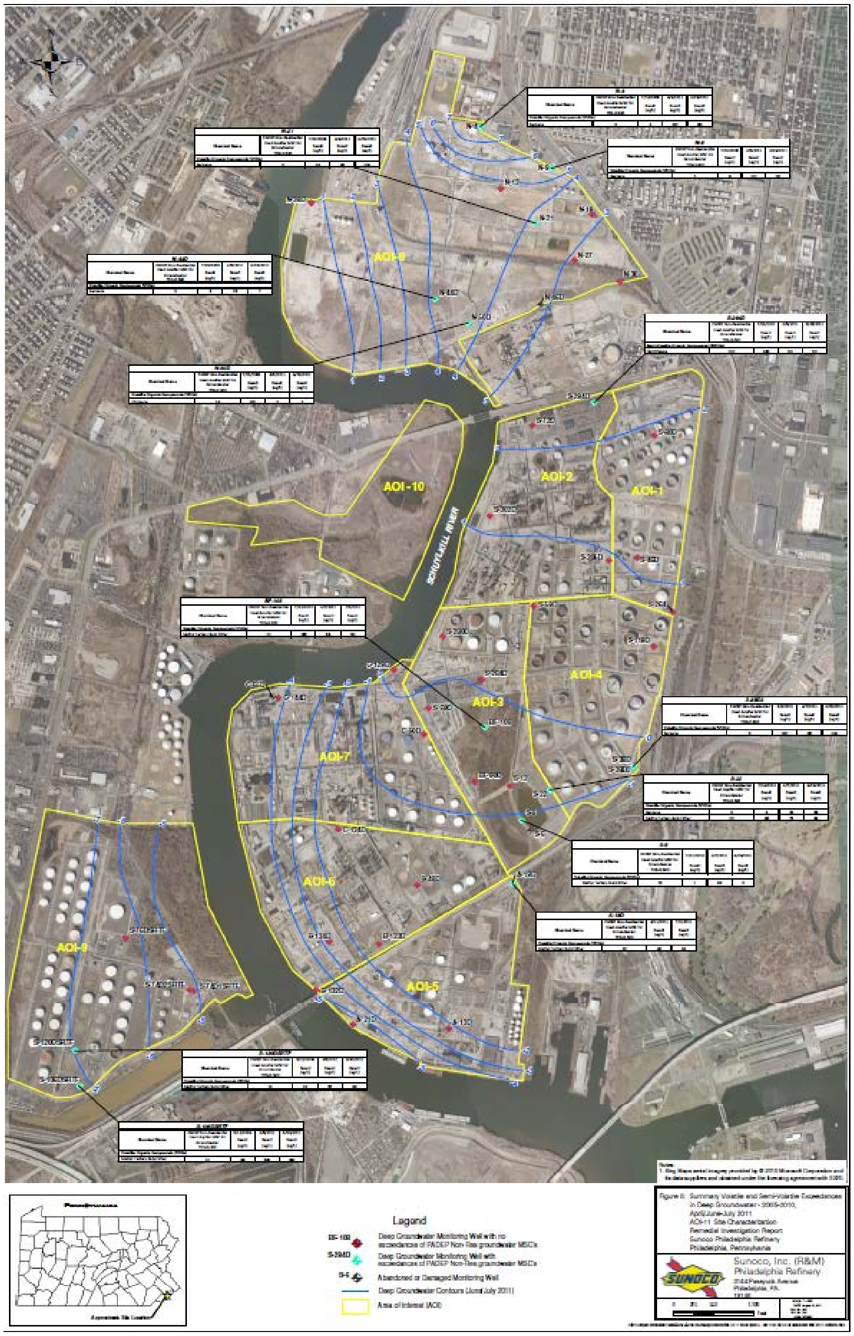
> Water quality in the lower aquifer is monitored through routine sampling of groundwater from approximately 80 wells, ***and to date significant contamination has not been observed in the lower aquifer beneath the Site.***

See Attachment 3 -- Q&A 19 (bold italics added for emphasis). It is not known what Evergreen means by this statement. Presumably, it means that there is contamination but that it is not significant. Reviewing the reports, it appears that the assertion is simply not correct.

In its comments on the first report for the deep aquifer, the Department noted exceedances of Medium-Specific Concentrations for a number of contaminants;

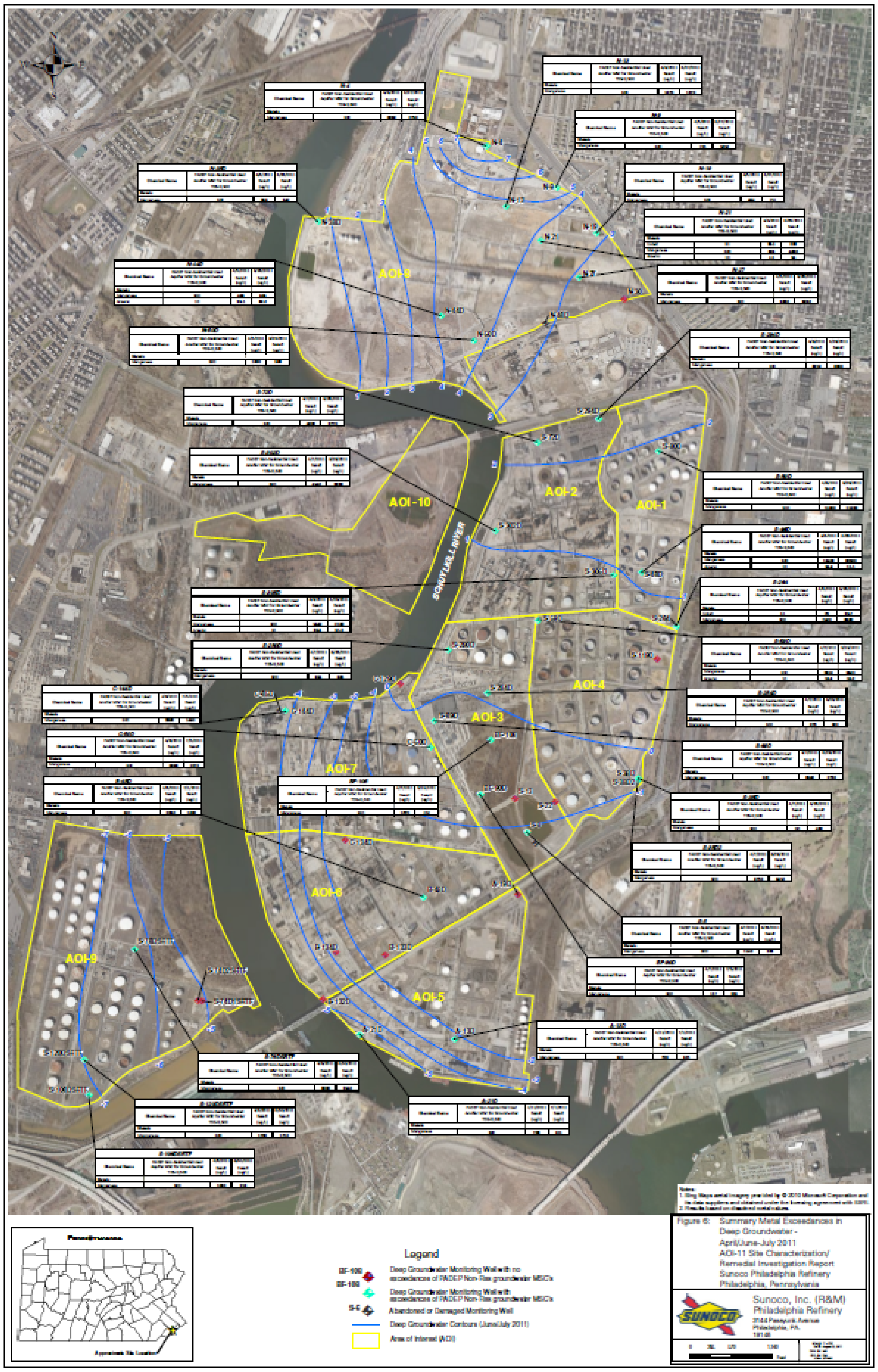
> ***Contaminants of concern (COC) that exceed the Department's non-residential statewide health standards*** (NRSWHS) in deep groundwater medium ***are***; ***chrysene, benzene, MTBE, naphthalene, cobalt, arsenic and manganese***. Iron exceeds the SMCL.

2011 Comments (AOI-11), paragraph 2 (bold italics added for emphasis). This was illustrated in the following Figures in the 2011 report. The figure for organic chemicals shows a large number of exceedances:



2011 Report (AOI-11), Figure 5 (Summary Volatile and Semi-Volatile Exceedances in Deep Groundwater - 2005-2010, April/June-July 2011); *see also id.*, Table 4 (2005-2010 Summary of Deep Groundwater Analytical Results); *see also id.*, Table 5 (April 2011 Summary of Deep Groundwater Analytical Results); *see also id.*, Table 6 (June-July 2011 Summary of Deep Groundwater Analytical Results), pdf pages 47-68, 75 of 76.

The figure for inorganic chemicals shows an even larger number of exceedances:

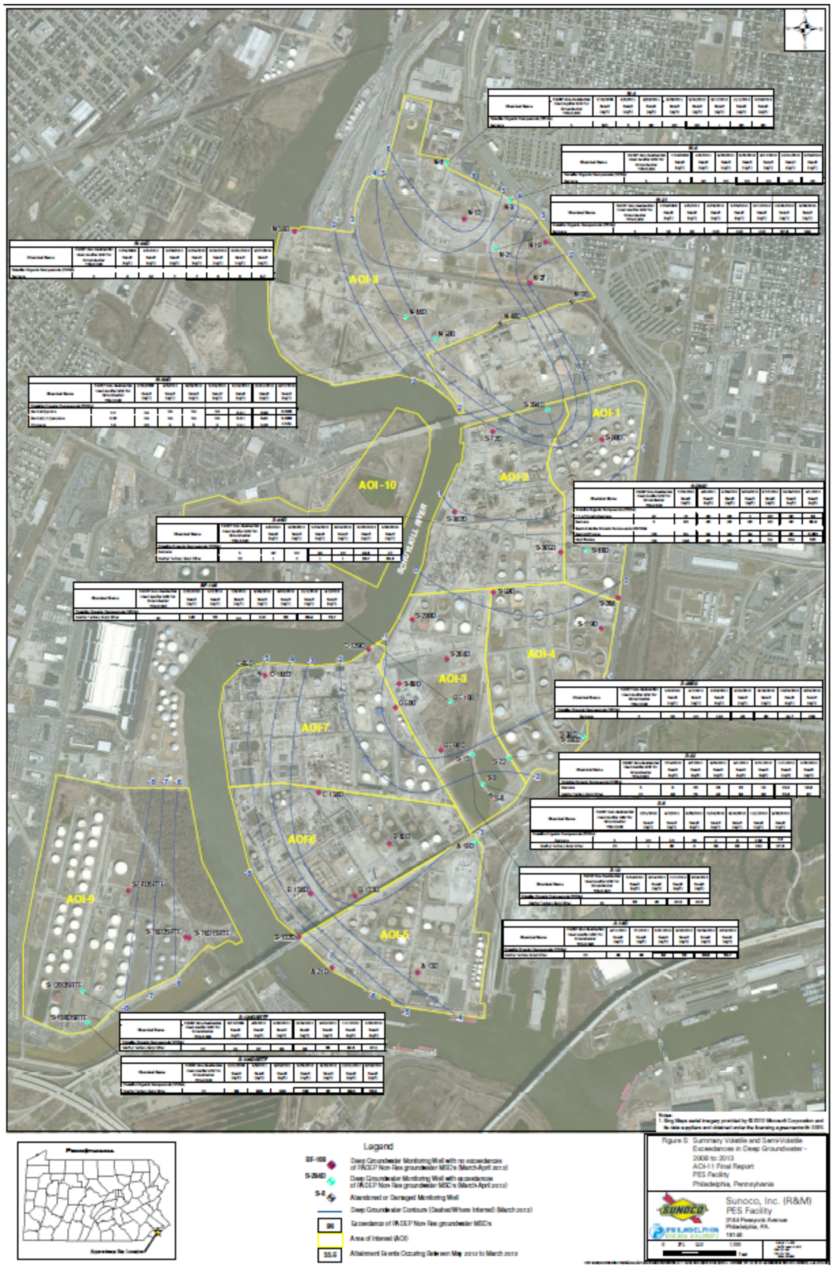


See id., Figure 6 (Summary Metal Exceedances in Deep Groundwater - April/June-July 2011); *see also id.*, Table 4 (2005-2010 Summary of Deep Groundwater Analytical Results); *see also id.*, Table 5 (April 2011 Summary of Deep Groundwater Analytical Results); *see also id.*, Table 6 (June-July 2011 Summary of Deep Groundwater Analytical Results), pdf pages 47-68, 76 of 76.

Evergreen also provides a textual narrative of the exceedances in its report. *See id.*, Section 5.1, pages 22-25.

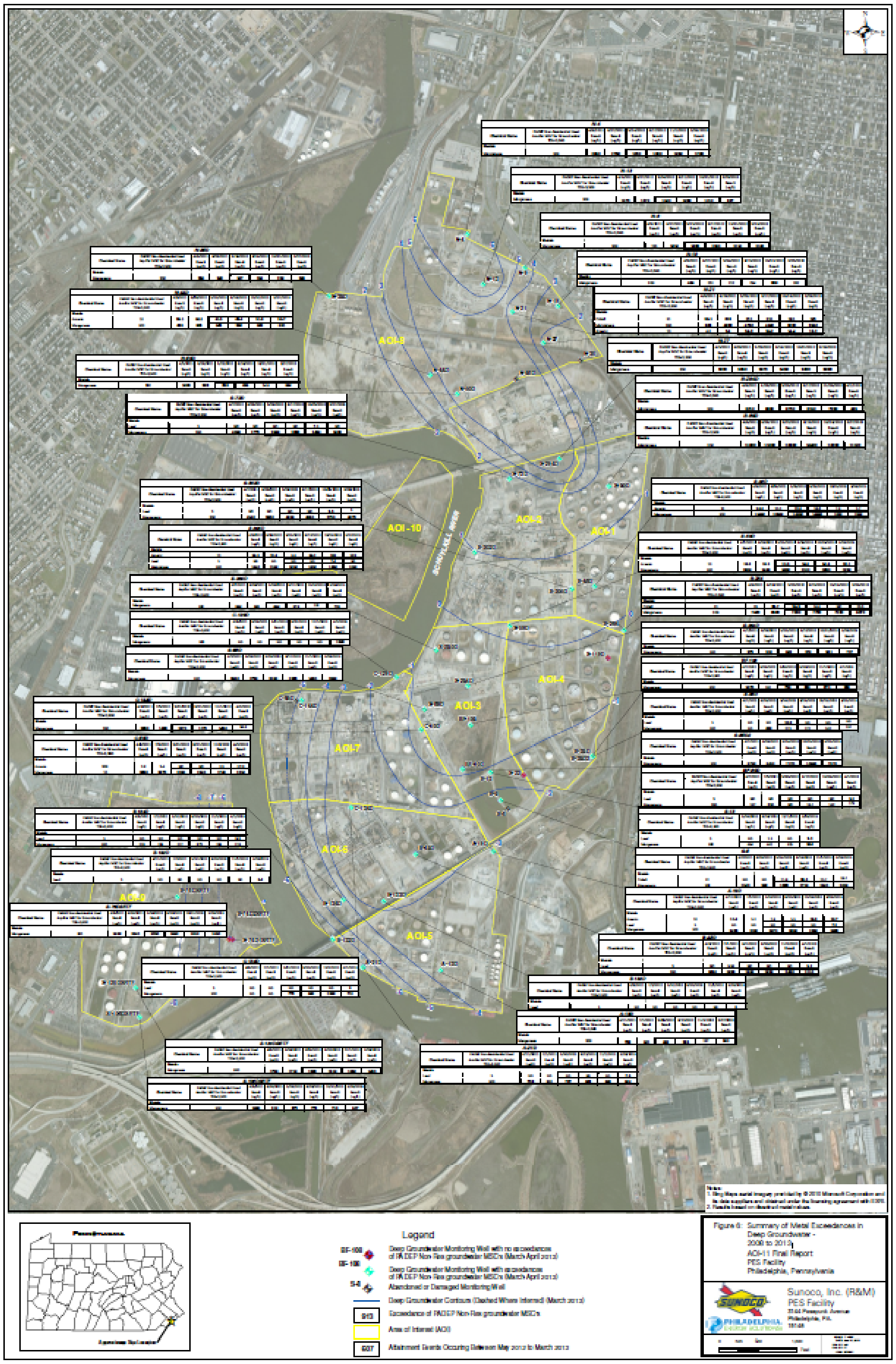
One would think that contamination is “significant” if the concentrations of contaminants are greater than a Medium-Specific Concentration for groundwater. That would make this contamination significant. If Evergreen is using another criterion to support its assertion regarding what is “significant,” it should explain what it means.

The 2013 reports also demonstrate contamination of the deep aquifer above medium-specific concentrations. *See* 2013 Report (AOI-13), Section 5.2, pages 14-18. The figure for organic chemicals shows a large number of exceedances:



See id., Figure 5 (Summary Volatile and Semi-Volatile Exceedances in Deep Groundwater -- 2008 to 2013); *see also id.*, Table 4 (Summary of Deep Groundwater Analytical Results - 2005 to 2011), Table 5 (Summary of Attainment Sampling Deep Groundwater Analytical Results 2012-2013), pdf pages 45-77, 84 of 85.

The figure for in organic chemicals shows an even larger number of exceedances:



See id., Figure 6 (Summary of Metal Exceedances in Deep Groundwater - 2008 to 2013); *see also id.*, Table 4 (Summary of Deep Groundwater Analytical Results - 2005 to 2011), Table 5 (Summary of Attainment Sampling Deep Groundwater Analytical Results 2012-2013), pdf pages 45-77, 85 of 85.

In its comments at the time it disapproved the report in 2013, the Department noted elevated levels of Volatile Organic Compounds:

> The AOI 11 conceptual site model (§8.0) does not address the cause(s) for the occurrence of hydrocarbons in the Lower Sand aquifer. ***If the Middle Clay is a barrier to vertical migration of contaminants, then why are there elevated VOC levels in many areas? For example, at wells S-22 (AOI 3) and N-21 (AOI 8) benzene and/or MTBE are consistently elevated***, but the Middle Clay is ~20′ thick at these locations.

See 2013 Comments (AOI-11), paragraph 1 (bold italics added for emphasis). In addition, the Department noted the existence of plumes that were not properly characterized:

> 12. ***Keep in mind that deep aquifer "plumes" were characterized with single, isolated wells***. Sunoco did not delineate sources with peripheral wells, so we don't know if the concentrations at the presumed "source" wells are really reflective of the source area. ***They could be hundreds of feet downgradient or side-gradient of the greatest contamination***.

See id., paragraph 12 (bold italics added for emphasis).

In addition, subsequent remedial investigation reports demonstrate contamination of the deep aquifer in a number of Areas of Interest:

Area of Interest	**Title**	**Evergreen's References to Exceedances in the Deep Aquifer**
AOI-1 Point Breeze No. 1 Tank Farm	2016 Report (approved)	Section 4.3, page 4.29 ("Concentrations of the following COCs were detected in lower aquifer groundwater above the SHS during the 2014 sampling events: benzene, MTBE, and lead. It is noted that the 2014 exceedances of the SHS for benzene were only observed in offsite wells ARCO-1D, S-399D, and S-394.")
AOI-2 Point Breeze Processing Area	2017 Report (approved)	Section 7.3, page 44 ("Prior to 2016, lead, 1,2,4-TMB, benzene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and naphthalene were the COCs in the lower aquifer groundwater that were detected above their respective PADEP non-residential groundwater MSCs.

		There were no detections of COCs in the lower aquifer above the respective PADEP non-residential MSCs during both the August and October 2016 groundwater sampling events.")
AOI 3 Point Breeze Impoundment Area	2017 Report (approved)	Section 5.4, page 32 ("Historically, lead, benzene, and MTBE are the only COCs that have been detected in the lower aquifer groundwater within monitoring wells in AOI 3 at concentrations exceeding their respective PADEP non-residential groundwater MSCs. EDB (also known as 1,2-dibromoethane) exceeded the PADEP non-residential groundwater MSC of 0.05 micrograms per liter (ug/l) at four of the seven lower aquifer wells sampled during the June 2015 event, with the highest detected concentration of 0.086 ug/l at monitoring well S-8. However, EDB (also known as 1,2-dibromoethane) was not detected in any of the six lower aquifer wells sampled, including monitoring well S-8, during the most-recent AOI 3 lower aquifer groundwater sampling event in December 2015.")
AOI-4 No. 4 Tank Farm	2013 Report (disapproved) 2017 Report (disapproved)	Section 5.3, pages 19-20 (only discussing samples for shallow aquifer) Section 10.5.2, page 10.64 ("Concentrations of the following COCs were detected above the SHS in lower aquifer groundwater during 2016 characterization sampling events (see Table 4-3): benzene, MTBE, and lead. Available historical analytical data from previous groundwater sampling events was reviewed by Stantec. That data indicates that no additional Evergreen Comprehensive List COCs were identified at concentrations in excess of the current SHS during past AOI 4 lower aquifer groundwater sampling; however, historical arsenic exceedances were noted.")
AOI-5 Girard Point South Tank Field	2011 Report/Cleanup Plan (disapproved)	Section 5.3, page 25 ("A MTBE concentration of 34 ug/L was detected in deep monitoring well A-19D located in the northern portion of AOI 5. No other COC concentrations above the PADEP nonresidential used aquifer (TDS<2,500) groundwater MSCs were

		detected in groundwater from monitoring well A-19D or the other two Lower Sand wells in AOI 5.”)
	2017 Report (approved)	Section 5.7, page 51 (“Lower aquifer groundwater in monitoring well A-19D historically exhibited concentrations of MTBE exceeding the respective PADEP non-residential groundwater MSC. No other COCs have historically been detected in the lower aquifer within AOI 5 above their respective PADEP non-residential groundwater MSCs.”)
AOI-6 Girard Point Chemicals Area	2013 Report (disapproved)	Section 5.3, pages 21-22 (only discussing samples for shallow aquifer)
	2017 Report (approved)	Section 9.3.2, page 36 (“None of the monitoring wells screened in the lower, semi-confined aquifer had exceedances of the non-residential groundwater MSCs.”)
AOI-7 Girard Point Fuels Area	2012 Report (disapproved)	Section 5.3, page 27 (“There were no COCs detected in deep monitoring wells at concentrations above their respective PADEP non-residential groundwater MSCs.”)
	2013 Addendum to Report (disapproved)	(only discussing samples for soil)
	2017 Report (approved)	Section 9.3.2, page 38 (“None of the monitoring wells screened in the lower, semi-confined aquifer had exceedances of the non-residential groundwater MSCs.”)
AOI-8 North Yard	2012 Report (approved)	Section 5.3, pages 25-26 (“Benzene was detected in three deep (Lower Sand) monitoring wells (N-9, N-21, N-44D) at concentrations slightly above its respective non-residential PADEP groundwater MSC. Toluene, MTBE, 1,2-dichoroethane, xylenes (total), cumene, ethylbenzene, ethylene dibromide, pyrene, phenanthrene, fluorene, naphthalene, and lead were not detected in deep

	2017 Report (approved)	groundwater in AOI 8 at concentrations above their respective PADEP non-residential groundwater MSCs." Section 9.4.2, page 9.63 ("Along with benzene, several SVOCs (benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, BEHP (also known as di(2-ethylhexyl) phthalate), phenanthrene, pyrene, and naphthalene), and metals (lead, manganese, arsenic, chromium, and cobalt) were detected above the respective SHS in certain lower aquifer wells (Table 4-3).")
AOI-9 Schuylkill River Tank Farm	2015 Report (disapproved) 2017 Report Addendum (approved)	Section 5.7, page 39 ("In 2009, MTBE was detected in the deep groundwater in monitoring wells at a concentration exceeding its respective PADEP non-residential groundwater MSC. …. During the baseline March 2015, August 2015, and November 2015 sampling events, benzene and MTBE were detected in deep groundwater and 1,2-dichloroethane was detected in newly installed well, S-110D SRTF, at concentrations exceeding their respective MSCs.") Section 4.3, page 18 ("In 2016, MTBE was the only site COC that was detected in the lower aquifer groundwater in two monitoring wells (S-118DSRTF and S-143SRTF) at concentrations exceeding its respective PADEP non-residential groundwater MSC.")
AOI-10 West Yard	2011 Report (approved)	Section 4.4, page 19 (only discussing results for shallow and intermediate wells)
AOI-11 Deep Aquifer Beneath Complex	2011 Report	Section 5.1, page 23 ("COCs at concentrations above their respective non-residential groundwater MSCs included: benzene, chrysene, methyl tertiary butyl ether (MTBE), naphthalene, arsenic, cobalt, and manganese.")

	2013 Report (disapproved)	Section 6.2, page 15 ("COCs detected at concentrations above their respective non-residential groundwater MSCs during the AOI 11 groundwater attainment sampling included: benzene, benzo(a)pyrene, benzo(G,H,I)perylene, methyl tertiary butyl ether (MTBE), 1,2,4 – trimethylbenzene, chrysene, naphthalene, lead, arsenic, cobalt, and manganese. Iron was detected over the SMCL.")

B. <u>Evergreen does not sufficiently address the concern for contamination potentially migrating to New Jersey</u>.

In its comments on the first report for AOI-11, the Department stated that Sunoco had not supported its assertion that the PRM aquifer system is not a pathway for exposure through a drinking water supply in New Jersey:

> 9. On Page 10 of the SCR/RIR, the following statement appears: "The PRM aquifer system no longer is used as a source of water supply in Philadelphia because of highly elevated concentrations of iron … etc." ***This statement is somewhat misleading since it is offered without any further information about water uses associated with this aquifer. DEP requests that the SCR/RIR also provide information to the effect that the PRM aquifer system is used as a source of water supply in New Jersey***. According to USGS's 2003 report, "Ground-water flow from areas of contamination in South Philadelphia to adjacent downgradient areas of New Jersey has the potential to affect supply wells drawing water from the lower aquifer of the PRM." (Sloto, 2003, page 35).

2011 Comments (AOI-11), paragraph 9 (bold italics added for emphasis).

The Department made a similar statement when it disapproved the report for AOI-11 in 2013:

> 21. ***The report did not address potential downgradient receptors of the Lower Sand aquifer contamination, particularly for inorganics.*** This was a concern in DEP's 9 Dec 2011 comments on the Sep 2011 RIR (item 9). The deep aquifer is a water supply for New Jersey. ***Sunoco proposes eliminating the groundwater exposure pathway in a 1-mile distance around the facility, but this would not include wells in New Jersey***.

2013 Comments (AOI-11), paragraph 21 (bold italics added for emphasis).

In fact, this was one of the deficiencies identified in disapproving the report;

> ***The evaluation of groundwater exposure pathways for potential human receptors was insufficient. Sunoco should examine an unidentified well downgradient of AOI 9 and water supply wells in New Jersey***. The receptor evaluation is required by Section 250.404(a).

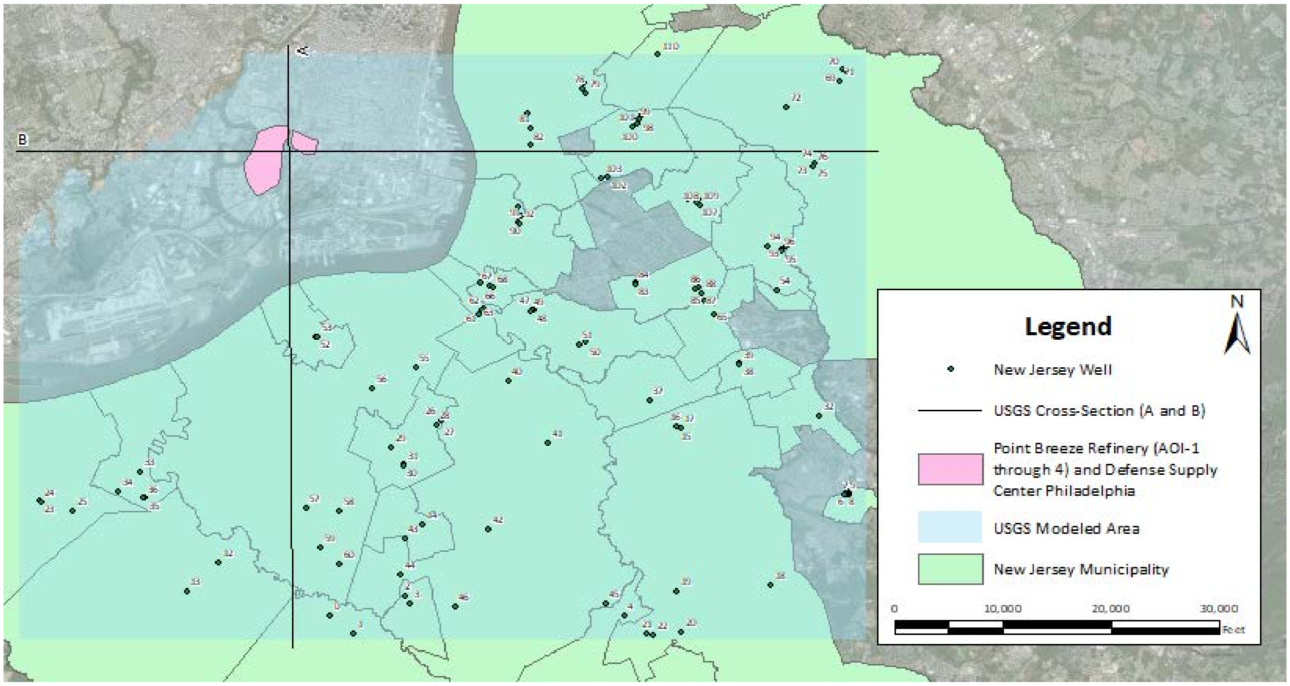
2013 Disapproval Letter (AOI-11), paragraph 2 (bold italics added for emphasis).

C. New Jersey's efforts to limit but not restrict withdrawals from the deep aquifer do not eliminate a pathway of contamination.

New Jersey continues to rely on the deep aquifer as a sole source supply. As of 2015, supply wells within the modeled study area in the 2001 USGS report were withdrawing approximately 4 billion gallons of water each year.

Created by the Council, the following Figure shows the New Jersey Potomac-Raritan-Magothy Aquifer supply wells used in the USGS model, in relation to the refinery site. The refinery site is colored in pink and is located to the west of the A cross-section and to the north and south of the B cross-section:

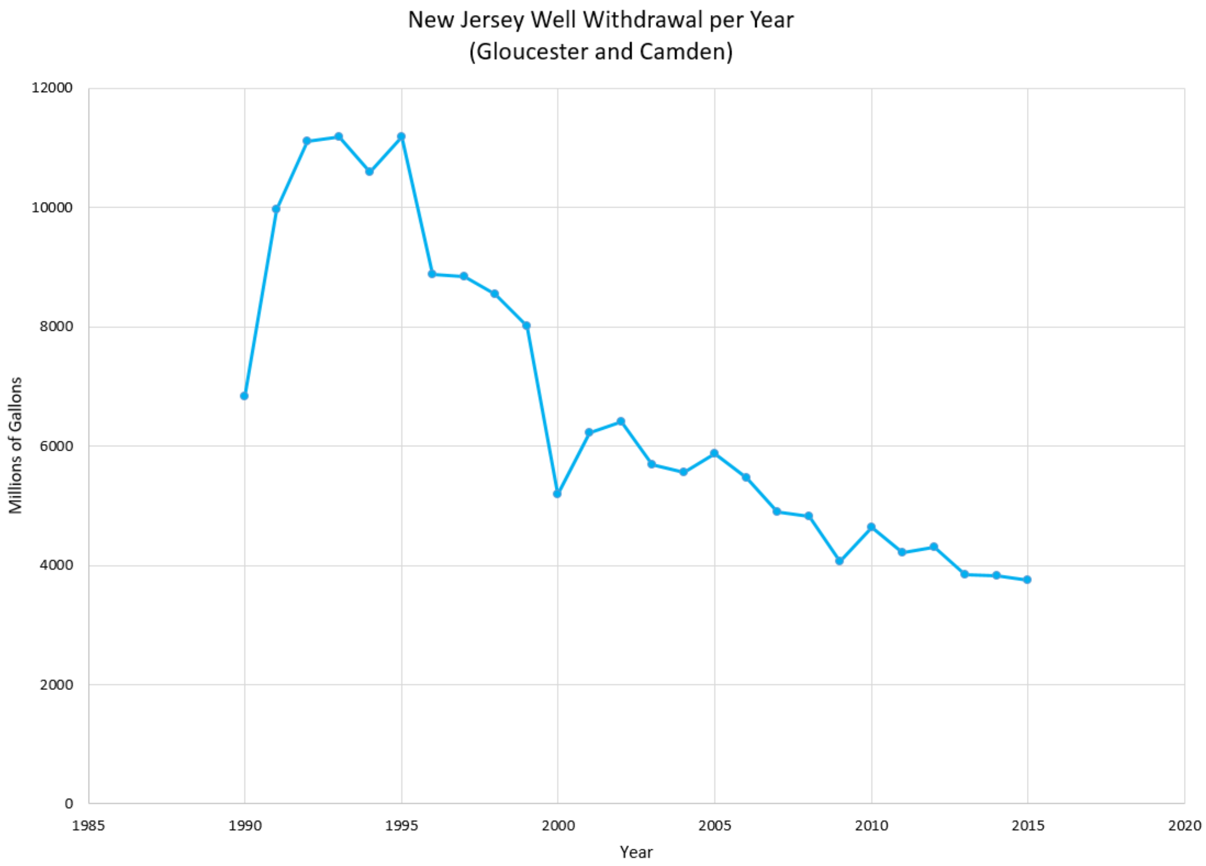
Modeled Wells in 2001 USGS Report
(prepared by Clean Air Council)



Source of data: [USGS Report 2001-4218]() (2001).

Created by the Council, the following Figure shows the amount of groundwater withdrawals from these supply wells, for the years 1990-2015:

Graph of Modeled Pumping Wells Withdrawal In 2001 USGS Report (prepared by Clean Air Council)



Source: USGS Report 2001-4218 (2001) and New Jersey Department of Environmental Protection Digital Geodata series DGS10-3, New Jersey Water Withdrawals.

The 2001 USGS report concluded that "the increased pumping in New Jersey maintained the downward vertical gradients." *See* USGS Report 2001-4218 (2001), page 22. This indicates a concern for the migration of contaminants to New Jersey.

There continues to be a risk of migration of contaminants by way of the deep aquifer to water supply wells in New Jersey, despite the fact that New Jersey has taken steps to decrease its reliance upon the deep aquifer for water supply. While the yearly withdrawal from Gloucester County and Camden County public supply wells declined from approximately 11,000 million gallons in 1995 to about 4,000 million gallons in 2015, that still is a significant level of withdrawal above the level of zero. *See* USGS 2001-4218 Report (2001), page 15; *see also* Graph of Modeled Pumping Wells Withdrawal In 2001 USGS Report (prepared by Clean Air Council, above).

The decrease appears to have resulted from the designation of Water Supply Critical Areas (N.J.A.C. 7:19-8) in two areas in the New Jersey Coastal Plain. The Department designated Water Supply Critical Area 2 to encompass all of Camden County and most of Gloucester County, as well as parts of other Counties. *See* N.J.A.C. 7:19-8.5(b), https://www.nj.gov/dep/rules/rules/njac7_19.pdf. It is the understanding of the Council that this program reduced groundwater withdrawals in areas of overdraft in conjunction with development of new surface water sources.

To support this initiative, the Tri-County Project is the primary water source to meet growing demands in the region. Major infrastructure improvements allowed the areas that previously solely relied upon the local PRM withdrawals to tap into this regional solution which is primarily a surface water source obtained from the Delaware River.

It is the understanding of the Council that Water Supply Critical Area 2 applies to the PRM aquifer system in parts of Ocean, Burlington, Camden, Gloucester and Atlantic Counties. Withdrawals are not prohibited from the PRM aquifer system in these counties, but are restricted. *See* N.J.A.C. 7:19-8.5, https://www.nj.gov/dep/rules/rules/njac7_19.pdf.

It is the Council's understanding that New Jersey has delineated well head protection areas for unconfined wells completed above the Potomac, but that this does not extend into Pennsylvania. *See* Spayd and Johnson, Guidelines for Delineation of Well Head Protection Areas in New Jersey (2003). To the extent that this report contemplates limiting wells tapping into the confined or deep aquifer, it only contemplates setting up a 50-foot wellhead protection area subject to a site-specific delineation based on the presence or absence and nature of intervening confining units. *See id.*, page 4. This does not suggest that the use of the confined aquifer in New Jersey is strictly prohibited.

While New Jersey maintains a database for water quality data, this is limited by the reporting by public supply wells in New Jersey, who are required to monitor and report water quality data quarterly. *See* NJ DEP, Drinking Water Watch. The presence or absence of an exceedance for a particular chemical in the raw water found in this database would not alone be dispositive of the question of a pathway between the refinery and the water supply in New Jersey.

D. The reports indicate the presence of a vertical pressure gradient, which Evergreen inappropriately attempts to avoid through the preparation of another remedial investigation report later in the year.

When Evergreen offers an analysis of "pressure gradients" in a future report, it admits that its analysis of the missing aquitard is deficient. *See* Comment 4 (relating to Evergreen's Q&A 19). It is not clear whether Evergreen's analysis of "pressure gradients" in a future report would involve new data or existing data. But at a minimum, Evergreen's analysis would be new because it is not located in the reports on which the public is now commenting.

In addition, available data in Evergreen's own reports indicates that there is a downward pressure gradient throughout most of the site:

Area of Interest	Title	Evergreen's References to Downward Gradients
AOI-1 Point Breeze No. 1 Tank Farm	2016 Report	Section 5.4, page 5.39 ("Overall, hydraulic head potentials range from approximately 5.5 feet to -2.5 feet."
AOI-2 Point Breeze Processing Area	2017 Report (approved)	Section 2.2.3, page 15 ("The observed head differences correspond to downward vertical hydraulic gradients ranging between 0.015 ft/ft to 0.051 ft/ft."
AOI 3 Point Breeze Impoundment Area	2017 Report (approved)	Appendix I, page I-5 ("The observed head differences correspond to downward vertical hydraulic gradients ranging between 0.005 to 0.05 feet/feet (ft/ft).")
AOI-4 No. 4 Tank Farm	2013 Report (disapproved)	Appendix F, Section F.5.3, page F-8 ("For these wells the hydraulic gradient (0.0035) measured in the southern portion of AOI 4 during the 2005 Site Characterization Report (SCR) was used for their QD simulations.")
	2017 Report (disapproved)	Section 10.2, page 10.59 ("Across most of the study area (including all well pairs in AOI 4), the hydraulic head potential between observed aquifers was positive (downward) in May 2016 (Figure 5-8)."
AOI-5 Girard Point South Tank Field	2011 Report/Cleanup Plan (disapproved)	Section 2.3.2, page 11 ("Groundwater elevations in A-13D, A-19D, and A-21D were lower than elevations observed in nearby shallow wells indicating a downward vertical gradient exists between the shallow and the deep monitoring wells.")
	2017 Report (approved)	Section 2.2.3, page 15 ("The observed head differences correspond to downward vertical hydraulic

		gradients of 0.082 and 0.16 ft/ft at the A-13 and A-21 monitoring well pairs, respectively.”)
AOI-6 Girard Point Chemicals Area	2013 Report (disapproved)	Section 2.2.1, page 8 (“Based on the December 2012 groundwater gauging event, the hydraulic gradient in the shallow/intermediate monitoring wells ranged from 0.003 near B-135 in the central portion of AOI 6 to 0.062 near B-169 in the western part of AOI 6 near the sheet pile wall”).
	2017 Report (approved)	Section 5.2.3, page 28 (“There is a downward gradient between the unconfined and lower aquifers. These gradients are consistent with previous data collected in AOI 6 (2013 RIR).”)
AOI-7 Girard Point Fuels Area	2012 Report (disapproved)	Section 2.3.2, page 13 (“Groundwater elevations in the deep zone are lower than the shallow/intermediate zone, exhibiting a downward vertical hydraulic gradient.”)
	2013 Addendum to Report (disapproved)	Section 9.2.3, page 37 (“There is a downward gradient between the unconfined and lower aquifers. These gradients are consistent with previous data collected in AOI 7 (2010 RIR and 2012 RIR).”)
	2017 Report (approved)	Section 5.2, page 30 (“It is also noted that hydraulic head potentials between the unconfined and lower aquifers are downward across AOI 7.”)
AOI-8 North Yard	2012 Report (approved)	Section 8.0 Site Conceptual Model, page 46 (“A downward vertical flow gradient exists between the shallow and deep zone as indicated by the groundwater elevations in the following monitoring well pairs: N-3/N-4, N-12/N-13, N-8/N-9, N-18/N-19, N-20/N-21, N-29/N-30, N-38/N-38D, N-43/N-44D, N-47/N-46D and N-51/N-50D. This is consistent with vertical gradients elsewhere in the refinery.”
	2017 Report (approved)	Section 5.4.1, page 5.44 (“The positive potentials in AOI 8 ranged from approximately 3 feet to 11 feet. Near-equal hydraulic heads are assumed to be present in the lower aquifer subcrop area, as exemplified by wells N-137 and N-4; however, separation of geologic

		units in the area is difficult using existing lithologic logs.”)
AOI-9 Schuylkill River Tank Farm	2015 Report (disapproved) 2017 Report Addendum (approved)	Section 2.2.3, page 14 (“As defined above, the deep aquifer is the Lower Sand which is a semi-confined to confined aquifer except where the clay aquitard is absent. Groundwater flow in the deep aquifer in the area where the Lower/Middle clay is absent is divergent due to gradual downward vertical groundwater migration through this area from the shallow aquifer. Following recharge from the shallow aquifer groundwater generally flows towards the southwest in the direction of regional flow patterns.”) Appendix I, page I-5 (“The head differences measured in October 2016 between paired monitoring wells in the unconfined and lower aquifer (S-74D2SRTF/S-7D1SRTF, S-118SRTF/S-118DSRTF S-137SRTF/S-138SRTF, and S-142SRTF/S-143SRTF) ranged between zero (S-118SRTF/S-118DSRTF) to 4.28 (S-74D2SRTF/S-74D1SRTF). The observed head differences correspond to a downward vertical hydraulic gradient of 0.067 feet per feet (ft/ft) near the potentiometric high point of the unconfined aquifer (S-74D2SRTF/S-74D1SRTF) and transition to an upward vertical hydraulic gradient of 0.016 ft/ft (S-142SRTF/S-143SRTF) near Mingo Creek basin. The upward vertical hydraulic gradients observed are most likely attributable to the artificial lowering of the unconfined aquifer potentiometric surface due to the pumping in Mingo Creek basin.”)
AOI-10 West Yard	2011 Report (approved)	Section 7.2, page 25 (“The vertical hydraulic gradient between the shallow and intermediate (Trenton Gravel) zones is downward at an average of 0.325 ft/ft”), but not addressing the gradient with respect to the deep aquifer)
AOI-11 Deep Aquifer Beneath Complex	2011 Report	Section 7.2, page 28 (“Downward vertical gradients exist between the shallow/intermediate and deep monitoring wells throughout the refinery with the exception of AOI 9 where deep groundwater flows vertically upward at the edges of the semi-confining clay.”)

	2013 Report (disapproved)	Section 8.2, page 25 ("Downward vertical gradients exist between the shallow/intermediate and deep monitoring wells throughout the facility with the exception of AOI 9 where deep groundwater flows vertically upward at the edges of the semi-confining clay.")

According to a report regarding a hydrogeologic reconnaissance of the Swope Oil Superfund site and vicinity in Camden and Burlington counties in New Jersey, the downward leakage of water through confining units are the primary sources of recharge to the confined lower aquifer:

> Induced recharge into the Potomac-Raritan-Magothy aquifer system from the Delaware River ***and downward leakage of water through confining units*** toward pumping centers in Camden County ***are the primary sources of recharge to the confined lower aquifer***.

USGS Report 89-402 (1990), page 1. The pressure gradients described by Evergreen across the AOIs supports the downward leakage as a primary source of recharge through the clay at the refinery site.

Evergreen should quantify the range of pressure gradients in the AOIs where those data are not specified in the table above. The predominantly downward vertical gradient is influenced in part due to the pumping of the NJ deep aquifer wells, but this variable is fairly constant site-wide.

The unconfined and semi-confined to confined deeper aquifer interactions are complex. Evidence of this complexity is shown in the pressure gradient values listed above, which suggest variable, heterogeneous and anisotropic subsurface conditions. Thus the presence or absence of and nature of the clay (whether it is lensed with sand, is silty, soft, muddy, hard, etc.) likely has a significant impact on the pressure gradients. Larger gradients may have greater propensity for vertical leakage of shallow groundwater contamination into deeper aquifers. Smaller gradients may have the opposite effect.

Evergreen should prepare an analysis of the vertical gradients by quantifying those gradients in all Areas of Interest, understanding the significance of the values and drawing relationships between the gradients and the nature of and extent and thickness of the clays.

Specifically for AOI-9, Evergreen maps a perching clay layer within the unconfined aquifer. In its analysis of vertical gradients, Evergreen should explore the impact of this perching clay layer. In its characterization of the vertical gradients in the table above, Evergreen does not reference or cite how the perching clay may impart influence on the gradients.

E. Evergreen fails to map the extent and thickness of the clay separating the unconfined and lower aquifer.

At the time of its disapproval of the report for AOI-11, the Department expressed a concern about the absence of the Middle Clay in AOI-9:

> 2. ***Why are there no downgradient property boundary wells at AOI 9 (i.e., along the western edge, see Fig. 5)?*** There are clearly potential storage tank and pipeline sources in the area between the existing deep monitoring wells and the property line. ***The Middle Clay is absent there***. Has Sunoco adequately determined conditions at the point of compliance?

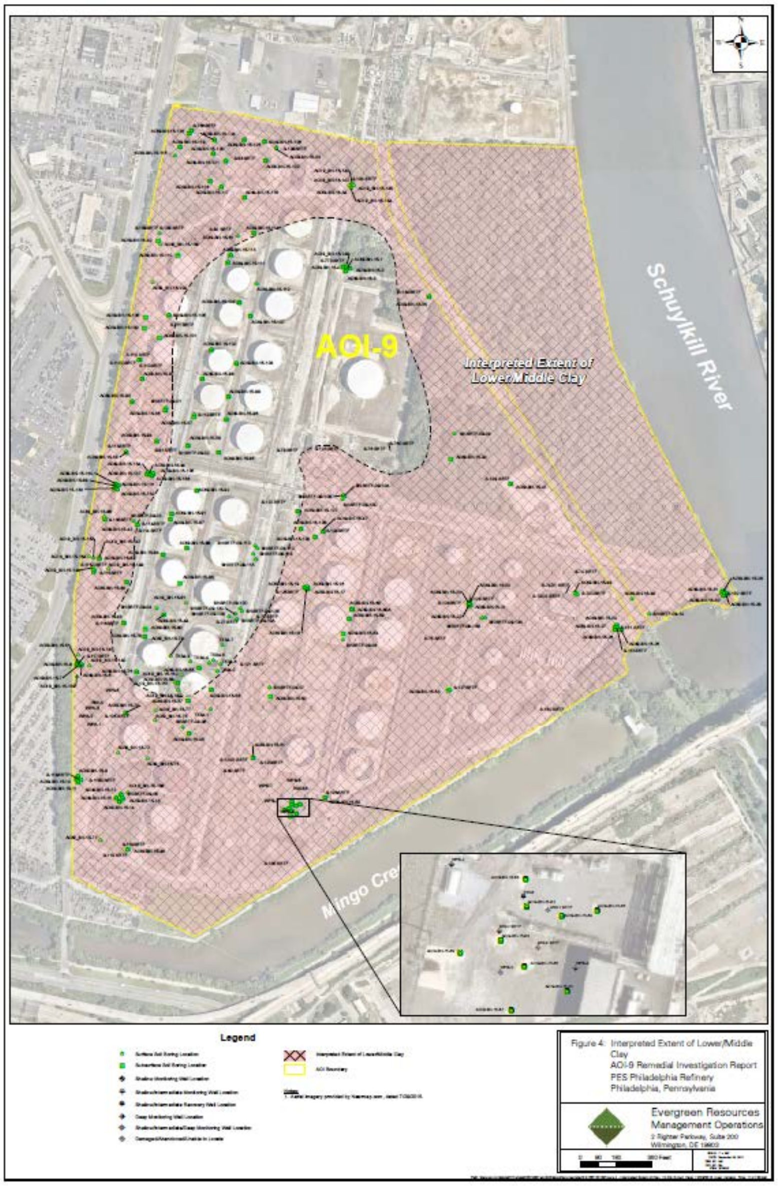
See 2013 Comments (AOI-11), paragraph 2 (bold italics added for emphasis).

As discussed above in the context of Evergreen's Q&A, Evergreen admits that its mapping of clay in the present reports is deficient, by offering to provide mapping of the middle clay unit aquitard in a future report. *See* Comment #4, above).

Evergreen fails to delineate the areal extent of the upper and middle/lower clay units. The unit is discontinuous across areas of the site. Where thick and present, this unit separates the unconfined shallow water table and deeper semi-confined and confined aquifer, and it may offer protection to the lower aquifer from shallow contaminants. The conceptual model does not map the continuity of this clay nor does it map areas of the site where it is thin to absent.

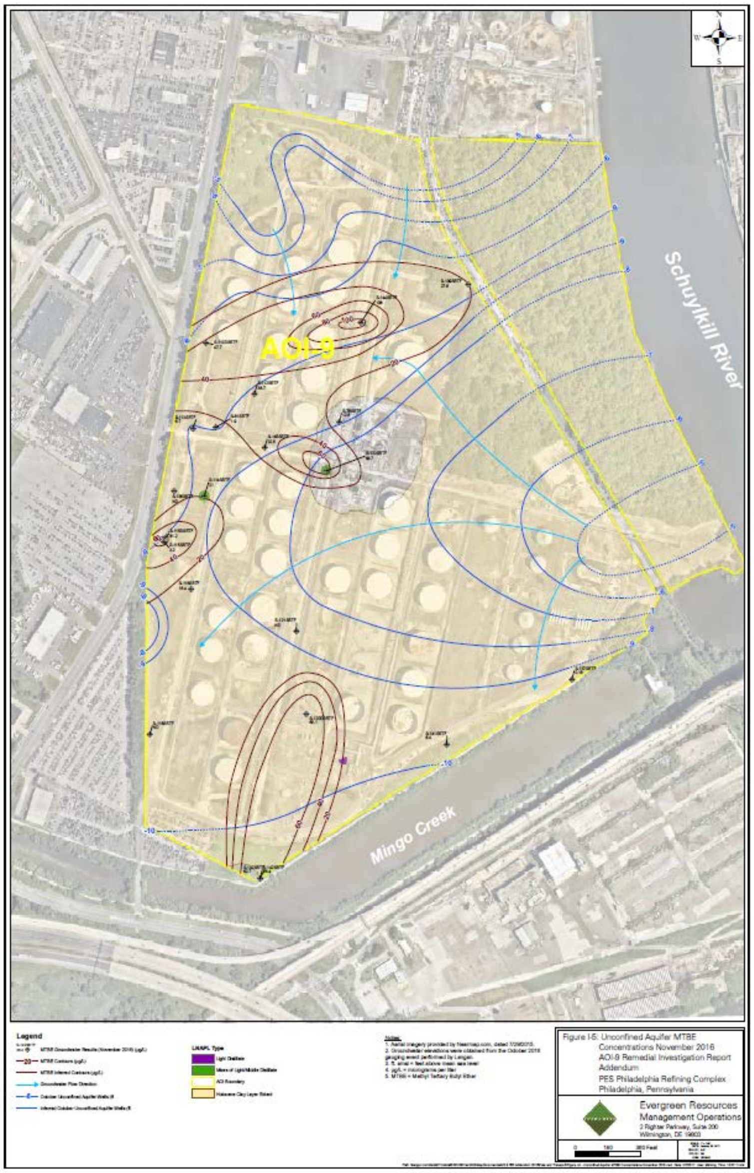
For example, for AOI-5 Evergreen asserts that the Lower/Middle Clay is believed to pinch out to the southeast in the direction of the confluence of the Schuylkill and Delaware Rivers. *See* 2017 Report, page 11. Cross sections provide more information. *See* 2017 Report, Figure 5a (Geologic Cross Section A-A') and Figure 5b (Geologic Cross Section B-B'). However, Evergreen fails to map the continuity of the clay and the areas where it is thin or absent.

Apparently in response to the Department's comment on the report for AOI-11, Evergreen has attempted to map the extent of a shallow (not deep) perching clay unit shown in AOI-9 reports:



See 2015 Report (AOI-9), Figure 4 (Interpreted Extent of Lower/Middle Clay); *see also id.*, Figures 4, 5, 7, 8, 9, 10.

Evergreen also did this in an addendum report for AOI-9:



2017 Report Addendum (AOI-9), Figure I-5 (Unconfined Aquifer MTBE Concentrations November 2016); *see also id.*, Figures I-2, I-3, I-4, I-5.

But Evergreen has not done this for the deep aquifer for AOI-9, and it has not done this for the other Areas of Interest. Evergreen should adopt a similar approach to mapping the extent of the clays for all Areas of Interest, for both shallow and deep units.

In its reports Evergreen fails to use isopach maps, which are a common technique for characterizing the nature of the geology at a site. Isopach maps can illustrate the extent of and thickness of intervening clay units. Where present and thick and uniformly clay, intervening clay units may protect the deeper aquifers from vertical leakage of shallow contaminated groundwater.

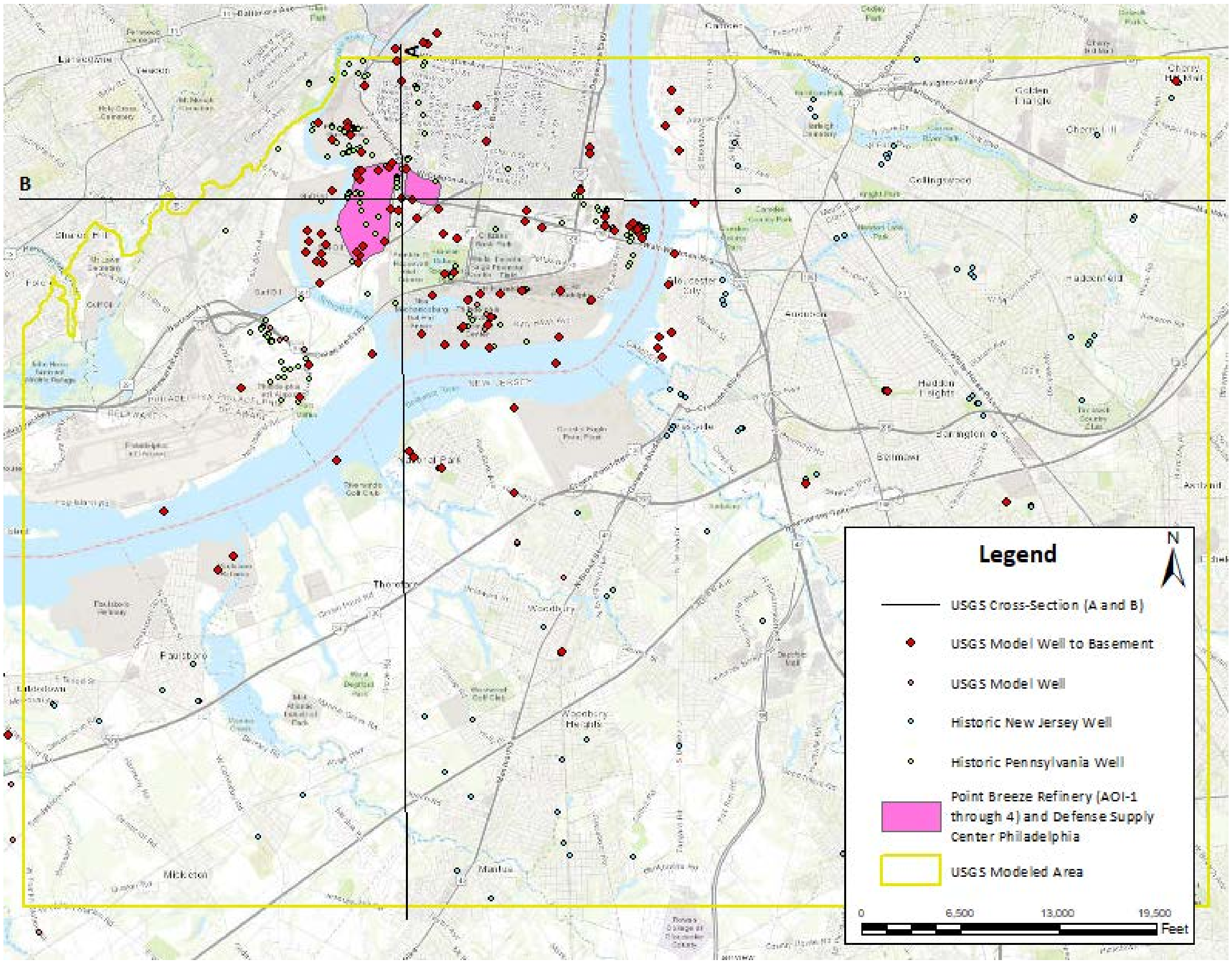
Conversely, in areas where the clay is absent, thin or non-uniform, the deeper aquifer may be less protected from vertical leakage of contaminated groundwater. Evergreen has included narrative and cross-section views to describe Areas of Interest where intervening clays may be present or absent.

Using the same example above, for AOI-5 Evergreen asserts that the Lower/Middle Clay is believed to pinch out to the southeast in the direction of the confluence of the Schuylkill and Delaware Rivers. *See e.g.* 2017 Report, Page 11. Cross section views provide more information *See e.g.* 2017 Report, Figure 5a (Geologic Cross Section A-A') and Figure 5b (Geologic Cross Section B-B'). However, Evergreen fails to present the information in planar or map view. The narrative and cross sections alone do not suffice or replace the need to characterize the clay spatially and vertically by also using isopach maps.

In contrast, the USGS has already developed a map of isopach clay thickness for the entire site, including AOI-1, AOI-2, AOI-3 and AOI-4. (In its own report, the USGS refers to these as the "Point Breeze Refinery"). The USGS actually uses some of the Evergreen wells in its analysis of geologic logs for borings extending to the basement rock. However, the USGS report pre-dates a number of the deep wells constructed at the refinery. Therefore, USGS has not integrated the whole of the refinery deep well logs and geologic data into its analysis.

Created by the Council, the following Figure shows a number of wells used by the USGS in its analysis, including many located on the refinery site:

Modeled Wells and
Cross-Sections A and B in 2001 USGS Report
(prepared by Clean Air Council)



Source of data: USGS Report 2001-4218 (2001), 10/22/2020 USGS email sharing the model archive summary for ancillary data used for this model.

From these data, the USGS has developed isopach thicknesses for the deeper clay units. Its isopach maps are an essential element of its conceptual model. The USGS sets them forth in the following three Figures:

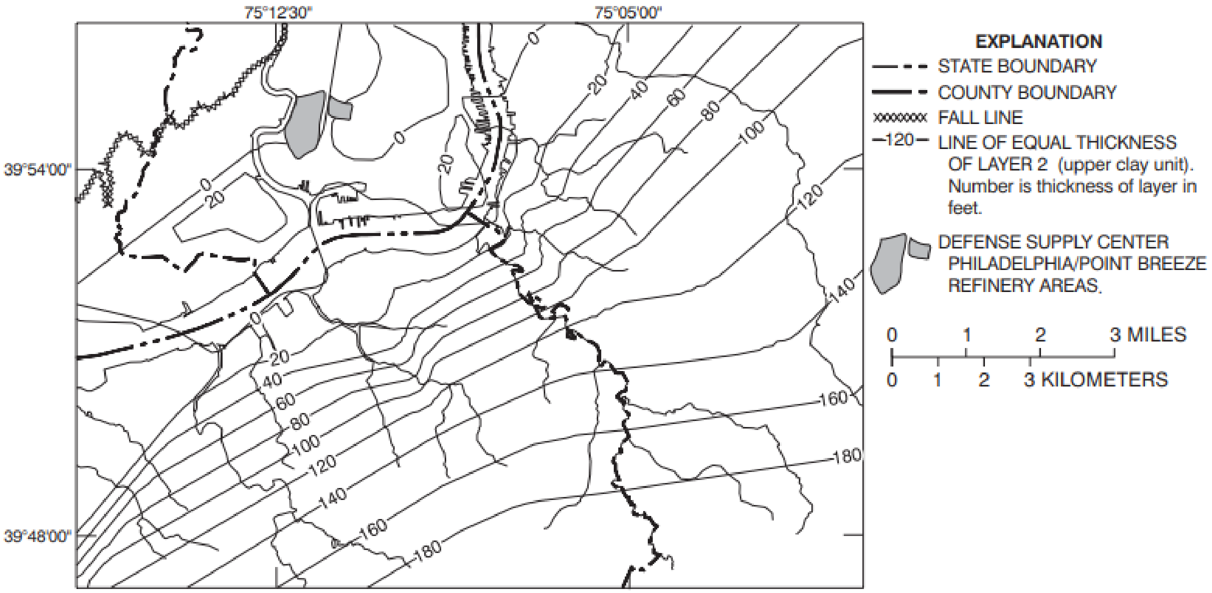


Figure 5. Thickness of the upper clay unit (model layer 2) of the Potomac-Raritan-Magothy aquifer system in the south Philadelphia area.

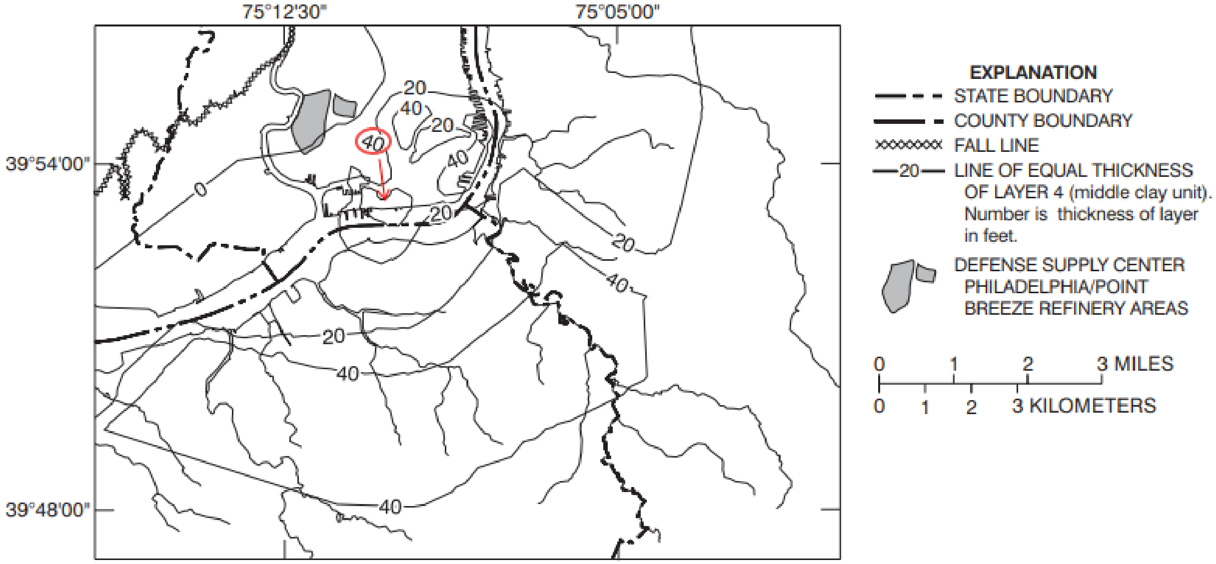


Figure 8. Thickness of the middle clay unit (model layer 4) of the Potomac-Raritan-Magothy aquifer system in the south Philadelphia area.

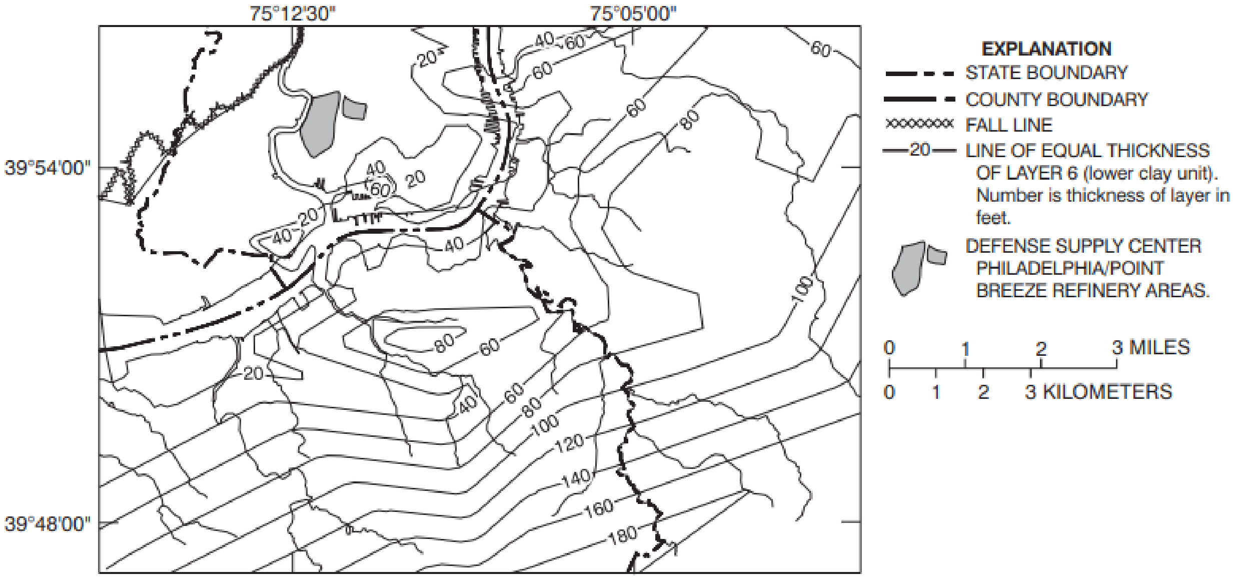


Figure 11. Thickness of the lower clay unit (model layer 6) of the Potomac-Raritan-Magothy aquifer system in the south Philadelphia area.

USGS Report 2001-4218 (2001), pages 8, 9, 11.

Evergreen did not prepare similar isopach maps for its reports. It should prepare similar maps to improve its conceptual model at the refinery site.

F. Evergreen has not established that the deep aquifer wells are properly located to sufficiently characterize the nature and extent of contamination.

While there are a number of deep wells throughout the site, it is not clear that they are all properly located and that the well network is reliable for delineating the nature and extent of contamination in the deep aquifer. The following comment addresses deep aquifer wells considered for the AOI-11 reports, subsequent remedial investigation reports for the different Areas of Interest, and the groundwater remediation status reports prepared up to 2020.

The Technical Guidance Manual underscores the importance of locating monitoring wells in areas of the property most likely to be impacted by contamination:

> B. Monitoring Well Types and Construction
>
> 3. Choice of Monitoring System
>
> Once ***the target zones, or areal locations and depths that are most likely to be impacted by the release are defined***, monitoring is often adequately accomplished by using ….wells that monitor the entire saturated thickness or a large portion of the target zone.

See Technical Guidance Manual, page A-7 (bold italics added for emphasis).

Locating wells in the deep aquifer is more challenging than locating wells in the unconfined aquifer:

> C. Locations and Depths of Monitoring Wells
>
> 5. Well Depths, Screen Lengths and Open Intervals
>
> Impacts to the aquifer under unconfined conditions are ***more easily evaluated than under confined or semi-confined conditions***…

See id., Technical Guidance Manual, page A-24 (bold italics added for emphasis).

The Technical Guidance Manual also underscores the importance of considering groundwater movement and the spatial distribution of contamination when establishing target zones for placement of monitoring wells:

> C. Locations and Depths of Monitoring Wells
>
> 4. Areal Placement of Wells
>
> For establishing the target zones, ***the remediator should consider the topics of groundwater movement and contaminant distribution…***.
>
> Even well-defined groundwater flow direction maps should be evaluated carefully ***when choosing the target zones for upgradient and downgradient wells.***

See id., Technical Guidance Manual, pages A-23 to A-24 (bold italics added for emphasis).

Moreover, it is important to evaluate a confined aquifer in combination with an unconfined aquifer:

> ***...Sites with confined aquifers that have potential to be impacted will need to be evaluated in combination with the unconfined aquifer***. Such a situation would require more detailed vertical and discrete zone monitoring

See id., Technical Guidance Manual, page A-25 (bold italics added for emphasis).

The existence of groundwater remediation status reports may help to evaluate the appropriateness of the deep well network, because they define target zones or areal locations most likely to be impacted by releases. *See* Groundwater Remediation Status Report (First Half 2020), Figure 3 (Apparent LNAPL Thickness Map).

As discussed above in Comment #7(A), the detection of contaminants of concern in the deep aquifer demonstrates that it not only has the potential to be impacted, but that it has been impacted. *See* 2013 Report, Figure 5 (Summary Volatile and Semi-Volatile Exceedances in Deep Groundwater 2008 to 2013). The presence of volatile or semi-volatile organic compounds that exceed the Medium-Specific Concentrations is apparent in approximately 30% or 13 of the 43 sampled wells across AOI-11. Because of the identified contamination in the deep aquifer, Evergreen should evaluate the deep aquifer in combination with the shallow unconfined aquifer.

In its comments on the report for AOI-11, the Department was critical of Evergreen's characterization of the deep aquifer:

> Keep in mind that deep aquifer "plumes" were characterized with single, isolated wells. ***Sunoco did not delineate sources with peripheral wells, so we don't know if the concentrations at the presumed "source" wells are really reflective of the source area***. They could be hundreds of feet downgradient or side-gradient of the greatest contamination.

See 2013 Comments (AOI-11), Comment 12, page 2. This underscores the importance of evaluating the existing well network.

Past site characterization has led to the implementation of remediation at ten currently active systems in AOI-1, AOI-2, AOI-4, AOI-7, and AOI-8. Based on a recent groundwater remediation status report, the ten remediation systems designated as "currently active" are listed in the table below, prepared by the Council. *See* Groundwater Remediation Status Report (First Half 2020, Figure 2 (Site Plan), page 13. The table summarizes the position of deep aquifer well(s) respective to these system boundaries, setting forth the separation distance (distance from remediation system boundary to well location), monitoring well system type (well clustered or not), and estimated percent of deep aquifer screened (the portion of the well through which water from the aquifer may flow). Fields left blank indicate that well information was either not available or not located.

Currently Active Remediation Systems and Deep Well Position

(Prepared by Clean Air Council)

Remediation System	**Deep Wells Under System**	**Well Cluster (Y/N)**	**Percent of Deep Aquifer Screened (Estimate)**	**Nearest Deep Wells Outside System (Estimate)**	**Well Cluster (Y/N)[4]**	**Percent of Deep Aquifer Screened (Estimate[5]**
AOI-1 (Belmont Terminal / Loading Rack Remediation System)[6]	None			S-80D (700ft S) S-294D (1100ft W) S-393D (150ft E)	N N Y	55% 30% 30%
AOI-1 (Shunk Street Sewer Ventilation System and Biofilter)	None			S-393D (<50ft W)	Y	30%
AOI-1 (26th Street North Remediation System)	None			S-871 (<100ft S) S-389D (100ft SW) S-388D (700ft S) S-390D (800ft SW) S-391D (1400ft W)	Y Y Y Y Y	 40% 30% 30% 25%

---

[4] A well cluster refers to at least one well screened in the unconfined aquifer and one well screened in the deep aquifer, that are in close proximity. This is based on Figures in the remedial investigation reports and the groundwater remediation status reports.

[5] Clean Air Council made these estimates based on a review of cross sections and geologic well logs provided in the appendixes to the reports. The Estimated Deep Aquifer Screen refers to the section of the well where groundwater flows from the aquifer into the well through perforations.

[6] This represents the Loading Rack System (the Frontage Road System is offline). *See* Groundwater Remediation Status Report (First Half 2020), page 2.

AOI-1 (26th Street and Packer Avenue Sewers Biofilter Remediation System)	None			S-388D (300ft N) S-46D (500ft W) S-264D (900ft S) ARCO-1D (800ft SE) S-392D (900ft SW) S-399 (900ft SW)	Y N Y Y Y Y	30% 70% 40% 30% 45% 0%
AOI-2 (Pollock Street Horizontal Well Remediation System)[7]	None			S-302D (100ft N) S-305D (100ft S) S-46D (300ft E) S-390D (700ft N) S-391D (1000ft N)	Y Y N Y Y	60% 55% 70% 30% 25%
AOI-4 (Penrose Avenue Remediation System)	S-38D S-38D2	Y Y	100%	S-22 (500ft W) S-218D (1000ft N) S-39D (1100ft N)	Y Y N	40% 40% 20%
AOI-4 (S-30 Remediation System)[8]	None			S-218D (400ft N) S-22 (500ft N) BF-108 (1100ft N)	Y Y N	40% 40% 5%
AOI-7 (Separator Remediation System)[9]	C-144D C-65D	N Y	90% 80%	C-129D (1400ft NW)	Y	50%
AOI-8 (PGW Border Remediation System)	N-46D N-50D N-148D	Y Y N	5%	N-149D (700ft W) N-33 (700ft N) N-27 (300ft N) N-44D (400ft NW) N-30 (300ft E)	Y N N Y Y	

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[7] The Pollock Street West End Remediation System has been turned off since 2016. *See id.*, page 3.

[8] The August presentation characterizes it as the "S-30 LNAPL Recovery System and the S-36 remediation system." *See* Evergreen, Act 2 Program Information Session (August 27 2020), page 47.

[9] The August presentation characterizes it as the "No. 3 Separator/Bulkhead Area." *See id.*

AOI-8 (Jackson Street Sewer Remediation System (Water Curtain)[10]	None			N-19 (200ft N) N-27 (300ft S) N-30 (300ft E) N-21 (600ft W)	Y N Y Y	
AOI-8 (Maiden Lane Remediation System)[11]	N-157 N-155	Y Y		N-9 (700ft E) N-4 (50ft N) N-13 (500ft S) N-21 (1100ft S)	Y Y Y Y	

Source: Groundwater Remediation Status Report (First Half 2020), 2013 Report (AOI-1), 2013 Report (part 2).

As indicated in the second column, there are no deep wells located under the area of the following active remediation systems: the four systems for AOI-1, the one system for AOI-2, one system for AOI-4, and one system for AOI-8. *See* Groundwater Remediation Status Report (June 2020), Figure 2 (Site Plan).

Moreover, at least 15 new deep wells have been installed since the time of the 2013 report for AOI-11. The data that are present in the groundwater remediation status reports do not establish that the deep aquifer well locations are sufficient to evaluate the nature and extent of the contamination in combination with the shallow aquifer. Those reports do not present a meaningful analysis regarding the appropriate location of the wells for purposes of the remedial investigation.

The movement of groundwater below the active remediation system boundaries should have been considered, but Evergreen has not explained or addressed it. While deep wells that are in or on the periphery of an active remediation system may help to characterize the nature and extent of contamination, the position (upgradient and downgradient) and presence or absence of clay layers separating the unconfined aquifer from the deep aquifer should be considered. Evergreen has not provided an explanation how it considered these groundwater movement details in placing deep monitoring wells.

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[10] The Jackson Street Sewer Remediation System is offline, and therefore inactive. *See* Groundwater Remediation Status Report (First Half 2020), page 2. But Figure 2 characterizes the water curtain as an active remediation system. *See id.*, Figure 2. *See id.*

[11] A new total fluids groundwater remediation system has been installed (Maiden Lane Remediation System) and is expected to be operational in the second half of 2020. *See* Groundwater Remediation Status Report (First Half 2020), page 7. *See id.*

If Evergreen had been limited in where it could access locations for installing deep wells when the site was operated as a refinery in the past, that concern is no longer prevalent following the shutdown of refinery operations.

Based on this analysis, Evergreen should develop a thorough analysis of the adequacy of the deep well network to delineate the nature and extent of contamination.

G. Evergreen does not explain why only some deep wells located inside the active remediation systems are sampled in the groundwater remediation status reports.

Another problem is that Evergreen is not sampling all the deep wells that it has installed, even in the course of the active remediation. Prepared by the Council, the table below summarizes the status of water quality sampling at the deep wells inside the currently active remediation systems discussed above. Although they are within the remediation system boundaries, the majority of them are not sampled or not available to be sampled. *See* Groundwater Remediation Status Report (Second Half 2019).

Water Quality Sampling Performed
For Deep Wells in Active Remediation Systems
(Prepared by Clean Air Council)

Remediation System	Deep Wells Under System	2016-2019 Groundwater Remediation Status Reports Water Quality Sampling Performed
AOI-1 (Belmont Terminal Remediation System)	None	N/A - No Deep Wells
AOI-1 (Shunk Street Sewer Ventilation System and Biofilter)	None	N/A - No Deep Wells
AOI-1 (26th Street North Remediation System)	None	N/A - No Deep Wells

AOI-1 (26th Street and Packer Avenue Sewers Biofilter Remediation System)	None	N/A - No Deep Wells
AOI-2 (Pollock Street Horizontal Well Remediation System)	None	N/A - No Deep Wells
AOI-4 (Penrose Avenue Remediation System)	S-38D S-38D2	Not Sampled Sampled
AOI-4 (S-30 Remediation System)	None	N/A - No Deep Wells
AOI-7 (Separator Remediation System)	C-65D	Not Sampled, well abandoned or damaged
AOI-8 (PGW Border Remediation System)	N-46D N-50D N-148D	Not Sampled, well abandoned or damaged Not Sampled Not Sampled
AOI-8 (Jackson Street Sewer Remediation System (Water Curtain)	None	N/A - No Deep Wells
AOI-8 (Maiden Lane Remediation System)	N-157 N-155	Sampled Not Sampled

Source: Groundwater Remediation Status Report (First Half 2020), Figure 3 (Apparent LNAPL Thickness Map), Groundwater Remediation Status Report (2nd Half 2019), Table 3 (October/November 2013 Groundwater Sampling Analytical Results), 2013 Report (AOI-11), Figure 5 (Summary Volatile and Semi-Volatile Exceedances in Deep Groundwater - 2008 to 2013), 2013 Report, Appendix C (Deep Soil Boring Logs and Monitoring Well Construction Summaries).

As demonstrated in the table above, the only deep wells under the active remediation systems that were sampled were the following wells: S-38D2 (AOI-4), N-157 (AOI-8). The other 6 wells under the active remediation systems were not sampled.

Evergreen does not provide an explanation why all these deep wells inside the remediation system are not sampled. For well N-46D in AOI-8 (PGW Border Remediation

System) Evergreen indicates that it is not sampled because it is abandoned or damaged. But there is no explanation why N-50D is not sampled. This is particularly important because there were exceedances for volatile organic compounds in this well in the 2013 report. *See* 2013 Report, Figure 5. In addition, N-148D was drilled and constructed sometime after the 2013 report was submitted, N-148D. But Evergreen has not sampled this well, and it has provided no explanation for this.

H. Evergreen has not constructed the deep aquifer wells to screen the entire saturated thickness to sufficiently characterize the nature and extent of contamination.

As noted in the table in Comment #7(F), the estimated deep aquifer screen is far less than 100% for most of the 23 deep aquifer levels for which we have actual construction information. (Clean Air Council made these estimates based on a review of cross sections and geologic well logs provided in the appendixes to the reports). The deep aquifer screen refers to the section of the well within the deep aquifer where groundwater flows into the well through perforations. This means that Evergreen is not necessarily characterizing the contamination for the full length of the well. Evergreen has not provided an explanation for this.

The Technical Guidance Manual underscores the importance of the depth and screen length of monitoring wells:

> C. Locations and Depths of Monitoring Wells
>
> 5. Well Depths, Screen Lengths and Open Interval
>
> Groundwater monitoring networks should ***monitor the entire saturated thickness of the target zone***, or a very large percentage of it. ***If large vertical intervals of the target zone are unmonitored, chances are dramatically increased that groundwater contamination may go undetected or be underestimated if detected.***

Technical Guidance Manual, page A-25 (Appendix A, Groundwater Monitoring Guidance) (bold italics added for emphasis).

Relying on deep wells with partially penetrating screen intervals (that is, where the deep aquifer screen is less than 100%) dramatically increases the risk of inadequate site characterization.

Evergreen has not offered an explanation as to why deep aquifer wells are partially penetrating, and it has not provided an analysis as to how the partially screened construction of deep wells impacts its characterization of the nature and extent of contamination.

I. Evergreen should provide an explanation for its failure to use well clustering for all deep wells under or near the active remediation systems.

As noted in connection with the Council's table in Comment #7(F), a well cluster refers to at least one well screened in the unconfined aquifer and one well screened in the deep aquifer, that are in close proximity. (Clean Air Council made determinations based on Figures in the remedial investigation reports and the groundwater remediation status reports). Approximately 25% of the wells identified in the table where construction information is available in Comment #7(F) are not clustered wells. This means that Evergreen is not necessarily characterizing the vertical stratification of contamination across the unconfined and deep aquifer. Evergreen has not provided an explanation for this.

The Technical Guidance Manual underscores the importance of the design of the monitoring wells using well clusters.

> Monitoring Well Types and Construction
>
> 3. Choice of Monitoring System
>
> Monitoring is often adequately accomplished by using….single-screened wells that monitor the entire saturated thickness or a large portion of the target zone.
>
> ***When contamination has been detected and definition of vertical contaminant stratification is desired***, ***wells that monitor more discrete intervals of the target zone, or individual aquifers, usually need to be constructed***. In this case, ***well clusters*** such as shown in Figure A-3 ***will often be the construction design of choice***.

Technical Guidance Manual, page A-7 (Appendix A, Groundwater Monitoring Guidance) (bold italics added for emphasis).

An objective of the monitoring system is to define the vertical contaminant stratification. The Technical Guidance Manual cites well cluster monitoring as a construction design of choice. Evergreen has not established that the non-clustered deep aquifer wells are of a sufficient design to characterize the nature and extent of contamination. Evergreen should provide an explanation as to why all the deep wells are not clustered.

J. Evergreen should provide a critical analysis of the reliability of its deep aquifer network and unconfined well network.

With respect to a deep well network, quality may be as important as quantity. While Evergreen reports the installation of 80 deep wells which have been installed and sampled over the years, there does not appear to be any analysis in the reports regarding whether the number and location of the wells is sufficient.

This is important because groundwater monitoring is a dynamic process. Data generated from successive sampling events provide an opportunity for evaluating the reliability of the network. Repeat sampling of the existing deep well network only provides additional data from the same perspective, but does not address whether that perspective is appropriate. Evergreen should provide a more complete analysis of the reliability of the network.

The Technical Guidance Manual underscores the importance of a reliable deep aquifer network, based on locations and depths of wells:

> C. Locations and Depths of Monitoring Wells
>
> 1. Importance
>
> ***The locations and depths of monitoring wells are the most important aspects of a groundwater monitoring network. A monitoring point that is misplaced***, or not constructed properly to monitor constituents with unique physical characteristics, ***is of little use and may misrepresent the quality of the groundwater migrating to or from a site***. On the other hand, a properly positioned and constructed monitoring well that detects the earliest occurrence of contamination could save both time and money spent on cleanup of a site. It is important to note that the placement and construction of a groundwater monitoring network at an Act 2 site shall be conducted by a professional geologist licensed in Pennsylvania (25 Pa. Code §§ 250.204(a), 250.312(a), and 250.408(a)).

See id., *See id.*, Technical Guidance Manual, page A-15 (Appendix A, Groundwater Monitoring Guidance) (bold italics added for emphasis).

In the report for AOI-11, the analytical data for the deep aquifer are over seven years old. *See* 2013 Report (AOI-11), Tables 4 and 5. While data from subsequent sampling events were apparently included in reports for individual Areas of Interest (as well as in the groundwater remediation status reports), those reports do not provide a meaningful analysis whether the number and location of deep aquifer wells is sufficient for the remedial investigation. *See* Evergreen, Semiannual Remediation Status Reports; *see also* Evergreen, Act 2 Documents.

The lack of approved reports for AOI-4 and AOI-9 contributes to the concern for deep aquifer network. *See* 2014 Disapproval Letter (AOI-4), 2016 Disapproval Letter (AOI-9). In order to characterize deep aquifer contaminants of concern, it is important to have a reliable understanding and characterization of shallow aquifer contaminant sources, which may be linked to the deep aquifer.

Evergreen should provide a critical analysis of the reliability of its deep aquifer network. It should also do the same thing for its unconfined well network.

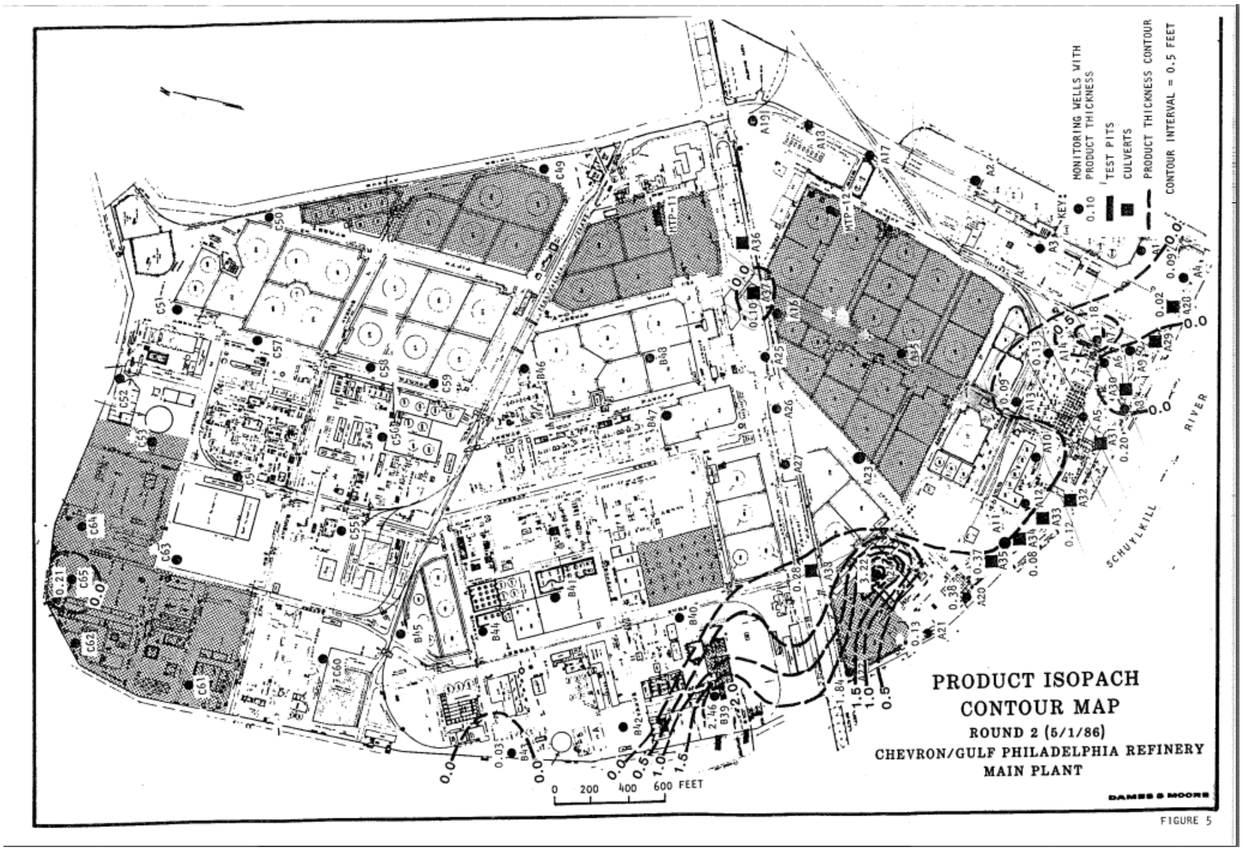
K. Evergreen should prepare isopach contour maps and synthesize the LNAPL analysis with deep aquifer monitoring data.

Evergreen presents the shallow aquifer free product thickness data separately from the deep aquifer groundwater monitoring data. *See e.g.*, 2016 Report (AOI-1), Figure 6-1 (Summary of Available LNAPL Sample Data – AOI 1 and Belmont Terminal), Figure 6-2 (May and Vicinity), Figure 10-6 (Historic Groundwater Analytical Results -- Deep Aquifer), Appendix E (LNAPL Conceptual Site Model), pdf pages 114, 115, 123 of 261. This makes it difficult to characterize the nature and extent of the contamination. Evergreen has not synthesized these data to evaluate whether contaminants are migrating from the LNAPL vertically into the deeper aquifer.

In the reports, Evergreen attempts to delineate the extent of Light Non-Aqueous Phase Liquids (also known as free products) floating on the surface of the shallow water table. As discussed above in Comment #6, the groundwater remediation status reports also map the apparent thicknesses of these liquids for a given shallow well location. But these reports do not analyze the extent of the free product in combination with the deep aquifer groundwater.

Also, Evergreen does not use isopach thickness maps. Isopach thickness maps are an important tool to characterize the extent of free product or LNAPL. Maps representing the thickness of liquids can provide important information regarding the nature and extent of the contamination. It is from these liquids that contaminants dissolve into groundwater and then spread laterally and/or vertically into the shallow and deep aquifers.

To illustrate, there is an isopach map in a historic report characterizing AOI-5, AOI-6 and AOI-7 from 1986, that the Council found deep in the documents:



See Phase I Final Progress Report, Figure 5 (Product Isopach Contour Map) (May 23, 1986), pdf page 19 of 39. The three sections in the Figure above correspond to AOI-7, AOI-6, and AOI-5 today.

This isopach map from 1986 is different from Evergreen's thickness maps because the latter only show distinct well points and identify the measured depth of the LNAPL. In contrast, the 1986 map delineates contour lines of equal thickness, characterizing an area of LNAPL.

Evergreen should expand upon the information and analysis set forth in its LNAPL thickness maps by adopting a similar approach. *See* Groundwater Remediation Status Report (First Half 2020), Figure 3.

In addition, Evergreen should update the data and map on water quality exceedances in the deep aquifer (*See* 2013 Report (AOI-11), Figure 5 (Summary of Volatile and Semi-Volatile Exceedances in Deep Groundwater – 2008 to 2013), and present and map those data along with the isopach contours and groundwater flow.

This exercise can help to evaluate the adequacy of the deep monitoring well network. Absent this analysis and mapping, the public cannot tell whether the deep aquifer wells are appropriately placed and adequate to characterize the nature and extent of the contamination.

L. Evergreen has inappropriately used detection limits that exceed relevant Medium-Specific Concentrations.

In a number of instances, the laboratory instrumentation used by Evergreen was not sufficient to gather reliable data on contaminants at concentrations necessary for making comparisons with Act 2 numeric values. The regulations require adherence to data quality standards set by EPA:

> Attainment of a standard shall be demonstrated with adherence to Data Quality Objective (DQO) and Data Quality Assessment (DQA) processes as specified by EPA.

See 25 Pa. Code § 250.702 (Attainment requirements).

In a guidance document, EPA states that a more sensitive method should be used if a method detection limit exceeds an action level:

> ***If the detection limit for a measurement method exceeds or is very close to the Action Level, then a more sensitive method should be specified*** or a different analytical approach should be used.

See EPA Guidance on Systematic Planning Using DQO (February 2006), page 41 (bold italics added for emphasis).

Where laboratory detection limits (which determine the ability of a laboratory to detect contaminants at threshold levels) are greater than a cleanup standard, one cannot reliably tell whether a cleanup level is met or not. To adequately characterize contaminants in groundwater, the laboratory detection limits appropriately need to be equal to or less than Medium-Specific Concentrations. Evergreen should address the data gaps arising from this problem.

To illustrate, for chrysene in the AOI-11, laboratory detection limits for chrysene were sometimes 5 ug/L or 10 ug/L, which are two to five times higher than the Medium-Specific Concentration of 1.9 ug/L. *See* 2013 Report (AOI-11), pdf pages 45-59, Table 4 (Summary of Deep Groundwater Analytical Results 2005-2011). In addition, laboratory detection limits exceeded the Medium-Specific Concentration for Benzo(A)Pyrene, Benzo(B)Fluoranthene, and Benzo(G,H,I)Perylene. *See id.*, pages 61- 77, Table 5 (Summary of Attainment Sampling Deep Groundwater Analytical Results 2012-2013).

In the case of the unconfined aquifer for AOI-5, a similar thing apparently happened for 1,2-dibromoethane (EDB). *See* 2017 Report (AOI-5), Table 7 (Summary of Groundwater Analytical Results), pdf pages 170-220 (setting forth laboratory detection limits as high as 0.5 mg/L, one order of magnitude higher than the Medium-Specific Concentration of 0.05 mg/L.

Similar anomalies may have occurred for other chemicals and other reports. Why certain sampling events and wells were subject to unreliable detection limits is unclear.

Evergreen should have used instrumentation with detection limits sufficient to allow the sampling to be meaningful.

Evergreen should address this explicitly in the narrative text of the reports, and it should conduct additional sampling to cure any unreliable data that have resulted from these anomalies.

8. Evergreen Fails to Properly Delineate the Contamination of Arsenic, Manganese, and Other Inorganics (Metals) in the Unconfined Aquifer and the Deep Aquifer.

Earlier in the course of this investigation, Evergreen was sampling for a wider array of inorganic chemicals (metals) than at present. There does not appear to be any explanation for why these chemicals were once sampled but are no longer sampled. Arsenic and manganese are two of the more notable metals, but there are others as well. Evergreen should provide a detailed explanation for why and how it has adopted this approach.

A. Evergreen's Q&A regarding the failure to sample for multiple metals is flawed.

In response to a recent question why Evergreen is focusing on lead to the exclusion of other metals, Evergreen asserts that this was decided by a 1992 RCRA Facility Investigation report, which is posted on its website:

> [New Q&A posted after December 30, 2020]
>
> ***Why is lead the only metals COC? Aren't there other contaminants such as copper, cadmium, arsenic that come from refining processes?***
>
> ***The site was tested for a complete list of metals as part of the 1992 RCRA Facility Investigation and none of these metals, except lead, were found to be a contaminant of concern and therefore were not identified as a contaminant of concern going forward. The 1992 Report is posted on the Evergreen website for reference.***
>
> However, both soil and groundwater samples from various areas of the facility with history of crude storage and processing have been sampled for a more comprehensive analyte list which included other metals as part of the remedial investigation activities. These data have all been included in the RIRs.
>
> Note: this response addresses other similar questions:
>
> The refinery was historically coal-fired. Where and how has the site been tested for Arsenic?
>
> Should other heavy metals be expected to be found given the history of heavy industrial use?
>
> .

See Evergreen, Q & A (bold italics added for emphasis). Presumably, Evergreen is referring to this report from 1992 in the historical reports section of its website: 1992 Results of a RCRA

Facility Investigation (ENSR, September 1992). Whether Sunoco considered something a contaminant of concern in 1992 is not dispositive as to the present remedial investigation, which is governed by a consent order executed in 2012 -- two decades later. That consent order does not exclude metals other than lead as Constituents of Concern .

In fact, the legal agreements do not identify Constituents of Concern. *See* 2003 Consent Order and Agreement (DEP Agreement); *see also* 2012 Consent Order and Agreement (DEP Agreement); *see also* 2012 Settlement Agreement and Covenant Not to Sue (EPA Agreement); *see also* 2020 First Amendment to Consent Order and Agreement (DEP Agreement). Rather, Evergreen proposed Constituents of Concern by including them in tables attached to reports that it submitted to the Department.

In addition, Evergreen's answer is contradicted by the fact that Sunoco did conduct sampling arsenic and manganese (and other metals), long after the 1992 report.

B. Over the course of time, Sunoco and Evergreen have pared down the focus of the remedial investigation for inorganics (metals) in groundwater.

When Evergreen prepared the reports for AOI-11, it identified arsenic and manganese (as well as several other metals) as Constituents of Concern with respect to the investigation of the deep aquifer. *See* 2011 Report (AOI-11), Table 1 (identifying arsenic, cobalt, iron, lead, and manganese), pdf pages 43-44 of 76; *see also* 2013 Report (AOI-11), Table 1 (identifying arsenic, cobalt, iron, lead, manganese, and mercury), pdf page 42 of 85. For arsenic and manganese, the form was "Total & Dissolved." *See id.*

But arsenic and manganese disappear as Constituents of Concern for the deep aquifer in subsequent reports, despite the fact that it was Evergreen's intent to shift its evaluation of the deep aquifer from the AOI-11 reports to the other reports:

Area of Interest	**Report**	**Comment:** **Metals As Constituents of Concern**
AOI-1 Point Breeze No. 1 Tank Farm	2016 Report (AOI-1), Table 1-1	(only metal identified is lead)
AOI-2 Point Breeze Processing Area	2017 Report (AOI-2), Table 1	(only metal identified is lead)
AOI 3	2017 Report (AOI-3), Table 2	(only metal identified is lead)

Point Breeze Impoundment Area		
AOI-4 No. 4 Tank Farm	2013 Report (AOI-4), Table 2 2017 Report (AOI-4), Table 1-1 Table 1-2	(only metal identified is lead) (only metal identified on Petroleum Short List is lead) (identifying cobalt, lead, nickel, vanadium, and zinc on Comprehensive List)
AOI-5 Girard Point South Tank Field	2011 Report/Cleanup Plan (AOI-5), Table 1 2017 Report (AOI-5), Table 1	(only metal identified is lead, for tables for soil and groundwater) (only metal identified is lead)
AOI-6 Girard Point Chemicals Area	2013 Report (AOI-6), Table 1 2017 Report (AOI-6), Table 1	(only metal identified is lead) (only metal identified is lead)
AOI-7 Girard Point Fuels Area	2012 Report (AOI-7), Table 1 2013 Addendum to Report 2017 Report (AOI-7), Table 1	(only metal identified is lead, for tables for both soil and groundwater) (not providing a table) (only metal identified is lead)
AOI-8 North Yard	2012 Report (AOI-8), Table 1 2017 Report (AOI-8), Table 1-2 Table 1-2	(only metal identified is lead, for both soil and groundwater) (only metal identified on Petroleum Short List is lead) (identifying cobalt, lead, nickel, vanadium, and zinc on Comprehensive List)
AOI-9	2015 Report (AOI-9), Table 1	(only metal identified is lead)

Schuylkill River Tank Farm	2017 Report Addendum (AOI-9), Table 1	(only metal identified is lead)
AOI-10 West Yard	2011 Report (AOI-10), Table 1a and 1b	(only metal identified is lead, for tables for both soil and groundwater)[12]

In addition, the table above shows an inconsistency in Evergreen's inclusion of some metals as Constituents of Concern for some Areas of Interest (AOI-4 and AOI-8), but not for others (cobalt, nickel, vanadium, and zinc). Evergreen should substantiate this inconsistency.

Evergreen should provide a detailed explanation for why and how it has arrived at its approach for identifying Constituents of Concern for sampling for metals in the deep aquifer.

C. Evergreen should revise the reports to include arsenic as a Constituent of Concern for all Areas of Interest, because this metal is associated with contamination at former refineries.

There are several reasons why Evergreen should be including arsenic as a Constituent of Concern during this remedial investigation. Arsenic can be a problem for refineries even if it is naturally occurring in the environment (if its "background") and not caused by a release of hazardous substances. The "natural attenuation" of hydrocarbon releases at a refinery may have the undesirable effect of mobilizing arsenic and causing it to disperse in groundwater. USGS, Natural Breakdown of Petroleum Results in Arsenic Mobilization in Groundwater, USGS GeoHealth Newsletter, Vol. 12, No. 1 (2015).

Of course, if there has been a direct release of arsenic from refinery operations, that would present another concern for the migration of arsenic in groundwater. In the case of the refinery, there appears to be such a concern, based on a report identifying a number of exceedances for arsenic in soils in AOI-10. *See* 2011 Report (AOI-10), 17, 18, 20, 25, 26, 27, 31, 32, 36, 37, Table 5 (Summary of Shallow Soil Sample Analytical Results for CAMU Delineation Samples), Table 6 (Summary of Shallow Soil Sample Analytical Results: CAMU Area Soil Samples), Table 7 (Summary of Analytical Results for Waste in CAMU Areas), Table 8 (Summary of Soil Sample Analytical Results for Vertical Delineation Soil Samples Beneath Waste in CAMU), pdf pages 63-89 of 762. From the report, it is not clear what was the source of the arsenic.

Evergreen should provide a complete explanation regarding the source of the arsenic -- whether it relates to an anthropogenic source or a background source. Evergreen should explain why it did not conduct similar sampling for all Areas of Interest.

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[12] In contrast to the approach to the deep aquifer, Evergreen does identify arsenic and manganese (as well as other metals) as Constituents of Concern for surface water and sediments. *See id.*, Table 1c, 1d.

D. Evergreen should revise the reports to address whether the widespread manganese contamination in the deep aquifer is truly attributable to "background levels" and not the legal responsibility of Sunoco.

In 2011, Evergreen identified manganese as a Constituent of Concern for the investigation of the deep aquifer:

> For AOI 11, four additional metals (arsenic, cobalt, iron and ***manganese***) and wet chemistry parameters including ammonia, chloride, fluoride, nitrate, nitrite, sulfate, alkalinity, total organic carbon (TOC), and total dissolved solids (TDS) ***were added to the COC list to further characterize deep groundwater at the site in accordance with the CO&A***.

See 2011 Report (AOI-11), Section 1.2, page 2 (bold italics added for emphasis). It also made the following observation about the highly elevated levels of manganese in the aquifer:

> ***The PRM aquifer system no longer is used as a source of water supply in Philadelphia because of highly elevated concentrations of*** iron (as high as 429,000 ug/L), ***manganese (as high as 4,000 ug/L),*** and sulfate (as high as 1,720,000 ug/L) ***that have contaminated the aquifer in south Philadelphia*** and have made the ground water unusable for most purposes (Sloto, 2003).

See id., Section 2.3, page 10 (bold italics added for emphasis). The problem was also local to the refinery:

> ***The 1994 ENSR investigation of the shallow and deep groundwater quality of the refinery noted that there were elevated levels of iron and manganese in the Farrington Sand Aquifer*** and that the results were consistent with those found by the USGS's regional report released in 1991.

See id., Section 2.3, page 13 (bold italics added for emphasis).

Evergreen found concentrations above the Medium-Specific Concentrations for manganese. *See id.*, Section 5.1, page 23; see also id., Table 5 (April 2011 Summary of Deep Groundwater Analytical Results), Table 6 (June-July 2011 Summary of Deep Groundwater Analytical Results), Figure 6 (Summary Metal Exceedances in Deep Groundwater, April/June-July 2011), pdf pages 51-68, 71 of 75.

In fact, there were exceedances in 33 of the 45 deep aquifer wells:

> ***A total of 33 deep monitoring wells exhibited concentrations of groundwater COCs above their respective MSCs for manganese***.

> The highest manganese detections were observed along the central and eastern portions of AOI 1.

See id., Section 5.1, page 24 (bold italics added for emphasis).

The 2013 report tells a similar story. *See* 2013 Report (AOI-11), Section 2.0, page 3, Section 3.4, page 7, Section 3.4.1, page 8, Section 4.0, page 11, Section 5.2, page 15, Section 5.2, page 16, 17, 18, Section 8.3, page 25, Section 8.4, page 26, Section 9.1, page 29, Section 12.0, page 30, Table 4 (Summary of Deep Groundwater Analytical Results 2005 to 2011), Table 5 (Summary of Attainment Sampling Deep Groundwater Analytical Results 2012 - 2013), Table 6 (Regional Wide Groundwater Chemistry), Figure 6 (Summary of Metal Exceedances in Deep Groundwater 2008 to 2013), pdf pages 45-78, 85 of 75.

Evergreen should bring sampling in 2011 and 2013 up to date, and it should delineate Sunoco's contribution to the problem of manganese in the deep aquifer.

9. Evergreen Fails to Demonstrate that the Sheet Pile Wall and Bulkhead Provide Sufficient Protection Against the Migration of Contamination to the Schuylkill River.

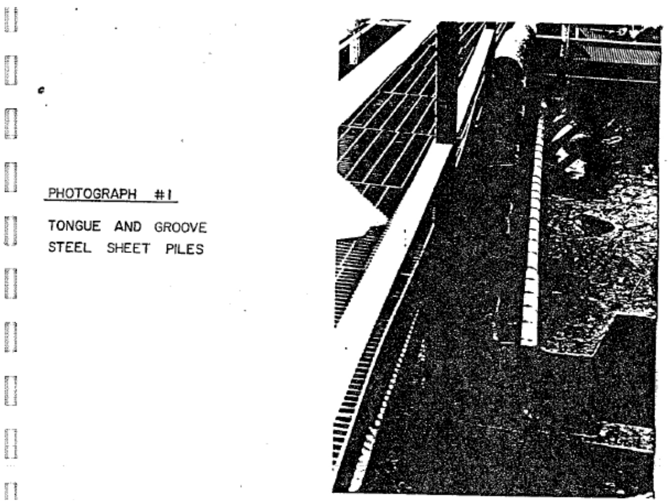
A. Evergreen has not fully characterized contamination in comparison with the sheet pile wall and bulkhead.

Along the perimeter of AOI-5, AOI-6, AOI-7, and AOI-2, a sheet pile wall was constructed in the 1950s -- presumably to protect the property from the influx of water from the Schuylkill River and to prevent the migration of contaminants into the river. In the reports, Evergreen assumes that it provides sufficient protection against migration of contamination to the river. But it offers no supporting evidence concerning the engineering specifications for this structure, its physical integrity, or any ongoing system of leak detection, maintenance, or repair. During this remedial investigation this failure is material because this means that Evergreen has not provided a sufficient delineation of the nature and extent of the contamination.

The most specific information we have about this structure is a 1985 memorandum identifying a tongue-and-groove steel sheet pile that is 8400 feet long:

> Initially, the fill materials were placed behind a wooden seawall constructed in the early 1920's. ***This was replaced in the 1950's by 1400 feet of concrete seawall near the oil and grease plant and by 8400 feet of tongue-and-groove steel sheet pile along the remaining waterfront (Photograph #1).*** This fill-and-bulkhead system has led to the development of a shallow water table which is perched on the underlying marsh deposits. This water table is encountered at depths of 5 to 7 feet and is recharged by rainfall. Discharge of these groundwaters is to the Schuylkill River. The configuration of the water table cannot be determined without a sufficient number of monitor wells but flow directions are expected to be generally towards the river.

See 2017 Report, Appendix J (AOI-5), Appendix A (Historical Reports Combined), Memorandum dated May 8, 1985, page 5 (bold italics added for emphasis). The photograph is located here:

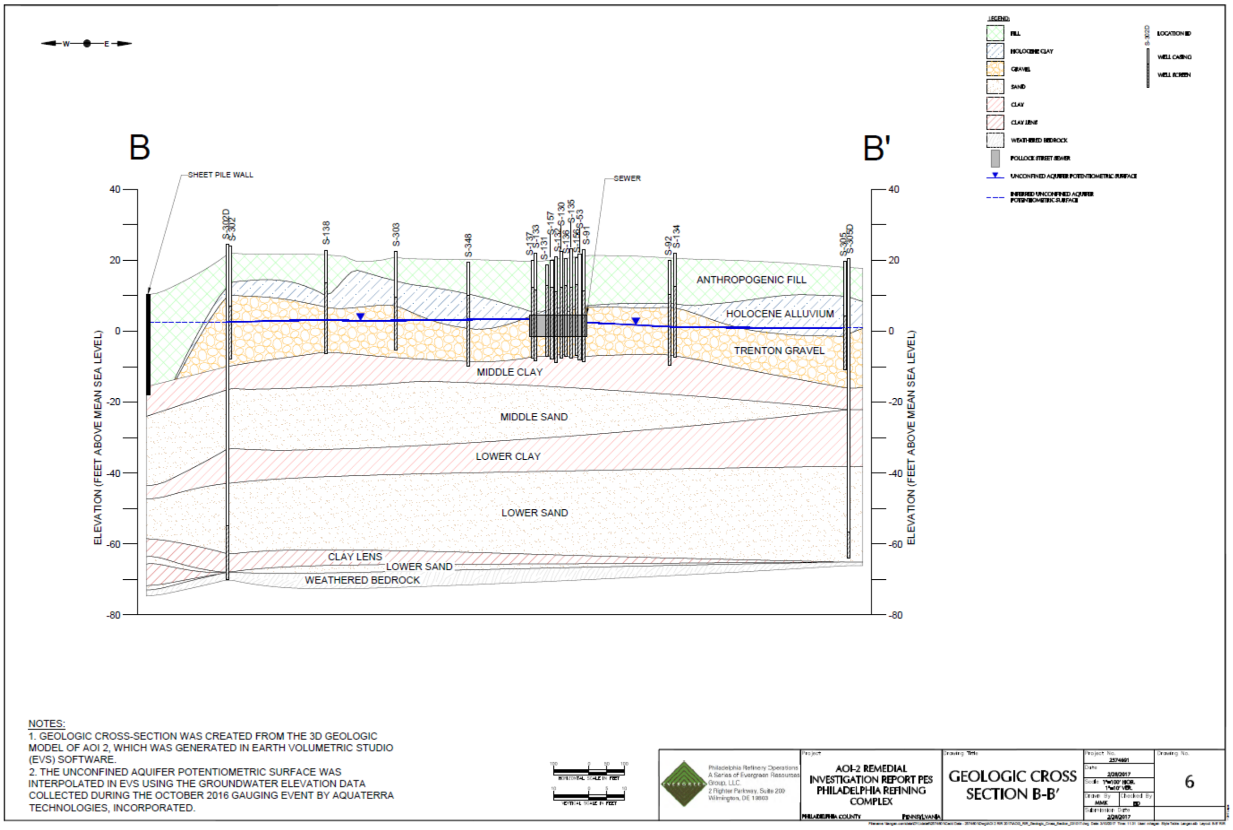


PHOTOGRAPH #1

TONGUE AND GROOVE
STEEL SHEET PILES

Id., pdf page 18. But this does not provide much detail regarding this structure, and it does not demonstrate that the sheet pile wall is effective.

A geologic cross section for AOI-2 provides some information regarding the relative position of the sheet pile wall:



NOTES:
1. GEOLOGIC CROSS-SECTION WAS CREATED FROM THE 3D GEOLOGIC MODEL OF AOI 2, WHICH WAS GENERATED IN EARTH VOLUMETRIC STUDIO (EVS) SOFTWARE.
2. THE UNCONFINED AQUIFER POTENTIOMETRIC SURFACE WAS INTERPOLATED IN EVS USING THE GROUNDWATER ELEVATION DATA COLLECTED DURING THE OCTOBER 2016 GAUGING EVENT BY AQUATERRA TECHNOLOGIES, INCORPORATED.

See 2017 Report (AOI-2), Figure 6 (Cross Section B-B’), pdf page 206 of 215; *see also id.*,

Figure 4 (Geologic Cross Section Location Plan), Figure 5 (Cross Section A-A'), According to the Figure above, the sheet pile appears to be lie even with the surface of the ground, and appears to have a depth of about 28 feet, extending into the clay by one or two feet. *See id.* Because the sheet pile wall appears to lie right on the Schuylkill River, Evergreen has an obligation to delineate whether contaminated groundwater is migrating into the river.

Other cross sections do not appear to provide more information. One would expect the sheet pile wall to be picked up near the end of the cross section B-B' for AOI-6, but it does not appear to be located there. *See* 2017 Report (AOI-5), Figure 2 (Site Plan), Figure 4 (Geologic Cross Section Location Plan), Figure 5A (Geologic Cross Section A-A'), Figure 5B (Geologic Cross Section B-B'), pdf pages 227, 229-231 of 238. It should be located at the end of cross section E-E' for AOI-6, but it does not appear to be there. *See* 2017 Report (AOI-6), Figure 2 (AOI 6 Site Plan), Figure 8 (Stratigraphic Profile), pdf pages 53, 59 of 155. It should also be picked up for AOI-7, but it is not there, either. *See* 2017 Report (AOI-7), Figure 2 (AOI 7 Site Plan), Figure 8 (Stratigraphic Profile), pdf pages 56, 62 of 281.

In the reports, Evergreen provides no other meaningful information about the nature of this sheet pile wall. Rather, it simply makes repeated assertions that it is "keyed" into the Middle Clay Layer. *See* 2011 Report (AOI-5), page 6 ("A sheet pile bulkhead, keyed into the Middle Clay Unit, extends along the entire southern boundary of AOI 5 along the Schuylkill River."); *see also* 2013 Report (AOI-6), page 2 ("A sheet pile bulkhead, which is keyed into the Middle Clay Unit, extends along the entire western boundary of the AOI, between the AOI and the Schuylkill River."); *see also* 2012 Report (AOI-7), page 2 ("The entire western and northern boundary of AOI 7 along the Schuylkill River is bound by a sheet pile wall which is keyed into the Middle Clay Unit."); *see also* 2017 Report (AOI-2) ("A sheet pile bulkhead, which is keyed into the Middle Clay layer, extends along a portion of the western boundary of the AOI, between the AOI and the Schuylkill River."). Again, this does not demonstrate that the sheet pile wall is effective.

On the question of effectiveness, Evergreen's language is guarded. It asserts that the sheet pile "limits" the flow of groundwater to the Schuylkill River -- and thereby acknowledges the possibility of flow into the river. *See* 2011 Report (AOI-5), page 11 ("[s]hallow groundwater interaction with the Schuylkill River is limited by the sheet pile wall"); *see also* 2013 Report (AOI-6), page 9 ("[s]hallow groundwater interaction with the Schuylkill River is limited by the presence of the sheet pile wall"); *see also* 2012 Report (AOI-7), page 14 ("[s]hallow/intermediate groundwater interaction with surface water is limited by the sheet pile wall"); *see also* 2017 Report (AOI-2), page 35 ("[t]he presence of the sheet pile wall and the vertical wall in this area limits the discharge of dissolved phase COCs in the unconfined aquifer groundwater to the Schuylkill River"). Again, this does not demonstrate that the sheet pile wall is effective. Evergreen offers no meaningful evidence about this sheet pile wall in support of the proposition that it is an effective barrier to the migration of groundwater.

In the absence of such evidence, Evergreen offers circular reasoning to advance its proposition. Begging the question, it asserts that the movement of groundwater toward the river is limited because the groundwater can discharge no faster than the sheet pile wall permits:

> Along the sheet pile wall, ***the movement of groundwater and contamination*** through the alluvium/fill towards the Schuylkill River (the POC) ***is limited by the hydraulic conductivity of the sheet pile wall. This is because groundwater behind the sheet pile wall can discharge no faster to the Schuylkill River than the sheet pile wall permits***. The lower hydraulic conductivity of the sheet pile wall also causes groundwater to mound up behind it.

See 2011 Report (AOI-5), Appendix H, Section H.5.6, page H-6 (Hydraulic Conductivity (K)). *See also* 2013 Report (AOI-6), part 2, Appendix H, Section H.5.6, page 7 of 12. This begs the question whether the sheet pile wall is effective.

When Evergreen refers to the "lower hydraulic conductivity of the sheet pile" in the last sentence quoted above, Evergreen is simply implying that the hydraulic conductivity of the sheet pile wall is less than that of regular fill. *See* 2013 Report (AOI-6), part 2, Appendix F, Section F.4, page 3 of 12 ("For assessment purposes it was assumed that groundwater flow through sediments near the sheet pile wall are affected more by the lower sheet pile permeability relative to the higher hydraulic conductivity of the sediments."). It is not remarkable to assume that a sheet pile wall would tend to have a lower permeability than sediments, assuming it is functioning properly. But again, Evergreen assumes that the sheet pile wall is effective, without offering meaningful evidence.

Evergreen attempts to bolster its assertion by appealing to a coefficient of hydraulic conductivity, but that information is not specific to this sheet pile wall. Rather, Evergreen offers a putative number for hydraulic conductivity for unsealed sheet pile walls, obtained from a manufacturer of sheet pile walls (Waterloo Barrier):

> To account for the presence of the sheet pile wall in the QD and SWLOAD models ***the effective hydraulic conductivity used for simulating Zones 1 through 5 was 0.283 ft/d*** (10^{-5} cm/sec) ***which represents unsealed sheet piling (Waterloo Barrier, Inc.).***

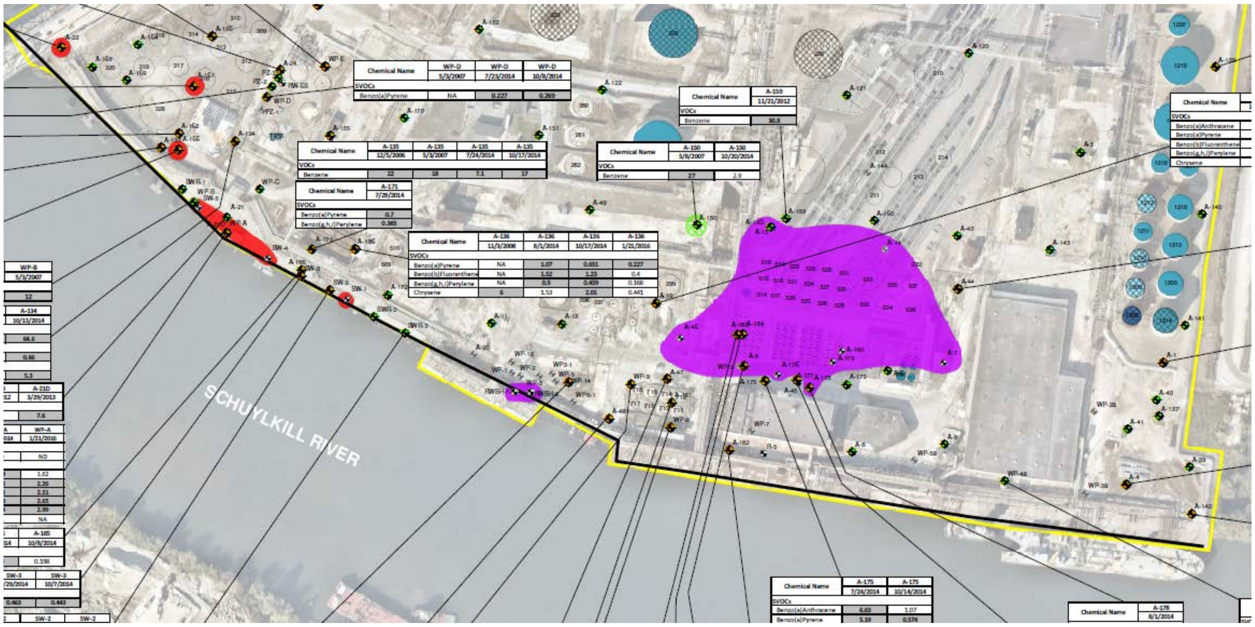
See 2011 Report (AOI-5), Appendix H, Section H.5.6, page H-6; *see also id.*, Figures H.4 through H.8. Evergreen does not provide any foundation for how Waterloo Barrier arrived at this coefficient, and Evergreen does not cite any written report of Waterloo Barrier as a source of authority for this coefficient.

Presumably, the coefficient provided by Waterloo was based on unsealed sheet pile walls marketed at that time this report was prepared (around 2011). Apparently, that company has a proprietary sheet pile wall product developed in 1989. *See* Waterloo Barrier Inc., Waterloo Barrier® Groundwater Containment Wall. But there is no reason to suggest that Waterloo manufactured the sheet pile wall at the oil refinery (it was installed in the 1950s), or that the coefficient that Waterloo provided is a reliable one when applied to a sheet pile wall constructed in the 1950s. It says nothing about the effectiveness of a sheet pile wall that has been subject to all the forces of nature and humankind for over sixty years.

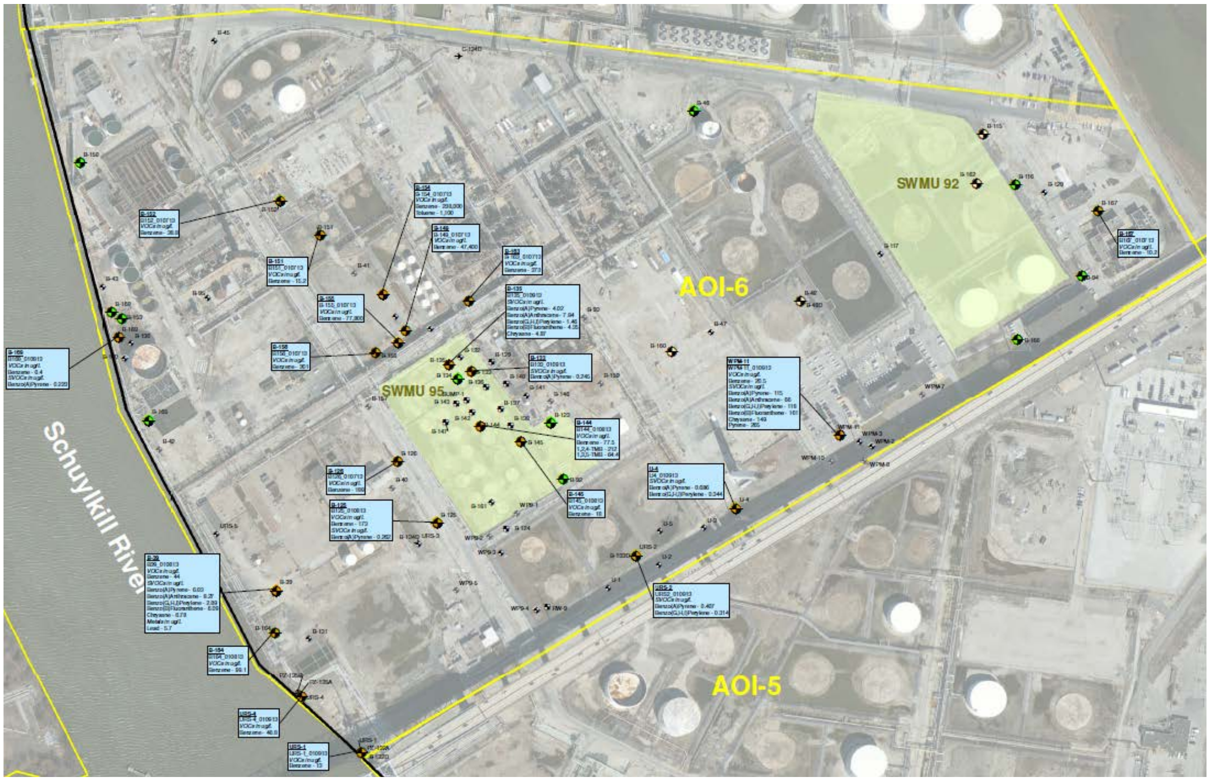
B. There are compelling concerns about the protectiveness of the sheet pile.

These forces include the migration of contaminants in groundwater that could contribute to corrosion of the sheet pile wall. Evergreen does not address this. This is important because Evergreen has gathered data demonstrating contaminants in monitoring wells in the shallow aquifer near the sheet pile wall, based on the reports for AOI-5, AOI-6, AOI-7, and AOI-2. (As discussed above, in AOI-2, the sheet pile appears to extend to a depth of approximately 28 feet, implicating the shallow aquifer).

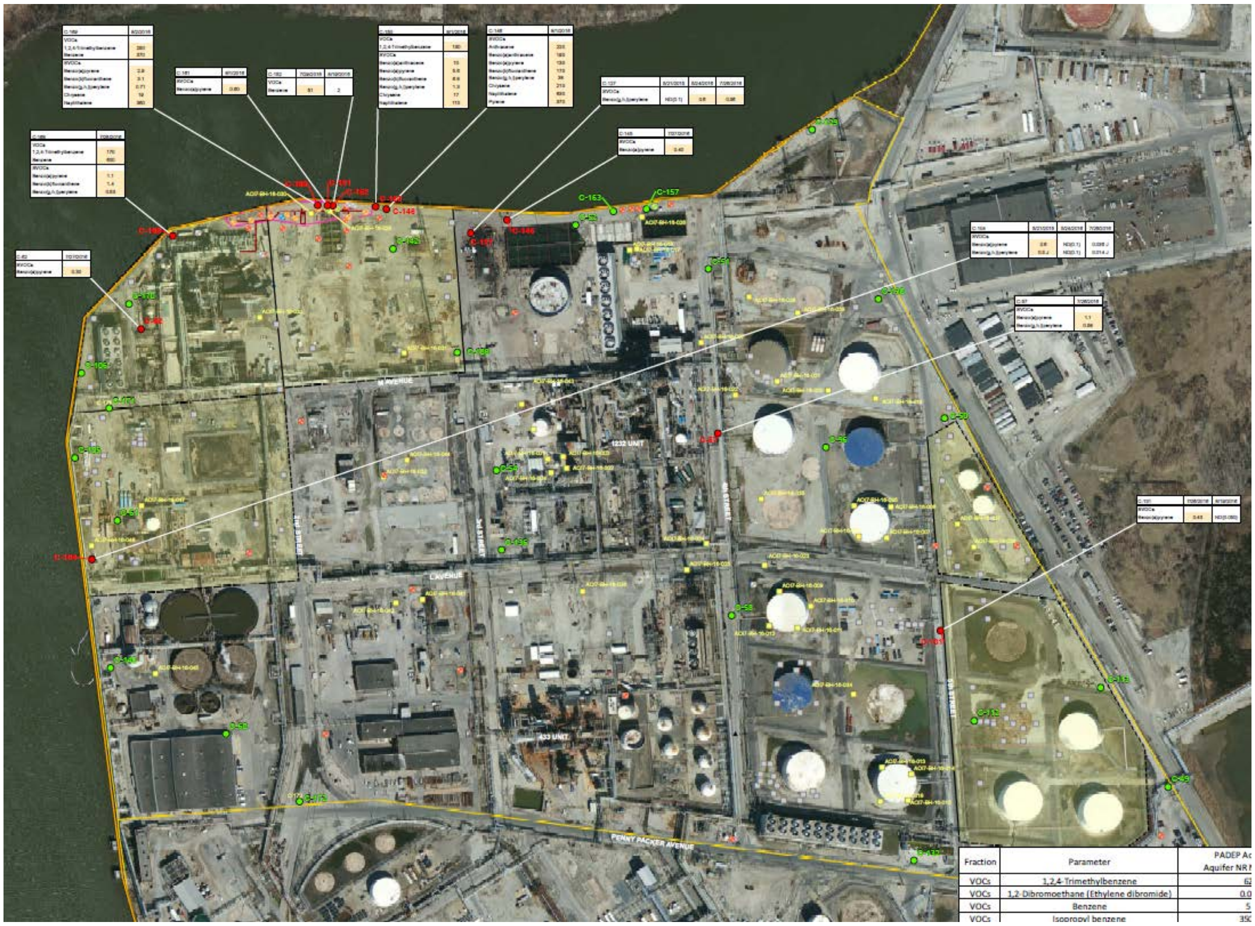
The following screenshots illustrate some of this contamination:



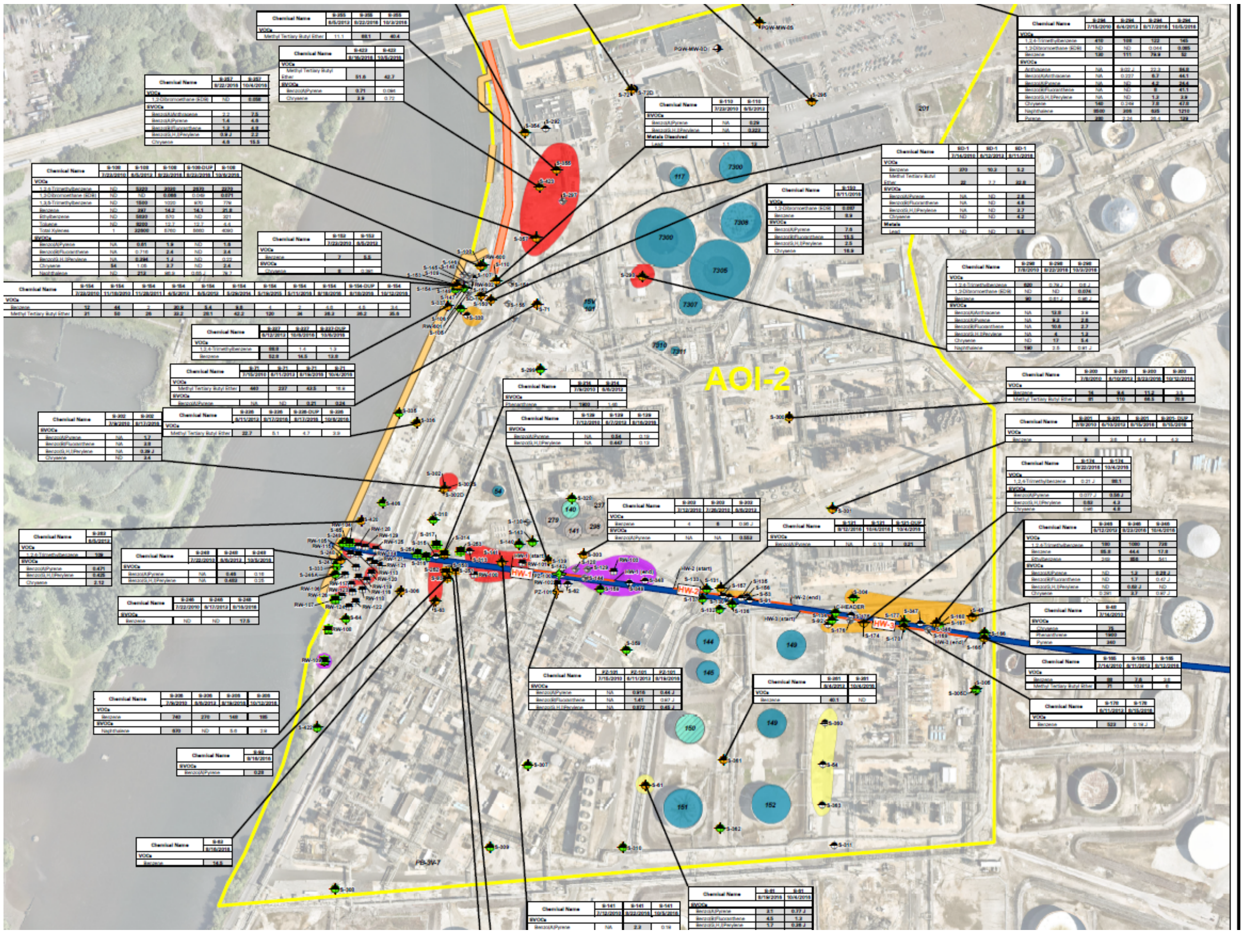
See 2017 Report (AOI-5), Figure 10 (Summary of Groundwater Sample Exceedances), pdf page 236 of 238.



See [2013 Report](#) (AOI-6), Figure 11 (Summary of Groundwater Sample Exceedances), pdf page 100 of 101.



See 2017 Report (AOI-7), Figure 19 (Water Table Groundwater Results), pdf page 74 of 281.



See 2017 Report (AOI-2), Figure 12A (Summary of Unconfined Aquifer Groundwater Sample Exceedances), pdf page 212 of 215.

These forces include seismic events. Just four months ago, a magnitude 3.1 earthquake struck in East Freehold, New Jersey, causing impacts that were felt in Philadelphia. CBS Philly, *3.1 Magnitude Earthquake Strikes New Jersey, Shaking Reported Across State Including Philadelphia-Area* (September 9, 2020). This is important because seismic events could cause pressure and stress on the sheet pile wall, weakening its structure and making it more susceptible to wear and tear.

These concerns are not simply academic. Evergreen has already identified at least one instance of a breach of the sheet pile wall that required repair. *See* 2012 Report (AOI-7), page 29 (noting that as an interim remedial measure, Sunoco "[s]ealed a penetration in the sheet pile wall adjacent to the junction box, eliminating groundwater flow to the Schuylkill River"). This statement implies that there was groundwater flow into the Schuylkill River through the breach.

C. With respect to prevailing engineering standards, Evergreen should consider resources such as the U.S. Army Corps of Engineers' engineering manual.

As Evergreen considers the sheet pile wall in this remedial investigation, it should review modern engineering standards for sheet pile walls. For example, the U.S. Army Corps of Engineers has prepared a section on the design of sheet pile walls in its engineering manual. *See* U.S. Army Corps of Engineers, *Design of Sheet Pile Walls*, March 31, 1994 (EM 1110-2-2504 31) (75 pages), available on the Army Corps of Engineers' webpage on Engineer Manuals.

According to that engineering manual, the problem of corrosion is an electrochemical question. *See id.,* page 9-1, Section 9.2.b(3) ("The corrosion process is electrochemical in nature and occurs wherever there is a difference in electric potential on the piles surface."). The engineering manual states that "[p]ermanent installations should allow for subsequent installation of cathodic protection should excessive corrosion occur." *Id.,* page 2-2, Section 2.4.b. Evergreen should provide an analysis of what systems are in place for cathodic protection.

D. Evergreen has not responded to the Department's Comment relating to the sheet pile wall in the report for AOI-11 (deep aquifer).

It does not appear that Evergreen has addressed a question from the Department regarding the use of the coefficient of hydraulic conductivity obtained from Waterloo. *See* 2013 Comments (AOI-6). Among other things, the Department questioned Evergreen's use of this coefficient not only for the migration of contaminants within the short distance between the sheet pile wall and the river, but also for an additional distance of 150 feet to the east of the sheet pile wall. *See id.*, Comments 28-31. Evergreen's response did not address these comments. *See* 2018 Response to Comments (AOI-6). Evergreen should respond to these comments now, as well as the comments of the Council.

10. The Remedial Investigation Reports are Deficient Because They Fail to Address the Impacts of Climate Change -- Including Sea Level Rise and Storm Surges.

For years, it has been known that emissions of greenhouse gases have caused changes in climate, including sea level rise and changes in precipitation patterns. Despite the existence of state and regional climate change plans to address these impacts, Evergreen has not incorporated any analysis of these impacts into its remedial investigation. The former refinery is located on the banks of the Schuylkill River, which is projected to rise by two feet in 2050, which would cause flooding over a number of areas of the facility. Because of the failure to consider these impacts, the delineation of the nature and extent of contamination is deficient.

Climate change implicates at least two concerns for this remedial investigation. First, climate change could potentially affect remediation systems through sea level rise and increased storm events. This is not merely a hypothetical future concern. Although the present public comment period concerns remedial investigation reports, there is an overlapping remediation aspect that is a part of these reports. *See* Evergreen, Act 2 Program Information Session (August 27, 2020), Remediation Timeline, slide 47 (bar graph displaying active and inactive remediations since 1995, and identifying 11 active remediations as of August 2020).

In addition, the remedial investigation reports themselves cover sewer remediation systems. *See e.g.*, 2016 Report (AOI-1), Section 10.43, page 10.65-10.66, 2017 Report (AOI-2), Section 8.0, pages 49-51, 2017 Report (AOI-4), Section 10.43, page 10.63, 2017 Report (AOI-7), Section 10.42, page 42, 2017 Report (AOI-8), Section 9.2.5, page 9.60.

Second, because climate change could potentially affect the flow of surface water and groundwater, Evergreen should have considered it when evaluating the fate and transport of contaminants in the reports.

A. State and local agencies have adopted plans to address the impacts of sea level rise, which is projected to amount to two feet for Philadelphia in 2050.

Under the Pennsylvania Climate Change Act of 2008, the Department of Environmental Protection must prepare a Climate Change Plan every three years. *See* Act 70 of 2008, Section 7(a). The most recent climate change action plan recognizes the impacts of flooding in the City of Philadelphia:

> Climate impacts in Pennsylvania are happening now and will continue to put Pennsylvanians and local industries at risk. ***Key impacts in Pennsylvania (Shortle et al. 2015) include***:
> ….
> ***More frequent flooding and associated disruptions due to sea level rise in communities and cities in the Delaware River Basin, including the city of Philadelphia***
> ….

See DEP, Pennsylvania Climate Change Plan (2018), pages 25-26.

At a regional level, the City of Philadelphia has projected an increase in sea level rise of two feet by 2050 and four feet by 2100:

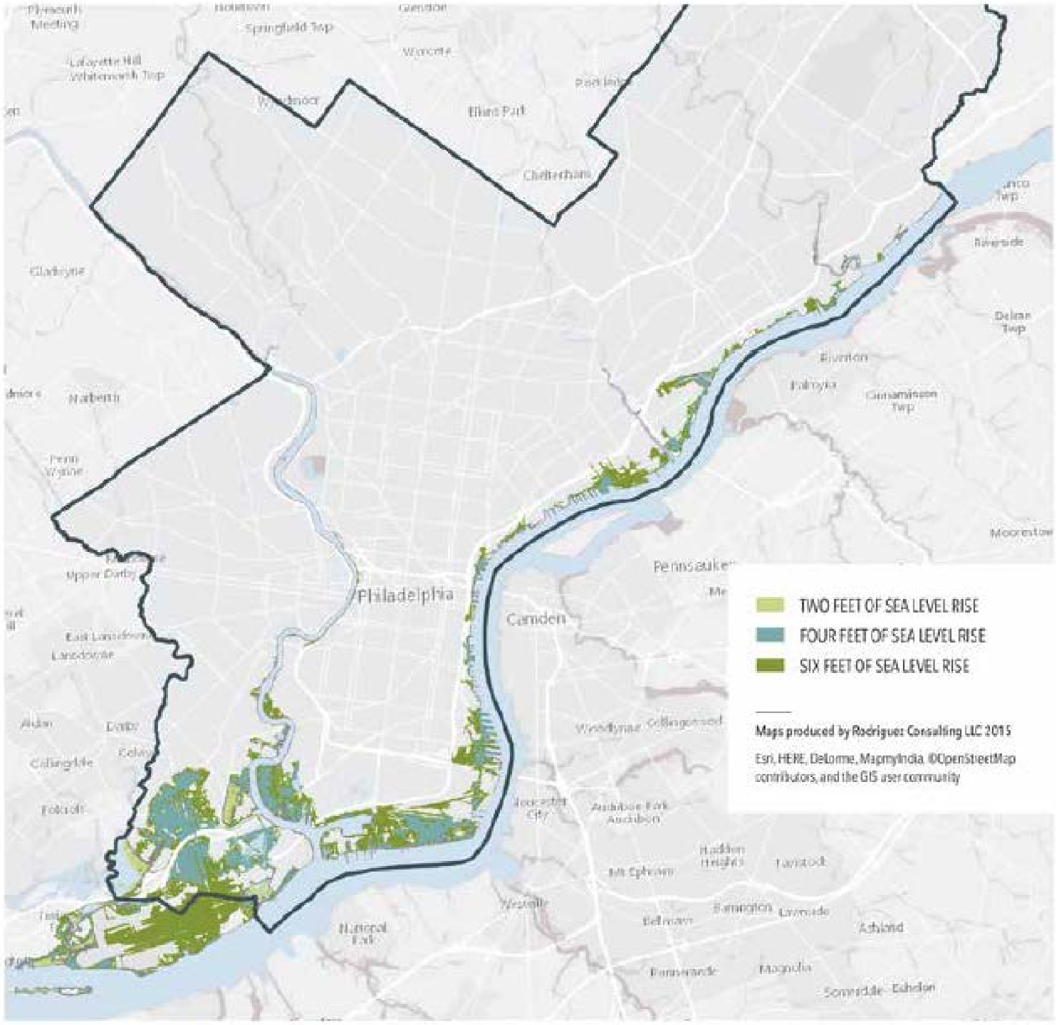
> SEA LEVEL RISE (SLR): Two scenarios consider just the impacts of sea level rise: ***two feet*** (***the local projection for 2050 assuming moderate carbon emissions worldwide***) and ***four feet*** (***the projection for 2100 given the same emissions assumptions***). [citing NOAA, the Digital Coast].

See City of Philadelphia, Mayor's Office of Sustainability and ICF International, *Growing Stronger: Toward a Climate-Ready Philadelphia* (November 2015) (bold italics added for emphasis).

This report includes a map of Philadelphia highlighting areas at risk of inundation from a sea level rise of two feet. Among them are a number of Areas of Interest at the former oil refinery (AOI-5, AOI-6, AOI-7, AOI-8, AOI-9, and AOI-10):

FIGURE 8

POTENTIAL INUNDATION FROM SEA LEVEL RISE



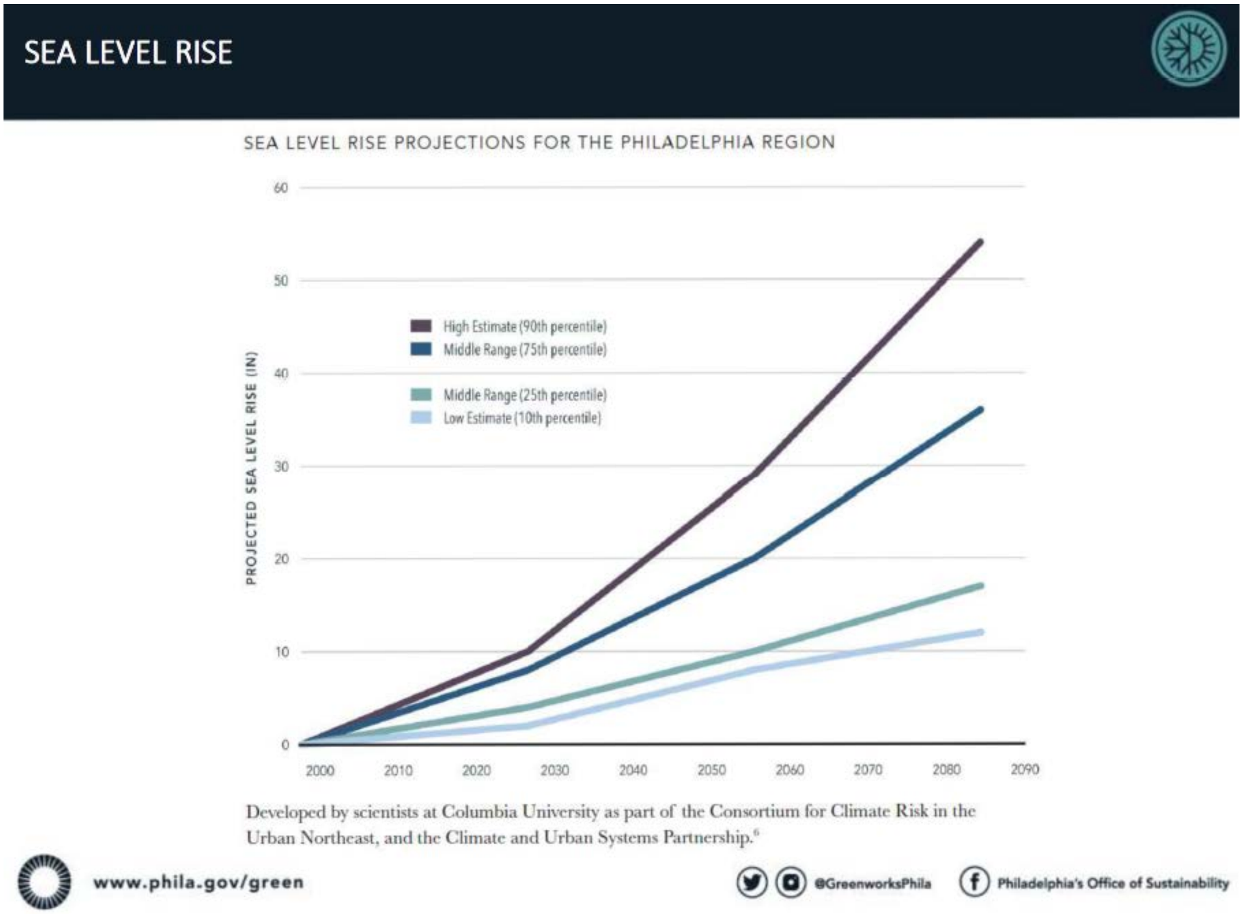
Maps produced by Rodriguez Consulting LLC 2015

Esri, HERE, DeLorme, MapmyIndia, ©OpenStreetMap contributors, and the GIS user community

Areas in Philadelphia at risk of inundation under two feet of sea level rise, which is the expected sea level rise in 2050 under a scenario of moderate greenhouse gas emissions; four feet of sea level rise, which is the expected sea level rise in 2100; and six feet of sea level rise, which is the expected level in 2100 under a high-greenhouse-gas emissions scenario.

Id., page 16.

A more recent report of the city’s Office of Sustainability projects an increase of sea level rise of two to seven inches during the period 2000-2020, with further increases thereafter:



SEA LEVEL RISE

SEA LEVEL RISE PROJECTIONS FOR THE PHILADELPHIA REGION

Developed by scientists at Columbia University as part of the Consortium for Climate Risk in the Urban Northeast, and the Climate and Urban Systems Partnership.[6]

www.phila.gov/green

@GreenworksPhila Philadelphia's Office of Sustainability

City of Philadelphia, Office of Sustainability, *Greenworks: A Vision for a Sustainable Philadelphia* (May 31, 2018), page 13.

B. <u>The projected sea level rise of 2 feet by 2050 will place extensive areas of the former refinery underwater.</u>

The Sea Rise Viewer of the National Oceanic and Atmospheric Administration provides a vivid description of what this will mean for the former refinery. The following are a series of snipped figures showing the implications of sea level rise on the refinery site, downloaded on January 4, 2021.

In the following figures, the blue areas are areas of sea level rise because they are hydrologically connected to the ocean:

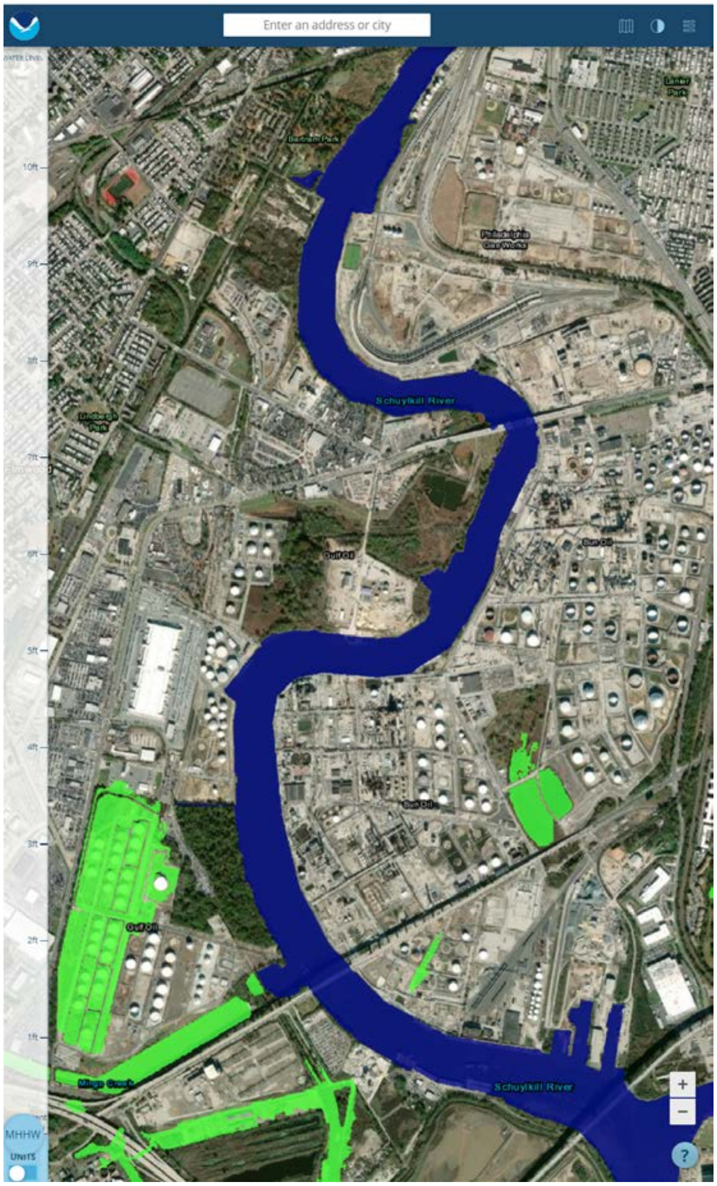
> Water levels are relative to local Mean Higher High Water Datum.
> ***Areas that are hydrologically connected to the ocean are shown in shades of blue (darker blue = greater depth)***.

See NOAA, Sea Level Rise Viewer (click on the circular icon with the letter "i" in the lower left hand corner) (bold italics added for emphasis). The green areas are areas that may also flood even though they are hydrologically "unconnected" to the ocean:

> Low-lying areas, displayed in green, ***are hydrologically "unconnected" areas that may also flood***.

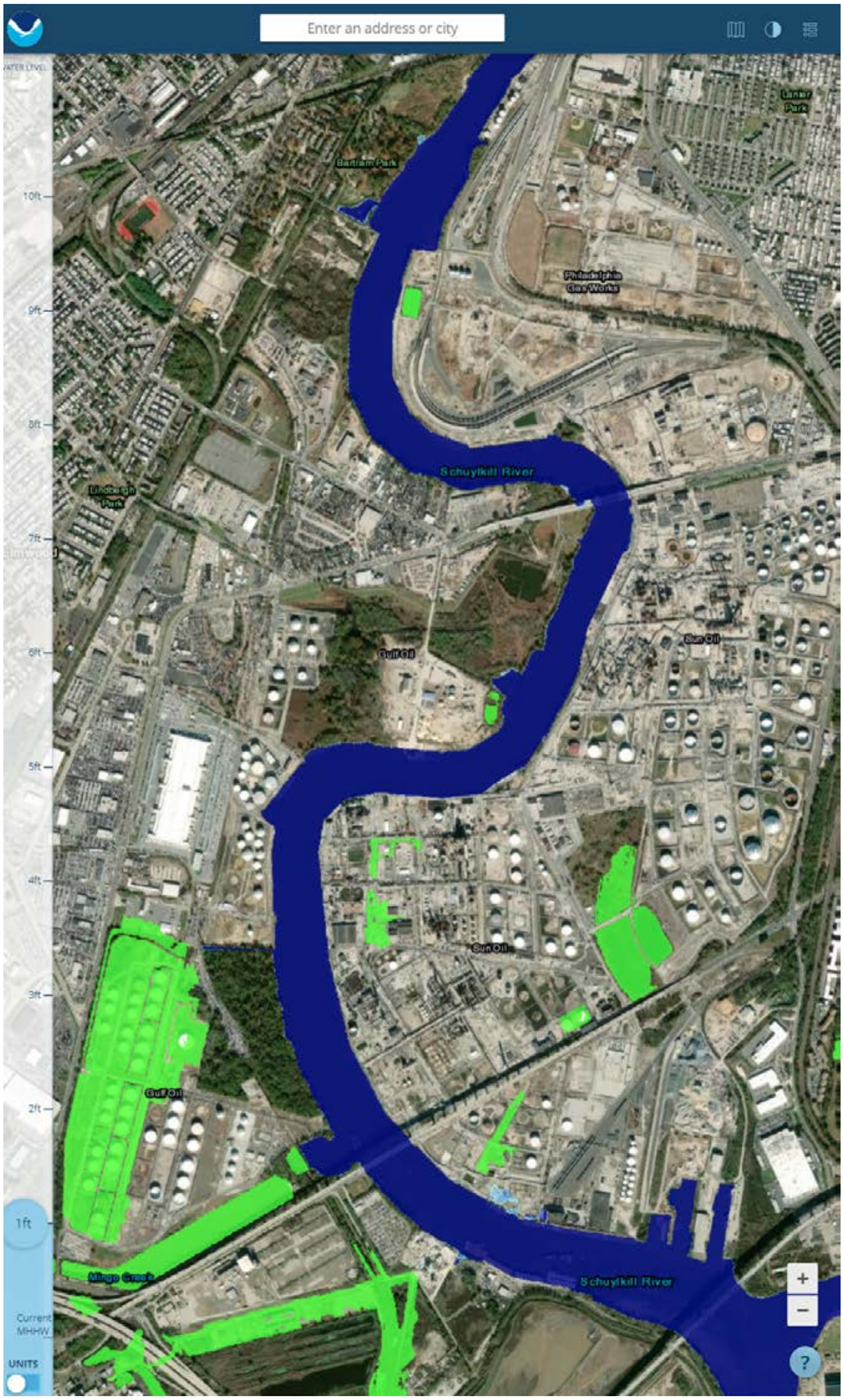
See id.

This first map shows current conditions:



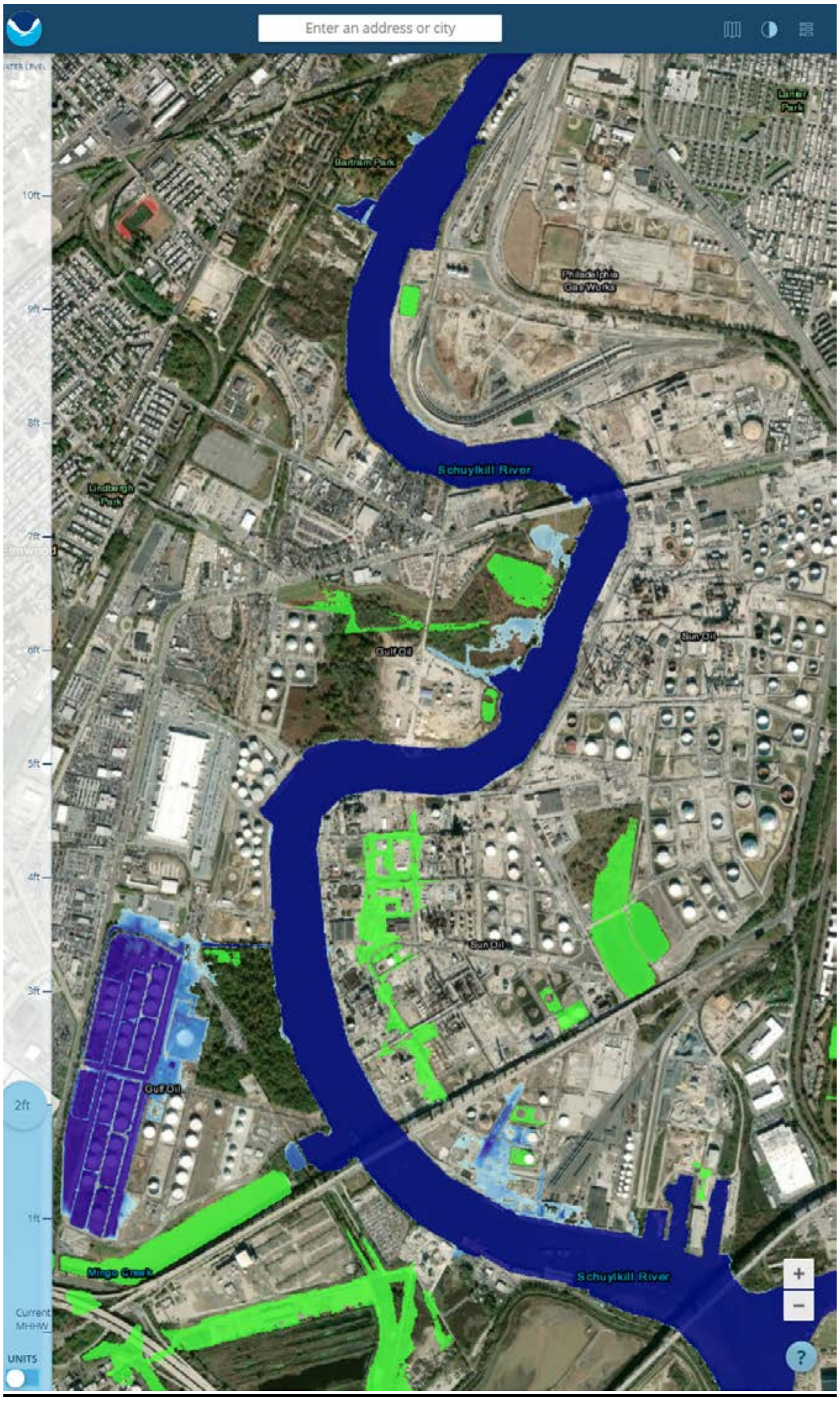
Source: NOAA Sea Level Rise Viewer (set for Mean Higher High Water (MHHW).

This second map shows that sea level rise of one foot will cover parts of AOI-5 and AOI-10:



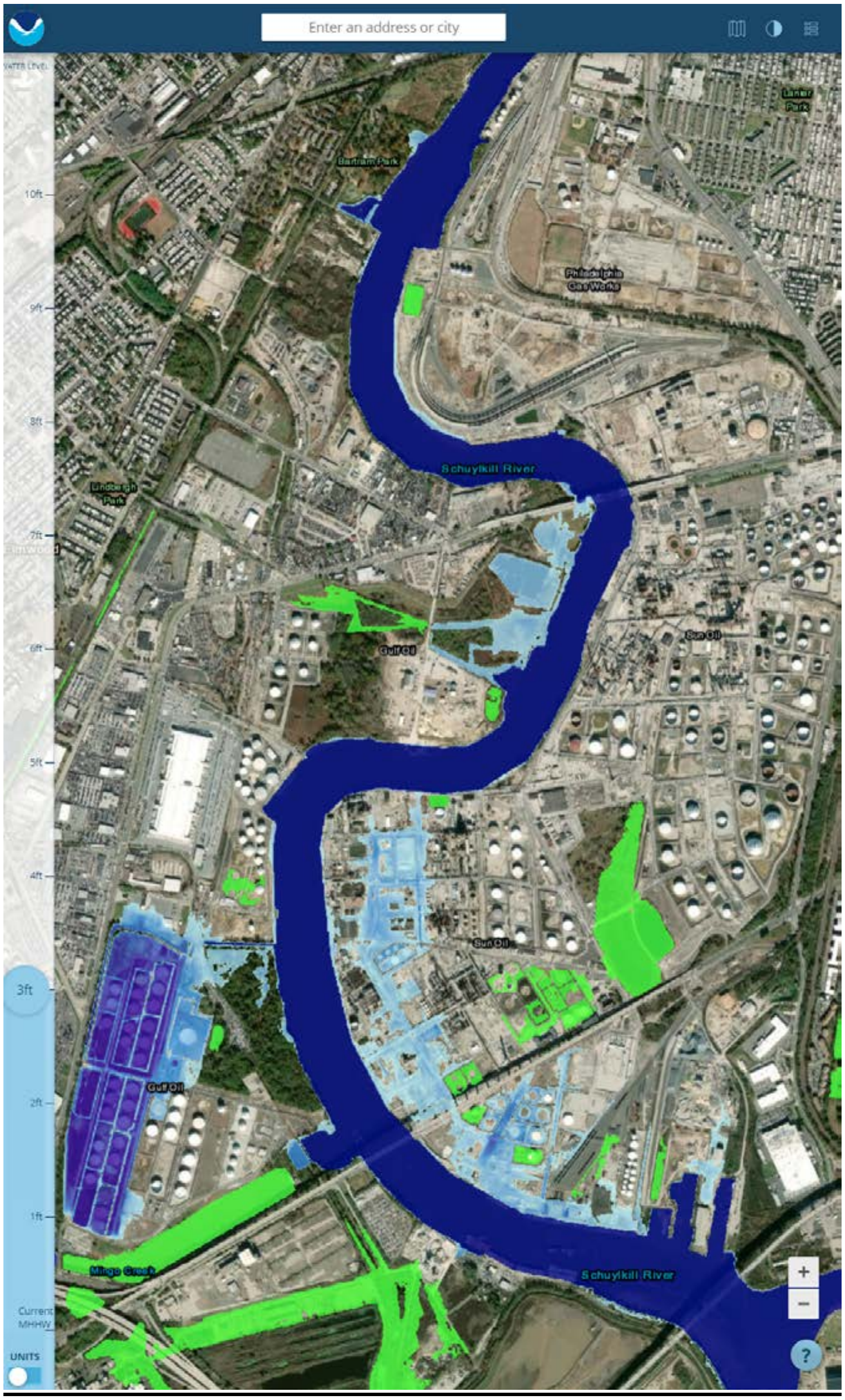
Source: NOAA Sea Level Rise Viewer (set for one foot)

The third map shows that sea level rise of two feet will cover extensive parts of AOI-5, AOI-9 and AOI-10, and small parts of AOI-6 and AOI-8:



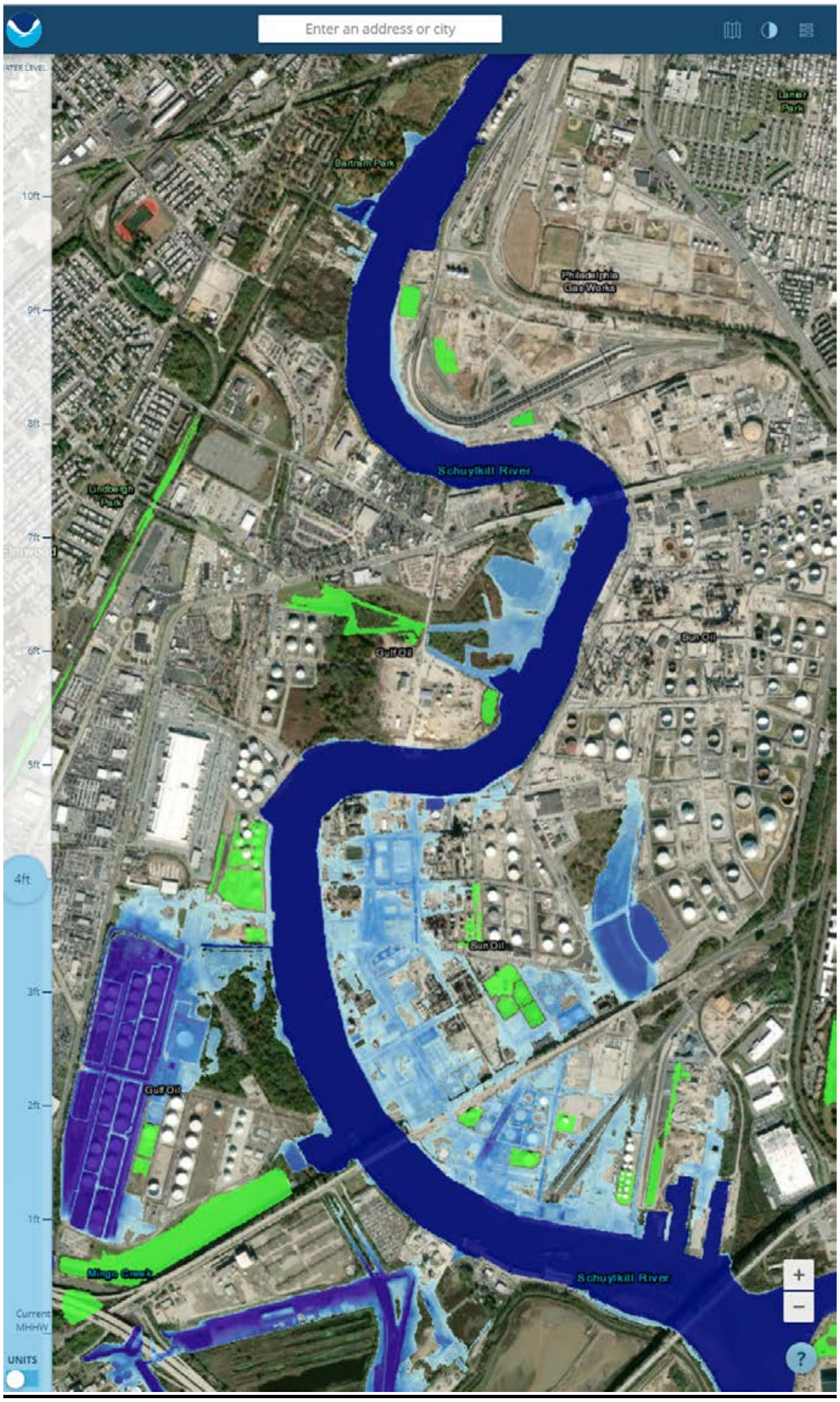
Source: NOAA Sea Level Rise Viewer (two feet)

The fourth map shows that sea level rise of three feet will cover extensive areas in AOI-5, AOI-6, AOI-7, AOI-9, and AOI-10, and parts of AOI-8:



Source: NOAA Sea Level Rise Viewer (three feet)

The fifth map shows that sea level rise of four feet will cover extensive areas in AOI-3, AOI-5, AOI-6, AOI-7, AOI-9, and AOI-10, and parts of AOI-8:



Source: [NOAA Sea Level Rise Viewer]() (four feet)

C. <u>According to EPA Region III, a responsible party should consider the impacts of climate change during a remedial investigation</u>.

EPA Region III has jurisdiction over the remedial investigation at the oil refinery. It is the policy of EPA Region III to consider sea level rise at the remedial investigation stage, and it encourages state agencies to do the same. Region III makes this clear in its Climate Change Adaptation Implementation Plan:

> Priority Actions, Goal 3 Cleaning Up America's Communities & Advancing Sustainable Development:
>
> ….
>
> ***Perform vulnerability analyses during site investigation***, cleanup design, operations and maintenance, five year reviews, etc. ***Encourage states to consider doing the same for state-led states***.

See EPA Mid-Atlantic Region III, Climate Change Adaptation Implementation Plan (May 30, 2014), page 25.

For example, Region III notes that shallow groundwater aquifers are likely to be the most sensitive part of the groundwater system to climate change:

> D. Water Quality impacts from climate changes
>
> ***Shallow groundwater aquifers that exchange water with streams are likely to be the most sensitive part of the groundwater system to climate change***. ***Small reductions in groundwater levels can lead to large reductions in stream flow and increases in groundwater levels can increase stream flow***. Further, the interface between streams and groundwater is an important site for pollution removal by microorganisms. Their activity may change in response to increased temperature and increased or decreased streamflow as climate changes, this may affect water quality and affect Clean Water Act goals related to water bodies in non-attainment and affect TMDL development.
>
> A specific mid-Atlantic water quality concern[] is the Delaware River Basin, which includes portions of New York, Pennsylvania, New Jersey, and Delaware that drain to the 330-mile long Delaware River and Bay...."

Id., page 14 (bold italics for emphasis). We know that the water table is high in areas of the site. *See* Comment #12, below.

In addition, Region III acknowledges the potential for impacts of sea level rise on aquifers and groundwater:

> E. Severe flooding from sea-level rise and extreme precipitation is likely to increase
>
> ***Sea-level rise is expected to increase saltwater intrusion into coastal freshwater aquifers***, making some unusable without desalination. Increased evaporation or reduced recharge (drought) into coastal aquifers exacerbates saltwater intrusion. Like water quality, ***research on the impacts of climate change on groundwater,*** ecosystems, and infrastructure ***has been minimal and remedies may be difficult***.

Id., page 15 (bold italics for emphasis).

Finally, Region III acknowledges that flooding could affect the migration and management of contaminants:

> A. Restoring and Preserving Land
>
> Increased flooding and sea-level rise may increase the risk of contaminant releases from vulnerable RCRA Corrective Action sites, Superfund sites, Brownfield sites, LUST sites, other contaminated sites, and landfills. ***Flooding from more intense and frequent storms and extreme storm events could affect the migration and management of contaminants***. Sea-level rise can lead to inundation and salt water intrusion which may impact the performance of the remedies ***and cause the transport of contaminants at sites in coastal areas***. Contaminant migration could also occur after prolonged power loss at cleanup sites with pump and treat systems dependent on grid electricity.
>
> Impacts may be most severe for cleanup sites that are not yet completed; however sites with waste in place following a cleanup and permitted facilities that manage hazardous materials may also be vulnerable. ***Sites with on-site containment or treatment remedies within the 100 or 500 year flood plain of a surface water body and/or within the sea-level rise zone 1.5 meters above high tide are of particular concern in Region III***. Sediment sites with in situ capping remedies are vulnerable to flood regime changes and re-suspension and deposition of contaminated sediment. Flooding from storms and inundation due to sea level rise could jeopardize land revitalization efforts

> including renewable energy generation, greener cleanups, and ecological revitalization projects, as well as other site reuse or redevelopment plans at Brownfield sites and completed Superfund Sites.
>
> Increased ambient temperatures and extreme heat may impact the design and operation of remediation systems. Cleanup sites with waste in place phytoremediation, or a vegetative cap may be vulnerable in areas that experience drought or changing plant hardiness zones. Slowed growth rates during heat waves could impact the success of the remedy or revitalization effort, and excessive vegetation loss could lead to erosion. Coastal, stream, and mountain ridge top habitats are examples of ecosystems in Region 3 that are vulnerable to increases in ambient temperature.

Id., page 17 (bold italics for emphasis).

Last year, the Government Accountability Office published a report recommending that EPA take additional actions to manage risks from climate change. U.S. Government Accountability Office, *Superfund: EPA Should Take Additional Actions to Manage Risks from Climate Change*, GAO-20-73 (2019). The GAO report described Region III's adoption of a policy considering climate change in cleanups of contaminated sites.

To illustrate, the Region III plan notes that increased flooding and sea level rise may increase risks of releases of contaminants:

> Each of the 10 EPA regional offices identified relevant regional climate change effects in their 2014 climate change adaptation implementation plans. [footnote 70]. For example, ***the Region 3 plan states that increased flooding and sea level rise may increase risks of releases of contaminants, salt water intrusion may impact the performance of remedies, and increased temperatures may impact vegetation that prevents erosion***.

Id., pages 36-37.

In addition, the plan notes that "Region 3 has developed a mapping tool on climate change vulnerability that provides site-level assessments of sea level rise, among other potential impacts." *Id.*, page 39.

The GAO report also noted that "[o]fficials from Region 3 told us that they take into account a number of factors, including climate change impacts, if any, when they design and select site remedies."). *Id.*, page 43.

Applying these principles, Region III has considered sea level rise and climate change in the context of the Publicker Industries site on the Delaware River, in southeast Philadelphia. The GAO Report noted that “Region 3 considered newly available information on projected sea level rise in the region to determine if those projections called into question the protectiveness of the existing remedies at the site." *Id.*, page 44.

It is notable that sea level rise was not a concern for the Publicker Industries site only because it is located at a high elevation above sea level (15-19 feet):

> Question C: Has any other information come to light that could call into question the protectiveness of the remedy?
>
> Answer: No other information has come to light that calls into question the protectiveness of the remedy. However, ***due to the proximity of the Publicker site and the Delaware River, EPA looked at the potential impacts from the effects of climate change for this Five-Year Review.*** In a joint report from the EPA and the Delaware River Basin Commission, ***an estimated 21-inch rise in global sea level by 2050 would imply a rise of 2.4 feet in the Delaware estuary***. Also, an estimated 7-foot global rise by 2100 would imply an 8.2-foot rise in the Delaware estuary. [footnote omitted]. ***The Publicker property is located at an elevation of approximately 15-19 feet above sea level***.”

See 2014 Five-Year Report for Publicker Industries, page 10 (bold italics for emphasis).

But the oil refinery is closer to sea level, making sea level rise more of a concern. The Publicker Industries site is located at 3223 South Delaware Avenue, Philadelphia, near the Walt Whitman Bridge. *See* EPA, Superfund Site: Publicker Industries Inc. This is about three miles from the oil refinery, and it is located in the same watershed. Just as EPA considered sea level rise in the context of that matter, Evergreen should have considered sea level rise in these reports.

D. The reports do not address climate change when delineating the nature and extent of contamination.

But none of the reports contains any meaningful discussion of the impact of climate change and sea level rise on the remedial investigation.

It would not be a satisfactory response for Evergreen to assert that this is a remediation question to be addressed in the future, rather than a remedial investigation question to be addressed now. That would be a false distinction. In fact, Evergreen has made it a remedial investigation question in its reports wherever it has asserted that pathways of exposure through soil and groundwater are not complete because of on-site permit personal protective equipment (PPE) procedures:

> **7.6 Potential Migration Pathways and Site Receptors**
>
> The following summarizes potential migration pathways and site receptors for AOI 5. AOI 5 is situated within a fenced and secured area to prevent unauthorized Access.
>
> - The potential direct contact pathway to soil greater than two feet is ***deemed incomplete based on PES's on-site permit and PPE procedures which limit exposure to soil encountered in excavations***.
>
> - The potential direct contact pathway to groundwater is ***deemed incomplete based on PES's on-site permit and PPE procedures which limit exposure to groundwater that may be encountered in excavations***.

See 2017 Report (AOI-5), Section 7.6, pages 60-61. Evergreen makes similar assertions in other reports. *See e.g.*, 2016 Report (AOI-1), Section 9.6, pages 9.57-9.58, 2017 Report (AOI-2), Section 7.6, pages 48-49, 2017 Report (AOI-3), Section 7.6, pages 42-43, 2017 Report (AOI-4), Section 9.7, pages 9.55-9.56, Section 7.6, page 42, 2017 Report (AOI-6), Section 9.6, page 37, 2017 Report (AOI-7), Section 9.6, pages 39-40, 2017 Report (AOI-8), Section 10.6, pages 10.75-10.77, 2017 Report Addendum (AOI-9), Section 6.5, page 27, 2011 Report (AOI-10), Section 7.6, pages 28-29. Because the impacts of sea level rise and climate change may affect pathways of exposure, those assertions are flawed.

Evergreen has not explained how on-site permit and PPE procedures will guard against the impacts of climate change -- including sea level rise and storm surge events. The reports are deficient and they need to be revised.

11. Evergreen May Not Fragment the Remedial Investigation Reports by Diverting its Deficiencies Into a Future Fate and Transport Remedial Investigation Report.

Evergreen unfairly attempts to respond to numerous flaws in the reports (including its insufficient characterization of the unconfined aquifer and lower aquifer), by simply promising a future remedial investigation report later this year. *See* 2020 First Amendment to Consent Order and Agreement, page 5 of 77 (setting forth a deadline of December 31, 2021 for a "Fate and Transport Remedial Investigation Report"). This would allow Evergreen to fragment the remedial investigation reports into different pieces, minimizing public scrutiny and delaying its responses to public concerns. It would be fundamentally unfair.

Under Evergreen's approach, the current reports would be approved individually and considered closed, preventing any further comments on them. But later on, the public would be commenting on material that was carved out of these reports and moved into a new report. The objection would then be made that the public may not comment on matters that were previously approved, even though the material is interrelated.

This is flawed for several reasons. The public cannot meaningfully comment on soil and groundwater sampling in the current reports without having a complete analysis of the relationship between the unconfined aquifer and the deep aquifer. Also, it cannot comment on a future fate and transport analysis without considering the underlying soil and groundwater data organized by Evergreen in the current reports.

It is worth noting that the Fate and Transport Remedial Investigation Report promised by Evergreen simply appears to be nothing more than a revised report for AOI-11 that was disapproved in 2013. Nothing in the Department's review of that report compels the conclusion that the remedial investigation reports should be fragmented in the manner proposed by Evergreen. *See* 2011 Comments (AOI-11), Comment 8, 2013 Comments (AOI-11), Comments 11-19, 2013 Memorandum (AOI-11), pages 3-4, 2013 Disapproval Letter (AOI-11). The implication of the Department's disapproval was merely that Sunoco had to submit another remedial investigation report that included an approvable fate and transport analysis. The implication was not that Sunoco should fragment the remedial investigation reports for AOI-11.

In its discussion of site characterization activities in Section II of the Technical Guidance Manual, the Department emphatically recognizes that a fate and transport analysis is a part of a site characterization, and not separate from it:

> The site characterization activities conducted must result in a thorough investigation which meets the requirements of Pa. Code § 250.204. **A complete and accurate site characterization, including fate and transport analysis, and its documentation in the final report is very important, as it is the basis for making remediation decisions and is used later in identifying the appropriate area for demonstrating attainment. Except for sites involving the excavation option for petroleum-**

> **contaminated soil (see 25 Pa. Code § 250.707(b)(1)(iii)), without a proper site characterization, attainment requirements cannot be met and the final report will be disapproved by the Department.**

See DEP, Technical Guidance Manual, Section II.A.4.a, page II-11 (bold in original).

The Department reiterates this point in Section III of the Technical Guidance Manual when it discusses the purpose of a fate and transport analysis:

> **Fate and transport analysis or modeling is a necessary part of site characterization and demonstrating attainment of an Act 2 standard**. However, the Chapter 250 regulations governing Act 2 use the term “fate and transport analysis” as opposed to “fate and transport model.” This particular distinction was made because it will not always be necessary to run an analytical or numerical quantitative “fate and transport model” to achieve a standard.
>
> Whether simple or complex, any fate and transport analysis must rely on having and/or obtaining valid data. Reliable field data will be critical in supporting the professional conclusions regarding any predictions of contaminant fate and transport and needs to be considered during the site characterization.
>
> Fate and transport analysis will be used in the Act 2 process to predict contaminant concentrations migrating through the unsaturated zone and the saturated zone, including the impact of soil contamination on groundwater. It will also include an analysis of diffuse groundwater flow into surface water (e.g., a stream) for purposes of determining compliance with surface water quality standards.

See DEP, Technical Guidance Manual, Section III.A, page III-1 (bold in original, underlining added for emphasis). Because “[f]ate and transport analysis or modeling is a necessary part of site characterization,” Evergreen may not break out parts of the current remedial investigation reports to address later in a Fate and Transport Remedial Investigation Report.

The proper way to do this is all at once as Sunoco originally attempted to do in 2013 (although it did this unsuccessfully because the report for AOI-11 was deficient).

When Evergreen revises the current reports to address the multiple flaws identified throughout these comments, it should include whatever fate and transport analysis it has been preparing since it submitted its last report over three years ago. Everything should be republished for another public comment period before submission to the Department.

12. Evergreen Fails to Sufficiently Delineate Exceedances of the Soil-to-Groundwater Numeric Value and the Direct Contact Numeric Value for All Constituents of Concern.

Throughout the reports, Evergreen looked for contamination at a distance with a telescope, rather than close-up with a magnifying glass. It conformed its discussion of exceedances to an expectation that it would have to meet less stringent cleanup levels, rather than more stringent cleanup levels. To illustrate, it focused its efforts on delineating lead contamination in surface soils with respect to a direct contact numeric value (1000 mg/kg) and a proposed site-specific standard (initially 1708 mg/kg, and later 2240 mg/kg), while marginalizing and at times even obliterating a discussion of the soil-to-groundwater numeric value (450 mg/kg).

To the extent that data regarding exceedances of the more stringent soil-to-groundwater numeric value are included in the reports, they are buried in dense tables and highlighted as many as three times to reflect three different numeric values being exceeded at the same time. This does not provide a clear delineation of the contamination for the public. The public is entitled to a picture of what the contamination looks like from the perspective of different numeric values.

There is no discussion of whether the soil-to-groundwater numeric value prevails over the direct contact numeric value in setting the Medium-Specific Concentration, which is particularly problematic because the water table is less than ten feet from the surface of the ground in areas of the site, necessitating the use of the soil-to-groundwater numeric value.

Evergreen does not provide an adequate explanation as to why it believes the contamination has been delineated. Often its summary conclusion is based on the assertion that it found a certain number of exceedances of the proposed site-specific standard, which is insufficient.

A statement of policy in Act 2 recognizes the importance of the public understanding how remediation standards are applied at a site:

> ***The public is entitled to understand how remediation standards are applied to a site*** through a plain language description of contamination present on a site, the risk it poses to public health and the environment and any proposed cleanup measure.

See Act 2, §102(9) (bold italics added for emphasis), 35 P.S. §6026.102(9) (same, in unofficial statute). In the case, Evergreen does not sufficiently explain the interplay between the soil-to-groundwater numeric value and the direct contact numeric value.

A. Under the regulations, a Medium-Specific Concentration is defined by the lower of the soil-to-groundwater numeric value or the direct contact numeric value, unless the responsible party makes a soil-to-groundwater pathway equivalency determination.

For surface soils (0-2 feet), the MSC is determined by the lowest of three numbers, one of which is the soil-to-groundwater pathway numeric value:

> (d) ***For the nonresidential standard***, the MSC for regulated substances contained ***in soil throughout the soil column to a depth of 2 feet from the existing ground surface*** is one of the following:
>
> (1) ***The lowest of the following***:
>
> (i) ***The ingestion numeric value as determined by the methodology in § 250.306***, using the appropriate default nonresidential exposure assumptions contained in § 250.306(e).
>
> (ii) ***The inhalation numeric value*** which is the lower of the values for volatilization into the outdoor air and the inhalation of particulates, ***as determined by the methodology in § 250.307***, using the appropriate default nonresidential exposure assumptions contained in § 250.307(d).
>
> (iii) ***The soil-to-groundwater pathway numeric value throughout the entire soil column as determined by the methodology in § 250.308***.

See 25 Pa. Code §250.308(d)(1) (bold italics added for emphasis). The other two numbers are the ingestion numeric value under §250.306 and the inhalation numeric value under 250.307. *See id.* Tables 3A (organics) and 4A (inorganics) in Appendix A list the other values (in the form of the direct contact numeric value) for each contaminant). *See id.*

A responsible party can avoid the soil-to-groundwater numeric value under paragraph (1)(iii), but only if it provides either a demonstration of a soil buffer or an equivalency demonstration:

> (2) ***The lowest of paragraph (1)(i) or (ii) and***, in addition, ***one of the following***:
>
> (i) ***A demonstration of the soil-to-groundwater pathway soil buffer*** as identified in § 250.308(b), if applicable.

> (ii) ***A soil-to-groundwater pathway equivalency demonstration*** as identified in § 250.308(d).

See id., 25 Pa. Code §250.308(d)(2) (bold italics added for emphasis).

The first cross-referenced section requires the identification of a soil buffer that meets a vertical distance value set forth in a Table in the regulations, as well as other requirements:

> (b) ***The soil-to-groundwater pathway soil buffer is the entire area between the bottom of the area of contamination and the groundwater or bedrock*** and ***shall meet the following criteria***:
>
> (1***) The soil depths established in Appendix A, Tables 3B and 4B*** for each regulated substance.
>
> (2) The ***concentration*** of the regulated substance ***cannot exceed the limit related to the PQL or background*** throughout the soil buffer.
>
> (3) No Karst carbonate formation underlies or is within 100 feet of the perimeter of the contaminated soil area.

See id., 25 Pa. Code §250.308(b) (bold italics added for emphasis). This means that the responsible party must look at Table 3B (setting forth soil buffer distances for organics) and Table 4B (setting forth soil buffer distances for inorganics), to compare with the depth of the soil sample.

In other words, assuming the soil-to-groundwater numeric value is the lowest of the three numbers in Section 306(d)(1), a responsible party must guide its soil samples according to the soil-to-groundwater numeric value or according to the PQL or background.

The second cross-referenced section allows the substitution of an equivalency demonstration if the groundwater is below the Medium-Specific Concentration or the background standard prior to remediation:

> (d) For any regulated substance, ***an equivalency demonstration may be substituted*** for the soil-to-groundwater numeric value throughout the site and the soil-to-groundwater pathway soil buffer ***if the groundwater is below the MSC value or the background standard prior to remediation***. This equivalency demonstration shall include the following:
>
> (1) ***Fate and transport analysis*** of the regulated substance from the deepest point of contamination in the soil through unsaturated zone soil ***and shall include the use of soil-to-water partition***

> ***coefficients***. The analysis ***shall demonstrate that the regulated substances will not migrate to bedrock or the groundwater within 30 years at concentrations exceeding the greater of the groundwater MSC or background groundwater*** as the endpoint in soil pore water directly under the site.
>
> (2) In addition to sampling required for attainment of the inhalation or ingestion numeric values for soils up to 15 feet, as applicable, **reporting and monitoring for eight quarters that shows no exceedances of the greater of the groundwater MSCs or of the background standard f**or groundwater beneath the contaminated soil and no indications of an increasing trend of concentration over time that may exceed the standard.

See id., 25 Pa. Code §250.308(d) (bold italics added for emphasis). To do this substitution, the responsible party would have to conduct groundwater modeling (a fate and transport analysis). In the present case, Evergreen has not performed an approvable fate and transport analysis. Therefore, this substitution is not available to Evergreen.

For subsurface soils (2-15 feet), the Medium-Specific Concentration is determined by the lowest of two numbers, one of which is the soil-to-groundwater pathway numeric value:

> (e) ***For the nonresidential standard***, the MSC for regulated substances contained ***in soils at depths greater than 2 feet through 15 feet from the existing ground surface***, is ***one of the following***:
>
> (1) ***The lowest of the following***:
>
> (i) ***The inhalation numeric value which considers volatilization to the outdoor air, as determined by the methodology in § 250.307***, using the appropriate default nonresidential exposure assumptions contained in § 250.307(d), and using a transfer factor (TF) based upon the calculated emission rate from subsurface soil as specified in the method of Jury, et al. 1990. Water Resources Research, Vol. 26, No. 1, pp. 13—20.
>
> (ii) ***The soil-to-groundwater pathway numeric value throughout the entire soil column as determined by the methodology in § 250.308***.

25 Pa. Code §250.308(e)(1) (bold italics added for emphasis). (The analysis is the same as for surface soils, except for the fact that the ingestion numeric value is not considered).

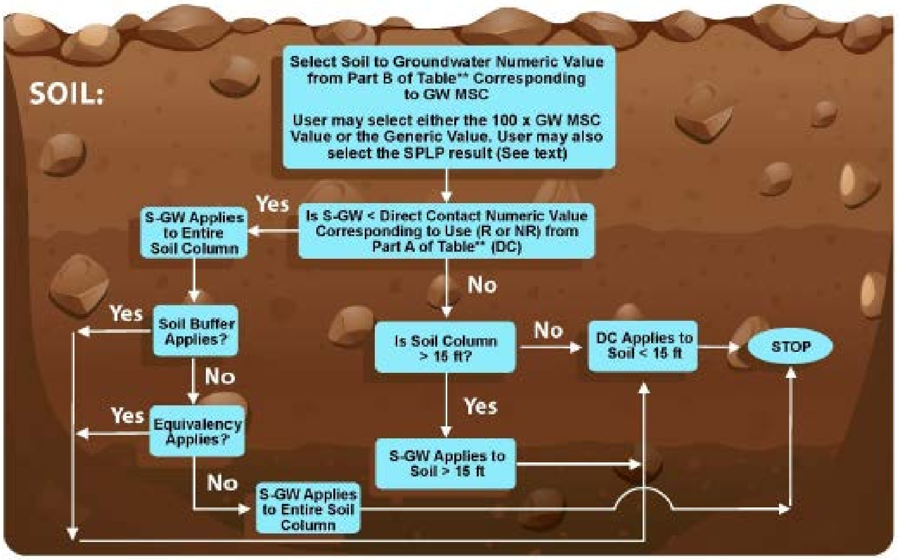
As in the case with surface soils, a responsible party can avoid the soil-to-groundwater numeric value under paragraph (e)(1)(ii), but only if it provides the same demonstrations as discussed above for surface soils:

> (2) ***The value identified in paragraph (1)(i)*** and ***one of the following***:
>
> (i) ***A demonstration of the soil-to-groundwater pathway soil buffer*** as identified in § 250.308(b), if applicable.
>
> (ii) ***A soil-to-groundwater pathway equivalency demonstration*** as identified in § 250.308(d).

25 Pa. Code §250.308(e)(2) (bold italics added for emphasis).

The Technical Guidance Manual confirms this analysis:

Figure II-11: Decision Tree for Selecting Statewide Health Standard MSCs for Groundwater and Soil



* For Organic Regulated Substances, use Table 1; Use Table 2 for Inorganic Regulated Substances

** For Organic Regulated Substances, use Table 3; Use Table 4 for Inorganic Regulated Substances

Note: Figure must be used in conjunction with the text. Reference Section II.B.2.c)

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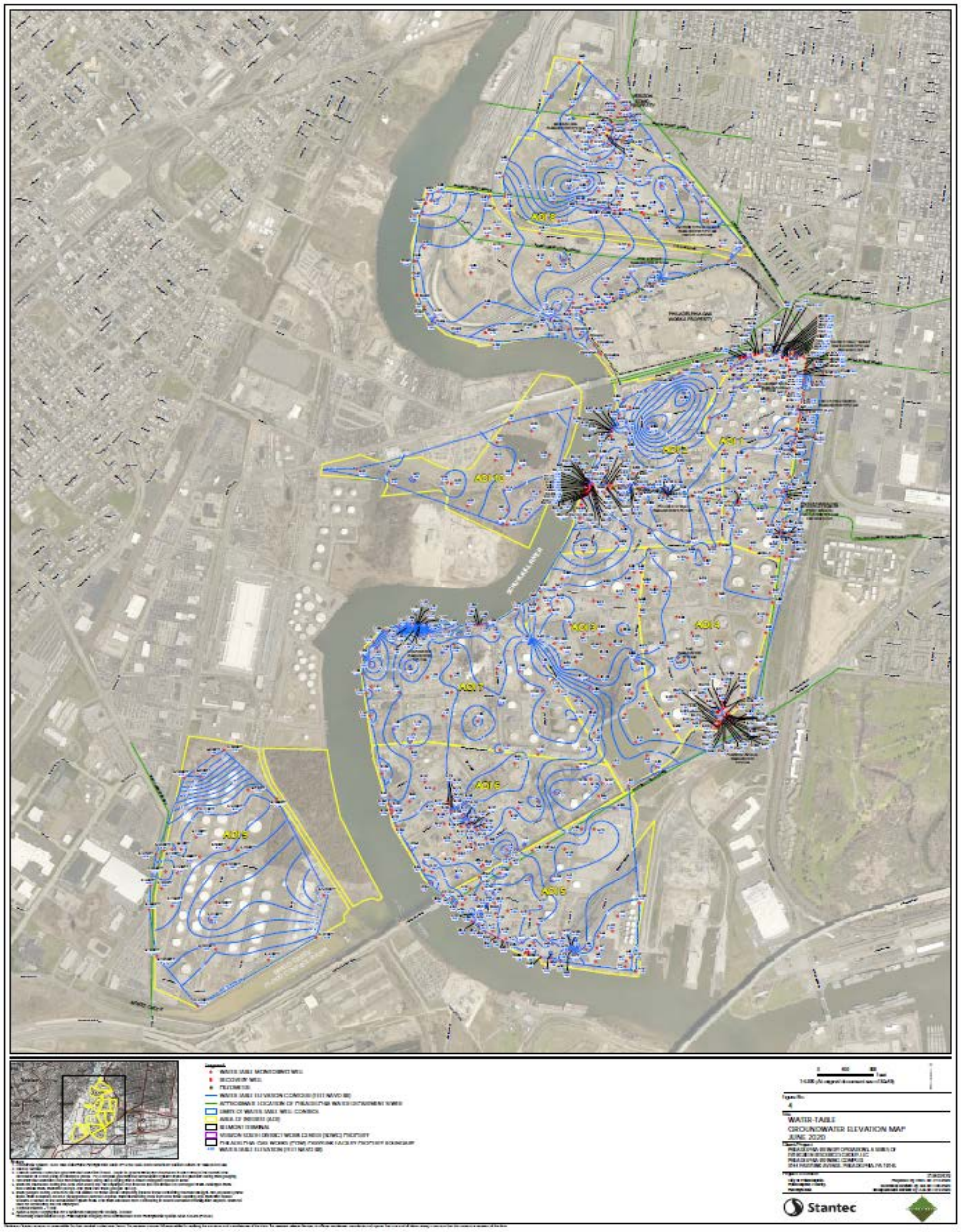
Technical Guidance Manual, page II-52.

B. <u>Because areas of the refinery site have a high water table, Evergreen must compare the soil buffer distance for each Constituent of Concern with the depth of each soil sample, to determine whether the soil-to-groundwater numeric value or the direct contact numeric value defines the Medium-Specific Concentration</u>.

According to a recent groundwater remediation status report, much of the site appears to have a high water table:

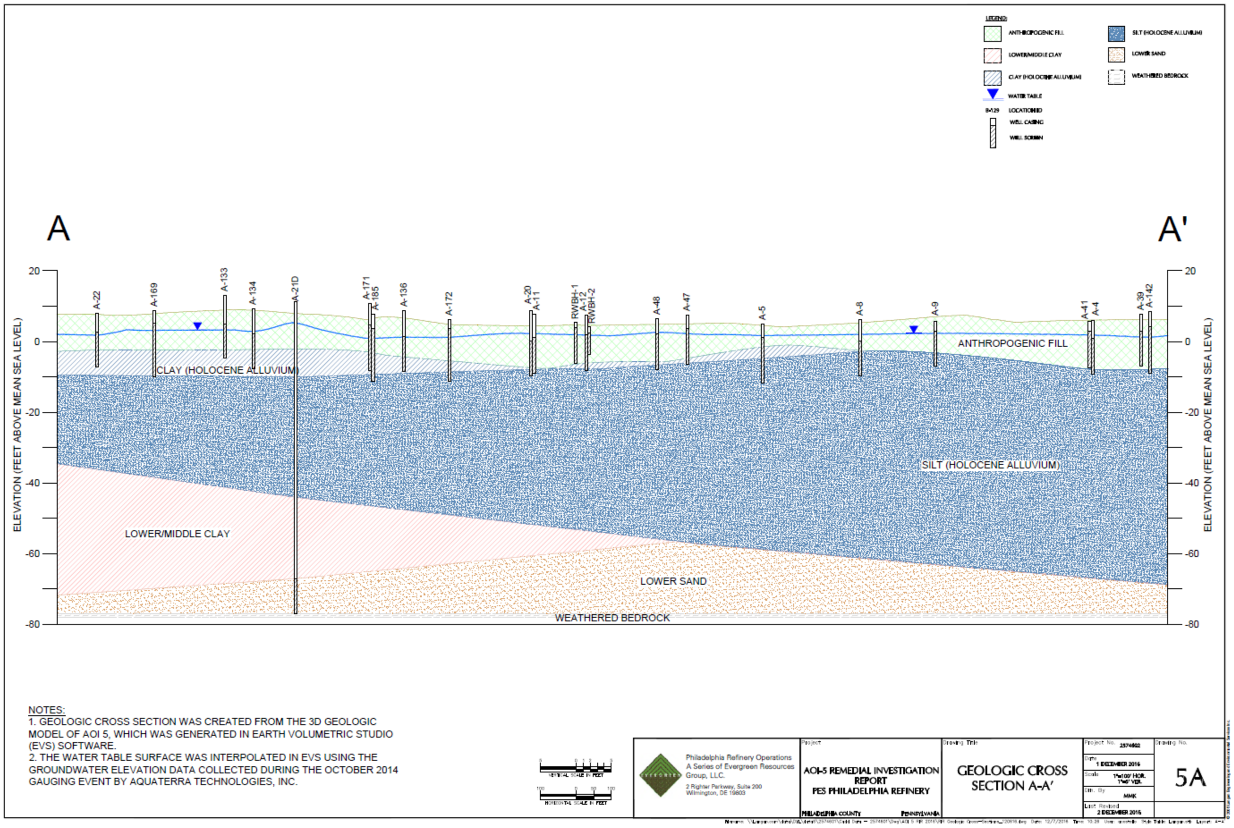


See Semi-Annual Remediation Status Report (June 2020), Figure 4 (Water-Table Groundwater Elevation Map). But the groundwater elevations on this contour map do not literally display the depth to groundwater from the surface, for two reasons. First, the map is defined by reference to sea level, and not all of the site is located exactly at sea level. Second, not all of the site is exactly flat.

Instead, one must look to other evidence to ascertain the depth to the water table from the surface. Evergreen has provided geologic cross sections for all Areas of Interest. To illustrate with respect to AOI-5, the following Figure from the 2017 report identifies two cross sections -- an A-A' cross section generally running from west to east (in pink), and a B-B' cross section generally running from north to south (in green):

2017 Report (AOI-5), Figure 4 (Geologic Cross Section Location Plan).

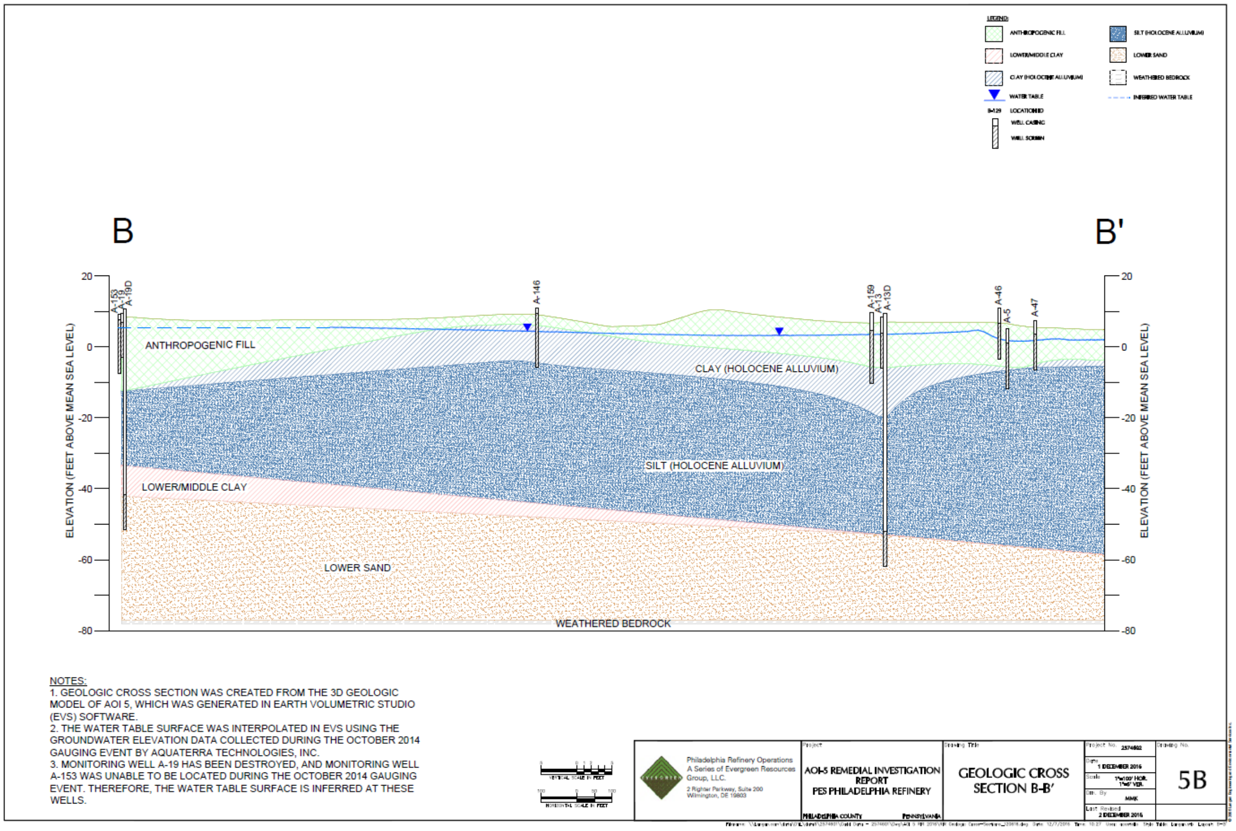
The following Figure displays a side view of cross section A-A', looking from the south toward the north. Throughout all of this cross section, the distance between the yellow line at the top (the surface) and the blue line below (the water table) is less than ten feet:



NOTES:
1. GEOLOGIC CROSS SECTION WAS CREATED FROM THE 3D GEOLOGIC MODEL OF AOI 5, WHICH WAS GENERATED IN EARTH VOLUMETRIC STUDIO (EVS) SOFTWARE.
2. THE WATER TABLE SURFACE WAS INTERPOLATED IN EVS USING THE GROUNDWATER ELEVATION DATA COLLECTED DURING THE OCTOBER 2014 GAUGING EVENT BY AQUATERRA TECHNOLOGIES, INC.

See id., Figure 5A: Geologic Cross Section A-A'.

The other cross section B-B' tells a similar story. The following Figure displays a side view of this cross section, looking from the west toward the east. Throughout all the cross section, the distance between the yellow line at the top (the surface) and the blue line below (the water table) is less than ten feet:



NOTES:
1. GEOLOGIC CROSS SECTION WAS CREATED FROM THE 3D GEOLOGIC MODEL OF AOI 5, WHICH WAS GENERATED IN EARTH VOLUMETRIC STUDIO (EVS) SOFTWARE.
2. THE WATER TABLE SURFACE WAS INTERPOLATED IN EVS USING THE GROUNDWATER ELEVATION DATA COLLECTED DURING THE OCTOBER 2014 GAUGING EVENT BY AQUATERRA TECHNOLOGIES, INC.
3. MONITORING WELL A-19 HAS BEEN DESTROYED, AND MONITORING WELL A-153 WAS UNABLE TO BE LOCATED DURING THE OCTOBER 2014 GAUGING EVENT. THEREFORE, THE WATER TABLE SURFACE IS INFERRED AT THESE WELLS.

See id., Figure 5B: Geologic Cross Section B-B'.

Despite this graphical evidence, Evergreen did not delineate the contamination in the 2017 report for AOI-5 according to the soil-to-groundwater numeric value. Rather, it delineated it according to the direct contact numeric value and the proposed site-specific value. (See discussion below). Evergreen does not provide a justification for this, and there does not appear to be one.

While Evergreen did use the soil-to-groundwater numeric value as a guide for some soil sampling for AOI-5, it did this for the limited purpose of making a hazardous waste determination under the Toxicity Characteristic Leaching Procedure (TCLP) for the management of hazardous waste under the Resource Conservation and Recovery Act (RCRA). (Once contamination is removed, it becomes waste if it is intended to be disposed). The purpose appears to have been simply to establish some criterion for limiting the amount of waste for consideration as hazardous waste. But Evergreen did not do this for all soil samples. This is insufficient to delineate contamination for these reports under Act 2.

A similar analysis may be performed for the other Areas of Interest. The following chart summarizes the geologic cross sections in the reports, and shows there are certain points where the depth to the water table is less than ten feet from the surface:

Area of Interest	**Title**	**Clean Air Council's Analysis of Evergreen's Geologic Cross Sections**
AOI-1 Point Breeze No. 1 Tank Farm	2016 Report (part 1)	Figure 5-1, 5-2 (suggesting water table is less than 10 feet below surface at certain points along cross sections)
AOI-2 Point Breeze Processing Area	2017 Report (part 1) (approved)	Figure 5, 6 (suggesting water table is less than 10 feet below surface at certain points along cross sections)
AOI 3 Point Breeze Impoundment Area	2017 Report (approved)	Figure 5, 6 (suggesting water table is less than 10 feet below surface at certain points along cross sections)
AOI-4 No. 4 Tank Farm	2013 Report (disapproved) 2017 Report (Figures) (disapproved)	Figure 5 (failing to show water table depth in cross section) Figures 2.6, 2.7. 2.8 (failing to show water table depth in cross sections)
AOI-5 Girard Point South Tank Field	2011 Report/Cleanup Plan (disapproved) 2017 Report (approved)	Figure 5 (failing to show water table depth in cross section) Figure 5A, 5B (suggesting water table is less than 10 feet below surface at certain points along cross sections)
AOI-6 Girard Point Chemicals Area	2013 Report (disapproved) 2017 Report (approved)	Figures 5, 6 (failing to show water table depth in cross section) Figure 8 (failing to show water table depth in cross section, apart from Schuylkill River)
AOI-7 Girard Point Fuels Area	2012 Report (disapproved) 2013 Addendum to Report (disapproved)	Figure 5A, 5B, 5C (suggesting water table is less than 10 feet below surface at certain points along cross sections) (not providing a geologic cross-section)

	2017 Report (approved)	Figure 8 (failing to show water table depth in cross section, apart from Schuylkill River)
AOI-8 North Yard	2012 Report 2012 Report (part 2) (approved) 2017 Report 2017 Report (part 2) (approved)	Figures 5a, 5b, 5C (failing to show water table depth in cross sections) Figures 2-6, 2-7, 2-8, 2-9, 2-10 (suggesting water table is less than 10 feet below surface at certain points along cross sections)
AOI-9 Schuylkill River Tank Farm	2015 Report (disapproved) 2017 Report Addendum (approved)	Figure 6A, 6B (suggesting water table is less than 10 feet below surface at certain points along cross sections) Figure 6a, 6b (suggesting water table is less than 10 feet below surface at certain points along cross sections)
AOI-10 West Yard	2011 Report (approved)	Figure 4A, 4B (suggesting water table is less than 10 feet below surface at certain points along cross sections)
AOI-11 Deep Aquifer Beneath Complex	2011 Report (part 1) 2011 Report (part 2) 2013 Report (part 1) 2013 Report (part 2) (disapproved)	Appendix D (Site Wide Geologic Cross Sections) (attaching 20 cross-sections for different Areas of Interest) Appendix C (Geologic Cross Sections) (attaching 23 cross-sections from historical reports) Appendix D (Site Wide Geologic Cross Sections) (attaching 20 cross-sections for different Areas of Interest) Appendix C (Geologic Cross Sections) (attaching 23 cross-sections from historical reports)

The regulations set forth a different buffer depth for a number of contaminants. To illustrate in the case of organics, the soil buffer distance for 1,2,4-trimethylbenzene is 15 feet and the soil buffer distance for 1,3,5-trimethylbenzene is 30 feet:

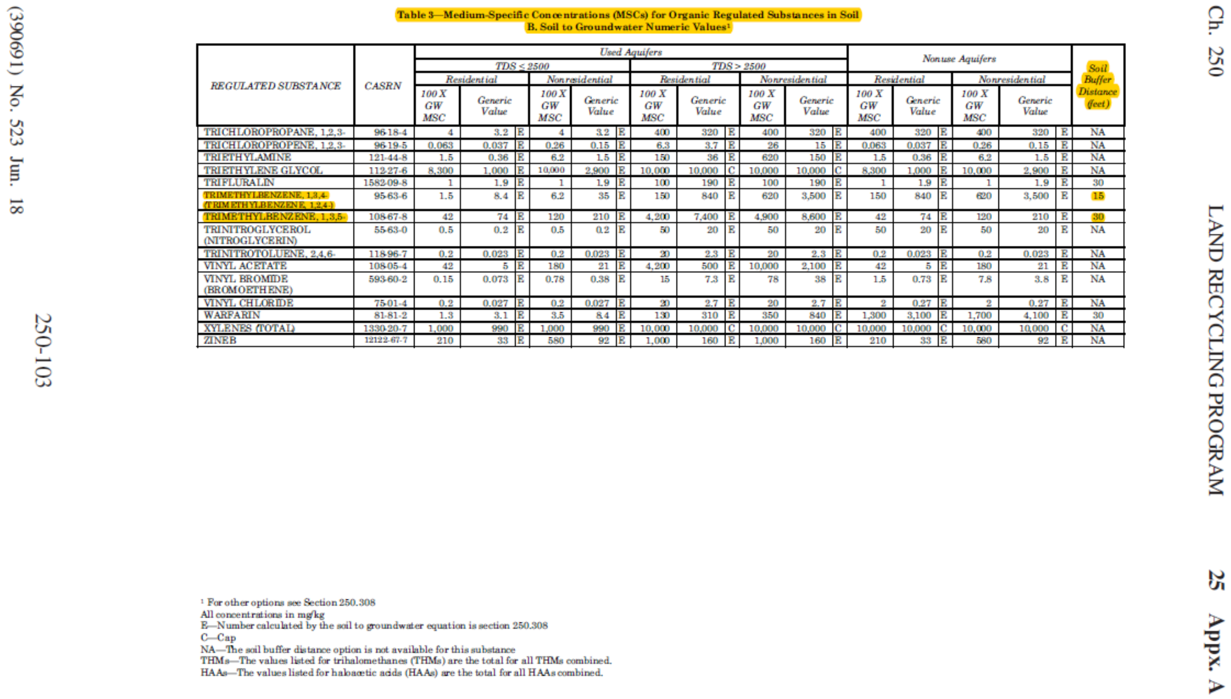


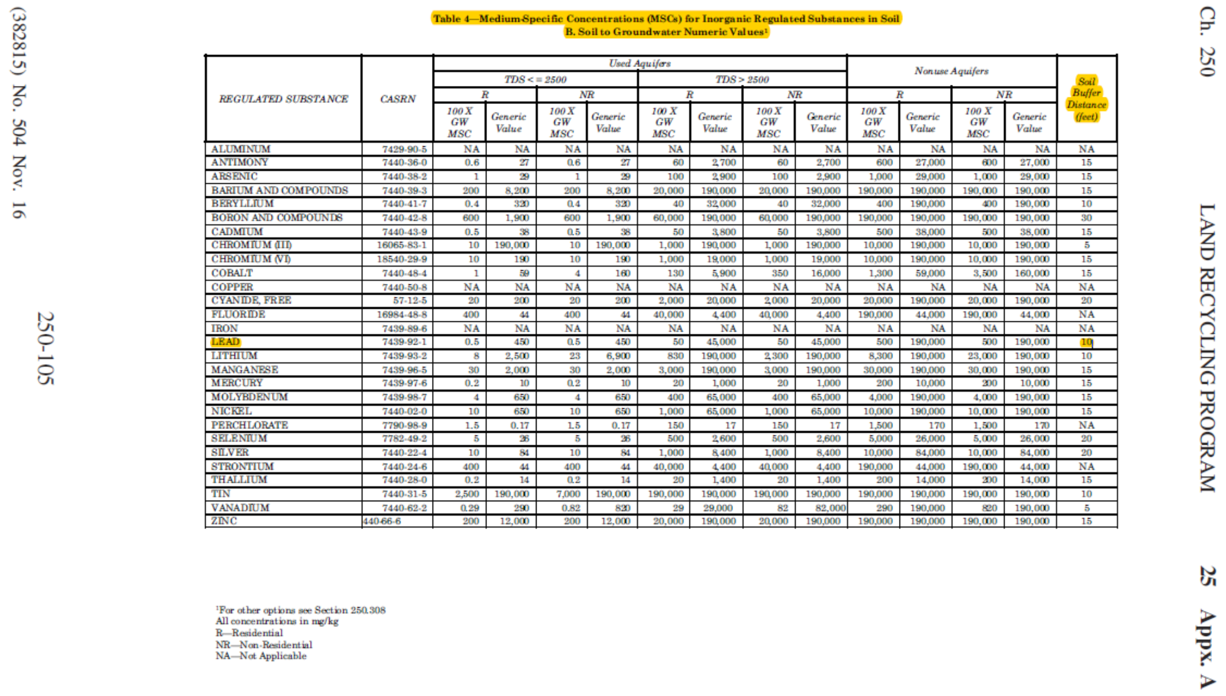
Table 3—Medium-Specific Concentrations (MSCs) for Organic Regulated Substances in Soil
B. Soil to Groundwater Numeric Values[1]

REGULATED SUBSTANCE	CASRN	Used Aquifers												Nonuse Aquifers						Soil Buffer Distance (feet)
		TDS ≤ 2500						TDS > 2500												
		Residential			Nonresidential			Residential			Nonresidential			Residential			Nonresidential			
		100 X GW MSC	Generic Value		100 X GW MSC	Generic Value		100 X GW MSC	Generic Value		100 X GW MSC	Generic Value		100 X GW MSC	Generic Value		100 X GW MSC	Generic Value		
TRICHLOROPROPANE, 1,2,3-	96-18-4	4	3.2	E	4	3.2	E	400	320	E	400	320	E	400	320	E	400	320	E	NA
TRICHLOROPROPENE, 1,2,3-	96-19-5	0.063	0.037	E	0.26	0.15	E	6.3	3.7	E	26	15	E	0.063	0.037	E	0.26	0.15	E	NA
TRIETHYLAMINE	121-44-8	1.5	0.36	E	6.2	1.5	E	150	36	E	620	150	E	1.5	0.36	E	6.2	1.5	E	NA
TRIETHYLENE GLYCOL	112-27-6	8,300	1,000	E	10,000	2,900	E	10,000	10,000	C	10,000	10,000	C	8,300	1,000	E	10,000	2,900	E	NA
TRIFLURALIN	1582-09-8	1	1.9	E	1	1.9	E	100	190	E	100	190	E	1	1.9	E	1	1.9	E	30
TRIMETHYLBENZENE, 1,3,4- (TRIMETHYLBENZENE, 1,2,4-)	95-63-6	1.5	8.4	E	6.2	35	E	150	840	E	620	3,500	E	150	840	E	620	3,500	E	15
TRIMETHYLBENZENE, 1,3,5-	108-67-8	42	74	E	120	210	E	4,200	7,400	E	4,900	8,600	E	42	74	E	120	210	E	30
TRINITROGLYCEROL (NITROGLYCERIN)	55-63-0	0.5	0.2	E	0.5	0.2	E	50	20	E	50	20	E	50	20	E	50	20	E	NA
TRINITROTOLUENE, 2,4,6-	118-96-7	0.2	0.023	E	0.2	0.023	E	20	2.3	E	20	2.3	E	0.2	0.023	E	0.2	0.023	E	NA
VINYL ACETATE	108-05-4	42	5	E	180	21	E	4,200	500	E	10,000	2,100	E	42	5	E	180	21	E	NA
VINYL BROMIDE (BROMOETHENE)	593-60-2	0.15	0.073	E	0.78	0.38	E	15	7.3	E	78	38	E	1.5	0.73	E	7.8	3.8	E	NA
VINYL CHLORIDE	75-01-4	0.2	0.027	E	0.2	0.027	E	20	2.7	E	20	2.7	E	2	0.27	E	2	0.27	E	NA
WARFARIN	81-81-2	1.3	3.1	E	3.5	8.4	E	130	310	E	350	840	E	1,300	3,100	E	1,700	4,100	E	30
XYLENES (TOTAL)	1330-20-7	1,000	990	E	1,000	990	E	10,000	10,000	C	10,000	10,000	C	10,000	10,000	C	10,000	10,000	C	NA
ZINEB	12122-67-7	210	33	E	580	92	E	1,000	160	E	1,000	160	E	210	33	E	580	92	E	NA

[1] For other options see Section 250.308
All concentrations in mg/kg
E—Number calculated by the soil to groundwater equation is section 250.308
C—Cap
NA—The soil buffer distance option is not available for this substance
THMs—The values listed for trihalomethanes (THMs) are the total for all THMs combined.
HAAs—The values listed for haloacetic acids (HAAs) are the total for all HAAs combined.

See 25 Pa. Code 250, Appendix A, Table 3B (organic regulated substances).

To illustrate in the case of inorganics (metals), the soil buffer distance for lead is 10 feet:



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LAND RECYCLING PROGRAM

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Appx. A

Table 4—Medium-Specific Concentrations (MSCs) for Inorganic Regulated Substances in Soil
B. Soil to Groundwater Numeric Values[1]

REGULATED SUBSTANCE	CASRN	Used Aquifers								Nonuse Aquifers				Soil Buffer Distance (feet)
		TDS < = 2500				TDS > 2500								
		R		NR		R		NR		R		NR		
		100 X GW MSC	Generic Value	100 X GW MSC	Generic Value	100 X GW MSC	Generic Value	100 X GW MSC	Generic Value	100 X GW MSC	Generic Value	100 X GW MSC	Generic Value	
ALUMINUM	7429-90-5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
ANTIMONY	7440-36-0	0.6	27	0.6	27	60	2,700	60	2,700	600	27,000	600	27,000	15
ARSENIC	7440-38-2	1	29	1	29	100	2,900	100	2,900	1,000	29,000	1,000	29,000	15
BARIUM AND COMPOUNDS	7440-39-3	200	8,200	200	8,200	20,000	190,000	20,000	190,000	190,000	190,000	190,000	190,000	15
BERYLLIUM	7440-41-7	0.4	320	0.4	320	40	32,000	40	32,000	400	190,000	400	190,000	10
BORON AND COMPOUNDS	7440-42-8	600	1,900	600	1,900	60,000	190,000	60,000	190,000	190,000	190,000	190,000	190,000	30
CADMIUM	7440-43-9	0.5	38	0.5	38	50	3,800	50	3,800	500	38,000	500	38,000	15
CHROMIUM (III)	16065-83-1	10	190,000	10	190,000	1,000	190,000	1,000	190,000	10,000	190,000	10,000	190,000	5
CHROMIUM (VI)	18540-29-9	10	190	10	190	1,000	19,000	1,000	19,000	10,000	190,000	10,000	190,000	15
COBALT	7440-48-4	1	59	4	160	130	5,900	350	16,000	1,300	59,000	3,500	160,000	15
COPPER	7440-50-8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CYANIDE, FREE	57-12-5	20	200	20	200	2,000	20,000	2,000	20,000	20,000	190,000	20,000	190,000	20
FLUORIDE	16984-48-8	400	44	400	44	40,000	4,400	40,000	4,400	190,000	44,000	190,000	44,000	NA
IRON	7439-89-6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
LEAD	7439-92-1	0.5	450	0.5	450	50	45,000	50	45,000	500	190,000	500	190,000	10
LITHIUM	7439-93-2	8	2,500	23	6,900	830	190,000	2,300	190,000	8,300	190,000	23,000	190,000	10
MANGANESE	7439-96-5	30	2,000	30	2,000	3,000	190,000	3,000	190,000	30,000	190,000	30,000	190,000	15
MERCURY	7439-97-6	0.2	10	0.2	10	20	1,000	20	1,000	200	10,000	200	10,000	15
MOLYBDENUM	7439-98-7	4	650	4	650	400	65,000	400	65,000	4,000	190,000	4,000	190,000	15
NICKEL	7440-02-0	10	650	10	650	1,000	65,000	1,000	65,000	10,000	190,000	10,000	190,000	15
PERCHLORATE	7790-98-9	1.5	0.17	1.5	0.17	150	17	150	17	1,500	170	1,500	170	NA
SELENIUM	7782-49-2	5	26	5	26	500	2,600	500	2,600	5,000	26,000	5,000	26,000	20
SILVER	7440-22-4	10	84	10	84	1,000	8,400	1,000	8,400	10,000	84,000	10,000	84,000	20
STRONTIUM	7440-24-6	400	44	400	44	40,000	4,400	40,000	4,400	190,000	44,000	190,000	44,000	NA
THALLIUM	7440-28-0	0.2	14	0.2	14	20	1,400	20	1,400	200	14,000	200	14,000	15
TIN	7440-31-5	2,500	190,000	7,000	190,000	190,000	190,000	190,000	190,000	190,000	190,000	190,000	190,000	10
VANADIUM	7440-62-2	0.29	290	0.82	820	29	29,000	82	82,000	290	190,000	820	190,000	5
ZINC	440-66-6	200	12,000	200	12,000	20,000	190,000	20,000	190,000	190,000	190,000	190,000	190,000	15

[1] For other options see Section 250.308
All concentrations in mg/kg
R—Residential
NR—Non-Residential
NA—Not Applicable

See id., Table 4B (inorganic regulated substances).

Because the geologic cross sections indicate a water table less than ten feet from the surface in areas of the refinery site, Evergreen should have identified the soil buffer distance listed in Table 3B and Table 4B for each contaminant and compared it with the depth of groundwater (namely, the number of feet below the surface at which groundwater is present). Only if Evergreen can satisfy the soil buffer distance test or provide a sufficient equivalency demonstration, can it use the direct contact numeric value to determine the Medium-Specific Concentration.

But Evergreen did not incorporate this analysis into the reports. It should revise the reports to correct this deficiency.

C. Constituents of Concern have soil buffer distances of 5 feet, 10 feet, 15 feet, and 30 feet, potentially causing the soil-to-groundwater numeric value to determine the Medium-Specific Concentration.

In the reports, Evergreen identifies Constituents of Concern for soil sampling and groundwater sampling. *See e.g.*, 2017 Report (AOI-7) (Table 1, "Constituents of Concern"). The following Table (prepared by the Council, not Evergreen) identifies the soil-to-groundwater numeric values and direct contact numeric values referenced by Evergreen.

There are two values that may be used to establish the soil-to-groundwater numeric value. One is based on 100 times the MSC for groundwater. Another is based on generic value calculations. The one used by Evergreen is highlighted in green. For each Constituent of Concern, the soil-to-groundwater numeric value used by Evergreen is lower than the direct contact numeric value.

In addition, the Table identifies the soil buffer distances corresponding to the Constituents of Concern, and they range from 5 feet (for chrysene) to 30 feet (for naphthalene).

All values in these tables are listed in the regulations as of January 14, 2021, and do not include proposed values in the Department's pending Act 2 rulemaking.

Volatile Organic Compounds (VOCs)
(Prepared by Clean Air Council)

Constituent of Concern	**Nonresidential Surface (0-2ft) soil MSC (mg/kg)**	**Buffer depth (ft)**	**Soil to groundwater 100*GW MSC (mg/kg)**	**Soil to groundwater generic value (mg/kg)**
1,2-Dichloroethane (CAS 107-06-2)	**86 (85)**	NA	**0.5**	0.1
1,2,4-Trimethylbenzene (CAS 95-63-6)	**560 (4700)**	15	6.2(53)	**35 (300)**
1,3,5-Trimethylbenzene (CAS 108-67-8)	**10,000 (4700)**	30	120(53)	**210 (93)**
Benzene (CAS 71-43-2)	**290 (280)**	NA	**0.5**	0.13
Cumene (CAS 98-82-8)	**7700 (7600)**	15	350	**2500**
Ethylbenzene (CAS 100-41-4)	**890 (880)**	NA	**70**	46
Ethylene Dibromide (EDB) (CAS 106-93-4)	**3.7**	NA	**0.005**	0.0012

Methyl Tertiary Butyl Ether (CAS 1634-04-4)	**8600/(8500)**	NA	**2**	0.28
Toluene (CAS 108-88-3)	**10,000**	NA	**100**	44
Xylene (Total) (CAS 1330-20-7)	**8000 (7900)**	NA	**1000**	990

Semivolatile Organic Compounds (VOCs)
(Prepared by Clean Air Council)

Constituent of Concern	**Nonresidential Surface soil MSC (mg/kg)**	**Buffer depth (ft)**	**Soil to groundwater 100*GW MSC (mg/kg)**	**Soil to groundwater generic value (mg/kg)**
Anthracene (CAS 120-12-7)	**190,000**	10	6.6	**350**
Benzo(a)anthracene (CAS 56-55-3)	**130**	5	0.49(0.39)	**430 (340)**
Benzo(a)pyrene (CAS 50-32-8)	**12 (91)**	5	0.02	**46**
Benzo(b)fluoranthene (CAS 205-99-2)	**76**	5	0.12	**170**
Benzo(g,h,i)perylene (CAS 191-24-2)	**190,000**	5	0.026	**180**
Chrysene (CAS 218-01-9)	**760**	5	0.19	**230**
Fluorene (CAS 86-73-7)	**130,000**	15	190	**3800**
Naphthalene (CAS 91-20-3)	**760/(66)**	30	10	**25**
Phenanthrene (CAS 85-01-8)	**190,000**	10	110	**10,000**
Pyrene (CAS 129-00-0)	**96,000**	10	13	**2200**

For areas where the water table is less than thirty feet from the surface, the Medium-Specific Concentration for the following Constituents of Concern may have to be set by the soil-to-groundwater numeric value:

1. 1,3,5-Trimethylbenzene (soil buffer distance of 30 feet).

For any areas where the water table is less than fifteen feet from the surface, the Medium-Specific Concentration for the following Constituents of Concern may have to be set by the soil-to-groundwater numeric value:

1. 1,2,4-Trimethylbenzene (soil buffer distance of 15 feet),
2. 1,3,5-Trimethylbenzene (soil buffer distance of 30 feet),
3. Cumene (soil buffer distance of 15 feet),
4. Fluorene (soil buffer distance of 15 feet), and
5. Naphthalene (soil buffer distance of 15 feet).

For any areas where the water table is less than ten feet from the surface, the Medium-Specific Concentration for the following Constituents of Concern may have to be set by the soil-to-groundwater numeric value:

1. Anthracene (soil buffer distance of 10 feet),
2. Phenanthrene (soil buffer distance of 10 feet), and
3. Pyrene (soil buffer distance of 10 feet).

For any areas where the water table is less than five feet from the surface, Evergreen should have used the soil-to-groundwater numeric value to determine the Medium-Specific Concentration for the following contaminants:

1. Benzo(a)anthracene (soil buffer distance of 5 feet),
2. Benzo(a)pyrene (soil buffer distance of 5 feet),
3. Benzo(b)fluoranthene (soil buffer distance of 5 feet),
4. Benzo(g,h,i)perylene (soil buffer distance of 5 feet), and
5. Chrysene (soil buffer distance of 5 feet).

But the reports do not include an analysis of soil buffer distances and their role in determining the Medium-Specific Concentration. When it revises the reports, Evergreen should be including a sufficient analysis.

D. Although Evergreen appears to have used the soil-to-groundwater numeric value to determine the Medium-Specific Concentration in some instances, it did not do this as a matter of course.

In the narrative text of the reports, when Evergreen identifies exceedances of the soil-to-groundwater numeric value, it is merely pointed to data tables. Evergreen does not provide an analysis of exceedances of this value or even identify the number of these exceedances in the narrative text. Rather, it shifts to the direct contact numeric value and the site-specific standard to delineate the contamination.

The following tables illustrate how Evergreen did this:

AOI-1: Point Breeze No. 1 Tank Farm

Title	Analysis of Evergreen's Tables	Analysis of Evergreen's Textual Narrative
2016 Report (part 1) 2016 Report (part 2) (approved)	Table 3-2 (historical, statewide health standards) (identifies only the MSC (apparently determined by the lower of the soil-to-groundwater numeric value or the direct contact numeric value), and highlights exceedances in orange) Table 3-3 (historical, characterization soil screening levels) (identifies only the direct contact numeric values for surface soils and subsurface soils (although the proposed site-specific standard for lead is substituted), and highlights exceedances in orange)	Section 3.5, page 3.25-3.26 (delineating only with respect to the direct contact numeric value and the proposed site-specific standard) Section 9.3.1, page 9.52 (vague summary does discuss exceedances of the soil-to-groundwater numeric value)

AOI-2: Point Breeze Processing Area

Title	Analysis of Evergreen's Tables	Analysis of Evergreen's Textual Narrative
2017 Report (part 1) 2017 Report (part 2) (approved)	Table 4 (identifies both the soil-to-groundwater numeric value and the direct contact numeric value (although it substitutes the proposed site-specific standard for the direct contact numeric value for lead), and highlights exceedances of each in different ways in the Table)	Section 5.1, page 31 (delineating only exceedances of the direct contact numeric value and the proposed site-specific standard, and not delineating exceedances of the soil-to-groundwater numeric value) Section 11.1, page 53 (asserting in a circular fashion that "[a]ny soils that exhibited exceedances of the soil-to-groundwater MSCs the corresponding soil-to-groundwater pathway will be

		evaluated through analysis and characterization of the groundwater pathway”)

AOI 3: Point Breeze Impoundment Area

Title	Analysis of Evergreen’s Tables	Analysis of Evergreen’s Textual Narrative
2017 Report (part 1) 2017 Report (part 2) (approved)	Table 4 (identifies only the direct contact numeric value (although it substitutes the proposed site-specific standard for the direct contact numeric value for lead), and highlights exceedances of this value in the Table).	Section 3.1, pages 18-19 (delineating only exceedances of the direct contact numeric value and the proposed site-specific standard, and not delineating exceedances of the soil-to-groundwater numeric value) Section 11.0, page 46 (dismissing the soil-to-groundwater pathway and using the confusing term “direct-contact pathway,” asserts that “[w]ith regard to the potential direct-contact pathway to subsurface soil within AOI 3 (i.e., greater than 2 feet deep) and the soil-to-groundwater pathway, the direct contact pathway to soil greater than 2 feet beneath the ground surface at the Complex is considered incomplete because of on-site procedures and PPE requirements that protect onsite workers from exposure.”)

Table 4 of the 2017 report obliterates any consideration of the soil-to-groundwater numeric value**.**

AOI-4: No. 4 Tank Farm

Title	Analysis of Evergreen’s Tables	Analysis of Evergreen’s Textual Narrative
2013 Report (disapproved)	Table 4 (identifies both the soil-to-groundwater numeric value and the direct contact numeric value, and	Section 5.2, page 18 (asserting that “1,2,4-TMB, 1,3,5-TMB, benzene, and lead exceeded their respective

	also identifies the MSC (determined by the lower of the soil-to-groundwater numeric value or the direct contact numeric value), and highlights exceedances of all three in Table).	non-residential MSCs," but not identifying how many soil samples had exceedances, which soil samples had exceedances, what was the numeric value used to determine the exceedances, or what was the extent of the exceedance of the numeric value) Section 12.0, page 35 (asserting that "[c]oncentrations of benzene, 1,2,4-TMB, 1,3,5-TMB, and lead detected in soil samples collected in AOI 4 were above their respective PADEP non-residential soil MSCs"), but not identifying how many soil samples had exceedances, which soil samples had exceedances, what was the numeric value used to determine the exceedances, or what was the extent of the exceedance of the numeric value)
2017 Report (part 1) 2017 Report (part 2) (disapproved)	Table 3-2 (statewide health standards) identifies only the MSC (apparently determined by the lower of the soil-to-groundwater numeric value or the direct contact numeric value), and highlights exceedances in orange). Table 3-3 (direct contact MSCs) (identifies only the direct contact numeric value for surface soil and subsurface soil (although it substitutes the proposed site-specific standard for lead), and highlights exceedances in orange).	Section 3.6, pages 22-23 (delineating only exceedances of the direct contact numeric value and the proposed site-specific standard, but in passing it mentions several exceedances of the soil-to-groundwater numeric value, while apparently neglecting the exceedance of 494 mg/kg for BH-13-101) Section 13.1, page 13.72 (delineating only exceedances of the direct contact numeric value and the proposed site-specific standard, by asserting that "[c]oncentrations of COCs in all other collected soil samples (including subsurface soil) were below the highest of the SHS, the non-residential direct contact MSC, or the numeric lead SSS.").

The 2013 report is extremely confusing because the same listed concentration may be highlighted in bold (with reference to one value), underlining (with reference to another value), or gray (with reference to yet another value) -- or a combination of several methods of highlighting.

The approach of the 2017 report is like the approach for the AOI-1 report.

Spot-checking data reveals the omission of an exceedance in the narrative for the exceedance of 494 mg/kg for BH-13-101.

In addition to checking the data in these reports again, Evergreen should prepare separate maps showing the locations of exceedances -- one for the soil-to-groundwater numeric value, one for the direct contact numeric value, and one for the proposed site-specific standard. This way, the public will have a better context for visualizing and understanding the data and its implications for delineating the extent of the contamination.

AOI-5: Girard Point South Tank Field

Title	Analysis of Evergreen's Tables	Analysis of Evergreen's Textual Narrative
2011 Report/Cleanup Plan (disapproved)	Table 4 (outside Solid Waste Management Unit (SWMU) areas) (identifies both the soil-to-groundwater numeric value and the direct contact numeric value, and highlights exceedances of each) Table 5 (SWMU areas) (identifies both the soil-to-groundwater numeric value and the direct contact numeric value, and highlights exceedances of each)	Section 5.0, pages 20-24, Figure 8 (attempts to delineate for both the soil-to-groundwater numeric value and the direct contact numeric value, for both non-SWMU areas and SWMU areas) Section 13.0, pages 36, 47-48 (attempts to delineate only for a calculated site-specific standard for lead of 1708 mg/kg)
2017 Report (part 1) 2017 Report (part 2) (approved)	Table 4 (identifies only the direct contact numeric value (although it substitutes the proposed site-specific standard for the direct contact numeric value for lead), and highlights exceedances of this value.	Section 5.1, 5.3, pages 19, 38-45, Figure 8 (legend) (attempting to delineate contamination only with respect to the direct contact numeric value and the proposed site-specific standard, and using the soil-to-groundwater numeric value only as a benchmark for limiting soil samples a hazardous waste determination

		through the use of the Toxic Characteristic Leaching Procedure) Section 10.0, pages 64-65 (attempting to delineate contamination only with respect to the direct contact numeric value and the proposed site-specific standard)

Table 4 of the 2011 report is very confusing because the same listed concentration may be highlighted in bold (with reference to the direct contact value), and gray (with reference to both). This buries the significance of the soil-to-groundwater numeric value, which is a concern where the water table is less than ten feet from the surface (the soil buffer distance for lead in Table 4B is 10 feet).

Table 5 of the 2011 report is extremely confusing because the highlighting because the same listed concentration may be highlighted bold (with reference to the direct contact value), or dark gray (with reference to both), and there is also an unrelated light gray shading of the entire rows immediately above and below the row displaying these data. (There is a fourth kind of highlighting where the sides of the rectangular cell are highlighted to denote exceedances of the Toxic Characteristic Leaching Procedure for purposes of determining whether the material constitutes hazardous waste under the Resource Conservation and Recovery Act). The public deserves a clearer presentation of the data regarding exceedances of the soil-to-groundwater numeric value.

In Table 4 of the 2017 report, Evergreen completely obliterated a reference to exceedances of the soil-to-groundwater numeric value. This is a problem because the proposed site-specific value is inappropriate and Evergreen has stated that it would follow any future changes by the Department with respect to the target blood lead level.

Given the concerns about the high water table, Evergreen should revise the report to include a discussion about the number and location of soil samples with exceedances of the soil-to-groundwater numeric value.

AOI-6: Girard Point Chemicals Area

Title	Analysis of Evergreen's Tables	Analysis of Evergreen's Textual Narrative
2013 Report (part 1) 2013 Report	Table 4 (identifies the soil-to-groundwater numeric value and the direct contact numeric	Section 5.1, 5.2, pages 19-22, Figure 10 (legend) (attempting to delineate for both the soil-to-groundwater numeric value and

(part 2) (disapproved)	values, as well as the MSC (apparently determined by the lower of the soil-to-groundwater numeric value or the direct contact numeric value), and highlights exceedances of all three).	the direct contact numeric value, for both non-SWMU areas and SWMU areas, but not identifying how many soil samples had exceedances, which soil samples had exceedances, what was the numeric value used to determine the exceedances, or what was the extent of the exceedance of the numeric value, forcing the reader to pick them off Figure 10) Section 12.0, page 41 (asserting that "[c]oncentrations of benzene, naphthalene, 1,2,4-TMB, 1,3,5-TMB, benzo(a)pyrene, ethylbenzene, ethylene dibromide, cumene, and lead detected in soil samples collected in AOI 6 were above their respective PADEP non-residential soil MSCs"), but not identifying how many soil samples had exceedances, which soil samples had exceedances, what was the numeric value used to determine the exceedances, or what was the extent of the exceedance of the numeric value)
2017 Report (part 1) 2017 Report (part 2) (approved)	Table 3a (current data) (identifies the soil-to-groundwater numeric value and the MSC (apparently determined by the lower of the soil-to-groundwater numeric value or the direct contact numeric value), and highlights exceedances of all three). Table 4a (historical data) (identifies the direct contact numeric value and the SHS (apparently determined by the lower of the soil-to-groundwater numeric value or the direct contact numeric value), and highlights exceedances of each with multiple superscripts, in addition to bold, underlining, and orange).	Section 3.5, page 22 (attempting to delineate contamination only with respect to the direct contact numeric value and the proposed site-specific standard) Section 3.6, pages 22-23 (referencing some exceedances of the soil-to-groundwater numeric value in additional soil sampling, but not discussing the implications of the exceedances and whether additional sampling should have been performed) Section 13.1, page 42 (attempting to delineate contamination only with respect to the direct contact numeric value and the proposed site-specific standard)

Table 4 of the 2013 report is extremely confusing because the same listed concentration may be highlighted in bold (with respect to one value), underlining (with respect to another value), and gray (with respect to yet another value). This is like the 2014 report for AOI-4

Table 4a of the 2017 report is very confusing because one has to read the superscript notes at the bottom of the spreadsheet to find out which value is being exceeded. The data relating to exceedances of the soil-to-groundwater numeric value should be broken out so that they may be understood.

AOI-7: Girard Point Fuels Area

Title	Analysis of Evergreen's Tables	Analysis of Evergreen's Textual Narrative
2012 Report (disapproved)	Table 4 (identifies only the soil-to-groundwater numeric value, and highlights exceedances)	Section 5.1, 5.2, pages 23-26, Figure 8 (legend) (attempting to delineate for the soil-to-groundwater numeric value, for both non-SWMU areas and SWMU areas) Section 12.0, page 45 (stating that "[c]oncentrations of benzene, naphthalene, 1,2,4-TMB, and lead detected in surface soil samples collected in AOI 7 were above their respective PADEP non-residential soil MSCs, but does not ___, and dismisses this under the rationale that "all but one location (BH-10-26 for lead) were below the calculated site-specific standards")
2013 Addendum to Report (disapproved)	Table 3 (identifies the soil-to-groundwater numeric value, the direct contact numeric value, and the MSC (apparently determined by the lower of the soil-to-groundwater numeric value or the direct contact numeric value), and highlights exceedances of all three).	Section 4.1, 4.2, pages 6-10, Figure 3 (legend) (attempting to identify exceedances of the soil-to-groundwater numeric value, for both non-SWMU areas and SWMU areas) Section 7.0, page 13 (stating that "[c]oncentrations of lead were detected in shallow soil samples above the non-residential soil MSC, and concentrations of 1,3,5-TMB, lead and

		benzene were detected in deep soils above the non-residential soil MSC," but not explaining why this is sufficient to delineate the contamination)
2017 Report (part 1) 2017 Report (part 2) (approved)	Table 3a (current data) (identifies the direct contact numeric value and the MSC (apparently determined by the lower of the soil-to-groundwater numeric value or the direct contact numeric value, but substitutes the proposed site-specific standard for the MSC for lead), and highlights exceedances of each). Table 4a (historical data) (identifies the direct contact numeric value and the SHS (apparently defining it as the lower of the soil-to-groundwater numeric value or the direct contact numeric value, but substituting the proposed site-specific standard for the direct contact numeric value for lead), and highlighting exceedances of each in orange, bold, and italics in the Table).	Section 3.6, page 25 (attempting to delineate contamination only with respect to the direct contact numeric value and the proposed site-specific standard) Section 3.7, page 26 (referencing some exceedances of the soil-to-groundwater numeric value in additional soil sampling, but not discussing the implications of the exceedances and whether additional sampling should have been performed) Section 13.1, page 45 (attempting to delineate contamination only with respect to the direct contact numeric value and the proposed site-specific standard)

Table 3 of the 2013 Addendum is extremely confusing because a listed concentration may be highlighted in bold (with respect to one value), underlining (with respect to another value), and gray (with respect to yet another value). This is like the 2014 report for AOI-4

Table 3a of the 2017 report is misleading because the proposed site-specific standard is the only value for lead that is listed, meaning that one reviewing this would know nothing about exceedances of the soil-to-groundwater numeric value or the direct contact numeric value for lead.

Table 4a of the 2017 report is confusing; while it identifies exceedances of the soil-to-groundwater numeric value, it suffers from too much highlighting by reference to multiple values, making it very difficult to evaluate the exceedances in terms of the multiple values.

AOI-8: North Yard

Title	Analysis of Evergreen's Tables	Analysis of Evergreen's Textual Narrative
2012 Report (part 1) 2012 Report (part 2) (approved)	Table 4 (non-SWMU) (identifies only the MSC (apparently defining it as the soil-to-groundwater numeric value) and highlights exceedances in gray) Table 5 (SWMU 2) (identifies only the MSC (apparently defining it solely by the soil-to-groundwater numeric value) and highlights exceedances in gray)	Section 5.1, 5.2, pages 24-25, Figure 8 (legend) (attempting to delineate for the soil-to-groundwater numeric value, for both non-SWMU areas and SWMU areas), but not identifying how many soil samples had exceedances, which soil samples had exceedances, what was the numeric value used to determine the exceedances, or what was the extent of the exceedance of the numeric value, forcing the reader to pick them off Figure 8) Section 12.0, page 55 (stating that "[c]oncentrations of benzene, naphthalene, benzo(a)pyrene and lead detected in shallow soil samples collected in AOI 8 were above their respective non-residential soil MSCs; however they were below the calculated site-specific standards," but not explaining why this is sufficient to delineate the contamination)
2017 Report (part 1) 2017 Report (part 2) (approved)	Table 3-2 (identifies only the SHS (apparently defining it as the lower of the soil-to-groundwater numeric value or the direct contact numeric value), and highlighting exceedances are highlighted in orange and bold and underlining) Table 3-3 (same data) (identifies only the direct contract numeric value for surface soils and subsurface soils (but characterizes the proposed site-specific standard as the direct contract	Section 3.5, pages 3.27-3.28 (attempting to delineate contamination only with respect to the direct contact numeric value and the proposed site-specific standard) Section 13.1, page 13.80 (attempting to delineate contamination only with respect to the direct contact numeric value and the proposed site-specific standard)

	numeric value for lead), and highlights exceedances in orange.	

Table 3-3 of the 2017 obliterates any characterization of exceedances of the direct contact numeric value where those exceedances are less than the proposed site-specific standard.

AOI-9: Schuylkill River Tank Farm

Title	Analysis of Evergreen's Tables	Analysis of Evergreen's Textual Narrative
2015 Report (part 1) 2015 Report (part 2) (disapproved)	Table 4a (PA inspection) (identifies only the MSC (apparently defining it as the lower of the soil-to-groundwater numeric value or the direct contact numeric value), and highlights exceedances in purple) Table 5 (identifies the Surface Soil MSC (apparently defining it as the lower of the soil-to-groundwater numeric value) and the Direct Contact MSC (another term for the direct contact numeric value), and highlights one in bold and underlining and the other in gray.	Section 5.2, pages 31-32, Section 5.4, pages 34-35, Figure 11 (legend) (implying an attempt to delineate for the soil-to-groundwater numeric value, but not identifying how many soil samples had exceedances, which soil samples had exceedances, what was the numeric value used to determine the exceedances, or what was the extent of the exceedance of the numeric value, forcing the reader to pick them off Figure 11, which actually only identifies exceedances of the direct contact numeric value and the proposed site-specific standard, and not exceedances of the soil-to-groundwater numeric value) Section 11.0, page 49 (stating that "[t]hirteen surface soil locations exhibited lead concentrations above the SSS or benzo(a)pyrene concentrations above the non-residential soil direct contact MSC," but not explaining why this is sufficient to delineate the contamination)
2017 Report Addendum (part 1)	Table 4 (identifies only the direct contact numeric value (substituting the proposed site-specific standard for the direct contact numeric value	Section 4.1, pages 16-17, Figure 16 (legend) (attempting to delineate contamination only with respect to the direct contact numeric value and the

2017 Report Addendum (part 2) (approved)	for lead), and highlights exceedances of this value).	proposed site-specific standard) Section 7.0, page 28 (attempting to delineate contamination only with respect to the direct contact numeric value and the proposed site-specific standard) Section 7.0, page 28 (stating that "[o]ne surface soil location exhibited a lead concentration above the SSS for lead. This exceedance has been delineated." Section 7.0, page 28 (stating that [o]ne surface soil location exhibited a benzo(b)flouranthene concentration above the PADEP non-residential surface soil direct contact MSC. This exceedance has been delineated.")

Evergreen's failure to identify exceedances on Figure 11 demonstrates why it should revise all these reports. What guided the entire investigation was a concern for establishing a less stringent standard (the direct contact numeric value or the proposed site-specific standard), rather than the more stringent soil-to-groundwater numeric value. If the latter numeric value had been used, Evergreen would have been able to characterize the contamination more precisely.

Instead, it established an approach that biased the investigation toward higher exceedances of the direct contact numeric value or the proposed site-specific standard, to the neglect of lower exceedances of the soil-to-groundwater numeric value. That latter approach would have presented a more detailed picture. We cannot see that picture because Figure 11 is flawed and missing data.

Table 5 of the 2015 report is extremely confusing, as it blurs terms (the MSC and the site-specific standard), its uses terms that have legal distinctions without making that distinction clear (Surface Soil MSC and Direct Contact MSC) and obliterating characterization of the soil-to-groundwater numeric value, at least with respect to lead. A site-specific standard is not an MSC. *Cf.* 25 Pa. Code 250, subchapter C (Statewide Health Standards) with 25 Pa. Code 250, subchapter D (Site-Specific Standard).

Table 4 of the 2017 report addendum obliterates any characterization of exceedances of the soil-to-groundwater numeric value where the exceedances are less than the proposed site-specific standard.

The 2017 Addendum does not even attempt to delineate exceedances of the soil-to-groundwater numeric value or the direct contact numeric value -- and there are 55 exceedances of the direct contact numeric value.

AOI-10: West Yard

Title	Analysis of Evergreen's Tables	Analysis of Evergreen's Textual Narrative
2011 Report (approved)	Table 4 (areas outside SWMU) (identifies the direct contact numeric value and the MSC (apparently defining it as the lower of the soil-to-groundwater numeric value or the direct contact numeric value), and highlights exceedances of both of each in gray) Tables 5-9 (similar)	Section 4.1, 4.2, pages 17-18, Figure 7 (legend), Figure 8 (legend) (attempting to delineate for the soil-to-groundwater numeric value, for both Corrective Action Management Unit (CAMU) areas and non-CAMU areas, but not identifying how many soil samples had exceedances, which soil samples had exceedances, what was the numeric value used to determine the exceedances, or what was the extent of the exceedance of the numeric value, forcing the reader to pick them off Figure 7 and Figure 8) Section 11.0, pages 36-37 (attempting to delineate contamination only with respect to proposed site-specific standards)

E. Evergreen fails to establish a soil buffer equivalency determination as required by the regulations, instead offering a "qualitative assessment" that defers its work to a future Fate and Transport Remedial Investigation Report, underscoring the interdependence of these reports and fragmenting the public comment process.

For all Areas of Interest, Evergreen uses the direct contact numeric value to delineate soil exceedances (for both surface soil and subsurface soil), rather than the soil-to groundwater numeric value. Evergreen offers no alternative equivalency determination to meet the requirements for an "an equivalency demonstration" in Section 250.308(d) of the regulations:

> (d) For any regulated substance, ***an equivalency demonstration may be substituted*** for the soil-to-groundwater numeric value throughout the site and the soil-to-groundwater pathway soil

> buffer ***if the groundwater is below the MSC value or the background standard prior to remediation***. This equivalency demonstration shall include the following:
>
> (1) ***Fate and transport analysis*** of the regulated substance ***from the deepest point of contamination in the soil through unsaturated zone soil*** and shall include the ***use of soil-to-water partition coefficients***. The analysis shall demonstrate that ***the regulated substances will not migrate to bedrock or the groundwater within 30 years*** at ***concentrations exceeding the greater of the groundwater MSC or background in groundwater*** as the ***endpoint in soil pore water directly under the site***.
>
> (2) In addition to sampling required for attainment of the inhalation or ingestion numeric values for soils up to 15 feet, as applicable, reporting and monitoring for eight quarters that shows no exceedances of the greater of the groundwater MSCs or of the background standard for groundwater beneath the contaminated soil and no indications of an increasing trend of concentration over time that may exceed the standard.

Section 250.308(d) (bold italics added for emphasis).

By its own admission, Evergreen avoids these quantitative requirements and instead offers its own “qualitative assessment.” Evergreen does not even ask the Department to accept a qualitative assessment in place of the quantitative assessment required by the regulations. Evergreen may not avoid the requirements of the regulations in this manner.

Any vague assertions by Evergreen about aboveground activities cited to support a “pathway elimination” argument are insufficient to meet the requirements of Section 250.308(d) with contamination underneath the surface of the ground.

AOI-1: Point Breeze No. 1 Tank Farm

The report uses the direct contact numeric value for soil to screen exceedances, and asserts that:

> ***The SHS value is usually driven by the soil-to-groundwater MSC, and the soil-to-groundwater pathway will be addressed in the groundwater investigation presented in this RIR (Section 4) and through subsequent remedial measures which will be further described in future Act 2 deliverables. In order to further evaluate the risk posed by the concentrations of COCs which were detected above their respective SHS, the next step in the screening process is to compare all of the soil analytical***

> ***results to the nonresidential direct contact MSCs***. Soil sample locations that will require further pathway evaluation or require a remedial measure in order to attain a standard under Act 2 were identified through comparison to the non-residential direct contact MSCs.

See 2016 Report (part 1), Section 1.6.1, page 1.7 (bold italics added for emphasis). But there is no discussion of "equivalency" as required by the Section 250.308(d) of the regulations. *See id*.

Contrary to the suggestion in the quotation, Section 4 does not contain a discussion of the "soil-to-groundwater pathway." *See id.,* Section 4.0, pages 4.27-4.29. Moreover, the fate and transport section of the report concerns groundwater only, and does not include a discussion of the soil-to-groundwater pathway. *See id.,* Section 10.0, pages 10.59-10.71 ("Qualitative Fate and Transport Assessment").

AOI-2: Point Breeze Processing Area

The report uses the direct contact numeric value and the proposed site-specific standard for lead to screen exceedances in surface soil. *See* 2017 Report (part 1), page 6. It uses the direct contact numeric value to screen exceedances in subsurface soil. *See id.*

It does not delineate exceedances of the soil-to-groundwater numeric value under the rationale that they will be evaluated through analysis and characterization of the groundwater pathway:

> Soil sample exceedances of the PADEP non-residential soil-to-groundwater MSCs are ***not displayed in Figure 11 as these exceedances will be evaluated through analysis and characterization of the groundwater pathway***.

See id., page 30 (bold italics added for emphasis).

However, Sunoco does not provide a discussion of this analysis and characterization. Rather, it simply assumed that its evaluation of groundwater data would suffice:

> No fate and transport modeling was completed for the soil analytical results ***since the soil-to-groundwater pathway is evaluated through groundwater data***. Potential exposure pathways for AOI 2 are discussed in more detail in Section 9.

See id., Section 6.1, page 40 (bold italics added for emphasis). That is insufficient because Section 9 provides no analysis of how it meets the requirements of Section 250.308(d) of the regulations. *See id.*, Section 9, pages 51-52 ("Exposure Assessment"). The fate and transport evaluation for groundwater does not provide this analysis. *See id.*, Section 6.2, page 40-41.

AOI 3: Point Breeze Impoundment Area

The report uses the direct contact numeric value and the proposed site-specific standard for lead to screen exceedances in surface soil. *See* 2017 Report (part 1), Section 1.4, page 6. It uses the direct contact numeric value to screen exceedances in subsurface soil. *See id.*

In addition, it stated

> ***No fate and transport modeling was completed for the soil analytical results since the soil-to-groundwater pathway is evaluated through groundwater data***. Potential exposure pathways for AOI 3 are discussed in more detail in Section 9.

See id., Section 6.1, page 35 (bold italics added for emphasis). *Accord*, Section 7.5, page 40. That is insufficient because Section 9 provides no analysis of how it meets the requirements of Section 250.308(d) of the regulations. *See id.*, Section 9, pages 44-45 ("Exposure Assessment"). The fate and transport evaluation for groundwater does not provide this analysis, either. *See id.*, Section 6.2, page 35-36.

AOI-4: No. 4 Tank Farm

The report states that non-residential direct contact MSC were used to screen exceedances for both surface and subsurface soil. *See* 2013 Report (part 1) (disapproved), page 5. Using circular reasoning, Sunoco stated that it did not have to perform a fate and transport analysis for the soil-to-groundwater pathway because it assumed there was no pathway of exposure other than direct contact:

> No fate and transport modeling was completed for the soil analytical results ***since the only potential exposure pathway to shallow soil is by direct contact***. PES's permit procedures and personal protective equipment (PPE) requirements eliminate the potential direct contact exposure pathway to subsurface soil. Potential exposure pathways for AOI 4 are discussed in detail in Section 9.0.

See id., Section 7.1, page 23 (bold italics added for emphasis). That is insufficient because Section 9 provides no analysis of how it meets the requirements of Section 250.308(d) of the regulations. *See id.*, Section 9, page 30 ("Human Health Exposure Assessment/Risk Assessment"). The fate and transport evaluation for groundwater does not provide this analysis, either. *See id.*, Section 7.2, page 23-24.

In the 2017 report, Evergreen again avoids the quantitative requirements of Section 250.308(d), Evergreen instead offers its own "qualitative assessment":

> ***A soil to groundwater model to evaluate the soil to groundwater pathway was not developed for the qualitative fate and transport assessment presented in this RIR***. Rather, a qualitative-level assessment of groundwater data has been completed (Section 10).

See 2017 Report, Section 9.5, page 9.52 (bold italics added for emphasis). That is insufficient because Section 10 provides no analysis of how it meets the requirements of Section 250.308(d) of the regulations. *See id.*, Section 10, pages 10.57-10.69 ("Fate and Transport Assessment").

AOI-5: Girard Point South Tank Field

The report uses the direct contact numeric value and the proposed site-specific standard for lead to screen exceedances in surface soil. *See* 2011 Report/Cleanup Plan (part 1) (disapproved), page 6. It uses the direct contact numeric value to screen exceedances in subsurface soil. *See id.*

> ***No fate and transport modeling was completed for the soil analytical results since the soil-to-groundwater pathway is evaluated through groundwater data***. Potential exposure pathways for AOI 5 are discussed in more detail in Section 9.

See id., Section 6.1, page 55 (bold italics added for emphasis). That is insufficient because Section 9 provides no analysis of how it meets the requirements of Section 250.308(d) of the regulations. *See id.*, Section 9, page 30 ("'Exposure Assessment' "). The fate and transport evaluation for groundwater does not provide this analysis, either. *See id.*, Section 6.2, page 55-56.

Avoiding the quantitative requirements of Section 250.308(d), Evergreen instead offers t simply use its groundwater data:

> ***No fate and transport modeling was completed for the soil analytical results since the soil-to-groundwater pathway is evaluated through groundwater data***. Potential exposure pathways for AOI 5 are discussed in more detail in Section 9.

2017 Report, Section 6.1, page 55 (bold italics added for emphasis). That is insufficient because Section 9 does not provide an analysis of how this meets the requirements of Section 250.308(d) of the regulations. *See id.*, Section 9.0, pages 62-63.

AOI-6: Girard Point Chemicals Area

Avoiding the quantitative requirements of Section 250.308(d), Evergreen instead offers t simply use its groundwater data:

> ***No fate and transport modeling was completed for the soil analytical results since the only potential exposure pathway to shallow soil is by direct contact***. PES's permit procedures and personal protective equipment (PPE) requirements eliminate the potential direct contact exposure pathway to subsurface soil. Potential exposure pathways for AOI 6 are discussed in detail in Section 9.0.

2013 Report, Section 7.1, page 25 (bold italics added for emphasis). That is insufficient because Section 9.0 does not provide an analysis of how this meets the requirements of Section 250.308(d) of the regulations. *See id.*, Section 9.0, pages 35-40.

As in AOI-1, the report states that:

> ***The SHS value is usually driven by the soil-to-groundwater MSC, and the soil-to-groundwater pathway will be addressed in the groundwater investigation presented in this report***. In order to further evaluate the risk posed by the concentrations of COCs which were detected above their respective SHS, the next step is to compare all of the soil analytical results to the non-residential direct contact MSCs. Soil sample locations that will require further pathway evaluation or require a remedial measure in order to attain a standard under Act 2 were identified through comparison to the non-residential direct contact MSCs.

See 2017 Report (part 1), Section 1.5.1, page 6 (bold italics added for emphasis). It did not perform a delineation to the lowest value (the soil-to-groundwater numeric value," but to the highest of the several values:

> Delineation was performed to the highest of the Act 2 non-residential SHS, the non-residential direct contact MSC, and the numeric SSS (for lead).

See id., page 17.

Avoiding the quantitative requirements of Section 250.308(d), Evergreen instead offers its own "qualitative assessment":

> ***A soil to groundwater model to evaluate the soil to groundwater pathway was not developed for the qualitative fate and transport***

> ***assessment presented in this RIR.*** Rather, a qualitative-level assessment of groundwater data was warranted at this stage of the investigation.

See id., Section 9.5, page 36 (bold italics added for emphasis). That is insufficient because Section 10 provides no analysis of how it meets the requirements of Section 250.308(d) of the regulations. *See id.*, Section 10, pages 37-41 ("Qualitative Fate and Transport Assessment").

AOI-7: Girard Point Fuels Area

Avoiding the quantitative requirements of Section 250.308(d), Evergreen instead offers t simply use its groundwater data:

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

2012 Report, Section 7.1, page 28 (bold italics added for emphasis). That is insufficient because Section 9.0 does not provide an analysis of how this meets the requirements of Section 250.308(d) of the regulations. *See id.*, Section 9.0, pages 39-44.

As in AOI-1 and AOI-6, the report states that;

> ***The SHS value is usually driven by the soil-to-groundwater MSC, and the soil-to-groundwater pathway will be addressed in the groundwater investigation presented in this report.*** In order to further evaluate the risk posed by the concentrations of COCs which were detected above their respective SHS, the next step is to compare all of the soil analytical results to the non-residential direct contact MSCs. Soil sample locations that will require further pathway evaluation or require a remedial measure in order to attain a standard under Act 2 were identified through comparison to the non-residential direct contact MSCs.

See 2017 Report (part 1), Section 1.5.1, page 6 (bold italics added for emphasis). It also stated that "Delineation was completed to the non-residential direct contact MSC and the numeric SSS (for lead)." *See id.*, Section 3, page 16.

Avoiding the quantitative requirements of Section 250.308(d), Evergreen instead offers its own "qualitative assessment":

> ***A soil to groundwater model to evaluate the soil to groundwater pathway was not developed for the qualitative fate and transport***

> ***assessment presented in this RIR.*** Rather, a qualitative-level assessment of groundwater data was warranted at this stage of the investigation.

See id., Section 9.5, page 38 (bold italics added for emphasis). That is insufficient because Section 10 provides no analysis of how it meets the requirements of Section 250.308(d) of the regulations. *See id.*, Section 10, pages 40-44 ("Qualitative Fate and Transport Assessment").

AOI-8: North Yard

Avoiding the quantitative requirements of Section 250.308(d), Evergreen instead offers t simply use its groundwater data:

> ***No fate and transport modeling was completed for the soil analytical results since the soil-to-groundwater pathway is evaluated through groundwater data***. Potential exposure pathways for AOI 8 are discussed in more detail in Sections 9.0 and 10.0 below.

2012 Report, Section 7.1, page 32 (bold italics added for emphasis). That is insufficient because Section 9.0 and 10.0 provide no analysis of how this meets the requirements of Section 250.308(d) of the regulations. *See id.*, Section 9.0 and Section 10.0, pages 49-54.

Similar to AOI 1, it is stated:

> ***The SHS value is usually driven by the soil-to-groundwater MSC, and the soil-to-groundwater pathway will be addressed in the groundwater investigation presented in this RIR (Section 4) and through subsequent remedial measures which will be further described in future Act 2 deliverables***. To further evaluate the risk posed by the concentrations of COCs which were detected above their respective SHS, the next step in the screening process is to compare all of the soil analytical results to the non-residential direct contact MSCs. Soil sample locations that will require further pathway evaluation or require a remedial measure in order to attain a standard under Act 2 were identified through comparison to the non-residential direct contact MSCs.

See 2017 Report (part 1), Section 1.6.1, page 1.9 (bold italics added for emphasis). Accordingly, exceedances in soil samples were determined by the direct contact MSC.

Contrary to the suggestion in the quotation above, Section 4 does not contain any discussion of a "soil-to-groundwater pathway." *See id.*, Section 4, pages 4.29-4.32.

The report states that

> ***A soil to groundwater model to evaluate the soil to groundwater pathway was not developed for the qualitative fate and transport assessment presented in this RIR***. Rather, a qualitative-level assessment of groundwater data has been completed (Section 9).

See id., Section 10.5, page 10.73 (bold italics added for emphasis). That is insufficient because Section 9 provides no analysis of how it meets the requirements of Section 250.308(d) of the regulations. *See id.*, Section 9, pages 9.55-9.67 ("Fate and Transport Assessment").

AOI-9: Schuylkill River Tank Farm

Evergreen makes the following statement:

> ***No fate and transport modeling was completed for the soil analytical results since the soil-to-groundwater pathway is evaluated through groundwater data***. Potential exposure pathways for AOI 9 are discussed in more detail in Section 9 below.

2015 Report, Section 6.1, page 42. That is insufficient because Section 9 provides no analysis of how it meets the requirements of Section 250.308(d) of the regulations. *See id.*, Section Section 9.0, page 48.

The report uses the direct contact numeric value and the proposed site-specific standard for lead to screen exceedances in surface soil. *See* 2017 Report Addendum (part 1), Section 1.1, page 2. It uses the direct contact numeric value to screen exceedances in subsurface soil. *See id.*

Again, Evergreen simply assumed that its evaluation of groundwater data would suffice to meet the requirements of Section 250.308(d) of the regulations:

> ***No fate and transport modeling was completed for the soil analytical results since the soil-to-groundwater pathway is evaluated through groundwater data***. Potential exposure pathways for AOI 9 are discussed in more detail in Section 6 below.

See id., Section 5.1 page 21 (bold italics added for emphasis). *Accord*, Section 6.4, page 25. However, no analysis related to 250.308(d) is provided.

Contrary to the suggestion in the quotation above, Section 6 does not contain any discussion of a "soil-to-groundwater pathway." *See id.*, Section 6.0, pages 22-27 ("Conceptual

Site Model”). Evergreen simply repeats the circular assertion above. *See id.*, Section 6.4, page 25 (“No fate and transport modeling was completed for the soil analytical results. The soil-to-groundwater pathway is evaluated through groundwater data.”).

AOI-10: West Yard

Using circular reasoning, Sunoco stated that it did not have to perform a fate and transport analysis for the soil-to-groundwater pathway because it assumed there was no pathway of exposure other than direct contact:

> ***No fate and transport modeling was completed for the soil analytical results since the only potential exposure pathway to soil is by direct contact to shallow soil***. The soil-to-groundwater pathway is evaluated through groundwater data. Potential exposure pathways for AOI 10 are discussed in more detail in Section 8.0.

See 2011 Report, Section 6.1 page 21 (bold italics added for emphasis). *Accord*, Section 7.5, pages 27-28 (Fate and Transport of COCs). That is insufficient because Section 8.0 provides no analysis of how it meets the requirements of Section 250.308(d) of the regulations. *See id.*, Section 8.0, pages 29-33 (“Human Health Exposure Assessment/Risk Assessment”).

13. The Department Should Disapprove Evergreen's Proposed Site-Specific Standard of 2240 mg/kg for Lead in Surface Soils.

Evergreen's proposed site-specific standard of 2240 mg/kg for lead in surface soil is flawed for several reasons. First, in its use of the Adult Lead Model, Evergreen inappropriately assumed a target blood lead level of 10 ug/dL in a fetus, rather than the target blood lead level of 5 ug/dL that the Centers for Disease Control and Prevention have been using since 2012 for case management for children exposed to lead. Changing this value alone would result in a standard of no more than 1050 mg/kg, rather than 2240 mg/kg.

In addition, the high water table in areas of the site complicates the notion that Evergreen could even develop a site-specific standard greater than the soil-to-groundwater numeric value. *See* Comment #7, above. Because the Adult Lead Model merely involves the multiplication of variables relating to exposure to lead in surface soils, it is insufficient as a risk assessment for the soil-to-groundwater pathway of exposure.

The Department should disapprove the proposal.

A. Evergreen inappropriately assumed a target blood lead level of 10 ug/dL in a fetus, rather than the target blood lead level of 5 ug/dL used by the Centers for Disease Control and Prevention for case management for children since 2012.

In 2015, Evergreen proposed a site-specific standard of 2240 mg/kg for lead in surface soil. 2015 Human Health Risk Assessment (Lead). The Department approved this proposal. 2015 Memo (lead), 2015 Approval Letter (lead). In its report, Evergreen assumed a target blood lead level of 10 ug/dL in a fetus:

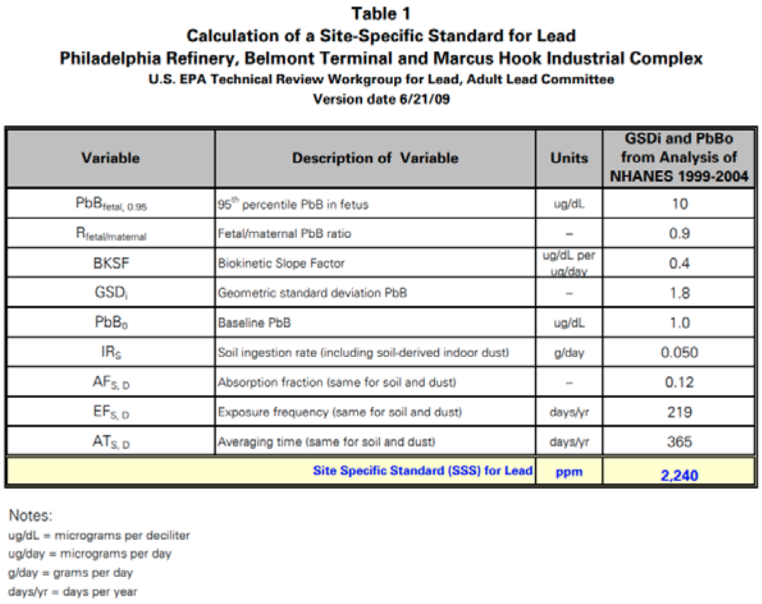

Table 1
Calculation of a Site-Specific Standard for Lead
Philadelphia Refinery, Belmont Terminal and Marcus Hook Industrial Complex
U.S. EPA Technical Review Workgroup for Lead, Adult Lead Committee
Version date 6/21/09

Variable	Description of Variable	Units	GSDi and PbBo from Analysis of NHANES 1999-2004
$PbB_{fetal,\ 0.95}$	95th percentile PbB in fetus	ug/dL	10
$R_{fetal/maternal}$	Fetal/maternal PbB ratio	–	0.9
BKSF	Biokinetic Slope Factor	ug/dL per ug/day	0.4
GSD_i	Geometric standard deviation PbB	–	1.8
PbB_0	Baseline PbB	ug/dL	1.0
IR_S	Soil ingestion rate (including soil-derived indoor dust)	g/day	0.050
$AF_{S,\ D}$	Absorption fraction (same for soil and dust)	–	0.12
$EF_{S,\ D}$	Exposure frequency (same for soil and dust)	days/yr	219
$AT_{S,\ D}$	Averaging time (same for soil and dust)	days/yr	365
	Site Specific Standard (SSS) for Lead	**ppm**	**2,240**

Notes:
ug/dL = micrograms per deciliter
ug/day = micrograms per day
g/day = grams per day
days/yr = days per year

2015 Human Health Risk Assessment (Lead), Table 1.

Last year, the Council submitted comments on a proposed Act 2 rulemaking that would have increased the direct contact numeric value from 1000 ppm to 2500 ppm. *See* Attachments 4-8 -- Clean Air Council Comments on Proposed Act 2 Rulemaking dated April 30, 2020. Just like Evergreen's proposal, that proposal was based on a target blood lead level of 10 µg/dL for a fetus. *See* Attachment 4 -- Clean Air Council Comments, pages 4-6. The value of 10 ug/dL was based on a "level of concern" value set by the Centers for Disease Control in 1991 -- nearly thirty years ago. *See id.*, pages 2, 8, 23.

In 2012, the Centers for Disease Control lowered the number to 5 µg/dL, and since then it has used this number as a "reference value" for case management for pregnant women and children up to 5 years old. *Id.*, pages 8-9. The Pennsylvania Department of Public Health, the Allegheny County Health Department, and the City of Philadelphia have also been using 5 µg/dL for case management. *Id.*, pages 10-13.

At its presentation to the Clean Standards Scientific Advisory Board (CSSAB) last month, the Department stated that it now intends to use the 5 ug/dL target blood lead level in the calculation of a direct contact numeric value, rather than the 10 ug/dL target blood lead level. Rounding to two significant figures, the Department intends to finalize a direct contact numeric value of 1100 mg/kg, rather than the proposed value of 2500 mg/kg. *See* DEP, Overview of Chapter 250 Draft-Final Rulemaking (December 16, 2020), pages 6-9; *see also* DEP, Draft Appendix A, Table 4A (December 16, 2020).

The fact that the Department has now embraced a target blood lead level of 5 ug/dL (rather than 10 ug/dL) underscores the error made in Evergreen's proposed site-specific standard.

The lowering of target blood lead level to 5 ug/dL would result in a proposed site-specific standard of no more than 1050 mg/kg. (While the Department intends to round up this figure to 1100 mg/kg for the proposed direct contact numeric value, rounding up would be inappropriate for a proposed site-specific standard. Evergreen did not round down its proposed standard of 2240 mg/kg to 2200 mg/kg).

B. Because the Adult Lead Model is a soil ingestion model, it is insufficient as a risk assessment for the soil-to-groundwater pathway of exposure.

Given the limitations of the Adult Lead Model, the failure of Evergreen to delineate soil contamination according to the soil-to-groundwater pathway, and the failure of Evergreen to characterize the relationship between the unconfined aquifer (water table) and the deep aquifer, it is questionable whether a site-specific standard higher than the soil-to-groundwater pathway would even be appropriate. *See* Comments #7, 12, above.

The inputs into the Adult Lead Model do not take into consideration the pathway of exposure through groundwater. It is a model based on the soil ingestion pathway. *See* Attachment 4 -- Clean Air Council Comments on Proposed Act 2 Rulemaking, page 16.

Under state law, a responsible party may propose a site-specific standard in place of a soil-to-groundwater numeric value or a direct contact numeric value. *See* Section 301(a)(3) of Act 2 of 1995. But any proposed standard must comply with the Act 2 regulations.

The regulations require a site-specific risk assessment. For a toxic chemical such as lead, they require a reduction of risk to a quantitative range of risk:

> (b) The site-specific standard ***shall be a protective level that eliminates or reduces any risk to human health*** in accordance with the following:
>
> (1) ***For known or suspected carcinogens***, soil and groundwater cleanup standards ***shall be established at exposures which represent an excess upperbound lifetime risk of between 1 in 10,000 and 1 in 1 million***. The cumulative excess risk to exposed populations, including sensitive subgroups, may not be greater than 1 in 10,000.

….

25 Pa. Code 250.402(b) (bold italics added for emphasis).

It is premature for Evergreen to propose a site-specific standard for lead in surface soil for a number of reasons. The Adult Lead Model does not address exposure through the soil-to-groundwater pathway. Evergreen has not properly delineated contamination according to the soil-to-groundwater numeric value. There is a high water table in areas of the site. Evergreen has failed to sufficiently characterize the relationship between the unconfined aquifer (water table) and the deep aquifer.

14. Evergreen's Flawed Site-Specific Standard Results in an Insufficient Delineation of Lead Contamination in Surface Soils.

In its reports, Evergreen has provided a distorted delineation of lead contamination in surface soils. It framed its discussion in terms of a proposed site-specific standard of 2240 mg/kg that is artificially lenient and erroneous. In terms of quantitative data, the reports would have been very different if the delineation had been based on the soil-to-groundwater numeric value (450 mg/kg) or even the direct contact numeric value (1000 mg/kg).

The anticipation of a lenient standard of 2240 mg/kg would naturally have affected decisions in the field regarding the number and locations of soil samples to be taken. The Department's guidance document underscores what common sense would suggest -- that with a less stringent standard in mind, fewer samples would be necessary:

> ***Soils must be characterized horizontally and vertically to concentrations below the selected numeric standards***, or to where it can be demonstrated that the pathway elimination measure is adequate to protect human health and the environment. This ensures that all soils containing regulated substances at or above the selected numeric standards have been adequately characterized to support a fate and transport analysis which shows where the contamination is currently located and those areas to which it is moving. ***The remediator determines the concentration level for characterization beyond the minimal level stated above***. The remediator must state what factors were used in determining the level used to define the site boundaries.

See Technical Guidance Manual, Section II.A.4.b.i, page II-12 (bold italics added for emphasis).

With respect to the quantitative data, the following table identifies the increase in the number of exceedances that would result if the soil-to-groundwater numeric value (450 mg/kg) or the direct contact numeric value (1000 mg/kg) were to be used to delineate the contamination, instead of the proposed site-specific standard (2240 mg/kg):

Area of Interest	**Title**	**Exceedances Under Different Numeric Values**
AOI-1 Point Breeze No. 1 Tank Farm	2016 Report, Table 3-2	16 exceedances of soil-to-groundwater numeric value (450 mg/kg) 7 exceedances of direct contact numeric value (1000 mg/kg) 4 exceedances of proposed site-specific standard

		(2240 mg/kg)
AOI-2 Point Breeze Processing Area	2017 Report, Table 4 (approved)	18 exceedances of soil-to-groundwater numeric value (450 mg/kg) 9 exceedances of direct contact numeric value (1000 mg/kg) 4 exceedances of proposed site-specific standard (2240 mg/kg)
AOI 3 Point Breeze Impoundment Area	2017 Report, Table 4 (approved)	15 exceedances of soil-to-groundwater numeric value (450 mg/kg) 6 exceedances of direct contact numeric value (1000 mg/kg) 5 exceedances of proposed site-specific standard (2240 mg/kg)
AOI-4 No. 4 Tank Farm	2013 Report, Table 3-2 (disapproved) 2017 Report (disapproved)	13 exceedances of soil-to-groundwater numeric value (450 mg/kg) 10 exceedances of direct contact numeric value (1000 mg/kg) 6 exceedances of proposed site-specific standard (2240 mg/kg)
AOI-5 Girard Point South Tank Field	2011 Report/Cleanup Plan, Table 4 (outside SWMU areas)	3 exceedances of soil-to-groundwater numeric value (450 mg/kg) 1 exceedance of direct contact numeric value (1000 mg/kg) 1 exceedance of proposed site-specific standard (2240 mg/kg)
	Table 5 (SWMU areas) (disapproved)	25 exceedances of soil-to-groundwater numeric value (450 mg/kg) (3 outside SWMU areas) 14 exceedances of direct contact numeric value (1000 mg/kg) (1 outside SWMU areas) 4 exceedances of proposed site-specific standard

		(2240 mg/kg) (1 outside SWMU areas)
	2017 Report, Table 4 (approved)	80 exceedances of soil-to-groundwater numeric value (450 mg/kg) 57 exceedances of direct contact numeric value (1000 mg/kg) 11 exceedances of proposed site-specific standard (2240 mg/kg)
AOI-6 Girard Point Chemicals Area	2013 Report, Table 4 (disapproved)	21 exceedances of soil-to-groundwater numeric value (450 mg/kg) 8 exceedances of direct contact numeric value (1000 mg/kg) 2 exceedances of proposed site-specific standard (2240 mg/kg)
	2017 Report, Table 3a (Recent Data) (approved)	12 exceedances of soil-to-groundwater numeric value (450 mg/kg) 5 exceedances of direct contact numeric value (1000 mg/kg) 4 exceedances of proposed site-specific standard (2240 mg/kg)
	Table 4a (Historical Data)	50 exceedances of soil-to-groundwater numeric value (450 mg/kg) 23 exceedances of direct contact numeric value (1000 mg/kg) 6 exceedances of proposed site-specific standard (2240 mg/kg)
AOI-7 Girard Point Fuels Area	2012 Report , Table 4 (disapproved)	11 exceedances of soil-to-groundwater numeric value (450 mg/kg) 3 exceedances of direct contact numeric value (1000 mg/kg)

		0 exceedances of proposed site-specific standard (2240 mg/kg)
	2013 Addendum to Report, Table 1 (disapproved)	21 exceedances of soil-to-groundwater numeric value (450 mg/kg) 5 exceedances of direct contact numeric value (1000 mg/kg) 0 exceedances of proposed site-specific standard (2240 mg/kg)
	2017 Report, Table 3a (approved)	6 exceedances of soil-to-groundwater numeric value (450 mg/kg) 0 exceedances of direct contact numeric value (1000 mg/kg) 0 exceedances of proposed site-specific standard (2240 mg/kg)
	Table 4a (Historical Data)	29 exceedances of soil-to-groundwater numeric value (450 mg/kg) 6 exceedances of direct contact numeric value (1000 mg/kg) 0 exceedances of proposed site-specific standard (2240 mg/kg)
AOI-8 North Yard	2012 Report, Table 4 (approved)	11 exceedances of soil-to-groundwater numeric value (450 mg/kg) 4 exceedances of direct contact numeric value (1000 mg/kg) 0 exceedances of proposed site-specific standard (2240 mg/kg)
	2017 Report, Table 3-2 (approved)	36 exceedances of soil-to-groundwater numeric value (450 mg/kg) 19 exceedances of direct contact numeric value (1000 mg/kg)

		7 exceedances of proposed site-specific standard (2240 mg/kg)
AOI-9 Schuylkill River Tank Farm	2015 Report, Table 5 (disapproved)	87 exceedances of soil-to-groundwater numeric value (450 mg/kg) 55 exceedances of direct contact numeric value (1000 mg/kg) 11 exceedances of proposed site-specific standard (2240 mg/kg)
	2017 Report Addendum (approved)	6 exceedances of soil-to-groundwater numeric value (450 mg/kg) 3 exceedances of direct contact numeric value (1000 mg/kg) 1 exceedance of proposed site-specific standard (2240 mg/kg)
AOI-10 West Yard	2011 Report, Table 4 (outside CAMU) (approved)	12 exceedances of soil-to-groundwater numeric value (450 mg/kg) 6 exceedances of direct contact numeric value (1000 mg/kg) 3 exceedances of proposed site-specific standard (2240 mg/kg)
	Table 5 (CAMU delineation samples)	5 exceedances of soil-to-groundwater numeric value (450 mg/kg) 2 exceedances of direct contact numeric value (1000 mg/kg) 0 exceedances of proposed site-specific standard (2240 mg/kg)
	Table 6 (CAMU area)	1 exceedance of soil-to-groundwater numeric value (450 mg/kg) 0 exceedances of direct contact numeric value (1000 mg/kg)

		0 exceedances of proposed site-specific standard (2240 mg/kg)

The disparity in the number of exceedances is most striking for the two Areas of Interest with the most lead contamination (AOI-5 and AOI-9). Therefore, it is a concern that Evergreen did not even attempt to compare the soil sample results with the soil-to-groundwater numeric value (450 mg/kg) or the direct contact numeric value (1000 mg/kg) in some reports for these areas. In a report for AOI-5, it simply lists 2240 mg/kg as the "PADEP Non-Residential Surface Soil Direct Contact MSC." *See* 2017 Report (AOI-5), Table 4, pdf pages 86-127. In a report for AOI-9, it lists 2240 mg/kg as both the "PADEP Non-residential Surface Soil MSC" and the "PADEP Non-residential Soil Direct Contact MSC." 2015 Report, Table 5, pdf pages 70-106.

As a matter of law, it is an error to identify 2240 mg/kg as the "PADEP Non-residential Surface Soil MSC" and the "PADEP Non-residential Soil Direct Contact MSC." An MSC is not a site-specific standard and a site-specific standard is not an MSC. *Cf.* 25 Pa. Code Subchapter D (Site-Specific Standard) with 25 Pa. Code § 250.305 (MSCs for soil).

Evergreen should have shown the work, but it did not. The Council had to identify these exceedances itself.

Evergreen's errors are also important on a qualitative level. By ruling out certain samples under the assumption that an artificially lenient standard would apply, Evergreen would have blocked off lines of investigation. Data on exceedances helps to inform one's judgment regarding additional sampling.

Finally, Evergreen does not provide an analysis that synthesizes the data in a meaningful and helpful way. There is no discussion in the conclusions of the reports about why it took the samples in the locations it did and stopped where it did. Rather, it points to data in tables and asserts in a conclusory fashion that it has delineated the contamination. This is not sufficient.

15. Evergreen Fails to Include Per- and Polyfluoroalkyl Substances (PFAS) as a Constituent of Concern, Despite a History of Catastrophic Fires at the Refinery.

Per- and Polyfluoroalkyl Substances (PFAS) are persistent, bioaccumulative, and harmful chemicals. Historically, some of them have been used in foam for firefighting at refineries. Evergreen does not identify PFAS as a Constituent of Concern in any of its reports. Given a history of catastrophic fires at the facility prior to the sale in 2012, Evergreen should prepare a work plan and revise its remedial investigation to include PFAS contaminants in the soil and groundwater.

A. The Department has acknowledged the harmful health effects of PFAS by proposing to establish Medium-Specific Concentrations for Perfluorooctanoic Acid (PFOA), Perfluorooctane Sulfonate (PFOS) and Perfluorobutane Sulfonate (PFBS).

PFAS are a group of man-made chemicals that includes PFOA, PFOS, PFBS, and many other chemicals. EPA, Basic Information on PFAS ("What is the difference between PFOA, PFOS and GenX and other replacement PFAS?"). According to EPA, "[s]tudies indicate that PFOA and PFOS can cause reproductive and developmental, liver and kidney, and immunological effects in laboratory animals." *Id.* ("Are there health effects from PFAS?"). In 2016, EPA issued drinking water health advisories for PFOA and PFOS. *See* EPA, Fact Sheet: PFOA & PFOS Drinking Water Health Advisories (November 2016).

EPA notes that PFAS is associated with firefighting at refineries:

> Drinking water can be a source of exposure in communities where these chemicals have contaminated water supplies. ***Such contamination is typically localized and associated with a specific facility, for example***,
>
> - an industrial facility where PFAS were produced or used to manufacture other products, or
> - ***an oil refinery, airfield or other location at which PFAS were used for firefighting***.

EPA, Basic Information on PFAS ("How are people exposed to PFAS?") (bold italics added for emphasis). Historically, PFAS are associated with fire-fighting foams. *Id.* ("What is the difference between PFOA, PFOS and GenX and other replacement PFAS?").

Last year, the Department proposed to add Medium-Specific Concentrations for PFOA, PFOS, and PFBS. *See* 50 Pa. B. 1011 (February 15, 2020), paragraph 1. It is anticipated that the Department will finalize this proposal. *See* DEP, Overview of Chapter 250 Proposed Rulemaking (July 30, 2020), pages 22-24 (summarizing public comments in presentation to Cleanup Standards Scientific Advisory Board); *see also* DEP, Draft Appendix A, Table 1 (December 16, 2020) (including MSCs for PFOs, PFOA, and PFBS in latest proposed draft).

B. Given the provision of foam for firefighting at the refinery before 2012, there is a concern for the presence of PFAS in the soil and groundwater.

There is a history of explosions and fires at the Philadelphia refinery. The following table summarizes this history:

Year	**Incident**	**Facility**
1931	explosion	Atlantic Refining plant at Point Breeze
1960	fire	Girard Point Refinery, then owned by Gulf
1970	explosion	Arco plant
1975	fire	Gulf refinery
1975	fire	Arco refinery
1977	explosion and fire	Arco plant
1988	explosion	Point Breeze, then operated by John Deuss' Atlantic Refining & Marketing Corp
1998	small fire	Girard Point

Source: Mariah Rush, Philadelphia Inquirer, *In Philly, a history of oil refinery fires going back decades* (Updated: June 21, 2019).

The 1975 fire was the worst. It was an 11-alarm fire that overwhelmed the facility and resulted in the deaths of eight firefighters. A video of the massive fire is available at 6ABC Action News, *Looking back at 1975 Philly refinery fire that killed 8 firefighters* (00:35-1:07). The owner of the refinery was fined $37,000. New York Times, *Gulf Fined $37,000 for Violations At South Philadelphia Refinery* (July 7, 1977).

PFAS is a concern at the refinery site because foam was provided to the firefighters to fight that fire:

> But more than 500 firemen fought all night to avert a catastrophe. ***They spread a blanket of foam to smother the flames***.

See Elmer Smith, Philadelphia Inquirer, *30 Yrs. Later, Memories of a Refinery Inferno* (August 17, 2005) (republication) (bold italics added for emphasis). The oil foam overwhelmed the sewer system, resulting in the flashing of the material and contributing to the death of several firefighters:

> During this catastrophe, firefighters successfully suppressed flames emanating from tank 231, roughly where the current stack is now visible north of the Platt Bridge. During the course of their operations, ***a massive quantity of oily foam began to overwhelm the refinery's sewage system and accumulate in tank dikes and along the major thoroughfares where most of the fire apparatuses were assembled***. Just before 5PM, ***this material flashed, capturing men and machines amid white hot sheets of flame***. Four entire firetrucks and their crews melted before the department's officers.

Christopher R. Dougherty, *A Petaled Rose Of Hell: Refineries, Fire Risk, And The New Geography Of Oil In Philadelphia's Tidewater* (December 10, 2013) (bold italics added for emphasis).

This is one example of foam being provided to firefighters to fight fires at the refinery. There may be others. Because foam was used in firefighting, there is a concern that it contained PFAS, and that these chemicals are now contaminants in the soil and groundwater.

C. Evergreen should revise the reports to include PFAS as Constituents of Concern in the soil and groundwater, and it should prepare a work plan for submission to the Department.

In its reports prior to the sale in 2012, Evergreen did not identify PFAS as a Constituent of Concern. *See e.g.*, 2004 Current Conditions Report, Table 5a and Table 5b (Constituents of Concern for Soil and Groundwater), pdf pages 120-121; *see also* Interim Activities Work Plan (2011), Table 2 (Constituents of Concern for Soil and Groundwater), pdf pages 16-17. Nor did Evergreen do this in reports after 2012. *See e.g.*, 2017 Report (AOI-7), Table 1 (Constituents of Concern), pdf page 76.

Evergreen should amend its list of Constituents of Concern to include the PFAS group, including PFOA, PFOS, and PFBS.

In addition, Evergreen should develop a work plan for a remedial investigation of PFAS in the soil and groundwater. In doing so, Evergreen should work with the City of Philadelphia fire department to gather records regarding historical fires, to identify the locations of the property where PFAS contamination is more likely to be located.

Thank you for your consideration of the Council's comments.

Sincerely,

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U.S. Department of the Interior
U.S. Geological Survey

Simulation of Ground-Water Flow in the Potomac-Raritan-Magothy Aquifer System Near the Defense Supply Center Philadelphia, and the Point Breeze Refinery, Southern Philadelphia County, Pennsylvania

Water-Resources Investigations Report 01-4218

Prepared for the
U.S. ENVIRONMENTAL PROTECTION AGENCY

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New Cumberland, Pennsylvania
2001

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Figures 1-14. Maps showing:

ILLUSTRATIONS—Continued

ILLUSTRATIONS—Continued

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	by	To obtain
	Length	
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Volume	
gallon (gal)	3.785	liter
gallon (gal)	0.003785	cubic meters
million gallons (Mgal)	3,785	cubic meters
	Flow	
million gallons per day (Mgal/d)	3,785	cubic meter per day
billion gallons per year (Bgal/yr)	10,370	cubic meters per day
inch per year (in/yr)	0.0000696	meters per day
	Hydraulic conductivity	
foot per day (ft/d)	0.3048	meters per day

Sea level: In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

SIMULATION OF GROUND-WATER FLOW IN THE POTOMAC-RARITAN-MAGOTHY AQUIFER SYSTEM NEAR THE DEFENSE SUPPLY CENTER PHILADELPHIA, AND THE POINT BREEZE REFINERY, SOUTHERN PHILADELPHIA COUNTY, PENNSYLVANIA

by Curtis L. Schreffler

ABSTRACT

Ground-water flow in the Potomac-Raritan-Magothy aquifer system (PRM) in south Philadelphia and adjacent southwestern New Jersey was simulated by use of a three-dimensional, seven-layer finite-difference numerical flow model. The simulation was run from 1900, which was prior to ground-water development, through 1995 with 21 stress periods. The focus of the modeling was on a smaller area of concern in south Philadelphia in the vicinity of the Defense Supply Center Philadelphia (DSCP) and the Point Breeze Refinery (PBR). In order to adequately simulate the ground-water flow system in the area of concern, a much larger area was modeled that included parts of New Jersey where significant ground-water withdrawals, which affect water levels in southern Philadelphia, had occurred in the past. At issue in the area of concern is a hydrocarbon plume of unknown origin and time of release.

The ground-water-flow system was simulated to estimate past water-level altitudes in and near the area of concern and to determine the effect of the Packer Avenue sewer, which lies south of the DSCP, on the ground-water-flow system. Simulated water-level altitudes for the lower sand unit of the PRM on the DSCP prior to 1945 ranged from pre-development, unstressed altitudes to 3 feet below sea level. Simulated water-level altitudes for the lower sand unit ranged from 3 to 7 feet below sea level from 1946 to 1954, from 6 to 10 feet below sea level from 1955 to 1968, and from 9 to 11 feet below sea level from 1969 to 1978. The lowest simulated water-level altitude on the DSCP was 10.69 feet below sea level near the end of 1974. Model simulations indicate ground water was infiltrating the Packer Avenue sewer prior to approximately 1947 or 1948. Subsequent to that time, simulated ground-water-level altitudes were lower than the bottom of the sewer.

INTRODUCTION

The Potomac-Raritan-Magothy (PRM) aquifer system in south Philadelphia historically has been a major water-supply source in the south Philadelphia region. Because of the abundant ground-water resource and subsequent ground-water withdrawals, the flow system in the PRM has changed through history. The south Philadelphia area historically has been a highly industrialized area, especially operations at the Philadelphia Naval Shipyard (PNSY). Industries and the PNSY withdrew large amounts of water from the PRM for day-to-day operations. Increasing development across the Delaware River in New Jersey has influenced ground-water levels in Pennsylvania in the past and currently (2001).

Because of the development in the area, the quality of water in the PRM has been degraded. Some degradation in the upper part of the aquifer is the result of numerous hydrocarbon plumes. Some of the accidental organic releases have been non-aqueous phase hydrocarbons (NAPL). Since the early 1990's, the Pennsylvania Department of Environmental Protection (PaDEP) has been overseeing investigations of multiple localized NAPL hydrocarbon plumes floating on the water-table surface in the south Philadelphia area (fig. 1). The PaDEP's oversight is for NAPL investigations focused on specific plumes. Although localized NAPL is a major concern, a more regional look at the entire area was needed to assess areal problems.

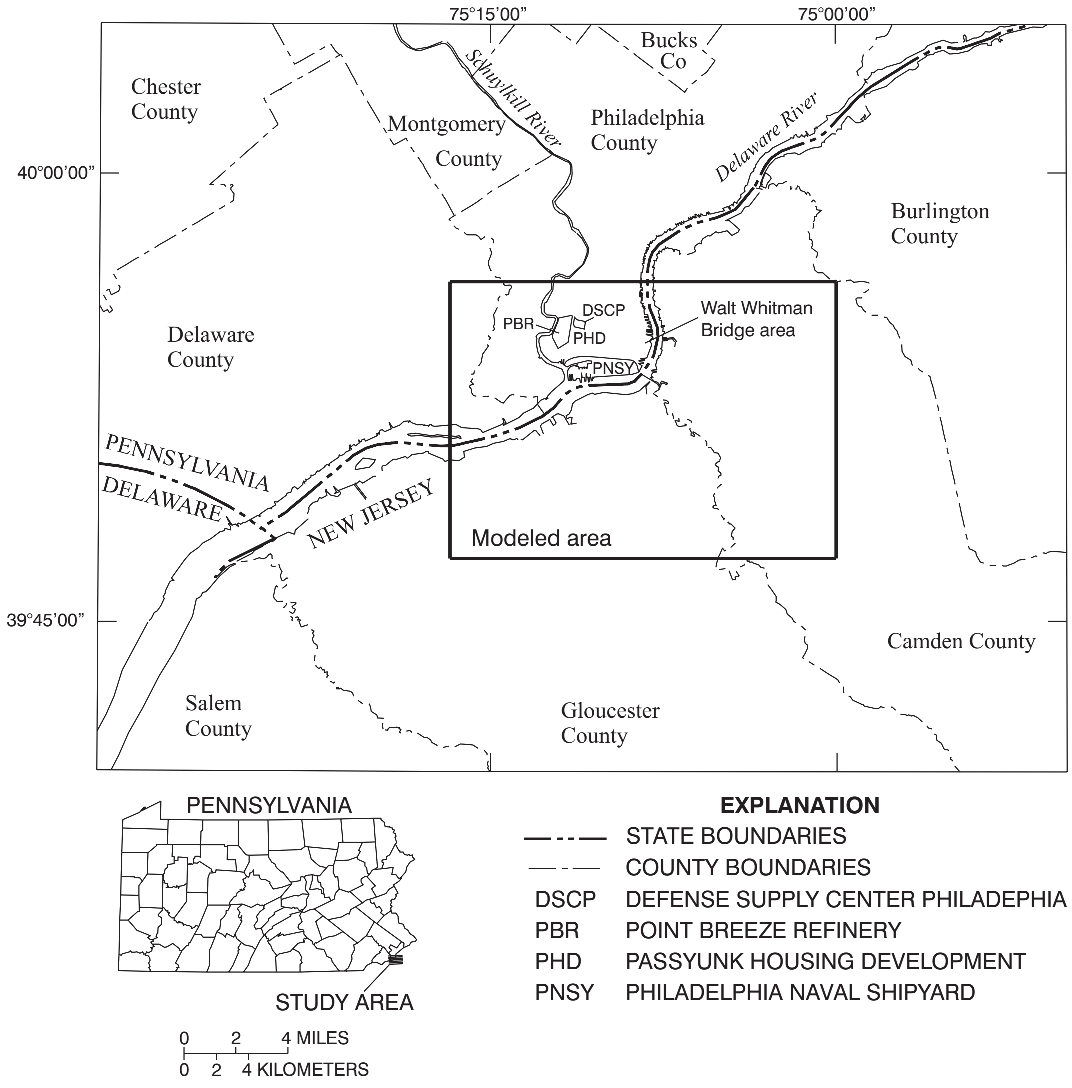


Figure 1. Location of study area.

An area of concern for the PaDEP is east of the Point Breeze Refinery (PBR) on the Defense Logistics Agency's Defense Supply Center, Philadelphia (DSCP), and the Philadelphia Housing Authority Passyunk Housing Development (PHD). During construction activities in 1989, a NAPL plume was discovered under the DSCP property. The PaDEP was notified by the DSCP of the plume, and PaDEP oversight began.

The source or sources of the NAPL in the area of concern and the migration pathways are unknown. The timing of the release(s) are unknown, and the migration of the NAPL depends on when the release or releases occurred. It is possible that the release(s) date from the late 1940's to 1980 (Pennsylvania Department of Environmental Protection, written commun., Dec. 9, 1998). Historically, the large ground-water pumping centers in the area, specifically at the PNSY to the south and at Publicker Industries, which was near the Walt Whitman Bridge to the east, and the associated affects on ground-water levels controlled the direction and gradient or rate of ground-water flow in the area. Another factor controlling hydrocarbon plume migration is the Packer Avenue sewer, which lies south of the DSCP.

Through the course of environmental investigations of the NAPL plume, a residual staining of aquifer material was identified beneath the water table in 1997. This indicates hydrocarbons existed below the present-day water table in this area. A NAPL floating on top of the water table would leave residual hydrocarbons in the soil matrix. Residual hydrocarbons in the soil were detected at an altitude of 4.08 to 14.88 ft below sea level on property between the DSCP and PBR, and on the DSCP. Therefore, evaluating historical water-level altitudes and determining at what time in the past water-level altitudes reached 4 to 14 ft below sea level would be beneficial in evaluating the timing of NAPL release(s).

The modeling effort described in this report is a continuation of investigations being done by U.S. Geological Survey (USGS), which started in 1997 at the request of the U.S. Environmental Protection Agency (USEPA). Most historical ground-water-level data in the vicinity was from the 1940's through the mid 1950's. Very little data are available for other time periods. The author of this report compiled all available historical ground-water-level data and summarized water-level altitudes for the following time intervals: prior to 1945, 1946 through 1954, 1955 through 1968, and 1969 through 1978. Those data and the results of the author's analyses of the data are freely used in this report. These time periods were chosen because potentiometric-surface maps of the lower sand unit in south Philadelphia have been published for 1945, 1954, 1968, and 1978. Potentiometric-surface maps for 1945 and 1954 were published by Greenman and others (1961). Gill and Farlekas (1976) published a potentiometric-surface map of the lower sand unit for 1968. Sloto (1988) published a potentiometric-surface map of the lower sand unit for 1978 from Walker (1983) and Paulachok (U.S. Geological Survey, written commun., 1982).

The results of simulations made with a calibrated ground-water-flow model would assist in evaluating past ground-water-level altitudes. The evaluation of ground-water-level altitudes would yield ground-water flow directions and the direction of ground-water flow is a controlling factor in migration of the hydrocarbon plume.

PURPOSE AND SCOPE

This report presents an abbreviated description of the hydrogeology and ground-water-flow system of the Potomac-Raritan-Magothy aquifer system in south Philadelphia. The report describes the construction of a model used to simulate ground-water flow in the PRM. The report presents an analysis of water-level altitudes in the area of concern at the DSCP and PBR sites from 1900 to 1995 and an evaluation of the effects of the Packer Avenue sewer, which lies just south of the DSCP, on the ground-water-flow system and subsequent plume migration.

LOCATION AND EXTENT OF STUDY AREA

The extent of the regional assessment of the PRM in southern Philadelphia County also includes areas in eastern Delaware County, Pa., and parts of northern Gloucester and western Camden Counties in New Jersey. The areas in New Jersey are included because of large ground-water withdrawals from the PRM historically and currently (2001).

PREVIOUS INVESTIGATIONS

Many water-resource investigations have been done in the south Philadelphia area. Bascom (1904) was the first to describe the water resources of the Philadelphia area. Hall (1934) described ground-water resources of southeastern Pennsylvania. Graham and Kammerer (1952) investigated the groundwater resources of the U.S. Naval Base in south Philadelphia. Barksdale and others (1958) summarized the ground-water resources in the tri-state region of the lower Delaware River that consisted of Pennsylvania, New Jersey, and Delaware. Greenman and others (1961) published a comprehensive assessment of geology and ground-water resources of the Coastal Plain area of southeastern Pennsylvania. Paulachok and Wood (1984) published a water-table map of Philadelphia County, and Paulachok and others (1984) published hydrologic data for Philadelphia County. Sloto (1988) simulated ground-water flow in the lower sand unit of the PRM in south Philadelphia. Paulachok (1991) published a comprehensive assessment of the ground-water resources of Philadelphia County. Many water-resource investigations have been done in the Gloucester and Camden County areas of New Jersey. A summary of water-resource investigation reports by the USGS New Jersey District are listed in table 1.

Table 1. *Summary of reports by the U.S. Geological Survey, New Jersey District, that includes area of Gloucester and Camden Counties, New Jersey*

Report title	Authors and year of publication	Period of investigation	Areas of investigation	Principle topic of investigation
Water levels in major artesian aquifers of the New Jersey Coastal Plain, 1983	Eckel and Walker, 1986	1983	Camden and Gloucester Counties, N.J., and some parts of southern Philadelphia County, Pa.	Ground-water levels
Water quality of the Potomac-Raritan-Magothy aquifer system in the Coastal Plain, west-central New Jersey, 1923-83	Ervin, Voronin, and Fusillo, 1994	1923-83	Camden and Gloucester Counties, N.J.	Ground-water quality
Geology and ground-water resources of Camden County, New Jersey	Farlekas, Nemickas, and Gill, 1976	1900-68	Camden County, N.J. and some parts of southern Philadelphia County, Pa.	Hydrology, geology and water-quality; includes ground-water levels.
Water-quality data for the Potomac-Raritan-Magothy aquifer system in southwestern New Jersey, 1980	Fusillo, Hochreiter, and Lord, 1984	1980	Camden and Gloucester Counties, N.J., and some parts of southern Philadelphia County, Pa.	Ground-water quality
Geohydrologic maps of the Potomac-Raritan-Magothy aquifer system in the New Jersey Coastal Plain	Gill and Farlekas, 1976	1900-68	Camden and Gloucester Counties, N.J., and some parts of southern Philadelphia County, Pa.	Ground-water levels and geohydrology
Digital-simulation and projection of head changes in the Potomac-Raritan-Magothy aquifer system, Coastal Plain, New Jersey	Luzier, 1980	1956-73	New Jersey Coastal Plain	Ground-water flow
Ground-water flow in the New Jersey Coastal Plain	Martin, 1998	1895-1981	New Jersey Coastal Plain	Ground-water flow
Ground-water flow and future conditions in the Potomac-Raritan-Magothy aquifer system, Camden area, New Jersey	Navoy and Carleton, 1995	1987	Camden and Gloucester Counties, N.J., and some parts of southern Philadelphia County, Pa.	Computer simulations of ground-water flow and water levels
Simulation of ground-water flow and movement of the freshwater -saltwater interface in the New Jersey Coastal Plain	Pope and Gordon, 1999	1896-1998	New Jersey Coastal Plain	Ground-water flow
Potentiometric surfaces of the Potomac-Raritan-Magothy aquifer system near National Park, New Jersey	Rosman, 1997	1996	New Jersey Coastal Plain	Ground-water levels
Water levels in major artesian aquifers of the New Jersey Coastal Plain, 1988	Rosman, Lacombe, and Storck, 1995	1988	New Jersey Coastal Plain and some parts of southern Philadelphia County, Pa.	Ground-water levels
Evaluation of water levels in major aquifers of the New Jersey Coastal Plain, 1978	Walker, 1983	1978	New Jersey Coastal Plain and some parts of southern Philadelphia County, Pa.	Ground-water levels

HYDROGEOLOGIC SETTING

GEOLOGY

The study area in Pennsylvania from the Fall Line to the Delaware River is underlain by Coastal Plain sediments that range in age from Late Cretaceous to Holocene. The unconsolidated Cretaceous sediments are referred to on a regional basis as the Potomac-Raritan-Magothy (PRM) aquifer system. These sediments consist of highly permeable sands and gravels separated by less-permeable layers of silts and clays. The PRM aquifer system in Pennsylvania can be subdivided into units: upper clay, upper sand, middle clay, middle sand, lower clay, and lower sand (Sloto, 1988, p. 8) (fig. 2). The PRM is overlain by Quaternary deposits referred to informally as the Trenton gravel by Owens and Minard (1979). These deposits are overlain by Holocene alluvium and fill. Large areas of south Philadelphia historically have undergone extensive filling activities. The thickness of the fill varies across the region and is not well defined. For purposes of this report, the Trenton gravel, alluvium, and fill material have been combined and referred to as alluvium. The unconsolidated deposits of the PRM aquifer system lie on pre-Cretaceous mica and hornblende schists and gneisses comprised primarily of the Wissahickon Formation. All beds dip to the southeast from the Fall Line. In areas near the Fall Line, many upper units pinch out, and the lower sand unit may be directly overlain by alluvium; confining units may not be present or are very thin. The unconsolidated deposits thicken toward the southeast. Greenman and others (1961) extensively characterize the Coastal Plain deposits in Pennsylvania.

From the Delaware River southeastward in New Jersey, the Coastal Plain consists of the PRM and other unconsolidated deposits that do not exist in Pennsylvania. For purposes of this report and the model, the unconsolidated deposits that do not exist in Pennsylvania have been grouped with the alluvial deposit layer in the model. Navoy and Carleton (1995, p. 7) characterize the Coastal Plain sediments in the Camden area.

SYSTEM	SERIES	HYDROGEOLOGIC UNIT		MODEL LAYER
Quaternary	Holocene	Alluvium		Layer 1
	Pleistocene	Trenton gravel (informal usage)		
Cretaceous	Upper Cretaceous	Potomac-Raritan-Magothy aquifer system	Upper clay unit	Layer 2
			Upper sand unit	Layer 3
			Middle clay unit	Layer 4
			Middle sand unit	Layer 5
			Lower clay unit	Layer 6
	Lower Cretaceous		Lower sand unit	Layer 7
Pre-Cretaceous		Wissahickon Formation		

Figure 2. Generalized stratigraphic section of the Coastal Plain in the Philadelphia, Pa., region and correspondence of hydrogeologic units to layers in model developed for this study.

AQUIFER AND CONFINING UNIT THICKNESSES AND ALTITUDES

A spatially related stratigraphic contouring software package was used to determine aquifer and confining-unit thicknesses. Geologic logs from borings were compiled from USGS references, drillers' well logs, and environmental consultant reports and entered into the stratigraphic software package. Unit thickness or isopach maps were generated and used as input for the model. A total of 93 geologic well logs in Pennsylvania and 39 geologic well logs in New Jersey were used to construct the unit isopach maps.

Altitudes of the top and bottom of units for the model were generated from isopach maps using MODFLOW-2000 pre-processing software Argus ONE (Argus Interware, Inc., 1997). The top of the model or land surface was derived from USGS Digital Elevation Models (DEM) of the study area.

Subsequently subtracting unit thicknesses from the unit isopach maps starting at the land surface yielded estimated structure contours of the top and bottom of the modeled units.

The alluvial unit (model layer 1) extends from the land surface to the top of the upper confining clay. The alluvial unit consists of many sand and clay lenses and, for purposes of this report, is combined with the fill material and the Trenton gravel to form one unit. The thickness of this combined alluvial unit in Pennsylvania ranges from 0 to 60 ft with local lenses up to 80 ft thick (fig. 3). The unit thickens toward the southeast in New Jersey, which does not depict a true representation of the system because the unit is further combined with unconsolidated deposits of the New Jersey Coastal Plain that do not exist in Pennsylvania. The altitude of the bottom of the alluvial unit is shown on figure 4.

The thickness of the upper confining clay (model layer 2) in Pennsylvania ranges from 0 to 10 ft with local lenses up to 20 ft thick (fig. 5). This unit is discontinuous in Pennsylvania. The unit thickens to the southeast in New Jersey.

The thickness of the upper sand unit (model layer 3) in Pennsylvania ranges from 0 to 30 ft with localized lenses up to 40 ft thick in Pennsylvania (fig. 6). This unit also is discontinuous in Pennsylvania and pinches out to the northwest near the Fall Line. In New Jersey, the unit ranges from 20 to 100 ft thick with a local lens up to 120 ft thick. The altitude of the top of the upper sand unit (model layer 3) is shown in figure 7.

The thickness of the middle confining clay unit (model layer 4) in Pennsylvania ranges from 0 to 20 ft with local lenses up to 40 ft thick (fig. 8). This unit is the least extensive of the Coastal Plain units in Pennsylvania and pinches out to the northwest near the Fall Line. In New Jersey, the unit ranges from 20 to 40 ft thick.

The thickness of the middle sand unit (model layer 5) in Pennsylvania ranges from 0 to 10 ft with a local lens up to 20 ft thick (fig. 9). Of the PRM aquifers in Pennsylvania, this unit is the least extensive and pinches out or is nonexistent as it grades to the northwest near the Fall Line. In New Jersey, the unit ranges from 20 to 160 ft thick. The altitude of the top of the middle sand unit is shown in figure 10.

The thickness of the lower confining clay (model layer 6) ranges from 0 to 20 ft with local lenses up to 60 ft thick (fig. 11). This unit pinches out towards the Fall Line. In New Jersey, the unit ranges from 20 to 180 ft thick.

The thickness of the lower sand unit (model layer 7) ranges from 0 ft at the Fall Line to 40 ft with local lenses up to 60 ft thick in Pennsylvania (fig. 12). This unit is the most continuous of the Coastal Plain units in Pennsylvania, and in areas near the Fall Line it may be unconfined. In New Jersey, the unit ranges from 40 to 260 ft thick. The altitude of the top of the lower sand unit is shown in figure 13. The altitude of the bottom of the lower sand unit, which is equivalent to the altitude of the top of the bedrock surface, is shown in figure 14. The north to south and west to east trending cross sections that depict the lithologic structure used in the model are shown in figure 15.

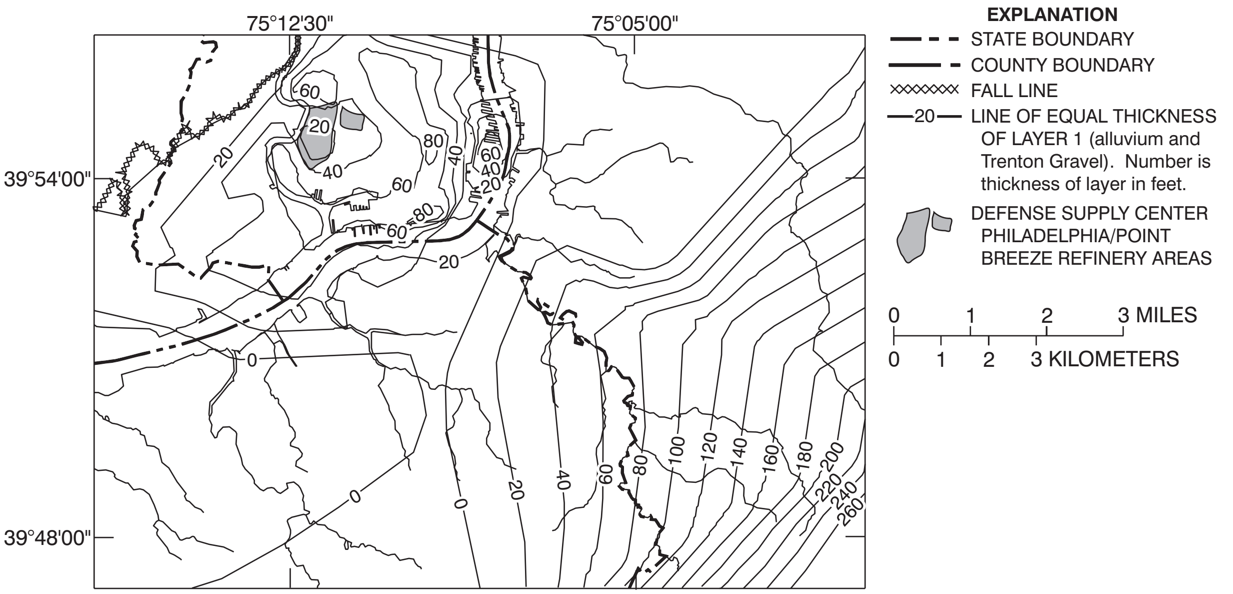


Figure 3. Thickness of the alluvium and Trenton gravel (model layer 1) in the south Philadelphia area and adjacent New Jersey.

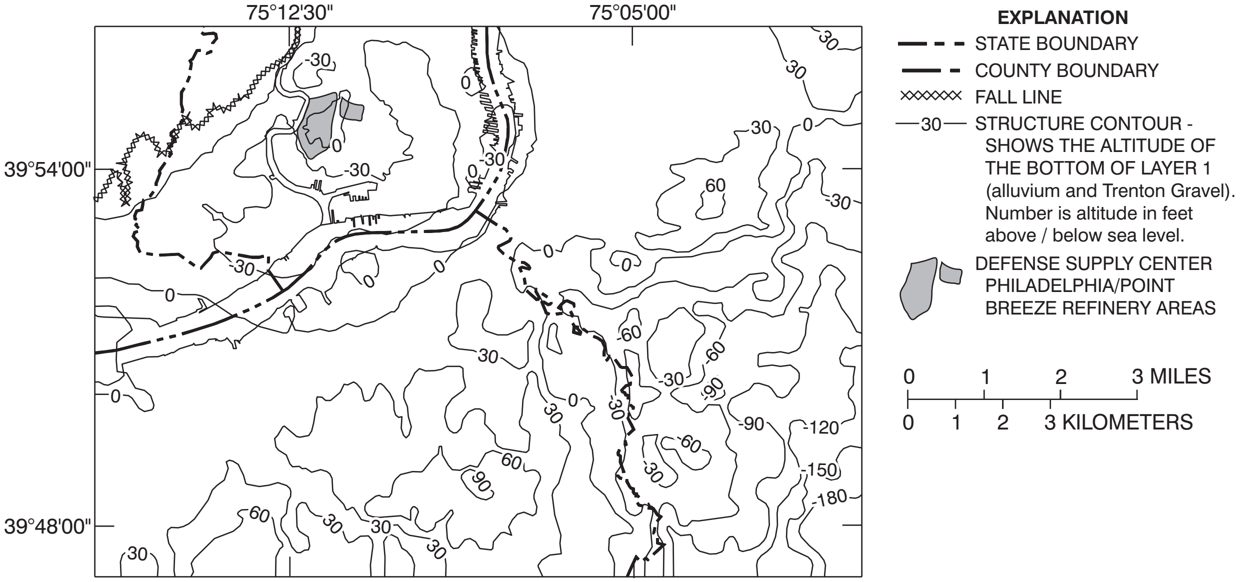


Figure 4. Altitude of the bottom of the alluvium and Trenton gravel (model layer 1) in the south Philadelphia, Pa., area and parts of Gloucester and Camden Counties, N.J.

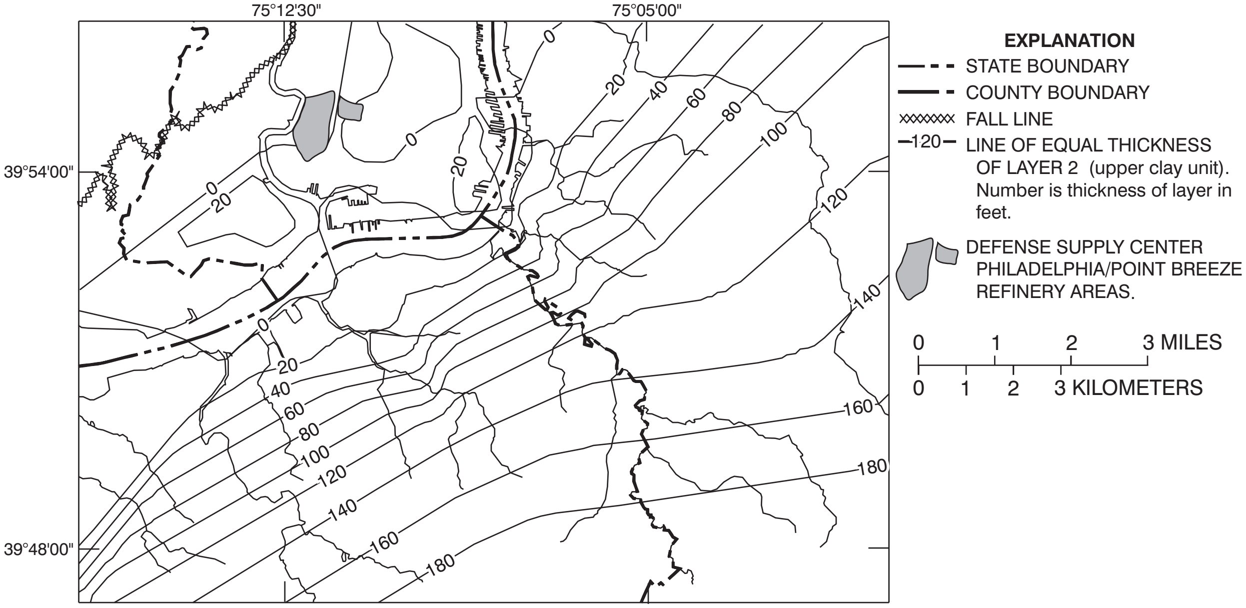


Figure 5. Thickness of the upper clay unit (model layer 2) of the Potomac-Raritan-Magothy aquifer system in the south Philadelphia area.

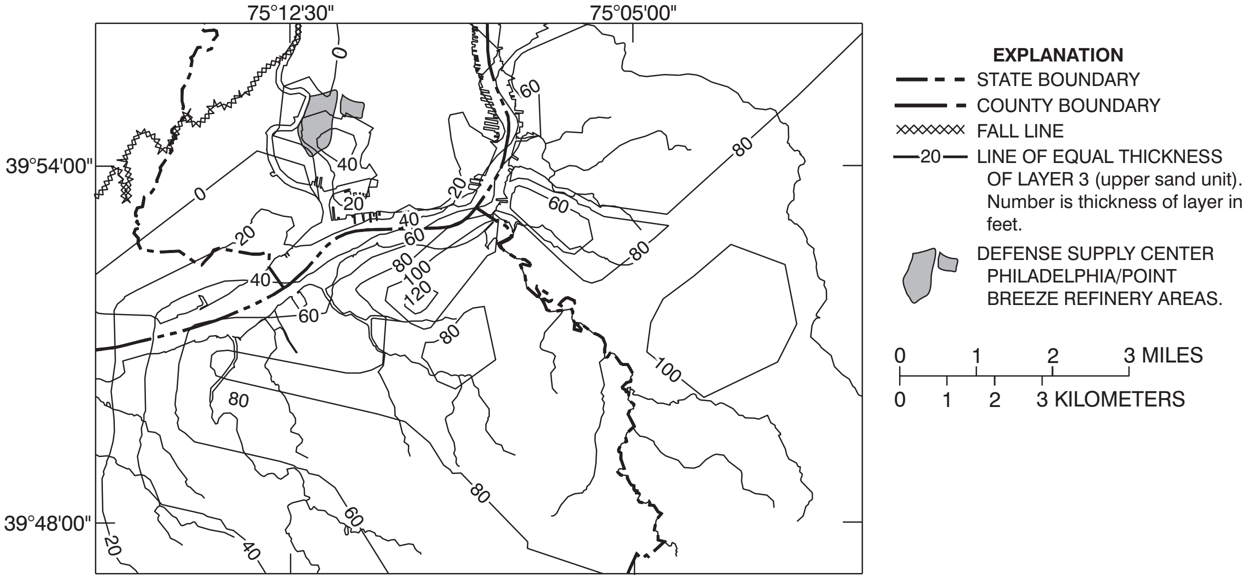


Figure 6. Thickness of the upper sand unit (model layer 3) of the Potomac-Raritan-Magothy aquifer system in the south Philadelphia area.

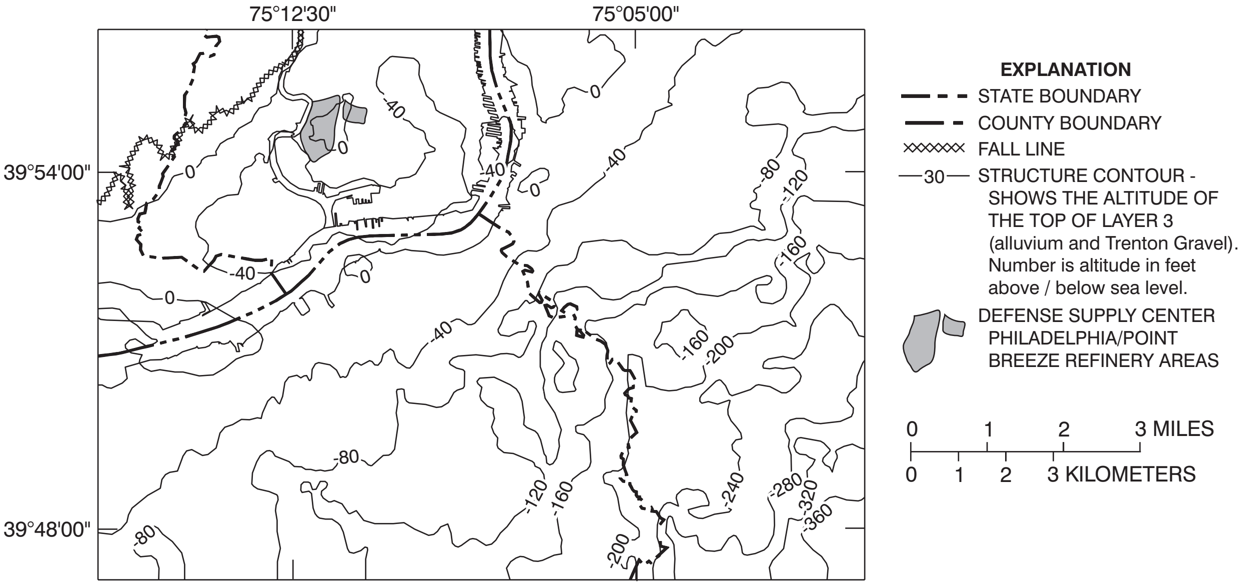


Figure 7. Altitude of the top of the upper sand unit (model layer 3) of the Potomac-Raritan-Magothy aquifer system in the south Philadelphia area.

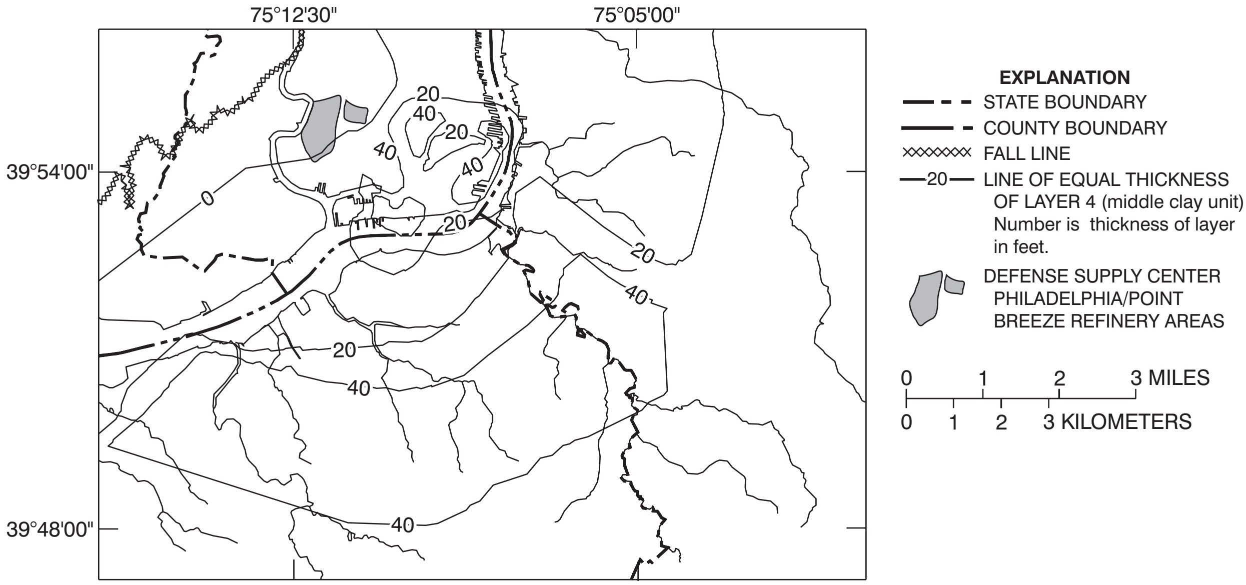


Figure 8. Thickness of the middle clay unit (model layer 4) of the Potomac-Raritan-Magothy aquifer system in the south Philadelphia area.

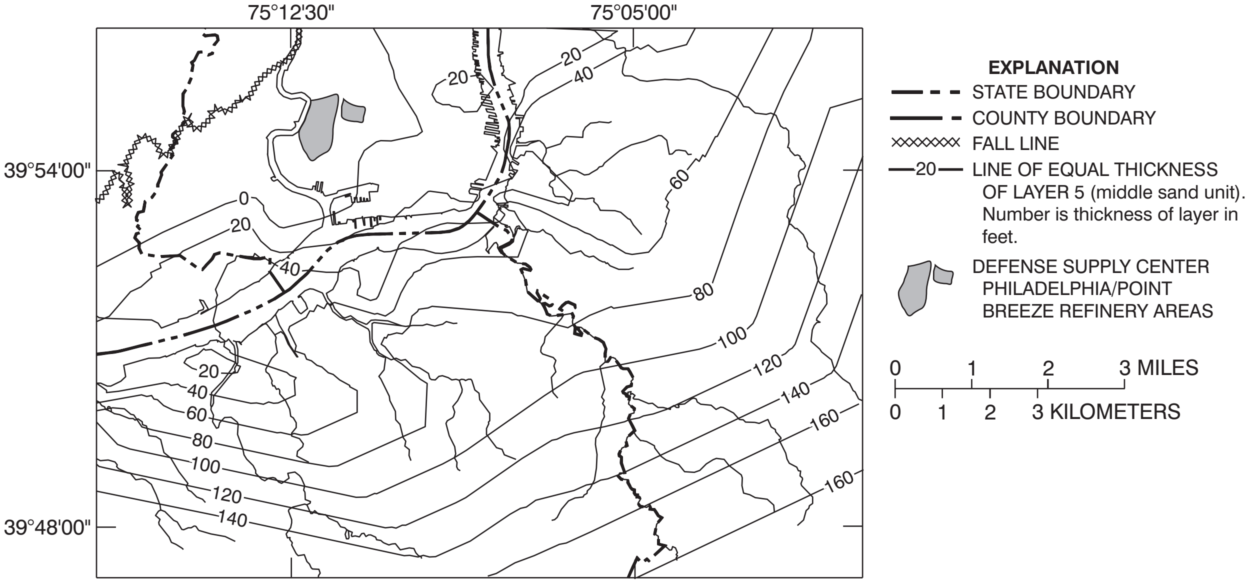


Figure 9. Thickness of the middle sand unit (model layer 5) of the Potomac-Raritan-Magothy aquifer system in the south Philadelphia area.

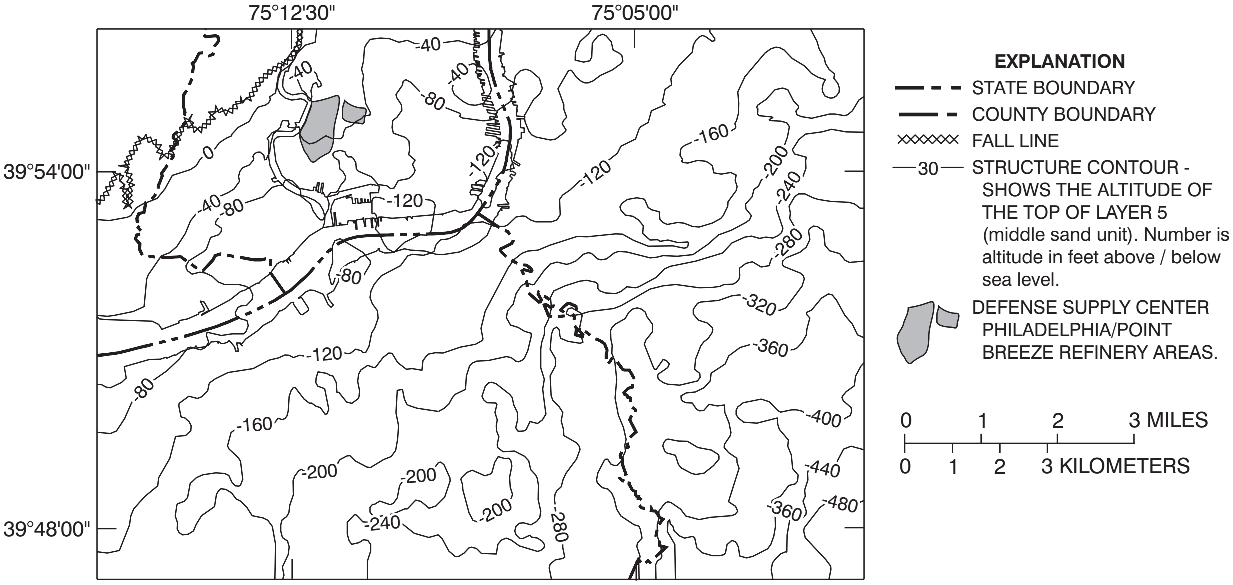


Figure 10. Altitude of the top of the middle sand unit (model layer 5) of the Potomac-Raritan-Magothy aquifer system in the south Philadelphia area.

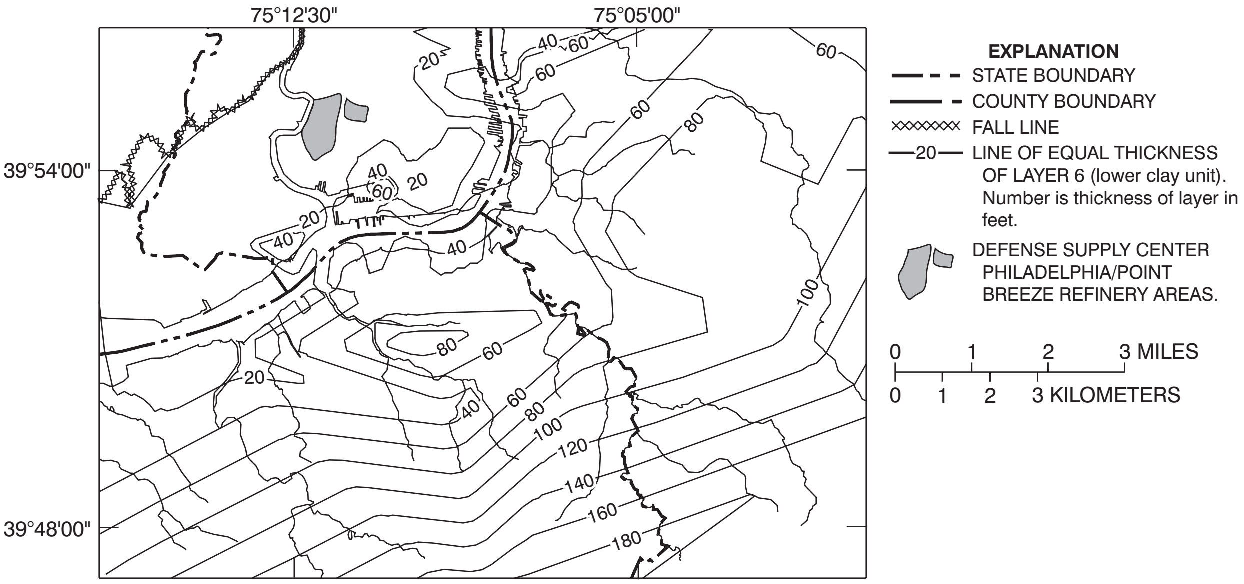


Figure 11. Thickness of the lower clay unit (model layer 6) of the Potomac-Raritan-Magothy aquifer system in the south Philadelphia area.

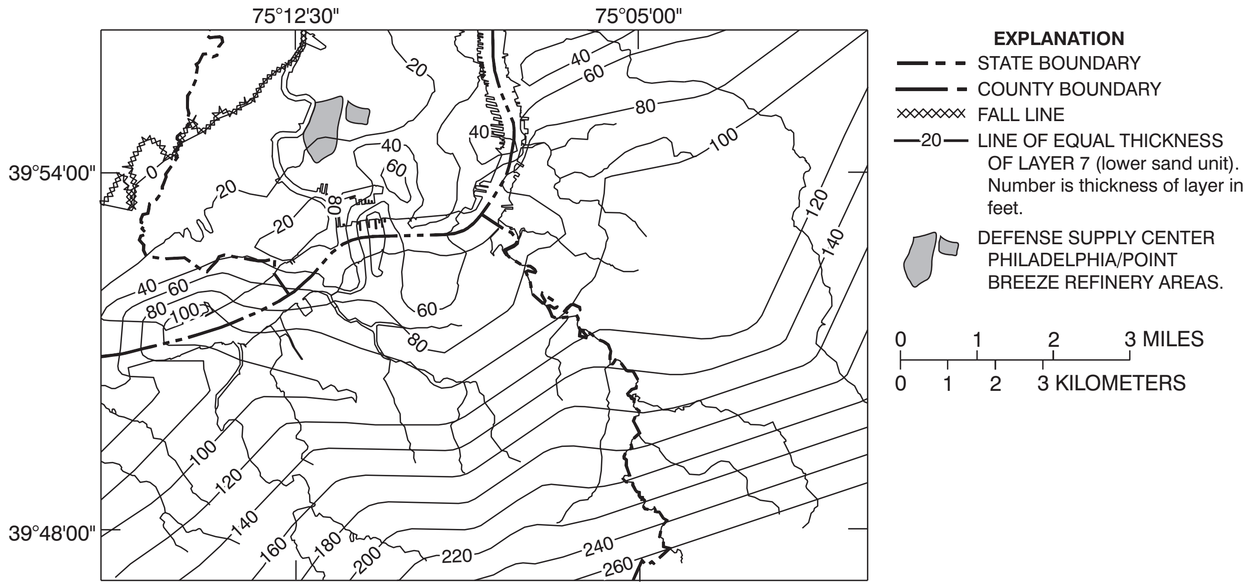


Figure 12. Thickness of the lower sand unit (model layer 7) of the Potomac-Raritan-Magothy aquifer system in the south Philadelphia area.

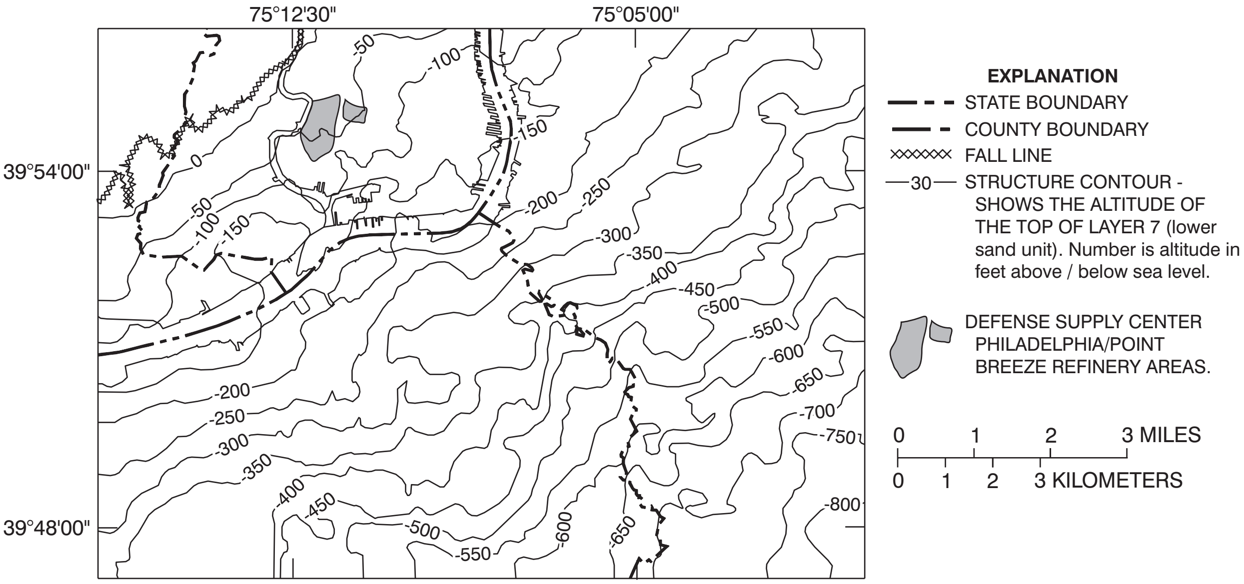


Figure 13. Altitude of the top of the lower sand unit (model layer 7) of the Potomac-Raritan-Magothy aquifer system in the south Philadelphia area.

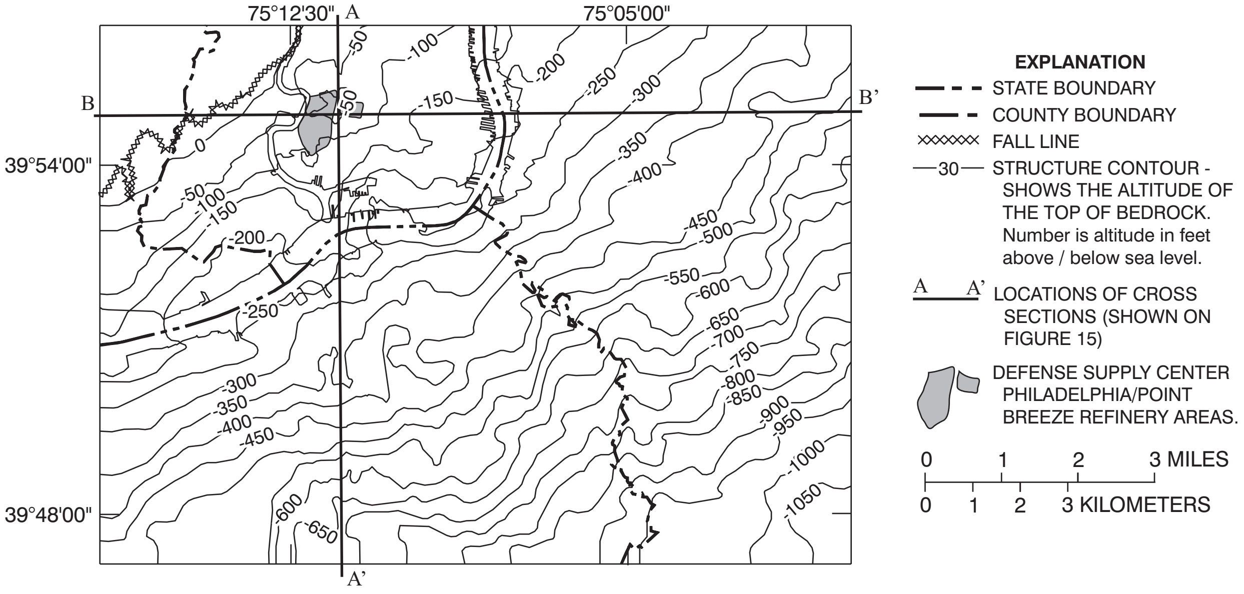


Figure 14. Altitude of the top of bedrock in the south Philadelphia area.

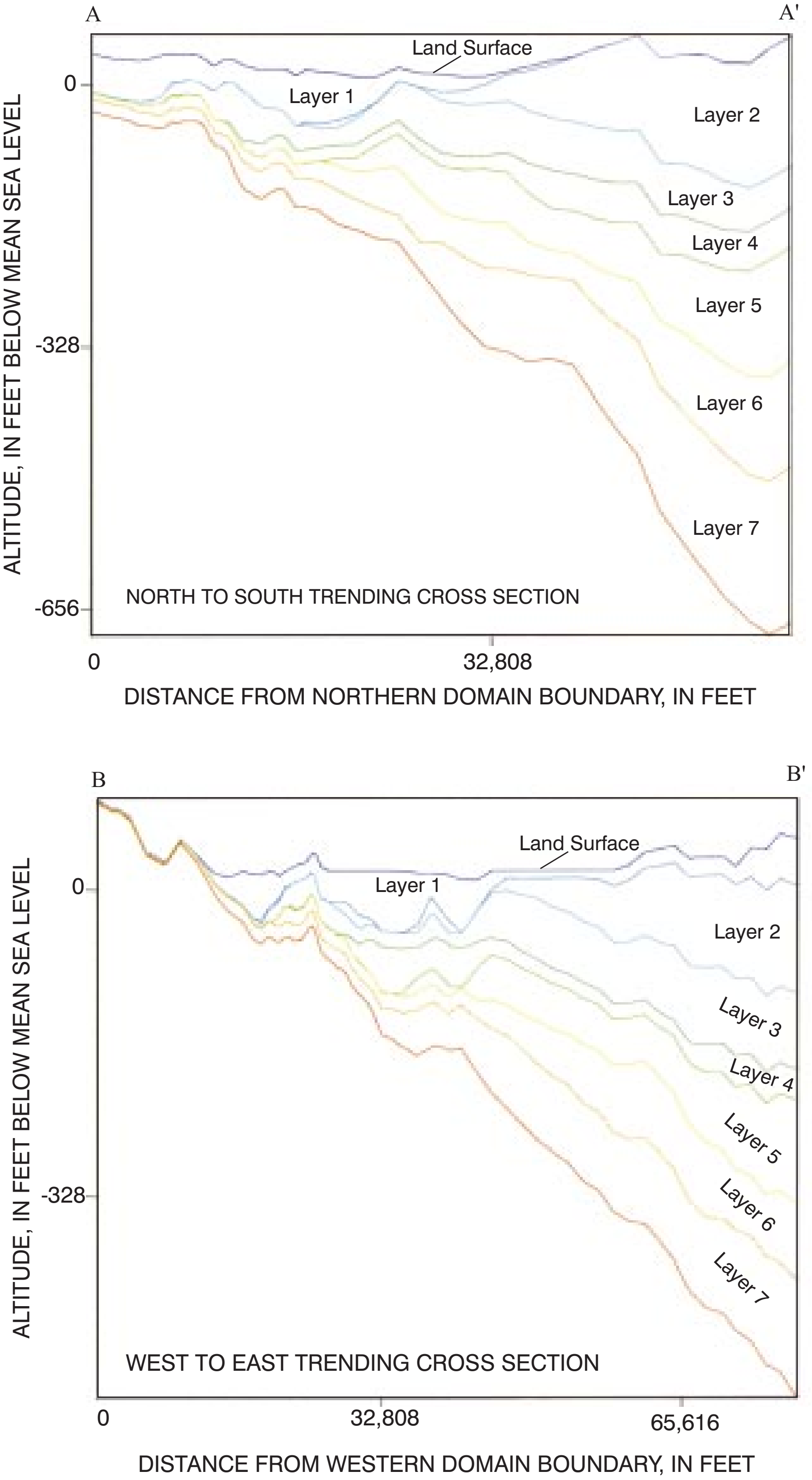


Figure 15. North to south and west to east trending cross sections of lithology used in the model of south Philadelphia and adjacent parts of New Jersey.

POTOMAC-RARITAN-MAGOTHY AQUIFER SYSTEM

Because the PRM aquifer system yields large amounts of water, withdrawals have been extensive in the south Philadelphia area. Starting in the early 1900's, pumping started to show an effect on the ground-water-flow system. Because of these withdrawals and the changes in the location of major pumping centers through the 1900's, ground-water flow directions have changed significantly from pre-development conditions. Recharge areas and the interaction between the PRM and the Schuylkill and Delaware Rivers also changed as a result of the withdrawals.

Pre-Development System

Barksdale and others (1958) theorized that before development of ground-water supplies began around 1900, regional ground-water flow was from high-altitude outcrop areas east of Trenton, N.J., towards the Delaware River. Ground-water flow was localized; precipitation recharged areas of high altitude and discharged to nearby streams and rivers. Vertical hydraulic gradients were upward in the discharge zones. Thus, before development of ground water, a large part of the water-table aquifer in south Philadelphia was a ground-water discharge zone. The hydraulic head in the lower sand unit was higher than the head in the middle and upper sand units and the Trenton gravel. Water flowed partly from the lower sand unit through and around confining units, especially in areas where the confining units pinched out into the middle and upper sand units, and subsequently into the alluvial water-table aquifer. Also, the rivers were gaining reaches in these areas. Greenman and others (1961, p. 54) constructed a pre-development representation of the potentiometric-surface map of the lower sand unit. Sloto (1988, p. 20) presented a pre-development, simulated potentiometric-surface map of the lower sand unit generated from a calibrated ground-water-flow model. Navoy and Carleton (1995) presented a simulated, pre-development potentiometric-surface map of the middle sand unit that was modified from Martin (1998, fig. 30).

Historical Ground-Water Withdrawals

By the 1920's, pumping in the City of Philadelphia had changed the natural ground-water-flow patterns. The principal change in the direction of ground-water flow from pre-development to the 1920's was in the area near the Walt Whitman Bridge (fig. 1), where the greatest withdrawals from the lower sand unit were made (Paulachok, 1991, p. 40). Withdrawals created water-level declines in this area, and ground water flowed toward these pumping centers. By 1940, continued and increasing pumping from the lower sand unit near the Walt Whitman Bridge had caused greater water-level declines in the lower aquifers and caused a still steeper hydraulic gradient towards these pumping centers. Also, lower heads in the lower sand unit relative to the heads in the alluvial and upper and middle sand units began to develop, which created a downward vertical ground-water-flow component. Recharge areas changed to areas near the Fall Line because of pumping from areas east of Trenton (Greenman and others, 1961, plates 21 and 22). Because of the increasing withdrawals from the unconfined alluvium and the confined upper, middle, and lower sand units, hydraulic heads were lowered below the levels of the Delaware and Schuylkill Rivers. Barksdale and others (1958) and Greenman and others (1961) document induced recharge from these rivers. Navoy and Carleton (1995, p. 35) give a detailed characterization of the Delaware River and the PRM aquifer interaction. These factors most likely have the same controlling effect on the interaction of the Schuylkill River and the underlying aquifer system. The rate and magnitude of flow from the rivers to the aquifer system are controlled by the relative head difference across the aquifer-river interface and by the riverbed and aquifer-system hydraulic conductivities.

Ground-water development for supply at the PNSY started in 1940, and heavy pumping at the facility continued until the mid 1960's. Large cones of depression in the lower sand unit were documented by Greenman and others (1961, fig. 16). According to Paulachok (1991), between 1943 and 1960, vertical leakage was the most important source of recharge to the lower sand unit in the vicinity of the PNSY. The downward vertical hydraulic gradients were more pronounced between 1943 and 1960 than prior to ground-water development in 1940 because of large withdrawals at the PNSY.

Because of poor water quality, mainly excessive concentrations of iron and manganese, ground-water withdrawals at the PNSY were discontinued in the mid-1960's. The decrease in pumping allowed water levels to recover. Coincident with decreasing pumpage and eventual shutdown of pumping at the PNSY, ground-water withdrawals on the New Jersey side of the Delaware River began to increase. According to Vowinkel (1984), total annual pumpage from the PRM in New Jersey in 1956 was 120 Mgal/d. The pumpage increased to 195 Mgal/d by 1966 and to 245 Mgal/d by 1980. Even though pumping stopped at the PNSY and water levels in the lower sand unit recovered in the PBR, DSCP, and PHD vicinity, the increased pumping in New Jersey maintained the downward vertical gradients.

In the modeled area, a total of 131 pumped wells are in Pennsylvania. Significant pumping in Pennsylvania began in the 1920's and steadily increased until 1941. A marked increase occurred after 1941, and pumpage in the modeled area peaked in 1948 at greater than 7 Bgal/yr or 20 Mgal/d. Overall pumpage steadily decreased until 1974 when pumping was slightly greater than 3 Bgal/yr or 8.5 Mgal/d because of increased use of public water supplies. From 1975 to 1982, pumping decreased to virtually nothing.

In the modeled area, a total of 125 pumped wells are in New Jersey. Significant pumping in New Jersey also began in the 1920's and slowly increased until 1946 with pumpage nearing 3 Bgal/yr or 8 Mgal/d. A dramatic increase occurred from 1947 and continued until it peaked in 1974 at greater than 16 Bgal/yr or 45 Mgal/d. Pumpage decreased from the peak until 1982 to almost 14 Bgal/yr or 38 Mgal/d. A sharp decline in pumpage occurred in 1984 with a slow decline continuing until 1995 when withdrawals totaled just less than 10 Bgal/yr or 27 Mgal/d. For the modeled area, annual pumpage from 1904 to 1995 in Pennsylvania and New Jersey is shown in figure 16.

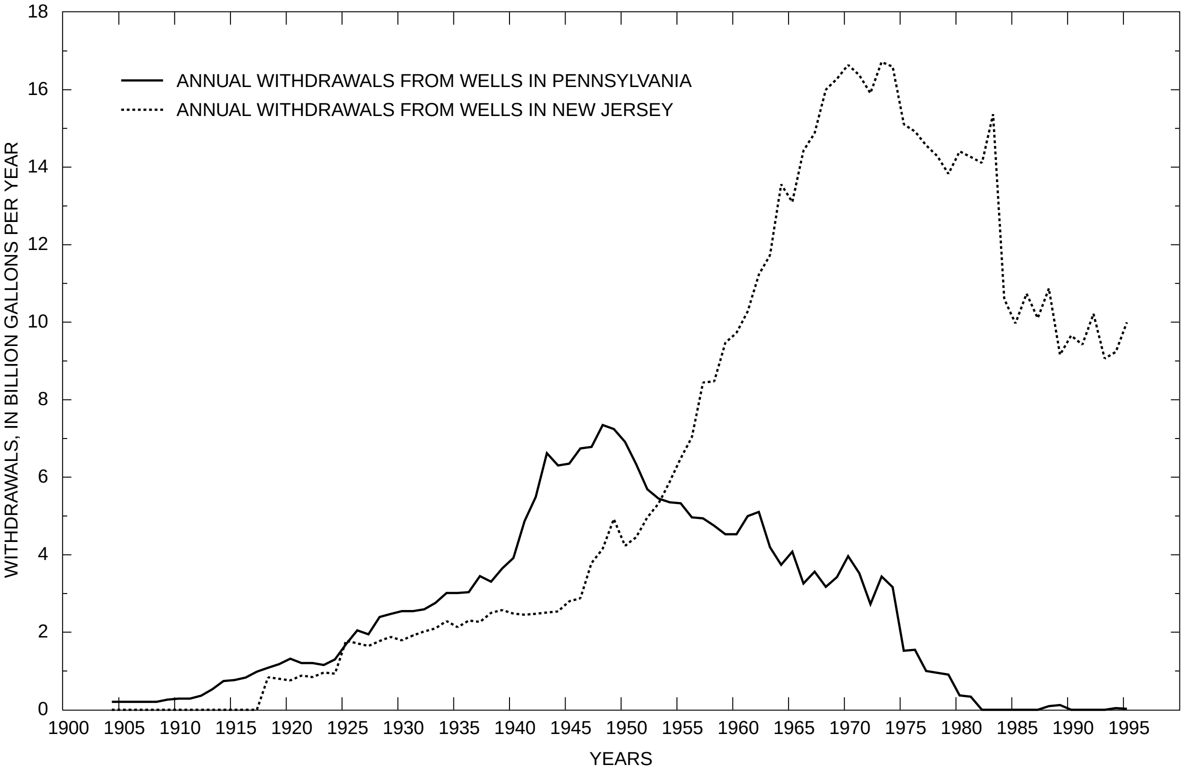


Figure 16. Annual ground-water withdrawals in the modeled area from the Potomac-Raritan-Magothy aquifer in Pennsylvania and New Jersey, 1904–95.

SIMULATION OF THE GROUND-WATER SYSTEM

An accurate understanding of the hydrogeologic system in the study area is needed to estimate historical water-level altitudes in the vicinity of the DSCP/PBR. This understanding or conceptualization of the flow system must then be constructed into a three-dimensional numerical ground-water-flow model. Boundary conditions of the model must be reasonably estimated to simulate the flow system and satisfy the objective. The geologic structure of the PRM and coinciding hydrologic parameters of the units, simulation of pinch-out units, spatial distribution of recharge, interactions of aquifers with the Schuylkill and Delaware Rivers, and historical withdrawal information all must be identified and defined to reasonably simulate the ground-water-flow system.

MODEL STRUCTURE AND BOUNDARY CONDITIONS

The model is a seven-layer three-dimensional representation of the hydrogeologic units of the study area. The three-dimensional, numerical flow model, MODFLOW (McDonald and Harbaugh, 1988), was used to simulate ground-water flow. The hydrogeologic units and corresponding model layers are shown in figure 2. The layer thicknesses and altitudes were described earlier in the section “Aquifer and Confining Unit Thicknesses and Altitudes.” In the DSCP/PBR vicinity, the spatial discretization per grid cell was 328 ft (100 m) on a side. The spatial discretization was increased outward from the DSCP/PBR vicinity to a maximum cell size of 1,640 ft (500 m) on a side (fig. 17).

In all model layers, the Fall Line boundary was simulated as a no-flow boundary. In all model layers, the lateral northern, eastern, southern, and western boundaries were defined by use of time-variable general head boundaries. The heads in each layer at each boundary were approximated by use of water-level data in wells near those boundaries at time periods corresponding to simulated stress periods. The bedrock interface beneath layer 7 was simulated as a no-flow boundary.

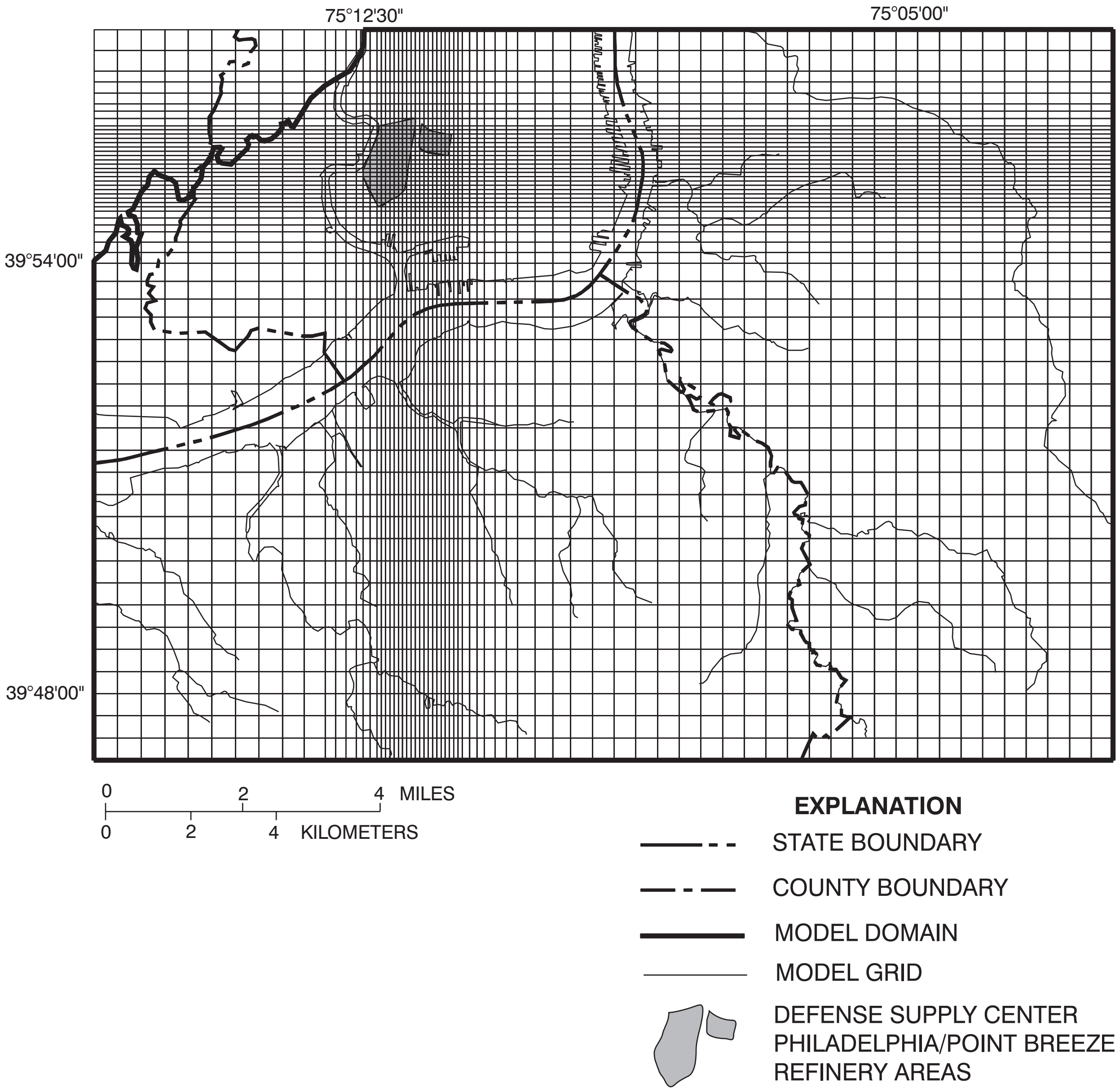


Figure 17. Finite-difference grid for the model.

Spatial Distribution of Aquifer and Confining Unit Hydraulic Properties

Aquifer and confining unit hydraulic properties of conductivity and specific storage varied spatially in all units except the lower sand unit, layer 7. The values for these parameters were obtained from the literature (Sloto, 1988; Navoy and Carleton, 1995). Using the pre-processing software (Argus Interware, 1997), different zones were used to represent the varying hydraulic parameters of the different units. The initial spatial aspect of the zonation was obtained from Navoy and Carleton (1995). Zones were changed in the model-calibration process. The zonation for hydraulic conductivity and specific storage are shown in figures 18 through 24. Because layer 7 did not pinch out, only one zone for hydraulic conductivity and specific storage was used.

All model layers were modeled as confined units. Although the alluvial unit in some locations is unconfined, the unit was modeled as a confined aquifer because of model instability, but the specific storage value for areas in Pennsylvania was increased to represent unconfined storage. Hydraulic parameters used in the model are listed in table 2.

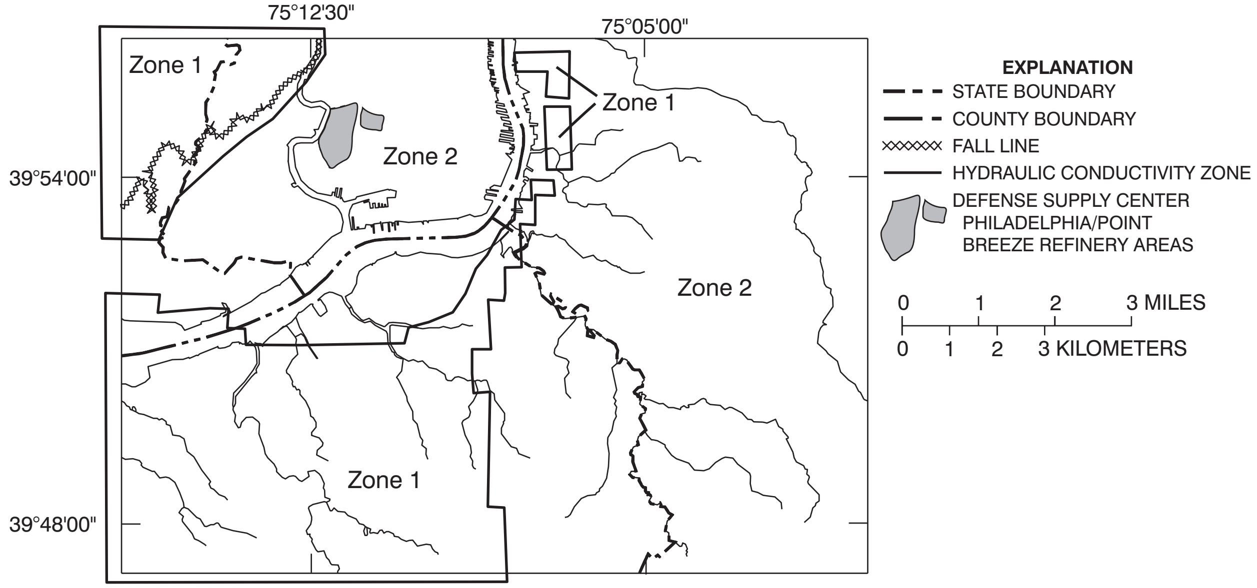


Figure 18. Hydraulic conductivity zones used in the model for the alluvial and Trenton gravel unit (layer 1).

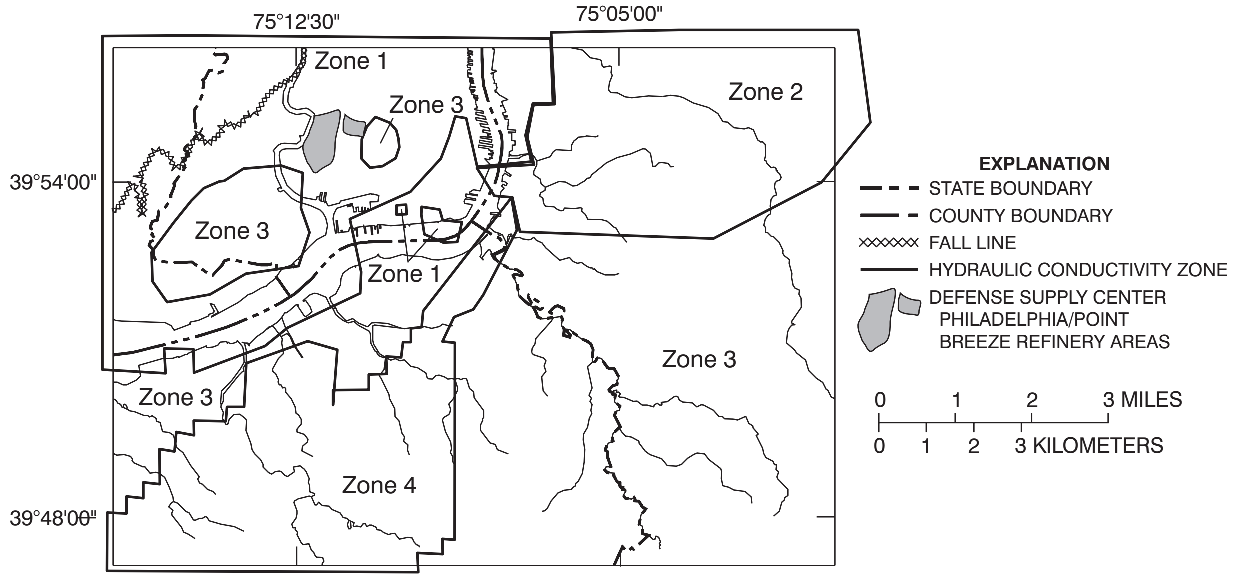


Figure 19. Hydraulic conductivity zones used in the model for the upper clay unit (layer 2) of the Potomac-Raritan-Magothy aquifer system.

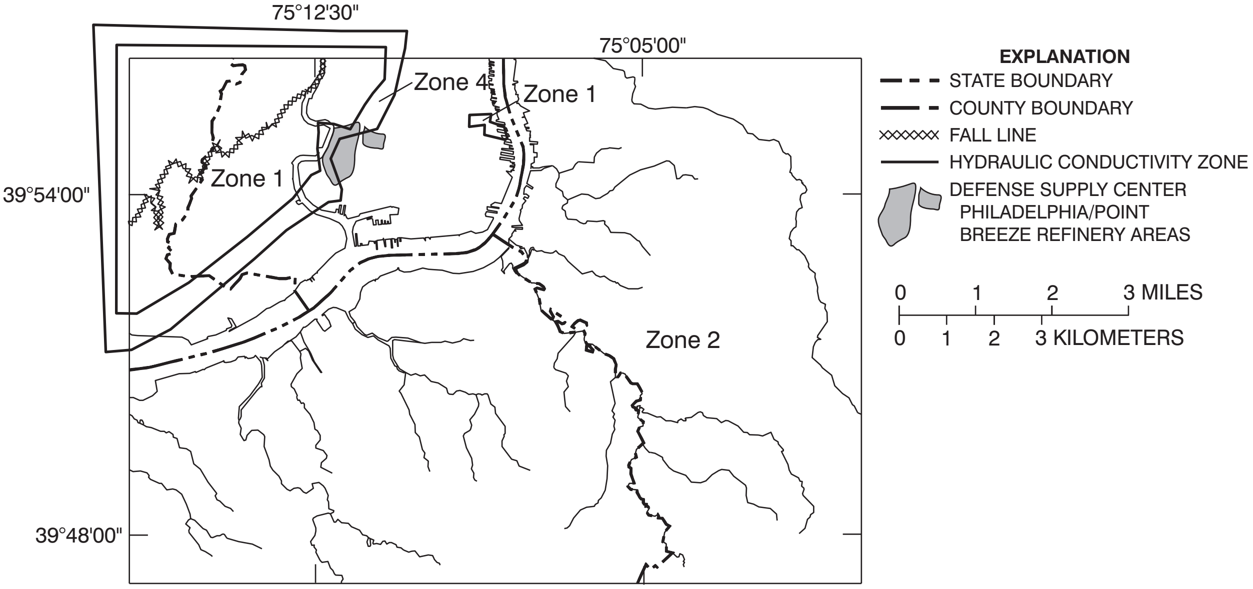


Figure 20. Hydraulic conductivity zones used in the model for the upper sand unit (layer 3) of the Potomac-Raritan-Magothy aquifer system.

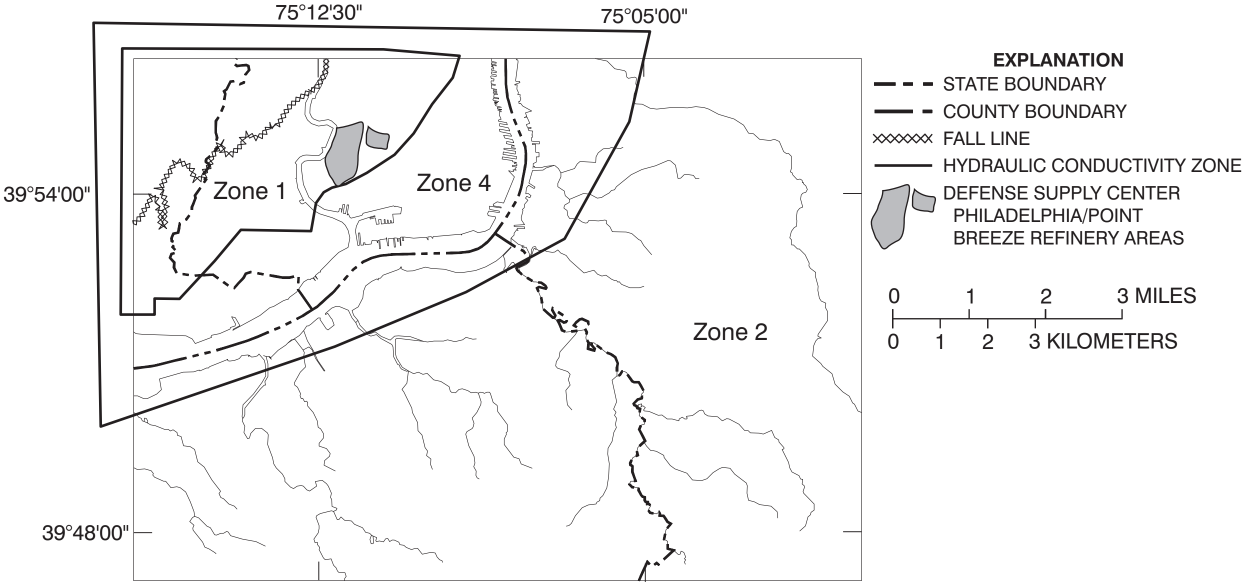


Figure 21. Hydraulic conductivity zones used in the model for the middle clay unit (layer 4) of the Potomac-Raritan-Magothy aquifer system.

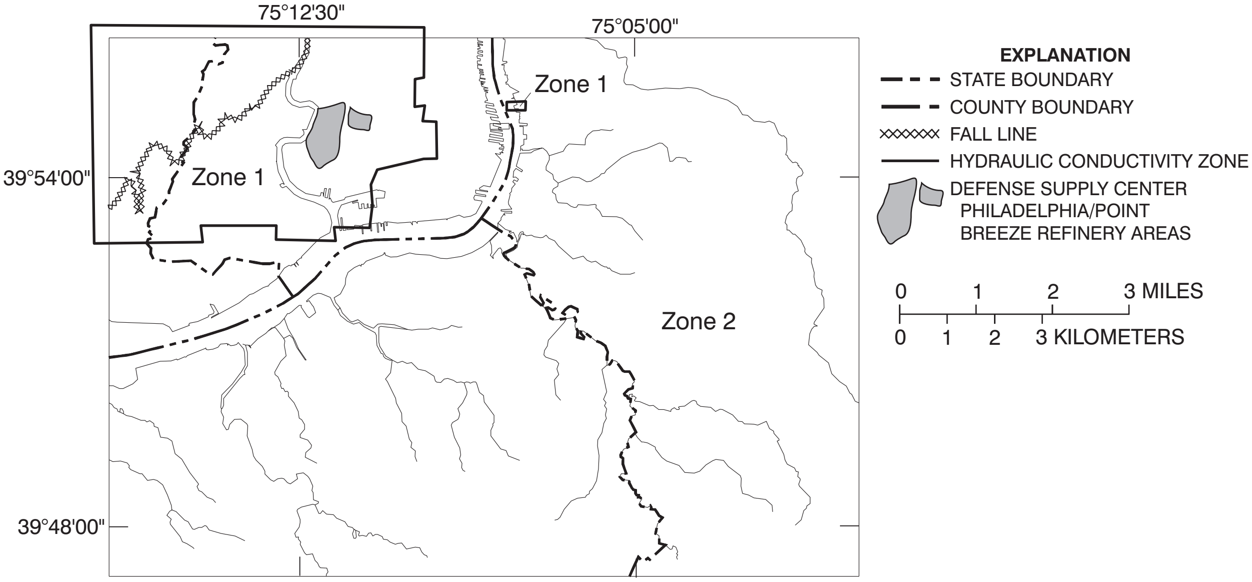


Figure 22. Hydraulic conductivity zones used in the model for the middle sand unit (layer 5) of the Potomac-Raritan-Magothy aquifer system.

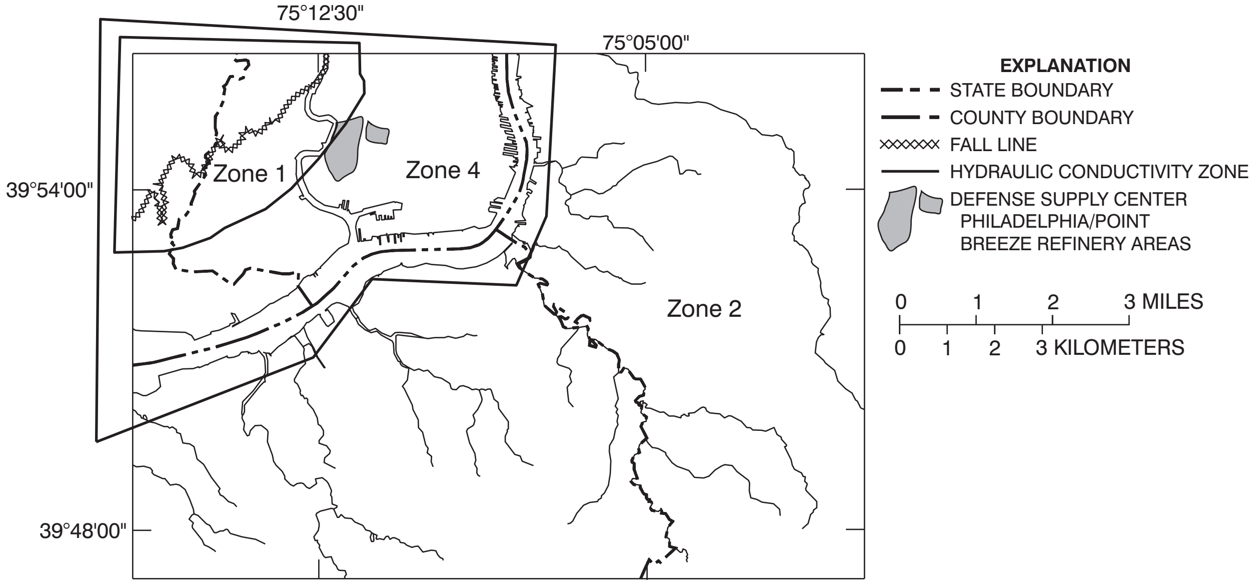


Figure 23. Hydraulic conductivity zones used in the model for the lower clay unit (layer 6) of the Potomac-Raritan-Magothy aquifer system.

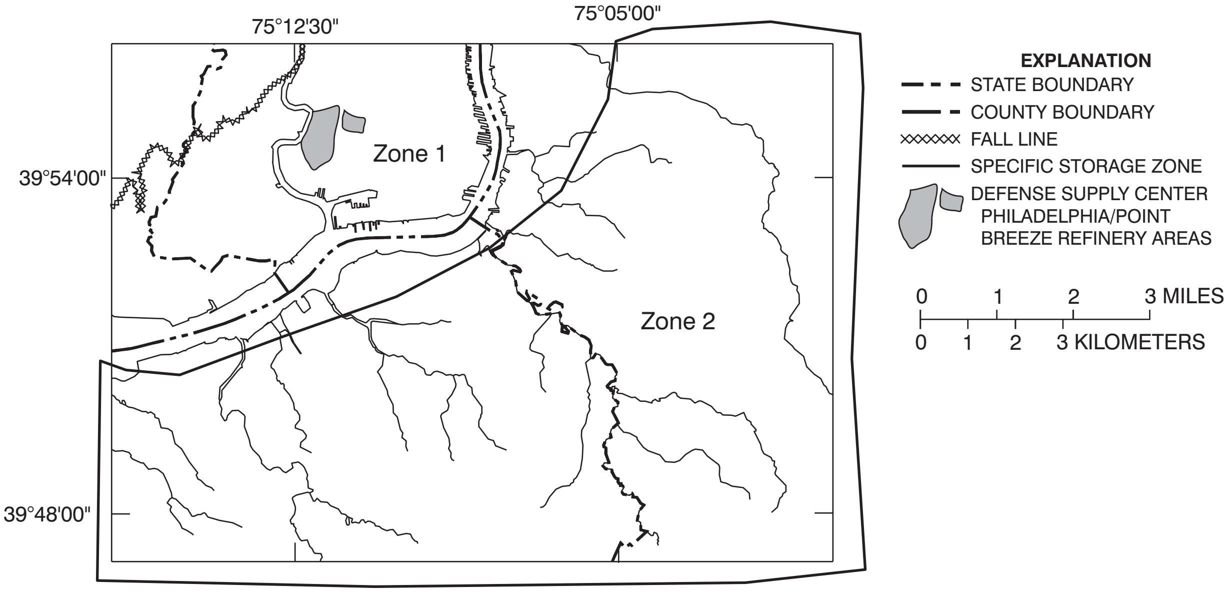


Figure 24. Specific storage zones used in the model for the alluvium and Trenton gravel (layer 1).

Table 2. *Summary of zonation of hydraulic conductivity and specific storage values used in the model*

[--, not defined]

Model layer	Zone	Hydraulic conductivity				Specific storage
		Horizontal		Vertical		
		feet per day	meters per day	feet per day	meters per day	
Layer 1	1	3.28×10^{-5}	1.0×10^{-5}	32,808	10,000	0.1
	2	5.472	1.668	5.472	1.668	.0001
Layer 2	1	3.28×10^{-5}	1.0×10^{-5}	32,808	10,000	1.0×10^{-7}
	2	.35	.10668	.35	.10668	--
	3	3.5×10^{-4}	1.067×10^{-4}	3.5×10^{-4}	1.067×10^{-4}	--
	4	.328	.1	.328	.1	--
Layer 3	1	3.28×10^{-5}	1.0×10^{-5}	32,808	10,000	1.0×10^{-4}
	2	35	10.668	35	10.668	--
	4	3.28×10^{-2}	.01	35	10.668	--
Layer 4	1	3.28×10^{-5}	1.0×10^{-5}	32,808	10,000	1.0×10^{-7}
	2	.35	.10668	.35	.10668	--
	4	1.2×10^{-2}	3.657×10^{-3}	1.2×10^{-2}	3.657×10^{-3}	--
Layer 5	1	3.28×10^{-5}	1.0×10^{-5}	32,808	10,000	1.0×10^{-4}
	2	98	30	98	30	--
Layer 6	1	3.28×10^{-5}	1.0×10^{-5}	32,808	10,000	1.0×10^{-7}
	2	.35	.10668	.35	.10668	--
	4	4.0×10^{-3}	1.219×10^{-3}	4.0×10^{-3}	1.219×10^{-3}	--
Layer 7	--	164	50	164	50	1.0×10^{-4}

Simulation of Pinched-Out Units

Because of the depositional environment and the underlying dipping bedrock, many units pinch out near the Fall Line in the northeastern part of the study area. Also, many units are discontinuous throughout the study area. In order to simulate these discontinuities, the method established was to determine from the isopach maps the zero thickness areas of individual units. The zero thickness areas were determined using the pre-processing software and the zero thicknesses were assigned a value of 0.328 ft (0.1 m). The horizontal hydraulic conductivity was set to 3.28×10^{-5} ft/d (1.0×10^{-5} m/d), and the vertical hydraulic conductivity was set to 32,808 ft/d (10,000 m/d). This procedure permitted water (in the model) to freely flow downward through the pinched out units to underlying units. On figures 17–23, zone 1 represented areas of pinched out or discontinuous units.

Spatial and Temporal Distribution of Recharge

Water directly enters the aquifer system as recharge from precipitation only on an outcrop area (Navoy and Carleton, 1995, p. 60). The outcrop areas are near the Fall Line in the northern part of the modeled area. Recharge was assigned to the uppermost active model layer. The spatial distribution of recharge for this model is shown on figure 25. The spatial distribution for the zoning of recharge parameters was obtained from Navoy and Carleton (1995, fig. 45). Navoy and Carleton (1995) used recharge estimates on the Pennsylvania side of the river in their calibrated model in the Camden, N.J., area that ranged from 4 to 9 in/yr (2.78×10^{-4}m/d to 6.26×10^{-4}m/d). In order to calibrate this model, recharge rates were changed temporally. The recharge values, zonation for spatial distribution, and temporal distribution of recharge rates are listed in table 3.

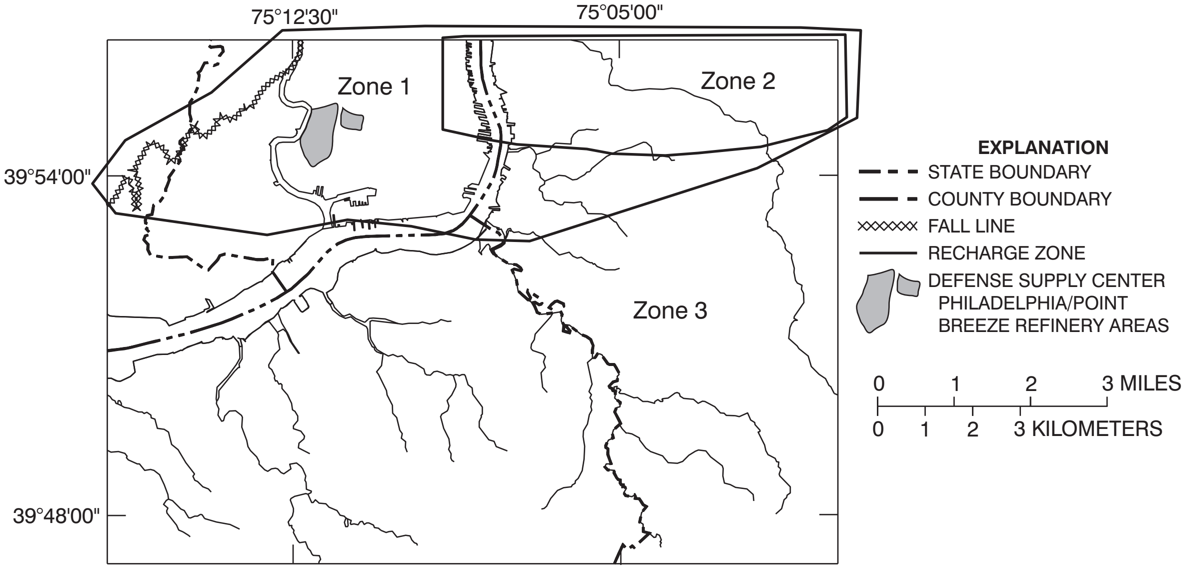


Figure 25. Recharge zones used in the model.

Table 3. *Summary of assigned recharge rates associated with spatial and temporal variability*

[Zones are shown in figure 25.]

Zone	Stress periods[1]	Recharge rate (inches per year)	Recharge rate (meter per day)
1	1 - 16	4	2.784×10^{-4}
	17 - 21	6	4.175×10^{-4}
2	1 - 16	6	4.175×10^{-4}
	17 - 21	8	5.552×10^{-4}
3	1 - 16	0	0
	17 - 21	0	0

[1] See table 5 for stress period time intervals.

River Interactions

The interaction between the Delaware and Schuylkill Rivers and the aquifer system is an important factor because the rivers changed from gaining streams to losing streams from pre- to post-development of ground-water resources. Factors that effect the aquifer/river interaction in the model are the vertical hydraulic conductivity of the riverbed, the altitude of the bottom of the river, the stage of the river, and the thickness of the riverbed. Because of the local hydrogeology, the bottoms of the rivers are in different units. For this model, the rivers were zoned spatially on the basis of which model layer the bottom of the river was located. Different riverbed hydraulic conductivities were assigned to each river area unit (fig. 26). The riverbed hydraulic conductivities are spatially variable and are based on work done by Navoy and Carleton (1995, fig. 23). Riverbed hydraulic conductivities were initially set to values used by Navoy and Carleton (1995) but were adjusted in the calibration process. The rivers in the study area are tidal, but only average river stages were used. The average river stage was held constant for all stress periods. The riverbed thickness was assigned 10 ft (3.048 m) for all area river units. The riverbed hydraulic conductivities, river-bottom altitudes, and average river stages for each river area unit are summarized in table 4.

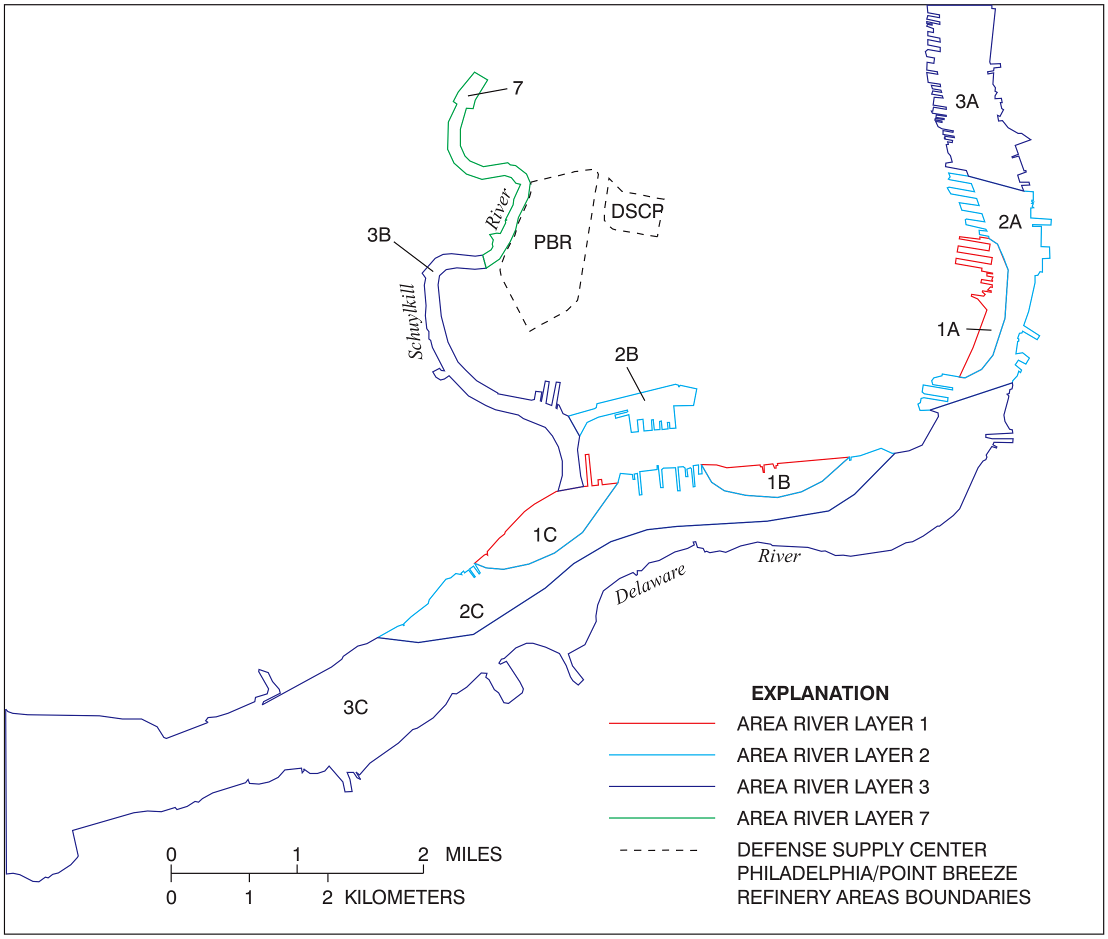


Figure 26. River area layers used in the model.

Table 4. *Summary of area riverbed hydraulic conductivities, average river stages, and altitudes of the bottom of the rivers*

River area	Model layer	Riverbed hydraulic conductivity		Average river stage		Altitude of river bottom	
		meters per day	feet per day	meter	feet	meter	feet
1A	1	1.299×10^{-2}	4.26×10^{-2}	0.1524	0.5	-3.0	-9.84
1B	1	1.299×10^{-2}	4.26×10^{-2}	.1524	.5	-3.0	-9.84
1C	1	1.299×10^{-2}	4.26×10^{-2}	.1524	.5	-3.0	-9.84
2A	2	2.60×10^{-5}	8.53×10^{-5}	.1524	.5	-6.5	-21.3
2B	2	2.60×10^{-5}	8.53×10^{-5}	.1524	.5	-16.6	-54.5
2C	2	2.60×10^{-5}	8.53×10^{-5}	.1524	.5	-12.0	-39.4
3A	3	6.40×10^{-3}	2.10×10^{-2}	.3048	1.0	-2.0	-6.56
3B	3	6.40×10^{-3}	2.10×10^{-2}	.1524	.5	-14.0	-45.9
3C	3	6.40×10^{-3}	2.10×10^{-2}	.1524	.5	-15.0	-49.2
7	7	1.299×10^{-2}	4.26×10^{-2}	.3048	1.0	-1.0	-3.28

Time Discretization and Stress Periods

The starting point for the model simulations was set to pre-development conditions. Withdrawals before 1900 are assumed to be insignificant; significant pumping started after 1904. The model used 21 stress periods that represented different time intervals from 1900 through 1995. Each stress period was based on changes in annual withdrawal rates. The stress periods and the corresponding simulated years are summarized in table 5. The first stress period was a steady-state simulation and the subsequent 20 stress periods were transient simulations. For each transient stress period, an average withdrawal rate was used to represent pumping. The annual withdrawals and corresponding assigned model stress-period withdrawal rates are shown in figure 27.

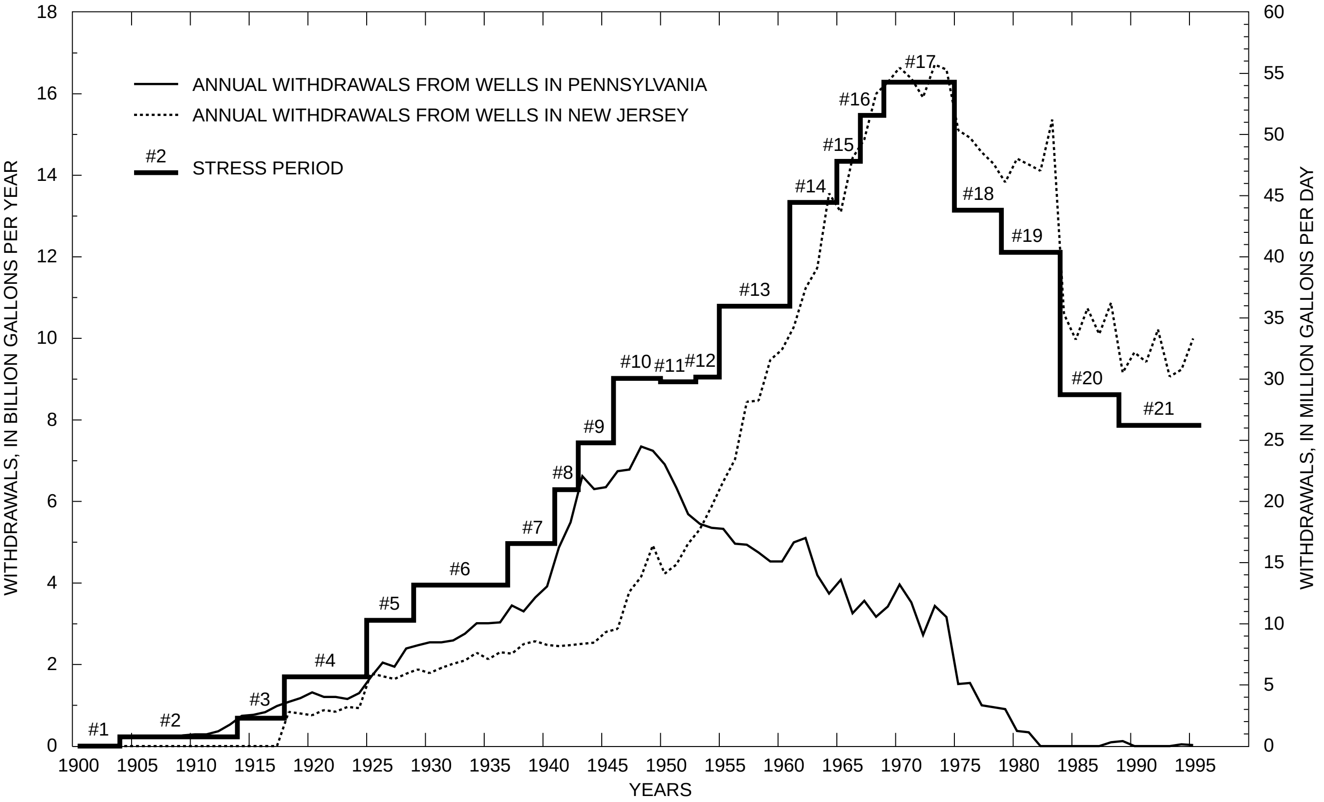


Figure 27. Annual ground-water withdrawals in the modeled area from the Potomac-Raritan-Magothy aquifer in Pennsylvania and New Jersey from 1904-95 and model stress-period withdrawals.

Table 5. *Summary of simulated stress periods and represented years*

Stress period	Represented years	Stress period	Represented years
1	1900–03	12	1953–54
2	1904–13	13	1955–60
3	1914–17	14	1961–64
4	1918–24	15	1965–66
5	1925–28	16	1967–68
6	1929–36	17	1969–74
7	1937–40	18	1975–78
8	1941–42	19	1979–83
9	1943–45	20	1984–88
10	1946–49	21	1989–95
11	1950–52		

MODEL CALIBRATION

In order to adequately simulate historical water-level altitudes, parameters such as hydraulic conductivities of the aquifer units and riverbed must be adjusted to reflect results of available observed data in the literature. The model parameters were adjusted by a trial-and-error approach to match the observed data.

The model was calibrated, meaning that input parameters were adjusted until simulated water levels matched published potentiometric-surface maps. Most potentiometric-surface maps done in Pennsylvania are of the lower sand unit (layer 7) of the PRM. Greenman and others (1961) published a potentiometric-surface map of the lower sand unit in the south Philadelphia area for August 1945. They also published a potentiometric-surface map of the lower sand unit in the south Philadelphia area for March 1954. Gill and Farlekas (1976) published a potentiometric-surface map of the PRM aquifer system in the New Jersey Coastal Plain that included part of south Philadelphia for 1968. Sloto (1988) published a potentiometric-surface map of the lower sand unit in south Philadelphia and southwestern New Jersey compiled from Walker (1983, pl. 1) and Paulachok (U.S. Geological Survey, written commun., 1982). Rosman (1997) published a potentiometric-surface map of the PRM aquifer system near National Park, N.J., for 1996, which included part of south Philadelphia.

The model was considered to be calibrated if altitudes on the simulated potentiometric-surface maps were within +/- 15 ft of altitudes on the published potentiometric-surface maps listed above. Navoy and Carleton (1995) set a 15-ft calibration accuracy for their model of the PRM in the Camden area. They based the 15-ft accuracy on several factors that included seasonal variations in water levels caused by seasonal variations in withdrawals and climatic factors, error in altitude data from the DEM, and error associated with synoptic water-level measurements. Because the purpose of the model was to simulate water-level altitudes over several decades, model stress periods were several years long. Thus, seasonal variations due to seasonal withdrawals and climatic factors were not incorporated into the model. Navoy and Carleton set a range attributable to the seasonal water-level variation of +/- 5 ft. The DEM error for level 2 DEM’s is set at one-half the contour interval, which would yield a range of +/- 5 ft. Associated error attributable from synoptic water-level measurements is related to the accuracy of the measurement-site altitude (Navoy and Carleton, 1995, p.53). Most water-level measurement site altitudes were derived from USGS topographic maps with 10-ft contour intervals that would yield a range of +/- 5 ft.

Available water-level data near the DSCP/PBR area were compared to simulated water-level altitudes in grid cells that contained those wells for a check of model fit. Model parameters were not adjusted in order to match these water-level data, however, because the data were limited spatially and temporally.

The purpose of the model was to simulate water-level altitudes over several decades. A result of the simulation shows that water-level altitudes were consistently below the bottom of the Packer Avenue sewer from 1940 through 1990 is acceptable when that result is put in the context that the model is simulating conditions over several years and seasonal variations in the water table were not simulated. Navoy and Carleton (1995) in their report on modeling ground-water flow in the PRM aquifer system of the Camden area state that seasonal variations in water levels in the aquifer system, caused by seasonal variations in withdrawals and climatic factors, can range from +/- 5 ft over several years.

Initial Conditions

In order to simulate pre-development conditions, a steady-state simulation was run with initial water levels for all layers placed at the land surface. The resulting steady-state potentiometric surface of the lower sand unit (layer 7) is shown in figure 28. The potentiometric surface agrees with pre-development conditions theorized by Barksdale and others (1958) that describe the pre-pumping, regional ground-water-flow system having upward vertical gradients with local recharge in upland areas and discharging to nearby rivers.

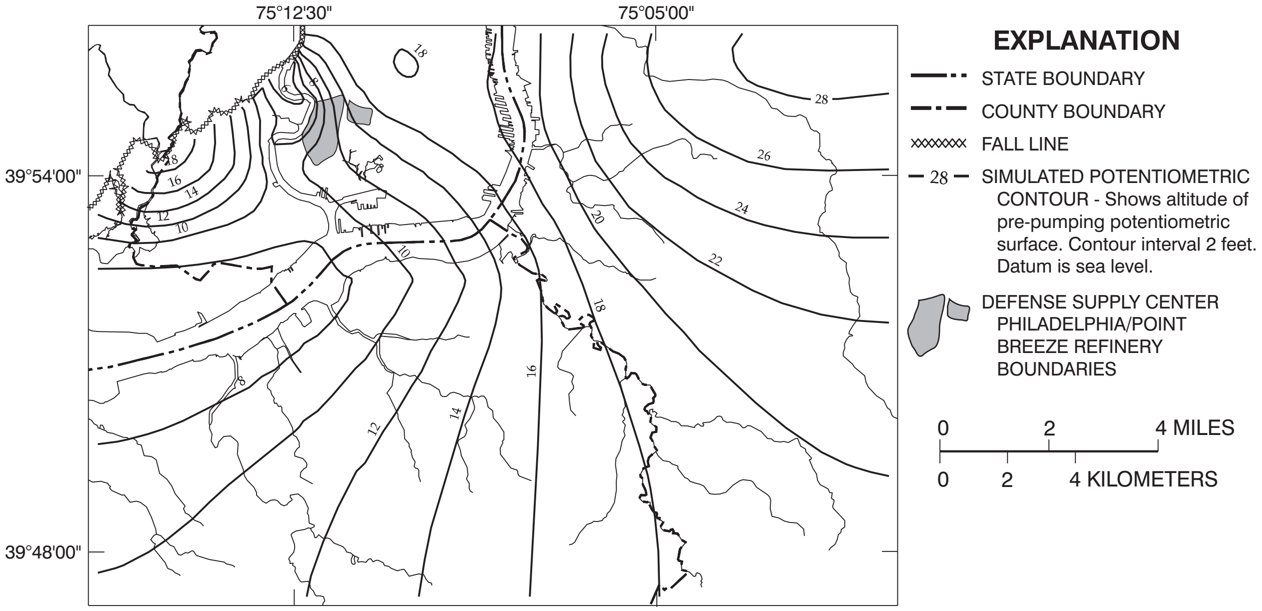


Figure 28. Simulated pre-development potentiometric surface of lower sand unit (model layer 7) of the Potomac-Raritan-Magothy aquifer system.

Comparison of Simulated Heads to Potentiometric Surface Maps

The simulated potentiometric surface of the south Philadelphia area for August 1945 is shown in figure 29. The August 1945 potentiometric-surface map of Greenman and others (1961) is shown in figure 30. The potentiometric-surface configurations are in agreement, but maximum drawdowns at the pumping centers are not. This could be the result of water-level data collected in pumping wells in which well-loss effects increase drawdown. Well-loss effects are negligible in non-pumping wells. Also, the grid-cell size may be too large to adequately represent drawdowns in the aquifer, especially in areas near large withdrawals.

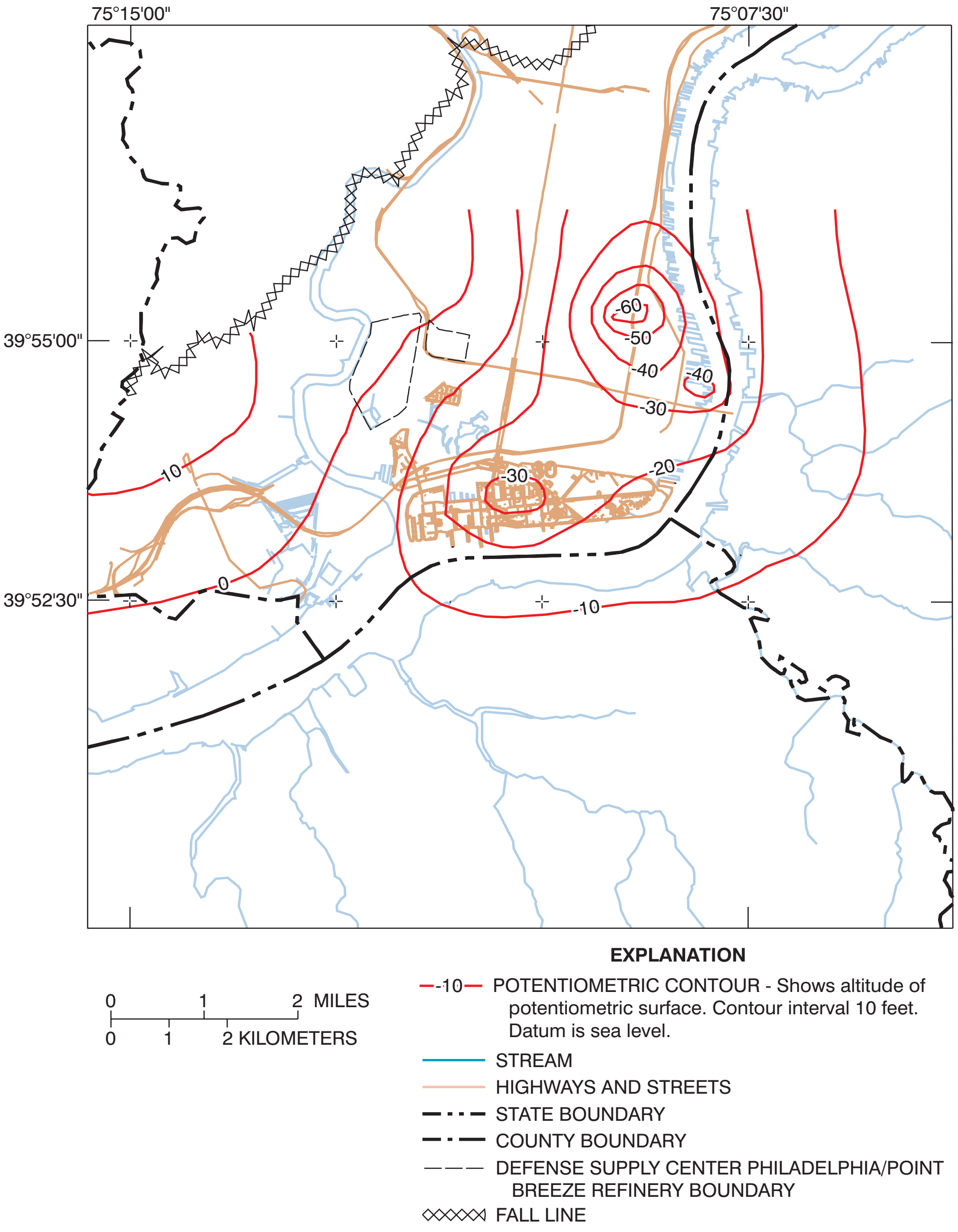


Figure 29. Simulated potentiometric surface for the lower sand unit of the Potomac-Raritan-Magothy aquifer system, August 1945.

For August 1945, simulated horizontal ground-water-flow direction in the lower sand unit (layer 7) near the area of concern was to the southeast towards areas with large cones of depression along the Delaware River. Simulated water-level altitudes in the lower sand unit (layer 7) ranged from 0 to -10 ft sea level, which caused downward vertical flow gradients in the upper units.

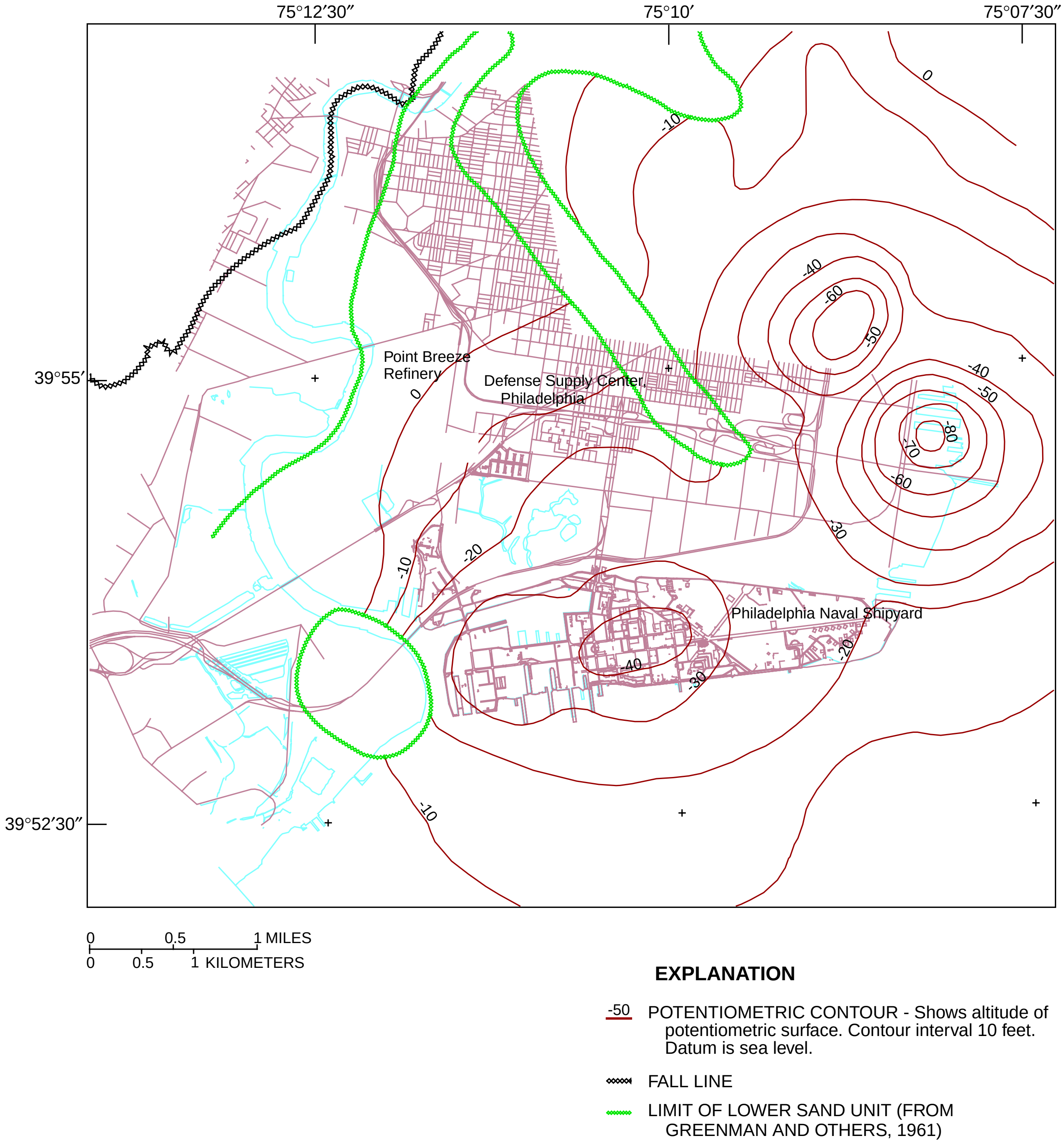


Figure 30. Potentiometric surface of the lower sand unit, August 1945 (modified from Greenman and others, 1961).

The simulated potentiometric surface of the south Philadelphia area for March 1954 is shown in figure 31. The March 1954 potentiometric-surface map of Greenman and others (1961) is shown in figure 32. The potentiometric-surface configurations are in agreement, but maximum drawdowns at the pumping centers once again are not. As described earlier, this could result from well-loss effects in pumping wells, and the large grid-cell size in areas of large withdrawals.

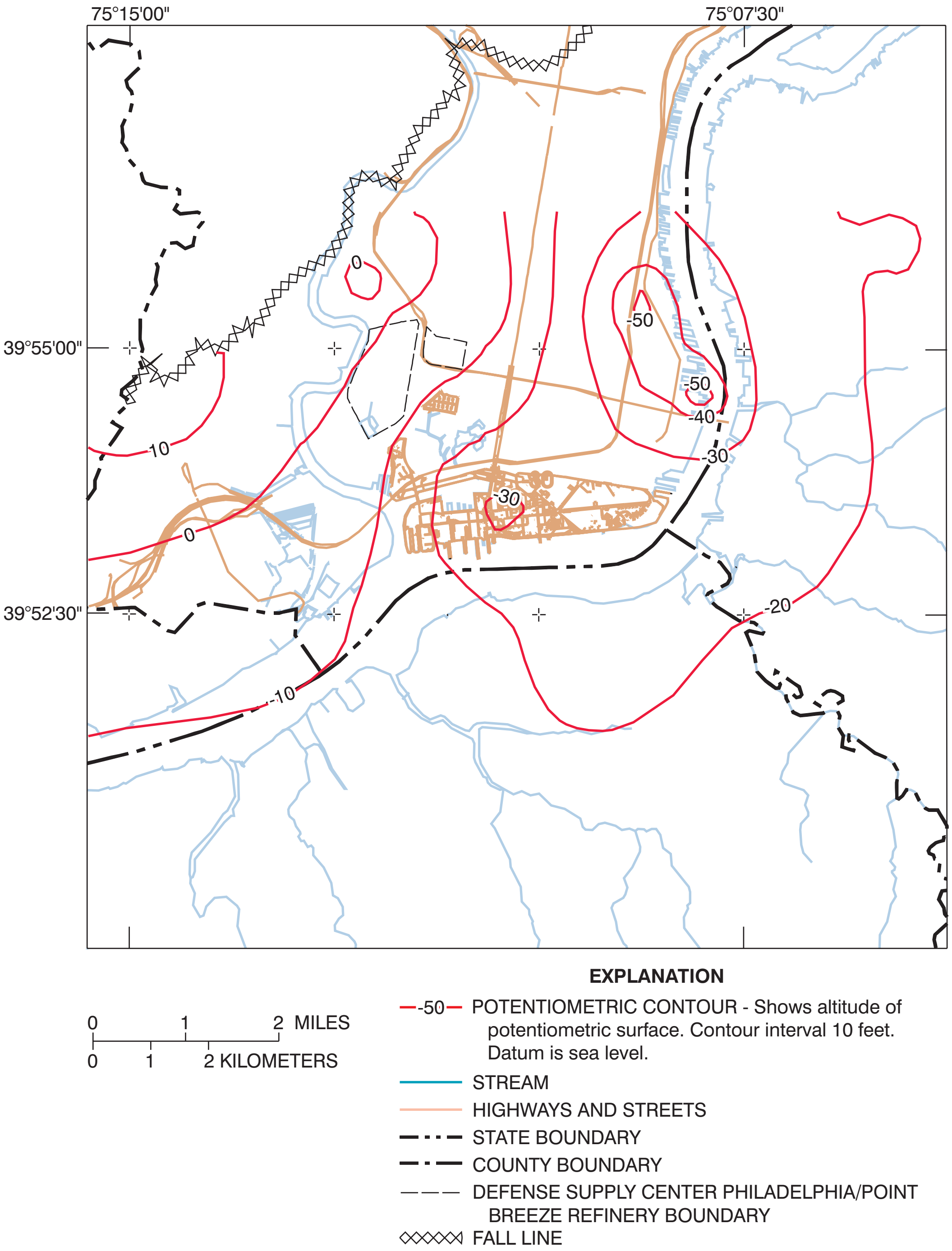


Figure 31. Simulated potentiometric surface for the lower sand unit of the Potomac-Raritan-Magothy aquifer system, March 1954.

For March 1954, simulated horizontal ground-water-flow direction in the lower sand unit (layer 7) near the area of concern was to the southeast towards areas with large cones of depression along the Delaware River. Simulated water-level altitudes in the lower sand unit (layer 7) ranged from 0 to -10 ft sea level, which caused downward vertical flow gradients in the upper units.

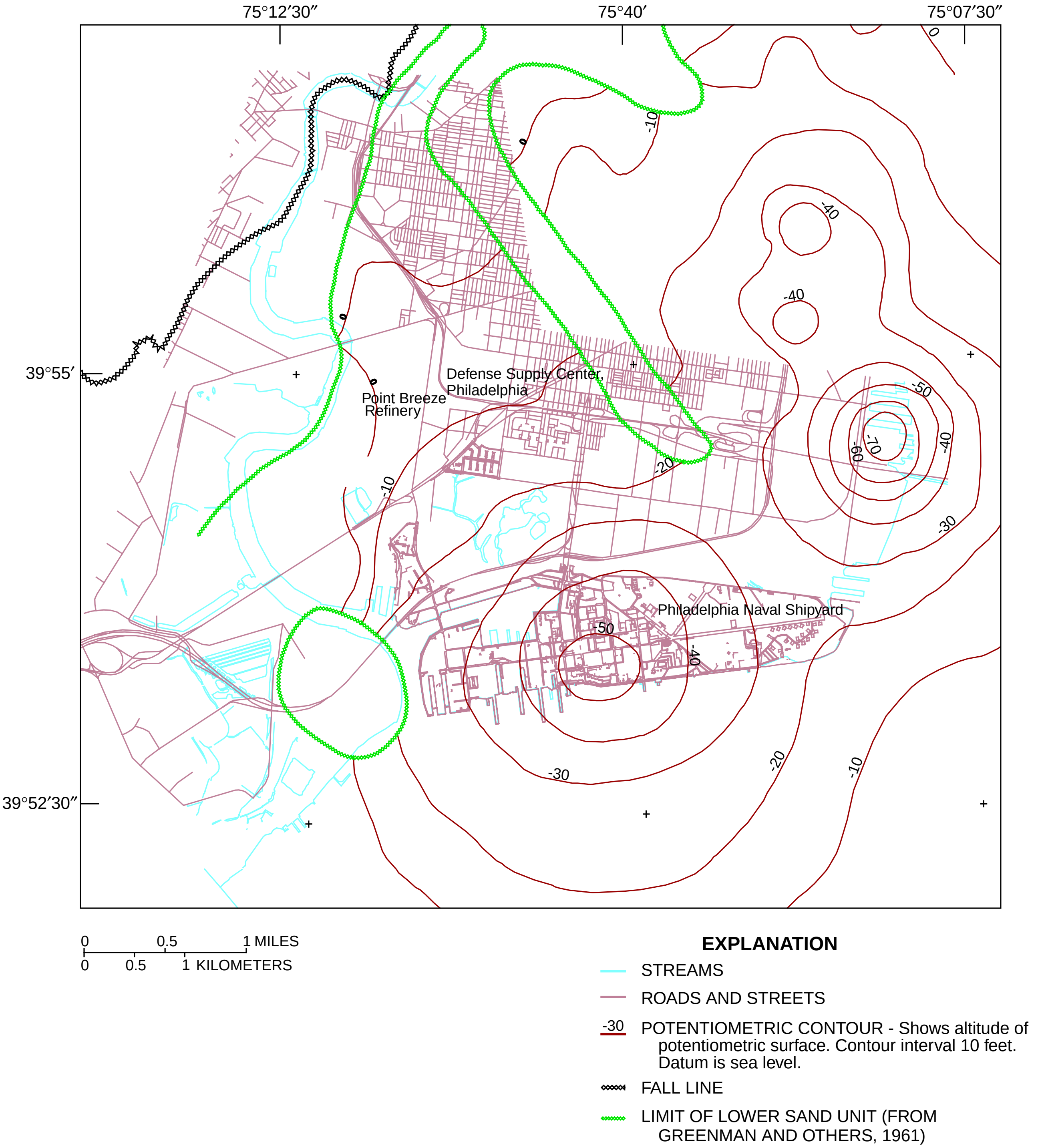


Figure 32. Potentiometric surface of the lower sand unit, March 24, 1954 (modified from Greenman and others, (1961).

The simulated potentiometric-surface map of the south Philadelphia area for 1968 is shown in figure 33. The 1968 potentiometric-surface map of Gill and Farlekas (1976) is shown in figure 34. The directions of ground-water flow are in agreement. However, maximum drawdowns of the simulated water surface near pumping centers are not in agreement. This could be the result of inaccurate water-withdrawal data; perhaps the withdrawals at these pumping centers were substantially less than reported.

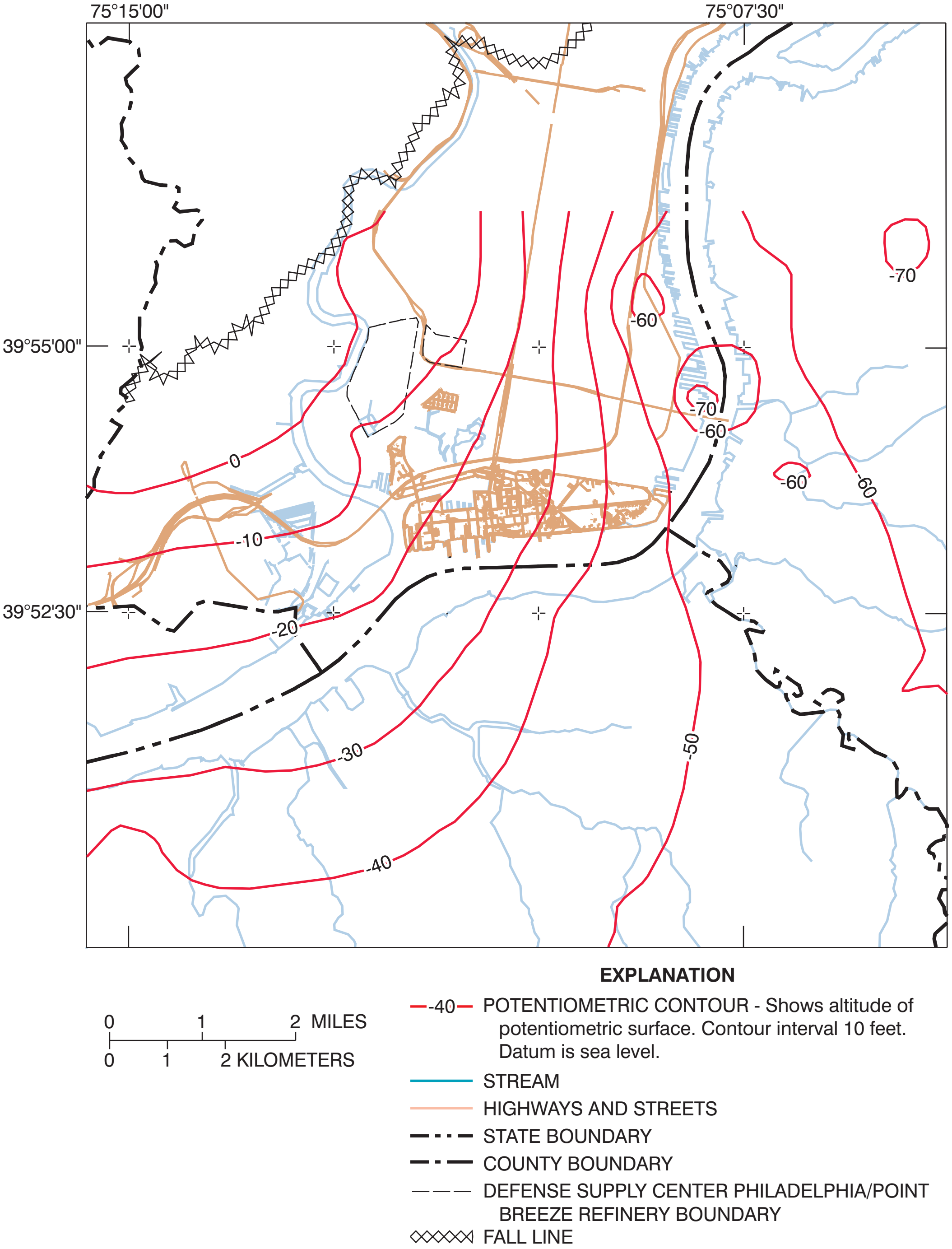


Figure 33. Simulated potentiometric surface for the lower sand unit of the Potomac-Raritan-Magothy aquifer system, December 1968.

For 1968, simulated horizontal ground-water-flow direction in the lower sand unit (layer 7) near the area of concern was to the east towards areas with large cones of depression in New Jersey and along the Delaware River. Simulated water-level altitudes in the lower sand unit (layer 7) ranged from -10 to -20 ft sea level, which caused a downward vertical flow gradients in the upper units.

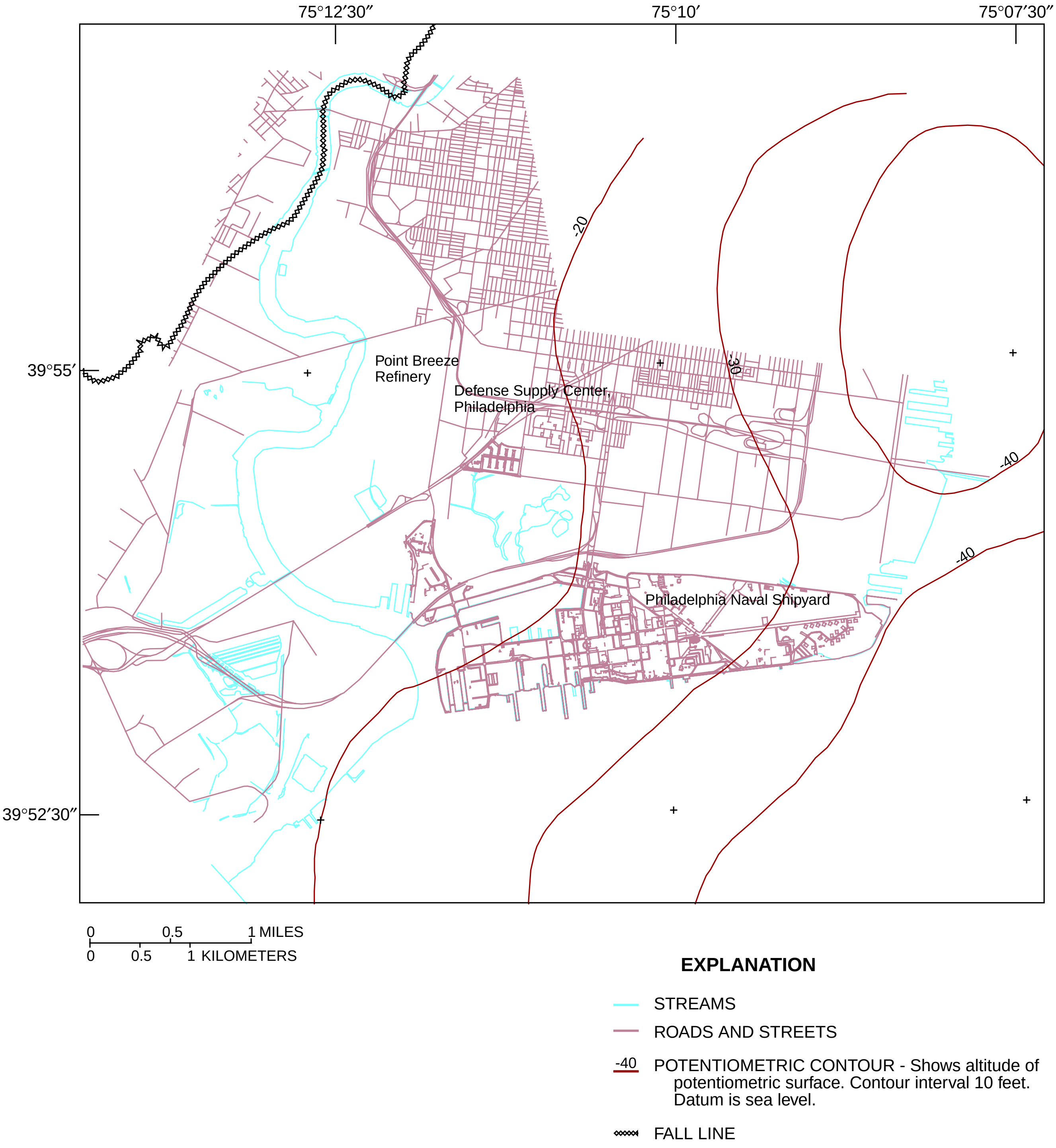


Figure 34. Potentiometric surface of the lower sand unit, 1968 (modified from Gill and Farlekas, 1976).

The simulated potentiometric-surface map of the south Philadelphia area for 1978 is shown in figure 35. The 1978 potentiometric-surface map of Sloto (1981) is shown in figure 36. The directions of ground-water flow indicated by the contour lines on the two maps are similar but not in agreement, and the water-level altitude contours are not in agreement. This could be the result of a small number of data points used to construct the original map, particularly on the Pennsylvania side of the river. Walker (1983) did not measure wells on the Pennsylvania side of the river to construct the map, and Paulachok (1991) measured only a few wells in the northwest corner of the study area.

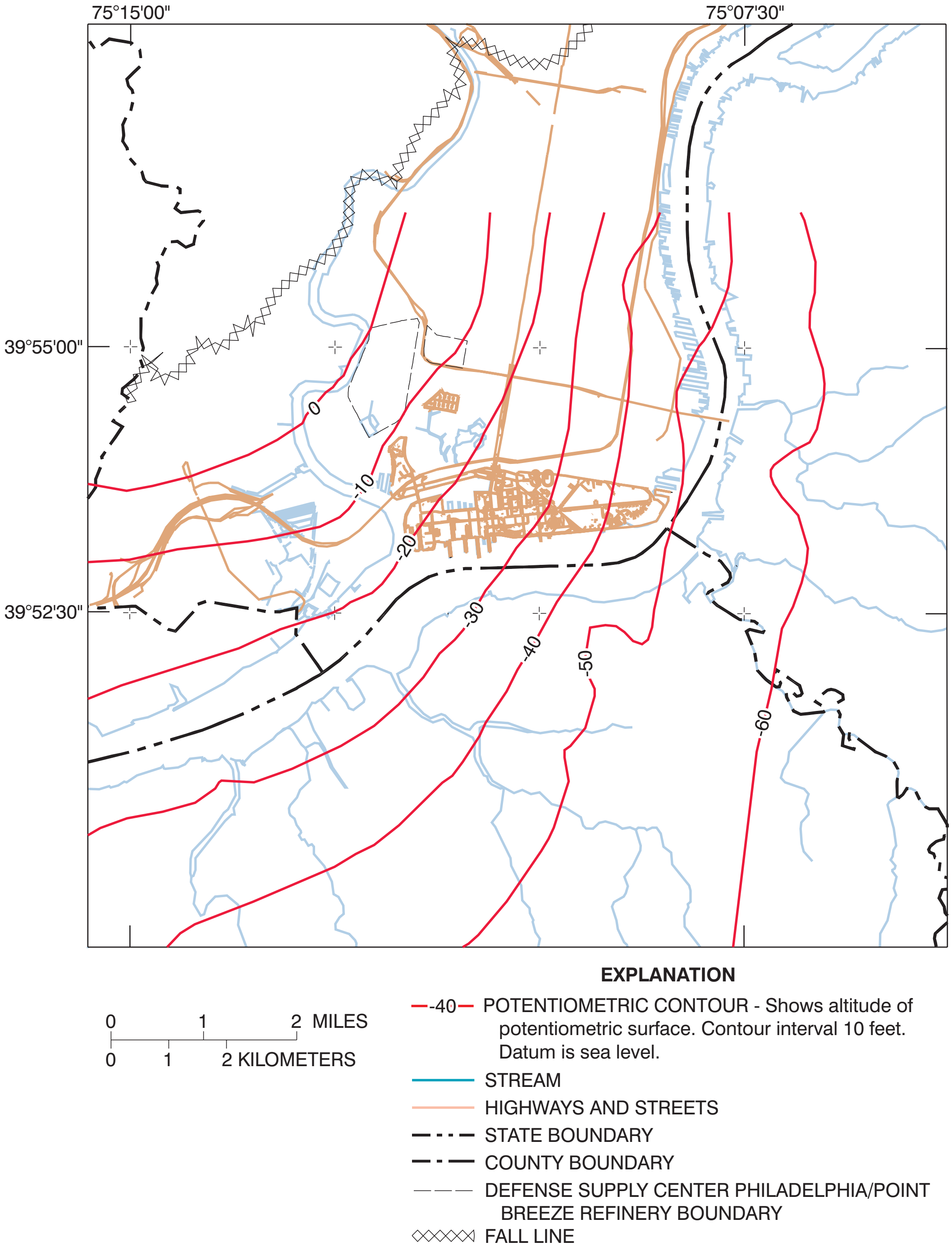


Figure 35. Simulated potentiometric surface for the lower sand unit of the Potomac-Raritan-Magothy aquifer system, December 1978.

For 1978, simulated horizontal ground-water-flow direction in the lower sand unit (layer 7) near the area of concern was to the east towards areas in New Jersey. Simulated water-level altitudes in the lower sand unit (layer 7) ranged from -10 to -20 ft sea level, which caused downward vertical flow gradients in the upper units.

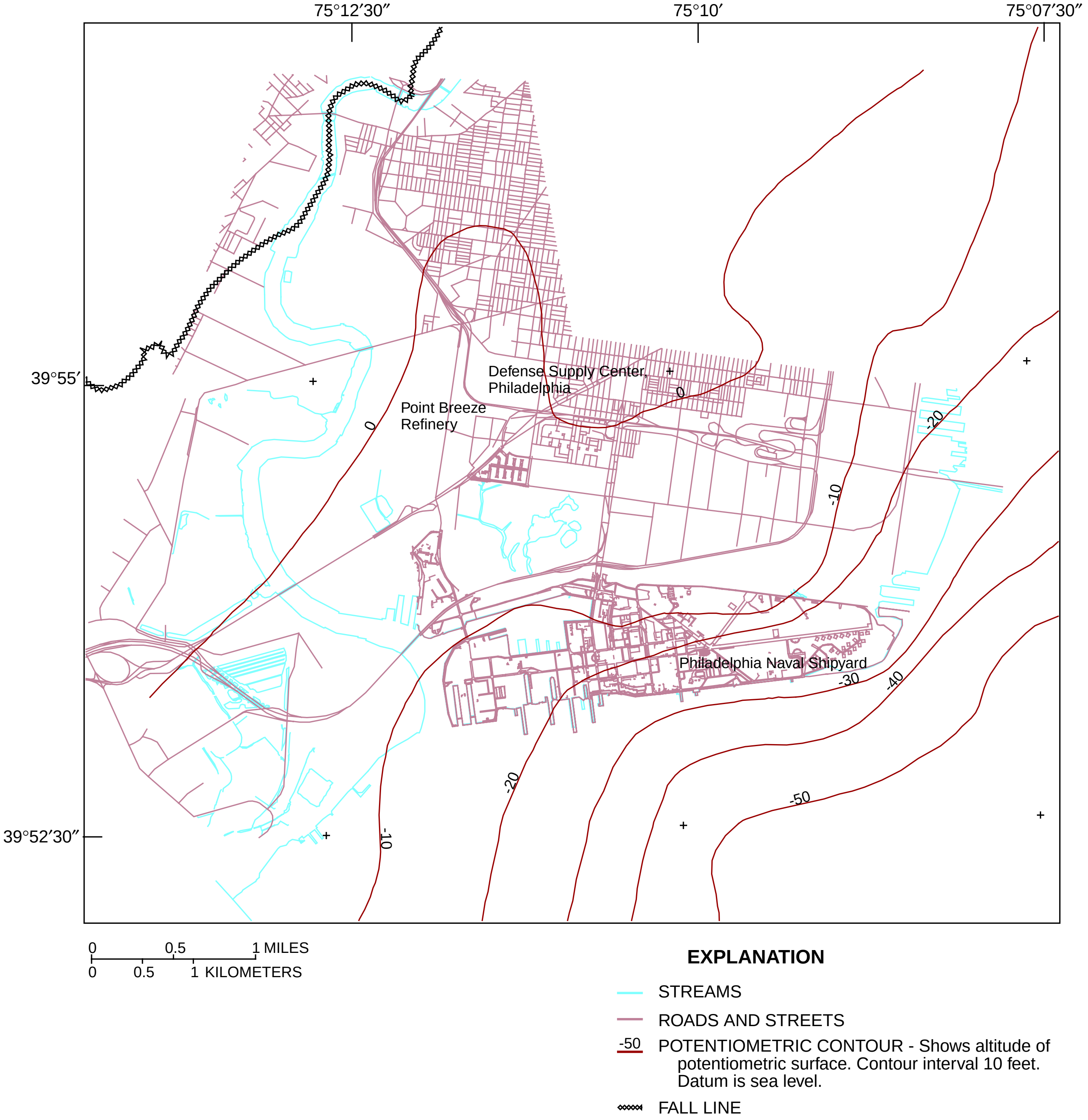


Figure 36. Potentiometric surface of the lower sand unit, 1978 (modified from Sloto, 1988).

The simulated potentiometric-surface map of the south Philadelphia area for 1995 is shown in figure 37. The potentiometric-surface map for 1996 of Rosman (1997) is shown in figure 38. The potentiometric-surface map configurations and the directions of ground-water flow indicated by the contour lines are in agreement. The simulated potentiometric contours are slightly west of the contour lines constructed from measured water levels.

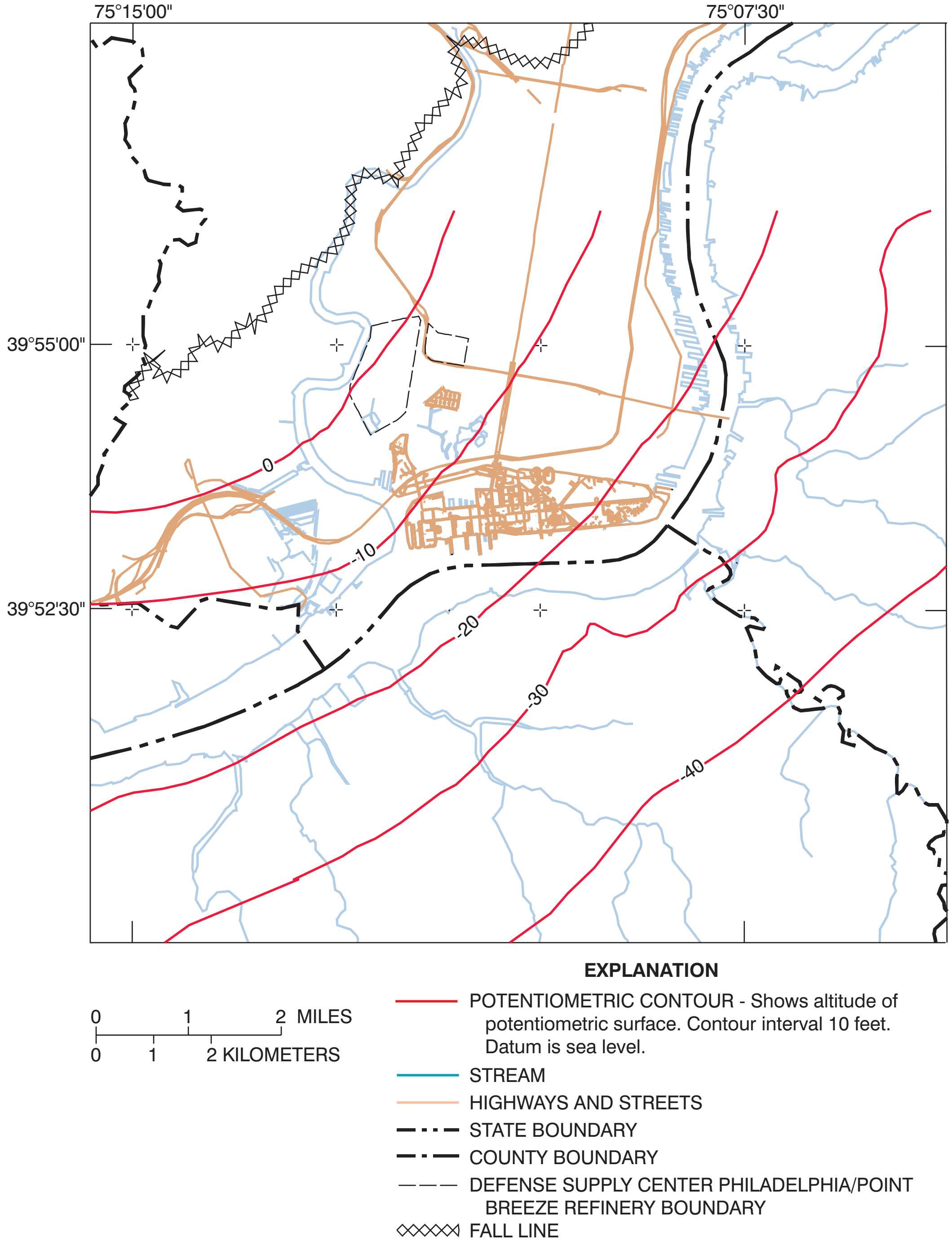


Figure 37. Simulated potentiometric surface for the lower sand unit of the Potomac-Raritan-Magothy aquifer system, December 1995.

For 1996, simulated horizontal ground-water-flow direction in the lower sand unit (layer 7) near the area of concern was to the southeast towards areas in New Jersey. Simulated water-level altitudes in the lower sand unit (layer 7) ranged from 0 to -10 ft sea level, which caused downward vertical flow gradients in the upper units.

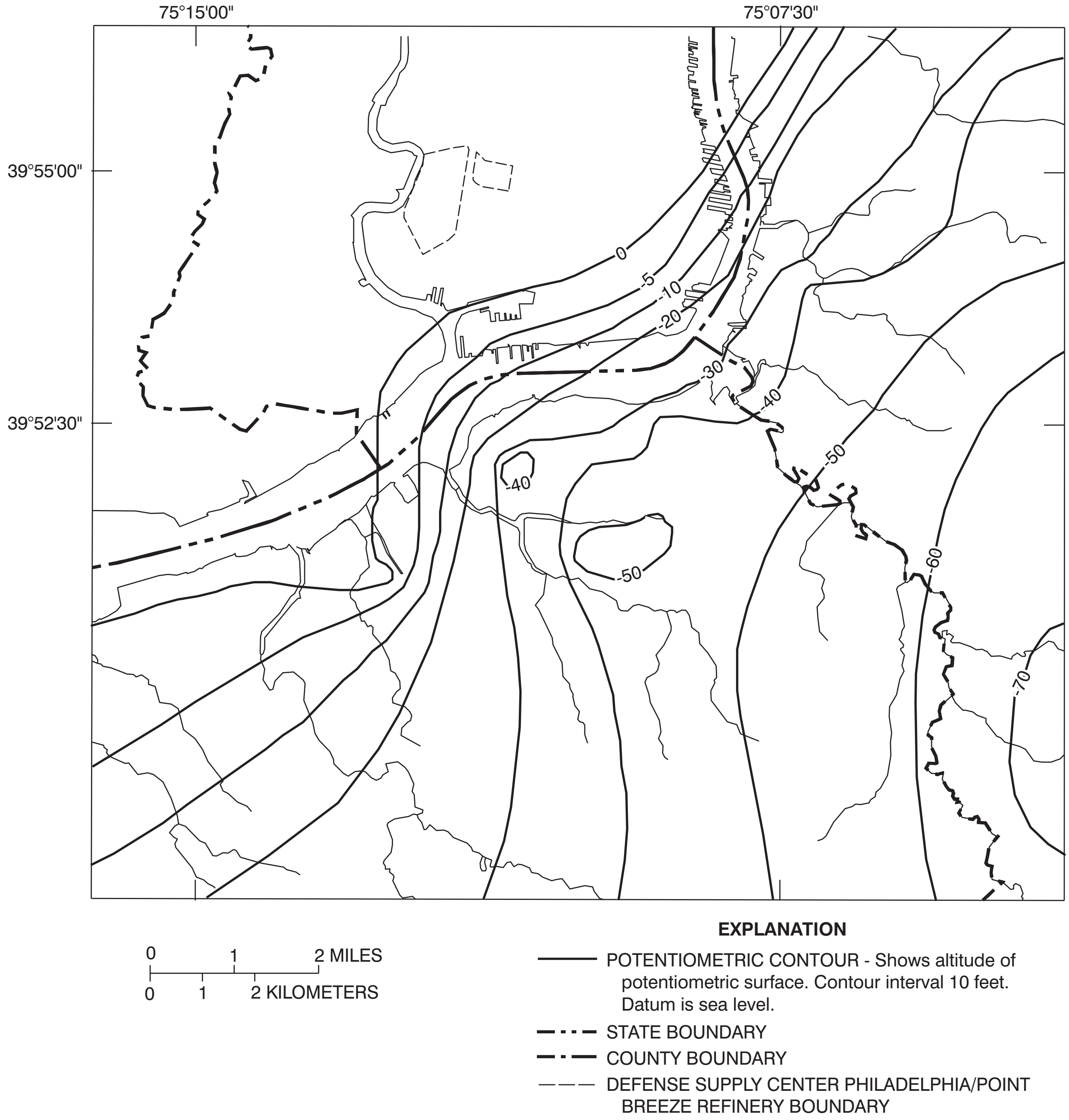


Figure 38. Potentiometric surface map of the lower sand unit, 1996 (from Rosman, 1997)

Comparison of Simulated and Measured Water-Level Hydrographs

Simulated water-level hydrographs were compared to measured water levels from wells near the DSCP/PBR area. Limited historical water-level data were available for comparison from wells Ph-32, Ph-61, Ph-77, Ph-85, and Ph-87 (fig. 39). When comparing simulated and measured hydrographs, some assumptions must be made. For this model, withdrawal rates were averaged on an annual basis. Therefore, seasonal water-level fluctuations exhibited in the hydrographs are not simulated. Measured water levels have more frequent and larger fluctuations than simulated water levels if the wells are near unknown pumping wells. On a regional basis, the effects of pumping on water-level altitudes would be insignificant, but locally, large fluctuations in water levels could occur. Also, the location of simulated water-level altitudes are at the center of the model grid cell, which most commonly does not coincide with the geographic location of the well. Starting elevation data were from the USGS DEM, not surveyed data. For example, for grid cell 15,29 containing well MW-6D, the land-surface elevation in the model cell is 22.43 ft above sea level; however, the surveyed land-surface elevation of well MW-6D is 21.45 ft above sea level.

Wells Ph-32, Ph-77, and Ph-87 are completed in the underlying crystalline rocks. Wells Ph-61 and Ph-85 are completed in the lower sand unit of the PRM. Hydrographic comparisons for the wells completed in the bedrock can be made because water levels in the crystalline rock and the unconsolidated sediments are about the same where a confining unit that lies on top of the crystalline rocks is either absent or thin (Greenman and others, 1961, p. 27-28). On the basis of available geologic logs in the DSCP/PBR area, the clay confining layer is thin. The geographic location of the wells and the corresponding grid cells are shown in figure 39.

The comparison between simulated and measured hydrographs for wells Ph-32, Ph-61, Ph-77, Ph-85, and Ph-87 are shown in figures 40 to 44, respectively. The top graph depicts the hydrograph for the entire simulation and the bottom graph focuses on the time periods when water-level data were collected. Most simulated hydrographs match the measured data to within 10 ft.

All hydrographs of measured wells show fluctuations caused by nearby withdrawals not incorporated into the model. Documented data for these withdrawals are not available, so the timing and the amount of withdrawal are unknown. These unknown withdrawals have an effect on the ground-water flow system but have not been simulated.

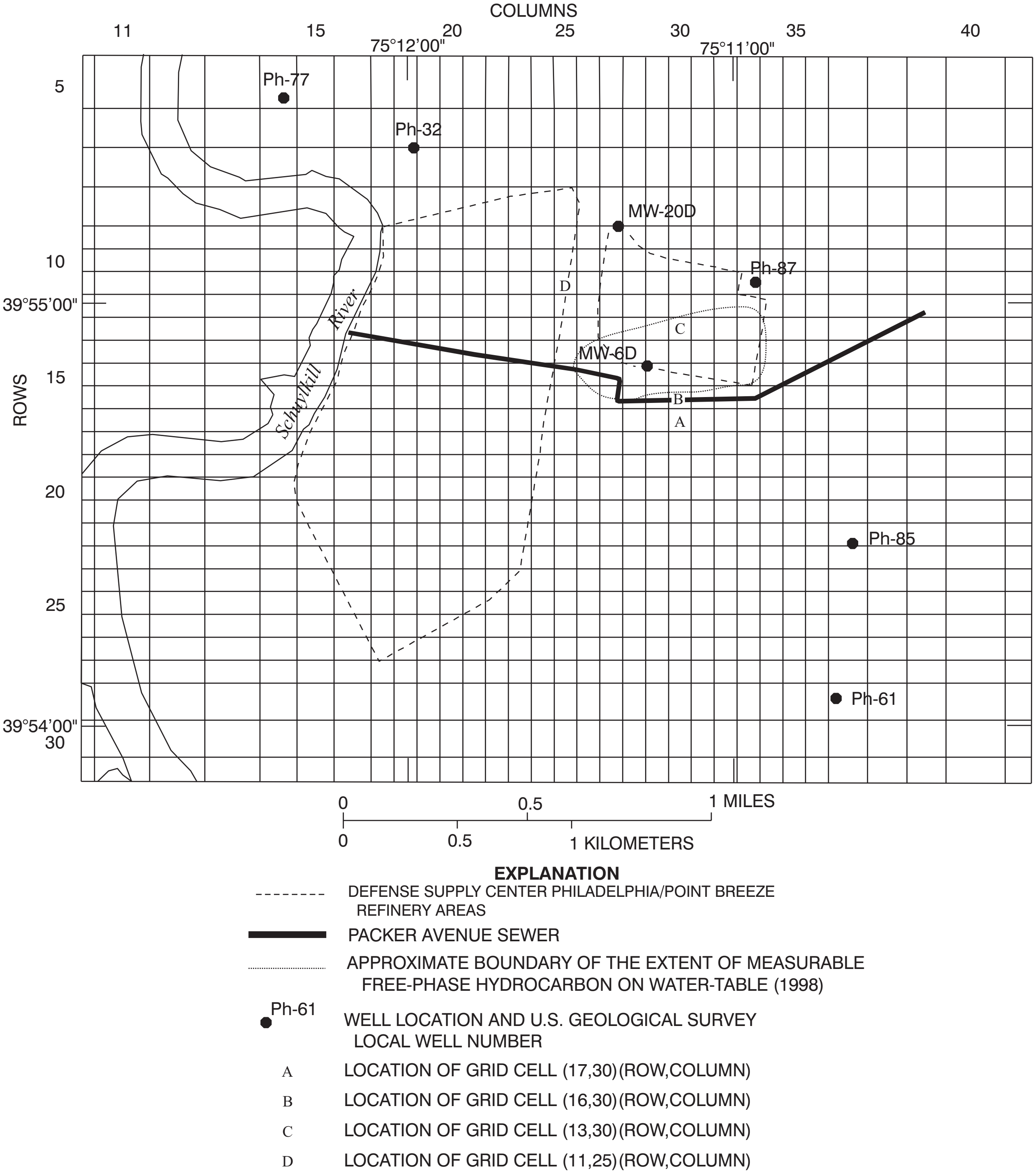


Figure 39. The Defense Supply Center Philadelphia/Point Breeze Refinery area showing selected observation wells, selected grid cell locations, and the Packer Avenue sewer.

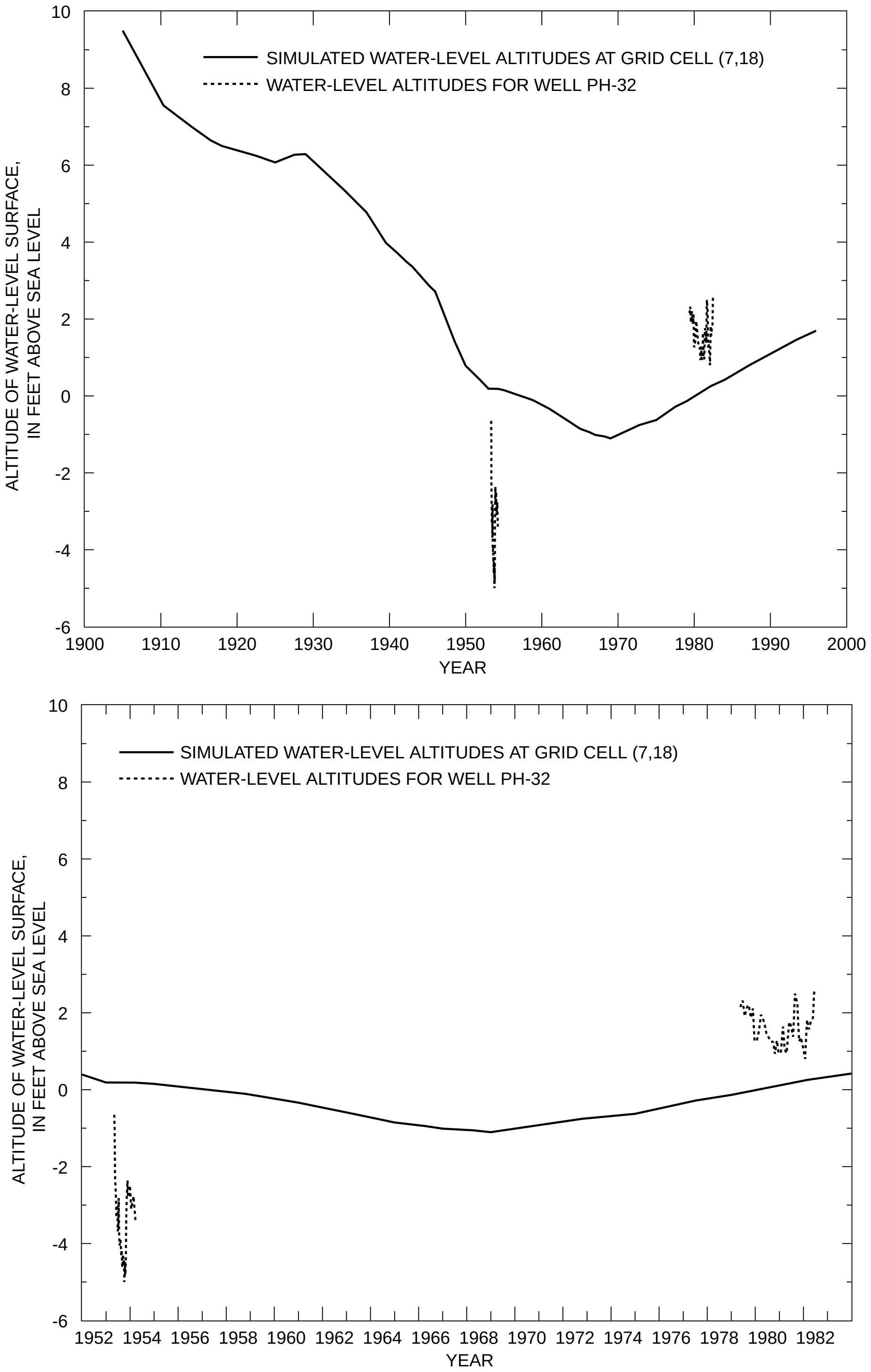


Figure 40. Simulated and measured water-level altitudes for well Ph-32.

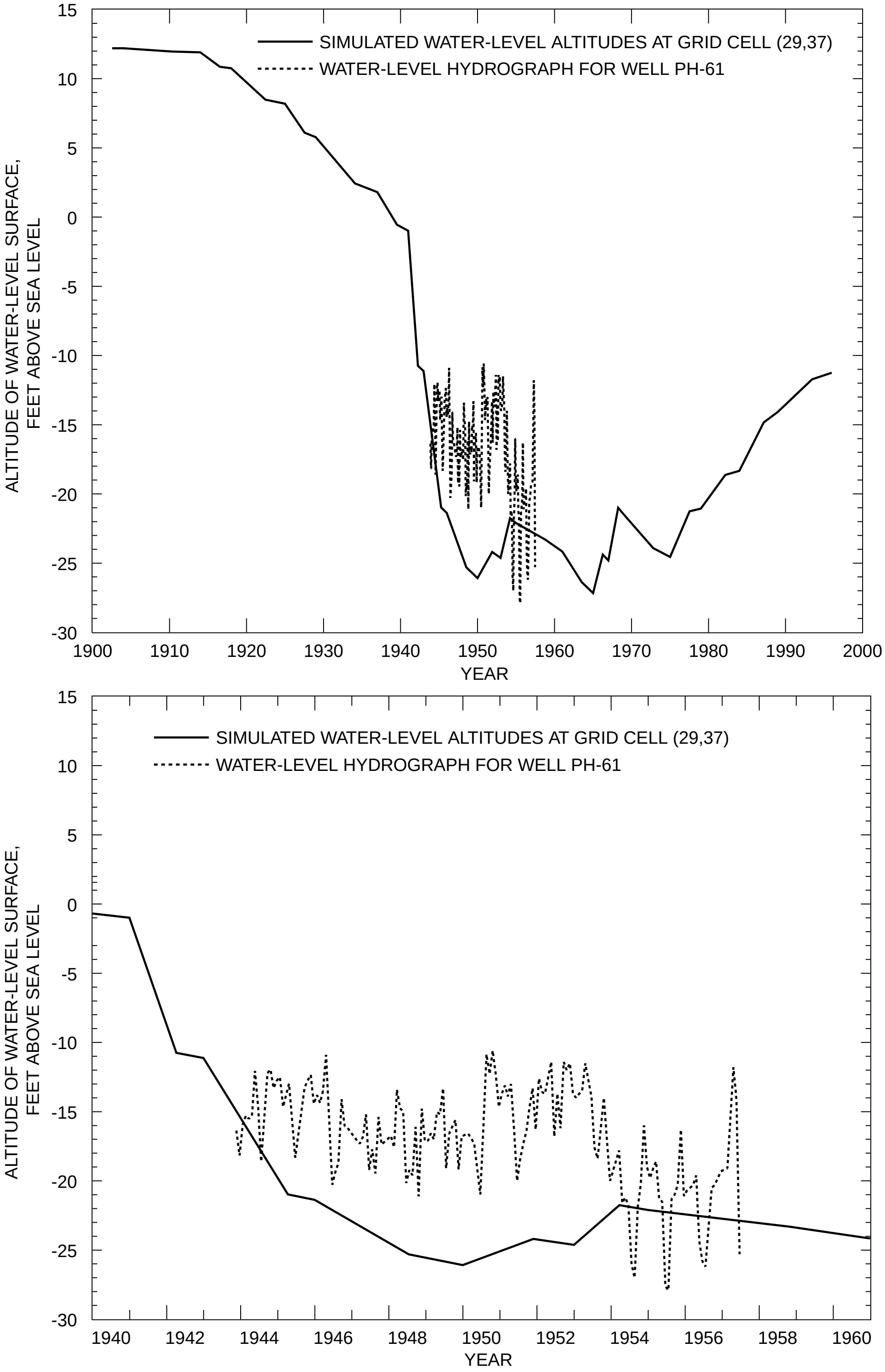
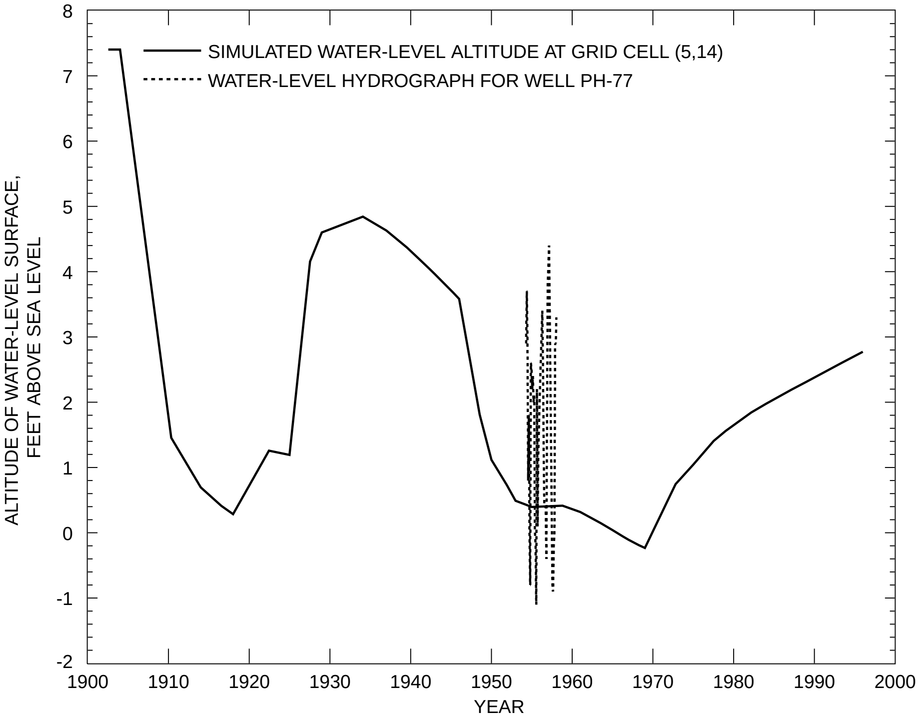


Figure 41. Simulated and measured water-level altitudes for well Ph-61.



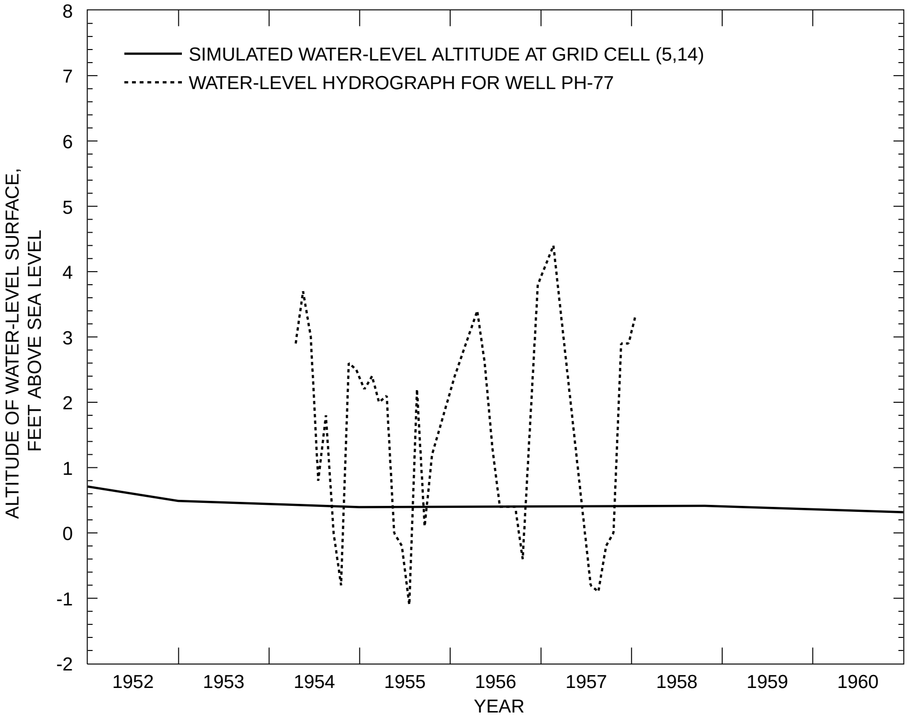


Figure 42. Simulated and measured water-level altitudes for well Ph-77.

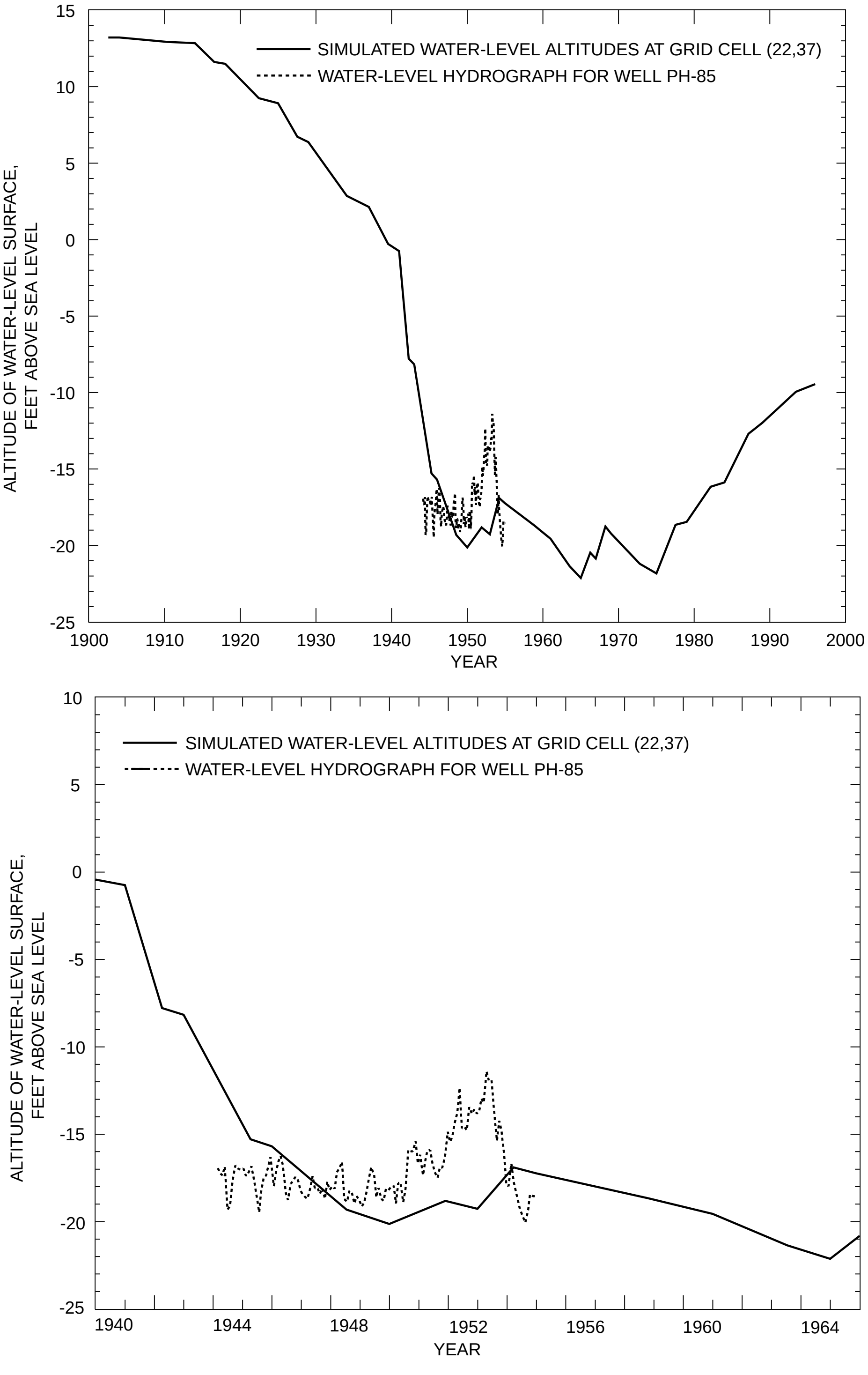


Figure 43. Simulated and measured water-level altitudes for well Ph-85.

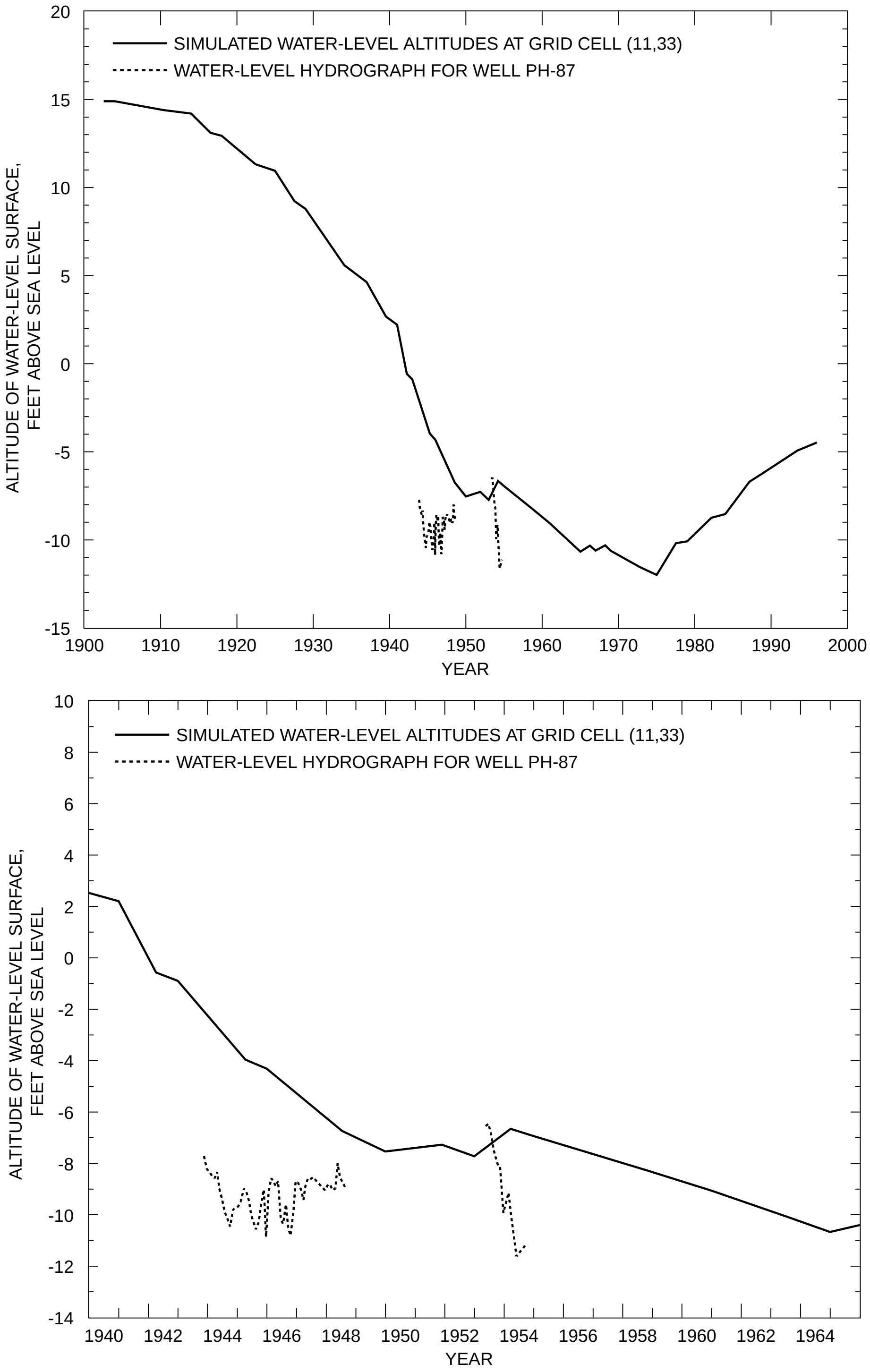


Figure 44. Simulated and measured water-level altitudes for well Ph-87.

SIMULATED WATER-LEVEL ALTITUDES IN THE DSCP/PBR AREA

The ground-water-flow system in the Defense Supply Center, Philadelphia, and the Point Breeze Refinery area was simulated in order to use the model results to estimate water-level altitudes in and near the area of concern and to determine the effect the Packer Avenue sewer may have had on water levels and hydrocarbon plume migration. The apparent location of the hydrocarbon plume in the area of concern is shown on figure 39. In comparing simulated water-level altitudes to altitudes of residual hydrocarbon-stained soils, a range in years of possible hydrocarbon release times can be deduced.

An assumption is made that the simulated water-level altitudes in layer 7 closely represent water-level altitudes of the actual water-table surface. The assumption is valid because the intervening confining units between the water-table aquifer and the lower sand unit are not continuous near the area of concern. Geologic logs from wells MW-6D and MW-20D show no distinct, continuous confining clay near the area of concern. Well MW-6D was drilled to 88 ft below land surface (-66.55 ft below sea level). Well MW-20D was drilled to 92 ft below land surface (-66.20 ft below sea level). Locally, clay layers or lenses are present but are discontinuous. From a regional perspective, however, the alluvial aquifer may lie directly on the lower sand unit, and water-level altitudes in the alluvial aquifer could be reasonably represented by simulated water-level altitudes in the lower sand unit (layer 7).

The author estimated water-level altitudes in the lower sand unit (layer 7) near the area of concern from all available historical measured water levels for time periods prior to 1945, 1946-54, 1955-68, and 1969-78 (fig. 45). This was done in order to determine the timing of the maximum depth to water near the area of concern and relate that to the maximum depth of the residual hydrocarbon smear zone detected below the current (2001) water table.

The author estimated water-level altitudes prior to 1945 ranged from slightly less than 8 ft below sea level to 11 ft below sea level, from 1946 to 1954 ranged from 7 to 12 ft below sea level, from 1955 to 1968 ranged from 7 to 14 ft below sea level, and from 1969 to 1978 ranged from 2 to 8 ft below sea level.

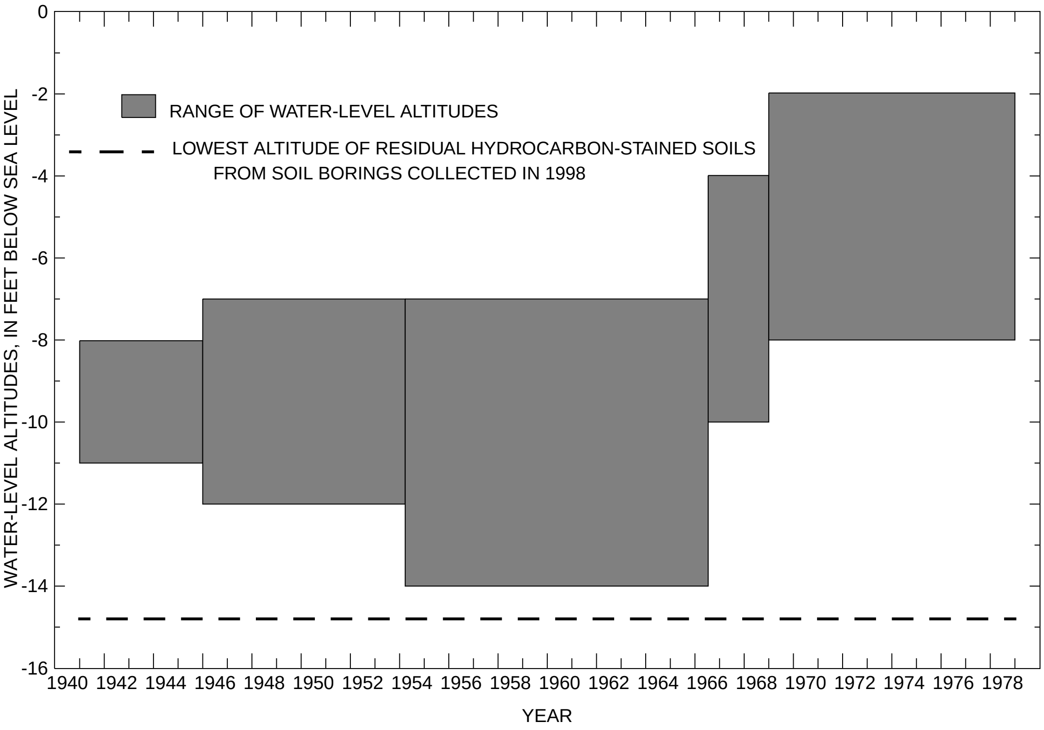


Figure 45. Range in water-level altitudes for time periods January 1941–December 1945, January 1946–March 1954, April 1954–April 1966, May 1966–December 1968, and January 1969–December 1978 in the Defense Supply Center Philadelphia, Point Breeze Refinery, and Passyunk Housing Development area, south Philadelphia, Pennsylvania.

Simulated water-level altitudes in model layers 1 and 7 near the center of the DSCP represented by grid cell 13,30 are shown on figure 46. Grid cell 13,30 is shown as location C on figure 39. Simulated water-level altitudes for layer 1 mimicked simulated water-level altitudes in layer 7, but they consistently were 3 to 5 ft higher in altitude. Simulated water-level altitudes for layer 7 prior to 1945 ranged from pre-development unstressed levels to 3 ft below sea level. Simulated water-level altitudes for layer 7 from 1946 to 1954 ranged from 3 to 7 ft below sea level, from 1955 to 1968 ranged from 6 to 10 ft below sea level, and from 1969 to 1978 ranged from 9 to 11 ft below sea level. The lowest water-level altitude, 10.69 ft below sea level, was during 1969-78, roughly near the end of 1974. The lowest altitude of residual hydrocarbon-stained soils on the DSCP property is 14.88[1] ft below sea level. Assuming that the lowest altitude of hydrocarbon staining occurred when water levels were lowest, some release of hydrocarbon had to occur prior to the end of 1974. The simulated hydrographs on figure 46 show the head in layer 7 (at cell 13,30) to be consistently below the head in layer 1, which indicates downward vertical ground-water-flow gradients.

Simulated water-level altitudes between the DSCP and PBR represented by grid cell 11,25 also are shown on figure 46. Grid cell 11,25 is shown as location D on figure 39. Simulated water-level altitudes for layer 7 prior to 1945 ranged from pre-development unstressed levels to 0.5 ft below sea level, from 1946 to 1954 ranged from 0.5 to 3.5 ft below sea level, from 1955 to 1968 ranged from 3 to 6 ft below sea level, and from 1969 to 1978 ranged from 5 to 6.5 ft below sea level. The lowest water-level altitude, 6.18 ft below sea level, was during 1969-78, roughly near the end of 1974.

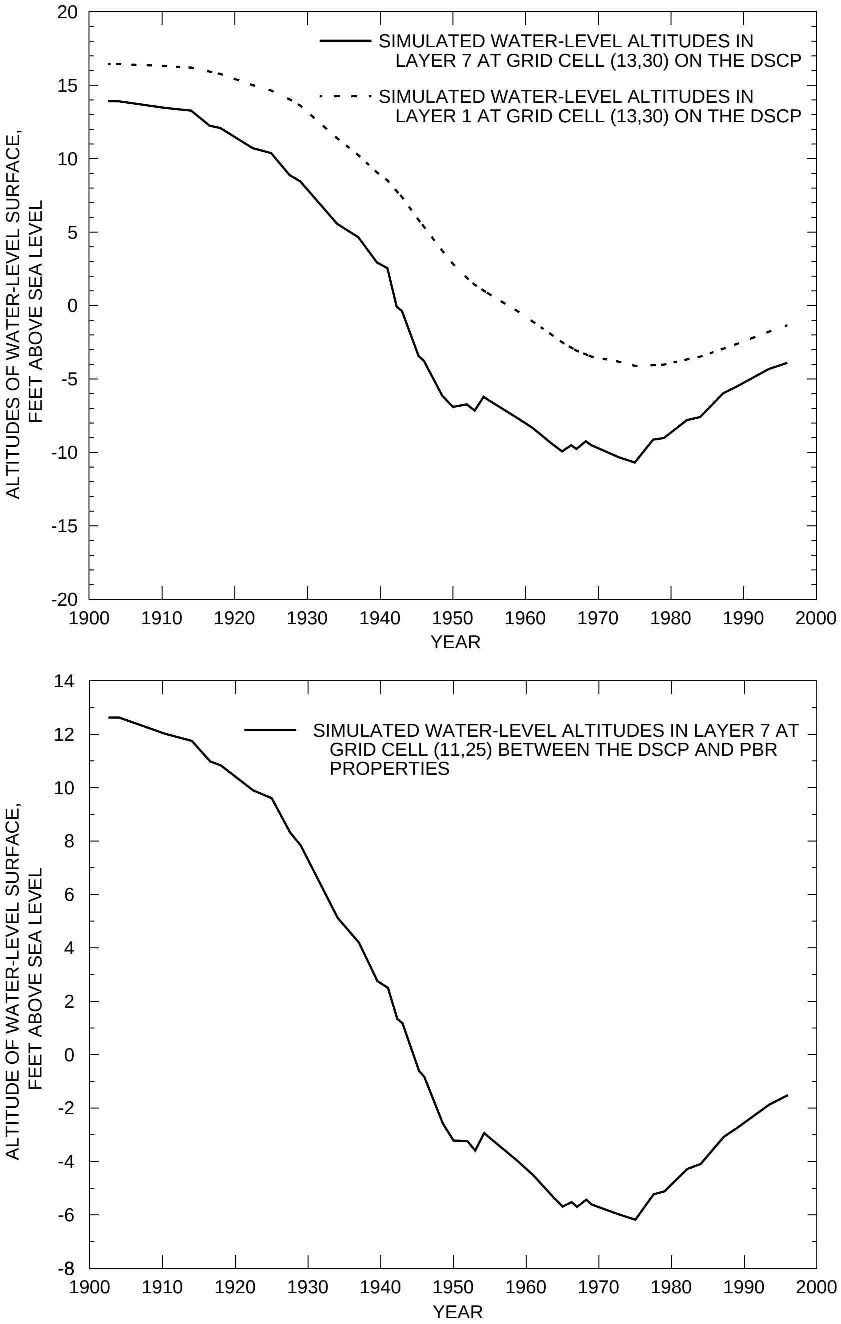


Figure 46. Simulated water-level altitudes in layers 1 and 7 for model grid cells row 13, column 30 on the Defense Supply Center Philadelphia property and in layer 7 row 11, column 25 between the Defense Supply Center Philadelphia and Point Breeze Refinery properties.

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[1] Source of data Sun Company, Inc., 1998, Technical third party neutral, empirical data request, May 1998.

SIMULATION OF PACKER AVENUE SEWER AND ITS EFFECT ON WATER LEVELS

The Packer Avenue sewer is important because if water-level altitudes are lower than the bottom of the sewer then any NAPL floating on the ground-water surface could migrate under the sewer. If water-level altitudes are higher than the bottom of the sewer, however, ground water can infiltrate the sewer and the sewer can be a barrier to hydrocarbon plume movement. The Packer avenue sewer is a 12-ft wide by 8-ft high concrete box culvert that was constructed in the early 1920's. Hydrocarbon vapors have been detected in the Packer Avenue sewer, and NAPL has been observed infiltrating into the sewer in the area just south of the DSCP (D. Burke, Pennsylvania Department of Environmental Protection, written commun., March 12, 1997). On March 11, 1997, Philadelphia Water Department personnel walked through the sewer in the area just south of the DSCP and NAPL was observed infiltrating the sewer along the north facing sewer wall at the floor of the sewer.

The sewer was simulated in the model by use of the drain package in MODFLOW-2000. Twenty-five point drains were used to simulate the sewer. The location of the sewer with respect to the area of concern is shown on figure 39. Point drains were used in order to change the bottom elevation of the sewer as it traversed from east to west. The grid-cell location, conductance, and bottom altitude of the point drains are summarized in table 6.

Simulated water-level altitudes for layers 1 and 7 at grid cells 16,30 and 17,30 are shown on figure 47. The locations of grid cells 16,30 and 17,30 are shown as locations B and A, respectively, on figure 39. The simulated water-level altitude in layer 7 was lower than the bottom of the sewer starting in 1943. The simulated water-level altitude in layer 1 was lower than the bottom of the sewer starting in 1957.

If the simulated water-level altitude of layer 7 closely represents the actual water-table altitude, then the time when water-table altitudes were below the sewer would be nearer to 1943 than 1957. A conservative estimate of the year when water-table altitudes receded below the bottom of the sewer would be sometime around 1947 or 1948. Therefore, the water-table altitude was below the Packer Avenue sewer from approximately 1947 or 1948 through 1995.

Table 6. *Summary of point drain locations, conductances, and bottom altitudes*

Grid cell (row,col)	Conductances (meters)	Altitude drain bottom	
		meters	feet
12,39	0.6999	0.56596	1.8568
13,38	2.651	.48324	1.5824
14,37	2.803	.40	1.3123
15,36	1.37	.3178	1.0426
15,35	1.638	.23511	.77135
16,34	1.424	.1524	.50
16,33	1.497	.10885	.3571
16,32	1.46	.06536	.21443
16,31	1.46	.02177	.07142
16,30	1.46	-.02177	-.07142
16,29	1.46	-.0653	-.2142
16,28	1.46	-.10885	-.3571
16,27	1.399	-.1524	-.50
15,27	1.693	-.1624	-.5328
15,26	1.495	-.22058	-.7237
15,25	1.476	-.2787	-.9148
15,24	1.457	-.3369	-1.1053
14,23	1.476	-.3951	-1.2962
14,22	1.476	-.4533	-1.4872
14,21	1.479	-.5115	-1.678
14,20	1.482	-.5696	-1.8687
14,19	1.482	-.6278	-2.059
14,18	1.482	-.686	-2.25
13,17	1.357	-.7442	-2.442
13,16	1.446	-.8024	-2.632

Because historical ground-water-flow directions were predominately to the southeast, the Packer Avenue sewer would have been a barrier to hydrocarbon plume migration to the southeast from 1900 to 1947. Subsequent to 1947 through 1995 the hydrocarbon plume could have been migrating to the southeast, unimpeded by the sewer. Also, the simulated hydrographs on figure 47 show the consistent lower head in layer 7 (compared to layer 1) at cells 16,30 and 17,30, which indicates downward vertical ground-water-flow gradients.

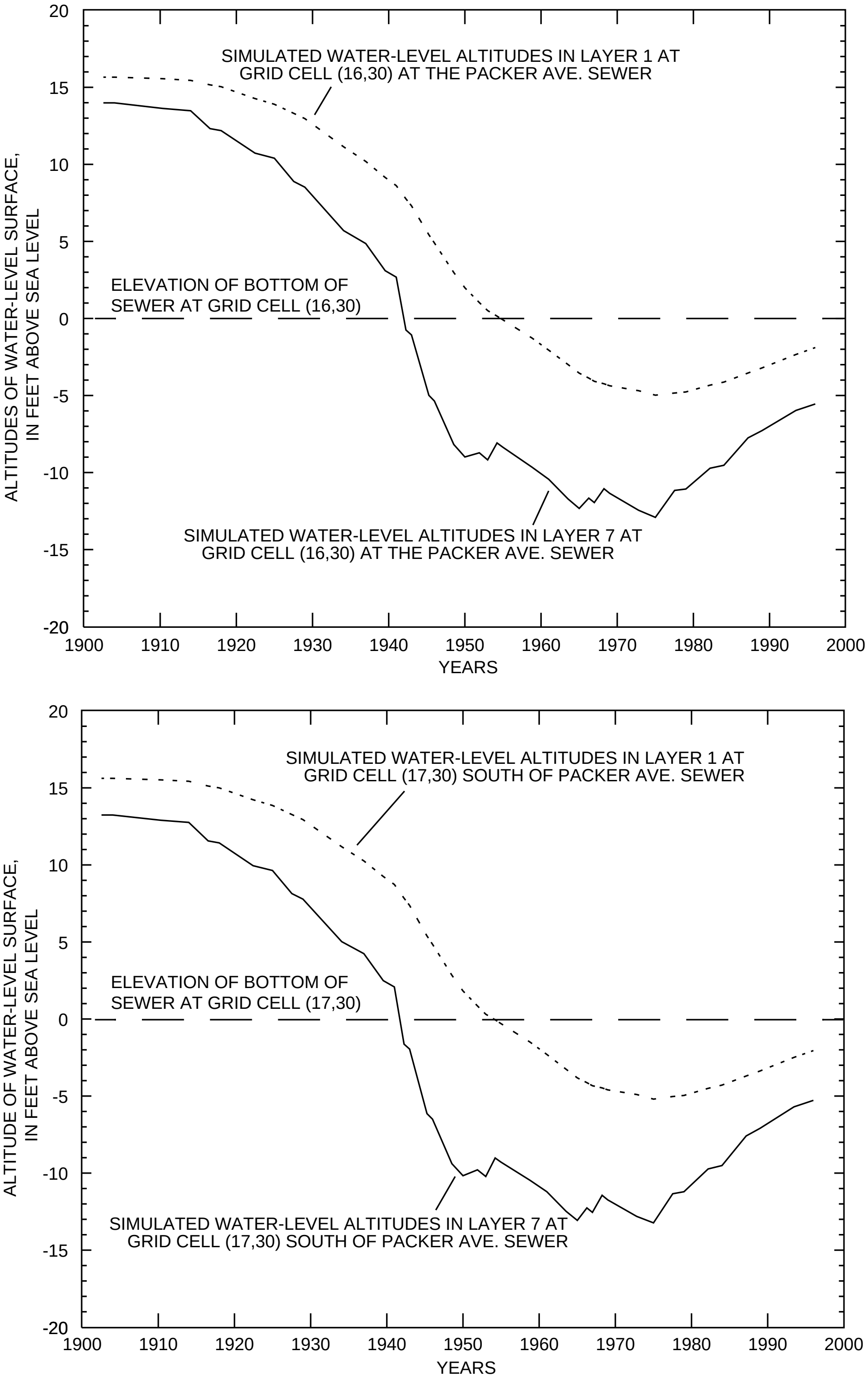

Figure 47. Simulated water-level altitudes in layers 1 and 7 for model grid cells row 16, column 30 and row 17, column 30 near the Packer Avenue sewer.

SUMMARY

The Potamac-Raritan-Magothy (PRM) aquifer system in south Philadelphia historically has been a major water-supply source in the south Philadelphia region. The Philadelphia Naval Shipyard and other industries in the area withdrew large amounts of water from the PRM for day-to-day operations in the past. A result of this past development in the area is that the ground-water quality of the PRM aquifer system has been degraded. Some degradation in the upper part of the aquifer is the result of numerous hydrocarbon plumes. Since the early 1990's, the Pennsylvania Department of Environmental Protection (PaDEP) has been overseeing investigations of multiple localized hydrocarbon plumes floating on the water-table surface in the south Philadelphia area. Although localized NAPL is a major concern, a more regional look at the entire area was needed to assess problems. The U.S. Geological Survey was tasked with assessing the historical ground-water-flow system using a more regional perspective while also focusing on an area of concern for the PaDEP near the Point Breeze Refinery and the Defense Logistics Agency's Defense Supply Center, Philadelphia.

The ground-water-flow system of the PRM in south Philadelphia and adjacent southwestern New Jersey was simulated by use of a 3-dimensional, 7-layer finite-difference numerical flow model. The simulation was run from 1900, prior to ground-water development, through 1995. The modeled area comprised parts of Philadelphia and Delaware Counties in Pennsylvania and Gloucester and Camden Counties in New Jersey. In order to adequately simulate the ground-water-flow system in the area of concern, a much larger area was modeled that included parts of New Jersey where significant ground-water withdrawals affecting water levels in south Philadelphia occurred in the past. At issue in an area of concern is a current (2001) hydrocarbon plume of unknown origin with an unknown time of release.

The ground-water flow system was simulated to estimate past water-level altitudes in and near the area of concern and to determine the effect of the Packer Avenue sewer, which lies south of the DSCP, on the ground-water-flow system. The model was calibrated to match five potentiometric-surface maps of the lower sand unit for 1945, 1954, 1968, 1978, and 1996.

Simulated water-level altitudes from the model for the lower sand unit of the PRM on the DSCP ranged from pre-development, unstressed altitudes to 3 feet below sea level prior to 1945, from 3 to 7 feet below sea level from 1946 to 1954, from 6 to 10 feet below sea level from 1955 to 1968, and from 9 to 11 feet below sea level from 1969 to 1978.

The lowest simulated water-level altitude on the DSCP, 10.69 ft below sea level, occurred near the end of 1974. The lowest altitude of residual hydrocarbon-stained soil on the DSCP is approximately 15 ft below sea level. Thus, if the lowest altitude of hydrocarbon staining were coincident with the lowest water levels, a hydrocarbon plume must have been present prior to the end of 1974.

Model simulations indicate that ground water in layer 7 was infiltrating the Packer Avenue sewer prior to approximately 1943, and ground water in layer 1 was infiltrating prior to approximately 1957. Assuming that simulated water-level altitudes in layer 7 closely represent actual water-table altitude at the sewer because of the absence of intervening confining layers, a conservative estimate of the year when altitudes were below the sewer would be 1947 or 1948. Because the historical ground-water-flow directions were predominately to the southeast, the Packer Avenue sewer would have been a barrier to hydrocarbon plume migration to the southeast from 1900 to 1947. Subsequent to 1947 through 1995, the hydrocarbon plume would be migrating to the southeast unimpeded by the sewer.

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Bureau of Environmental Cleanup & Brownfields

Cleanup of the Philadelphia Refinery

City of Philadelphia Refinery Advisory Group
Environmental and Academic Committee Meeting
August 27, 2019

Outline

- Regulatory cleanup programs
- Refinery regulatory history under DEP
- Overview of the Act 2 cleanup
- Current status and future activities
- Key cleanup issues

Scope

- DEP's mission is to protect human health and the environment; we do not control land use
- "Cleanup" here refers to contamination in soil, groundwater, and surface water
- The cleanup addresses the primary risk drivers but not every contaminant present at the site
- The law does not require a cleanup to conditions before there was a refinery

Regulatory Cleanup Programs

Regulatory Cleanup Programs

DEP's **Land Recycling Program** (Act 2 of 1995)

- Encourage cleanup of properties to return them to productive use (i.e., brownfields)
- A "voluntary" cleanup program
- Remediator chooses cleanup standard and property use
- Remediator obtains liability protection

Regulatory Cleanup Programs

Land Recycling Program—Standards

- Statewide health standard
  - Defined cleanup standards for soil and water
  - Example: drinking water standards
- Site-specific standard
  - Demonstrate acceptable risks, and/or
  - Eliminate exposures to contamination
  - Examples: cap over soil, vapor controls

Regulatory Cleanup Programs

Land Recycling Program—Reporting

- Notice of intent to remediate
- Remedial investigation report: characterization of the contamination
- Risk assessment report
- Cleanup plan
- Final report

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Regulatory Cleanup Programs

Land Recycling Program—Public Involvement

- Newspaper notices and notification letters to city required for each submission
- City may request a public involvement plan
- The public involvement plan allows public participation in the cleanup and reuse plans
    - The public may comment throughout the Act 2 process

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Regulatory Cleanup Programs

DEP's Storage Tanks Corrective Action Program

- Applies to regulated storage tanks
    - Underground and aboveground tanks
    - Releases of substances to the environment
- Reporting similar to Act 2
- Cleanup standards same as Act 2

Regulatory Cleanup Programs

EPA's RCRA Corrective Action Program

(Resource Conservation and Recovery Act)

- RCRA regulates facilities that handled hazardous wastes
- Corrective action requirements apply to past releases of those materials
- Site characterization
- Evaluation of remedial alternatives
- Remedy implementation

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Regulatory Cleanup Programs

DEP and EPA One Cleanup Program

- Allows Act 2 cleanups to satisfy RCRA corrective action requirements
- DEP is the lead agency
- EPA also reviews all submittals
- Additional community participation provisions

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Refinery Regulatory History

Regulatory Cleanup Programs

Cast of Characters

- Sunoco, Inc.
- Evergreen Resources Management Operations
- Philadelphia Energy Solutions (PES)
- Energy Transfer Partners

Refinery Regulatory History

- Sunoco, Inc. owned and operated the refinery from 1988 until 2012
    - Responsible for historic (legacy) contamination and releases during their period of ownership
    - Energy Transfer acquired Sunoco, Inc. in 2012
    - Subsidiary Evergreen manages cleanup (2013–)
- PES acquired the facility in 2012
    - Responsible for releases from 2012 to present
    - Energy Transfer holds a minority ownership

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Refinery Regulatory History

- Significant environmental investigation did not occur until the 1980s
- DEP consent order & agreement with Sunoco for Point Breeze Refinery (1993)
    - Discharges to Schuylkill River
    - Infiltration into city sewer system
    - Offsite petroleum migration
    - Recovery of oil in subsurface

Refinery Regulatory History

- The 1993 agreement required environmental investigation and monitoring of several areas
    - Sunoco agreed to remediate at least six areas
    - Included submittal of work plans and progress reports for DEP review
- Neighborhood sewer odors in 1990s
    - Sewer vapor collection system installed (1998)
- Defense Supply Center Philadelphia site (DSCP)

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Refinery Regulatory History

- DEP renewed the consent order and agreement with Sunoco in 2003
  - Point Breeze Processing Area, Girard Point Processing Area, Schuylkill River Tank Farm
  - Comprehensive characterization
  - Characterization reports for review (2005–2011)
  - Quarterly progress reports
  - Continued remediation projects
  - Required to attain Act 2 cleanup standard

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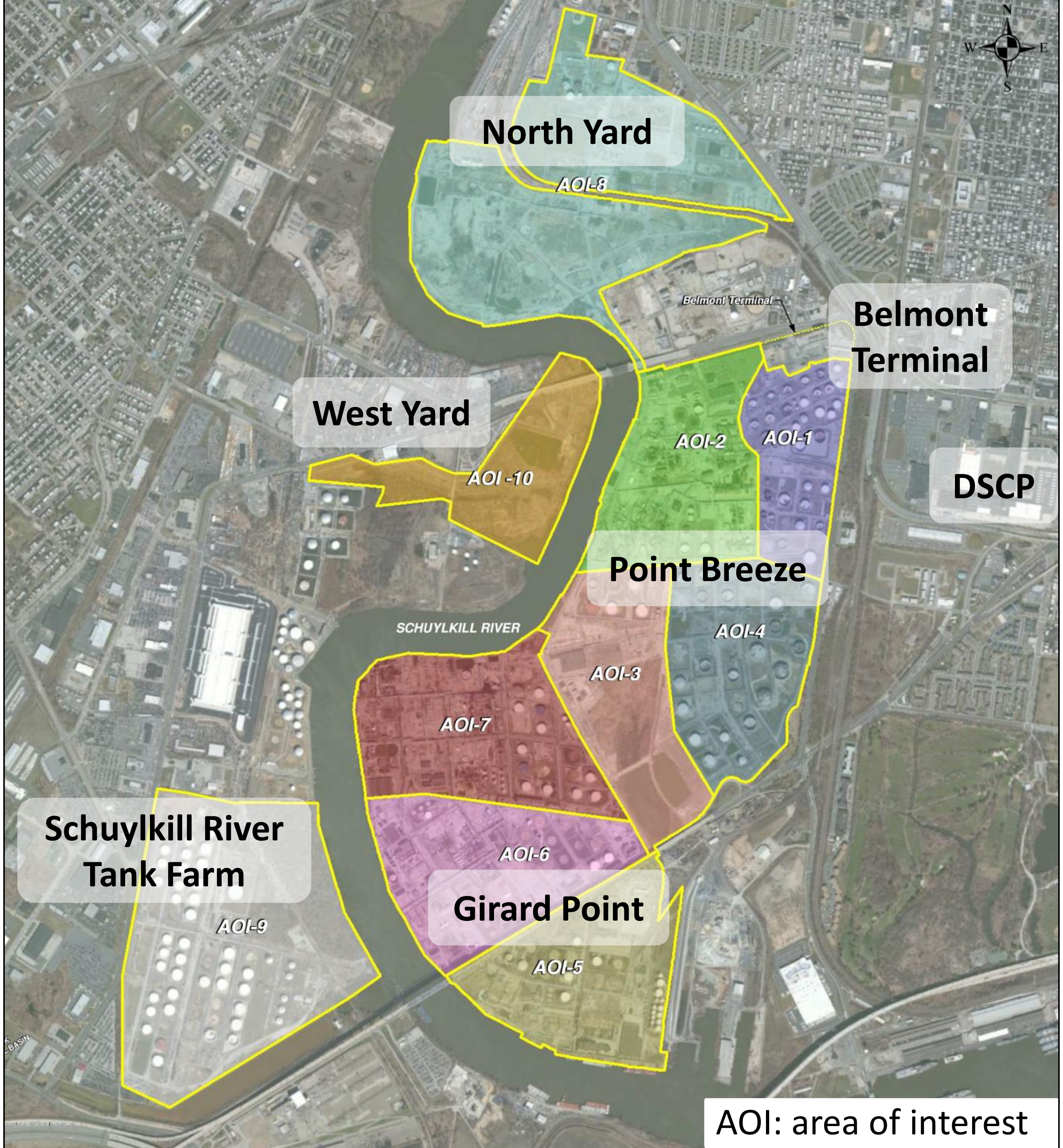
Refinery Regulatory History

- Sunoco filed an Act 2 notice of intent to remediate in October 2006
- City requested a public involvement plan
  - Sunoco prepared a PIP
  - Public information session held September 2007
- DEP and EPA accepted the site into the One Cleanup Program in November 2011
- Act 2 reporting commenced in 2011

Refinery Regulatory History

- Buyer–seller agreement September 2012
  - Sunoco’s (and Evergreen’s) obligations:
    - Complete site characterizations, submit reports
    - Develop cleanup plan(s)
    - Submit final report(s) by December 2020
  - PES’s and subsequent owners’ obligations:
    - Commercial or industrial use only
    - Maintain needed engineering controls
- EPA agreement with Sunoco and PES (2012)
  - Financial assurance conditions

Overview of the Act 2 Cleanup



AOI: area of interest

Overview of Act 2 Cleanup

- DEP has received Act 2 remedial investigation reports for all ten areas of interest (AOIs)
  - Submitted 2011–2017
  - Reports were reviewed for compliance
  - Eight remedial investigation reports approved
  - Two remedial investigation reports disapproved
  - Deficiencies: incomplete delineation of groundwater contamination beyond property line

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Overview of Act 2 Cleanup

Additional Act 2 reporting:

- AOI 11 (deep aquifer) 2011–2013
  - Disapproved
  - Work since incorporated into other RI reports
- Lead risk assessment report 2015
  - Established a risk-based soil lead standard
  - Approved

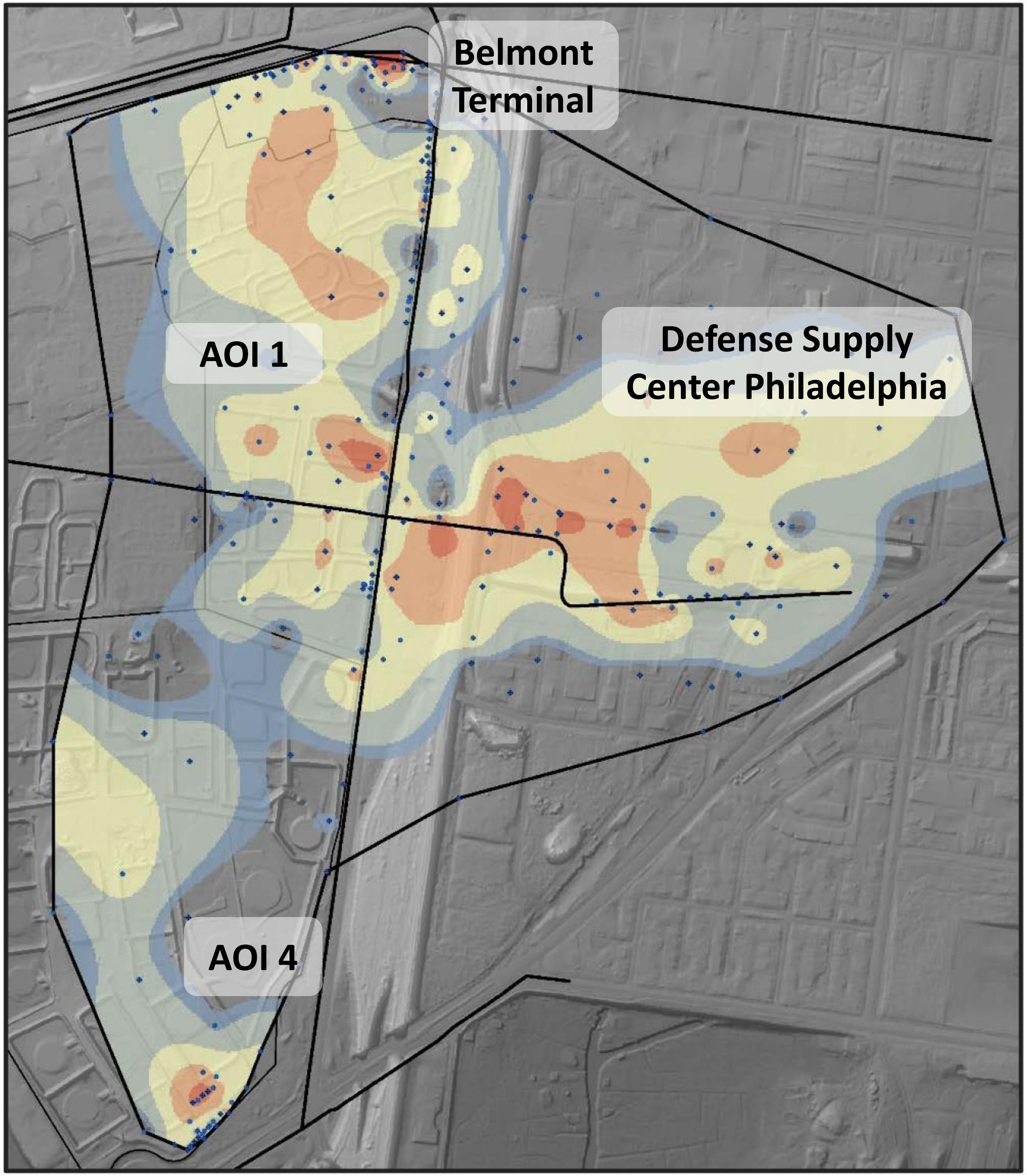
Contaminants of Concern

Volatile Organic Compounds	Semi-Volatiles	Metals
Benzene	Anthracene	Lead
Cumene	Benzo(a)anthracene	
1,2-dibromoethane	Benzo(a)pyrene	
1,2-dichloroethane	Benzo(b)fluoranthene	
Ethylbenzene	Benzo(g,h,i)perylene	
Methyl tert-butyl ether (MTBE)	Benzo(k)fluoranthene	
Toluene	Chrysene	
1,2,4-trimethylbenzene	Dibenz(a,h)anthracene	
1,3,5-trimethylbenzene	Fluorene	
Toluene	Naphthalene	
Xylenes	Phenanthrene	
	Pyrene	

Overview of Act 2 Cleanup

Most significant contaminants of concern:

- Benzene is a primary risk driver
- Soil:
  - Benzo(a)pyrene, lead
- Groundwater:
  - MTBE, 1,2,4-trimethylbenzene, naphthalene
- Light nonaqueous phase liquids (LNAPL)
  - Oil floating on groundwater



Maximum Benzene in shallow groundwater (2014–2017)

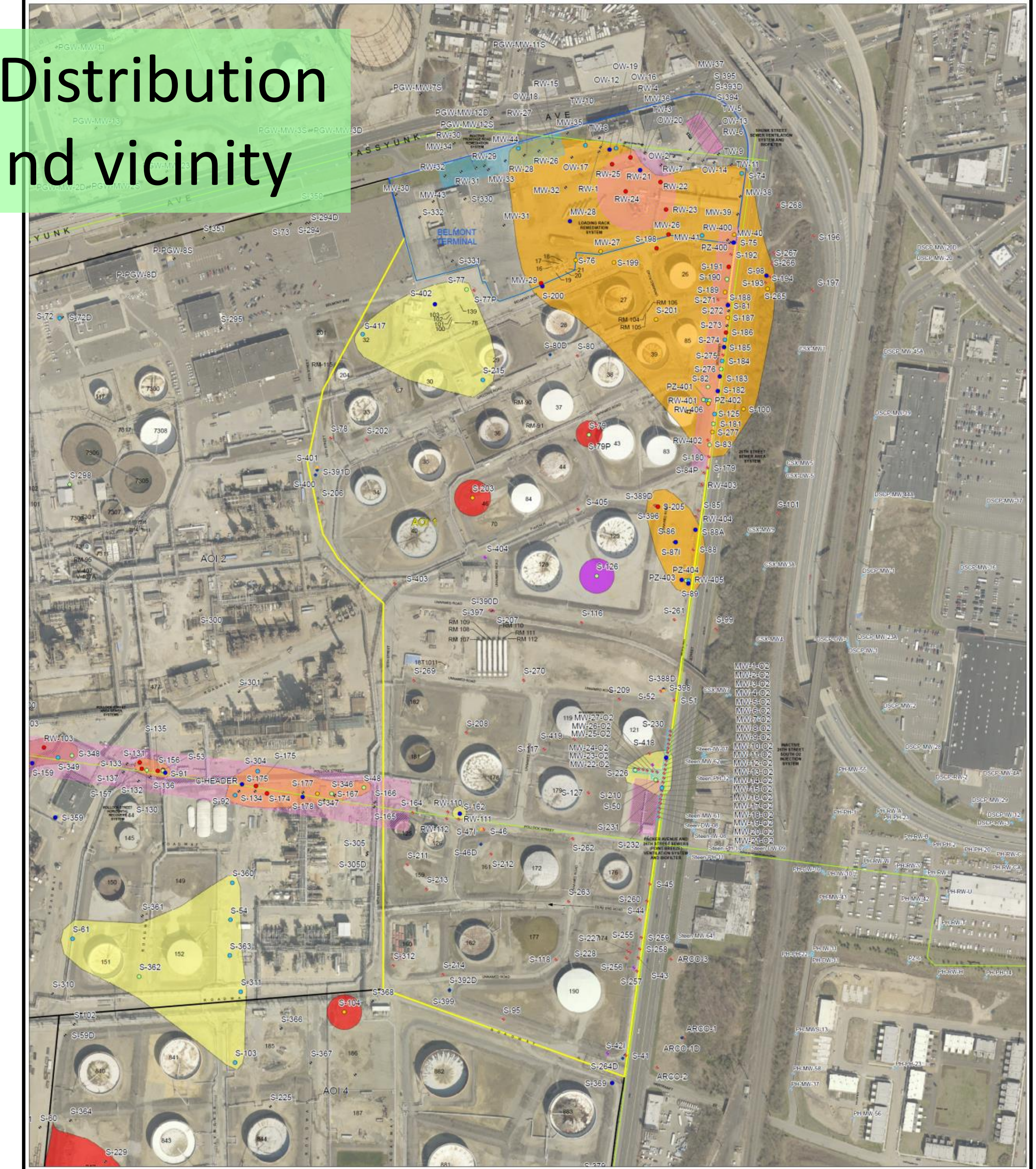
[Stantec, 2018]

Legend

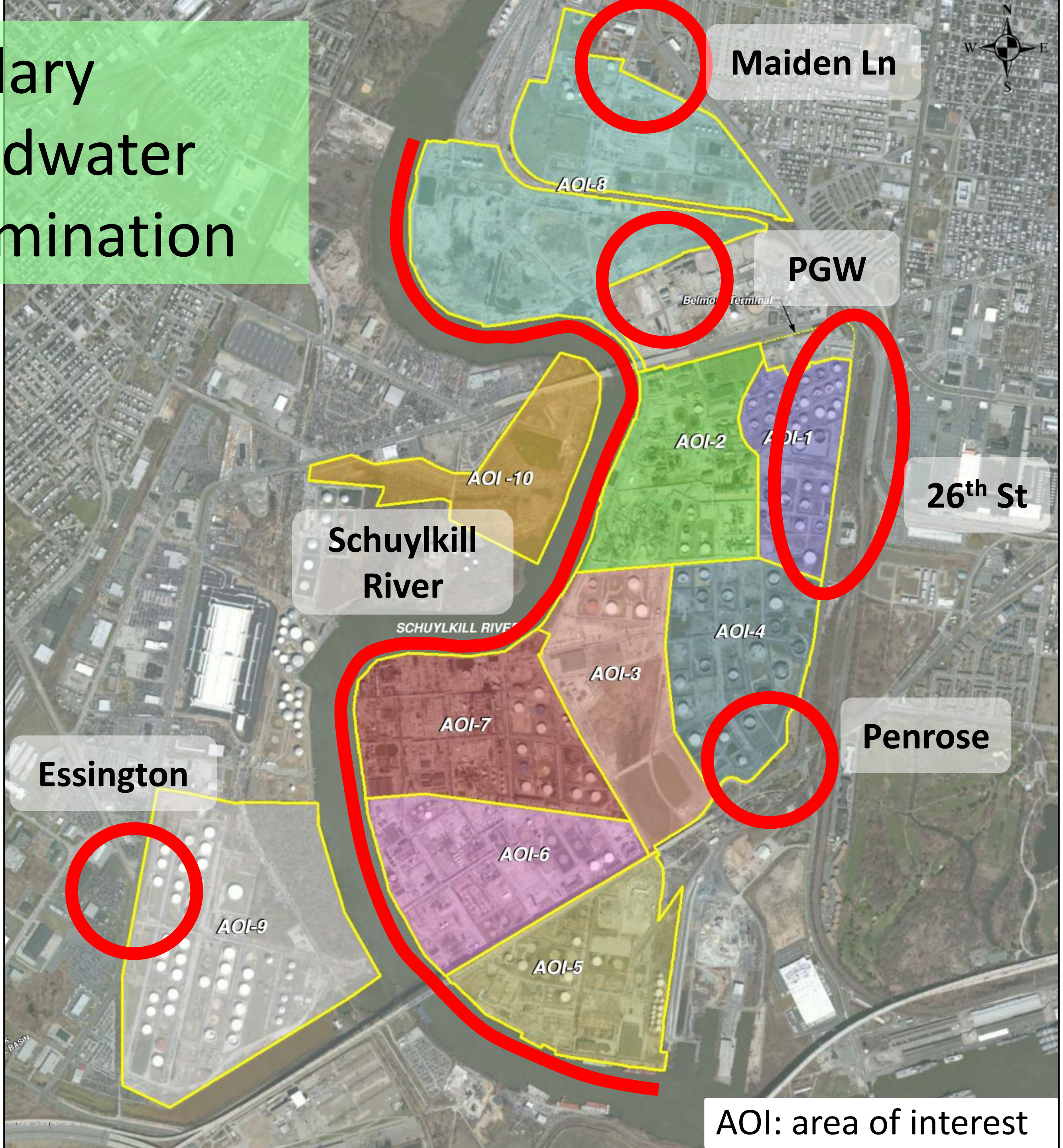
ug/L

⬜ 0 - 5 (no color)
🟦 5 - 10
▨ 10 - 100
🟨 100 - 1,000
🟧 1,000 - 10,000
🟧 10,000 - 100,000
🟥 100,000+

LNAPL Distribution AOI 1 and vicinity



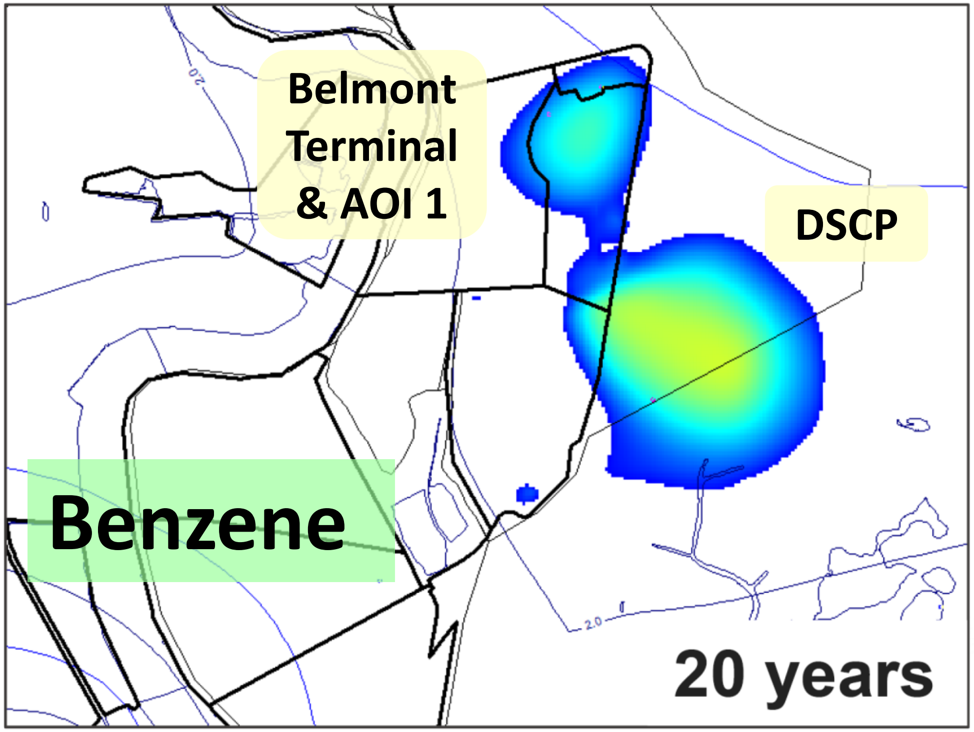
Boundary Groundwater Contamination



AOI: area of interest

Overview of Act 2 Cleanup

- Computer modeling of contaminant migration in the lower aquifer
  - Predict spread of plumes in the future
  - Results have not been submitted for DEP review



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Overview of Act 2 Cleanup

- Storage tank cleanups
  - PES operates 196 regulated tanks
  - Numerous tank releases since 1989
  - Sunoco/Evergreen have satisfactorily addressed and closed 65 tank incidents
  - Approximately 35 tank incidents are still open and are being addressed through the Act 2 process
  - PES has one open tank incident

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Overview of Act 2 Cleanup

- Groundwater remediation
    - At least 18 remedial systems since the 1990s
    - Objectives to protect river, prevent migration outside the facility, and collect sewer vapors
    - Designed to recover oil, groundwater, vapors
    - Recovered oil: > 325,000 gallons
    - Nine systems continue to operate
    - Evergreen assesses upgrades and reactivation

Areas of Interest

AOI 1 – Point Breeze No. 1 Tank Farm

AOI 2 – Point Breeze Processing Area

AOI 3 – Point Breeze Impoundment Area

AOI 4 – No. 4 Tank Farm

AOI 5 – Girard Point South Tank Field

AOI 6 – Girard Point Chemicals Area

AOI 7 – Girard Point Fuels Area

AOI 8 – North Yard

AOI 9 – Schuylkill River Tank Farm

AOI 10 – West yard

AOI 11 – Deep Aquifer Beneath the Complex

VIEW REPORTS

Overview of Act 2 Cleanup

Where to get more information

- Evergreen website:

  phillyrefinerycleanup.info

- T. Donatucci & Eastwick Free Library branches
- DEP's eFACTS database: www.dep.pa.gov

  Data and Tools → Tools → eFacts

- DEP public file review: www.dep.pa.gov

  Public Records → Informal File Review

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Cleanup of the Philadelphia Refinery

Current Act 2 Status and Future Activities

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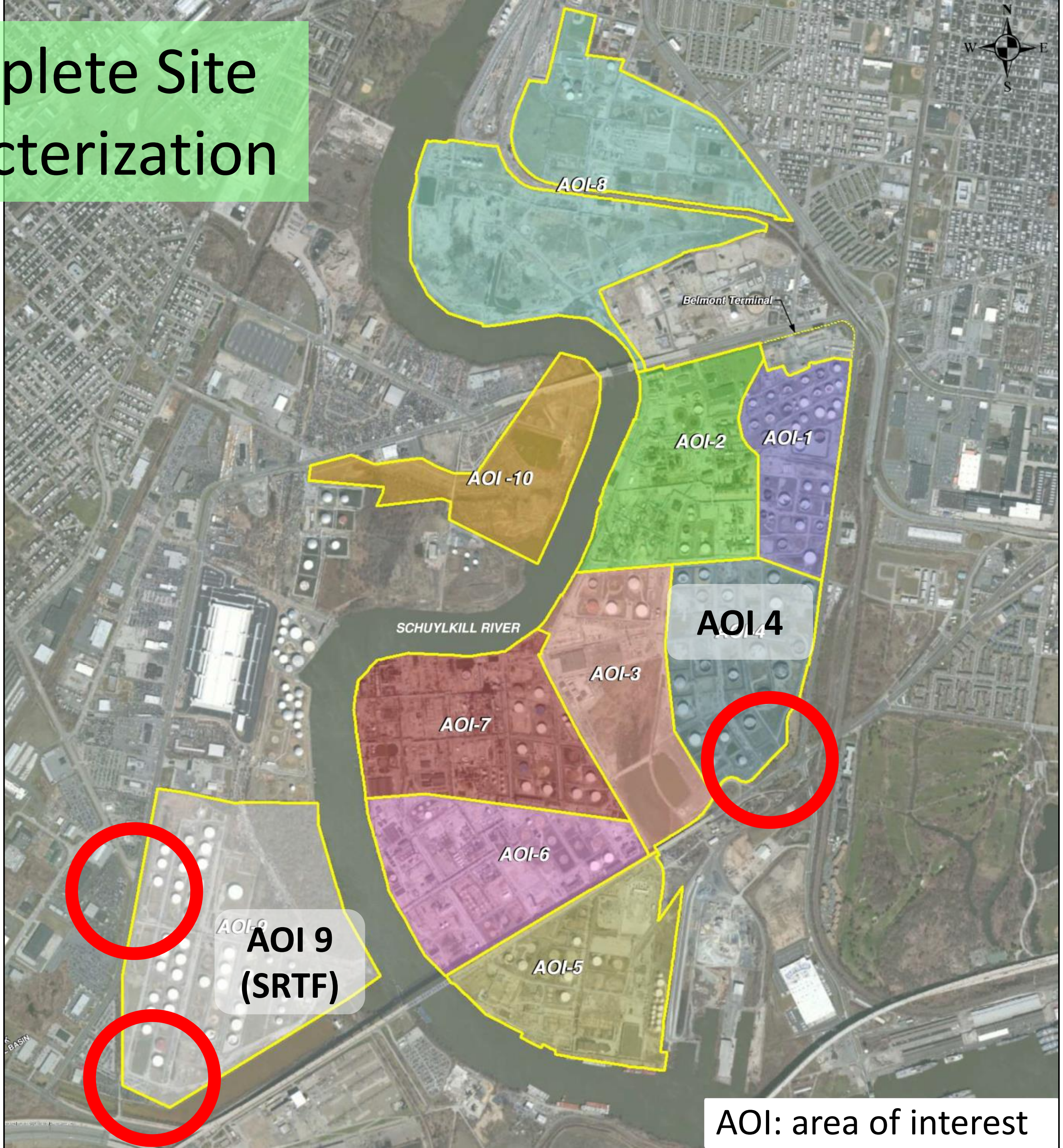
Status and Future Work

- Evergreen must complete site characterization
  - AOI 4: Evergreen installed and sampled offsite monitoring wells near Penrose Avenue
  - AOI 9: Evergreen installed and sampled offsite monitoring wells near Essington Avenue
  - Evergreen will prepare and submit revised remedial investigation reports to DEP and EPA
  - DEP & EPA review and decision

Incomplete Site Characterization



AOI: area of interest

Status and Future Work

- Forthcoming Act 2 work and reporting
    - Ongoing semiannual progress reports
    - Groundwater fate-and-transport modeling
    - Evaluation of impacts to Schuylkill River
    - Human health risk assessment
    - Ecological risk evaluation
    - Cleanup plan
    - Final report
    - Environmental covenant(s)

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Status and Future Work

- Act 2 public involvement requirements
  - No public participation occurred since 2007
  - Evergreen will remedy this lapse with:
    - Revised public involvement plan (June 2019)
    - Two public meetings (anticipated fall and spring)
    - A 120-day public comment period, via website
    - Submittal of a site-wide remedial investigation report addendum responding to all public comments
  - All future Act 2 reports must comply with public involvement requirements

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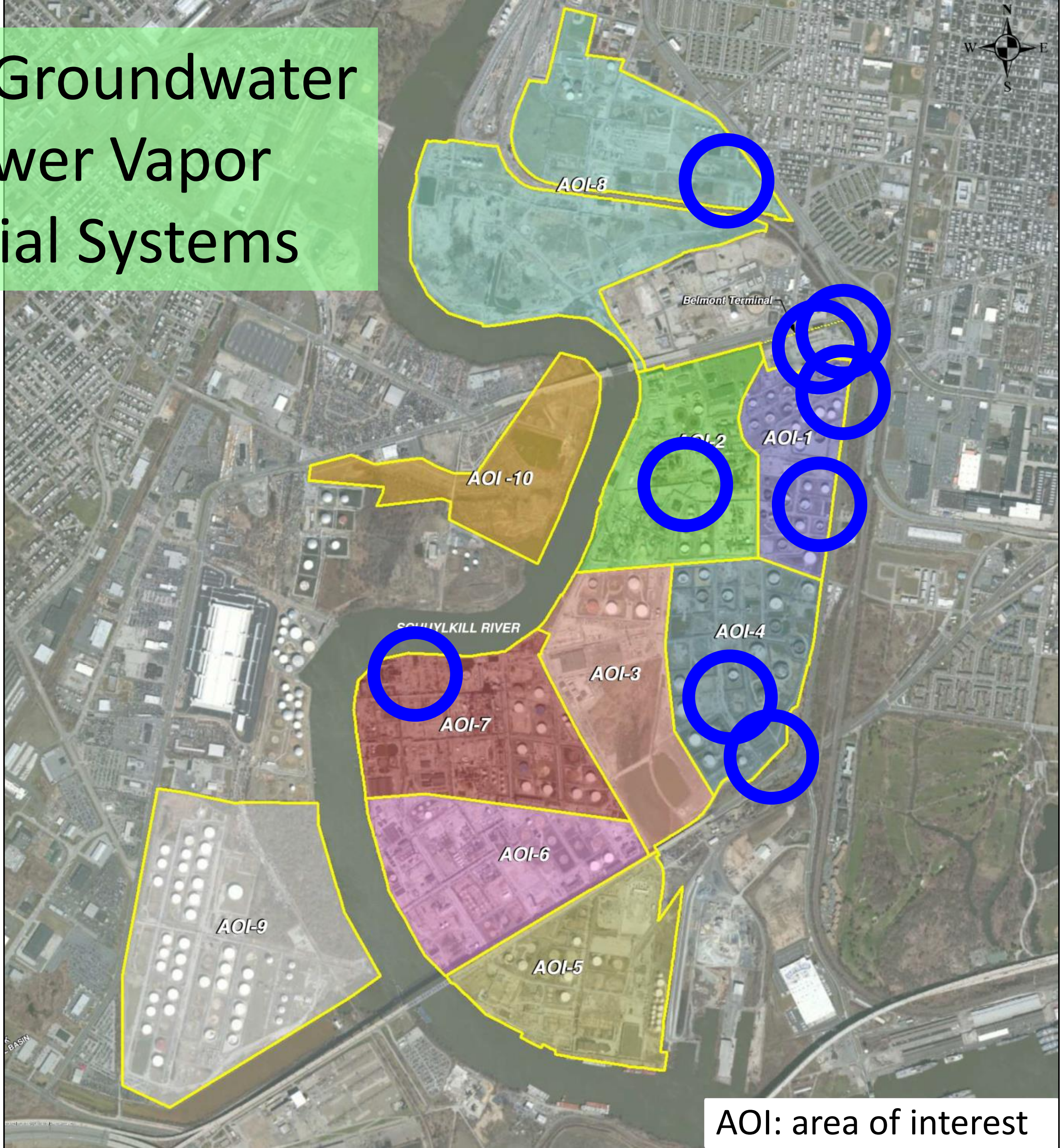
Active Groundwater and Sewer Vapor Remedial Systems



AOI: area of interest

Key Cleanup Issues

Key Cleanup Issues

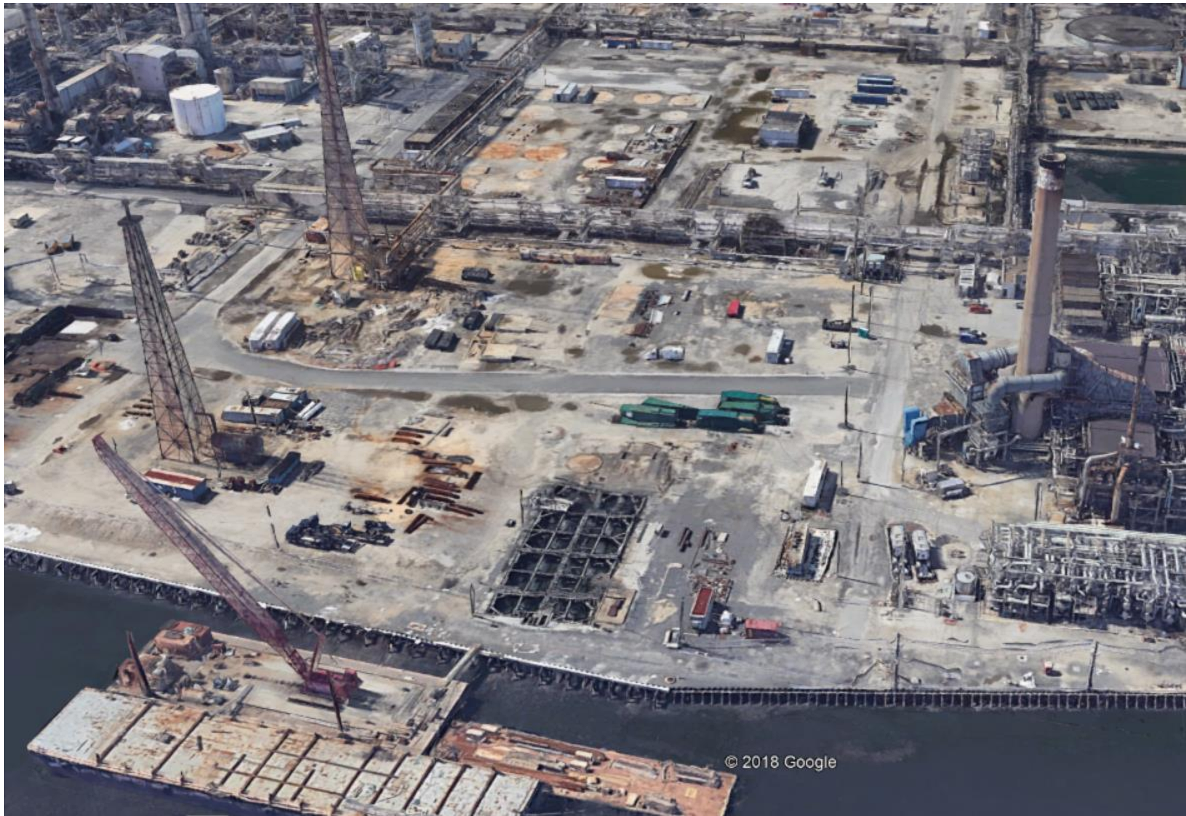
- The refinery property is deed-restricted to commercial or industrial activities
  - Cleanup will be to a nonresidential Act 2 standard
- North Yard ball field
  - Evergreen must achieve residential cleanup standard for recreational use

Key Cleanup Issues

- Site characterization has been performed under conditions of an operating refinery
  - If facility is permanently shut down, process areas will become accessible for investigation
  - Further site characterization would be required
  - Implications for timeline and costs

Key Cleanup Issues

- PES is responsible for environmental releases during its period of ownership (since 2012)
  - Unknown if PES or another party will perform their cleanups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Key Cleanup Issues

- Public comments may influence Evergreen's progress through Act 2
- How will Evergreen's Act 2 milestones interplay with decisions on the site's future?
    - Development of the risk assessment depends on current and known future uses
    - Evergreen will need to obtain an extension of the December 2020 final report deadline

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Key Cleanup Issues

- Does Act 2 constrain future uses of the site?
  - Attainment must be consistent with the present or currently planned future use
  - Act 2 does not preclude cleanup of the site to a higher standard
  - If the use changes, future owners could re-enter Act 2 and remediate consistent with that use

Key Cleanup Issues

- Does the buyer–seller agreement constrain future uses of the site?
  - Evergreen is only obligated to attain a nonresidential cleanup standard
  - Changing the nonresidential deed restriction would require concurrence of all three parties: Evergreen, PES, and DEP

EPA Contact

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keyword: “Land Recycling”

Appendix A

Groundwater Monitoring Guidance

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APPENDIX A: GROUNDWATER MONITORING GUIDANCE

When groundwater is an affected medium, monitoring it is an extremely important part of site characterization, fate and transport assessment, and ultimately, demonstrating attainment of a cleanup standard at Act 2 sites. Taking this under consideration, the Groundwater Monitoring Guidance identifies technical considerations for performing detailed yet concise hydrogeologic investigations and groundwater monitoring programs at Act 2 sites. The purpose of this guidance is to ensure consistency within the Department and to inform the regulated community of DEP's technical recommendations and the basis for them.

The methods and practices described in this guidance are not intended to be the only methods and practices available to a remediator for attaining compliance with Act 2 regulations. The procedures used to meet requirements should be tailored to the specific needs of the individual site and Act 2 project and based on the history, logistics, and unique circumstances of those sites. The guidance is not intended to be a rigid step-by-step approach that is utilized in all situations. The Department recommends that site remediators consult with DEP Regional Office staff for assistance in evaluating and understanding site characterization information for a more efficient Act 2 cleanup.

A. Overview

1. Introduction

Monitoring of groundwater quality is an important component in the application of and compliance with Act 2 of 1995, the Land Recycling and Environmental Remediation Standards Act (Act 2, 35 P.S. §§ 6026.101-2026.908). The goal for monitoring groundwater quality is to obtain reliable data and information that is representative of aquifer characteristics, groundwater flow direction, and physical and chemical characteristics of the groundwater.

Before beginning a hydrogeologic investigation at an Act 2 site, a conceptual site model (CSM) should be developed based on site geology and hydrogeology and the characteristics of the release. The CSM should estimate distribution of predominant geologic units, flow conditions, location of aquifers and aquitards (if known), water table surface and other pertinent hydrogeologic factors present at the site. Coupled with hydrogeologic properties at the Act 2 site, the CSM should consider the type of contaminant which has been released and its physical properties (e.g., petroleum-based or solvent-based, weathered vs. fresh, etc.), the manner of release to the environment, and the volume of the release as can best be determined.

Typical groundwater quality monitoring at Act 2 sites may include:

- Background monitoring: relating to determination of background conditions in accordance with the Act 2 background cleanup standard (e.g. establishing if a groundwater contaminant is naturally occurring, an areawide problem typically resulting from historic, areawide releases, or from an upgradient source). The results of background groundwater monitoring will form a basis against which future monitoring results will be compared to established background values for specific regulated substances of concern, develop groundwater quality trend analyses, or remediation effectiveness under Act 2 when the background cleanup standard is selected.

- Site Characterization: During site characterization, groundwater monitoring wells may be installed and sampled at an Act 2 site throughout the area(s) of contamination, as well as in areas not affected by the release of any regulated substance. Some of the data collected at the monitoring well locations may include groundwater elevations, which are then used to calculate groundwater flow direction and hydraulic gradient, permeability of aquifer materials, porosity of the aquifer, the types of regulated substances present and their concentrations, and the spatial variation in concentration, both horizontally and vertically. A fate and transport assessment most likely should be implemented during this phase of the Act 2 investigation.

- Attainment monitoring: Attainment monitoring of groundwater is performed to demonstrate that the selected Act 2 cleanup standard has been attained at the Point of Compliance (POC). Refer to Section II.B of this guidance for additional information on this concept. Attainment monitoring is also utilized to determine the effectiveness of groundwater cleanup activities.

- Postremedial monitoring: Postclosure monitoring is conducted to determine any changes in groundwater quality after the cessation of a regulated activity or activities. This monitoring may also be part of a postremedial care plan, such as periodic monitoring of sentinel wells. Analytes most likely to be included are those which were monitored during site characterization and/or attainment monitoring.

2. References

Alaska Department of Environmental Conservation, September 2013, Division of Spill Prevention and Response Contamination Sites Program, Monitoring Well Guidance.

B. Monitoring Well Types and Construction

1. Objectives of Monitoring Wells

Monitoring wells should be located and constructed to provide the controlled access necessary to characterize the groundwater at an Act 2 site. Wells should be constructed by a driller who is licensed by the Commonwealth of Pennsylvania (Act 610 of 1956, 32 P.S. § 645.12, and 17 Pa. Code Chapter 47). Drillers do not need to be licensed to install piezometers, temporary well points, or in-situ sampling probes.

Monitoring wells should effectively achieve one or more of the following objectives:

- Provide access to the groundwater system for collection of water samples.
- Measure the hydraulic head at a specific location in the groundwater flow system.
- Provide access for conducting tests or collecting information necessary to characterize the chemical properties of aquifer materials or their hydrologic properties.

While achieving these objectives, the groundwater monitoring system should also preserve the conditions of the subsurface that is penetrated, but not monitored. For example, a well designed to monitor a bedrock aquifer should be designed and installed with minimal or no impact to the flow system in the unconsolidated material overlying the bedrock.

Although monitoring (or observation) wells may be used to measure water levels and then determine the configuration of the water table, or other potentiometric surface, the focus of this appendix is groundwater quality monitoring. Specifically, this appendix provides guidance for the monitoring of groundwater at Act 2 sites.

2. Types of Groundwater Monitoring Systems

Groundwater monitoring systems range from the simple to the complex. Each system has its own value and use in the monitoring environment. Various types of groundwater monitoring systems are described below. General recommendations for the construction of single-screened wells and open boreholes are shown in Figures A-1 and A-2. Site-specific circumstances may require modifications to the recommended construction details.

Open boreholes - These boreholes are typically drilled into competent bedrock with the casing extending completely through the overburden (unconsolidated material) and into the competent rock below. Note that a vertical conduit is created which may intercept active groundwater flow zones (controlled by primary porosity and secondary porosity; i.e. fractures, bedding planes, solution cavities) previously not in contact with each other, potentially resulting in cross contamination. Recommended installation details are shown in Figure A-1.

Figure A-1: Recommended Construction of an Open Borehole Well

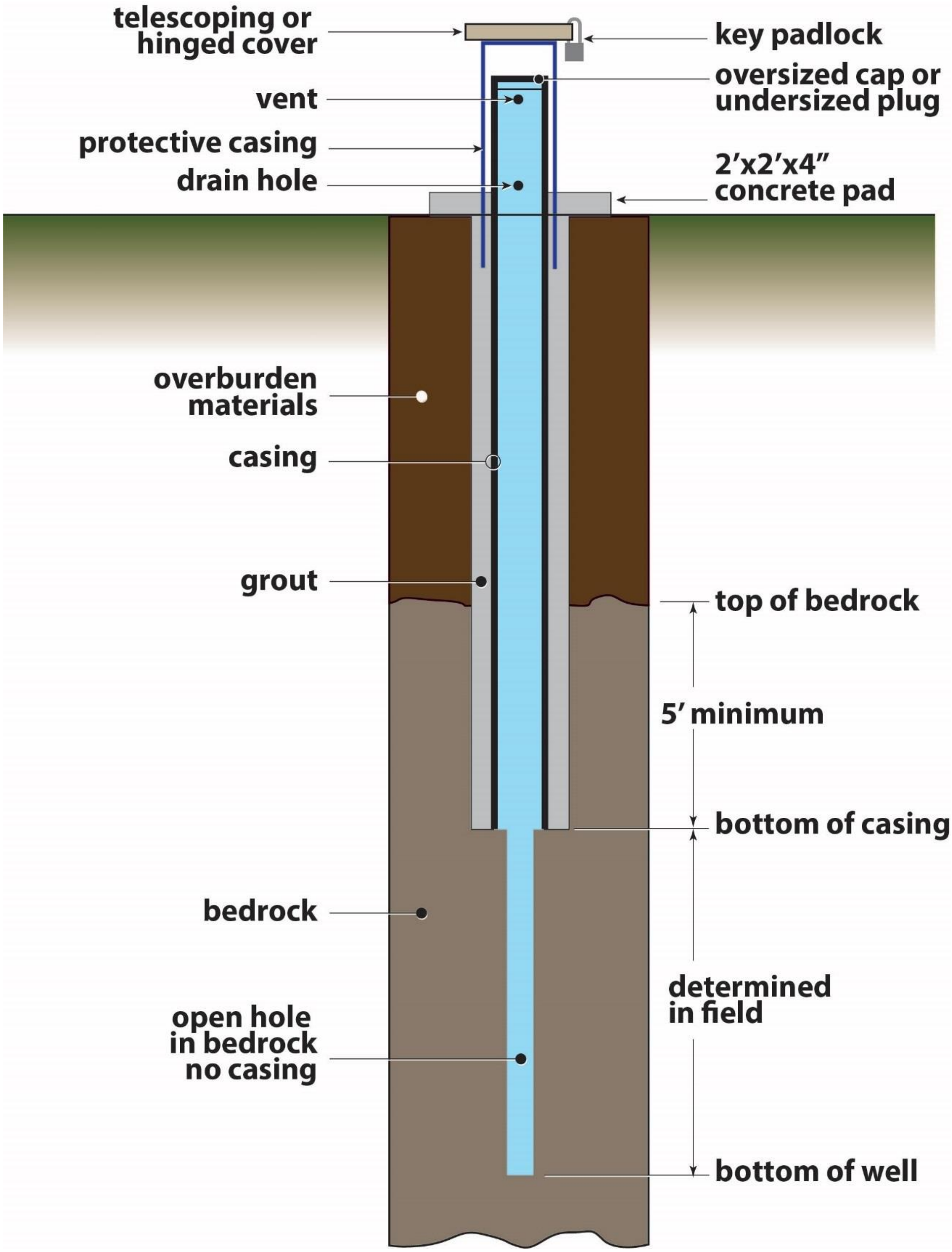


Figure A-2: Recommended Construction of a Single-Screened Well

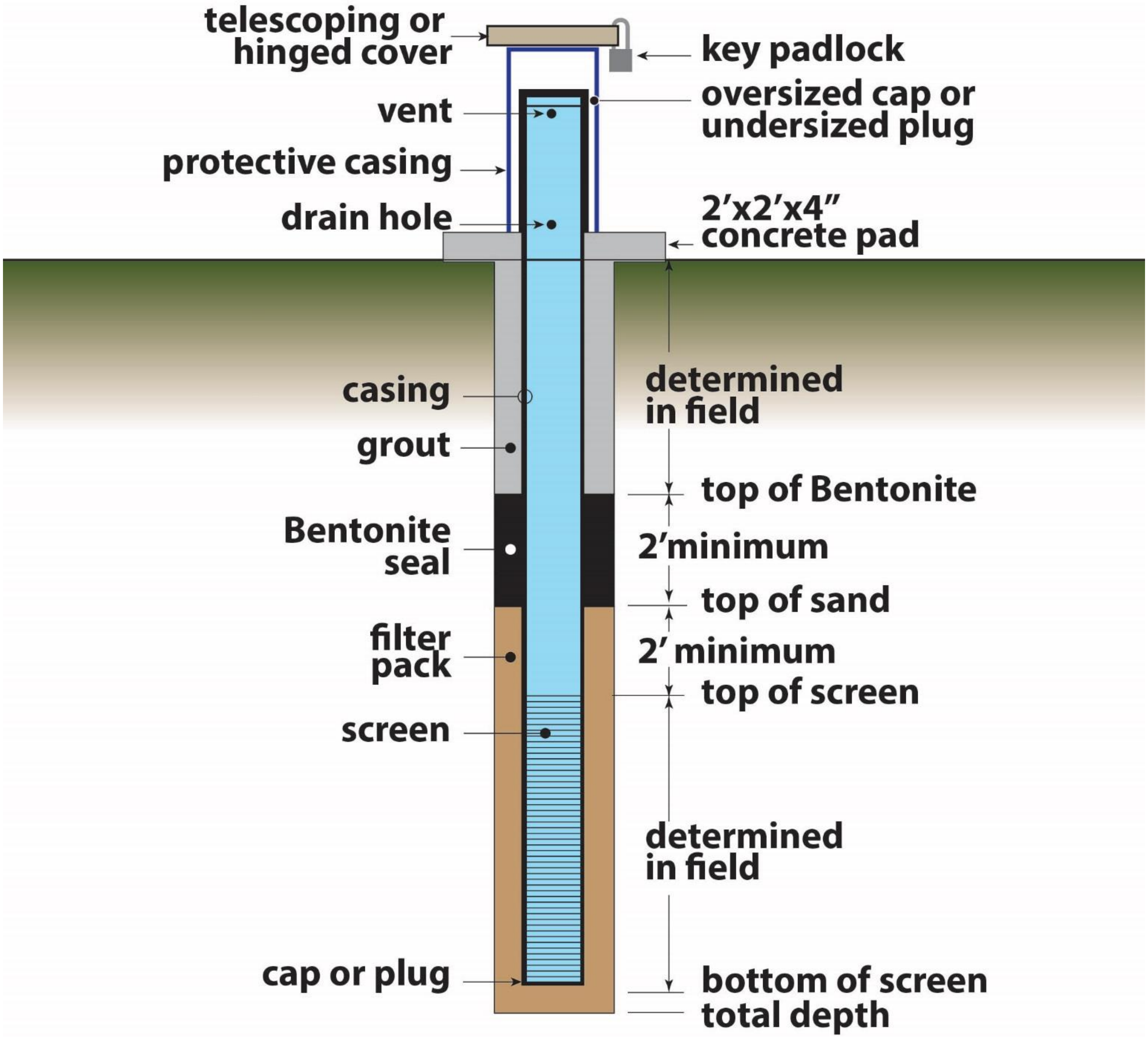
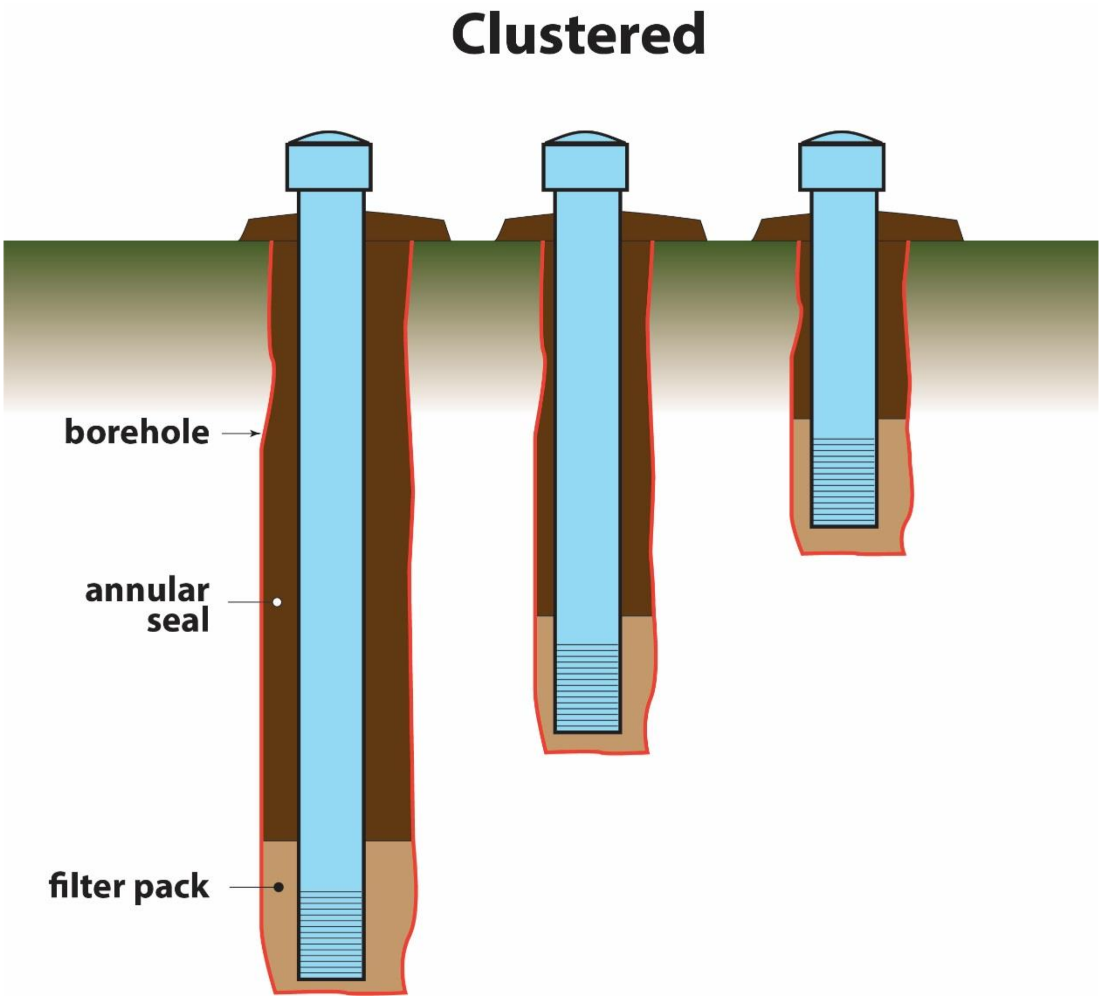


Figure A-3: Example of a Well Cluster



Single screened wells - These wells consist of a prefabricated screen of polyvinylchloride plastic, stainless steel, etc., that is inserted into an open borehole. Clean sand or gravel is placed around the annular space of the screen for the entire vertical distance of the screen length and slightly higher past the connecting screen and well casing. Recommended installation details are shown in Figure A-2.

Well clusters - Well clusters, or a well nest, consist of the construction of open boreholes or screened monitoring wells in a specific location, with each well monitoring a different depth or zone of groundwater. An example of a well cluster is shown in Figure A-3.

Well points - Well points are usually short lengths (i.e., 1-3 feet) of screen attached to a hardened metal point so that the entire unit can be driven, pushed, or drilled to the desired depth for monitoring. (This method is usually limited to shallow, unconsolidated formations.)

Piezometers - These are small diameter wells, generally non-pumping, with a very short well screen or section of slotted pipe at the end that is used to measure the hydraulic head at a certain point below the water table or other potentiometric surface.

3. Choice of Monitoring System

The type of monitoring system chosen depends on the objectives of monitoring at the site. Once the target zones, or areal locations and depths that are the most likely to be impacted by the release are defined, monitoring is often adequately accomplished by using open rock boreholes or single-screened wells that monitor the entire saturated thickness, or a large portion of the target zone.

Where contamination has been detected and definition of vertical contaminant stratification is desired, wells that monitor more discrete intervals of the target zone, or individual aquifers, usually need to be constructed. In this case, well clusters such as shown in Figure A-3 will often be the construction design of choice, although open holes that monitor a short vertical interval or single water-bearing zone also may have application. As the flow beneath the site is better understood, the monitoring system typically will target more specific depths and locations.

Well points, or in-situ sampling probes (direct push technology), can be valuable reconnaissance tools for preliminary site characterizations, or for determining the locations of permanent monitoring wells (see EPA, 1993 and ITRC, 2006). However, in-situ sampling probes can miss a light nonaqueous phase liquid (LNAPL) on the water table and may have problems penetrating coarse sands and gravel (where contamination may be located). Other potential problems include very slow fill times in clayey sediments and significant capture of fines in the sample.

Special well construction will be needed to monitor for certain types of contaminants. **For example, if an LNAPL is a concern, the well screen should be open, bridging the top of the water table and within the zone of fluctuation, so that the LNAPL contaminants will not be cased-off.**

4. Minimum Construction Standards

To properly meet the objectives listed in Section B.1, monitoring wells should be designed and constructed using minimum standards in each of the following categories.

1) Materials

2) Assembly and installation

3) Well development

4) Recordkeeping and reporting

Figure A-4: Examples of Target Zones

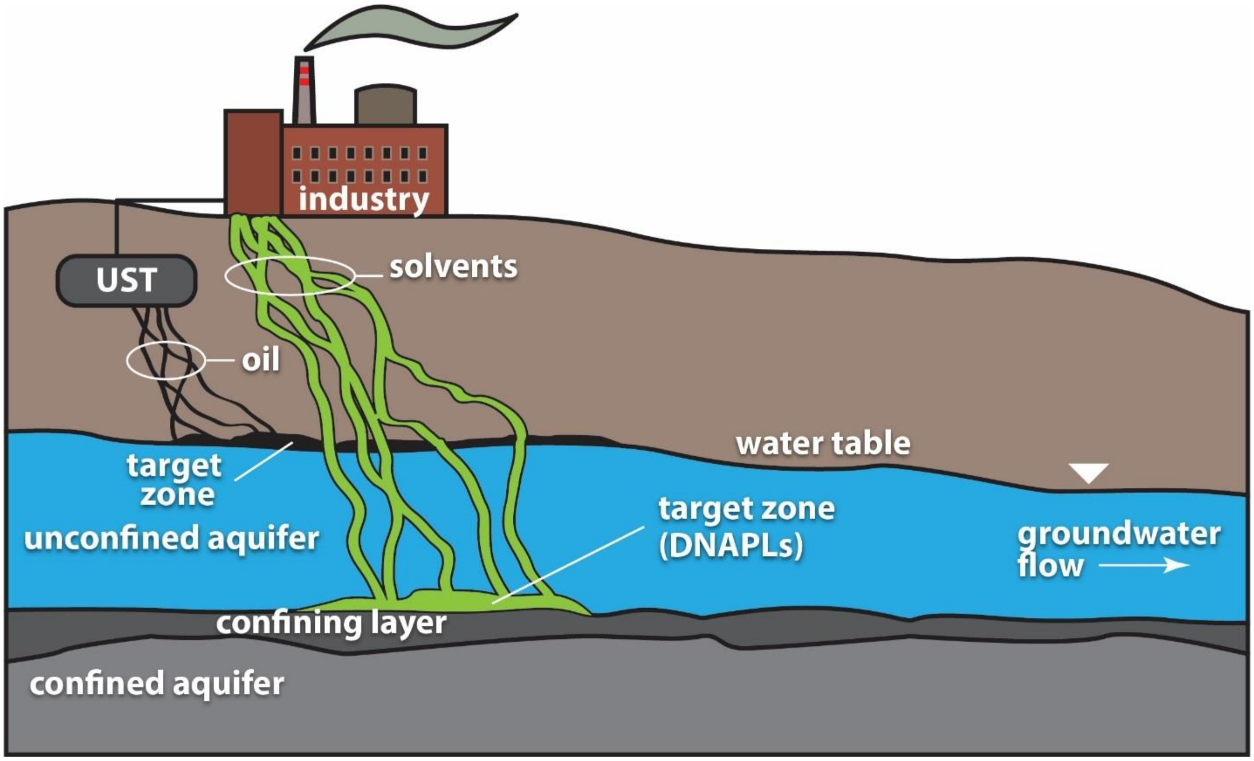
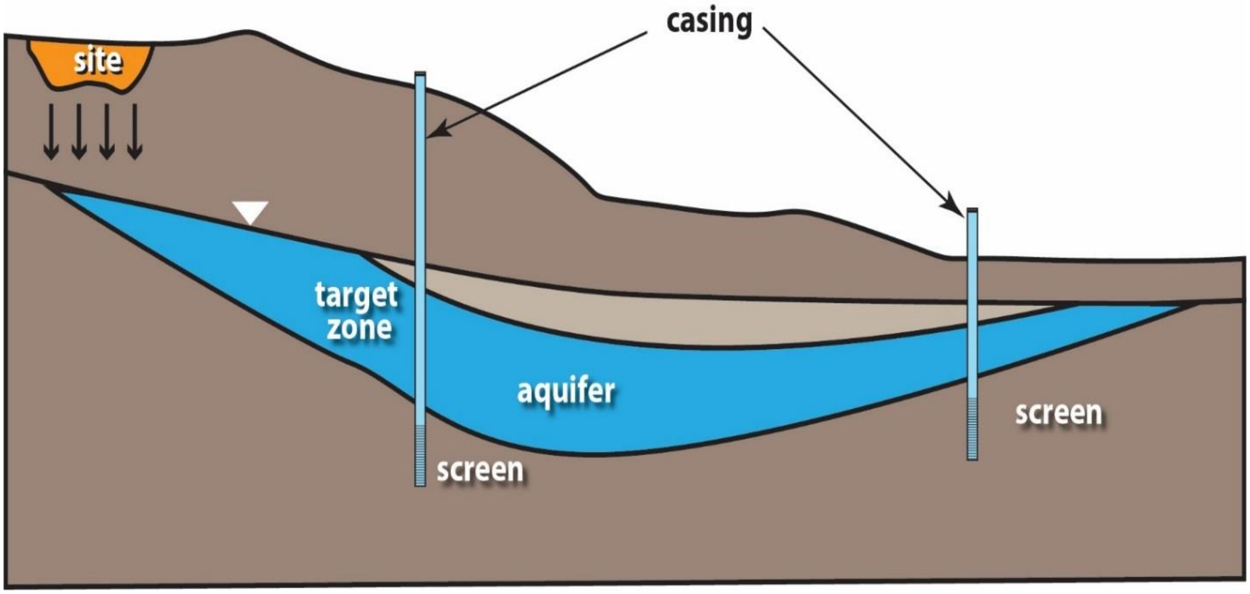


Figure A-5: Monitoring Well Screens Placed Too Deeply Below the Target Zone to Detect Contamination



Different standards and practices may be necessary depending upon the monitoring objectives of an individual site. Monitoring wells constructed to meet multiple objectives should employ the standards of the most rigorous objective. For instance, a well point may be suitable for monitoring hydraulic head, but may not be optimum for collecting samples. Therefore, a well proposed to monitor head and collect water samples should be designed as a conventional, screened well and not as a well point. In addition, construction methods, materials, and well development of each point in the plan must not compromise the objective of other monitoring wells in the well system.

a) Materials

Materials that are used in construction of a monitoring well should not contaminate the groundwater being monitored. A list of materials should include, but not be limited to, the drilling tools and equipment, casing, riser pipe, well screen, centralizers (if needed), annular sealant, filter pack, and drilling fluids or additives. All materials should be of adequate size and of competent strength to meet the objectives of the monitoring point. All materials introduced into the boring should be free of chemicals or other contaminants that could compromise the monitoring well or other downgradient wells. Practices must be employed to minimize the potential for contamination of the materials during storage, assembly, and installation. Specific cleaning procedures should be employed in situations where the materials might introduce contaminants to the groundwater system. Well screens and risers should be coupled using either water-tight flush-joint threads or thermal welds. Solvent welded couplings are not recommended for monitoring well construction.

b) Assembly and Installation

Equipment and techniques should be used that create a stable, open, vertical borehole of large enough diameter to ensure that the monitoring well can be installed as designed, while minimizing the impact on the zone(s) being monitored. When drill cuttings and groundwater removed during construction will likely be contaminated, procedures commensurate with the type and level of contamination should be followed for the handling, storage, and disposal of the contaminated material. Whenever feasible, drilling procedures that do not introduce water or other liquids into the borehole should be utilized. When the use of drilling fluids is unavoidable, the fluid should have as little impact on the constituents of interest as possible. If air or other gas is used as the drilling fluid, the compressor should be equipped with an oil air filter or an oil trap.

The well screen and riser assembly should be installed using procedures that ensure the integrity of the assembly. If water or other ballast is used, it should be of known and compatible chemistry with the water in the boring. Unless designed otherwise, the assembly should be installed plumb and in the center of the boring. Centralizers of proper spacing and diameter can be used. Depending upon the physical environment, the well should be finished as a secure stick-up or flushmount at the discretion of the project geologist. Either completed type of well should be securely capped to prevent the entry of foreign material.

Installation of the filter pack, sealants, or other materials in the annular space should be done using tremie pipes or other accepted practices. Protective casing and locking well caps must be installed, and any other necessary measures must be taken to ensure that the monitoring well is protected from vandalism and accidental damage. To reduce misidentification, all monitoring wells constructed in developed areas, or in any location where they may be mistaken for other structures (such as tank-fill tubes, drains, and breather tubes), should have a locking cap conspicuously labeled “Monitoring Well” (preferably by the well-cap manufacturer). In addition, locks for the monitoring wells should use a key pattern different from locks on other structures at the site. It is also advisable that the well identification number be placed on both the inside and outside of the protective casing.

c) Well Development

After installation, groundwater monitoring wells should be developed to:

- Correct damage to the geological formation caused by the drilling process;
- Restore the natural water quality of the aquifer in and around the well;
- Optimize hydraulic communication between the geologic formation and the well screen; and
- Create an effective filter pack around the well screen.

Well development is necessary to provide groundwater samples that represent natural undisturbed hydrogeological conditions. When properly developed, a monitoring well will produce samples of acceptably low turbidity (less than 10 Nephelometric Turbidity Units (NTUs) as recommended by U.S. EPA, 2013). Low turbidity is desirable as turbidity may interfere with subsequent analyses, especially for constituents that sorb to fine-grained materials, such as metals (CEPA, 2014). Well development stresses the formation and filter pack so that fine-grained materials are mobilized, pulled through the well screen into the well, and removed by pumping.

Well development should continue until as much of the fine-grained materials present in the well column have been removed as possible. It is important to record pumping rates utilized during well development. Purging and sampling rates should not exceed the maximum pumping rate used during well development. When it is likely that the water removed during development will be contaminated, procedures commensurate with the type and level of contamination should be utilized and documented for the handling, storage, and disposal of the contaminated material. Development methods should minimize the introduction of materials that might compromise the objective of the monitoring. If air is used, the compressor should have an oil air filter or oil trap.

Repeated well development may be conducted as necessary at the discretion of the project geologist, especially if clogged screens or biofouling are evident.

d) Recordkeeping and Reporting

Because interpretation of monitoring data from a monitoring well is spatially dependent on both the activity being monitored and other monitoring wells in the system, records and samples of the materials used to construct and drill the monitoring well should be kept. Following construction, accurate horizontal and vertical surveys should be performed. The surveys should be completed by personnel knowledgeable in land surveying techniques. A permanent reference point should be made by notching the riser pipe. Whenever possible, all reference points should be established in relation to an established National Geodetic Vertical Datum (NGVD). Monitoring well locations should be surveyed to ±1 linear foot, and monitoring well elevations should be to the nearest .01 foot. Elevations of the protective casing (with the cap off or hinged back), the well casing, and the ground surface should be surveyed for each monitoring well (see Nielsen, 1991). DEP-permitted facilities are generally required to record the latitude and longitude for each monitoring well (this also is recommended for non-permitted facilities).

A groundwater monitoring network report should be prepared. This report should include copies of the well boring logs, test pit and exploratory borehole logs; details on the construction of each monitoring point; maps, air photos or other information necessary to fully describe the location and spatial relationship of the points in the monitoring system; and a recommended decommissioning procedure consistent with the applicable regulatory program and the well decommissioning procedures recommended in Section E of this appendix.

Monitoring well logs should be prepared and should describe, at a minimum, the date of construction; the thickness and composition of the geologic units (identification of stratigraphic units should be completed on the well log using the Unified Soil Classification System); the location and type of samples collected; the nature of fractures and other discontinuities encountered; the nature and occurrence of groundwater encountered during construction, including the depth and yield of water-bearing zones; headspace of photoionization detector (PID) readings collected; any observations of contamination (e.g. NAPL); and the static water level upon completing construction.

A well completion plan should also be included in the monitoring network report. Each plan should include information on the length, location, slot size, and nature of filter pack for each screen; type, location and quantity of material used as annular seals and filler; description of the type and effectiveness of well development employed; and notes describing how the well, as constructed, differs from its original design and/or location.

The reports described above do not relieve the driller from the obligation to submit, for each well drilled, a Water Well Completion Report to the Department of Conservation and Natural Resources (DCNR), Bureau of Topographic and Geologic Survey, as required by Act 610 (the Water Well Drillers License Act).

5. Direct Push Technology

Direct Push Technology (DPT) devices are investigative tools that drive or ‘push’ small-diameter rods into the subsurface via hydraulic or percussive methods without the use of conventional drilling. DPT has been in use in the environmental industry for more than two decades and its utilization as a tool for performing subsurface investigations in Pennsylvania and many other states has grown concurrently with its evolving technology.

Monitoring wells installed using DPT could either be field-constructed, similar to conventionally drilled and installed wells, or installed using pre-packed well screens. The pre-packed well screen assemblies consist of an inner slotted screen surrounded by a wire mesh sleeve which acts as a support for filter media (sand). The sand is packed between the slotted screen and the mesh. It is important to note that only DPT pre-packed wells are considered suitable for Act 2 sites, due to quality assurance concerns regarding field-construction and associated problems placing the filter pack around the screens of small-diameter wells.

a) Advantages of DPT

Depending on site conditions, DPT offers an attractive alternative to conventional auger drilling and split spoon sampling. The smaller size of DPT rigs enables well installation and sampling in areas not accessible to traditional large auger rigs.

As DPT methods utilize a smaller diameter boring than conventional drilling, less solid waste is generated. Similarly, less liquid waste will be generated from smaller diameter monitoring wells. Because less waste is generated, worker exposures are reduced.

Overall, there is minimal disturbance to the natural formation using DPT in comparison with auger drilling.

From an economic standpoint, DPT has several advantages versus conventional drilling. In relation to project schedule and budget, the time-effectiveness of DPT installation may enable the remediator to investigate more areas of a site than traditional hollow stem auger (HSA) drilling would allow and in a shorter time. Fewer well construction materials may enable a remediator to install additional monitoring points on a limited budget.

Most importantly, short-term and long-term groundwater monitoring studies conducted by others have produced results demonstrating that water samples collected from DPT installed wells are comparable in quality to those obtained from conventionally constructed wells.

b) Disadvantages of DPT

DPT cannot completely replace the use of conventional drilling/monitoring well installation as limitations of the technology are evident in certain situations. DPT is only useful at generally shallow depths (less than 100 feet below surface grade) and in unconsolidated formations. DPT is not suitable for formations containing excessive gravel, cobbles, boulders, etc., or for bedrock drilling due to the obvious lack of augering capabilities.

DPT may be utilized for monitoring well installation below confining layers or as ‘nested’ wells with extreme caution. DPT utilizing only a macrocore barrel and drive rods may not provide for the advancement of casing to keep the borehole open and seal off each separate zone of saturation, which therefore can potentially allow for the mixing of separate zones of saturation when the push rods are withdrawn from the borehole. Therefore, DPT may be utilized for this purpose only if the project geologist can ensure that the threat of cross-contamination from separate zones of saturation above clean zones of saturation will not occur.

If large volumes of aqueous sample are required, DPT installed monitoring wells may not be suitable due to the small diameter of the well screen.

Since DPT causes smearing and compaction of the borehole sides, proper well development techniques are vital to ensure that natural hydraulic permeabilities are maintained. Several studies have demonstrated that hydraulic conductivities can vary by an order of magnitude lower for wells installed by DPT versus wells installed by conventional HSA. For this reason, DPT-installed wells may not be suitable for aquifer characteristics testing, nor for efficient groundwater recovery. Great care needs to be taken to ensure adequate well development when using DPT for well installations.

6. References

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C. Locations and Depths of Monitoring Wells

1. Importance

The locations and depths of monitoring wells are the most important aspects of a groundwater monitoring network. A monitoring point that is misplaced, or not constructed properly to monitor constituents with unique physical characteristics, is of little use and may misrepresent the quality of the groundwater migrating to or from a site. On the other hand, a properly positioned and constructed monitoring well that detects the earliest occurrence of contamination could save both time and money spent on cleanup of a site. It is important to note that the placement and construction of a groundwater monitoring network at an Act 2 site shall be conducted by a professional geologist licensed in Pennsylvania (25 Pa. Code §§ 250.204(a), 250.312(a), and 250.408(a)).

2. Approach to Determining Monitoring Locations and Depths

Different approaches and efforts for determining the location and depth of wells may be necessary based on the type of monitoring to be done. However, before well locations are chosen for any type of monitoring, the existing data should be evaluated. This can reduce the costs of implementing the monitoring program and can help to make appropriate choices for three-dimensional monitoring locations.

The most efficient way to accomplish the location and depth of monitoring wells for an Act 2 study is to formulate a CSM, or conceptual groundwater flow model. A conceptual groundwater flow model is the illustrative delineation and formulation of the important controlling components of groundwater flow and thus contaminant transport from recharge areas to discharge zones or withdrawal points. Without a proper conceptualization of groundwater flow, a groundwater model can give spurious results. On the other hand, a well-developed conceptual model may allow groundwater flow to be accurately approximated without using computer modeling or complex analytical procedures. The groundwater conceptual model is an important tool in the study of groundwater flow on both a local and even larger scale. The goal of the conceptual model is to represent the controlling aspects of groundwater flow at the site being investigated. Important controlling components of groundwater flow can include geological characteristics, geologic structural and stratigraphic relationships, anisotropy, calculated groundwater flow directions and recharge and discharge relationships.

Information may be obtained through site visits, site records and previous studies, interviews with present and past workers, aerial photographs, scientific publications on the local and regional hydrogeology, geophysical surveys, borings, wells, aquifer tests, etc. If enough information is available, the designer can determine the groundwater flow paths and design a complete monitoring network. However, actual testing of aquifer parameters and borehole geophysics provides the best information to evaluate placement and construction of monitoring wells, especially in newly established sites or facilities where little site information is available.

a) Background Monitoring

The determination of background water quality is paramount in understanding the effect of an activity or site on groundwater quality. Often, insufficient site information is available so that initial well locations may depend on casual observations and assumptions regarding groundwater flow. If subsequent information shows that monitoring wells are misplaced, new wells should be installed.

b) Site Characterization Monitoring

Appropriately placed monitoring wells are necessary to detect groundwater quality at an Act 2 site. The more that is known about the history of operations at the site, (potential) contaminant flow paths, and the constituents that may have been discharged to the environment, the more likely that monitoring wells installed during the site characterization phase of the investigation will be optimally placed and constructed to monitor the impact on groundwater quality. Monitoring well locations should be concentrated in those areas that will most likely first be impacted by the known discharges on the site, which typically will be located within or comprise the uppermost aquifer. As groundwater data is collected, additional monitoring wells may need to be installed to fully characterize the groundwater contaminant plume(s) present. The greater the complexity of the hydrogeology and the spread of contamination, the more monitoring wells that may be necessary to characterize the contamination.

c) Attainment and Postremedial Monitoring

Any number of wells, including all installed during the site characterization phase, may be used for attainment monitoring. These wells will demonstrate attainment of the chosen cleanup standard at the POC. The impact of any remediation conducted at the Act 2 site on the groundwater flow paths (e.g. pumping the aquifer) should be considered for placement of attainment monitoring wells. Postremedial monitoring would likely be conducted in the same wells as attainment monitoring to monitor for any residual rebound occurring in the aquifer after remediation activities have been completed.

3. Factors in Determining Target Zones for Monitoring

The prime requirement for a successful monitoring system is to determine the “target” zones - the spatial locations and depths that are the most likely areas to be impacted by the site being investigated. The dimensions of target zones depend on the vertical and horizontal components of flow in the aquifers being monitored, the size of the Act 2 site, the potential contaminants released, and the distance that contamination may have traveled from the facility since being released. Figure A-4 shows how different target zones could be formed based on these factors.

Horizontal and vertical components of groundwater flow are best determined by constructing planar and cross-sectional flow nets based on the measurement of water levels in piezometers. Where the vertical components of flow are negligible, wells, rather than piezometers, drilled into the aquifer to about the same depth, will allow preparation of a contour map of water levels representing horizontal flow. This should be adequate to prepare a planar flow net and determine the target zone.

With regard to upgradient wells, target zones (as defined above) do not exist. Upgradient wells should be drilled to depths that are screened or open to intervals similar to that of the downgradient wells, or to depths that yield water that is otherwise most representative of the background quality of the water being monitored by the downgradient wells. In other words, upgradient wells should be installed within the same hydrogeologic aquifer to the respective downgradient wells.

The numerous site details to consider when establishing target zones may be grouped into either groundwater movement or the spatial distribution of contamination.

a) Groundwater Movement

In what direction is groundwater flowing? If flow paths are not easily determined, what will influence the direction of groundwater flow? The answers to these questions are critical to selecting target zones and the optimal locations of monitoring wells.

Using the groundwater levels from piezometers or wells at the site, the groundwater flow direction and hydraulic gradient can be determined. At least three monitoring points are needed to determine the horizontal flow direction and hydraulic gradient; however, at some sites, knowledge of the vertical component of flow may be important. This is best accomplished by using well pairs of “shallow” and “deep” piezometers or short-screened wells.

It may appear to be a simple task to place monitoring wells in downgradient positions using a map of the groundwater elevation contours, or by anticipating the flow direction based on topography or discharge points. However, at many sites, three-dimensional flow zones must be understood to install appropriate monitoring points (see Section C.5 of this appendix). Figure A-5 shows how a well can miss the vertical location of contamination at a site. Water level measurements, piezometer and well construction logs, geologic well logs, and groundwater flow direction maps should be reviewed carefully when assessing the dimensions of target zones.

i) Geologic Factors

The geology of a site can complicate the selection of the target zones for monitoring. Geologic factors can produce aquifers that are anisotropic. In an anisotropic aquifer, the hydraulic conductivity is not uniform in all directions so that groundwater moves faster in one direction than another and oblique to the hydraulic gradient. Anisotropy can result from various sedimentary or structural features such as buried channels, bedding planes, folds, faults, voids, and fractures.

In Pennsylvania, most of groundwater flow in bedrock is through fractured rocks. Fracture flow in bedrock (or hardened sediments) requires additional considerations compared to flow in unconsolidated materials. Consolidated materials may exhibit small effective porosities and low hydraulic conductivities that impede groundwater flow. However, the development of secondary porosity may allow substantial flow of groundwater through fractures, joints, voids, cleavage planes and foliations. These features tend to be highly directional, exhibit varying degrees of interconnection, and may produce local groundwater flow regimes that are much different from the regional trends.

Geologic factors influence the direction of groundwater flow by controlling the transmissivity. For example, Figure A-6 shows the effect of fractures on the spread of contamination. Although the gradient indicates flow to the north, groundwater also follows the major fractures and spreads to the northeast. Monitoring wells “1” and “2” located to the north of the site may detect contamination, but the lack of a monitoring well to the northeast will miss an important direction of migration. Common sedimentary bedding planes also could have a similar effect on groundwater flow.

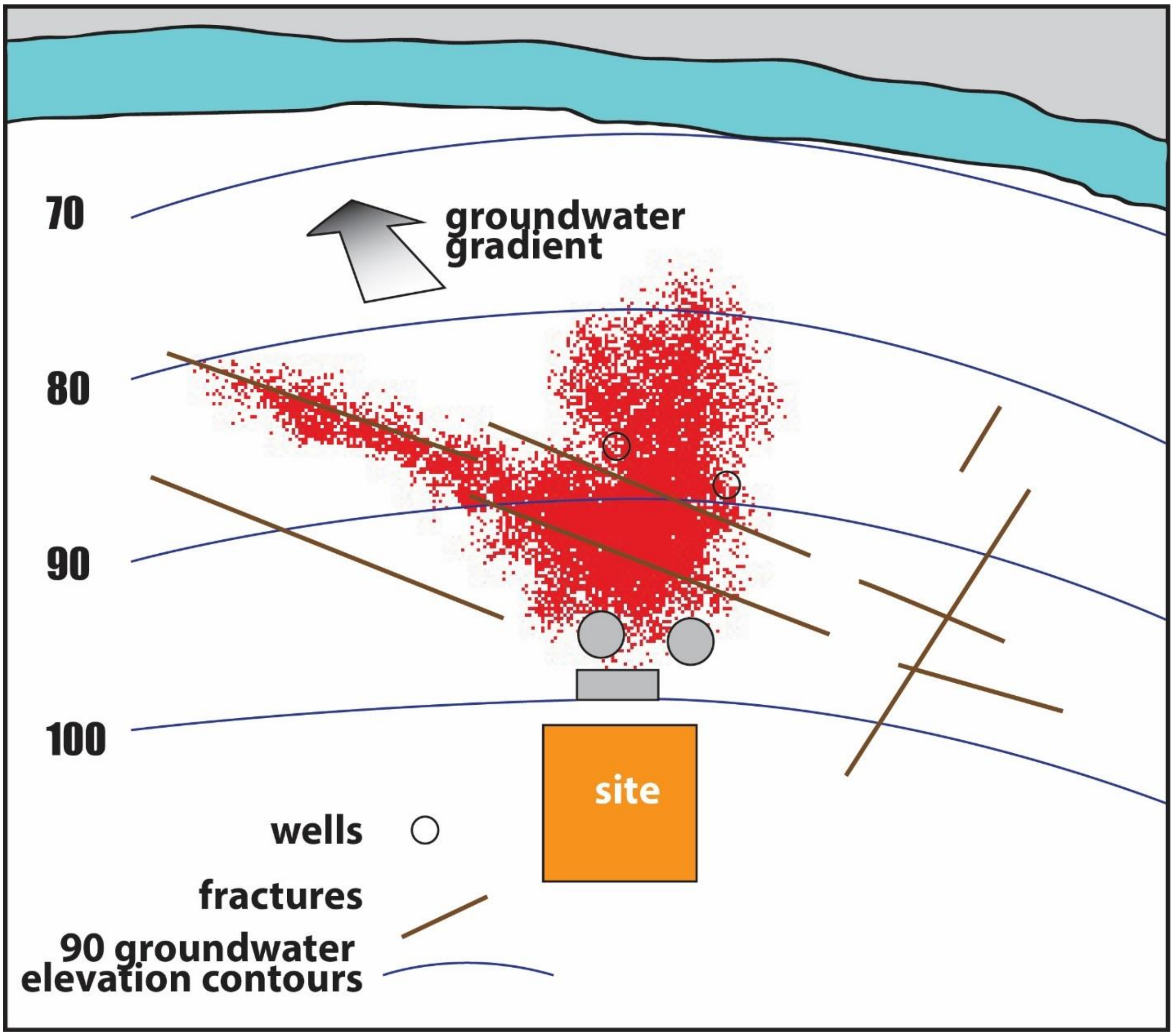
It is important to identify hydrostratigraphic intervals which may or may not be interconnected at the site when conducting a groundwater investigation. Monitoring wells should not be screened across two intervals as groundwater flow and concentrations of contaminants may differ significantly in each interval.

ii) Groundwater Barriers

The presence of hydrogeologic barriers should also be considered when locating wells in a groundwater monitoring system. A groundwater barrier is a natural geologic or artificial obstacle to the lateral movement of groundwater. Groundwater barriers can be characterized by a noticeable difference in groundwater levels on opposite sides of the barrier. Geologic faults and dikes along with tight lithologic formations such as shale and clay layers are common examples. Important types of barriers include the following:

<u>Geologic faults</u> - Fault planes that contain gouge (soft rock material) or bring rock bodies of widely differing hydraulic conductivity into juxtaposition can influence groundwater flow direction and velocity. Location of downgradient wells across fault zones or planes should not be approved until the nature of the influence of the fault zone on groundwater flow has been evaluated. One method of evaluating fault zones is to conduct pumping tests with wells on either side of the fault plane to evaluate the degree of hydraulic connection.

Figure A-6: Effect of Fractures on the Spread of Contamination



Dikes - Diabase dikes, common in southeastern Pennsylvania, can function as lithologic barriers to groundwater flow because of their very low permeability. If a dike lies between a site and a proposed downgradient well, the role of the dike should be evaluated prior to approving the well's location.

Others - Geologically "tight" layers (aquitards) or formations can function in a similar way: they can create subsurface "dams" that cause groundwater to flow in unexpected directions. Additional barriers to flow can include inclined confining beds, groundwater divides, and artesian aquifers.

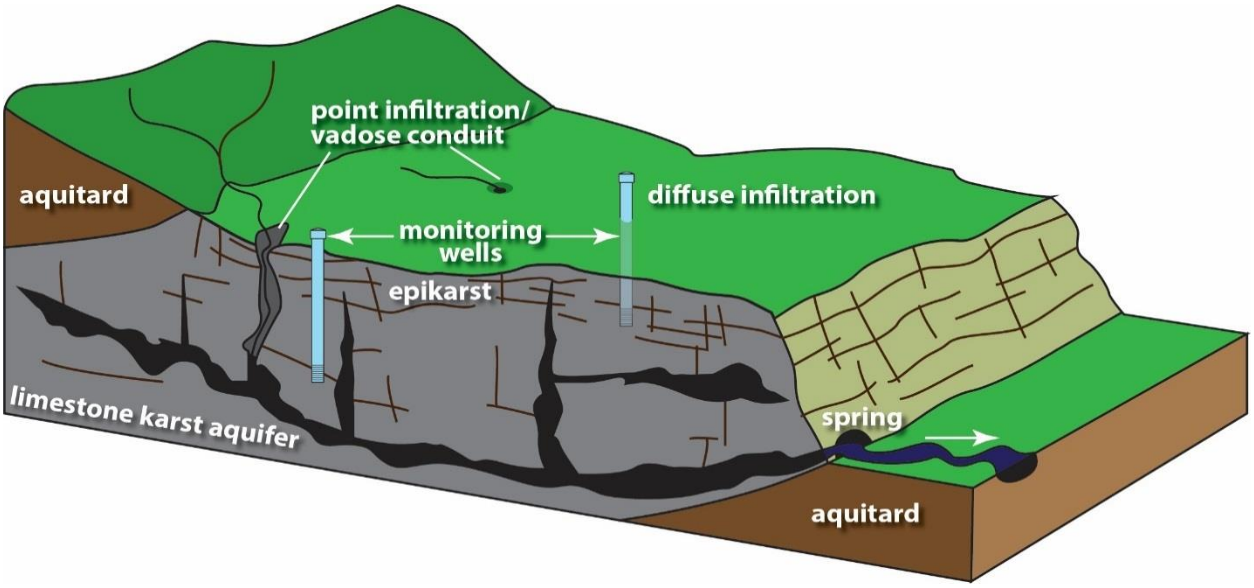
iii) Karst Terrane

Carbonate rock such as limestone and dolomite is susceptible to the formation of sinkholes, solution channels, and caverns. In Pennsylvania, almost all carbonate rock will exhibit some degree of karst development. Resulting flow patterns can be very complicated; flow depends on the degree of interconnection of the joints, fractures, and solution openings (small and large), the hydraulic gradient, and geologic barriers. The resulting anisotropic setting can make it difficult to effectively monitor and model a site in a karst area. Even a relatively small cavernous opening with its connecting drainage paths can control a significant amount of the flow from an area, and may perhaps effectively carry all the groundwater that discharges from underneath a site. In addition, karst geology has the potential to rapidly transmit groundwater over a large distance.

Groundwater flow in a karst terrane can be highly affected by precipitation events, and groundwater divides can be transient. To determine monitoring locations in limestone and dolomite areas, the remediator should investigate the degree to which the rocks are susceptible to dissolution. The more dissolution features that are recognized, the more likely that conduit flow will occur. Dissolution features may be identified through site visits, aerial photographs, geologic well logs, and geophysical techniques.

Thus, it would seem logical that monitoring locations should be based on major conduits of flow. However, Figure A-7 shows how a monitoring well can easily miss a primary conduit. It may be futile to attempt to establish the locations of such flow zones because they probably represent only a small fraction of a site. However, several procedures can be used to increase the odds of monitoring the site of concern. (Note that many of the procedures discussed here also can be used in other types of fractured rocks.)

Figure A-7: Ineffective Monitoring Wells in a Carbonate Aquifer



<u>Tracer tests</u> - Tracer tests offer the best possibility of determining where groundwater is flowing and discharging. They are conducted to establish a hydraulic connection between a downgradient monitoring point and the facility of concern. Tracer tests should be combined with a thorough inspection for the presence of local and regional springs, surface streams, and dry stream channels that could serve as discharge points for groundwater at the site. It also could be possible that groundwater beneath a site could discharge to several features, or that the flow directions could be different during flood or high groundwater stages. A determination of the point of regional base flow should also be made and possibly included as a monitoring point when possible.

It is important to understand the potential chemical and physical behavior of the tracer in groundwater. The objective is to use a tracer that travels with the same velocity and direction as the water and does not interact with solid material. It should be easily detected and be present in concentrations well above natural background quality. The tracer should not modify the hydraulic conductivity or other properties of the medium being studied. Investigations using tracers should have the approval of local authorities and the Department, and local citizens should be informed of the tracer injections.

Various types of tracers are used including water temperature, solid particles, ions, organic acids, and dyes. Fluorescent dyes are the most common type of tracer used in karst areas. These dyes are used because they are readily available, are generally the most practical and convenient tracers, and they can be adsorbed onto activated coconut charcoal or unbleached cotton. Fluorescent dyes can be detected at concentrations ranging from one to three orders of magnitude less than those required for visual detection of non-fluorescent dyes. This helps to prevent the aesthetically unpleasant result of discoloring a private or public water supply.

Fluorescein (CI Acid Yellow 73 - $C_{20}H_{10}O_5Na_2$) is one of the most widely used water-tracers in karst terrane studies because of its safety, availability, and ready adsorption onto activated coconut charcoal. It is a reddish-brown powder that turns vivid yellow-green in water, is photochemically unstable, and loses fluorescence in water with pH less than 5.5.

Rhodamine WT is another commonly used dye tracer. Rhodamine WT is a conservative dye and generally efficient tracer because it is water soluble, highly detectable (strongly fluorescent), fluorescent in a part of the spectrum not common to materials generally found in water, thereby reducing the problem of background fluorescence, harmless in low concentrations, inexpensive, and reasonably stable in a normal water environment (U.S. EPA 2013).

The toxicity of the dyes should also be considered, especially when there is a chance of private or public water supplies being affected. Smart (1984) presents a review of the toxicity of 12 fluorescent dyes. Other excellent references include U.S. EPA and the USGS (1988) and Davis and others (1985).

The mapping of outcrops and associated joints and faults can distinguish directional trends that groundwater might follow. Fracture trace analysis using aerial photographs can detect local and regional trends in fractures, closed depressions, sinkholes, stream alignments, and discharge areas. However, tracer tests are still recommended to verify where groundwater is flowing.

Additional site investigation techniques may be helpful in determining flow paths. Geophysical methods such as self-potential (a surface electromagnetic method) and ground penetrating radar can enhance the understanding of karst systems.

Effort should be made to monitor at or near the site of concern rather than depend on springs that discharge away from the site. Wells sited on fracture traces or other structural trends can be tested with tracers to see if they intercept groundwater flowing from the site. A monitoring network should not be solely dependent on water levels to establish the locations of monitoring wells in such fractured rock settings. These uncertainties and the potential traveling distances may cause monitoring in karst areas to be involved and expensive.

For more information regarding tracer tests, please refer to the USGS website on tracer studies.

iv) Deep-Mined Areas

When designing a groundwater monitoring program for a site in which coal or noncoal deep mining has occurred, it is important to consider the effect of the underlying mine on the hydrologic system.

Because of the mine workings and the associated subsidence fractures, the deep mine often acts as a large drain for the overlying water-bearing zones. Groundwater monitoring of this zone may be considered on a case-by-case basis.

Saturated zones within deep mines may be characterized as a mine pool, which is a body of water at a relatively stable elevation, or it may be a pathway for channelized water. Because of these special problems, a drilling plan should be devised that includes provisions for drilling through the coal pillar, mine void or collapsed structures. Several attempts should be made at each well location to intercept the pool, saturated zone and/or mine void.

Well construction requires the placement of a grout basket or plug attached to the riser pipe that is placed above the zone to be monitored. This helps to seal the bentonite grout.

b) Contaminant Distribution

In addition to normal groundwater flow (advection), the distribution of contamination is critical to the correct placement of monitoring points. This distribution is based on 1) the chemical and physical characteristics of groundwater and contaminants present that affect the migration of the monitored contaminant, and 2) its occurrence or source at the site. For example, the density of a contaminant is one of the most important factors in its distribution in the aquifer, and especially for determining the depth of a target zone (see Section C.5 of this appendix). Petroleum hydrocarbons tend to remain in shallow groundwater. Chlorinated VOCs tend to migrate deeper into the aquifer, sometimes following structural features that may be contrary to groundwater flow direction. These factors are extremely important to consider when designing a groundwater monitoring network.

Isoconcentration maps can be useful in plume interpretation and for placement of groundwater recovery wells. Also, the remediator should keep in mind the relationship of the flow lines with the activity's location or potential sources of contamination.

4. Areal Placement of Wells

For establishing the target zones, the remediator should consider the topics of groundwater movement and contaminant distribution that were discussed above. For the initial placement of wells at a site where little information is available, the downgradient well positions are typically assumed to be downslope. In apparent flat-lying sites, drainage patterns can be used to estimate the flow direction. The site boundary that is closest to a body of water is a likely choice for downgradient well locations. An upgradient well is typically placed upslope.

As more information is obtained about the site, groundwater gradients will be more accurately defined. Upgradient and downgradient monitoring points may need to be added or moved. However, even well-defined groundwater flow direction maps should be evaluated carefully when choosing the target zones for upgradient and downgradient wells. Because of structural controls in fracture flow described in Section C.3.a, groundwater can move obliquely to the regional gradient. Some monitoring points may need to be moved as target zones are refined.

In general, when comparing sites, intervals between monitoring wells probably should be closer for a site that has one or more of the following:

- a small area
- complicated geology such as folding, faulting, closely spaced fractures, or solution channels
- heterogeneous lithology and hydraulic conductivities
- steep or variable hydraulic gradient
- high seepage velocity
- had liquid contaminants
- tanks, buried pipes, trenches, etc.
- low dispersivity potential

Sites without these features may have well interval distances that are greater. See also Section C.6 on the number of wells.

Reconnaissance tools and screening techniques such as surface geophysical techniques and soil gas studies can help to locate plumes before wells are drilled and thus help to determine optimal well locations. Methods for selecting sample locations range from random yet logical picks to probability sampling (such as a grid pattern). Random sampling is very inefficient. When selecting many monitoring points in an area where little is known, such monitoring points should be placed in a grid or herringbone pattern.

5. Well Depths, Screen Lengths, and Open Intervals

The first zone of saturation is typically an unconfined or water-table aquifer, which is recharged from direct infiltration of precipitation. Impacts to the aquifer under unconfined conditions are more easily evaluated than under confined or semi-confined conditions. The shallowest aquifer should be the target zone for chemicals and substances that are less dense than water.

Sites with confined aquifers that have the potential to be impacted will need to be evaluated in combination with the unconfined aquifer. Such a situation would require more detailed vertical and discrete zone monitoring.

Once the subsurface geometry of the monitoring target zone is determined, decisions can be made with respect to the depth and screen lengths of individual wells that will be used. Groundwater monitoring networks should monitor the entire saturated thickness of the target zone, or a very large percentage of it. If large vertical intervals of the target zone are unmonitored, chances are dramatically increased that groundwater contamination may go undetected or be underestimated if detected.

Choosing the length of the open interval in a monitoring well is in many respects a balancing act. Shorter open intervals or screen lengths provide better accuracy in determining hydraulic head at a specific point in the flow system. If a sufficient number of shorter well screens or open intervals are stacked or clustered vertically so that the entire saturated thickness of the target zone is adequately monitored, they will, when taken together, provide better resolution of the vertical distribution of any contamination that may be detected. In addition, the possibility of cross-contamination is minimized. Disadvantages of shorter intervals include reduced water volume from each well and the increased cost of installing, sampling, analyzing, and interpreting the data from the more numerous sampling points, which can be considerable.

Some disadvantages also are likely for longer screen lengths or open intervals. Resolution of hydraulic head distribution in the aquifer decreases, contamination entering the well at a specific point may be diluted by other less contaminated water, and there is less certainty regarding where water is entering the well.

It would be preferable from a strictly technical point of view to monitor the entire saturated thickness of any target zone with a number of individual, shorter-screened wells drilled to different depths that, together, monitor the entire target zone. However, the remediator/hydrogeologist designing the project must decide if the increased cost over single, longer-screened wells is justified for background and compliance monitoring. The goal is to establish screens and open intervals that will detect any contamination emanating from any portion of the site as quickly as possible. A Pennsylvania-licensed professional geologist should make all decisions related to the construction of monitoring wells at Act 2 sites.

Care should be taken when monitoring target zones in bedrock formations. In this case, by geologic necessity, the portion of the target zone which is monitored will be determined by the location and number of water-producing fractures that are intercepted by the well. Care must be taken not to drill wells too deeply below the target zone in search of a water-producing fracture.

Where multiple aquifers exist, such as an unconsolidated aquifer overlying a bedrock aquifer, or where two permeable aquifers are separated by a confining layer, the target zones within each aquifer should be monitored separately.

The specific gravity of a contaminant and whether it will most likely be introduced to the environment as a free phase or in a dissolved phase also will influence how a well is constructed. In conducting monitoring for an LNAPL or a petroleum-based dissolved contaminant, such as gasoline, wells should be constructed with screens, or open intervals, that intercept the water table surface at all times of the year during periods of both high and low water table elevations. LNAPL can then accumulate into a distinct layer and flow into the monitoring well. For materials that exhibit specific gravities greater than water (such as many chlorinated solvents), it is desirable, though not always possible, to locate subsurface boundaries on which such contaminants might accumulate if released to the environment in a free phase.

6. Number of Wells

The number of wells needed depends on site-specific factors. In general, the spacing of background or upgradient wells should be adequate to account for any spatial variability in the groundwater quality. Downgradient wells should be positioned to adequately monitor the activity and any other variability of the groundwater quality. Compliance wells should be considered downgradient wells and positioned as close to the downgradient boundary of the site. The estimate of the separation distance will depend on the extent and type of activity, the geology, and the potential contaminants (see also Section C.4 on the Areal Placement of Wells).

7. Well Yield

Monitoring wells should produce yields that are representative of the formation in which they are drilled. Wells located in anomalously low-yielding zones are undesirable for several reasons. First, flow lines tend to flow around low-permeability areas rather than through them. In effect, this results in potential contaminants bypassing low-permeability areas, consequently not being detected in representative concentrations. In addition, by the time a potential contaminant shows up in a very low-yielding well that is unrepresentative of the formation, other potential contamination may have traveled extensively downgradient beyond the monitoring well. Therefore, in settings where well yields are variable, the best monitoring wells will be those that are open to the highest permeability flow lines that are potentially more likely to be contaminated by the site.

The best information regarding representative yield for the target zones selected for any site should come from the wells and borings used in the investigation to characterize the groundwater flow system for the site. Borehole geophysics can be a valuable tool for determining the location of higher-yielding zones and the presence of contaminants. For more detailed descriptions of borehole geophysical techniques and devices, see EPA (1993) Chapter 3 - Geophysical Logging of Boreholes, and Nielsen (1991). Additional regional hydrogeologic information may be obtained from:

- The Pennsylvania Bureau of Topographic and Geologic Survey (BTGS)
- The United States Geological Survey (USGS)

Water Resource Reports have been published by the USGS and BTGS for select counties and areas in Pennsylvania. Many of these reports are available electronically on their respective websites.

In Pennsylvania, there are three general hydrogeologic settings that merit special discussion from a well-yield perspective.

a) Fractured Rock

In aquifers composed of fractured bedrock, groundwater flow is generally restricted primarily to the fractures. If a well fails to intersect any fractures or a very few small fractures in this setting, the well will not detect potential contamination, or it will be inefficient in detecting potential contamination. For this reason, wells that fail to intersect fractures in the target zone that are representative of the formation should be approved with caution, and wells that are essentially dry are not acceptable. Such wells should be relocated nearby and another attempt made to obtain a better yield when it is determined that it is likely that more representative yields can be obtained. Likewise, wells drilled below the proper target zone, strictly to increase yield, are not reliable for site characterization purposes.

b) Heterogeneous Unconsolidated Formations

Low permeability, clay-rich formations with interbedded or lenticular, higher permeability sand or gravel units can present a significant challenge to designers and installers of monitoring wells. Wells need to be located so that they are open to any high permeability zones within the target zone that are hydraulically connected to the site being monitored. These wells will produce a higher yield than wells drilled exclusively into the clay-rich portions of the site.

c) Areas of Uniformly Low Yield

Certain geologic formations and hydrogeologic settings are characterized by exhibiting naturally low yield over a wide area. Other geologic formations may exhibit low yield locally in certain settings such as ridge tops, steeply dipping strata, or slopes. In these settings, a permanent or seasonal perched water table or shallow flow system may develop on the relatively impermeable bedrock that may or may not be hydraulically connected to the bedrock system. Depending on the permeability of the soils and unconsolidated material overlying the solid, less permeable bedrock, the shallow groundwater flow can express itself as a rather rapid “subsurface storm flow” or a more sluggish, longer-lasting condition in poorly drained soils.

It is important to be sure that the shallow systems are part of the target zone of the site being monitored. In these cases, the shallow system may constitute the most sensitive target zone for monitoring a facility. While wells drilled into the bedrock system may be needed to monitor for vertical flow of contaminants, the importance of sampling monitoring wells or springs in the shallow intermittent flow system should not be underestimated, although the usual periodic monitoring schedules may not always be necessary in these settings. If the systems are intermittent, one must be aware of when they are active (e.g. in Spring or after significant or extended precipitation events) and be prepared to monitor the systems at that time. Monitoring can be conducted in wells, springs that are properly developed, or in some cases, by sampling man-made underdrain systems that are constructed to collect the shallow flow system in some cases.

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D. Groundwater Sampling Techniques

1. Importance of Sampling Technique

Proper sampling procedures which result in a representative measure of groundwater quality are critical to any monitoring program. The accuracy of the sample analysis in the laboratory is dependent upon the sampling methodology in the field. A laboratory cannot generate reliable data if the sample was collected improperly. Therefore, taking precautions and selecting the correct sampling methods are imperative to produce accurate and representative analyses.

Some of the reasons groundwater samples may not be representative of aquifer conditions include the following:

- The sample was taken from stagnant water in the well. Water standing in a well and exposed to the atmosphere may undergo a gas exchange (oxygen and carbon dioxide), allowing chemical reactions to occur. Biological organisms capable of driving reactions might also be introduced. Obviously, such altered waters will no longer be representative of the water within the aquifer and therefore should be purged prior to sample collection.

- The sample was not collected at the appropriate time. The sample should be collected as soon as possible after purging is completed. This reduces the possibility of chemical reactions occurring because of gas exchange and temperature variations. In addition, if the well is pumped too long, the sample may be comprised of water far from the well site and not be representative of groundwater chemistry for the site being monitored.

- The sample contained suspended or settleable solids. Groundwater is generally free of suspended solids because of the natural filtering action and slow velocity of most aquifers. However, even properly constructed monitoring wells will often fail to produce samples that are free of sediment or settleable solids (turbidity). When samples containing suspended solids are analyzed for metals, this sediment is digested (dissolved) in the laboratory prior to performing the analysis. Consequently, any of the metals present in the sediment (primarily iron, manganese, and aluminum) will be included in the results of the analysis of the water that includes these metals. The analysis of the water samples containing sediment will result in certain analytes, such as these metals, being reported at higher levels than the actual levels in groundwater.

In addition to common metals, other metals such as lead, chromium, arsenic, and cadmium, which occur naturally in trace amounts may also show up in the analysis. Additionally, the sediment content of the monitoring wells will often vary across a site, so that samples collected from the same well at different times can vary in sediment content. This problem can make analysis of monitoring well data for metals where samples have not been filtered to remove turbidity an almost futile exercise.

- Release of carbon dioxide during pumping increased the pH, allowing many metallic ions to come out of solution (i.e. iron, manganese, magnesium, cadmium, arsenic, selenium, and boron). Pumping can also cause volatilization of VOCs. This emphasizes the importance of conducting field measurements such as pH, specific conductance, temperature, etc., within the well before the sample is brought to the surface.

- Chemical changes occurred from oxidation of the sample during sampling. Dissolved oxygen is usually very limited within aquifers. Bringing the sample to the surface allows oxygen to dissolve within the water sample. Oxidation also can occur in the pump, or it can be caused by water cascading into a well installed in “tight” formations. Depending on the chemical makeup of the sample, the addition of dissolved oxygen may allow chemical reactions to occur. Some of the changes that can be expected include oxidation of: 1) organics, 2) sulfide to sulfate, 3) ferrous iron and precipitation of ferric hydroxide, 4) ammonium ion to nitrate, and 5) manganese and precipitation of manganese dioxide or similar hydrous oxide. In cases where oxidation would be expected to impact chemical quality, precautions should be employed to reduce oxidation potential (e.g. minimize agitation during purging and sample collection, minimize the length of time the sample is exposed to air, fill the sample container completely to the top, and promptly chill the sample).

- The sample was not preserved correctly. Increases in temperature will allow certain chemical reactions to occur. Certain metals, especially iron, may coat the inside of the sample container. If the sample is not properly preserved for shipment to the laboratory, the sample arriving at the lab may be quite different chemically from the sample which was collected in the field.

- The sample was contaminated by residues in sampling equipment. Residues may cling to the sampling equipment if it is not properly cleaned or decontaminated. Those residues may become mobile in successive samples, yielding unreliable results. This becomes critical when the analytes being sampled are in the parts per billion or parts per trillion range. As a result, all sample pumps, tubing, and other associated materials should be properly decontaminated prior to sampling at each monitoring well location.

- The sample was contaminated by the mishandling of bottleware. Care should be taken to avoid contamination by mishandling bottleware, whether in the field or during transport. All sample bottleware and coolers should be stored and transported in clean environments to avoid potential contamination. In addition, care should be taken when storing and transporting bottleware that already contains a preservative. For example, the preservative may leak from a sample bottle or be altered by extreme heat or cold.

- The sample was contaminated by residuals on the hands of the sampler. To avoid contamination that may result from bare skin, protective sampling gloves should be worn during sample collection. New gloves should be worn for each well location.

DEP recommends utilizing a consistent sampling methodology throughout the monitoring program.

2. Sample Collection Devices

The most common devices available for the collection of water from monitoring wells include bailers, suction-lift pumps, air-lift samplers, bladder pumps, submersible centrifugal pumps, and passive samplers. Each has its advantages and disadvantages, as shown in Table A-1, and should be considered before selecting the sample collection device.

3. Sample Collection Procedures

The following are general procedures that should serve as a framework for sampling groundwater. These procedures should be modified as necessary for each situation encountered in the field and to conform to monitoring objectives. In addition, appropriate health and safety measures should always be taken before, during, and after sampling.

a) Protective Clothing

Protective clothing should be worn as dictated by the nature of the contaminants. Different types of protective clothing are appropriate for different contaminants. Protective sampling gloves should always be worn during sample collection to ensure a representative sample and to protect the sampler.

b) Water Levels

Every effort should be made to determine and record the static water level of the well prior to purging. Static water levels should be recorded in each well prior to any well purging when part or all of a groundwater monitoring network is sampled in one event. Water level measurements should also be measured and recorded during well purging to document associated drawdown.

c) Field Measurements

In most cases, field measurements should be taken before and during the sampling to gauge the purging of the well and to measure any changes between the time the sample is collected compared to when it is analyzed in the laboratory. Measurements in the field also provide a record of actual, onsite conditions that may be useful for data analysis. The following measurements and observations are often determined in the field:

- pH
- Eh
- water level (static and purged)
- temperature

- specific conductance
- dissolved oxygen
- acidity/turbidity
- climatic conditions

The specific techniques for obtaining each of these measurements depend upon the instruments used. The operator should carefully read and follow the manufacturer's instructions, including those for equipment maintenance and calibration. A record of the calibration and maintenance checks should be kept. Field measurements should always be made with properly calibrated instrumentation.

d) Purging

The purpose of purging a well prior to sampling is to remove stagnant water from the well bore and assure that the sample is representative of the groundwater in the geologic formation. Stagnant water in the well bore results from the water's contact with the casing and atmosphere between sampling events. What might seem to be a relatively simple and straightforward procedure, purging technique has been the subject of considerable scientific investigation and discussion.

There are two basic approaches to purging a well. The first is to use dedicated equipment in which the water is pumped from a fixed position in the well. This technique eliminates the possibility of cross-contamination, but tends to purge only the well section, or screen section opposite of the purge pump. (This is especially a concern when purge rates are much lower than the yield of the water-bearing zone supplying water to the purge pump.)

The second basic approach is to use a transportable pump and purge from the water surface, or preferably by gradually lowering the pump in the well as stagnant water is evacuated. This technique is considered as being more reliable in terms of evacuating the entire well bore. However, the disadvantage is that the equipment must be decontaminated between wells, which in turn increases the potential for cross-contamination.

It is important to recognize the impact of equipment location in relation to the well and other sampling equipment. Often purging and sampling equipment require the use of generators to power pumps and other equipment. The engines of vehicles and generators produce exhausts which contain VOCs as well as various metals and particulates. If engines or generators need to be operating while sampling, they should be located upwind from the well and sampling equipment since water contacting these exhausts has been shown to contaminate samples with various compounds.

Table A-1: Advantages and Disadvantages of Different Sampling Devices

	ADVANTAGES	DISADVANTAGES
Bailer	Portable Simple to use No need for an electrical source	Difficult to ascertain where within the water column the sample is collected Allows for oxidation of the sample Disturbance of the water column by the sampler Impractical for removing large volumes of water
Suction-lift Pump	Allows sample to contact only Teflon (less decontamination) Very portable Simple to use for shallow applications Flow rates easily controllable	Limited to shallow groundwater conditions (approximately 30 feet) Causes sample mixing, oxidation, and allows for degassing Not ideal for collection of gas-sensitive parameters
Air-lift Sampler	Suited for small diameter wells	Causes extreme agitation Significant redox, pH, and specie transformations Plastic tubing source of potential contamination
Bladder Pump	Provide a reliable means for highly representative sample Mixing and degassing minimized Portable Noted by EPA as an excellent sampling device for inorganic and organic constituents	Somewhat more complex than other samplers Turbid water may damage the inner bladder Water with high suspended solids may damage check valves

	ADVANTAGES	DISADVANTAGES
Submersible Centrifugal Pump	Higher extraction rates	Considerable agitation and turbulent flow Potential to introduce trace metals from the pump materials
Passive Samplers	Low cost Easily deployed Minimal purging and water disposal Able to monitor a variety of analytes	Some devices are incompatible with certain analytes. May have sample volume limitations. Results may differ from conventional methods.

An excellent summary of purging methods and techniques is given by Herzog et al. (in Nielsen, 1991). The following discussion is based in part on that summary. Four techniques for determining the volume of water to be purged from a well are discussed. These techniques include criteria based on:

- Numbers of well bore volumes
- Stabilization of indicator parameters
- Hydraulic and chemical parameters
- Special problems with low-yielding wells

By far, the most common choices have been to base the purging volume on either a certain number of well volumes, or stabilization of chemical and physical parameters, or some combination of these two.

An alternative approach, also described below, eliminates purging the well altogether by using passive sampling devices.

i) Criteria Based on the Number of Bore Volumes

The purging of three well volumes was universally accepted at one time and ingrained in monitoring practice. However, Herzog et al., provides references from numerous studies which conclude that anywhere from less than one to more than 20 bore volumes might variously be purged from wells prior to being acceptable for sampling. Herzog, et al. conclude:

"It is obvious that it is not possible to recommend that a specific number of bore volumes be removed from monitoring wells during purging. The range of suggested volumes is too large and the cost of improper purging is too great to permit such a recommendation."

DEP recommends that if the borehole volume technique is going to be used, the number of borehole volumes required for each well should have a technical or scientific basis, such as stabilization of indicator parameters (see following section) conducted at least once for each well during initial sampling events, rather than being based on some arbitrary criterion such as "three well volumes."

When purging is based on some set number of borehole volumes, the borehole volume calculation should take into account the entire original borehole diameter, corrected for the porosity of any sand or filter pack, and not be based just on the innermost casing diameter.

ii) Criteria Based on Stabilization of Indicator Parameters

Stagnant water in a well bore differs from formation water with respect to many parameters. Field measurement of indicator parameters such as temperature, pH, specific conductance, dissolved oxygen, and Eh has been used as the criteria for determining the amount of water to purge and when to sample a well. These parameters are measured in the purge water during purging until they reasonably stabilize. DEP encourages the use of this method.

DEP recommends that all of the above indicators be measured during the initial and first few sampling events for the monitoring well. The data should then be reviewed to determine which indicator parameters are the most sensitive indicator that stagnant water has been evacuated from the well. The most sensitive parameters will be those showing the greatest changes and longest times to achieve stabilization. During the initial sampling, the purging time should be extended beyond what initially appears to be stabilization as a check to ensure that the parameter stability is maintained.

iii) Low Flow Purging

Another purge method using the stabilization of indicator parameters is low-flow (minimal drawdown) well purging. This technique is based upon placing the pump intake at the screened interval, or in the case of fractured rock, the water-bearing zone of interest. The well is pumped at a very low rate, commonly less than 0.5 liters per minute, while producing less than 0.1 meters of drawdown. Pumping continues until various indicator parameters stabilize. The objective is to produce minimal drawdown and less stress upon the aquifer while obtaining a sample from the aquifer interval of interest. Lack of definitive well construction or water-producing interval information negates the use of this purge method.

Low-flow purging often creates much less purge water. Some purge water contains various substances which cannot be disposed of on the ground necessitating disposal. In these cases, low-flow purging can greatly reduce the costs of disposal. In addition, purge time is often substantially less. Set-up is usually more complex, and costs may therefore be higher than when using other purge methods.

Indicator parameters typically include temperature, pH, redox potential, conductivity, dissolved oxygen (DO), and turbidity. These common stabilization parameters are often used to indicate that the water coming from the pumped interval is aquifer water. Although often not very sensitive to changes between borehole and aquifer water, temperature and pH are usually included because they are easy to measure, and the data is commonly used for other field analysis reasons. The minimum number of parameters to measure should include pH, conductivity, and dissolved oxygen. Stabilization is indicated after three successive readings taken at 3- to 5-minute intervals. Indicator parameters should show a change of less than ± 0.1 for pH, ± 3% for conductivity, ± 10% mv for redox potential, and ± 10% for turbidity and dissolved oxygen. The stabilization rates put forth are a guideline. Experience may dictate the need for more or less tolerance in particular wells or situations.

If a well has a history of water quality data produced using a different well purging method, the result should be compared with the new low-flow purge results. Significant variation in data will require justification of continued use of the low-flow purge method. Depending upon the situation, purge methods may need to return to the original method.

iv) Special Problems of Low-Yielding Wells

Low-yield wells present a special problem for the sampler in that they may take hours, or even days, to recover after purging so that there is enough water to sample. This waiting period not only increases the cost of sampling, but also allows changes in water quality to occur between the time the sample water enters the casing and the time it is collected. This is especially problematic when sampling volatile constituents.

In practice, very low-yield wells are commonly pumped dry and sampled the following day if necessary. This practice is believed to result in water being sampled that is not representative of the aquifer being sampled from the well due to the loss of volatiles and oxygenation of the water during the waiting period. This results from pumping the well dry and exposing the formation to the atmosphere. While there does not appear to be any method uniformly agreed upon to eliminate these concerns, the following considerations are suggested:

- Purge in such a way that the water level does not fall below the well screen.

- Evaluate the use of larger diameter wells that may deliver the required amount of sample water more quickly than small diameter wells.

- If full recovery cannot be achieved within two hours, collect the required amount of water as it becomes available, collecting samples for parameters in order of decreasing volatility.

v) No-Purge Methods

Passive samplers offer an alternative to traditional purge methods. Commonly used technologies include polyethylene (or passive) diffusion bags (PDBs) and HydraSleeves^{TM}. Some sampler types operate through diffusion of contaminants into the device; others collect a discrete grab sample. A key advantage of passive samplers is that no purge water is generated that requires treatment or disposal. Other advantages include reduction of field sampling time and potentially less variability in sample results. It should be noted that passive sampling methods that detect only the presence or absence of contaminants may be utilized for characterization, but are not recommended for attainment sampling. Additionally, if the screening investigation indicates that regulated substances are present, and if the aquifer recharge rate is reasonable, conventional grab sampling should be performed to obtain quantitative data on contaminant concentrations as part of a complete characterization effort.

Some important limitations should be evaluated when considering the use of passive samplers. The well construction, hydraulic properties of the aquifer, and contaminant type and distribution should be known and discussed with DEP prior to engaging in a full-scale sampling program (see the references for further information).

- No-purge sampling methods rely on adequate groundwater flow through the well screen. If the seepage velocity is low or the screen is fouled, then the exchange rate of water in the well could be slow, the water may be stagnant, and the sample may not be representative of groundwater in the formation.

- Some devices are incompatible with certain analytes. For example, most VOCs readily diffuse through polyethylene, but some (such as MTBE) do not. Polyethylene diffusion bags cannot be used to sample semi-volatile organic compounds (SVOCs) or inorganics.

- Because passive samplers collect from a discrete interval, results may be sensitive to the depth at which the device is placed. If flow is stratified in the formation or localized at bedrock fractures, or if the contaminant is density-stratified in the water column, then deployment depth is important. Some sampler types allow multiple devices to be arrayed vertically on a tether, allowing the remediator to better determine an optimal depth.

Passive samplers will not necessarily produce results equivalent to purge methods. Ideally, a consistent purge and sampling methodology will be used for all wells in the site network from the beginning of characterization until the end of attainment. If a change in the sampling method is being proposed midway through a monitoring program, then sufficient side-by-side testing with the current approach should be performed and discussed with DEP to determine if the change in method is appropriate.

vi) Summary on Purging

The following general statements can be made with respect to purging:

- Every groundwater monitoring plan should contain a section discussing how wells will be purged.
- It is often desirable to use the same device for sampling that was used for purging. In this case the purge pump can be set within the screened section of the well or across from the yielding zone being monitored.
- If different devices are used for purging and sampling, purging should begin at the static water surface and the device should be lowered down the well at a rate proportional to water stored in the well bore. Because of the better mixing of water in wells with multiple yielding zones, this technique is considered preferable for sampling wells with multiple yielding zones where a composite sample of water in the yielding zones is desired (see Section C.5 on Well Depths, Screen Lengths, and Open Intervals).
- Where the same device is used to sample and purge a well, it should be established that the sampling device will not change the quality of the groundwater it contacts.
- In sampling for some analytes, such as volatile organics, it is critical that the discharge be reduced to approximately 100 ml/minute to minimize degassing and aeration (Barcelona et al., 1984). Flow control should be achieved by means of an electric current using a rheostat rather than by valving or other flow restrictors.
- Purging should be completed without lowering the water level in the well below the well screen or water-bearing zone being sampled.

Never purge a well at a rate or in a way that causes water to cascade into the well bore, resulting in increased degassing and volatilization.

e) Management of Purge Water

The first step in the management of monitoring well purge water is to minimize its generation. Consideration should be given to techniques that minimize the amount of purge water produced, such as low-flow or low-volume purging, or a no-purge method. Purge water should be handled in a way that is environmentally compatible with the volume generated, the type and concentration of confirmed or suspected contaminants, and the specific site conditions. A procedure that can be used is outlined in Table A-2. The procedure is designed to ensure that potentially contaminated purge water is disposed properly without contaminating other environmental media.

The following items should be considered when handling purge water:

- Purge water should be containerized until it is characterized by laboratory analysis. Containers with purge water comingled from multiple wells should use the highest concentration seen in any one of the wells from which the comingled purge water was produced, unless the comingled purge water is sampled.

- Purge water that has been characterized with no detections (i.e., with analytical results less than method detection limits (MDLs)) may be handled as uncontaminated groundwater under Table A-2.

- Purge water that has been characterized with detections of constituents that do not exceed the Act 2 Residential, Used Aquifer Groundwater MSCs may utilize any of the actions described in the contaminated groundwater section of Table A-2. Discharging to the ground surface to return water to the impacted groundwater plume (re-infiltration) under action (d) is an option if it does not create runoff. Discharge to a surface water, wetland, storm drain or paved surface that drains to a channel or stormwater conveyance requires a permit or other appropriate regulatory authorization.

- Purge water that has been characterized with detections of constituents that exceed the residential used aquifer MSCs should be managed as contaminated groundwater utilizing one of the actions described in (a), (b), (d), or (e) of Table A-2. If action (e) is utilized, one of the approved methods is as follows (for organic constituents only):

    - Place up to 20 gallons/well of contaminated purge water onto the ground surface of the site in a controlled manner for re-infiltration after treatment with portable engineered carbon adsorption units designed and operated to remove the organic contaminants to levels below residential used aquifer MSCs according to the following:

- Re-infiltration may only occur within the area of groundwater contamination exceeding Act 2 residential, used aquifer MSCs;

- Placement on site should not create runoff that will enter surface water, wetlands, storm drains or other water conveyances to surface water;

- All contaminants should be capable of being treated by carbon adsorption;

- Carbon adsorption units should be designed to provide contact time for the amount of carbon at the expected levels of raw water contamination to reach residential used aquifer MSCs;

- A sample should be collected to demonstrate the unit has functioned as intended. Samples should be collected at the beginning and end of the filtration cycle; and

- Purge water should contain no free product.

f) Private Wells

If a well is a private water supply, sample as close to the well as physically practical and prior to any treatment or filtering devices if possible and practical. If sample collection must be from a holding tank, allow water to flow long enough to flush the tank and the lines; when the pump in the well is triggered and turned on, verification of tank flushing is provided. If a sample that passes through a treatment tank must be taken, the type, size, and purpose of the unit should be noted on the sample data sheet and in the field log book.

g) Filtering

When possible, avoid collecting samples which are turbid, colored, cloudy or contain significant suspended matter. Exceptions to this include when the sample site has been pumped and flushed or has been naturally flowing for a sufficient time to confirm that these conditions are representative of the aquifer conditions.

Unless analysis of unfiltered samples for “total metals” is specifically required by program regulation or guidance, all samples for metals analysis should be field-filtered through a 0.45-micron filter prior to analysis. Filtering samples for SVOC analysis is not appropriate to be conducted in the field as SVOCs have been known to adhere to certain materials used during the filtration process.

Table A-2: Procedure for the Management of Well Purge Water from Groundwater Sampling

TYPE OF GROUNDWATER	ACTION
Purge Water – Shown to not exceed the Act 2 residential, used aquifer groundwater standards contained in Tables A-1 and A-2 of 25 Pa. Code Chapter 250.	Purge water may be placed on the ground surface (onsite) provided precautions are in place to avoid erosion or runoff. Discharge to a surface water, wetland, storm drain or paved surface is prohibited without a permit or other appropriate regulatory authorization.
Purge Water – Shown to exceed the Act 2 residential, used aquifer groundwater standards contained in Tables A-1 and A-2 of 25 Pa. Code Chapter 250.	Management of purge water may proceed with one of the following options: a) Convey directly into an on-site treatment plant or leachate collection system for final treatment. b) Transport to off-site treatment facility. c) Place in a temporary storage unit onsite for analysis to determine the final disposition. d) De minimis quantities may be treated and placed on the ground surface onsite provided the type and concentration of contamination(s) will not adversely impact surface water or wetlands, or further contaminate soil or groundwater. The treatment unit must be rated to remove the identified contaminants and must be operated and maintained to ensure contaminant removal to Act 2 residential used aquifer standards. e) Other methods approved by DEP (may require a permit for specific site conditions).
Purge Water where water quality is not determined	Purge water that is not characterized needs to be containerized until laboratory analysis is complete. Containers with purge water comingled from multiple wells should use the highest concentration seen in any one of the wells from which the comingled purge water was produced, unless the comingled purge water is sampled. Following analysis of purge water, it may be treated as one of the two categories above.

h) Sample Preservation

Perform sample preservation techniques onsite as soon as possible after the sample is collected. Complete preservation of samples is a practical impossibility. Regardless of the nature of the sample, complete stability for every constituent can never be achieved. For this reason, samples should be analyzed as soon as possible. However, chemical and biological changes occurring in the sample may be slowed significantly by proper preservation techniques.

Chemical changes generally happen because of a shift in the physical conditions of the sample. Under a fluctuation in reducing or oxidizing conditions, the valence number of the cations or anions may change; other analytes may volatilize or dissolve; metal cations may form complexes or precipitate as hydroxides, or they may adsorb onto surfaces.

Biological changes can also alter the valence of a constituent. Organic processes may bind soluble material into the cell structure, or cell material may be released into solution.

Methods of preservation are relatively limited and are generally intended to: 1) retard biological activity, 2) retard hydrolysis of chemical compounds and complexes, 3) reduce the volatility of constituents, and 4) reduce sorption effects. Preservation methods are generally limited to pH control, chemical addition, refrigeration, freezing, and selecting the type of material used to contain the sample.

The best overall preservation technique is refrigeration at, or about, 4°C. Refrigeration primarily helps to inhibit bacteria. However, this method is not always applicable to all types of samples.

Acids such as HNO_3 and H_2SO_4 can be used to prevent precipitation and inhibit the growth of bacteria. Preservation methods for any specific analysis should be discussed with the accredited laboratory that is analyzing the samples.

i) Decontamination of Sampling Devices

All non-disposable and non-dedicated equipment that is submerged in a monitoring well or contacts groundwater will need to be cleaned between sampling additional wells to prevent cross-contamination. Generally, the level of decontamination is dependent on the level and type of suspected or known contaminants. Extreme care should be taken to avoid any decontamination product from being introduced into a groundwater sample.

The decontamination area should be established upwind of sampling activities and implemented on a layer of polyethylene sheeting to prevent surface soils from contacting the equipment. The following steps summarize recommended decontamination procedures for an Act 2 site:

- Wash with non-phosphate detergent and potable water. Use bristle brush made from inert material to help remove visible soil;
- Rinse with potable water - pressure spray is recommended;
- If collecting samples for metals analysis, rinsing with 10% hydrochloric or nitric acid;

- Rinse liberally with deionized/distilled water –pressure spray is recommended;

- If collecting samples for organics analysis, rinsing with solvent-grade isopropanol, acetone, or methanol (should not be a solvent of potential interest to the investigation);

- Rinse liberally with deionized/distilled water – pressure spray is recommended;

- Air-dry;

- Wrap with inert material (such as aluminum foil) if equipment is not being used promptly.

j) Field Sampling Logbook

A field logbook or field sampling forms should be completed and maintained for all sampling events. The following list provides some examples of pertinent information that should be documented:

- date/time of sample collection for each well

- well identification

- well depth

- presence of immiscible layers and detection method (i.e., an interface probe)

- thickness of immiscible layers, if applicable

- estimated well yield (high, moderate, or low)

- purging device, purge volume, and pumping rate

- duration of well purging

- measured field parameters (see 4.3.3)

- sample appearance

- description on any abnormalities around the wellhead (standing/ponded water, evidence of vandalization, etc.)

- description of any wellhead materials that were or need to be replaced (sanitary well cap, well lid or well lid bolts, locking devices, etc.)

k) Chain-of-Custody

A chain-of-custody record provides a legal document that traces sample procession from time of collection to final laboratory analysis. The document should account for all samples collected that require laboratory analyses and provide the following information:

- sample identification number
- printed name and signature of sample collector(s)
- date/time of collection for each sample
- sample media type (i.e., groundwater)
- thickness of immiscible layers, if applicable
- well identification
- type and number of containers for each sample
- laboratory parameters requested for analyses
- type(s) of preservatives used
- carrier used, if applicable
- printed name and signature of person(s) involved in the chain of possession
- date/time samples were relinquished by the sampler and received by the laboratory
- presence/absence of ice in cooler or other sample holding device
- special handling instructions for the laboratory, if applicable

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E. Well Decommission Procedures

1. Introduction

Unsealed or improperly sealed wells may threaten public health and safety and the quality of the groundwater resources. Therefore, the proper abandonment (decommissioning) of a well is a critical final step in its service life.

Act 610, the Water Well Drillers License Act (32 P.S. § 645.1, et seq), includes a provision for abandonment of wells. This legislation makes it the responsibility of a well owner to properly seal an abandoned well in accordance with the rules and regulations of DCNR. In the absence of more stringent regulatory standards, the procedures outlined in this section represent minimum guidelines for proper decommissioning of wells and borings. These procedures may be applicable for, but not limited to, public and domestic water supply wells, monitoring wells, borings or drive points drilled to collect subsurface information, test borings for groundwater exploration, and dry wells (drains or borings to the subsurface).

Proper well decommissioning accomplishes the following: 1) eliminates the physical hazard of the well (the hole in the ground and the wellhead protruding above surface grade when applicable); 2) eliminates a pathway for the introduction and migration of contamination; and 3) prevents hydrologic changes in the aquifer system, such as the changes in hydraulic head and the mixing of water between aquifers. The proper decommissioning method will depend on both the reason for abandonment and the condition and construction details of the boring or well and the specific threat of existing and potential contamination sources near the well bore.

An unused and decommissioned well could be the conduit for spread of contamination. The lack of well decommissioning and a poorly sealed well could both result in the spread of contamination into previously uncontaminated areas for which the well owner or contractor may be responsible.

2. Well Characterization

Effective decommissioning depends on knowledge of the well construction, site geology, and hydrogeology. The importance of a full characterization increases as the complexity of the well construction, site geology, and the risk of aquifer contamination increases. Construction information for wells drilled since 1966 may be available from the DCNR BTGS PaGWIS database. Additional well construction data and information describing the hydrologic characteristics of geologic formations may be available from reports published by BTGS and the USGS. Site or program records also may exist. The well should be positively identified before initiating the decommissioning. Field information should be compared with any existing information.

Water levels and well depths can be measured with a well sounder, weighted tape measure, or downhole camera. In critical situations, well construction details and hydrogeology can be determined with borehole geophysics or a downhole camera. For example, a caliper log, which is used to determine the borehole diameter, can be very helpful in locating cavernous areas in open hole wells.

3. Well Preparation

If possible, the borehole should be cleared of obstructions prior to decommissioning. Obstructions such as pumps, pipes, wiring, and air lines must be pulled. Well preparation also may involve “fishing” obstacles out of the borehole. An attempt should be made to pull the casing when it will not jeopardize the integrity of the borehole. Before the casing is pulled, the well should be grouted to near the bottom of the casing. This will at least provide some seal if the well collapses after the casing is pulled.

The presence of nested or telescoped casing strings complicates well decommissioning. Inner strings should be removed when possible, but only when removal will not jeopardize the decommissioning of the well. If inner strings cannot be removed and sealing of the annular space is required, then the inner string should be vertically split (plastic-cased wells) or cut (metal-cased wells) at intervals necessary to ensure complete filling of the annular space.

Damaged, poorly constructed or dilapidated wells may need to be re-drilled prior to application of proper decommissioning techniques. Also, in situations where intermixing of aquifers is likely, the borehole may need to be re-drilled.

4. Materials and Methods

a) Aggregate

Materials that eliminate the physical hazard and open space of the borehole, but do not prevent the flow of water through the well bore, are categorized as aggregate. Aggregates consist of sand, crushed stone or similar material that is used to fill the well. Aggregates should be uncontaminated and of consistent size to minimize bridging during placement.

Aggregate is usually not placed in wells smaller than two inches in diameter. Nominal size of the aggregate should be no more than 1/4 of the minimum well diameter through which it must pass during placement. Because aggregate is usually poured from the top of the well, care should be taken to prevent bridging by slowly pouring the aggregate and monitoring the progress with frequent depth measurements. The volume of aggregate needed should be calculated prior to placement into the well.

Aggregates may be used in the following circumstances: 1) there is no need to penetrate or seal fractures, joints or other openings in the interval to be filled; 2) a watertight seal is not required in the interval to be filled; 3) the hole is caving; 4) the interval does not penetrate a perched or confined aquifer; and 5) the interval does not penetrate more than one aquifer. If aggregate is used, a casing seal should be installed (see Section E.5.a). The use of aggregate and a casing seal should be consistent with the future land use.

b) Sealants

Sealants are used in well decommissioning to provide a watertight barrier and prevent the migration of water in the well bore, in the annular spaces or in fractures and openings adjacent to the well bore. Sealants usually consist of Portland cement-based grouts, “bentonite” clay, or combinations of these substances. Additives are frequently used to enhance or delay specific properties such as viscosity, setting time, shrinkage, or strength.

Sealing mixtures should be formulated to minimize shrinkage and ensure compatibility with the chemistry of the groundwater in the well.

To avoid the bridging of sealants in the well, sealing should be performed under pressure from the bottom upward. A grout pump and tremie pipe are preferred for delivering grout to the bottom of the well. This method ensures the positive displacement of the water in the well and will minimize dilution or separation of the grout.

If aggregate is to be placed above sealant, sufficient curing time should be allotted before placing the aggregate above the seal. Curing time for grout using Type 1 cement is typically 24-48 hours, and 12 hours for Type III cement.

General types of sealants are defined as follows:

<u>Neat cement grout:</u> Neat cement grout is generally formulated using a ratio of one 94-pound bag of Portland cement to no more than 6 gallons of water. This grout is superior for sealing small openings, for penetrating any annular space outside of the casings, and for filling voids in the surrounding rocks. When applied under pressure, neat cement grout is strongly favored for sealing artesian wells or those penetrating more than one aquifer. Neat cement grout is generally preferred to concrete grout because it avoids the problem of separation of the aggregate and the cement. Neat cement grout can be susceptible to shrinkage, and the heat of hydration can possibly damage some plastic casing materials.

<u>Concrete grout:</u> Concrete grout consists of a ratio of not more than six gallons of water, one 94-pound bag of Portland cement, and an equal volume of sand. This grout is generally used for filling the upper part of the well above the water-bearing zone, for plugging short sections of casings, or for filling large-diameter wells.

Concrete grout, which makes a stronger seal than neat cement, may not significantly penetrate seams, crevices or interstices. Grout pumps can handle sand without being immediately damaged. Aggregate particles bigger than this may damage the pump. If not properly emplaced, the aggregate is apt to separate from the cement. Concrete grout should generally not be placed below the water level in a well, unless a tremie pipe and a grout pump are used.

<u>Grout additives:</u> Some bentonite (2 to 8 percent) can be added to neat cement or concrete grout to decrease the amount of shrinkage. Other additives can be used

to alter the curing time or the permeability of the grout. For example, calcium chloride can be used as a curing accelerator.

<u>High-solids sodium bentonite:</u> This type of grout is composed of 15-20 percent solids content by weight of sodium bentonite when mixed with water. To determine the percentage content, the weight of bentonite is divided by the weight of the water plus the weight of the bentonite. For example, if 75 pounds of powdered bentonite and 250 pounds of granular bentonite were mixed in 150 gallons of water (at 8.34 pounds per gallon), the percentage of high-solids bentonite is approximately 20 percent [325/(1251+325)]. High-solids bentonite must be pumped before its viscosity is lowered. Pumping pressures higher than those used for cement grouts are usually necessary. Hydration of the bentonite must be delayed until it has been placed down the well. This can be done by: 1) using additives with the dry bentonite or in the water; 2) mixing calcium bentonite (it expands less) with sodium bentonite; or 3) using granular bentonite, which has less surface area.

In addition, positive displacement pumps such as piston, gear, and moyno (progressive cavity) pumps should be used because pumps that shear the grout (such as centrifugal pumps) will accelerate congealing of the bentonite. A paddle mixer is typically used to mix the grout. A high-solids bentonite grout is not made from bentonite that is labeled as drilling fluid or gel.

c) Bridge Seals

A bridge seal can be used to isolate cavernous sections of a well, to isolate two producing zones in the well, or to provide the structural integrity necessary to support overlying materials, and thus protect underlying aggregate or sealants from excessive compressive force. Bridge seals are usually constructed by installing an expandable plug made of wood, neoprene, or a pneumatic or other mechanical packer. Additional aggregate can be placed above the bridge.

5. Recommendations

The complexity of the decommissioning procedure depends primarily on the site hydrogeology, geology, well construction, and the groundwater quality. Four principal complicating factors have been identified, which include: 1) artesian conditions, 2) multiple aquifers, 3) cavernous rocks, and 4) the threat or presence of contamination. The recommended procedures for abandoning wells will be more rigorous with the presence of one or more complicating factors. The procedures may vary from a simple casing seal above aggregate to entirely grouting a well using a tremie pipe after existing casing has been ripped or perforated. Figure A-8 summarizes the general approach to well decommissioning.

a) Casing Seal

The transition from well casing to open borehole is the most suspect zone for migration of water. To minimize the movement of water (contaminated or otherwise) from the overlying, less consolidated materials to the lower water-bearing units, this zone should be sealed. Generally, this can be accomplished by filling at least the upper 10 feet of open borehole and the lower five feet of casing with sealant. The length of open borehole sealed should be increased if extenuating circumstances exist. Such circumstances would include a history of bacterial contamination, saprolitic bedrock, or possibly deep fracture zones. Water-bearing zones reported in the upper 20 feet or so of open borehole are indications of fractures and warrant the use of additional sealant. Casing that is deteriorated should be sealed along its entire length. If the casing is to be pulled, the sealant used should remain fluid for an adequate time to permit removal of the casing.

If the casing is to remain, then whenever feasible, it should be cut off below land surface. After the casing seal discussed above achieves adequate strength, the open casing should, at a minimum, be filled with aggregate. It is strongly suggested that a sealant be used in the upper two to five feet of casing.

b) Wells in Unconfined or Semi-Confined Conditions

These are the most common well types in Pennsylvania. The geology may consist of either unconsolidated or consolidated materials. When applicable, unconfined wells in non-contaminated areas may be satisfactorily decommissioned using aggregate materials up to 10-15 feet below the ground surface. Monitoring wells located at sites with no known contamination might be decommissioned in this manner. The casing seal should be installed above the aggregate. A sealant may be used over the entire depth.

c) Wells at Contaminated Sites

A decommissioned, contaminated well often mixes contaminated groundwater with uncontaminated groundwater. Complete and uniform sealing of the well from the bottom to the surface is required. Therefore, proper well preparation (Section E.3) should be accomplished before the well is sealed with a proper sealant (Section E.4.b).

d) Flowing Wells

The sealing of artesian wells requires special attention. The flow of groundwater may be sufficient to make sealing by gravity placement of concrete, cement grout, neat cement, clay or sand impractical. In such wells, large stone aggregate (not more than 1/4 of the diameter of the hole), or well packers (pneumatic or other) will be needed to restrict the flow and thereby permit the gravity placement of sealing material above the zone where water is produced. If plugs are used, they should be several times longer than the diameter of the well to prevent tilting. Seals should be designed to withstand the maximum anticipated hydraulic head of the artesian aquifer.

Because it is very important in wells of this type to prevent circulation between water yielding zones, or loss of water to the surface or annular spacing outside of the casing, it is recommended to pressure grout the well with cement using the minimum volume of water during mixing that will permit handling.

For wells in which the hydrostatic head producing flow to the surface is low, the movement of water may be stopped by extending the well casing to an elevation above the artesian pressure surface.

e) Wells with Complicating Factors at Contaminated Sites

Wells with one or more of the above complicating factors that are to be decommissioned in areas with contaminated groundwater, or in areas where the groundwater is at a high risk for future contamination, require the most rigorous decommissioning procedures. In general, the entire length of these wells should be sealed.

When the threat of contamination has been established, the elimination of a potential flowpath is critical. For example, a contaminated well in a karst terrane must be carefully sealed to avoid exacerbating the situation. In general, the entire lengths of these wells should be sealed. In some situations, a bridge seal may need to be installed, and casing may have to be perforated. In each case, a prudent method should be selected which will eliminate all potential vertical flowpaths.

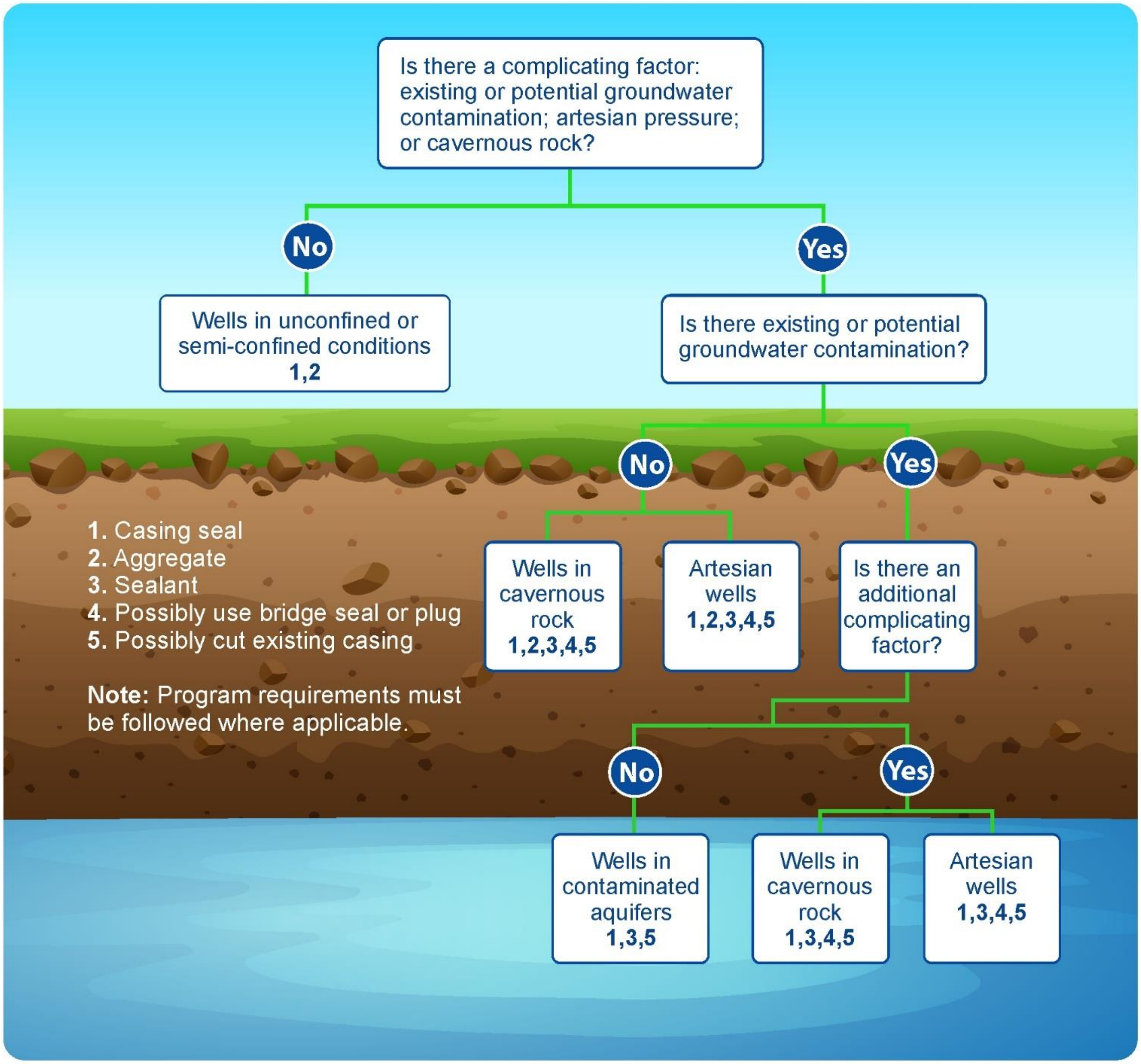
f) Monitoring Wells

Monitoring wells which are installed for an investigation, cleanup or other monitoring in a program that has no rules or regulations for decommissioning, such as the Act 2 program, should be decommissioned in accordance with the following guidelines.

Monitoring wells that were installed and continue to function as designed can usually be decommissioned in place after they are no longer needed. Exceptions would include wells whose design precludes complete and effective placement of sealant and wells in locations subject to future disturbance that could compromise the decommissioning. In such instances, all tubing, screens, casings, aggregate, backfilling, and sealant should be cleaned from the boring and the hole should be completely filled with an appropriate sealant.

Monitoring wells that are abandoned in place should be completely filled with sealant. Screened intervals can be backfilled with inert aggregate if sealant may alter the groundwater chemistry, thereby jeopardizing ongoing monitoring at the facility. Intervals between screens, and between the last screen and the surface, must be filled with sealant. Generally, sealant should be emplaced from the bottom of the interval being sealed to the top of that interval. Protective casings, riser pipes, tubing, and other appurtenances at the surface which could not be removed should be cut off below grade after the sealant has properly set. When decommissioning will be completed below the finished grade, the area of the boring should be covered with a layer of bentonite, grout, concrete, or other sealant before backfilling to grade.

Figure A-8: Summary of Procedures for Well Decommissioning



Note: Figure must be used in conjunction with the text. Reference Section A.E.

6. Existing Regulations and Standards

17 Pa. Code § 47.8 requires that the owner or consultant who is to abandon the well notify DCNR's BTGS of the intent to decommission a well at least 10 days before the well is sealed or filled.

7. Reporting

All decommissioned wells shall be reported to BTGS, along with any bureau that requires a report, on forms required by BTGS (and any other pertinent forms). If available, the original driller's log should be included, along with the details of the well decommissioning procedure. A photograph should be taken of the site, and a reference map should be made, showing the location of the decommissioned well. It also may be appropriate to survey the exact location of the well (if not already completed). Licensed drillers may use the online application WebDriller to complete the well decommissioning report.

8. References

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F. Quality Assurance/Quality Control Requirements

1. Purpose

A Quality Assurance/Quality Control Plan (QA/QC Plan) is a detailed account of methods and procedures used for data collection (i.e., monitoring) activities. This plan, when properly developed and implemented, ensures that adequate control and documentation procedures are utilized, from initiation to completion of the monitoring, so that the data generated is of the highest quality and can be used for the intended purpose with confidence. A QA/QC plan is also an effective tool in assessing and assuring the completeness and adequacy of the basic monitoring plan.

2. Design

A QA/QC plan should be designed to satisfy the objectives of the monitoring project. Although the elements of each QA/QC plan described below will be similar, the intended uses of the collected data will determine the requirements associated with the monitoring activity. In most cases, there will be sufficient differences within monitoring activities for each project to require a specific QA/QC plan.

The following paragraphs describe the basic elements of a QA/QC plan. In most cases, the proper development and adherence to this format will be sufficient to ensure that the data collection meets the objectives of a project. However, in some cases it may be necessary to include additional considerations that may be unique to a specific site and/or project.

3. Elements

- <u>Project Name or Title:</u> Provide the project identification and location.

- <u>Project Required by:</u> Provide the reason(s) or requirement(s) for the project.

- <u>Date of Requirement:</u> Provide date the project was required, either by legal or other order.

- <u>Date of Project Initiation:</u> Provide date that the project was implemented.

- <u>Project Officer(s):</u> Provide name(s) of individual(s) responsible for managing or overseeing the project.

- <u>Quality Assurance Officer(s):</u> Provide name(s) of individual(s) responsible for development of and adherence to the QA/QC plan.

- <u>Project Description:</u> Provide the following: 1) an objective and scope statement which comprehensively describes the specific objectives and goals of the project, such as determining treatment technology effectiveness, or remediation effectiveness for specific parameters; 2) a data usage statement that details how the monitoring data will be evaluated, including any statistical or other methods; 3) a description of the location of monitoring stations and reasons for the locations, including geologic, hydrogeologic or other considerations; and 4) a description of the monitoring analytes and frequency of sample collection, including the expected number of samples to be collected for each analyte, the sample matrix (i.e., water), the exact analytical method, reasons for selection of analytes, and sample preservation method(s) and holding time(s).

- Project Organization and Responsibility: Provide a list of key personnel and their corresponding responsibilities, including the position and/or individual in charge of the following functions: field sampling operations, field sampling QA/QC, laboratory analyses, laboratory analyses QA/QC, data processing activities, data processing QA/QC and overall project coordination.

- Project Fiscal Information: Provide an estimate in work days of the project time needed for data collection, laboratory support, data input, quality assurance and report preparation in work days.

- Schedule of Tasks and Products: Provide a projected schedule for completing the various tasks and developing the products associated with the project, such as sample collections (monthly, quarterly, etc.), data analysis/reports (quarterly, annual, biennial, etc.).

- Data Quality Requirements and Assessments: Provide a description of data accuracy and precision, data representativeness, data comparability, and data completeness.

- Sampling Procedures: Provide a description of the procedures and equipment/hardware used to collect samples from monitoring wells or other sites, including sampling containers and field preservation and transport procedures.

- Sampling Plan: A sampling plan should provide necessary guidance for the number and types of sampling QCs to be used. The following is a list of common sample QC types and the recommended minimum frequency if used. It is important to remember that all QC samples should be treated with the same dechlorination and/or preserving reagents as the associated field samples.

    - Trip Blanks - These are appropriate sample containers filled with laboratory-quality reagent water that are transported to and from the sampling site(s) and shipped with the samples to the laboratory for analysis. The intent of these samples is to determine whether cross contamination occurred during the shipping process. They are also used to validate that the sampling containers were clean. Each sampling event that uses this type of QC should have a minimum of one trip blank for each container type used.

    - Field Blanks - These are appropriate sample containers that are filled with laboratory-quality reagent water at the sampling site(s) and shipped with the samples to the laboratory for analysis. These samples are intended to determine if cross-contamination occurred during the sampling process due to ambient conditions. They are also used to validate that the sampling containers were clean. Each sampling event that uses this type of QC should have a minimum of one field blank for each sampling site and of each container type used. This type of sampling QC is most useful when sampling for VOC's.

- Rinsate Blanks - These are samples of laboratory-quality reagent water used to rinse the collection device, including filtration devices and filters, which contact the same surfaces as the sample. The QC samples(s) are then submitted with the field samples for analysis. This type of QC sample helps to determine if the sample collection device is contributing any detectable material to the sample. The minimum number of blanks needed, if this type of QC is utilized, is dependent upon operational considerations. A minimum of two rinsate blanks should be submitted (one before sampling and one after sampling) if multiple samples are being collected with the same decontaminated collection device. If you are using disposable sample collection devices or multiple pre-cleaned devices, then a single representative sample should suffice.

- Split/Duplicate Samples - This is a single, large sample that has been homogenized, split into two or more individual samples, with each sample submitted independently for analysis. This QC determines the amount of variance in the entire sampling/analysis process. This type of QC is not recommended for samples analyzed for analytes that would be adversely affected by the homogenization process (i.e. VOC's). The minimum number of this type of sampling QC, if utilized, is one per sampling event, with a rate of 5 percent to 10 percent commonly used.

- Replicate Samples - Comprised of two or more samples collected from the same source, in a very short time frame (i.e., minutes), with each sample submitted independently for analysis. This QC measure, like the split/duplicate sample, determines the amount of variance in the entire sampling/analysis process. The amount of variance determined by this type of QC may be larger than that of a split/duplicate sample. The use of this type of QC also presumes that the sample's materials are already homogenous. This type of QC is recommended for samples where analytes could be adversely affected by an external homogenization process (i.e. volatile organics). The minimum number of this type of sampling QC, if utilized, is one per sampling event, with a rate of 5 percent to 10 percent commonly used.

- Known Samples - These are reference materials that have been characterized as acceptable to the range of values for the analytes of concern. These materials are available from commercial sources. This type of QC helps determine if the analytical work is sufficiently accurate. It must be noted that improper handling or storage of this type of reference material can invalidate the materials characterization. The minimum number of this type of QC, if used, is one per subject.

  - Spiked Samples - These are split/duplicate or replicate samples that have been fortified with the analytes of concern. This QC is intended to determine if there have been changes in concentration due to factors associated with the sample or the shipping and analysis process. This type of QC is very difficult to use in a field environment and routinely is done as part of the analysis process. If this type of QC is necessary, the minimum required is one per project.

- Sample Custody Procedures: Provide information which describes accountability for sample chain-of-custody including sample collector identification, sample location identification, sample number, date and time of collection, parameters to be analyzed, preservatives and fixatives, identification of all couriers, identification of laboratory and receiver, time and date of receipt at laboratory, laboratory analyzer, and time and date of analysis.

- Calibration Procedures and Preventative Maintenance: Equipment maintenance and calibration should be performed in accordance with manufacturer's instructions. Calibration and maintenance sheets should be maintained on file for all equipment.

- Documentation, Data Reduction, and Reporting: Provide discussion on where field data are recorded, reviewed, and filed.

- Data Validation: Provide a discussion and reference to the protocols used for validation of chemical data and field instrumentation and calibration. Describe procedure for validating database fields (i.e., through error checking routines, automatic flagging of data outside of specified ranges, and manual review and spot checking of data printouts against laboratory analytical results).

- Performance and Systems Audits: Provide a description of how field staff performance is checked and how data files are verified for accuracy and completeness.

- Corrective Action: Provide a discussion on what corrections are made when errors are found and actions taken to prevent future recurrence of errors.

- Reports: Provide a list of the types and frequency of reports to be generated (i.e., performance and systems audits, compliance analyses, remediation effectiveness, etc.).

4. References

U.S. Environmental Protection Agency, May 1984, Guidance for Preparation of Combined Work/Quality Assurance Project Plans for Environmental Monitoring, (OWRS QA-1), US EPA Office of Water Regulations and Standards.

Mueller, D.K., Schertz, T.L., Martin, J.D., and Sandstrom, M.W., 2015, Design, analysis, and interpretation of field quality-control data for water-sampling projects: U.S. Geological Survey Techniques and Methods, book 4, chap. C4, 54 p.

U.S. Geological Survey, 2006, Collection of water samples (ver. 2.0): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A4, September 2006.

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SECTION IV: VAPOR INTRUSION

A. Introduction

Releases of volatile and some semi-volatile regulated substances to soil or groundwater can result in vapor-phase intrusion of these regulated substances into indoor air. The resulting impacts to indoor air may pose a threat to human health in inhabited buildings. For this exposure pathway to exist there must be a source of volatile substances in the unsaturated zone soil or groundwater at the water table, current or future inhabited buildings, and a transport pathway along which vapors may migrate from the source into the inhabited building(s). Inhabited buildings are buildings with enclosed air space that are used or planned to be used for human occupancy. In order to properly address this pathway, the remediator first develops a Conceptual Site Model (CSM) based on the site characterization to guide further assessment and, if necessary, mitigation or remediation.

This section provides guidance for addressing potential vapor intrusion (VI) of volatile organic compounds (VOCs) and certain semi-volatile organic compounds (SVOCs) from soil and/or groundwater sources, including those impacted by separate phase liquid (SPL), into inhabited buildings at sites using the Statewide health standard (SHS) and the site-specific standard (SSS). As such, this guidance establishes screening values and assessment options that can be used under the SHS to address VI for existing or potential future inhabited buildings. The potential VI impacts from volatile inorganic substances (e.g., mercury and cyanide) can only be addressed using the SSS or mitigation. **The VI screening value tables in this guidance are not meant to evaluate VI under the SSS except under certain circumstances.** Guidance on VI evaluations under the SSS, including the use of a human health inhalation risk assessment, is provided in Section IV.K.

25 Pa. Code § 250.312 requires an assessment of the VI exposure pathway in an SHS final report (FR). An exposure pathway assessment that includes VI is required by 25 Pa. Code § 250.404, and a risk assessment is required by 25 Pa. Code § 250.405 under the SSS. VI must be addressed for existing inhabited buildings and undeveloped areas of the property where inhabited buildings are planned to be constructed in the future. The VI pathway must be addressed for Special Industrial Area (SIA) sites and for storage tank corrective action sites because cleanups at these sites ultimately achieve either the SHS or the SSS. A VI evaluation is generally not required for the background standard.

It is important to note that mitigation measures may be used for existing inhabited buildings to eliminate unacceptable risks associated with VI under the SHS and SSS at any time in the evaluation process. Mitigation can be used in lieu of a complete evaluation of the VI pathway. When choosing preemptive mitigation, the remediator needs to implement postremediation care to ensure: (1) that potential risks associated with VI will be evaluated and addressed when an inhabited building is constructed in the future or (2) that appropriate mitigation measures will be taken in lieu of a complete evaluation in buildings that exist or are constructed on the property. Mitigation, even if preemptive, requires a cleanup plan or remedial action plan (RAP). It is also important to note that any unplanned change to a property’s use that results in a change in the VI exposure pathway will require additional VI evaluation to account for that change in exposure. In order to demonstrate attainment of an Act 2 standard for soil and/or groundwater, current or future planned inhabited buildings need to be evaluated for VI in the FR. If there are no

plans for future construction of inhabited buildings at the site, the remediator may choose, but is not required, to use an activity and use limitation (AUL) to address possible future VI issues.

If there is a petroleum release to surface or subsurface soil and a full site characterization has not been performed, a remediator may attain the SHS by following the requirements in 25 Pa. Code § 250.707(b)(1)(iii). Further VI analysis is not needed in these situations for soil if the following conditions are also satisfied: (1) all requirements of 25 Pa. Code § 250.707(b)(1)(iii) have been met; (2) at least one soil sample is collected on the sidewall nearest the inhabited building unless there are substantially higher field instrument readings elsewhere; and (3) contamination has not contacted or penetrated the building foundation based on observations of obvious contamination and the use of appropriate field screening instruments. Evaluation of groundwater for VI potential may still be necessary if groundwater contamination is identified as a potential VI concern.

The Department will not require remediators to amend or resubmit reports that have been approved under previous versions of this guidance.

This guidance provides multiple options for addressing VI including soil and groundwater screening values, alternative assessment options, mitigation with an environmental covenant, and remediation. The alternative assessment options consist of screening values for indoor air, sub-slab soil gas, and near-source soil gas in addition to VI modeling. Use of the screening values and other options as well as important terms is described below.

B. Definition and Use of Important Terms

Several of the terms used in this guidance may have multiple meanings within the context of the Land Recycling Program (LRP) or other DEP programs. Therefore, it is important that their intended use in this guidance be well-defined. The following definitions and uses are provided only for application under this VI guidance. They are presented in the order that allows the reader to make the best sense of each definition as opposed to alphabetical order.

- **Hydrogeologic Zones:**
  - ***Definition*** - When used in this guidance, the following hydrogeologic terms are related to one another as shown in Figure IV-1. In the *saturated zone*, all interconnected voids are filled with water. In practice, the top of the saturated zone is identified as the *water table*, which is the water surface at atmospheric pressure in appropriately constructed monitoring wells. *Groundwater* refers to water in the saturated zone, below the water table. The *capillary fringe* is the zone of tension saturation directly above the water table and its thickness is dependent on the soil type in which it occurs. The base of the capillary fringe is saturated, and soil pore space becomes progressively less filled with water upward from the water table. In the *vadose zone* above the capillary fringe the pores are not filled with water. The capillary fringe and the vadose zone are not readily distinguished in the field. The *unsaturated zone* is defined here as the zone above the water table, including both the capillary fringe and the vadose zone.
  - ***Use*** - These terms are used to define points of application for various screening values as shown in Figure IV-1 and applicable sampling intervals for soil, groundwater and near-source soil gas. They also pertain to the sources, fate, and transport of vapors in the subsurface.
- **Point of Application (POA):**
  - ***Definition*** - The locations in an inhabited building, the unsaturated zone, and the saturated zone where screening values are applied to evaluate VI.
  - ***Use*** - POAs guide the selection of indoor air, sub-slab soil gas, near-source soil gas, soil, and groundwater sampling locations. See Section IV.C.2. The relationship of the POAs to the building, the hydrogeologic zones, and the contamination are displayed in Figure IV-1. Sampling guidance for each POA is provided in Table IV-6 and Appendix IV-C.
- **Acceptable Soil or Soil-like Material:**
  - ***Definition*** - Any unconsolidated material containing some amount of organic material that occurs in the vadose zone above a potential VI source (soil and/or groundwater) that does not exceed the saturated hydraulic conductivity of sand or the net air-filled porosity of silt at residual water content, both as derived from Table 13 in U.S. EPA (2017). Natural soils and fill (including gravel) coarser than sand or with air-filled porosity greater than silt may not constitute acceptable soil. Conversely, fill material that is otherwise soil-like and does not exceed the

characteristics described above may constitute acceptable soil-like material (e.g., mixtures of granular material comprised predominantly of sand, silt and clay with brick, block and concrete fragments where the granular material occupies virtually all of the interstitial space between the fragments).

- ○ ***Use*** - A minimum of five feet of acceptable soil or soil-like material needs to be present between a potential VI source and foundation level to permit the use of the calculated groundwater screening values. The presence of acceptable soil or soil-like material is also a condition for using vertical proximity distances and applying separation distances for preferential pathways. Acceptable soil or soil-like material should NOT exhibit any of the following characteristics:

    - obvious contamination by a regulated substance of VI concern (e.g., staining or odors);

    - readings from an appropriate field screening instrument in the headspace above soil samples that are greater than 100 ppmv;

    - evidence of SPL; and

    - exceedances of soil screening values.

  Material that is suspected to be contaminated (via observation or from field equipment readings) may be sampled to determine if the soil screening values are exceeded. If screening values are not exceeded, then that soil can be regarded as an acceptable soil or soil-like material. Soil does not need to be sampled in areas beyond where soil has been directly impacted by a release of regulated substances to demonstrate an acceptable soil or soil-like material. For the purposes of the petroleum substance vertical proximity distances described below, the Department further defines acceptable soil or soil-like material as exhibiting greater than 2% oxygen in soil gas near the building slab.

- **<u>Preferential Pathway:</u>**

    - ○ ***Definition*** - A natural or man-made feature that enhances vapor migration from a potential VI source to or into an inhabited building. An *external preferential pathway* is a channel or conduit that allows for a greater vapor flux than ordinary diffusion through vadose zone soil. A *significant foundation opening* is a breach in a building foundation or basement wall that may amplify the entry of subsurface vapors.

    - ○ ***Use*** - A feature must be proximal to both the contamination and a building and have sufficient volume to be a preferential pathway. A significant opening in a building foundation, such as a dirt basement floor, can also act as a preferential pathway. A suspected preferential pathway should be investigated to determine if it results in an excess VI risk. The presence of a preferential pathway may preclude the use of proximity distances or certain screening values. Significant foundation openings may be sealed to inhibit vapor entry. Additional information regarding how to identify and evaluate preferential pathways is provided in Section IV.D and an example is shown in Figure IV-3.

- **Proximity Distance:**

    - ***Definition*** - The minimum distance, in the absence of a preferential pathway, which a potential VI source (see definition below) must be from a building or where a future inhabited building is planned to be constructed, to not pose a potential unacceptable VI risk.

    - ***Use*** - The presence of SPL or exceedances of soil or groundwater VI screening values within a proximity distance constitute a potential VI source. For petroleum substances, the horizontal proximity distance is 30 feet. The vertical proximity distance for petroleum hydrocarbons is five feet for adsorbed- or dissolved-phase contamination and 15 feet for SPL. The use of the vertical proximity distances requires the presence of acceptable soil or soil-like material. The horizontal proximity distance for non-petroleum contamination is 100 feet. There is no vertical proximity distance for non-petroleum contamination. Refer to Section IV.E for further guidance on proximity distances, and see Figure IV-4 for an example.

- **Separate Phase Liquid:**

    - ***Definition*** - That component of a regulated substance present in some portion of the void space in a contaminated environmental medium (i.e., soil or bedrock) that is comprised of non-aqueous phase liquid (NAPL). As such, SPL is distinct from the mass of a regulated substance in the contaminated environmental medium that is adsorbed onto or diffused into the soil or rock matrix, or dissolved in water or diffused into air that may also occupy a portion of that void space.

    - ***Use*** - SPL may be a potential VI source if it contains substances of VI concern. SPL may be analyzed to make this determination (Appendix IV-C, Section IV-C.7). The presence of SPL containing substances of VI concern provides one basis for limiting the applicability of screening values and the modeling assessment option. As shown in Figure IV-5, the presence of an SPL layer on the water table or SPL within a smear zone associated with such a layer precludes the use of the groundwater screening values or the modeling assessment option to evaluate groundwater contamination. This is the case whether the water table occurs in the soil or bedrock beneath a site. These options are available, however, beyond the limits of the SPL. In the unsaturated zone, soil contamination that includes interstitial residual SPL precludes the use of soil screening values and the modeling assessment option to evaluate soil contamination since the model assumes partitioning from adsorbed mass on the soil to pore water and then to soil gas, as opposed to direct evaporation from SPL to soil gas. The same is true for screening values based on the generic soil-to-groundwater numeric values since they also rely on this partitioning equation. However, near-source soil gas screening values may be used provided the sampling is performed above the SPL-impacted soil or groundwater (Figure IV-5). The soil gas version of the Johnson and Ettinger (J&E) model (Appendix IV-B) may also be used to evaluate near-source soil gas sampling results under the modeling assessment option.

- **Potential VI Source:**
  - ***Definition*** - Contamination by a regulated substance of VI concern under any one of the following conditions constitutes a potential VI source:
    - in the unsaturated zone, soil exceeding SHS screening values within proximity distances;
    - in the saturated zone, groundwater exceeding SHS screening values within proximity distances;
    - as SPL within proximity distances; and
    - associated with a preferential pathway.
  - ***Use*** - Identifies areas of a site where VI must be addressed through alternative assessment options, remediation, mitigation, or restrictions established in an environmental covenant. See Section IV.D and Figure IV-3 for preferential pathways and Section IV.E and Figure IV-4 for proximity distances. When utilizing the SSS VI evaluation process, a potential VI source is determined by exceedances of SHS soil and groundwater screening values (Section IV.K.4.).

C. Overview of the VI Evaluation Process

This guidance offers a flexible VI evaluation process for the SHS and SSS that provides multiple alternatives to the remediator. Figures IV-6 and IV-7 present flowcharts outlining the process for each standard, which is described in detail in the following sections. It is important to note that the purpose of Figures IV-6 and IV-7 is to illustrate how all of the steps in the VI evaluation process fit together. Figures IV-6 and IV-7 should not be used as your sole guide for performing a VI evaluation; rather, they should be used in conjunction with the text of this guidance.

The principal steps of a VI evaluation under the SHS (Figure IV-6) are:

- Develop the CSM and assess the presence of preferential pathways;
- Identify potential VI sources from exceedances of soil and groundwater screening values within proximity distances and/or the occurrence of SPL;
- Utilize alternative assessment options including screening near-source soil gas, sub-slab soil gas, or indoor air data, or conducting VI modeling;
- Mitigate buildings using activity and use limitations;
- Remediate the soil and/or groundwater contamination and reassess the pathway;
- Address the 25 Pa. Code Chapter 250 SHS requirements.

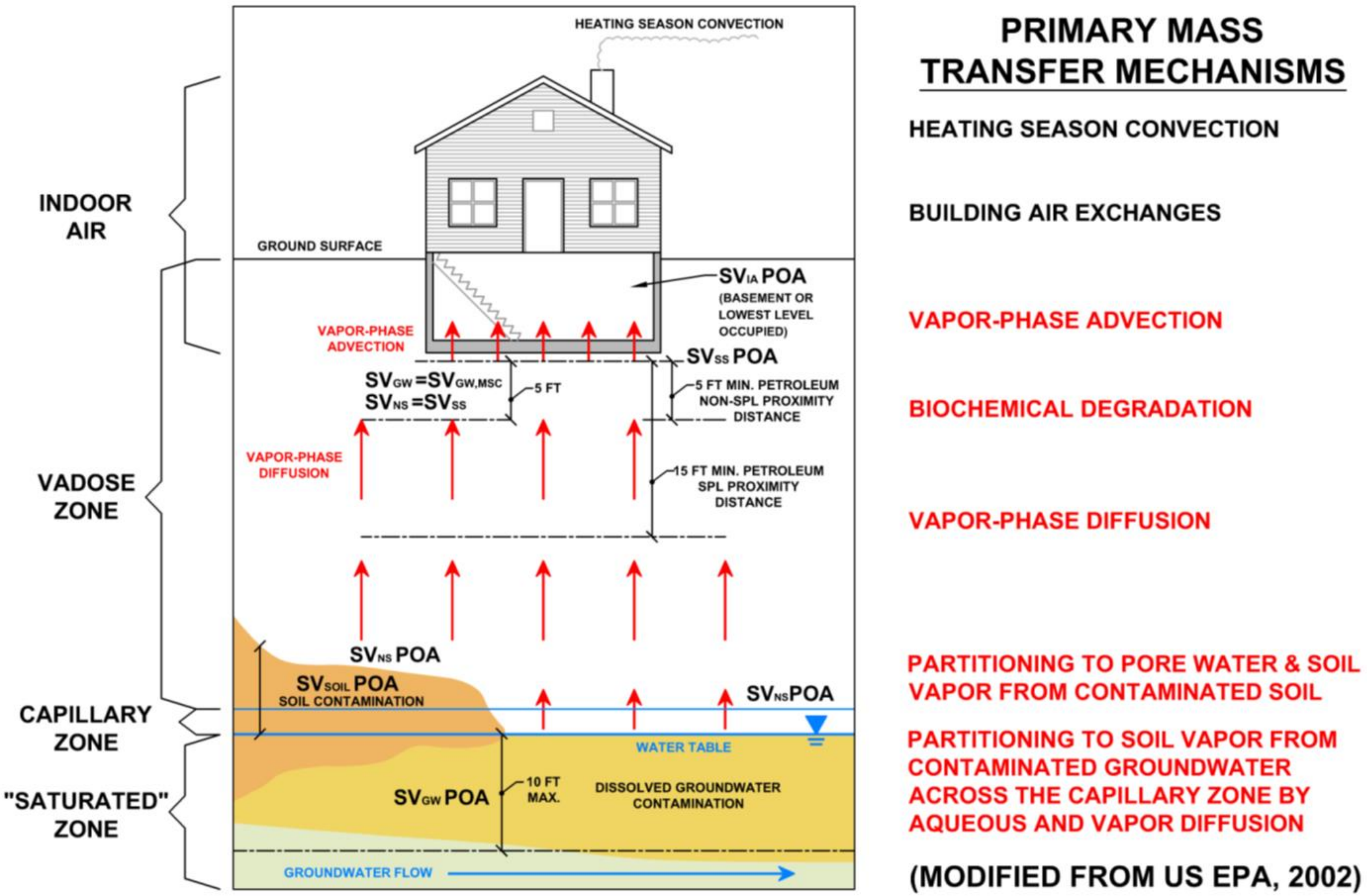
In most cases, all of the above steps will not be necessary and the remediator is not required to follow the process sequentially. For instance, buildings with a potentially complete VI pathway may be mitigated without the collection of soil gas or indoor air data. (See Section IV.K.1. for an overview of the SSS process.)

If conditions are identified that pose an immediate threat to human health or safety at any time in the VI evaluation process, prompt interim actions should be taken to protect human health. Such conditions include, but are not limited to, those that may result in injury or death resulting from inaction, such as acute toxicity to sensitive receptors (e.g., fetal cardiac malformations from TCE exposure (U.S. EPA, 2011a)), a fire or explosion hazard, or atmospheres that cause marked discomfort or sickness.

1. VI Conceptual Site Model

The VI CSM is central to the VI evaluation. The CSM is a representation of contaminant sources, migration pathways, exposure mechanisms, and potential receptors. The CSM drives the design of a sampling plan (Appendix IV-C), and as the CSM is revised, data gaps may be identified that will guide further sampling. The CSM is also a prerequisite for VI modeling (Appendix IV-B). The source description and contaminants of concern are components of the CSM supported by soil, groundwater, and possibly near-source soil gas data. The CSM development may also rely on sampling the vapor migration pathway (sub-slab soil gas) or receptor exposures (indoor air).

Figure IV-1: VI Screening Value POAs and Vertical Petroleum Proximity Distances



POA = Point of Application
SV_{IA} = Indoor air screening value
SV_{SS} = Sub-slab soil gas screening value
SV_{NS} = Near-source soil gas screening value
SV_{SOIL} = Soil screening value
SV_{GW} = Groundwater screening value

Vapor Intrusion Illustration4.dwg / 5-12-2016

The goal of the VI CSM is to describe how site characteristics, such as subsurface and building conditions, might influence both the distribution of substances of VI concern in soil gas and the potential indoor air quality of structures in the vicinity of a soil or groundwater source of substances of VI concern. Concentrations of substances of VI concern in soil gas attenuate, or decrease, as the substances of VI concern move away from the source, through the soil, through the foundation, and into indoor air. The extent of attenuation is related to site conditions, building characteristics, and chemical properties. The soil vapor attenuation is quantified in terms of an attenuation factor defined as the ratio of indoor air concentration to source vapor concentration (Appendix IV-A).

The level of detail of the CSM should be tailored to the complexity of the site, the available data and the selected Act 2 remedial standard. For the VI pathway, complex relationships exist among the many factors that influence VI. Hence, multiple lines of evidence are often used to evaluate risks associated with the vapor pathway. Finally, it should be remembered that the CSM is a dynamic tool to be updated as new information becomes available during site characterization.

Some important elements of the VI CSM are included in the list below (California EPA, 2011a; Massachusetts DEP, 2011; U.S. EPA, 2012a, 2015a; Hawaii DoH, 2014). Some elements may not be known or pertinent to the case, and this does not imply a deficient CSM.

- Sources of contamination—origins, locations, substances, and concentrations; presence of SPL

- Transport mechanisms—route from source to indoor air, potential preferential pathways

- Subsurface and surface characteristics—soil type, depth to bedrock, heterogeneities; ground cover

- Groundwater and soil moisture—depth to water, water level changes, capillary fringe thickness, perennial clean water lens

- Fate and transport—biodegradation of petroleum hydrocarbons, transformation of substances into regulated daughter products

- Weather—precipitation, barometric pressure changes, wind, frozen ground

- Building construction—basement, slab on grade, or crawl space; a garage that is open to the atmosphere in between the ground surface and the occupied areas

- Foundation openings—cracks, gaps, sumps, French drains, floor drains

- Building heating and ventilation

- Background sources—indoor air contaminants, ambient air pollution

- Receptor types—residential, nonresidential, sensitive receptors; potential future development

2. Screening Values and Points of Application (POA)

SHS screening values for regulated substances of VI concern are published in Tables IV-1 through IV-5 for soil, groundwater, near-source soil gas, sub-slab soil gas and indoor air. These tables can be accessed on the VI page of the LRP website. Separate screening values are provided in these tables for residential and nonresidential uses of potentially affected inhabited buildings. In addition, there are two distinct nonresidential building categories: "nonresidential" and "converted residential." The first category refers to buildings constructed for nonresidential use, and the second category refers to buildings that presently have a purely nonresidential use although they were originally constructed for residential use. An example is a dentist's office in a converted home. The converted residential screening values are based on attenuation factors representative of residential structures but exposure factors for nonresidential settings. When a building has both residential and nonresidential uses (e.g., apartments over a retail store), the remediator may need to evaluate VI with both residential and nonresidential screening values.

The remediator should determine which structures at a site are inhabited and intended for human occupancy. Structures that are not routinely occupied, such as storage sheds or confined spaces, are not considered inhabited buildings. Structures that are not fully enclosed (e.g., carports, shelters) are also not inhabited buildings. Basements are generally regarded as an occupied space in a building; crawl spaces are not regarded as occupied space.

The POA for each of the screening values is shown on Figure IV-1. Groundwater screening values (SVGW) apply within the zone of groundwater saturation that will exhibit concentrations of regulated substances representative of concentrations at the water table. This is an interval within ten feet or less of the water table. Soil screening values (SVSOIL) apply throughout the volume of contaminated soil in the unsaturated zone. Near-source soil gas screening values (SVNS) apply just above an unsaturated zone soil VI source and just above the capillary fringe for a groundwater VI source. Near-source soil gas screening is also applicable to a preferential pathway, except in some cases if it penetrates the building foundation (Section IV.D). Sub-slab soil gas screening values (SVSS) apply immediately below the slab of a building potentially impacted by VI, whether the building has a basement or is slab-on-grade construction. Finally, indoor air screening values (SVIA) apply in the lowest occupied space of a potentially impacted building.

Screening values cannot be calculated for substances that have no inhalation toxicity data (Appendix A). Therefore, SHS and SSS VI evaluations are not required for substances without screening values. However, the remediator could choose to address the VI pathway by demonstrating that the concentrations for such substances are below practical quantitation limits (PQLs) or by installing a mitigation system. If soil concentrations are less than generic soil-to-groundwater numeric values and groundwater concentrations are less than used aquifer medium-specific concentrations (MSCs), then there is no potential VI source. In addition, proximity distances are applicable to substances that do not have screening values (see Section IV.E). The remediator could also evaluate VI using the SSS by developing toxicity values or utilizing published information (§ 250.605).

Table IV-6 summarizes data collection conditions for VI screening and how to apply the POAs. Methods for VI screening are described in Sections IV.F and IV.G and in Table IV-7. Appendix IV-A describes the methodology for developing the screening values. SSS screening is explained in Section IV.K.

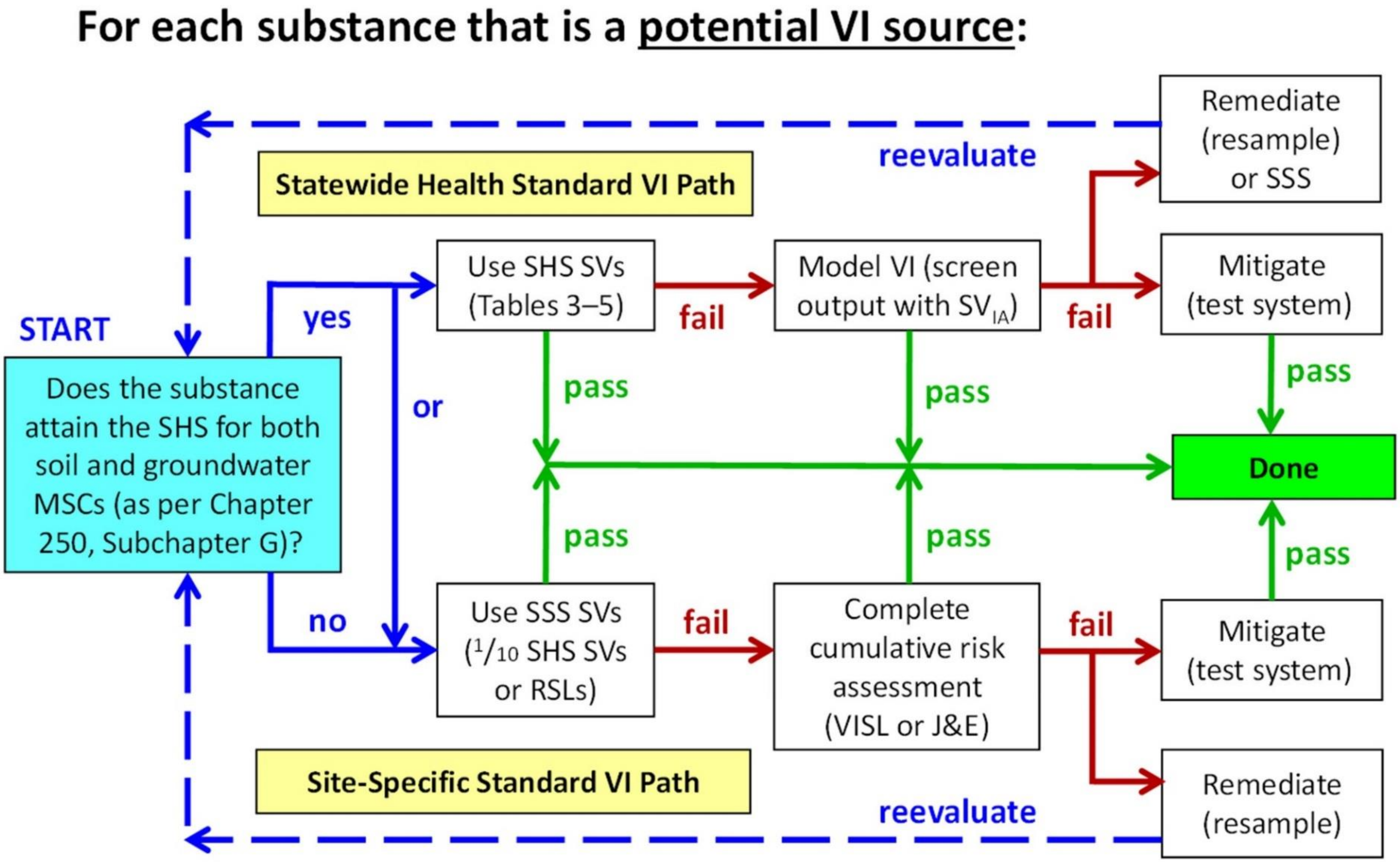
3. Guidelines for Evaluating VI Using a Combination of Standards

The VI pathway can be evaluated under the SHS, the SSS or a combination of both standards. When using a combination of standards, the VI pathway must be evaluated along with all of the other requirements of each standard being used. The screening values presented in Tables IV-1 through IV-5 were designed to be used only when attaining the SHS. However, under specific circumstances, adjusted SHS VI screening values can be used when evaluating VI under the site-specific standard. See Section IV.K.4 for additional detail on using screening values under the SSS.

The VI pathway must be assessed to satisfactorily attain the SHS for soil and groundwater (see 25 Pa. Code § 250.312(a)). Under the SHS, a remediator cannot evaluate the VI pathway without also evaluating soil and/or groundwater because Act 2 does not define indoor air or soil gas as environmental media. However, when using a combination of standards, a remediator can, for instance, evaluate soil under the SHS and groundwater under the SSS then separately evaluate VI entirely under the SSS. This is permissible because the SSS evaluates individual exposure pathways and Act 2 considers VI to be an exposure pathway, not an environmental medium. Under the SSS, a risk assessment is needed to evaluate the VI pathway if pathway elimination is not being used. The SHS does not evaluate individual exposure pathways separately so remediators cannot evaluate the VI pathway under the SHS if soil and groundwater are being evaluated under the SSS. The remediator may also choose to evaluate VI for each substance and medium using the process for the corresponding standard. Figure IV-2 shows how to treat substances independently with a combination of standards.

When using VI modeling under the SHS, the desired output is a predicted indoor air concentration (Appendix IV-B). This modeled concentration should be used in the evaluation of VI by comparing it to the associated indoor air screening value. The J&E model (U.S. EPA, 2017) also calculates risk values which should not be used for SHS evaluations. Use of risk calculations to evaluate VI is considered to be a risk assessment, which is a tool to be used under the SSS and is subject to additional reporting requirements and fees. If calculated risk values are used in the VI analysis, it will be assumed that the site is being remediated under a combination of standards and all associated fees and requirements of both standards will apply.

Figure IV-2: Representative Process to Evaluate VI with a Combination of Standards



Note: Figure must be used in conjunction with the text. Reference Section IV.C.3.

If the remediator uses the site-specific standard to evaluate the VI pathway, either solely or under a combination of standards, the SSS VI process described in Section IV.K should be used.

The following matrix illustrates the assessment needs for addressing the VI pathway using a combination of standards.

VI Assessment Needs When Using a Combination of Standards

Act 2 Standard Used to Address Soil and Groundwater	**VI Evaluation Tools**					
	Use Screening Values in Tables IV-1–5	**Use 1/10 Screening Values in Tables IV-1–5***	**Modeling**	**Risk Assessment**	**Mitigation with EC (i.e., pathway elimination)**	**Remediation**
Statewide Health Standard (SHS)	✓		✓		✓	✓
Site-Specific Standard (SSS)		✓	✓	✓	✓	✓
Combination of Standards**	✓	✓	✓	✓	✓	✓

* When defining a potential VI source, a one-tenth adjustment to soil and groundwater screening values is not required for the SSS.

** Some media and/or substances may attain the SHS while others may attain the SSS.

D. Preferential Pathway Evaluation

A preferential pathway is a feature that increases the rate of vapor migration between a source and an inhabited building (see definition in Section IV.B). DEP defines two classes of preferential pathways. **An external preferential pathway** is a channel or conduit that allows for a greater vapor flux than ordinary diffusion through vadose zone soil (Figure IV-3). **Significant foundation openings** are breaches in the building foundation and basement walls that may enhance the entry of subsurface vapors. (Typical cracks, gaps, and utility line penetrations are not generally significant foundation openings; see Section IV.D.2.) The presence and significance of these features should be identified whenever possible during CSM development (Section IV.C.1.). When building access is not possible, other preferential pathway assessment and investigation techniques should be used, when available, to complete the CSM. Guidance for assessing and investigating external preferential pathways and significant foundation openings is provided in Sections IV.D.1. and IV.D.2., respectively. Guidance for using screening values when external preferential pathways and significant foundation openings are present is provided in Sections IV.F and IV.G.

Some recognized instances of preferential pathways include the following.

- **An external preferential pathway that does not penetrate the building foundation.** External preferential pathways can impact buildings through VI even if they do not penetrate the building foundation. If the external preferential pathway is not fully enclosed, vapors can migrate into a building via typical cracks and gaps in building foundations. An example is permeable backfill material (e.g., gravel or sand) around a utility line close to a building slab or a basement wall. The vapors can travel through the backfill material and then migrate through soil into the building via typical cracks and gaps in the building foundation. If a utility trench is backfilled with native soil, then it is unlikely to act as a preferential pathway. Another example is a drain line or cracked sewer pipe (Guo *et al.*, 2015). Water will travel through the line, but vapors can escape through cracks in the pipe and can migrate through soil into a building. Natural features such as open bedrock fractures could also transport vapors near a building.

- **A conduit (external preferential pathway) that enters the building.** This is when a utility line itself, not the backfill material, acts as a conduit for vapors. For example, liquid- and vapor-phase contamination can enter breaks in sewer and drain lines, permitting vapors to pass into buildings through failed plumbing components (Jarvela *et al.*, 2003; Pennell *et al.*, 2013).

- **A significant foundation opening without an external preferential pathway.** In this case, vapors migrate by diffusion through soil from the source to the building. All building foundations have minor cracks and gaps, but if there is a large opening—such as a dirt basement floor—then that opening will amplify the flux of vapors into indoor air. Sealing the opening(s) (e.g., pouring a concrete slab over the dirt floor) can eliminate the preferential pathway.

- **A combination of an external preferential pathway with a significant opening.** For example, vapors may migrate through gravel backfill around a utility line and then flow through a gap where the line penetrates the foundation. Sealing the gap would resolve VI through the significant opening but not the role of the external preferential pathway.

Reasonable effort should be made to determine whether external preferential pathways or significant foundation openings are present. It is recommended that remediators discuss how they plan to evaluate external preferential pathways and significant foundation openings with their Department Project Officer to ensure that all parties agree on the proposed approach.

As described later in this guidance, a preferential pathway may be eliminated by appropriate site remediation or mitigation actions.

1. External Preferential Pathways

Utility corridors and pipes are potential external preferential pathways common to most sites (U.S. EPA, 2015a, Sections 5.4, 6.3.2). When a preferential pathway is external to a building, the proximity distances to a source area (as described in Section IV.E) are insufficient to eliminate the source from consideration because proximity distances are based on the movement of vapors, and associated attenuation, through soil. Therefore, an area of contamination that exceeds screening values beyond a proximity distance from a building may be a potential VI source when an external preferential pathway is present (Figure IV-3). Heightened attention should be paid to external preferential pathways which may contain SPL.

For a subsurface feature that is external to a building, the following conditions allow it to be excluded as an external preferential pathway:

- Soil and groundwater contamination exceeding VI screening values is at least 30 horizontal or five vertical feet from the feature, and any SPL is at least 30 horizontal or 15 vertical feet from the feature; OR

- The feature is at least five feet away from the building foundation.

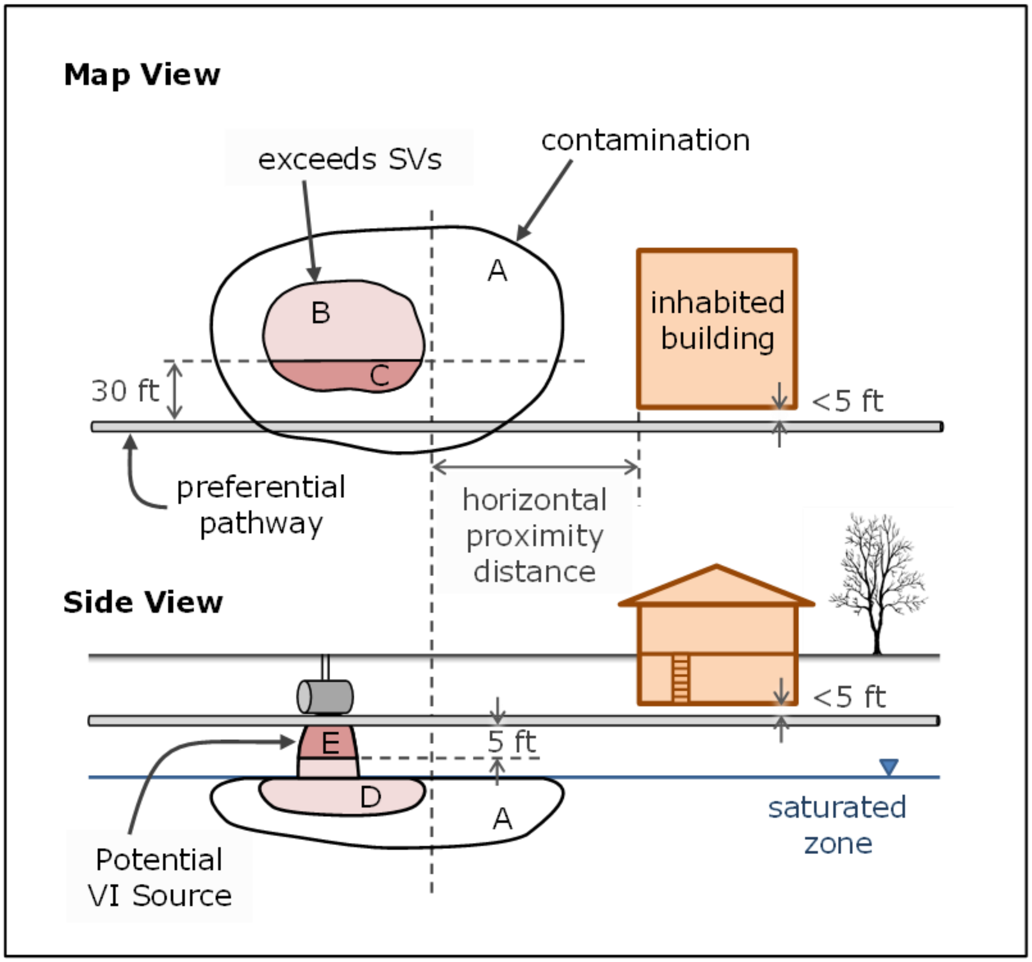
To exclude a feature as a preferential pathway, soil between the subsurface feature and the building foundation within the separation distances specified above should consist of acceptable soil or soil-like material. (For SPL, a minimum of five vertical feet of acceptable soil or soil-like material should be present within the overall 15-foot minimum separation.) As an example, consider an area of contaminated soil exceeding screening values which is beyond the horizontal proximity distance from a building. If a high-permeability backfilled trench passes through the soil contamination and near the building, but six feet of acceptable soil or soil-like material is present between the trench and the building foundation, then no further VI analysis would be necessary.

Figure IV-3 illustrates the evaluation of a potential external preferential pathway associated with a release from an underground storage tank (UST). (The assessment described here is not limited to USTs or petroleum hydrocarbons.) As shown in the separate map and side views, the distribution of contamination relative to the preferential pathway is important both horizontally and with depth. Zone A, shown in both views, is the volume of contaminated media identified in the site characterization. In the map view, the contamination in Zones B and C exceeds the soil and/or groundwater screening values, but these areas are beyond the horizontal proximity distance from the building.

However, Zone C represents the portion of contamination that exceeds screening values that is within 30 feet horizontally of the potential preferential pathway.

The side view of Figure IV-3 shows that some of the contamination is above the water table and some is below it. Zone D represents the contamination that exceeds soil and groundwater screening values but is greater than five feet below the potential preferential pathway, so the groundwater and soil contamination in Zone D is not of concern for vapor migration into the feature. Zone E, which is a portion of Zone C in unsaturated soil, is within five feet vertically of the feature, which means vapors from Zone E could enter the potential preferential pathway. Since the feature is separated by less than five feet from the building foundation, the feature is considered to be a preferential pathway with Zone E as a potential VI source. In this case, further VI assessment is required.

Figure IV-3: The Role of an External Preferential Pathway in the VI Evaluation



If a utility line trench is backfilled with native, low-permeability soil and the feature is intact (i.e., there is no evidence of the ability of groundwater or soil vapors to enter the pipe) then the feature is not considered to be an external preferential pathway. The Department does not expect remediators to prove that underground features do not have high-permeability backfill or are intact. However, if there is an indication that these conditions exist, then remediators should evaluate the feature further. For example, if the underground feature is the trench for a large diameter water line which is likely to be backfilled with gravel, it should be considered to be a potential external preferential pathway. If the underground feature is a small diameter fiber optic line, it is likely to have native soil backfill and the remediator could work under the assumption that it is not an external preferential pathway.

The Department recommends a progressive approach to evaluating external preferential pathways. The investigation can include sampling at the source (soil, groundwater, SPL, near-source soil gas), within the preferential pathway (soil gas or vapor), under the building (sub-slab soil gas), and within the building (indoor air). If a series of buildings is associated with one underground feature (e.g., a sewer line servicing multiple buildings along a street), then the buildings closest to the vapor source should be evaluated first. If it is determined that there are no VI concerns with the first building along the potential preferential pathway, then it is generally not necessary to evaluate the rest of the buildings along the line since they are increasingly farther away from the source.

Access to buildings is not always necessary for the evaluation of external preferential pathways because much of the pertinent information relates to their condition outside of the building. Examples of non-intrusive investigation techniques include a visual inspection of the exterior of the property for utility line entry points, an inspection of nearby streets and sidewalks for signs of underground utility lines and vaults, a Pennsylvania One Call notification, or a review of building plans.

The following recommendations pertain to assessing and screening external preferential pathways. (See Appendix IV-C, Figure IV-C-2 for an illustration.) The evaluation is described in terms of VI screening, but the remediator may also use the data with appropriate attenuation factors (Appendix IV-A) to carry out an SSS risk assessment (Section IV.K.5.). This is not a checklist of required evaluations; rather, if any of the following items is satisfied such that screening values or risk thresholds are not exceeded, then other items do not need to be examined.

- **Use of soil and groundwater screening values** – Contamination in the source area may be screened using soil and groundwater screening values unless SPL is present or contaminated groundwater enters the preferential pathway. Groundwater that is within a preferential pathway may be screened with used aquifer MSCs.

- **Use of indoor air modeling** – The default model for predicting indoor air concentrations (see Appendix IV-B) using soil, groundwater, or soil gas data may be used in the absence of an external preferential pathway. The default model should not be used if an external preferential pathway is present because this model is based on the diffusion of vapors through soil.

- **Use of near-source soil gas screening values** – If contaminated groundwater or SPL does not enter the preferential pathway, then near-source soil gas samples may be collected in the source area and the data screened with near-source soil gas screening values. Near-source soil gas data can also be screened against sub-slab soil gas screening values if an external preferential pathway or significant foundation opening is present or if a potential VI source is less than five feet below foundation level (see Section IV.G). This option is not available if the source is less than five feet below grade.

- **Soil gas sampling within a preferential pathway** – Soil gas samples may be collected in the preferential pathway (e.g., within trench backfill) between the source area and the building. These are not near-source soil gas samples (Section IV.G). They should be collected at a depth of at least 5 feet if the area is not paved and satisfy the other soil gas sampling criteria in this guidance (Table IV-6, Appendix IV-C). The data may be screened with sub-slab screening values.

- **Sampling within a sewer line** – If the preferential pathway is a sewer line or similar enclosed conduit that contains contamination, then the remediator may consider analysis of SPL, water, and vapor in the line. Flows and concentrations are likely to be highly variable, and there can be other sources of contamination in sewer lines. For these reasons, such sampling can be used as an informational line of evidence but not for screening.

- **Sub-slab sampling** – If the preferential pathway does not penetrate the foundation (e.g., trench backfill without a significant opening or a conduit that does not enter the building), then sub-slab samples through the foundation may be obtained (Section IV.G). This data may be screened with sub-slab screening values.

- **Sealed utility penetrations** – If the preferential pathway does penetrate the building, then the remediator should examine potential entry routes to indoor air. The basement or slab should be inspected for significant openings; foundation openings can be sealed (see Section IV.D.2.). If vapors travel within a sewer or drain line, then plumbing components could be inspected for integrity and repaired if necessary. Sampling should be performed to demonstrate that the pathway is incomplete, and this may require indoor air sampling.

- **Indoor air sampling** – Indoor air may be sampled at any time when there is an external preferential pathway, and the data may be screened with indoor air screening values (Section IV.G).

2. Significant Foundation Openings

Significant openings internal to a building’s structure, such as a dirt basement floor, may enhance vapor entry (U.S. EPA, 2015a, Sections 2.3, 6.5.2). Typical cracks, gaps, and utility line penetrations on their own are generally not considered to be significant openings. In fact, all foundations, even new ones, will have these minor openings which will permit the ingress of some vapors if a potential VI source or an external preferential pathway comes close to a building foundation. Common foundation openings such as sealed sumps, French drains, and floor drains are not necessarily significant openings.

Significant foundation openings will have any one of the following characteristics.

- The combined area of openings in the foundation surface is more than five percent of the total foundation surface area (Appendix IV-A).
- There are direct indications of contaminant entry into the building through openings, such as seepage of SPL or contaminated groundwater, chemical odors, or elevated readings on a field screening instrument.
- An opening is connected directly to an external preferential pathway; for instance, a gap around a utility line penetration permits unimpeded vapor entry from the permeable backfill in the utility line trench.

The most effective way to evaluate a building for significant foundation openings is to gain access to the building and visually inspect the foundation and basement walls for utility penetrations and overall foundation condition. Remediators should try to access buildings whenever possible so that they can get the best possible information when evaluating significant foundation openings. However, visual inspections are not always possible. Sometimes property owners do not grant access to buildings. It is also possible for finished basements to have coverings on walls and floors (e.g., paneling, carpet, etc.) making openings difficult to see. If the remediator cannot gain access to a building to inspect for significant foundation openings, there are several assessment options presented below that do not require building access.

The Department recommends sealing significant foundation openings to inhibit the pathway (U.S. EPA, 2008, Section 3.2). Proper sealing should be done with durable materials as a long-term solution such that the former openings are no more transmissive to vapors than the rest of the foundation. Although sumps, when dry, are not generally considered to be significant openings, if a sump contains contaminated groundwater it may need to be sealed. Sealing openings is a building repair and is therefore not considered an activity and use limitation.

The recommendations listed below concern the assessment and screening of significant foundation openings. (See Appendix IV--C, Figure IV-C-3 for an illustration.) The evaluation is described in terms of VI screening, but the remediator may also use the data with appropriate attenuation factors (Appendix IV-A) to carry out an SSS risk assessment (Section IV.K.5.). Unless otherwise noted, the methods below cannot be used if contaminated soil, groundwater, or SPL is present within the building. This is not a checklist of required evaluations; rather, if any of the following items is satisfied such that screening values or risk thresholds are not exceeded, then other items do not need to be examined.

Options to assess significant foundation openings that do not require building access include the following.

- If there is no external preferential pathway, then the horizontal proximity distances discussed in Section IV.E are applicable to the potential VI source. Vertical proximity distances do not apply because they are based on attenuation across an intact slab.

- Soil data may be screened using generic soil-to-groundwater numeric values. Groundwater data may be screened with used aquifer MSCs. These screening values are acceptable even if contaminated soil or groundwater is present inside the building.

- Near-source soil gas samples may be collected in the source area. This data should be screened with sub-slab screening values or modeled.

- Modeling of soil, groundwater, or near-source soil gas data may be performed by assuming that no slab is present as a conservative scenario (as described in Appendix IV-B).

Options to assess significant foundation openings when building access is available and possible include the following.

- Sub-slab soil gas samples may be obtained if the building does not have a dirt floor. Sub-slab data should be screened with indoor air screening values.

- If foundation openings are sealed, then soil and groundwater data may be screened with standard screening values, near-source soil gas data may be screened with near-source soil gas screening values, and sub-slab soil gas data may be screened with sub-slab screening values (Sections IV.F and IV.G).

- Indoor air screening can be used at any time, even when contaminated soil, groundwater, or SPL is present within the building.

E. Use of Proximity Distances

The remediator may use horizontal and vertical proximity distances from existing or planned future inhabited buildings to identify potential VI sources (Figure IV-6). To accomplish this step, existing and/or future inhabited buildings are located and proximity distances from each of these buildings are delineated. Then, relying on the results of site characterization and/or postremediation sampling, any areas of contaminated groundwater at the water table and volumes of contaminated unsaturated zone soil that exceed applicable screening values within a proximity distance from an existing or future inhabited building are identified (Figure IV-4). Areas of SPL and areas predicted to exceed the screening values in a fate-and-transport analysis are identified. If there is no SPL present or soil or groundwater screening values are not exceeded within these proximity distances, then no VI sources are present to address under the SHS.

If there is contamination both within a proximity distance (e.g., Figure IV-4) and near a potential preferential pathway (e.g., Figure IV-3), then the remediator evaluates each area of contamination separately. There may be potential VI sources in both locations. The process outlined in Figure IV-6 would be repeated for each area of contamination and each potential vapor migration route. The use of proximity distances should also account for future plume migration as determined in a fate-and-transport analysis.

A proximity distance is the distance between an existing or future inhabited building and contaminated groundwater or soil within which VI could pose a risk. Proximity distances are a function of the mobility and persistence of the chemical as well as, in the case of petroleum substances, the depth of the source and the characteristics of the subsurface materials. There are distinct proximity distances for petroleum and non-petroleum regulated substances:

- For contamination associated with non-petroleum substances present in soil and/or groundwater, a horizontal proximity distance of 100 feet applies between the building and SPL or soil or groundwater screening value exceedances; and

- For soil and/or groundwater contamination associated with petroleum substances and related hydrocarbons, a horizontal proximity distance of 30 feet and a vertical proximity distance of five feet apply between the building and soil or groundwater screening value exceedances. For petroleum SPL, a further vertical proximity distance of 15 feet applies between the SPL and foundation level.

A vertical proximity distance is not applicable for non-petroleum substances. Proximity distances are based on the attenuation of vapors caused by diffusion through soil. A non-petroleum vertical proximity distance would be deeper than bedrock and groundwater at many sites, and it would not account for vapor advection through fractures.

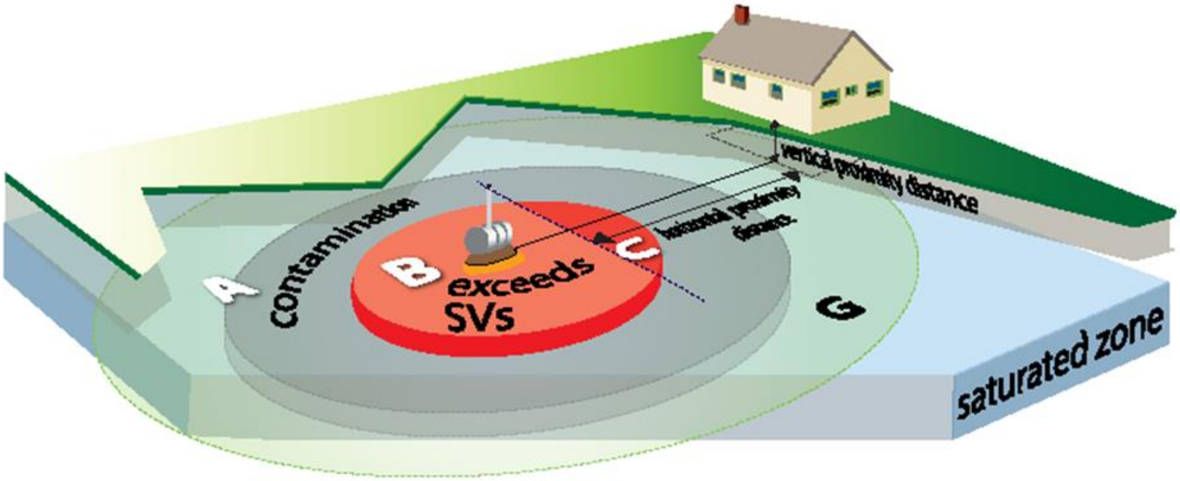
Note: The petroleum proximity distances apply to any petroleum substance, not just the hydrocarbons listed on the Petroleum Short List from the LRP Technical Guidance Manual. (Note that 1,2-dibromoethane, 1,2-dichloroethane, and MTBE are not petroleum hydrocarbons.) Petroleum substances are either aliphatic or aromatic compounds. Aliphatic compounds are composed of straight-chained, branched, or cyclic compounds and can be saturated (alkanes) or unsaturated (alkenes, alkynes, and others). Aromatic compounds have one or more conjugated, benzene or heterocyclic rings within their structures.

Petroleum substances are treated differently than non-petroleum substances in setting proximity distances because their high rates of biodegradation play a key role in diminishing the effects of VI (U.S. EPA, 2013, 2015b; ITRC, 2014). Petroleum hydrocarbons typically biodegrade under both anaerobic and aerobic conditions, with aerobic degradation occurring much more rapidly. Since soil oxygen content is generally higher in surface and shallow sub-surface soils, vapors from petroleum hydrocarbons biodegrade rapidly as they migrate upward through the soil column, reducing their concentrations prior to migrating into inhabited buildings. The Department defines an acceptable soil or soil-like material as having greater than 2% oxygen for purposes of applying proximity distances for petroleum substances. Measurement of soil oxygen content is not required unless there is reason to believe the soil is anaerobic (see Appendix IV-C for a recommended methodology). For instance, in the case of a large SPL plume or a large building overlying SPL, oxygen may be depleted and the 15-foot vertical proximity distance might not be protective for VI.

If only petroleum substances have been detected, the remediator determines the horizontal and vertical distance of the building foundation to the groundwater plume or soil contamination. If a current or future inhabited building is greater than or equal to 30 horizontal feet from an area of petroleum substance SPL or screening value exceedance, then there is adequate distance for aerobic biodegradation to occur to reduce the vapor concentrations to acceptable levels. Likewise, if there is greater than or equal to five feet of acceptable soil or soil-like material vertically between the bottom of a current and/or future inhabited building foundation and the top of the dissolved phase contaminated groundwater plume or unsaturated zone area of soil petroleum screening value exceedance, then there is adequate distance for biodegradation to occur to reduce the vapor concentrations to acceptable levels. The minimum vertical proximity distance is 15 feet for petroleum SPL, at least five feet of which should be acceptable soil or soil-like material. Vertical distances are calculated using the maximum groundwater elevation and the top of the measured or inferred SPL (smear zone or residual NAPL). If neither the horizontal nor vertical proximity condition is met, the remediator must evaluate VI further.

An example of the application of proximity distances is shown in Figure IV-4. (The assessment described here is not limited to USTs or petroleum hydrocarbons.) Zone A is the area of contamination identified in the site characterization. Zones B and C include groundwater contamination that exceeds screening values, and Zone G represents the horizontal proximity distance from Zones B and C. Zone C is the area within the horizontal proximity distance from the existing building, so it is the only portion of groundwater contamination that could pose a VI problem. Therefore, Zone C is a potential VI source, at least for non-petroleum substances, that requires additional assessment.

Figure IV-4: Use of Proximity Distances to Evaluate Potential VI Sources



The vertical proximity distance can be applied to the petroleum portion of the contamination. If this release contains only petroleum, then the contamination in groundwater is not of VI concern because groundwater is entirely below the vertical proximity distance line. The brown and orange zones below the tank represent contaminated soil that exceeds screening values, with the brown zone being the portion of contaminated soil that is above the vertical proximity distance. However, the contaminated soil is entirely beyond the horizontal proximity distance from the building. Therefore, if the contamination consists only of petroleum hydrocarbons, then there is no potential VI source and no further VI evaluation would be required for the currently occupied building.

F. Soil and Groundwater VI Screening

This section describes the development and application of soil and groundwater screening values to properly collected characterization and attainment data. Remediators may choose from the following soil and groundwater screening options.

Soil or Groundwater Screening	Additional Considerations
Soil concentrations < SVSOIL	Not available if SPL is present or if there is a significant foundation opening that has not been sealed.
Soil concentrations < generic soil-to-groundwater numeric value	Available with significant foundation openings. Not available if SPL is present.
Groundwater concentrations < SVGW	Not available if groundwater is less than five feet below foundation level, if SPL is present, if contaminated groundwater enters an external preferential pathway, or if there is a significant foundation opening that has not been sealed.
Groundwater concentrations < used aquifer groundwater MSC	Available if groundwater is less than five feet below foundation level, if contaminated groundwater enters an external preferential pathway, or if there is a significant foundation opening. Not available if SPL is present.

When evaluating VI for the Converted Residential Category using the generic soil-to-groundwater numeric values or the used aquifer groundwater MSCs, the non-residential values should be used since the current use of the property, and therefore the exposure parameters, are non-residential. A summary of screening value restrictions and the reasoning for the restrictions is provided in Figure IV-9.

1. Soil and Groundwater Screening Values

There are two sets of groundwater VI screening values: (1) at depths less than five feet below the building foundation, they are the Act 2 groundwater MSCs, and (2) at depths greater than or equal to five feet below the foundation, they are the values provided in Table IV-1. The soil VI screening values are provided in Table IV-2. Both Tables IV-1 and IV-2 are located on the Department's Vapor Intrusion web page. The derivation of these values is explained in Appendix IV-A. Table IV-6 describes important conditions for collecting soil and groundwater data to be used for VI screening.

The groundwater VI screening values (SV_{GW}) for depths less than five feet below foundation level are the used aquifer groundwater MSCs (Chapter 250, Appendix A, Table 1). The groundwater screening values for depths greater than or equal to five feet below foundation level are the higher of the groundwater MSCs and the calculated groundwater screening values based on empirical attenuation factors. The groundwater MSCs are considered suitable VI screening values because groundwater with concentrations at or below the MSCs is acceptable for use inside buildings (e.g., cooking, showering, cleaning, etc.). The maximum groundwater elevation should be compared to the 5-ft. depth criterion when selecting the applicable groundwater SVs (Table 1 or MSCs). Because the water table elevation changes over time, the VI investigation should recognize that soil in the intermittently saturated zone may be a VI source.

The soil VI screening values (SVSOIL) are the higher of the generic soil-to-groundwater numeric values (Chapter 250, Appendix A, Table 3B) and calculated soil screening values. Soil screening values may be applied at any depth below a building foundation. The calculated soil screening values are established using the acceptable risk-based indoor air concentrations and model-derived attenuation factors. The generic soil-to-groundwater numeric values are considered appropriate for VI screening because soil contamination that is unable to impact aquifers in excess of groundwater MSCs is also unlikely to pose an excess inhalation risk. Furthermore, VI sources associated with contaminated soil are typically not directly beneath buildings and they do not have an infinite lateral extent, making the assumptions of the model for calculating soil screening values conservative.

If a preferential pathway or significant foundation opening restricts the use of soil or groundwater screening values (Section IV.D), the remediator may still utilize groundwater MSCs and generic soil-to-groundwater numeric values for VI screening (unless SPL is present). These values may be applied even if contamination is present within the building (e.g., contaminated groundwater in a sump or contaminated soil in a dirt basement floor).

2. Soil and Groundwater Screening Methods

The presence of residual SPL in soil or mobile SPL in groundwater prevents the use of soil or groundwater screening values (Figure IV-5). (Although Figure IV-5 illustrates a UST, the criteria indicated are not limited to tank cases or petroleum hydrocarbon contaminants.) Screening values for soil and groundwater may be used to address VI for buildings beyond the appropriate horizontal proximity distance from SPL (Figure IV-6). If there is a preferential pathway or a significant foundation opening, then additional restrictions may apply (Section IV.D). The remainder of this subsection assumes that neither SPL nor preferential pathways prevent the use of soil and groundwater screening values. Potential sampling locations are illustrated in Appendix IV-C, Figures IV-C-1-3.

For purposes of screening soil and groundwater data to evaluate the VI pathway using one or a combination of remediation standards, the concentration of a regulated substance is not required to be less than the limits relating to the PQLs for a regulated substance in accordance with 25 Pa. Code § 250.701(c).

VI can be addressed by screening either characterization data or postremediation data for soil and groundwater. The soil and groundwater sampling results combined with applicable proximity distances are used in the screening analysis to determine if any potential VI sources are present (see Figure IV-4). Important conditions for screening are listed in Table IV-6. Among these are that groundwater must be sampled at or near the water table because it will be the source of vapors that can migrate to buildings.

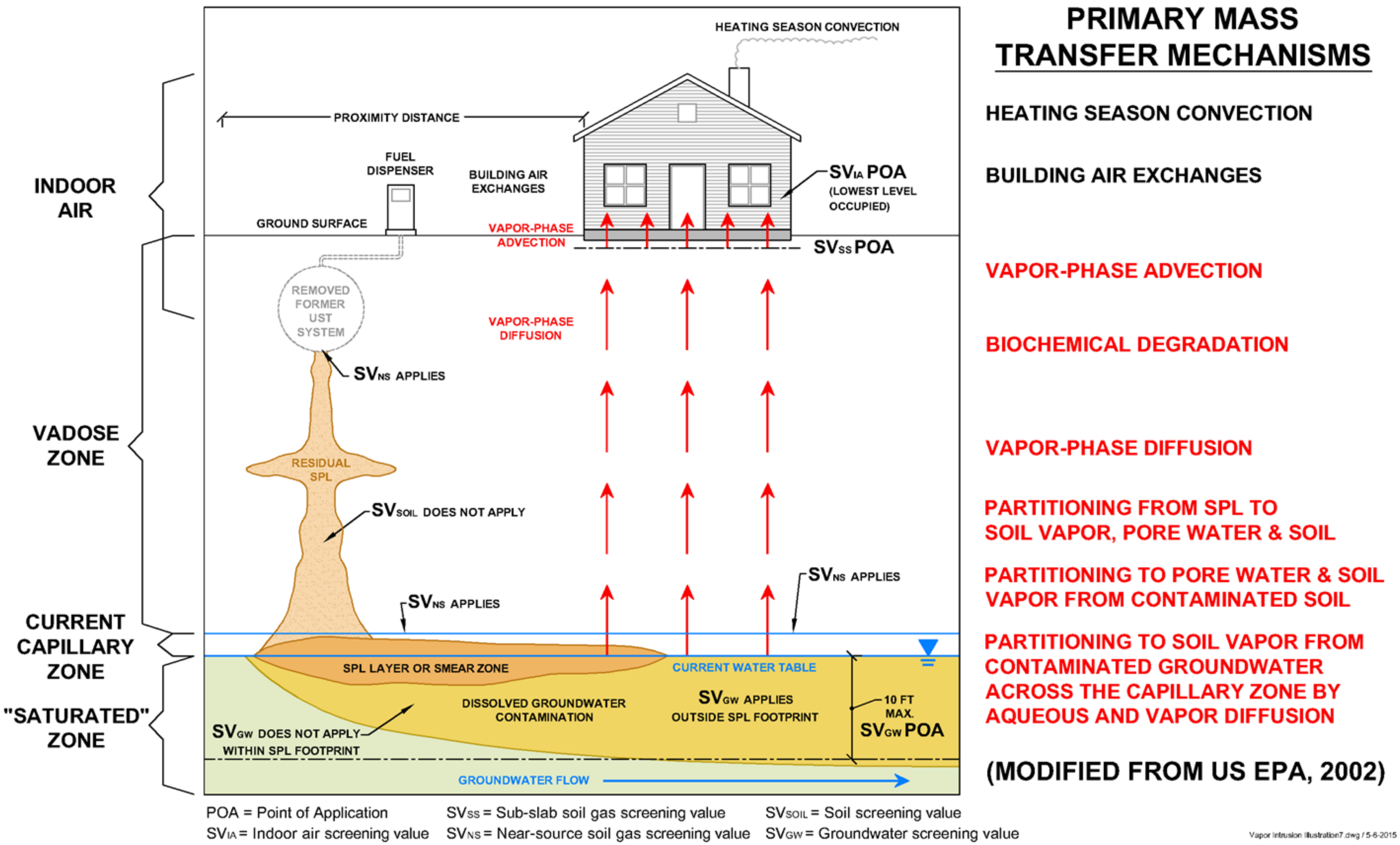
Proper characterization of soil and groundwater contamination is required at all Act 2 sites and this data alone may be sufficient for the VI assessment. If the site soil and groundwater characterization data are below MSCs without remediation being performed, then the site characterization data may be used for VI screening (Tables IV-6 and IV-7). No potential VI source exists if the applicable characterization data does not exceed soil and groundwater VI screening values (SVSOIL, SVGW). If the characterization data exceed MSCs but the remediator intends to pursue the SHS (i.e., by means of remediation), then the characterization data should be used to identify potential VI sources. If there are none, then no further VI evaluation is necessary.

When a potential VI source is remediated, VI screening may be performed with the soil or groundwater attainment data in accordance with the sampling methodologies and related statistical tests of Chapter 250, Subchapter G (Table IV-7). Note, however, that the groundwater data evaluated for VI is within the horizontal proximity distance from current or planned future inhabited buildings, not just at the point of compliance. For example, when at least eight consecutive quarters of groundwater attainment data have been collected, the remediator may apply the 75%/10x test to monitoring wells on the property and the 75%/2x test for off-site monitoring wells for VI screening (§ 250.707(b)(2)(i)). Fewer than eight consecutive quarters of data may be screened for no exceedances with Department approval pursuant to § 250.704(d).

For soil remediated *in situ*, the POA is throughout the volume of soil originally determined to exceed the soil screening value(s) (i.e., the potential VI source). For soil excavated and removed from the site, the POA is the margins of the excavation.

The number and locations of groundwater monitoring wells are selected on the basis of their representativeness with respect to water quality in the relevant portion of the plume. For groundwater on developed properties, the POA is throughout the area of a plume that has been identified as a potential VI source prior to VI assessment or remediation. For groundwater on undeveloped properties or in undeveloped portions of properties where future inhabited buildings may be constructed, the POA is throughout the area of a plume that has been identified as a potential VI source prior to VI assessment or remediation and is not within an area subject to an AUL restricting construction of future inhabited buildings.

Figure IV-5: Effect of Separate Phase Liquid on the Applicability of Screening Values



G. Alternative VI Assessment Options

The purpose of the VI assessment options is to gather and evaluate enough information to adequately determine whether a potential VI source is present that must be addressed under the SHS. Remediators may choose from the following alternative assessment options.

Alternative Assessment Option	Additional Considerations
Near-source soil gas concentrations < SVNS	Not available if contaminated groundwater or SPL enters a preferential pathway, if there is a significant foundation opening, if an external preferential pathway penetrates the building foundation, or if a potential VI source is less than five feet below foundation level.
Near-source soil gas concentrations < SVSS	Available for preferential pathways and significant foundation openings, and available for a potential VI source less than five feet below foundation level, but not if it is less than five feet below grade.
Sub-slab soil gas concentrations < SVSS for existing buildings	Not available if an external preferential pathway penetrates the building foundation or if there is a significant foundation opening that has not been sealed.
Sub-slab soil gas concentrations < SVIA for existing buildings	Available if a preferential pathway penetrates the foundation or there is a significant foundation opening.
Indoor air concentrations < SVIA at existing buildings	No restrictions.
Vapor intrusion modeling using acceptable input parameters	Not available for soil or groundwater where an external preferential pathway or SPL is present. Not available for near-source soil gas if an external preferential pathway is present.

A summary of screening value restrictions and the reasoning for the restrictions is provided in Figure IV-9.

1. Soil Gas and Indoor Air Screening Values

The near-source soil gas screening values (SVNS) are provided in Table IV-3, the sub-slab soil gas screening values (SVSS) in Table IV-4, and the indoor air screening values (SVIA) in Table IV-5. All three of the Tables are located on the Department’s Vapor Intrusion web page. The derivation of these values is explained in Appendix IV-A. Table IV-6 describes important conditions for collecting soil gas and indoor air data to be used for VI screening. Detailed information on sampling methodologies is provided in Appendix IV-C.

The near-source soil gas screening values are based on attenuation factors derived from modeling and endpoint concentrations equal to the acceptable indoor air screening values. Near-source soil gas is measured within or directly above an unsaturated zone soil source or directly above the capillary fringe for a groundwater source. Screening near-source soil gas data against near-source soil gas screening values is an option when a preferential pathway does not penetrate the building foundation (Section IV.D). Vapor concentrations measured in near-source soil gas are theoretically the highest possible concentrations because they are directly adjacent to the source.

The sub-slab soil gas screening values are based on EPA's empirical attenuation factors and endpoint concentrations equal to the acceptable indoor air screening values. As a result, screening sub-slab soil gas data against sub-slab screening values cannot be done in the presence of a preferential pathway that penetrates the building foundation (Section IV.D). Sub-slab samples are collected immediately below the foundation, and their proximity to the receptor makes them a reliable indicator of potential exposures. Sub-slab sampling may also be done beneath intact paved areas large enough to be representative of future inhabited buildings without basements.

The indoor air screening values (SV_{IA}) are calculated using the inhalation risk equations in EPA's risk assessment guidance. Indoor air data represent conditions that are as close to the receptor as possible and, therefore, provide the most accurate representation of concentrations at the point of exposure. Indoor air can be influenced by other vapor sources inside or outside of the structure not attributable to soil or groundwater contamination. This can lead to false positive indoor air detections which increases uncertainty in VI investigations. The likelihood of false negative indoor air detections is relatively low. If the remediator suspects that there are indoor sources of vapor contamination at the site, indoor air sampling is not recommended.

2. Soil Gas and Indoor Air Screening Methods

Near-source soil gas, sub-slab soil gas, and indoor air data may be acquired during the site characterization phase or following soil or groundwater remediation. VI sampling requirements and statistical tests are not specified in 25 Pa. Code Chapter 250. Therefore, the number of sample points for addressing VI is determined based on the CSM, professional judgment, and the guidance in this document. DEP recommends a minimum of two sample locations per building for sub-slab soil gas, and indoor air sampling and at least two near-source soil gas sample locations at the source. Potential sampling locations are illustrated in Appendix IV-C, Figures IV-C-1-3.

The characterization data and CSM are used to determine the size and location of the area of potential VI sources. For most sites, sampling should be biased toward the most contaminated areas or the most appropriate locations for the sample type. When a large number of samples is necessary, the sample locations should be determined by an appropriate randomization method (e.g., systematic random sampling, stratified random sampling, etc.) as described in the RCRA SW-846 manual (U.S. EPA, 2007, Chapter 9). These decisions are made on a case-by-case basis. Other important conditions for collecting data for the VI evaluation are listed in Table IV-6 and Appendix IV-C.

The presence of SPL does not prevent the use of near-source soil gas or sub-slab soil gas screening values (Figure IV-5) unless the SPL has entered an external preferential pathway or significant opening. Indoor air screening values are available even in circumstances when SPL, an external preferential pathway, and/or a significant opening are present.

The POA for near-source soil gas is at least five feet below grade (Figure IV-1). If near-source soil gas samples are collected at least five feet below foundation level, then the data may be screened using near-source soil gas screening values (SV_{NS}). If near-source soil gas samples are collected less than five feet below foundation level, then the data may be screened using sub-slab soil gas screening values (SV_{SS}). Acceptable soil or soil-like material should be present between the sampling depth and the building foundation.

For near-source soil gas above a groundwater source, the number and locations of soil gas vapor probes are selected on the basis of their representativeness with respect to water quality in the relevant portion of the plume. When the water table occurs in soil, the POA for near-source soil gas is nominally within one foot of the top of the capillary fringe or as close to this interval as sampling can reasonably be performed given typical fluctuations in groundwater levels. Theoretical capillary fringe thicknesses for different soil types are provided in Appendix IV-C, Table IV-C-1. When the water table occurs within bedrock, the POA for near-source soil gas is within one foot of the soil-bedrock interface.

Sub-slab and indoor air samples should be biased toward areas of the building with the greatest expected VI impact. Indoor air samples should be collected in the basement, if present, or the lowest occupied floor. DEP recommends obtaining a concurrent ambient air sample (in addition to at least two indoor samples) to account for potential background contamination from outside the building.

The indoor air data collected for screening purposes should be collected when the daily average outdoor temperature is at least 15°F (8°C) below the minimum indoor temperature in the occupied space and when the heating system is operating normally. Indoor air sampling can be performed during warmer seasons, but that data should be used for informational purposes only and should not be used to screen out the VI pathway. If a building is not heated, then indoor air samples collected at any time of the year may be used for screening.

The remediator may initially characterize VI with a minimum of two rounds of near-source soil gas, sub-slab soil gas, or indoor air sampling (Table IV-7). This data will normally be collected during the site characterization, but it can also be obtained following soil or groundwater remediation or during attainment monitoring. The two sampling events should occur at least 45 days apart for statistical independence.

When preparing a sampling plan many factors should be considered (Appendix IV-C). Two sample locations and two sampling rounds will not be sufficient at all sites and for all buildings. Spatial and temporal variability of VI data is significant, and small data sets have the potential of under-representing true mean concentrations and inhalation risks. Larger buildings will likely require more sample locations as source concentrations, vapor entry rates, and indoor ventilation rates will vary across the structure. If an as-yet undeveloped area is being evaluated, then there will need to be enough near-source soil gas points to encompass future building construction. Because petroleum hydrocarbons tend to pose a relatively low risk for VI owing to bioattenuation, DEP regards chlorinated VOCs as a greater concern for potential under-sampling.

If the near-source soil gas, sub-slab soil gas, or indoor air characterization data are equal to or less than the screening values (SV_{NS}, SV_{SS}, SV_{IA}), then no potential VI sources are present to address under the SHS. (However, be aware of potential restrictions associated with preferential pathways, as described above.) If there are screening value exceedances, then the remediator has two options to continue evaluating the VI pathway. One option is to collect sufficient near-source soil gas, sub-slab soil gas, or indoor air data to apply statistical screening tests (Table IV-7). The other option is to select another assessment or remedial alternative (Figure IV-6). For example, if sub-slab sample results exceed screening values, then indoor air samples could be collected and screened, a mitigation system could be installed, or a risk assessment could be performed under the SSS. In this case, the remediator should not collect near-source soil gas samples because they are farther from the point of exposure.

To screen near-source soil gas, sub-slab soil gas, and indoor air data using statistical tests, at least eight data points must be obtained at the existing or planned future building. This data can be a combination of sample locations and sampling rounds as long as there are at least two rounds collected at all of the same points (e.g. two rounds of sampling at four locations or four rounds of sampling at two locations). Sample locations should be biased toward areas with the greatest expected VI impact. The following soil and groundwater statistical tests of § 250.707(b) may be applied to the collective data from the near-source soil gas, sub-slab soil gas, or indoor air sampling at each building:

- Seventy-five percent of all samples shall be equal to or less than the applicable VI screening value with no individual sample exceeding ten times the screening value on the property (75%/10x test) and two times the screening value beyond the property boundary (75%/2x test).

- As applied in accordance with EPA-approved methods on statistical analysis of environmental data, as identified in 25 Pa. Code § 250.707(e), the 95% upper confidence limit of the arithmetic mean shall be at or below the applicable VI screening value (95% UCL test). The minimum number of samples is specified by the method documentation.

As an example, if there are two sub-slab sampling points in an onsite building that have been sampled four times, the 75%/10x test may be applied to those eight sets of analytical results. These tests should not be used for combinations of near-source and sub-slab data or soil gas and indoor air data. Data should be collected concurrently from all sample locations at the building.

Near-source soil gas, sub-slab soil gas, and indoor air sampling rounds should be performed in subsequent quarters or twice per quarter. Samples should be collected at least 45 days apart. DEP may allow alternative sampling frequencies with prior written approval.

3. Vapor Intrusion Modeling

VI modeling can be used to predict indoor air concentrations in current or future buildings. Modeling of any kind has an inherent amount of uncertainty involved, but, if acceptable input parameters are used with measured data, it can be a useful tool. The J&E model is currently the most widely used and accepted VI model available (Appendix IV-B). The J&E model does have its limitations, namely it does not account for bioattenuation of petroleum hydrocarbons in its predictions. As a result, other models, such as BioVapor, can be used to predict indoor air concentrations at petroleum VI sites. Each model has its own set of conservative default input parameters that should be used when applicable. However, some parameters such as soil type, depth to the source, and building size can be adjusted to site-specific conditions.

Soil and groundwater data cannot be used for modeling if an external preferential pathway or SPL is present. In addition, near-source soil gas data may not be modeled when there is an external preferential pathway. However, near-source data may be collected above SPL and modeled. The J&E model also may be applied when a building has significant foundation openings, such as a dirt floor, as described in Appendix IV-B.

For sites that are completely or partially undeveloped, many of the modeling input parameters will have to be estimated. The remediator can use information from building plans, if available, and conservative parameter values. A list of input parameters that can be adjusted based on site conditions is provided in the modeling guidance presented in Appendix IV-B.

Pennsylvania versions of EPA's J&E model spreadsheets are available on DEP's website. They should be used for Act 2 and storage tank corrective action J&E modeling. These versions have DEP default parameter inputs as well as physical/chemical properties and toxicological values from Chapter 250, Appendix A, Table 5A. It is important to remember that when using VI modeling under the SHS, the desired output is a predicted indoor air concentration.

This modeled concentration should be used in the evaluation of VI by comparing it to the associated indoor air screening value. The J&E model can calculate risk values, but these should not be used for SHS evaluations. Use of risk calculations to evaluate VI is considered to be a risk assessment, which is a tool to be used under the SSS, and is subject to additional reporting requirements and fees. If calculated risk values are used in the VI analysis, then the site is being remediated under a combination of standards and all associated fees and requirements of both standards will apply.

H. Mitigation and Activity and Use Limitations

Properly installed and maintained mitigation measures eliminate or greatly reduce VI exposure and therefore remain protective regardless of changes in subsurface concentrations or toxicity levels. Many areas of Pennsylvania have high levels of naturally occurring radon gas, which can pose a significant public health threat. VI mitigation systems not only address potential VI concerns associated with the release of regulated substances at remediation sites, but also provide additional public health benefits associated with reducing the significant threat caused by naturally occurring radon gas. However, mitigation systems may not be feasible in all cases. The feasibility of using a mitigation system to address VI impacts for existing buildings and planned future buildings will depend on the specific details of the site, the building, and the design of the system. Mitigation most commonly involves the installation of an active sub-slab depressurization system (similar to a fan-driven radon abatement system) (U.S. EPA, 2008).

For residential buildings, standard radon-type mitigation systems should be installed by individuals or firms certified by DEP for radon mitigation pursuant to 25 Pa. Code Chapter 240 of the regulations (Pennsylvania DEP, 1997). Standard residential systems do not need to be designed or approved by a Licensed Professional Engineer. The remediator is not required to perform indoor air confirmation sampling. Active sub-slab depressurization systems can be tested by measuring pressure differentials to demonstrate depressurization throughout the slab or by collecting one or more indoor air samples that do not exceed screening values. The system should be tested following its installation, if a significant modification or repair is made, after a change in ownership, or upon request by the Department. Performance and testing guidelines for these systems are provided in Appendix IV-C, Section IV-C.9.

Other engineering controls that mitigate VI, such as the installation of a vapor barrier, can be used to prevent VI. Vapor barriers should be designed and manufactured for use in VOC mitigation. The material should be chemically resistant and have demonstrated low permeability for the VOCs present. Moisture barriers typically do not meet these criteria. Vapor barriers should be installed and tested pursuant to the manufacturer's recommendations.

The following AULs can be used to maintain the attainment of the SHS.

- Using mitigation as a means of eliminating or reducing vapor migration
- Committing to mitigation (as described below) of currently planned future inhabited buildings on the property.
- Committing to evaluate potential VI sources at the time currently planned future inhabited buildings are constructed. The results of the evaluation should be submitted to DEP for review.
- Prohibiting construction of basements or future residential and/or nonresidential inhabited buildings in a specified area of the property where the VI pathway may be complete.

If there are no plans for future construction of inhabited buildings at the site, the remediator may still choose to use an AUL to address possible future VI issues. In this case, controls would not be required to maintain the SHS, but the remediator may wish to have additional protection for unplanned uses. Any combination of the above four conditions may be utilized. For example, Figure IV-4 depicts the proximity distance evaluation for a current building (Section IV.E). Groundwater contamination in Zones B and C and the soil contamination zone in orange also represent potential VI sources at the site if a future inhabited building is constructed within the applicable proximity distances from these areas. Zone G, indicated by the outer dotted perimeter, is the area within the horizontal proximity distance from the potential VI source (Zones B and C) which exceeds soil and/or groundwater screening values. The remediator could evaluate VI within Zone G, for instance, with near-source soil gas sampling or modeling. Alternatively, the remediator could incorporate AULs requiring future evaluation if a new building is constructed, preemptive mitigation of new buildings, or the prohibition of occupied buildings within Zone G.

As required by the Uniform Environmental Covenants Act (Act 68 of 2007, 27 Pa. C.S. §§ 6501–6517, "UECA") and the accompanying regulations (25 Pa. Code Chapter 253), engineering and institutional controls needed to address the VI pathway to demonstrate attainment of the SHS or SSS are to be in the form of an environmental covenant, unless waived by DEP. The environmental covenant should include language that requires the property owner to maintain the VI mitigation system. In most cases the environmental covenant does not need to include language requiring periodic indoor air sampling or reporting to DEP. However, mitigation systems that have electric motors or other moving parts, such as sub-slab depressurization systems, will eventually break down or wear out and will need periodic monitoring to ensure they are operating properly. DEP should be notified in the event of a property transfer, if there is a problem with the system, or upon request by DEP.

Natural attenuation resulting in decreasing concentrations of soil and groundwater contamination over time can occur at sites with releases of substances that naturally degrade in soil. At sites for which an environmental covenant was used to address the VI pathway from potential VI source(s), it may include a provision that allows for termination of the covenant or the AULs related to VI if the remediator can demonstrate to DEP that the AUL(s) is/are no longer necessary under current site conditions to comply with the selected standard.

The following language is provided as a guide for environmental covenants with only one AUL related to VI:

> *This Environmental Covenant may be terminated if: (1) an evaluation is performed that demonstrates that mitigation to address a complete or potentially complete vapor intrusion pathway is no longer necessary and appropriate, and (2) the Department reviews and approves the demonstration.*

Alternatively, the following language is provided as a guide for environmental covenants with multiple AULs including AULs unrelated to VI:

> *This Environmental Covenant may be modified with respect to the VI AUL if: (1) an evaluation is performed that demonstrates that mitigation to address a complete or potentially complete vapor intrusion pathway is no longer necessary and appropriate, and (2) the Department reviews and approves the demonstration*

I. Remediating and Reassessing the VI Pathway

Under some circumstances mitigation may not be practical or cost effective. The remediator may choose to perform further soil and/or groundwater remediation to address the VI pathway. Following the remediation, additional data must be collected for VI screening. This can include new soil or groundwater attainment data, or it can consist of soil gas or indoor air sampling data. The postremediation data is evaluated following the process illustrated in Figure IV-6 and described in Sections IV.F and IV.G.

The timing of the remediation is an important consideration. If there is an excess VI risk but remediation is a long-term action (such as a pump-and-treat system), then excess inhalation risks may exist for an unacceptably long time. In such cases the remediator is responsible for implementing interim measures to protect human health.

J. Addressing 25 Pa. Code Chapter 250 Requirements

The final step in the process flowchart on Figure IV-6 is to address the requirements of 25 Pa. Code Chapter 250 with respect to VI. This step is necessary to demonstrate compliance with the SHS in order to receive liability protection under Act 2. The submitted report should include a description of the CSM for VI with a preferential pathway assessment. The flowchart endpoint can be reached in the following three ways, and compliance should be documented in either the FR (Chapter 250) or the site characterization and/or remedial action completion reports (Chapter 245):

- **Soil and Groundwater Screening.** The remediator may screen soil and groundwater concentration data within proximity distances of existing or planning buildings. If no potential VI sources are identified, then no further analysis is necessary. Maps and cross sections that show the spatial relationship between soil and groundwater data, any SPL, any potential preferential pathways, and existing or planned future inhabited structures should be used to document that no potential VI sources are present. Applicable proximity distances should be shown on these exhibits. Soil and groundwater data should be tabulated and compared to applicable screening values. If statistical methods for screening the data are used, they should be explained.

- **Alternative Assessment Options.** The remediator may evaluate the VI pathway by screening near-source soil gas, sub-slab soil gas, or indoor air data, or by performing modeling. If the site data satisfy the screening criteria, then no further analysis is necessary. Sampling locations relative to potential VI sources and existing or planned future inhabited buildings should be shown on maps. The methodology for collecting the samples should be described and the results tabulated with applicable screening values. If statistical methods for screening the data are used, they should be explained. Refer to Appendix IV-B for recommended modeling documentation.

- **Mitigation and Environmental Covenants.** The remediator may address the VI pathway by installing a mitigation system or implementing activity and use limitations in an environmental covenant. Installation of the mitigation system must be documented, for instance, with plans, manufacturer specifications, and the installer’s certification. Testing to demonstrate the system’s effectiveness should be performed (Appendix IV-C) and the results described in the report. If mitigation is successful, no further analysis is required. The conditions to be included in a covenant to maintain the remedy should be detailed in the report.

When a potential VI source in soil or groundwater is remediated, new samples should be collected to reevaluate the VI pathway and data should be presented as described above. If the remediator chooses the SSS to address VI, then the remediator should follow the process and reporting described in Section IV.K.

K. Evaluating the VI Pathway Under the Site-Specific Standard

1. Overview

A remediator may perform a SSS VI evaluation for one of three reasons:

- The remediator has selected the SSS for substances of VI concern in soil and/or groundwater;
- Soil and groundwater attain the SHS MSCs, but the VI pathway is not satisfactorily addressed by the SHS VI assessment process described previously in this guidance;
- The remediator wishes to evaluate VI for substances to which the SHS process cannot be applied, such as mercury, cyanide, or organics without inhalation toxicity values.

The SSS VI evaluation process shares many elements with the SHS process, but the screening values are not the same and a human health risk assessment is an option. The SSS VI process is outlined in Figure IV-7. It is important to note that the purpose of Figure IV-7 is to illustrate how all of the steps in the VI evaluation process under the SSS fit together. Figure IV-7 should not be used as your sole guide for performing a VI evaluation; rather, it should be used in conjunction with the text of this guidance. The principal steps of a VI evaluation under the SSS are:

- Develop the CSM and assess the presence of preferential pathways.
- Identify potential VI sources from exceedances of SHS soil and groundwater screening values within proximity distances and/or the occurrence of SPL.
- Screen near-source soil gas, sub-slab soil gas, or indoor air data.
- Perform a cumulative human health risk assessment, which may include modeling.
- Mitigate buildings using activity and use limitations.
- Remediate the soil and/or groundwater contamination and reassess the pathway.
- Address the 25 Pa. Code Chapter 250 SSS requirements.

In most cases, all of the above steps will not be necessary, and the remediator is not required to follow the process sequentially. For instance, buildings with a potentially complete VI pathway may be mitigated without the collection of soil gas or indoor air data.

The SHS VI screening values presented in this guidance are based on a carcinogenic target risk level of 10^{-5} and a non-carcinogenic hazard quotient of 1.0. These screening values are not appropriate for use in risk assessments being performed under the SSS because the SHS target risk levels may not be sufficiently conservative to account for cumulative risks to receptors from multiple contaminants and/or multiple pathways. However, screening can be performed under the SSS for VI according to Section IV.K.4 below.

2. Preferential Pathway Evaluation

The remediator must assess potential preferential pathways and significant foundation openings as part of the SSS CSM development. The presence of a preferential pathway or significant opening may limit the use of proximity distances, screening values, and modeling.

The conditions listed in Section IV.D to identify and evaluate preferential pathways and significant openings also apply under the SSS. Specifically, contamination in soil and groundwater that exceeds SHS screening values within 30 horizontal and five vertical feet of a preferential pathway constitutes a potential VI source (Figure IV-3). Acceptable soil or soil-like material is qualified by no exceedances of SHS soil screening values. However, soil, groundwater, near-source soil gas, sub-slab, and indoor air sample data should be screened with appropriate site-specific screening values as described in Section IV.K.4.

3. Use of Proximity Distances

The remediator may utilize proximity distances to identify potential VI sources, as described in Section IV.E. For non-petroleum substances, the horizontal proximity distance is 100 feet, and for petroleum hydrocarbons it is 30 feet. When dissolved or adsorbed petroleum hydrocarbons are at least five feet below a building foundation and petroleum SPL is at least 15 feet below a building foundation, they are not considered to be a potential VI source. These vertical proximity distances must encompass acceptable soil or soil-like material.

Potential VI sources are established by the presence of SPL and exceedances of SHS soil and groundwater screening values within the applicable horizontal proximity distance. Appropriate site-specific screening values are explained in Section IV.K.4. For petroleum vertical proximity distances to apply, there must be acceptable soil or soil-like material (i.e., no exceedances of SHS soil screening values) in the upper five feet.

4. Site-Specific Standard VI Screening

Screening of soil, groundwater, near-source soil gas, sub-slab soil gas, and indoor air data is available under the SSS. This step in the evaluation allows substances to be eliminated prior to performing a risk assessment. Samples should be collected pursuant to the guidance in Table IV-6 and Appendix IV-C. An assessment of external preferential pathways, significant foundation openings, and the presence of SPL needs to be performed prior to screening as these are conditions that can limit the use of screening values.

If no limiting conditions exist, then soil and groundwater data may be screened using appropriate screening values. If limiting conditions are present, near-source soil gas, sub-slab soil gas, and indoor air may be screened with the following exceptions (Section IV.G and Figure IV-9):

- Near-source soil gas screening values are not available if there is a source less than five feet below the building foundation, if SPL or contaminated groundwater has entered a preferential pathway, if an external preferential pathway penetrates the building foundation, or if there is a significant foundation opening. Despite these limitations, if the potential VI source is at least five feet below grade, then near-source soil gas data may be screened with sub-slab screening values.

- Sub-slab soil gas screening may not be performed if an external preferential pathway penetrates the building foundation or in the presence of a significant foundation opening. In those cases, the data may be screened with indoor air screening values.

The Department permits remediators to define potential VI sources using SHS soil and groundwater screening values, even if the substances and media will be attaining the SSS. However, when screening soil or groundwater attainment data to eliminate substances from a risk assessment, the remediator must use SSS screening values as described below.

The SHS VI screening values listed in Tables IV-1 through IV-5 may not be used as is, without adjustment, for SSS screening. The SHS criteria are based on a 10^{-5} target cancer risk and a 1.0 target hazard quotient, and on groundwater MSCs and soil-to-groundwater numeric values (Appendix IV-A). Attainment for the SSS is demonstrated for cumulative risks to receptors from all substances, media, and pathways.
VI evaluations using a combination of standards are discussed in Section IV.C.3.

As illustrated in Figure IV-8, substance-by-substance SSS VI risk screening values can be determined using either of the following methods:

- Select the appropriate values for soil, groundwater, near-source soil gas, sub-slab soil gas, or indoor air from Tables IV-1 through IV-5, or used aquifer groundwater MSCs and generic soil-to-groundwater numeric values if limiting conditions apply (see Section IV.F and Figure IV-9). Reduce each screening value by a factor of 10.

- Use the current EPA residential or industrial indoor air Regional Screening Level (RSL) values (based on a target cancer risk of 10^{-6} and a target hazard quotient of 0.1) (U.S. EPA, 2018a). RSLs based on a 10^{-5} cancer risk may be used for screening when it can be demonstrated that VI is the only complete exposure pathway for a receptor. RSLs may be used for screening indoor air data or for screening near-source or sub-slab soil gas data by using the following attenuation factors (refer to Appendix IV-A):

Sample Type	Attenuation Factor		
	Residential	Non-Residential	Converted Residential
Sub-slab soil gas	0.026	0.0078	0.026
Near-source soil gas	0.005	0.001	0.005

The methodology for soil and groundwater screening is described in Section IV.F.2, and the methods for near-source soil gas, sub-slab soil gas, and indoor air are provided in Section IV.G.2. Screening may be applied to characterization and postremediation data. A sufficient number of sample locations and rounds must be collected to satisfactorily evaluate the pathway. DEP recommends a minimum of two sample locations and two sampling rounds for screening.

For the SSS, the only acceptable screening criterion is no exceedances of the applicable screening values. Substances that screen out using either one-tenth of the SHS VI screening values or the EPA RSLs do not need to be included in a VI risk assessment.

5. Performing a VI Risk Assessment and Modeling

In a risk assessment, the VI pathway should be considered when developing the CSM. The CSM should use a qualitative fate and transport analysis to identify all current and future potentially complete and incomplete exposure pathways, including source media, transport mechanisms, and all potential receptors (25 Pa. Code § 250.404). The risks associated with all complete exposure pathways must be combined for individual receptors in order to evaluate the total cumulative risk to each receptor. For example, if ingestion of contaminated soil, dermal contact with contaminated groundwater, and inhalation of vapor-phase contamination via VI are all complete exposure pathways for the same receptor, the calculated risk values for each of these pathways must be combined to evaluate the total risk to the receptor. For the SSS, the cumulative excess risk for known or suspected carcinogens may not be greater than 10^{-4} and the hazard index may not exceed one for systemic toxicants (25 Pa. Code § 250.402).

Current toxicity values should be used in a SSS risk assessment (25 Pa. Code § 250.605). Therefore, if a toxicity value has been updated since the last revision of the SHS screening values, that new information must be included in a cumulative risk assessment. This provision is consistent with DEP's discretion in allowing screening to substitute for a risk assessment.

VI modeling is one option for SSS risk assessments. DEP's modeling guidance is provided in Appendix IV-B. For SSS modeling, the user inputs soil, groundwater, or near-source soil gas concentrations into the Pennsylvania versions of EPA's J&E models. The desired output is the incremental risks for each substance, not the predicted indoor air concentrations. The model risk results are then incorporated into the cumulative risk assessment.

The second option is to use indoor air, sub-slab soil gas, or near-source soil gas data for the risk assessment. Soil gas data must be converted to estimated indoor air concentrations using the conservative attenuation factors tabulated in Section IV.K.4.

Inhalation risks are calculated using standard equations. (See Appendices IV-A and IV-B)

The VI risk assessment must be submitted in a risk assessment report meeting the procedural and substantive requirements of Act 2. For regulated storage tank sites, the risk assessment is provided in the site characterization and/or remedial action completion reports. Human health risk assessment guidance is found in Section III.H. Screening of chemicals of concern may follow the methodology described in Section IV.K.4.

6. Mitigation and Remediation

If site contamination does not screen out using the SSS screening values or the cumulative risks are excessive, then the remediator may choose to mitigate the VI pathway or remediate the VI sources. The remediator can also select these options before screening field data or carrying out a risk assessment. Mitigation and remediation require submittal of a cleanup plan.

Current and planned future inhabited buildings may be mitigated to eliminate the VI pathway (Section IV.H). Mitigation measures that prevent the migration of vapor, such as vapor barriers or sub-slab depressurization systems, are considered to be engineering controls. The standard mitigation approach is an active sub-slab depressurization system (U.S. EPA, 2008). Performance and testing guidelines are provided in Appendix IV-C. Measures taken that limit or prohibit exposure are considered to be institutional controls. Engineering or institutional controls used to mitigate the VI pathway must be addressed in the postremediation care plan and must be memorialized in an environmental covenant.

Remediation of soil and/or groundwater is also an alternative to address the VI pathway (Section IV.I). Postremediation data must be collected and evaluated through screening or a risk assessment. If remedial action is not completed promptly, then the remediator may be responsible for employing interim measures to protect human health.

7. Using an OSHA Program to Address VI

VI can be difficult to evaluate when vapors from soil or groundwater sources enter industrial (or commercial) facilities that use the same chemical(s) in their processes. DEP does not regulate indoor air. Rather, worker exposure to chemical vapors associated with an onsite industrial process is regulated by the Occupational Safety and Health Administration (OSHA). It is nearly impossible to accurately isolate and measure the VI component of the indoor air that can be attributed to soil and groundwater contamination using indoor air sampling. As a result, workers who are not properly trained to work in areas that contain these vapors can still be exposed to soil or groundwater related vapors due to VI.

Therefore, an OSHA program can be used to address VI as an institutional control within the SSS. The remediator should demonstrate that the substances in the soil or groundwater contamination they are evaluating are currently being used in a regulated industrial process inside the inhabited building(s) and that OSHA regulations are fully implemented and documented **in all areas of the building(s)**. This means that a hazard communications plan is in place, including the posting of Safety Data Sheets [SDSs; formerly known as Material Safety Data Sheets (MSDSs)], so that workers and others who might be exposed to all chemicals of concern have full knowledge of the chemicals' presence, have received appropriate health and safety training, and have been provided with the appropriate protective equipment (when needed) to minimize exposure. Remediators should not use an OSHA program to evaluate risk from VI in cases where the regulated substances being evaluated for the VI pathway are not used in the work place. It is also expected that a quantitative analysis of indoor air data using occupational screening values will be included in the VI assessment. Data is needed to show that OSHA worker protection measures are satisfied and also to demonstrate compliance and attainment of the SSS. If OSHA implementation cannot be documented, then an OSHA program cannot be used as a means of addressing VI. A checklist is included in Appendix IV-D to help remediators and reviewers ensure that the OSHA program is adequately documented. All items on the checklist should be provided to demonstrate that a complete OSHA program is present to provide protection. Additional guidance regarding the use of industrial hygiene/occupational health programs to address the VI pathway can be found in EPA's *OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air* (U.S. EPA, 2015a).

The use of an OSHA program to address VI is an institutional control because it limits exposure through the implementation of the OSHA requirements. If the future owner does not use the same chemical(s) in their industrial process as the previous owner and/or does not fully implement an OSHA program for the same chemical(s), then VI would need to be reevaluated by the new owner.

8. Addressing Chapter 250 Requirements

The final step in the process flowchart on Figure IV-7 is to address the requirements of Chapter 250 with respect to VI. This step is necessary to demonstrate compliance with the SSS under Act 2. The submitted report should include a description of the CSM for VI with a preferential pathway assessment. The flowchart endpoint can be reached in the following four ways. Compliance should be documented in Act 2 (Chapter 250) or storage tank corrective action (Chapter 245) reports:

- **Soil and Groundwater Screening.** The remediator may screen soil and groundwater concentration data within proximity distances to existing or currently planned inhabited buildings. If no potential VI sources are identified, then no further analysis is necessary. Documenting this conclusion requires the production of maps and cross sections that show the spatial relationship between soil and groundwater data, any SPL, any potential preferential pathways, and existing or planned future inhabited structures. Applicable proximity distances should be shown on these exhibits. Soil and groundwater data should be tabulated and compared to applicable screening values. This information is submitted in the remedial investigation and FR or the site characterization and remedial action completion reports, as appropriate.

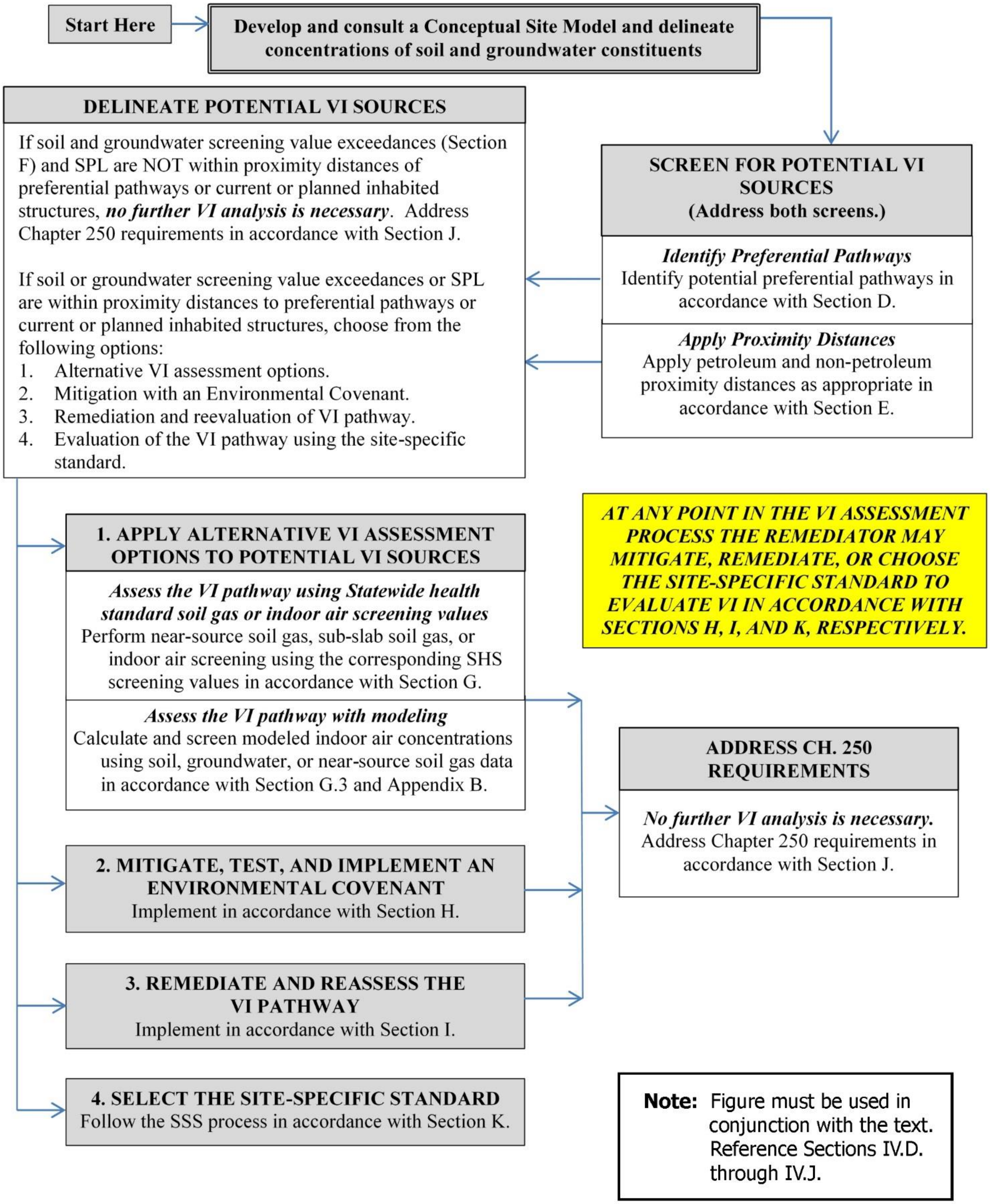
- **Alternative Assessment Options.** The remediator may evaluate the VI pathway by screening near-source soil gas, sub-slab soil gas, or indoor air data. If the site data satisfy the screening criteria, then no further analysis is necessary. Sampling locations relative to potential VI sources and existing or planned future inhabited buildings should be shown on maps. The methodology for collecting the samples should be described and the results tabulated with applicable screening values. Supporting information is submitted in the remedial investigation and FR or the site characterization and remedial action completion reports, as appropriate.

- **Risk Assessment.** If VI screening values are not applicable or they are exceeded, then a human health risk assessment may be performed. If the site-specific risk thresholds (cumulative 10^{-4} cancer risk and hazard index of 1.0) are satisfied, no further analysis is required. Risk assessment requirements are described in 25 Pa. Code § 250.409 and Section III.H. Documentation is supplied in a risk assessment report or a risk assessment submitted as part of a site characterization report and remedial action completion report, as appropriate. The risk evaluation may include modeling, as described in Appendix IV-B.

- **Mitigation and Activity and Use Limitations.** The remediator may address the VI pathway by installing a mitigation system or implementing AULs in an environmental covenant. Submittal of a cleanup plan is required when an engineering control is used to mitigate the exposure pathway for a current receptor. Installation of the mitigation system must be documented, for instance, with plans, manufacturer specifications, and the installer’s certification. Testing to demonstrate the system’s effectiveness should be performed (Appendix IV-C) and the results described in the report. The conditions to be included in a covenant to maintain the remedy or eliminate the pathway should also be detailed in a postremediation care plan. Documentation for mitigation systems and covenant remedies is provided in the FR or remedial action completion report, as appropriate.

When a potential VI source in soil or groundwater is remediated, new samples are collected to reevaluate the VI pathway. That data is presented as described above for the SSS or through the SHS process, as appropriate.

Figure IV-6: Statewide Health Standard Vapor Intrusion Assessment Process



Develop and consult a Conceptual Site Model and delineate concentrations of soil and groundwater constituents

DELINEATE POTENTIAL VI SOURCES

If soil and groundwater screening value exceedances (Section F) and SPL are NOT within proximity distances of preferential pathways or current or planned inhabited structures, ***no further VI analysis is necessary***. Address Chapter 250 requirements in accordance with Section J.

If soil or groundwater screening value exceedances or SPL are within proximity distances to preferential pathways or current or planned inhabited structures, choose from the following options:

1. Alternative VI assessment options.
2. Mitigation with an Environmental Covenant.
3. Remediation and reevaluation of VI pathway.
4. Evaluation of the VI pathway using the site-specific standard.

SCREEN FOR POTENTIAL VI SOURCES
(Address both screens.)

Identify Preferential Pathways
Identify potential preferential pathways in accordance with Section D.

Apply Proximity Distances
Apply petroleum and non-petroleum proximity distances as appropriate in accordance with Section E.

AT ANY POINT IN THE VI ASSESSMENT PROCESS THE REMEDIATOR MAY MITIGATE, REMEDIATE, OR CHOOSE THE SITE-SPECIFIC STANDARD TO EVALUATE VI IN ACCORDANCE WITH SECTIONS H, I, AND K, RESPECTIVELY.

1. APPLY ALTERNATIVE VI ASSESSMENT OPTIONS TO POTENTIAL VI SOURCES

Assess the VI pathway using Statewide health standard soil gas or indoor air screening values
Perform near-source soil gas, sub-slab soil gas, or indoor air screening using the corresponding SHS screening values in accordance with Section G.

Assess the VI pathway with modeling
Calculate and screen modeled indoor air concentrations using soil, groundwater, or near-source soil gas data in accordance with Section G.3 and Appendix B.

ADDRESS CH. 250 REQUIREMENTS

No further VI analysis is necessary.
Address Chapter 250 requirements in accordance with Section J.

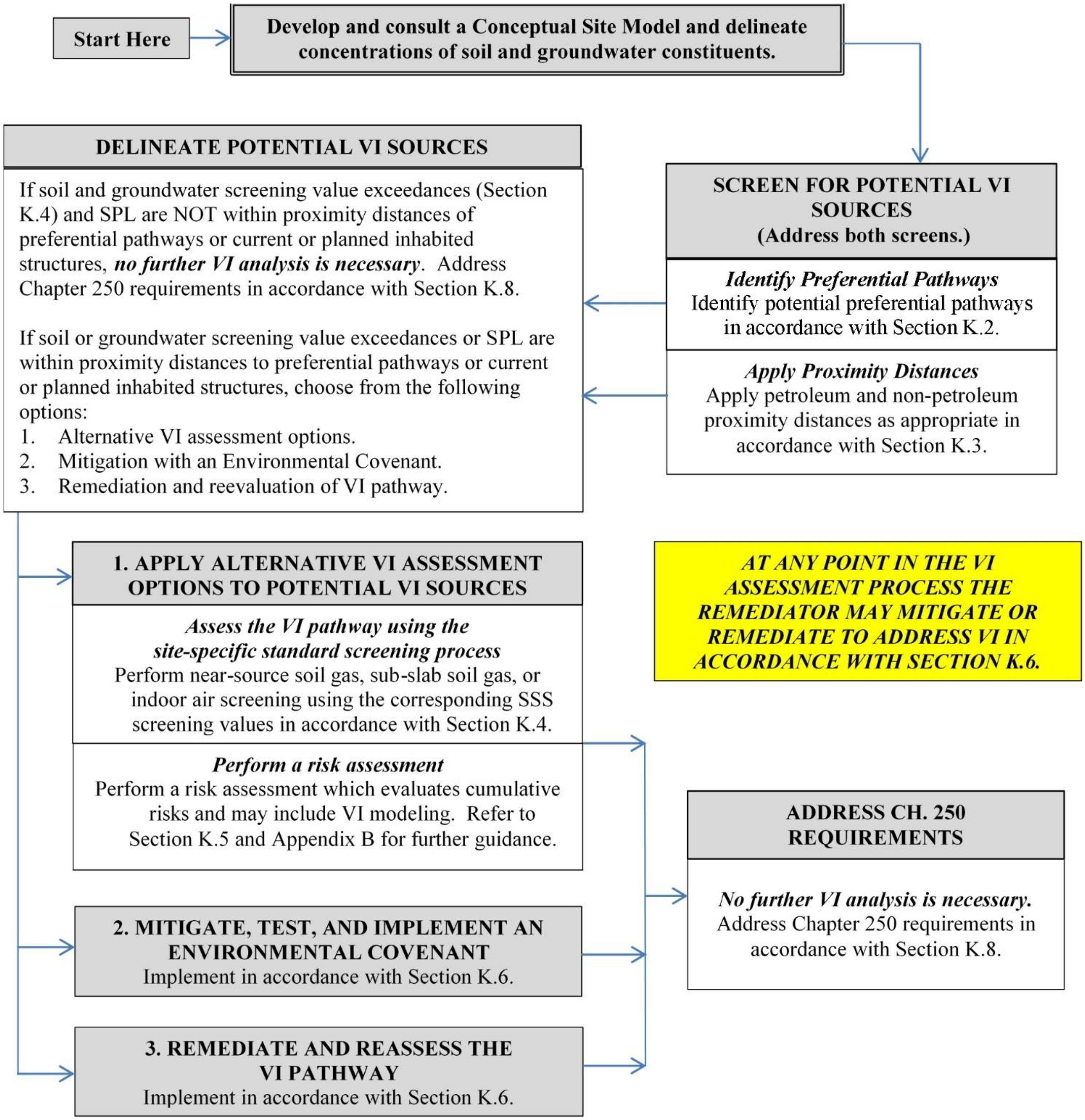
2. MITIGATE, TEST, AND IMPLEMENT AN ENVIRONMENTAL COVENANT
Implement in accordance with Section H.

3. REMEDIATE AND REASSESS THE VI PATHWAY
Implement in accordance with Section I.

4. SELECT THE SITE-SPECIFIC STANDARD
Follow the SSS process in accordance with Section K.

Note: Figure must be used in conjunction with the text. Reference Sections IV.D. through IV.J.

Figure IV-7: Site-Specific Standard Vapor Intrusion Assessment Process



Start Here

Develop and consult a Conceptual Site Model and delineate concentrations of soil and groundwater constituents.

SCREEN FOR POTENTIAL VI SOURCES
(Address both screens.)

Identify Preferential Pathways
Identify potential preferential pathways in accordance with Section K.2.

Apply Proximity Distances
Apply petroleum and non-petroleum proximity distances as appropriate in accordance with Section K.3.

DELINEATE POTENTIAL VI SOURCES

If soil and groundwater screening value exceedances (Section K.4) and SPL are NOT within proximity distances of preferential pathways or current or planned inhabited structures, ***no further VI analysis is necessary***. Address Chapter 250 requirements in accordance with Section K.8.

If soil or groundwater screening value exceedances or SPL are within proximity distances to preferential pathways or current or planned inhabited structures, choose from the following options:

1. Alternative VI assessment options.
2. Mitigation with an Environmental Covenant.
3. Remediation and reevaluation of VI pathway.

1. APPLY ALTERNATIVE VI ASSESSMENT OPTIONS TO POTENTIAL VI SOURCES

Assess the VI pathway using the site-specific standard screening process
Perform near-source soil gas, sub-slab soil gas, or indoor air screening using the corresponding SSS screening values in accordance with Section K.4.

Perform a risk assessment
Perform a risk assessment which evaluates cumulative risks and may include VI modeling. Refer to Section K.5 and Appendix B for further guidance.

2. MITIGATE, TEST, AND IMPLEMENT AN ENVIRONMENTAL COVENANT
Implement in accordance with Section K.6.

3. REMEDIATE AND REASSESS THE VI PATHWAY
Implement in accordance with Section K.6.

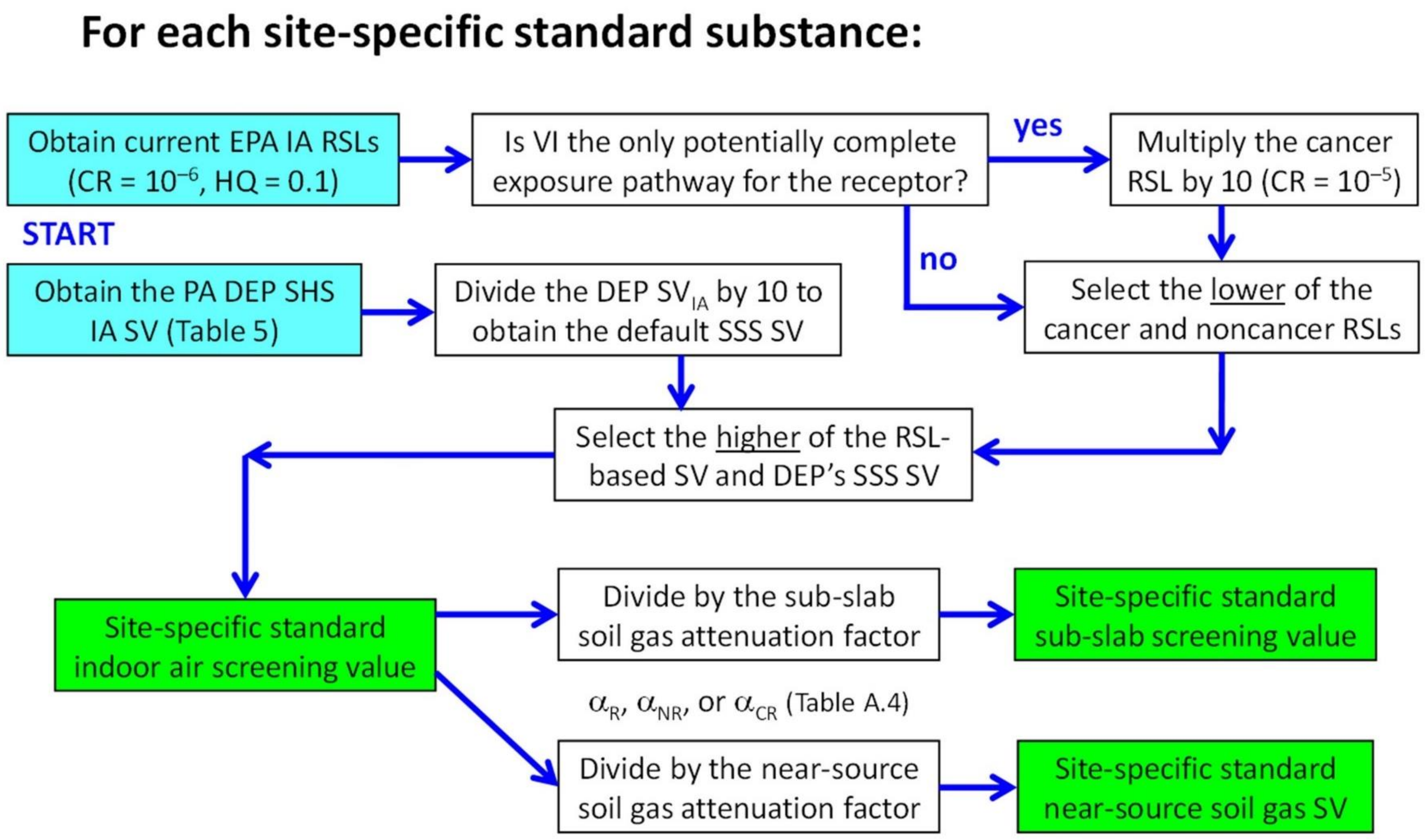
AT ANY POINT IN THE VI ASSESSMENT PROCESS THE REMEDIATOR MAY MITIGATE OR REMEDIATE TO ADDRESS VI IN ACCORDANCE WITH SECTION K.6.

ADDRESS CH. 250 REQUIREMENTS

No further VI analysis is necessary.
Address Chapter 250 requirements in accordance with Section K.8.

Note: Figure must be used in conjunction with the text. Reference Section IV.K.

Figure IV-8: Process to Determine Site-Specific Standard Vapor Intrusion Screening Values



Note: Figure must be used in conjunction with the text. Reference Section IV.K.4.

Figure IV-9: Screening Value Use Restrictions

Source	Data Type	Screening Value	Screening Value Use Restriction	Reason for Restriction
Groundwater **within proximity distances**	**Groundwater**	**SV_{GW}**	1. Presence of SPL within appropriate horizontal proximity distance 2. Presence of a significant foundation opening 3. Contaminated GW enters an external preferential pathway 4. GW < 5 feet below foundation level	1. SV_{GW} values or the used aquifer GW MSCs cannot be used in the presence of SPL because both values assume no SPL is present. 2. SV_{GW} values cannot be used in the presence of significant foundation openings because the calculated SV_{GW} values assume the presence of a slab. 3. SV_{GW} values cannot be used when GW enters a preferential pathway because the calculated SV_{GW} values assume attenuation through soil. 4. SV_{GW} values cannot be used when GW < 5 feet below foundation level because the calculated SV_{GW} values require at least 5 feet of soil. • NOTE: For site-specific standard screening, use 1/10th of the Table 1 or1/10th of the MSC values.
		Used Aquifer GW MSC	1. Presence of SPL within appropriate horizontal proximity distance	
Soil **within proximity distances**	**Soil**	**SV_{SOIL}**	1. Presence of SPL within appropriate horizontal proximity distance 2. Presence of a significant foundation opening	1. SV_{SOIL} values and the generic soil-to-GW numeric values cannot be used in the presence of SPL because both values assume no SPL is present. 2. SV_{SOIL} values cannot be used in the presence of a significant foundation opening because the calculated SV_{SOIL} values assume a slab is present. • NOTE: For SSS screening, use 1/10th of the Table 2 or 1/10th of the MSC values.
		Generic Soil-to-GW Numeric Value	1. Presence of SPL within appropriate horizontal proximity distance	
Groundwater or Soil **within proximity distances**	**Near-Source Soil Gas**	**SV_{NS}**	1. Contaminated GW or SPL enters a preferential pathway 2. Presence of a significant foundation opening 3. External preferential pathway penetrates the building foundation 4. Potential VI source is < 5 feet below foundation level	1. SV_{NS} values cannot be used when contaminated GW or SPL enters an external preferential pathway because the SV_{NS} values assume attenuation through soil. 2. SV_{NS} values cannot be used in the presence of a significant foundation opening because the SV_{NS} values assume the presence of a slab. 3. SV_{NS} values cannot be used if an external preferential pathways penetrates the building foundation because the SV_{NS} values assume the presence of a slab. 4. SV_{NS} values cannot be used if the potential VI source is < 5 feet bleow foundation level because the SV_{NS} values assume 5 feet of soil between the source and the foundation. 5. A comparison of near-source soil gas data to SV_{SS} values cannot be performed if the potential VI sourse is < 5 feet below grade because shallow soil gas data can be unreliable. • NOTE: For SSS screening, use 1/10th of the Table 3 values or use EPA indoor air RSLs with an appropriate attenuation factor.
		SV_{SS}	1. Potential VI source is < 5 feet below grade	
	Sub-Slab Soil Gas	**SV_{SS}**	1. Presence of a significant foundation opening 2. Preferential pathway penetrates the building foundation	1. The comparison of sub-slab data to SV_{SS} is not available in the presence of a significant foundation opening because the calculation of the SV_{SS} values assumes the presence of an intact slab. 2. The comparison of sub-slab data to SV_{SS} is not available if an external preferential pathway penetrates the building foundation because the SV_{SS} values presume the presence of soil between the source and foundation. • NOTE: For SSS screening, use 1/10th of the Table 4 values or use EPA indoor air RSLs with an appropriate attenuation factor.
		SV_{IA}	No Restrictions	
	Indoor Air	**SV_{IA}**	No Restrictions	• NOTE: For SSS screening, use 1/10th of the Table 5 values or use EPA indoor air RSLs.

Note: Figure must be used in conjunction with the text.
Reference Sections IV.F. and IV.G.

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M. Tables

Tables IV-1 through IV-5 are located on the vapor intrusion web page of the DEP website.

Table IV-6: Collection of Data for Vapor Intrusion Screening

Sample	Conditions for VI Data Collection
Soil	• Collect an appropriate number of samples to characterize the source(s) and/or demonstrate attainment. • The samples are from unsaturated soil. • No SPL is present.
Groundwater	• Install an appropriate number of monitoring wells to characterize the source(s) and/or demonstrate attainment. • Sample from properly constructed monitoring wells. • Sample at or near the water table. • Monitoring well screens cross the water table. • The wetted length of the well screen should be no more than 10 feet. • If the depth to water below the foundation is less than 5 feet then MSC-based screening values should be used. • Acceptable soil or soil-like material exists between the water table and the building foundation. • No SPL is present.

Sample	Conditions for VI Data Collection
Near-Source Soil Gas	• Account for potential spatial variability in the sampling design based on the soil and groundwater data. • Collect at least two rounds of samples from at least two locations. • Locate sample points where they will be most representative of soil gas in potential VI sources and preferential pathways (if applicable). • The sample depth is within about 1 foot of the top of the capillary fringe for groundwater sources, considering the effects of water table fluctuations. • Sample above bedrock when the water table is within bedrock. • Sample within or no more than 1 foot above vadose zone soil sources. • Sample at least 5 feet below grade. • Acceptable soil or soil-like material exists between the source and the building foundation. • Refer to Appendix IV-C.
Sub-Slab Soil Gas	• Account for potential spatial variability in the sampling design. • Collect at least two rounds of samples from at least two locations. • Bias sample points towards areas of greatest expected impact. • Refer to Appendix IV-C.
Indoor Air	• Account for potential spatial variability in the sampling design. • Collect at least two rounds of samples from at least two locations. • Sample in the lowest occupied floor (basement and/or first floor). • Sample when the daily average outdoor temperature is at least 15°F (8°C) below the minimum indoor temperature of the occupied space. • Refer to Appendix IV-C.

Table IV-7: Application of Statewide Health Standard Vapor Intrusion Screening Criteria

Characterization Data	Vapor Intrusion Screening Conditions
Soil Characterization	• Soil attains the Statewide health standard on the basis of the characterization data without remediation. • Use all applicable soil characterization data for VI screening. • If there are no exceedances of VI soil screening values (SV_{SOIL}), then the VI evaluation is complete.*
Groundwater Characterization	• Groundwater attains the Statewide health standard on the basis of the characterization data without remediation. • Use all applicable groundwater characterization data for VI screening. • Collect at least two rounds of data. • If there are no exceedances of vapor intrusion groundwater screening values (SV_{GW}), then the VI evaluation is complete.*
Near-Source Soil Gas, Sub-Slab Soil Gas, or Indoor Air Characterization	• The remediator may characterize and screen soil gas or indoor air with a limited number of sampling rounds. • Sample at least two locations and perform a minimum of two sampling events. • Collect samples at least 45 days apart. • If there are no exceedances of VI screening values (SV_{NS}, SV_{SS}, SV_{IA}) then the VI evaluation is complete. *
Attainment Data	**Vapor Intrusion Screening Conditions**
Soil Attainment	• Use all applicable soil attainment data. • The attainment requirements for soil in Sections 250.702, 250.703, and 250.707(b)(1) of the regulations may be utilized for vapor intrusion soil screening (e.g., 75%/10x test).

Characterization Data	Vapor Intrusion Screening Conditions
Groundwater Attainment	• Use all applicable groundwater attainment data. • When eight or more consecutive quarters of data are available then the attainment requirements for groundwater in 25 Pa. Code §§ 250.702, 250.704, and 250.707(b)(2)(i) of the regulations may be utilized for vapor intrusion groundwater screening (e.g., 75%/10x test on the property and 75%/2x test beyond the property boundary). • Fewer than eight rounds of data may be screened with DEP approval pursuant to 25 Pa. Code § 250.704(d) of the regulations. The VI evaluation is complete if all concentrations are less than or equal to the groundwater screening values (SV_{GW}). • The alternate groundwater attainment statistical method found at 25 Pa. Code § 250.707(b)(2)(ii) of the regulations may be applied to VI screening when the minimum number of samples specified by the documentation of the method have been collected.

Table IV-7: Application of Statewide Health Standard Vapor Intrusion Screening Criteria (cont.)

VI Monitoring Data	Vapor Intrusion Screening Conditions
Near-Source Soil Gas, Sub-Slab Soil Gas, or Indoor Air Monitoring	• Soil gas and indoor air monitoring is performed on a quarterly basis or twice per quarter with samples collected at least 45 days apart. • The Department may approve alternative sampling frequencies. • Near-source and sub-slab soil gas samples are collected from all of the same probes in each event. • Indoor air samples are collected at all of the same locations in each event. • There is a minimum of two sampling rounds. • Statistical tests for screening are applied to the collective data from all near-source soil gas, sub-slab soil gas, or indoor air locations and rounds at each building or portion of a building with a potential VI impact. • Statistical tests may be used when there is a combination of at least eight sample locations and sampling rounds of any given type (near source soil gas, sub-slab soil gas, or indoor air) at each current or planned future building. • The following statistical test may be applied when screening VI data: Seventy-five percent of all samples are equal to or less than the applicable screening value with no individual sample exceeding ten times the screening value on the property (75%/10x test) and two times the screening value beyond the property boundary (75%/2x test). • An alternative statistical method may be applied to VI screening when the minimum number of samples specified by the documentation of the method have been collected: As applied in accordance with EPA approved statistical methods, the 95% UCL of the arithmetic mean is at or below the applicable screening value.

* The use of screening values may be restricted due to the presence of SPL, external preferential pathways, or significant foundation openings. See Sections IV.F and IV.G and Figure IV-9 for additional information on screening value use.

APPENDICES

Appendix IV-A: Methodology for Developing SHS Vapor Intrusion Screening Values

DEP has calculated screening values (SVs) for regulated substances of VI concern for use with the SHS. These SVs may be applied to appropriately collected data for indoor air, sub-slab soil gas, near-source soil gas, soil, and groundwater. The methods used to develop the SVs are explained in the following sections.

The SVs for subsurface media are derived using attenuation factors (α). An attenuation factor is the ratio between the contaminant concentration in indoor air and the equilibrium soil gas concentration in the unsaturated zone or sub-slab area ($\alpha \equiv C_{IA}/C_{SG}$).

DEP's approach is to first calculate indoor air SVs (SV_{IA}), then to determine sub-slab soil gas, near-source soil gas, soil, and groundwater SVs based on attenuation factors established for each of those POA.

As there are distinct attenuation factors for residential (α R) and nonresidential (α NR) structures, DEP carries out separate calculations for SVs that apply to buildings constructed for residential use that have been converted to a purely nonresidential use. These attenuation factors (α CR) are equal to the residential factors under the assumption that vapor flow rates and indoor air exchange rates are comparable to residential structures. The converted residential SVs are derived from the nonresidential indoor air SVs.

The VI screening values are provided in Tables IV-1-5 on the Department's Vapor Intrusion web page. They will be updated periodically using current scientific information when the 25 Pa. Code Chapter 250 MSCs are revised, consistent with the 25 Pa. Code § 250.11.

1. Indoor Air

Indoor air represents the point of exposure for inhalation of volatile chemicals in the VI pathway. The POA for indoor air screening is the basement or lowest occupied level of the building.

Contaminants that pose a risk for VI either have a boiling point less than 200°C or a Henry's law constant greater than or equal to 1×10^{-5} atm-m^3/mol and a molecular weight less than 200 g/mol. Certain regulated substances meet these criteria but currently have no inhalation toxicity values; they are listed in Table IV-A-1 on the Department's Vapor Intrusion web page. DEP has not published VI SVs for most of these chemicals. SHS VI evaluations are not available for substances without SVs. The remediator may choose to evaluate VI using the SSS for these chemicals. In addition, DEP does not consider the polycyclic aromatic hydrocarbons (PAHs) in Table IV-A-1 to be of VI concern because of their high boiling points, relatively low Henry's law constants, and very low vapor pressures.

In the case of 1,3,5-trimethylbenzene, DEP has chosen 1,2,4-trimethylbenzene as a surrogate for inhalation toxicity (U.S. EPA, 2016a). These two substances have similar chemical and toxicological characteristics.

Indoor air SVs (SV_{IA}) are determined from the inhalation risk equations in U.S. EPA (2009). This method is equivalent to that used by EPA for RSLs and in the VISL Calculator (U.S. EPA, 2014a, 2018b, 2018c). SVs for systemic toxicants ($SV_{IA(nc)}$) and carcinogens ($SV_{IA(c)}$) are calculated in units of micrograms per cubic meter ($\mu g/m^3$).

For systemic toxicants (non-carcinogens) the indoor air SV is:

$$\mathrm{SV_{IA(nc)}} = \frac{\mathrm{THQ} \times \mathrm{RfC_i} \times \mathrm{AT_{nc}} \times (365\,\frac{\mathrm{days}}{\mathrm{yr}}) \times (24\,\frac{\mathrm{hr}}{\mathrm{day}})}{\mathrm{ET} \times \mathrm{EF} \times \mathrm{ED}} \times \frac{1{,}000\ \mu\mathrm{g}}{\mathrm{mg}}$$

For carcinogens, the indoor air SV is:

$$\mathrm{SV_{IA(c)}} = \frac{\mathrm{TR} \times \mathrm{AT_c} \times (365\,\frac{\mathrm{days}}{\mathrm{yr}}) \times (24\,\frac{\mathrm{hr}}{\mathrm{day}})}{\mathrm{IUR} \times \mathrm{ET} \times \mathrm{EF} \times \mathrm{ED}}$$

For substances classified as mutagens, except for vinyl chloride and trichloroethylene, the residential carcinogenic indoor air SV is:

$$\mathrm{SV_{IA(c,m,R)}} = \frac{\mathrm{TR} \times \mathrm{AT_c} \times (365\,\frac{\mathrm{days}}{\mathrm{yr}}) \times (24\,\frac{\mathrm{hr}}{\mathrm{day}})}{\mathrm{IUR} \times \mathrm{ET} \times \mathrm{EF} \times \mathrm{AED}}$$

For vinyl chloride, the residential carcinogenic indoor air SV is:

$$\mathrm{SV_{IA(c,vc,R)}} = \frac{\mathrm{TR}}{\frac{\mathrm{IUR} \times \mathrm{ET} \times \mathrm{EF} \times \mathrm{ED}}{\mathrm{AT_c} \times (365\,\frac{\mathrm{days}}{\mathrm{yr}}) \times (24\,\frac{\mathrm{hr}}{\mathrm{day}})} + \mathrm{IUR}}$$

For trichloroethylene, the residential carcinogenic indoor air SV is:

$$\mathrm{SV_{IA(c,TCE,R)}} = \frac{\mathrm{TR} \times \mathrm{AT_c} \times (365\,\frac{\mathrm{days}}{\mathrm{yr}}) \times (24\,\frac{\mathrm{hr}}{\mathrm{day}})}{(\mathrm{IUR_k} \times \mathrm{AED} + \mathrm{IUR_l} \times \mathrm{ED}) \times \mathrm{ET} \times \mathrm{EF}}$$

As TCE has a mutagenic mode of action for the kidneys, the residential carcinogenic SV is calculated using distinct IUR values for kidney cancer and non-Hodgkin lymphoma and liver cancer (U.S. EPA, 2011a).

The nonresidential indoor air carcinogenic SVs for mutagens are determined using the non-mutagenic equation $\mathrm{SV_{IA(c)}}$ given above.

The variables and exposure factors in the above equations are defined in Table IV-A-2. Certain conditions are explained in § 250.307(h) of the regulations.

Residential and nonresidential indoor air SVs are defined as the lower of the applicable systemic, carcinogenic, and mutagenic values. The toxicity parameters used are from Chapter 250, Appendix A, Table 5A (Table IV-A-5 on the Department’s Vapor Intrusion web page).

Table IV-A-2: Inhalation Risk Variables

Symbol	Term	Residential	Nonresidential
THQ	Target Hazard Quotient, systemic toxicants	1.0	1.0
RfCi	Inhalation Reference Concentration (mg/m^3)	Table IV-A-5	Table IV-A-5
ATnc	Averaging Time for systemic toxicants (yr)	30	25
ET	Exposure Time (hr/day)	24	8
EF	Exposure Frequency (days/yr)	350	250
ED	Exposure Duration (yr)	30	25
TR	Target Risk, carcinogens	1 x 10–5	1 x 10–5
IUR	Inhalation Unit Risk ((µg/m^3)$^{-1}$)	Table IV-A-5	Table IV-A-5
ATc	Averaging Time for carcinogens (yr)	70	70
AED	Combined Age-Dependent Adjustment Factor and Exposure Duration (yr)	76	N/A
IURk	TCE IUR, residential, kidney cancer ((µg/m^3)$^{-1}$)	1.0 x 10–6	N/A
IURl	TCE IUR, residential, non-Hodgkin lymphoma and liver cancer ((µg/m^3)$^{-1}$)	3.0 x 10–6	N/A

2. Sub-Slab Soil Gas

The POA for sub-slab soil gas screening is immediately beneath the slab or basement of a building. In some circumstances, samples may be collected from behind basement walls or below intact paved areas large enough to be representative of future inhabited buildings. Sub-slab SVs (SV_{SS}) are defined using attenuation factors from U.S. EPA (2012b, 2015a). These SVs have units of micrograms per cubic meter (µg/m^3).

EPA derived a sub-slab attenuation factor (α_{SS}) from a statistical evaluation of 431 paired sub-slab and indoor air sampling data at over 400 residential buildings at 12 sites. The data was limited to chlorinated VOCs. The empirical attenuation factors are defined as $\alpha_{SS} = C_{IA}/C_{SS}$.

EPA's recommended residential attenuation factor is $\alpha_{SS,R} = 0.026$, the 95th percentile of the screened data. DEP has adopted this attenuation factor for all chemicals, including petroleum hydrocarbons, as a conservative approach. This residential factor also applies to nonresidential buildings that were originally constructed for residential use ($\alpha_{SS,CR}$) or that have mixed residential and commercial uses.

For nonresidential buildings that were constructed purely for nonresidential use (e.g., commercial, industrial, and institutional buildings), DEP adjusts EPA's attenuation factor to account for a higher air exchange rate in such structures. The 10th percentile air exchange rates for residential and commercial buildings are 0.18 and 0.60 air changes per hour, respectively (U.S. EPA, 2011b, Ch. 19). These are conservative rates, particularly for modern nonresidential buildings which typically have values exceeding 1 hr^{-1}. The adjusted nonresidential sub-slab attenuation factor is:

$$\alpha_{\mathrm{SS,NR}} = (0.026) \times \frac{0.18\ \mathrm{hr}^{-1}}{0.60\ \mathrm{hr}^{-1}} = 0.0078$$

Sub-slab SVs are calculated directly from the indoor air SVs using the applicable attenuation factor:

$$\mathrm{SV_{SS}} = \frac{\mathrm{SV_{IA}}}{\alpha_{\mathrm{SS}}}$$

3. Near-Source Soil Gas

Near-source soil gas samples are collected proximal to the source to minimize the influence of variable effects such as soil moisture, atmospheric conditions, and leakage from the surface into the sample that can bias shallow soil gas measurements. For groundwater and SPL the POA is immediately above the capillary zone throughout the area of the plume. For soil in the vadose zone the POA is within or immediately above the contaminated soil. Screening may be applied when at least a 5-foot vertical section of acceptable soil or soil-like material is present between the bottom of the building foundation and the depth where the near-source soil gas sample is obtained. (If a near-source soil gas sample is collected less than 5 feet below the foundation it may be screened using sub-slab soil gas SVs.) Near-source soil gas SVs ($\mathrm{SV_{NS}}$) are defined using attenuation factors derived from modeling as explained below. These SVs have units of micrograms per cubic meter (µg/m^3).

DEP estimated a near-source soil gas attenuation factor (α_{NS}) by running numerous J&E model simulations (Johnson and Ettinger, 1991; U.S. EPA, 2004). DEP utilized EPA's advanced soil model (version 3.1, February 2004) to determine soil gas source concentrations corresponding to specified indoor air SVs. The simulations encompassed 12 to 16 different chemicals, the full suite of soil types, and water-filled porosities ranging from residual saturation to the EPA default values in the J&E manual. DEP made conservative assumptions of a shallow source (5 feet) and a high vapor flow rate (Q_{soil} = 5 L/min). EPA's default building characteristics for a small, slab-on-grade building were retained. The models had low, 10th percentile values for the air exchange rate (0.18 hr^{-1} residential, 0.60 hr^{-1} nonresidential; U.S. EPA, 2011b, Ch. 19).

The results of this modeling indicated that there is relatively little variability in the soil gas attenuation factor for different conditions. The silt soil type has the highest attenuation factor because of its low residual water content and relatively high air-filled porosity. Representative factors are $\alpha_{\mathrm{NS,R}} = 0.005$ and $\alpha_{\mathrm{NS,NR}} = 0.001$ for residential and nonresidential scenarios. To further assess these values DEP examined the soil gas data in EPA's VI database (U.S. EPA, 2012b). Of 46 buildings at four sites with paired deep soil gas (> 10 feet) and indoor air measurements, only one exceeded the modeled attenuation factor of 0.005. (This exception had a calculated attenuation factor of 0.0075.)

Near-source SVs are calculated directly from the indoor air values using the applicable attenuation factor:

$$\mathrm{SV_{NS}} = \frac{\mathrm{SV_{IA}}}{\alpha_{\mathrm{NS}}}$$

4. Soil

Soil samples may be collected in the unsaturated zone as part of the site characterization or a demonstration of attainment following remediation. The POA is throughout the area of contamination. Screening may be applied to samples collected at any depth below the building foundation and above the water table. SPL should not be present. Soil SVs (SV_{SOIL}) are defined as the higher of a calculated SV and the generic soil-to-groundwater pathway numeric value for a used aquifer in 25 Pa. Code Chapter 250. Soil SVs have units of milligrams per kilogram, dry basis (mg/kg).

The calculated SVs are based on equilibrium partitioning of the contaminant between the sorbed phase on soil, the dissolved phase in pore water, and the vapor phase in the pore space. This relationship is given in § 250.308(a)(3) of the regulations, with the dilution factor set to 1:

$$\mathrm{SV}'_{\mathrm{SOIL}} = \left(f_{\mathrm{oc}}K_{\mathrm{oc}} + \frac{\theta_{\mathrm{w}}}{\rho_{\mathrm{b}}}\right)C_{\mathrm{pw}} \times \frac{1\ \mathrm{mg}}{1{,}000\ \mu\mathrm{g}}$$

where SV'_{SOIL} is the calculated SV for soil (mg/kg) and C_{pw} is the concentration in pore water (µg/L). The other parameters are defined in Table IV-A-3. The value of f_{oc} is from § 250.308(a)(3). The dry bulk density used is representative of typical soil types (U.S. EPA, 2004, 2017). DEP defines θ_w equal to 0.1 to represent relatively dry conditions, close to residual saturation, beneath a building.

The pore water concentration is related to the pore vapor concentration (C_{pv}) by Henry's law:

$$C_{\mathrm{pw}} = \frac{C_{\mathrm{pv}}}{H'} \times \frac{1\ \mathrm{m}^3}{1{,}000\ \mathrm{L}}$$

where Cpv has units of micrograms per cubic meter (µg/m^3). H' is calculated at a soil temperature of 16°C (61°F) (Appendix IV-B).

The value of the pore vapor concentration is determined from the SV_{IA} by means of soil attenuation factors:

$$C_{\mathrm{pv}} = \frac{\mathrm{SV}_{\mathrm{IA}}}{\alpha_{\mathrm{SOIL}}}$$

The soil attenuation factors were determined through testing with the J&E model as described in Section IV-A.3 of this appendix, but with a source depth of 0.5 feet, directly below the slab. The corresponding factors are $\alpha_{SOIL,R} = 0.01$ and $\alpha_{SOIL,NR} = 0.002$.

The soil SVs are limited by the residual saturation value of 10,000 mg/kg as defined in § 250.305(b).

Each calculated SV is compared to the generic soil-to-groundwater pathway numeric value for a used aquifer with total dissolved solids less than or equal to 2,500 mg/L (25 Pa. Code Chapter 250, Appendix A, Table 3B), and DEP defines the higher of the two values as the soil SV for VI (SV_{SOIL}). The generic soil-to-groundwater numeric values are considered appropriate for VI screening because soil contamination that is unable to impact aquifers in excess of groundwater MSCs is also unlikely to pose an excess inhalation risk. DEP also recognizes that the infinite source assumption used to calculate SVs is very conservative, that soil contamination commonly occurs outside the footprint of potentially impacted buildings, and that these SVs do not account for the natural biological degradation of petroleum hydrocarbons in soil vapor.

Table IV-A-3: Soil Partitioning Parameters

Symbol	Description	Value
f_{oc}	fraction organic carbon in soil	0.0025
K_{oc}	organic carbon partitioning coefficient (L/kg)	Table IV-A-5
θ_w	water-filled porosity of soil	0.1
ρ_b	dry bulk density of soil (kg/L)	1.5
H'	Henry's law constant at soil temperature	Table IV-A-5

5. Groundwater

Groundwater data that have been collected as part of the site characterization or a demonstration of attainment may be used for VI screening. The POA is throughout the area of the groundwater plume. Certain conditions apply to groundwater screening. Groundwater samples are collected from properly constructed monitoring wells screened across the water table, and the wetted length of the well screen should be no more than 10 feet. SPL is not present. When using screening values for groundwater that is at least 5 feet below the foundation, acceptable soil or soil-like material should be present between the groundwater and the foundation.

Groundwater SVs (SV_{GW}) for depths less than 5 feet below the foundation are defined by the groundwater MSCs for a used aquifer. Groundwater SVs for depths of 5 feet below the foundation and greater are defined as the higher of calculated SVs based on empirically determined attenuation factors and the groundwater MSCs for a used aquifer. SVs have units of micrograms per liter (µg/L).

EPA developed a database of 774 paired groundwater and indoor air sampling data at over 600 residential buildings located at 24 sites (U.S. EPA, 2012b). The data was limited to chlorinated VOCs. EPA performed a statistical evaluation of the database, and they recommended an attenuation factor of 0.001. This value is the 95th percentile of the screened data. The groundwater attenuation factor is defined as $\alpha_{GW} = C_{IA}/C_{GW}$.

The Department has reexamined EPA's database by considering two additional factors. One is the uncertainty in the groundwater temperatures selected for each site. In some instances the assigned temperatures may have been underestimated. The other is that EPA's evaluation included some data from buildings over shallow groundwater (less than 5 feet below the foundation). DEP reanalyzed the database with a range of plausible annual average groundwater temperatures and without the shallow groundwater data.

DEP has derived a residential groundwater attenuation factor of 0.0009 for groundwater that is at least 5 feet below the foundation. DEP has adopted this attenuation factor for all chemicals, including petroleum hydrocarbons, as a conservative approach. This residential factor ($\alpha_{GW,R}$) also applies to nonresidential buildings that were originally constructed for residential use ($\alpha_{GW,CR}$) or that have mixed residential and commercial uses.

For nonresidential buildings that were constructed purely for nonresidential use (e.g., commercial, industrial, and institutional buildings), DEP adjusts the residential attenuation factor to account for a higher air exchange rate in these structures. The 10th percentile air exchange rates for residential and commercial buildings are 0.18 and 0.60 air changes per hour, respectively (U.S. EPA, 2011b, Ch. 19). The adjusted nonresidential groundwater attenuation factor is:

$$\alpha_{\mathrm{GW,NR}} = (0.0009) \times \frac{0.18\ \mathrm{hr}^{-1}}{0.60\ \mathrm{hr}^{-1}} = 0.0003$$

Calculated groundwater SVs ($\mathrm{SV}'_{\mathrm{GW}}$) are determined from the indoor air SVs using the applicable attenuation factor and a conversion from soil gas to a dissolved concentration via Henry's law:

$$\mathrm{SV}'_{\mathrm{GW}} = \frac{\mathrm{SV}_{\mathrm{IA}}}{\alpha_{\mathrm{GW}}} \times \frac{1}{(1{,}000\ \mathrm{L/m^3})H'}$$

where H' is the nondimensional Henry's law constant at the groundwater temperature (Table IV-A-5 on the Department's VI web page). DEP calculates the Henry's law constant at a groundwater temperature of 16°C (61°F) (Appendix IV-B).

DEP compares each calculated SV to the groundwater MSC for a used aquifer with total dissolved solids less than or equal to 2,500 mg/L (Chapter 250, Appendix A, Table 1). DEP defines the groundwater SV for VI ($\mathrm{SV}_{\mathrm{GW}}$) for depths of 5 feet below the foundation and greater as the maximum of the calculated SV ($\mathrm{SV}'_{\mathrm{GW}}$) and the MSC, limited by the aqueous solubility (S). DEP regards the groundwater MSCs as suitable for VI screening at any depth because they are acceptable for water used inside homes, including inhalation exposures.

6. Building Foundation Openings

The sub-slab soil gas and groundwater attenuation factors are derived from EPA's database of residential VI sampling. DEP recognizes that many of the buildings used in EPA's study likely had typical foundation openings such as sumps, French drains, floor drains, and gaps around utility penetrations. (For instance, over three-quarters of the homes included in the sub-slab attenuation factor analysis had basements, and EPA did not filter the data for the presence of foundation openings.) For this reason, DEP considers the attenuation factors and screening values to be applicable to buildings with common openings. For a small house with a sump and an open, interior French drain, the size of these openings would not be more than a few percent of the foundation area. DEP's threshold for significant openings, which preclude the use of the attenuation factors and SVs, is 5% of the foundation area (Section IV.D.2).

DEP establishes attenuation factors for near-source soil gas and soil based on J&E model simulations. These tests assume a conservative, high vapor flow rate into the building, which would be representative of vapor entry through typical foundation openings. Therefore, the near-source soil gas and soil attenuation factors and SVs are also applicable to buildings that do not have foundation openings exceeding 5% of the foundation area.

7. Attenuation Factor Summary

The attenuation factors used to calculate the VI SVs are listed in Table IV-A-4. The sub-slab and groundwater attenuation factors are based on EPA's empirical database (U.S. EPA, 2012b). The near source soil gas and soil attenuation factors are defined from DEP's modeling studies.

Table IV-A-4: Attenuation Factors

Sample Type	α R	α NR	α CR
Sub-slab soil gas	0.026	0.0078	0.026
Near-source soil gas	0.005	0.001	0.005
Soil	0.01	0.002	0.01
Groundwater	0.0009	0.0003	0.0009

R: residential building
NR: nonresidential building
CR: residential building converted to nonresidential use

The near-source and sub-slab soil gas attenuation factors may also be used within a SSS risk assessment for estimating indoor air concentrations (Section IV.K.4) or for calculating SVs from EPA’s indoor air RSLs (Section IV.K.5).

Appendix IV-B: Vapor Intrusion Modeling Guidance

DEP recommends the use of EPA's J&E model (U.S. EPA, 2004) for analyzing VI with the SHS and SSS. Remediators may use DEP's versions of the model which are based on EPA's advanced model version 3.1 spreadsheets. These versions are posted on DEP's website, and they will be updated periodically with the most recent toxicological and other model input parameters.

This appendix describes key assumptions and limitations of the J&E model, acceptable adjustments to default input values, and the use of alternative models for petroleum hydrocarbons.

1. Background

The J&E model solves for the transport of vapor-phase contaminants into a building above the source (Johnson and Ettinger, 1991; U.S. EPA, 2004, 2017). There are three spreadsheets for the different source types: groundwater, soil, and soil gas. The model calculates the vaporization of dissolved or adsorbed contaminants, the diffusion of these vapors toward the surface, their advection through the foundation or slab into the occupied space, and their dilution in indoor air. The calculations rely on five sets of parameters integral to this process and the inhalation risk assessment:

- source description (e.g., depth)
- chemical properties
- toxicological properties
- capillary fringe and vadose zone properties (e.g., soil type)
- building characteristics (e.g., air exchange rate).

The J&E model is an approximation that is dependent on many parameters, not all of which are well known. It is not easily calibrated; therefore, the user should input conservative values to avoid underestimating inhalation risks. Users submitting J&E models to DEP are expected to be familiar with EPA's *User's Guide* and should understand the model's assumptions and limitations (U.S. EPA, 2004, 2017).

Several studies have compared J&E model results to field data (Hers *et al.*, 2003; Provoost *et al.*, 2009, 2010) and to numerical analyses (Yao *et al.*, 2011). This research indicates that J&E gives reasonable, conservative results in most cases, within about one order of magnitude. These studies reinforce the need to use J&E with caution because the model is highly sensitive to some parameters. It is essential to have adequate site data and a strong CSM when modeling VI.

The objective of VI modeling is to determine if an Act 2 standard is attained. Although the EPA spreadsheets can calculate screening values, models submitted to DEP should not be used in this manner. Users must instead input the contaminant concentration on the DATENTER worksheet to calculate the incremental risk. The DEP versions give results in two forms, depending on the Act 2 standard selected for the contaminant.

For SHS evaluations, the user compares the predicted indoor air concentration on the RESULTS sheet to the SHS indoor air screening value (SV_{IA}) (Table IV-5 on the Department's VI web page).

For SSS risk assessments, the user obtains the incremental carcinogenic and noncarcinogenic inhalation risks from the RESULTS sheet, determines the cumulative risks for all SSS contaminants of concern, and compares the cumulative risks to the Act 2 thresholds (Section IV.K.5).

Under appropriate conditions in the SSS, predicted indoor air concentrations can be compared to occupational limits (OSHA PELs) (Section IV.K.7).

2. Assumptions

Users are referred to EPA's J&E *User's Guide* for a complete description of the model (U.S. EPA, 2004, 2017). It has several critical assumptions and limitations that all users must be aware of.

- The source extent is horizontally and vertically infinite. Source mass does not diminish with time. These are conservative assumptions.
- No SPL is present for soil and groundwater modeling.
- The solution is one-dimensional, accounting only for vertical vapor transport; lateral migration of vapors is ignored.
- Soil properties are homogeneous.
- There is no biodegradation of contaminant vapors in the vadose zone, a conservative assumption.
- There are no preferential pathways between the source and the building.
- The system is in steady state; that is, vapor transport is in equilibrium.
- The model does not account for the combined effects of multiple contaminants.

In addition, see U.S. EPA (2004, 2017) Section 2.4.

3. J&E Model Parameter Adjustments

Key input parameters and allowable changes to these values for VI modeling are explained in this section. The Department's conservative default model parameter values, as input on the DATENTER sheet of the J&E spreadsheet, are given in Table IV-B-1. Most input values used are EPA's defaults.

EPA developed their J&E model as a screening tool, and they recommend against using it to predict a unique indoor air concentration or risk (U.S. EPA, 2017). However, because DEP accepts J&E model results as a single line of evidence when sufficient supporting information is available, users should bias inputs (including source concentrations) to upper range values, not average or central tendency values.

Table IV-B-1: Adjustable J&E Model Input Parameters and Default Values

Parameter	Symbol	Residential	Nonresidential
Average soil/groundwater temperature (°C)	T_s	Table IV-B-2	Table IV-B-2
Depth below grade to bottom of enclosed space floor[1] (cm)	L_F	10 / 200	15 / 200
Depth below grade to source (cm)	L_{WT}, L_t, L^s	150	150
Thickness of soil strata (cm)	h	150	150
Capillary and vadose zone USDA soil types		sandy loam	sandy loam
Soil dry bulk density[2] (g/cm^3)	ρ_b	1.62	1.62
Soil total porosity[2]	n	0.387	0.387
Soil water-filled porosity[2]	θ_w	0.1	0.1
Enclosed space floor thickness (cm)	L_{crack}	10	10
Enclosed space floor length (cm)	L_B	1000	1000
Enclosed space floor width (cm)	W_B	1000	1000
Enclosed space height[3] (cm)	H_B	244 / 366	244 / 366
Indoor air exchange rate (hr^{-1})	E_R	0.18	0.60
Average vapor flow rate into building[4] (L/min)	Q_{soil}	5	5

Notes to Table IV-B-1

1 Default is 15 cm for a slab-on-grade building and 200 cm for buildings with basements.
2 The values shown are for a sandy loam. Models must use the J&E default values associated with the selected soil type unless soil samples are tested for physical characteristics.
3 Default is 244 cm for slab-on-grade buildings and 366 cm for buildings with basements.
4 Adjust default based on building size; see text.

- **Source concentration (C_W, C_R, C_g):** The user enters an appropriate contaminant concentration for groundwater (C_W, µg/L), soil (C_R, µg/kg), or soil gas (C_g, µg/m^3). Source data should conform to the conditions in Table IV-6. Input concentrations should generally be the maximum from recent sampling in the source area near current or future buildings (see Appendix IV-C, Figures IV-C-1-3). If sufficient data are available, a 95% UCL of the mean may be a suitable value. The data selected for determining the source concentration may have been collected for the site characterization and/or the demonstration of attainment. When the vapor source is a groundwater plume, fate-and-transport modeling may be used to estimate groundwater concentrations at downgradient receptors if monitoring well data is unavailable. The groundwater model should be calibrated, conservative, and applied in a manner consistent with DEP's Quick Domenico (QD) user's guide (Pennsylvania DEP, 2014). For the soil gas J&E model only near-source soil gas data may be used, and the source may include SPL.

- **Building foundation:** The default foundation type is slab-on-grade construction. The type of foundation establishes the value of the depth below grade of the enclosed space floor (L_F). For slab-on-grade foundations the EPA default is L_F = 10 cm (0.3 feet); for basements it is L_F = 200 cm (6.6 feet). This value may be altered with supporting documentation for the site building.

- **Depth below grade to source (L_{WT}, L_t, L_s):** The default value is 150 cm (5 feet). The user enters the actual minimum depth based on the site characterization and/or monitoring data. For groundwater, it should be the seasonally high water table depth of the contaminated aquifer (L_{WT}). For soil, it should be the depth to the top of contaminated soil (L_t). DEP recommends using the shallowest depth that either exceeds the soil screening value (SV_{SOIL}) or that is contaminated as indicated by field screening. For soil gas the source depth is the top of the screen in the soil gas probe (L_s).

  Acceptable soil or soil-like material should be present between the building foundation and the contaminant source. Acceptable soil or soil-like material will not have the following characteristics: obvious contamination (staining or odors), field instrument readings in the head space above soil samples greater than 100 ppmv, evidence of SPLs, or exceedances of soil screening values (refer to Section IV.B of the guidance). The thickness of acceptable soil or soil-like material may be less than 5 feet.

  Where there is a basement, the source must be entirely below the foundation as J&E does not model lateral vapor transport. Soil or groundwater with concentrations exceeding screening values cannot be in contact with the foundation. J&E simulates vapor diffusion through homogeneous, isotropic porous media. Therefore, it cannot determine vapor migration through fractured bedrock. If the water table is below the bedrock interface, then the model groundwater source depth (L_{WT}) should be input as the depth to bedrock. A continuous layer of acceptable soil or soil-like material should be present between the bedrock surface and the building foundation.

- **Depth below grade to bottom of contamination (L_b):** A finite source calculation is allowed for the soil model if the depth to the bottom of the contaminated soil has been delineated.

- **Soil/groundwater temperature (T_S):** Long-term average subsurface temperatures depend on the average air temperature of the locale and the nature of the surface material. Ground temperatures are higher in developed areas with buildings and pavement than where the land is undeveloped. DEP has compiled shallow groundwater temperature data collected during low-flow purging of monitoring wells at sites in the Southeast Region of Pennsylvania. In addition, DEP has examined continuous soil temperature data from three U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS), Soil Climate Analysis Network stations (Mahantango Creek, PA; Rock Springs, PA; and Powder Mill, MD). Each data set was compared to air temperature data collected from weather stations during corresponding periods. This information was supplemented with the study by Taylor and Stefan (2008).

  Average shallow subsurface temperatures are typically ~4°C higher than local air temperatures. DEP recommends using a model soil/groundwater temperature that is 4°C greater than the long-term average air temperature for the region. Thirty-year average temperatures for 1986–2015 available from the National Oceanic and Atmospheric Administration’s (NOAA) NOWData application ranged from 50°F to 56°F (10–14°C) for Pennsylvania. Therefore, estimated regional average soil/groundwater temperatures are 14–18°C (Table IV-B-2).

Table IV-B-2: Pennsylvania Shallow Soil and Groundwater Temperatures

Northwest Region	**Northcentral Region**	**Northeast Region**
14°C	15°C	14°C
Southwest Region	**Southcentral Region**	**Southeast Region**
15°C	16°C	18°C

Users may input a site-specific soil and groundwater temperature based on data from a local weather station. The long-term average air temperature should be increased by 4°C for input as T_S. Discrete groundwater temperature measurements collected over a short period of time may not be representative of long-term conditions.

- **Soil type:** It is the user's responsibility to assess soil boring logs to select an appropriate soil type for input to the model. Field logging of borings should be performed by a qualified environmental professional (i.e., a geological scientist or a soil scientist). Where the soil is heterogeneous or there are different interpretations of the soil type, professional judgment must be used, but the best practice is to select the soil type with the greatest VI potential. This may require sensitivity testing of the model. The user may define up to three soil layers in the model if sufficient data has been obtained to support this option. The soil type entry in DEP's model versions is a sandy loam as a conservative default.

  EPA categorized soil using the U.S. Department of Agriculture's Soil Conservation Service (SCS) (now the NRCS) soil types. To select the soil type, the environmental professional interprets boring logs based on the Unified Soil Classification System (ASTM, 2011a) in terms of the SCS classifications. A gradation analysis of soil samples is the best means to select the proper soil type in J&E (ASTM, 2007). Table IV-B-3 can also assist the user with this selection, and Figure IV-B-1 shows the SCS soil types in terms of the proportions of clay, silt, and sand.

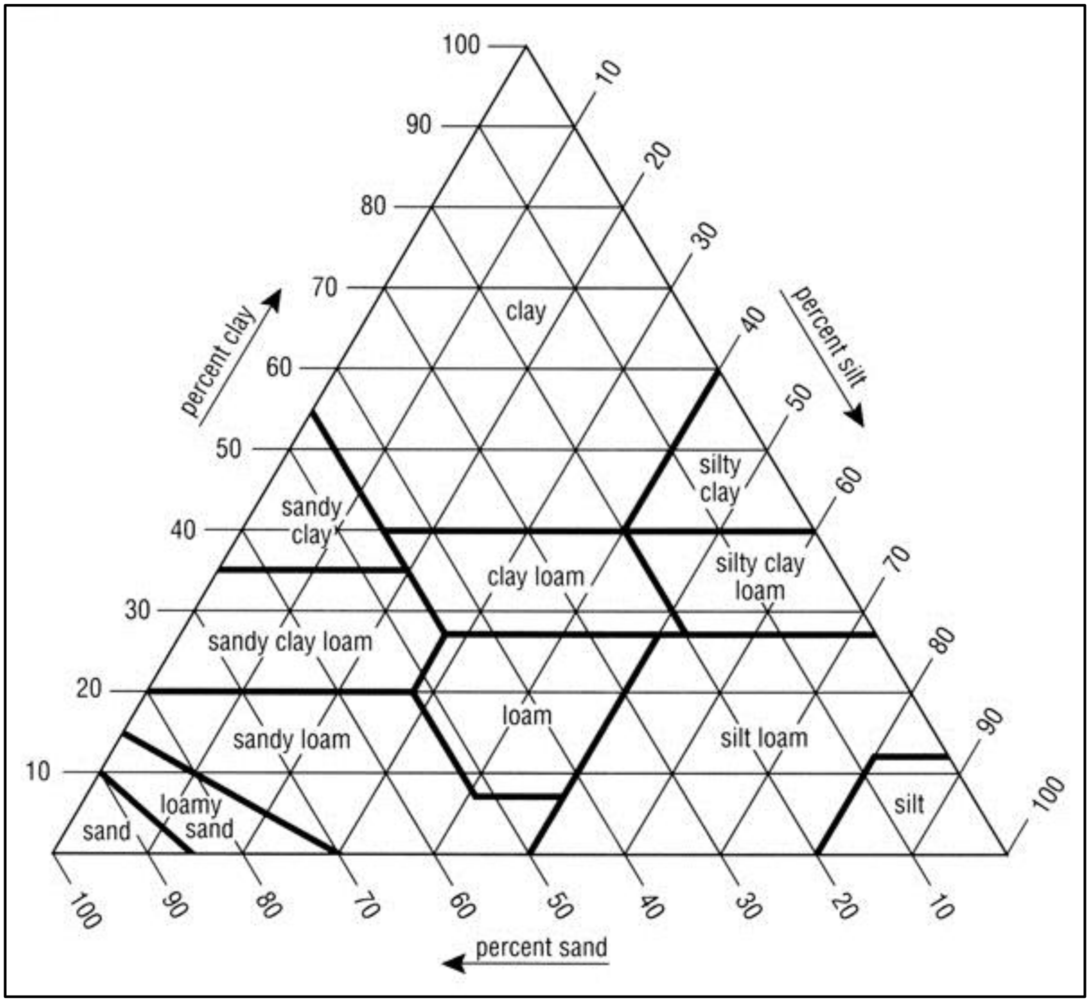
  If artificial fill is present, then the user must be cautious in applying the J&E model to the site. The fill might have characteristics sufficiently close to a USDA soil type to be acceptable for modeling; if so, the user can choose an appropriate soil type with justification in the report.

Table IV-B-3: Guidance for the Selection of the J&E Model Soil Type

	Predominant Soil Types in Boring Logs	Recommended Soil Classification
•	Sand or Gravel or Sand and Gravel, with less than about 12% fines, where “fines” are smaller than 0.075 mm in size.	Sand
•	Sand or Silty Sand, with about 12% to 25% fines	Loamy Sand
•	Silty Sand, with about 20% to 50% fines	Sandy Loam
•	Silt and Sand or Silty Sand or Clayey, Silty Sand or Sandy Silt or Clayey, Sandy Silt, with about 45 to 75% fines	Loam
•	Sandy Silt or Silt, with about 50 to 85% fines	Silt Loam

Source: U.S. EPA (2017), Table 14

Figure IV-B-1: USDA SCS Soil Classification Chart



Source: USDA (1993, Ch. 3).

- **Soil properties:** DEP has adopted the EPA default values for bulk soil density (ρ_b) and total porosity (n), which depend on the soil type. These values should not be altered unless properly collected samples (e.g., in thin-walled tubes) have been analyzed for these parameters (ASTM, 2009, 2010a). DEP does not consider the EPA default water-filled porosity values (θ_w) to be sufficiently conservative because soil beneath buildings is relatively dry. DEP's default value is 0.1 or the residual saturation (θ_r), whichever is greater for the soil type. The user can change θ_w only based on laboratory analyses of the moisture content of properly collected soil samples from underneath the building or an intact paved area large enough to be representative of a future inhabited building (ASTM, 2010b).

- **Fraction of organic carbon (f_{oc}):** The default value is 0.0025 from EPA and § 250.308(a). The user may change this value for soil modeling only with laboratory measurements of f_{oc} in site soils (e.g., U.S. EPA Method 9060A). However, the f_{oc} may be set to zero if the material is not believed to contain any organic carbon.

- **Floor thickness (L_{crack}):** The EPA default value is 10 cm (4 inches). This may be changed by the user if the actual (or planned) slab thickness is known. A dirt floor may be simulated with a value of zero.

- **Building dimensions (L_B, W_B, H_B):** The EPA default residential floor space area is 1,080 ft^2 (100 m^2) for a 10- by 10-m home. Default enclosed space heights (H_B) are 244 cm (8 feet) for slab-on-grade buildings and 366 cm (12 feet) for structures with basements. Note, however, that if indoor air does not communicate efficiently between the basement and the first floor, then the default value is not conservative and it should be reduced. The user may input the actual (or planned) building dimensions.

- **Air exchange rate (ER):** Air exchange rates exhibit a large range for different buildings and seasons. DEP adopts the current 10th percentile residential value of 0.18 hr^{-1} (U.S. EPA, 2011b, Ch. 19). The measured range in a study of 100 office buildings was approximately 0.2–4.5 per hour (Persily and Gorfain, 2009). A 10th percentile nonresidential value is 0.60 hr^{-1} (U.S. EPA, 2011b, Ch. 19). The user should input these 10th-percentile values for residential and nonresidential buildings. The actual air exchange rate of an existing or planned building may be input to the J&E model if it has been measured or is documented in the heating, ventilation and air conditioning (HVAC) system design and settings.

- **Vapor flow rate (Q_{soil}):** The soil gas flow rate into buildings is highly uncertain, and it depends on the material in contact with the foundation, the arrangement of cracks and other foundation openings, the pressure differential, and other factors. The EPA default value is 5 L/min based on tracer gas studies at five sites summarized by Hers *et al.* (2003). In the absence of better information on this parameter, DEP's default Q_{soil} is 5 L/min. If the user changes the building dimensions (LB and WB) then the value of Q_{soil} should be scaled correspondingly. Assuming vapor entry through foundation perimeter cracks, the scale factor is the ratio of the building perimeters. The default perimeter for the 10- by 10-m building is 40 m (130 feet). For example, if the building dimensions are 50 feet by 100 feet, the perimeter is 300 feet, the scale factor is 2.3, and Q_{soil} = 12 L/min.

  Another option is to enter a soil vapor permeability value and allow the model to calculate Q_{soil}. This is permitted only if the user obtains vapor permeability test data for the soil in contact with the foundation (ASTM, 2013a).

> Although the prior version of J&E (U.S. EPA, 2004) provided for a calculation of Q_{soil} based on the soil type, this option is no longer available in the DEP and EPA models (U.S. EPA, 2017). The pressure differential (ΔP) and crack width (w) inputs were used only for the Q_{soil} calculation and are therefore disabled in the DEP spreadsheets.

Chemical, physical, and toxicological properties for substances with VI potential are found in the VLOOKUP sheet. DEP's default values are listed in Table IV-A-5 on the Department's VI web page. These default properties and the default residential or nonresidential exposure factors cannot be changed in SHS modeling. (Model-predicted indoor air concentrations for the SHS do not depend on the exposure factors on the DATENTER sheet or the toxicological parameters in the VLOOKUP sheet.)

The EPA J&E model versions do not account for the effect of mutagenic chemicals on the cancer risks for residential exposure scenarios. The inhalation risk equations for mutagens are provided in Appendix IV-A. DEP's versions of the spreadsheets include a mutagenic risk adjustment factor (MRF) that is applied when the exposure time is entered as 24 hr/day. For the default conditions, MRF = 1.4 for trichloroethylene, 3.4 for vinyl chloride, and 2.5 for other mutagens.

4. Site-Specific Standard Parameter Adjustments

Users of the J&E model may change certain chemical and toxicological properties in the VLOOKUP sheet for the SSS.

- **Organic carbon partition coefficient (K_{oc}):** The default values are from Chapter 250, Appendix A, Table 5A. The values may be changed only if the user obtains laboratory test data of soil samples collected at the site.

- **Toxicity parameters (IUR, RfC_i):** The inhalation unit risk (or unit risk factor, URF) and the inhalation reference concentration are from Chapter 250, Appendix A, Table 5A. For a SSS risk assessment, the user should determine if there is more recent toxicity information available. Current values should be substituted for the Chapter 250 values, if available.

Exposure factors are entered on the DATENTER sheet for SSS risk assessments. The default values are listed in Table IV-B-4. Residential factors should not be changed. The user may adjust nonresidential factors based on conditions at the site. For instance, the daily exposure time could depend on the workplace shift length. EPA currently recommends a residential exposure duration of 26 years (U.S. EPA, 2014b), which may be used in SSS models. (DEP's versions of the J&E spreadsheets include a field for the exposure time (ET), allowing it to be altered from the residential default of 24 hr/day.)

Table IV-B-4: J&E Model Default Exposure Factors

Symbol	Term	Residential	Nonresidential
AT_{nc}	Averaging Time for systemic toxicants (yr)	30	25
ET	Exposure Time (hr/day)	24	8
EF	Exposure Frequency (days/yr)	350	250
ED	Exposure Duration (yr)	30	25
AT_c	Averaging Time for carcinogens (yr)	70	70

5. Petroleum Hydrocarbons

DEP can accept the use of models that account for biodegradation when evaluating petroleum hydrocarbon VI. Examples include the American Petroleum Institute's BioVapor (API, 2010) and EPA's PVIScreen (U.S. EPA, 2016b).

BioVapor and PVIScreen have several additional parameters that must be assessed in the modeling. The user should test the model sensitivity to these values.

- **Oxygen boundary condition:** The user should normally select a constant air flow rate (Q_f), and this is typically set equal to the vapor flow rate through the foundation (e.g., Q_{soil} = 5 L/min). If site data is collected to determine vertical profiles of oxygen, carbon dioxide, and methane concentrations, then the user may estimate the depth of the aerobic zone for model input.

- **Baseline soil oxygen respiration rate:** The model scales this rate with the fraction of organic carbon (f_{oc}), which is not typically known for the site. A default value is provided in PVIScreen.

- **Biodegradation rate constants (k_w):** BioVapor selects default first-order, aqueous phase, aerobic decay rates. Actual degradation rates are extremely variable, and PVIScreen accounts for their uncertainty. Vertical profiling of contaminant concentrations in soil gas may allow the user to estimate the decay rates.

EPA produced an NAPL version of the J&E model (U.S. EPA, 2004). This model was limited to residual NAPL in soil; it was not applicable to mobile NAPL on groundwater. DEP has not developed an updated version of EPA's NAPL spreadsheet, and it is not available in EPA's current J&E version (U.S. EPA, 2017). DEP recommends the collection of near-source soil gas data in areas of SPL (NAPL) for purposes of VI modeling.

6. Attenuation Factor Risk Calculations

SSS screening and risk assessments may also be performed under certain conditions with near-source soil gas and sub-slab soil gas data by using conservative attenuation factors (α). An attenuation factor is the ratio between the contaminant concentration in indoor air and the equilibrium soil gas concentration in the unsaturated zone ($\alpha \equiv C_{IA}/C_{SG}$). Therefore, conservative indoor air concentrations may be estimated using a measured or calculated soil gas concentration and an appropriate attenuation factor. Refer to Appendix IV-A for the relevant equations and Table IV-A-4 for DEP's default attenuation factors. The conditions for using near-source soil gas attenuation factors are the same as those listed for the screening values in Section IV, Table IV-6.

Other soil gas attenuation factors may be used with adequate justification for the SSS. For instance, a tracer test could be used to determine a sub-slab attenuation factor (α_{SS}) for the building. The default attenuation factors may be scaled with actual air exchange rates (AER) for the building. DEP's default indoor air exchange rates are 0.18 hr^{-1} for residential properties and 0.60 hr^{-1} for nonresidential facilities. The adjusted attenuation factor (α') is the product of the default attenuation factor and the ratio of the default AER and the actual AER. For example, if a nonresidential building has a measured air exchange rate of 1.2 hr^{-1}, then the sub-slab attenuation factor may be reduced as follows:

$$\alpha'_{\text{SS,NR}} = \alpha_{\text{SS,NR}} \frac{0.60\ \text{hr}^{-1}}{1.2\ \text{hr}^{-1}} = (0.0078) \frac{0.60\ \text{hr}^{-1}}{1.2\ \text{hr}^{-1}} = 0.0039$$

7. Report Contents

The J&E modeling should be fully documented in the submitted report. The information provided should be sufficient for DEP to understand how the modeling was performed and to reproduce the results. The model description should include the following.

- An explanation for how the model is being used to evaluate the VI pathway; that is, for a SHS prediction of indoor air concentrations or a SSS human health risk assessment.

- A list of the contaminants of concern being modeled and the source concentration inputs.

- An explanation of how source concentrations were selected (for example, the maximum groundwater concentrations from monitoring well data).

- A table of all input parameters, such as source depth and soil type.

- The reasoning for any changes to default input values.

- References for any changes to toxicological values in SSS models.

- A table of the predicted indoor air concentrations for each contaminant of concern in SHS reports, or a table of the individual and cumulative inhalation risks in SSS reports.

- A figure showing the source area, the locations of sample points used for the source concentrations, any preferential pathways, and potentially impacted buildings.

- An appendix with J&E worksheet printouts for the modeling. The DATENTER and RESULTS sheets should be provided for each contaminant of concern. One copy of the VLOOKUP sheet should be included.

Appendix IV-C: Vapor Intrusion Sampling Methods

1. Introduction

This appendix provides guidance on sampling and testing procedures to support VI investigations and mitigation. It describes recommendations for collecting VI-related samples, but it is not meant to be a manual with step-by-step instructions for VI sampling requirements. Professional judgment should be exercised during the development of sampling plans considering that every site will have its own unique conditions. Remediators are encouraged to communicate with the DEP Project Manager to determine the best path forward for VI sampling.

The information in Appendix IV-C includes descriptions of the methods and (QA) procedures to be used when collecting and analyzing VI-related samples. DEP's focus is on sampling with Summa canisters and U.S. EPA Method TO-15 analyses. When other methods are used the remediator should refer to alternative sources and consult with the laboratory. This appendix also provides guidance on testing to confirm the effectiveness of sub-slab depressurization systems which are the most commonly used VI mitigation technology for existing buildings.

a) Applicability

The guidance supplied by this appendix applies whenever sampling and analysis of soil gas or indoor air is performed:

- During site characterization;
- During site monitoring following site characterization;
- Following remediation; or
- When mitigation is performed using sub-slab depressurization (SSD) systems.

The information provided herein may be used to address VI sampling or mitigation activities under either the SHS or the SSS or under a combination of these two standards. These procedures also apply regardless of the size or scope of the VI evaluation when sampling and analysis of indoor air or soil gas is performed or a SSD System is used to mitigate VI.

b) Conceptual Site Model Development

A comprehensive CSM is an important tool in the development of a sampling and analysis plan. The CSM is needed to determine the locations and types of samples that are to be taken. More information on the development of a comprehensive CSM can be found in Section IV.C.1.

c) Spatial and Temporal Variability Considerations

When preparing a VI sampling plan it is important to consider the spatial and temporal variability of contamination in soil gas and indoor air. Spatial variability refers to non-uniform concentrations at different locations within or beneath the same building.

Temporal variability involves concentrations that change from one sampling event to the next. Compared to groundwater concentrations, there are many complicating factors that can cause significant variability in vapor data.

Some causes of spatial variability include:

- Distribution of the source in soil or groundwater;
- Natural heterogeneity (different soil types, soil moisture, bedrock fractures);
- Oxygen distribution in the soil (aerobic/anaerobic conditions);
- Subsurface building structures (footers, utilities);
- Surface features (pavement).

Some causes of temporal variability include:

- Wind, barometric pressure, temperature;
- Precipitation, infiltration, soil moisture, frozen ground;
- Building ventilation, heating, cooling;
- Ambient contaminants (indoor and outdoor sources);
- Sampling errors (equipment leaks).

Research studies have been conducted regarding the spatial variability of vapor concentrations by collecting multiple samples beneath, around, or within buildings (e.g., McHugh *et al.*, 2007; Luo *et al.*, 2009; U.S. EPA, 2012b, 2015c). The results of these studies have shown that sub-slab and soil gas concentrations can span orders of magnitude at a given building, even for moderately sized homes. Indoor air concentrations tend to show less variability as indoor air is typically well mixed in homes and smaller nonresidential buildings. Larger buildings may show greater room-to-room variability influenced by spatial heterogeneity of VI in those areas, possible indoor sources, and different ventilation conditions. For the same reasons, a sample collected at one building may not be representative of conditions at a neighboring building.

Accounting for VI spatial variability in the sampling plan is similar to adequately characterizing soil contamination at a site: a sufficient number of sample points must be installed to evaluate representative concentrations. The CSM should be the guide for choosing these locations. The horizontal and vertical distribution of the vapor source relative to the building, the soil and bedrock conditions, likely pathways to and through the foundation, and the building characteristics (construction, ventilation, etc.) should be considered by the environmental professional developing the sampling approach. Based on site-specific conditions, a single sample location may not be adequate.

Repeat sampling of the same location at several study sites has similarly demonstrated substantial changes in vapor concentrations over time (e.g., Folkes *et al.*, 2009; U.S. EPA, 2010, 2012b, 2012c, 2015c, 2015d; Holton *et al.*, 2013; Schuver *et al.*, 2018). Soil gas, sub-slab, and indoor air concentrations have been found to vary by up to three orders of magnitude over periods of months to years. Shallow soil gas tends to have much greater variability than deeper soil gas, making near-source soil gas a more reliable measure of VI. Much of the variability of indoor air data can be attributed to conditions other than VI.

Temporal and spatial variability in soil gas and indoor air sample results is addressed by using a combination of multiple rounds of samples and multiple sample locations. The goal is to collect sufficient data to determine representative concentrations beneath or within the building. Refer to Section IV.G.2. and Table IV-7 for recommendations on the appropriate number of sampling events and sample locations.

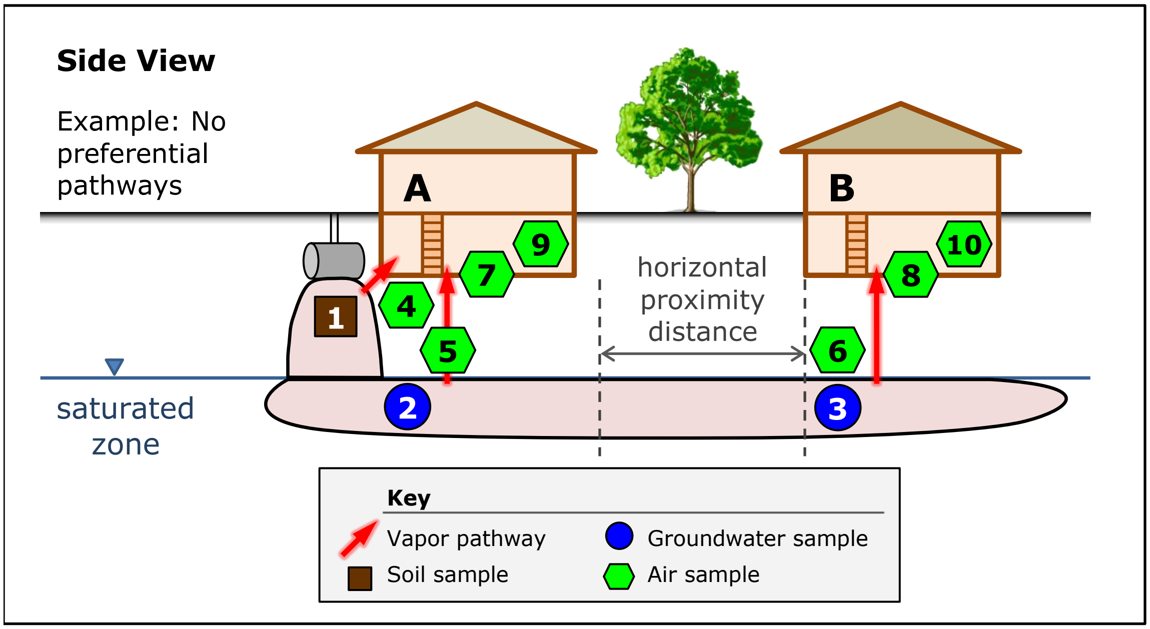
2. Sampling Locations

Figures IV-C-1 through IV-C-3 depict simplified VI scenarios that illustrate sampling location options for the application of screening values and modeling. They include situations without any preferential pathways (Figure IV-C-1), an external preferential pathway (Figure IV-C-2), and a significant foundation opening (Figure IV-C-3). Vertical proximity distances are not considered in these examples. (See Figures IV-3 and IV-4 for additional illustrations of the relationships between sources and buildings in the context of preferential pathways and proximity distances.) The information conveyed in Figures IV-C-1-IV-C-3 must be used in association with the sampling and screening conditions discussed in Sections IV.D, IV.F, IV.G, and IV.K.4., Tables IV-6 and IV-7, and the other parts of this appendix. Refer to Appendix IV-B for further details on using sample data in VI models.

In Figure IV-C-1 a release has contaminated soil adjacent to one building, and the resultant groundwater plume potentially affects it and a downgradient building. Building B is beyond the horizontal proximity distance from the soil contamination, so potential VI from soil only needs to be evaluated for Building A. Potential VI impacts from groundwater beneath Building B should be evaluated with monitoring well data near or upgradient of that building. Note that if the remediator chooses to sample near-source soil gas then distinct samples may be required for the soil and groundwater sources near a given building.

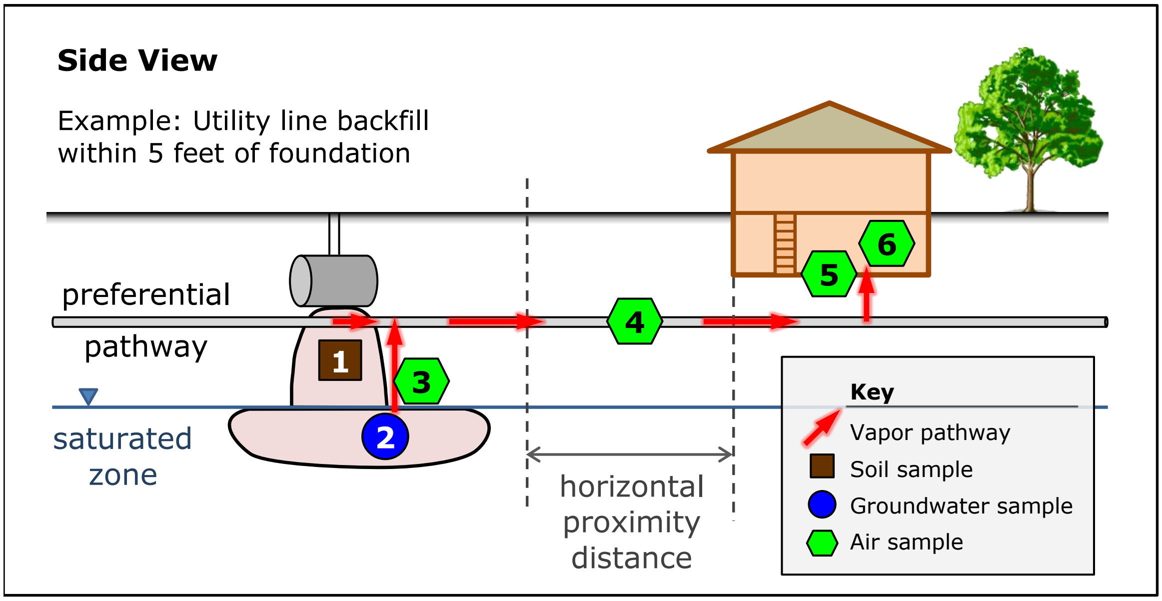
Figure IV-C-2 illustrates an external preferential pathway, such as gravel backfill around a utility line that allows vapors to migrate to a building from a source farther than the horizontal proximity distance. (No significant foundation openings are present.) Modeling is not an assessment option for the pathway to the existing building. The remediator may attempt to collect soil gas samples from within the backfill (location 4); they should be evaluated with sub-slab soil gas screening values. See Section IV.D.1. for additional information.

Figure IV-C-1: Sampling Location Options: Soil and Groundwater Sources



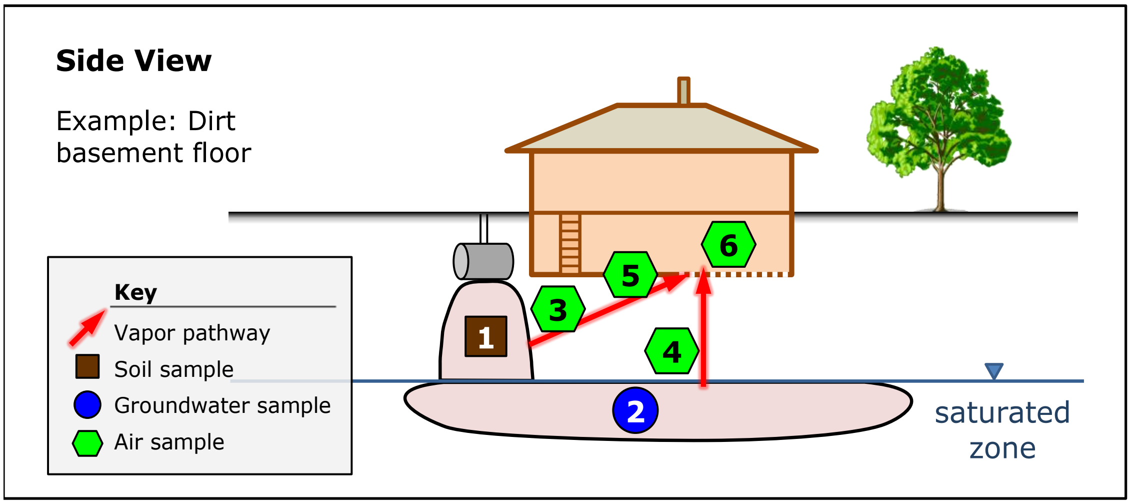
Sample	Description	Screen
1	Soil samples in source area, evaluation of Building A. Restriction: No SPL. Modeling: Yes.	SV_{SOIL}
2	Groundwater samples in source area, evaluation of Building A. Restriction: No SPL. Modeling: Yes.	SV_{GW}
3	Groundwater samples in plume, evaluation of Building B. Restriction: No SPL. Modeling: Yes.	SV_{GW}
4	Near-source soil gas samples at soil source, evaluation of Building A. Modeling: Yes.	SV_{NS}
5	Near-source soil gas samples above groundwater source, evaluation of Building A. Modeling: Yes.	SV_{NS}
6	Near-source soil gas samples above groundwater plume, evaluation of Building B. Modeling: Yes.	SV_{NS}
7	Sub-slab soil gas samples beneath Building A foundation.	SV_{SS}
8	Sub-slab soil gas samples beneath Building B foundation.	SV_{SS}
9	Indoor air samples, evaluation of Building A.	SV_{IA}
10	Indoor air samples, evaluation of Building B.	SV_{IA}

Figure IV-C-2: Sampling Location Options: External Preferential Pathway



Sample	Description	Screen
1	Soil samples in source area. Restriction: No SPL. Modeling: Permitted for future use over source, but not for current use via preferential pathway.	SV_{SOIL}
2	Groundwater samples in source area. Restriction: No SPL. Modeling: Permitted for future use over source, but not for current use via preferential pathway.	SV_{GW}
3	Near-source soil gas samples in source area (soil and/or groundwater). Restriction: No groundwater contamination or SPL migrating through preferential pathway. Modeling: Permitted for future use over source, but not for current use via preferential pathway.	SV_{NS}
4	Soil gas samples within preferential pathway. Restriction: Preferential pathway must contain a permeable material, such as backfill in a utility line trench. Modeling not permitted.	SV_{SS}
5	Sub-slab soil gas samples beneath building foundation. Restriction: Preferential pathway does not penetrate foundation.	SV_{SS}
6	Indoor air samples.	SV_{IA}

Figure IV-C-3: Sampling Location Options: Significant Foundation Opening



Sample	Description	Screen
1	Soil samples in source area. Restriction: No SPL. Modeling: Enter floor thickness of zero ($L_{crack} = 0$).	SGN*
2	Groundwater samples in source area. Restriction: No SPL. Modeling: Enter floor thickness of zero ($L_{crack} = 0$).	MSC
3	Near-source soil gas samples in soil source area. Modeling: Enter floor thickness of zero ($L_{crack} = 0$).	SVSS
4	Near-source soil gas samples above groundwater plume. Modeling: Enter floor thickness of zero ($L_{crack} = 0$).	SVSS
5	Sub-slab soil gas samples beneath building foundation. Restriction: Foundation slab must be present.	SVIA
6	Indoor air sampling.	SVIA

* Generic soil-to-groundwater numeric value.

Figure IV-C-3 shows sampling locations for a significant foundation opening, such as a section of dirt floor in the basement. In the example the contamination is beneath the building, and there is no external preferential pathway. Soil data can be screened with generic soil-to-groundwater numeric values; groundwater data can be screened with used aquifer MSCs. For screening of near-source soil gas data only sub-slab soil gas screening values should be used. Modeling of soil, groundwater, and near-source soil gas data may be carried out by setting the floor thickness equal to zero (Appendix IV-B). Both sub-slab and indoor air sample data should be screened with indoor air screening values; sub-slab points require an area of intact floor slab. See Section IV.D.2 for further information.

3. Near-Source Soil Gas Sampling

a) Description

Near-source soil gas is sampled from within the vadose zone, specifically from within nominally one (1) foot of the contamination source (contaminated soil or groundwater). For a groundwater source, near-source soil gas samples should be collected within one (1) foot of the top of the capillary fringe if the water table occurs in soil. If the water table occurs in bedrock, the near-source soil gas samples should be collected within one (1) foot of the soil–bedrock interface.

The height of the capillary fringe is not readily determined in the field. The following table provides theoretical estimates from U.S. EPA (2017, Table 13) which may be used as a guide. (Refer also to Appendix IV-B, Section IV-B.3 for additional information on soil type identification.)

Table IV-C-1: Capillary Fringe Height Estimates

Soil Type	L_{cz} (cm)	L_{cz} (ft)
Sand	17	0.6
Loamy Sand	19	0.6
Sandy Loam	25	0.8
Sandy Clay Loam	26	0.9
Sandy Clay	30	1.0
Loam	38	1.2
Clay Loam	47	1.5
Silt Loam	68	2.2
Clay	82	2.7
Silty Clay Loam	130	4.4
Silt	160	5.3
Silty Clay	190	6.3

L_{cz}: capillary fringe thickness

b) Sample Point Installation

Near-source soil gas sampling points can be temporary (used for one sampling event and decommissioned) or semi-permanent (used for multiple sampling events). Recommended resources for soil gas points include API (2005), California EPA (2015), ASTM (2012a), Hawaii DoH (2014), and ITRC (2014).

i) Installation of Temporary Points

Installation and construction of temporary points may be less time and cost sensitive. However, these potential savings may be offset over the life of the project as new points must be installed for each round of sampling. In general, temporary points rely on the use of boring advancement tools for the collection of the soil gas sample and the sealing of the point from the atmosphere. This is accomplished with the compression of the soil along the sides of the boring against the boring advancement tools. Use of temporary points is not recommended but may be necessary due to site conditions or site development. Prior to the utilization of temporary points, the feasibility of the following factors should be carefully considered:

- Proper sealing of the sampling interval from the surface;
- Isolation of the sampling interval within the boring;
- Potential of negative effects of boring advancement using drive-point techniques (e.g., decrease of soil gas permeability due to smearing or compression); and
- Unknown correlation of analytical results for multiple sampling rounds.

ii) Installation and Construction of Semi-Permanent Points

Semi-permanent points are generally constructed in borings advanced using conventional drilling technologies and sealing of the point is accomplished using bentonite or grout in the annulus of the boring. Boring advancement techniques should attempt to minimize disturbance of the vadose zone geologic strata and soil vapor column. Drilling methods that introduce air (e.g., air rotary) or liquid (e.g., mud-rotary) should be avoided.

4. Sub-Slab Soil Gas Sampling

a) Description

Sub-slab soil gas is sampled immediately below the floor slab of a building. The slab can be at grade (slab-on-grade) or below grade (basement).

b) Location

Sub-slab soil gas is located beneath the slab in the porosity of the native soil, ballast stone, or gravel that the building slab was placed over. Sub-slab soil gas sampling locations should be determined based on the specific characteristics of the building being sampled and the objectives of the sampling plan. Whenever possible, sampling locations should be biased toward areas of the building with the greatest expected VI impact, based on a combination of the location of VI sources and building occupancy and use. In general, sampling locations are at least 5 feet from perimeter foundation walls and sampling next to footers, large floor cracks, and apparent slab penetrations (e.g., sumps, floor drains) should be avoided.

c) Sample Point Installation

Sub-slab soil gas sampling points can be temporary (used for one sampling event and decommissioned) or semi-permanent (used for multiple sampling events). The building occupancy, use, and project goals are influential in the determination of which type of sampling point to use. A pre-survey, as described in Section IV-C.8(a)(i) herein, can be completed to assist in determining this information. Generally, installation and construction of temporary points is less time and cost intensive. However, these potential savings may be offset over the life of the project as new points must be installed for each round of sampling.

Sub-slab soil gas sampling points are generally installed inside penetrations through the building slab. Penetrating the floor slab can be accomplished using a hammer drill and bit, a core drill, or direct-push technology. Care should be taken during the floor slab penetration activities to avoid the creation of cracks in the slab. Additionally, the use of water or other lubricants and coolants during the advancement of the floor slab penetration should be compatible with the sampling analyte list and may result in the need for additional point equilibration time (see Section IV-C.8(a)(iv) herein) or the need to develop the sampling point to limit potential interaction of the sample with the water or lubricants.

Recommended resources for sub-slab points include California EPA (2011a), New Jersey DEP (2013), Hawaii DoH (2014), and ITRC (2014).

5. Indoor Air Sampling

a) Sampling Indoor Air

Indoor air sampling is performed when the potential for VI exists through other lines of evidence, and other investigative tools are not able to eliminate the VI pathway. Indoor air sampling may also be considered as a method for mitigation system verification. When compared to the other investigative tools available, indoor air sampling represents the most direct measure of exposure due to the VI pathway however it also can be heavily influenced by background conditions.

Recommended resources for indoor air sampling include New York DoH (2006), California EPA (2011a), New Jersey DEP (2013), Hawaii DoH (2014), and ITRC (2014).

When collecting indoor air samples, it is preferable to collect samples at a time and location that will result in the highest potential concentrations. Samples should be collected from the lowest level of the structure with appropriate accessibility where vapors are expected to enter, including basements, crawl spaces, and where preferential pathways have been identified. Existing environmental data (e.g., groundwater, soil, sub-slab soil gas, etc.), site background information, building construction (e.g., basement, slab-on-grade, or multiple types of foundations, elevator shafts, tunnels, etc.), and building operation details (e.g., number and operation of HVAC systems) as evaluated through the development of the CSM should be considered when selecting locations within the building for indoor air sampling. Indoor air samples may be collected concurrently and collocated with sub-slab soil gas sampling locations, and concurrently with an outdoor ambient air sample.

To characterize contaminant concentrations trends and potential exposures, indoor air samples are commonly collected:

- From the crawl space area;

- From the basement (where vapor infiltration is suspected, such as near sump pumps or indoor wells, or in a central location);

- From the lowest level living space (in centrally located, high activity use areas);

- From multiple tenant spaces if in a commercial setting.

If the pre-survey (Section IV-C.8(a)(i) herein) determines that chemicals of concern for VI are used, handled, or stored in the building being investigated, then those materials should be removed prior to collecting indoor air samples, if possible. The building should be ventilated for at least 24 hours following removal and before sampling. Other lines of evidence may be necessary, such as collocated sub-slab soil gas and indoor air samples, if the materials cannot be removed.

b) Outdoor Ambient Air Sampling

To understand potential background influences during indoor air sampling, an outdoor ambient air sample is commonly collected. This sample provides background concentrations outside of the building being investigated at the time of the indoor air sampling event. The investigator commonly designates a sample location and the site conditions at the time of sampling. The investigator also should be aware of the weather conditions during the sampling event. The sampler should be placed in a secure outside location.

Atmospheric pressure and temperature data from nearby weather reporting stations or through portable meteorological equipment should be collected in conjunction with the ambient air samples. Two web sites that may be useful to the investigator are NOAA’s National Weather Service and the Weather Underground.

The following actions are commonly taken to document conditions during outdoor air sampling and ultimately to aid in the interpretation of the sampling results:

- Outdoor plot sketches are drawn that include the building site, area streets, outdoor air sampling location(s), the location of potential interferences (e.g., gasoline stations, dry cleaners, factories, lawn mowers, etc.), compass orientation (north), and paved areas;

- Weather conditions (e.g., precipitation and outdoor temperature) are reported;

- Predominant wind direction(s) during the sampling period are reported using wind rose diagrams; and

- Pertinent observations, such as odors, readings from field instrumentation, and significant activities in the vicinity are recorded.

6. Sampling Soil Gas for Oxygen Content

Note: This section of the guidance is intended only for remediators using the vertical proximity distances for petroleum hydrocarbons.

If the remediator chooses to screen a site using the vertical proximity distances for petroleum hydrocarbons, the acceptable soil or soil-like material should contain greater than 2% oxygen, on a volumetric basis. Oxygen content above this level indicates an aerobic environment that enables biodegradation of petroleum vapors. The investigator can measure the oxygen concentration in the vadose zone at buildings that are potential receptors to demonstrate that the aerobic soil condition is met.

DEP recommends collecting a soil gas sample beneath the building for oxygen content when there is reason to suspect that the soil may be anaerobic (Section IV.E). Only one grab sample collected at a single location is sufficient. A hole should be drilled approximately 12 inches into acceptable soil or soil-like material (i.e., beneath any gravel or similar fill material underlying the slab). Tubing with a probe tip is dropped into the hole, which is then filled with clean sand (e.g., Hawaii DoH, 2014, Section 7.9.3).

When it is not feasible to obtain the soil gas sample beneath the building, a near-slab soil gas sample may be collected. The sample point should be as close to the building as practical, and no farther than 10 feet. It should be located in the area of greatest anticipated soil vapor contamination. The screen depth should be above the top of the soil or groundwater contamination (e.g., smear zone) and below the bottom of the building foundation. The screen should also be at least 5 feet below the ground surface. The investigator may also collect samples at multiple depths to obtain a concentration profile demonstrating biodegradation. The sample probe should be allowed to equilibrate with the subsurface and purged.

In addition to analysis of oxygen (O_2), additional compounds such as carbon dioxide (CO_2) and methane (CH_4) can be measured to document biodegradation. One grab sample is sufficient to demonstrate that the 2% O_2 criterion is satisfied. The sample may be analyzed using a properly calibrated portable instrument. Oxygen should be calibrated at around 2% and 21%. Alternatively, the sample may be collected using a Tedlar bag or a Summa canister and analyzed at a mobile or offsite laboratory using EPA Reference Method 3C.

7. Sampling Separate Phase Liquids

When SPL is present, soil and groundwater screening and modeling are not options available for assessing VI. However, the remediator may obtain a sample of the SPL from a monitoring well to determine if VOCs posing a VI risk are present. This section describes how to evaluate the SPL data for VI.

The SPL sample should be analyzed with U.S. EPA Method 8260C. The results may be reported in units of mass per volume (micrograms per liter, µg/L) or mass per mass (micrograms per kilogram, µg/kg). If the data is reported on a volumetric basis, then the SPL density must be estimated or measured to calculate the mass fraction of each volatile component (e.g., ASTM, 2012b). In addition, the molecular weight of the SPL must be estimated from reference values or an analysis to calculate the mole fraction of each component (e.g., ASTM, 2014).

The vapor concentration (C_v) of each volatile component over the SPL, in units of micrograms per cubic meter (µg/m^3), equals:

$$C_\mathrm{v} = \frac{x_\mathrm{i}(\mathrm{VP})(\mathrm{MW})}{RT} \times (10^9)$$

Where x_i is the calculated liquid phase mole fraction of the component in the SPL, and the other quantities are defined in Table IV-C-2. (The 10^9 factor converts from units of g/L to µg/m^3.)

Table IV-C-2: SPL Vapor Phase Parameters

Symbol	Description	Value	Units
VP	vapor pressure	VISL	mm Hg
MW	molecular weight	Table IV-A-5	g/mol
R	universal gas constant	62.4	L (mm Hg) mol–1 K–1
T	temperature	Table IV-B-2	K

VISL: U.S. EPA’s VISL Calculator spreadsheet (U.S. EPA, 2014a).

The vapor concentrations calculated for each substance of concern in the SPL using the above equation are comparable to near-source soil gas concentrations. Therefore, they may be evaluated with near-source soil gas screening values (Table IV-3 on the Department’s VI web page for the SHS) to determine if each chemical poses a potential VI risk. Alternatively, the calculated vapor concentrations may be used with a near-source soil gas attenuation factor in a cumulative risk assessment under the SSS (Appendix IV-B, Section IV-B.6). If the SPL is less than 5 feet below the building foundation, then one should apply sub-slab soil gas screening values (Table IV-4 on the Department’s VI web page) and sub-slab soil gas attenuation factors.

As an example, consider SPL that is inferred to be No. 6 fuel oil present beneath a nonresidential building. Analysis of a sample of the SPL finds that benzene is nondetect, with a quantification limit of 50,000 µg/L. The density of the SPL is measured, and the result is 8.1 lb/gal (0.97 kg/L). The molecular weight of benzene is 78 g/mol, and the approximate molecular weight of No. 6 fuel oil is 300 g/mol. Therefore, using these values we first estimate an upper bound on the mole fraction of benzene in the SPL, which equals $x_{benzene} = 2.0 \times 10^{-4}$. Next, given a subsurface temperature of 18°C, the estimated maximum vapor concentration of benzene over the SPL, calculated with the above equation, is C_v = 82,000 µg/m^3.

The nonresidential SHS near-source soil gas screening value for benzene is SV_{NS} = 16,000 µg/m^3. The estimated benzene vapor concentration based on the detection limit in this example exceeds the screening value. Therefore, at this analytical accuracy, sampling the SPL cannot rule out benzene as a contaminant of VI concern. Possible alternative investigative approaches include near-source soil gas, sub-slab soil gas, or indoor air sampling.

8. Quality Assurance and Quality Control Procedures and Methods

a) Sampling Procedures and Methods

i) Pre-Sampling Survey

Prior to the installation and construction of indoor air and sub-slab soil gas sampling points and the collection of samples, a pre-sampling survey should be conducted. The survey should include a short interview with a representative of the owner/occupant of the building and a visual review of accessible portions of at least the lowest level of the building (basement or first floor). Results of the survey are documented and supplemented by sketch maps and photographs as necessary. The investigator may also choose to use a photoionization detector (PID) or flame ionization detector (FID) during the survey to screen for the presence of VOCs in the building. (Note: The non-compound specific VOC detection levels of PIDs and FIDs are much higher than compound-specific laboratory reporting limits.) The pre-sampling survey should review building-specific factors that could influence VOC concentrations in indoor air including:

- Building construction characteristics;
- Building features, such as the condition of the floor slab, floor penetrations, and floor cracks;
- Heating and ventilations systems;
- Items within the lowest level of the building that could serve as potential VOC sources (paint cans, solvents, fuel containers, etc.);
- Occupant activities in the building (painting, smoking, etc.); and
- Exterior characteristics and items or occupant activities outside the building that could serve as potential VOC sources (mowing, paving, etc.).

These observations and others should be documented on a building survey form.

For additional information see ITRC (2007), California EPA (2011a), and New Jersey DEP (2013).

ii) Sampling Equipment

Near-source soil gas, sub-slab soil gas, and indoor air samples are commonly collected in passivated stainless steel canisters (e.g., Summa) with laboratory-calibrated flow controllers for U.S. EPA Method TO-15, or other appropriate U.S. EPA methods if TO-15 is not applicable. Other types of sampling containers (e.g., Tedlar bags, glass bulbs, syringes) may be used under certain conditions, but stainless steel canisters are preferred.

Canister volumes should be selected to minimize sample volume while still meeting data quality objectives. Minimizing sampling volumes for near-source soil gas and sub-slab soil gas reduces the potential for ambient air entering around the sampling point and limits the potential for migration of soil gas from relatively long distances away from the sampling point during sample collection. Generally, 1-L canisters are used for near-source soil gas and sub-slab soil gas sample collection and 6-L canisters are used for indoor air and ambient sampling.

Canisters should be connected to the soil gas sampling point using small diameter stainless steel, nylon (Nylaflow type LM), polytetrafluoroethylene (PTFE, Teflon), or polyether ether ketone (PEEK) tubing and stainless steel compression-type fittings. (Other appropriate non-reactive materials may be used. Polyethylene, Tygon, and silicone are not acceptable tubing materials.) The number of connections in the sampling system should be minimized to reduce the number of locations where leaks could occur. Minimizing the length and diameter of the tubing reduces the sample residence time and the required purge volume.

iii) Sampling Point Construction

Near-source and sub-slab soil gas sampling point construction materials should be selected to minimize potential interaction with the sample. The probe should be connected to small diameter tubing; the tubing and all fittings should be clean and dry. The tubing is recommended to be capped or plugged at the surface to isolate the sample from the atmosphere or indoor air.

Sub-slab sample points are sealed in the penetration to eliminate short circuiting of air from inside the building through the slab penetration and into the sample. The materials and methods used to create this seal will depend on site-specific factors such as the condition of the slab and the type and volume of traffic in the building as well as the data quality objectives and planned QA and quality control (QC) protocols. Temporary points may be sealed in the penetration with silicone sleeves, silicone rubber stoppers, sculpting clay, putty, or wax. Semi-permanent points may involve the drilling of nested holes in the slab and the use of hydraulic cement or epoxy to seal the tubing and possibly additional fittings in the penetration below the finished elevation. All materials used for construction and completion of the sub-slab soil gas sampling point should be clean, dry and free of materials that could affect the sampling or analysis.

The diameter of the floor slab penetration should be minimized (generally between 3/8 and 1 inch). The surface and sidewalls of the penetration should be cleaned with a stiff bristle brush to remove material created by the advancement of the penetration. Removal of this material is important to limit entrainment of dust in the sub-slab soil gas sample and to promote adherence of the sealing materials to the sidewalls of the penetration or the surface of the slab. Care should be taken to limit interaction with the sub-slab soil gas beneath the slab if a vacuum is used to remove dust during/after advancement of the penetration. If a vacuum is used, additional point equilibration time may be necessary.

Some manufacturers offer alternative sub-slab soil gas sampling point equipment that relies on driving (hammering) a specialized barbed-metal fitting into the slab penetration. The metal fitting is sealed inside the slab penetration by the compression of a sleeve of flexible tubing between the fitting's barbs and the sidewalls of the penetration. These "hammer-in" points may be considered for use during VI investigations.

For indoor and outdoor air sampling, the sampling port should be placed in the breathing zone, approximately 3 to 5 feet above the floor. Mount the canister on a stable platform or attach a length of inert tubing to the flow controller inlet and support it such that the sample inlet will be at the proper height.

Ambient air samples should be collected at breathing zone height (if possible) and in close proximity to the building being tested. For nonresidential buildings, the investigator may elect to collect the ambient air sample near representative HVAC intake locations (i.e., on the roof). Other locations for ambient sampling could be upwind of the building to be sampled. The ambient air sample should have the same sample collection time and be analyzed in the same manner as the interior sample collection method.

iv) Equilibration

After installation, near-source and sub-slab soil gas points should be allowed to equilibrate to natural conditions. This is commonly a minimum of 2 hours up to 24 hours.

v) Leak Testing/Detection for Subsurface Sample Collection

Leakage during soil gas sampling may dilute samples with ambient air resulting in data that underestimates actual site concentrations or causes false negatives. A shut-in check (sampling assembly integrity) and a leak check (surface seal integrity) can be conducted to determine whether leakage is present and then corrected in the field prior to collecting the sample. Recommended resources for leak testing include ASTM (2012a), California EPA (2015), New Jersey DEP (2013), Hawaii DoH (2014), and ITRC (2014).

A shut-in test of the sampling train is recommended to be completed at each location and during each sampling event to verify aboveground fittings do not contain leaks. A shut-in test consists of assembling the above-ground apparatus (valves, lines, and fittings downstream of the top of the probe), and evacuating the lines to a measured vacuum of about 15 inches mercury (200 inches water or 50,000 Pascals), then shutting the vacuum in with closed valves on opposite ends of the sample train. The vacuum gauge is observed for at least 1 min, and if there is a loss of vacuum greater than 0.5 inches mercury (7 inches water or 2000 Pascals), the fittings should be adjusted as needed to maintain the vacuum.

Leak check tests are recommended for near-source and sub-slab soil gas points after construction and equilibration. One method employs a shroud placed over the point. An inert tracer gas (such as helium) is released into the shroud with a target concentration of 10–20%. With the canister valve closed, a soil gas sample is collected from the sample point and measured with a portable helium detector. A leak is occurring when the helium concentration is greater than 10% of the concentration within the shroud. In this case, the leak must be fixed and the leak check repeated.

Helium is the preferred tracer as it is readily available, non-toxic, and easily measured in the field provided high methane levels are not present (false positives). Helium may also be analyzed in the Summa canister sample at the laboratory.

Note: Balloon-grade helium may contain hydrocarbons that could interfere with sample analysis.

vi) Purging

Purging occurs after the sampling system has been assembled (i.e., the canister has been connected to the flow controller and the sampling point has been connected to the canister/flow controller). A “T” fitting can be placed in the sampling train to allow for purging of the connected sampling system. The purging leg of the “T” is commonly isolated from the rest of the sampling train using a valve. There are several acceptable methods for purging the system. For example, either a graduated syringe or a personal sampling pump can be used.

Purge rates for near source and sub-slab soil gas samples should be less than 200 mL/min to limit the potential for short-circuiting or desorbing VOCs from soil particles. Purging volumes should be about three times the volume of the total sampling system (i.e., the sampling point and tubing connected to the sampling canister).

If water is encountered in the soil gas sampling point or observed in the sample tubing during purging, then sampling of the point should not be performed. Commonly, when water is encountered during purging an effort is made to evacuate the water from the soil gas sampling point and then allow a minimum of 48 hours before reattempting purging and sampling.

vii) Sampling Rates

Sampling rates for near-source and sub-slab soil gas samples should be less than 200 mL/min. Sample rates are determined by the laboratory-calibrated flow controller attached to the canister.

Vacuum levels during sampling should not exceed 7.5 inches mercury (100 inches water or 25,000 Pascals). If low permeability materials are encountered during point installation or if there are issues during purging or sampling that suggest low permeability, testing should be performed to measure flow rates and vacuum levels in the near-source soil gas sampling point to determine acceptable purging and sampling flow rates.

Indoor air and ambient air samples are typically collected over a 24-hour period; however, in a nonresidential setting an 8-hour sampling period may be used to coincide with the hours of operation and thus the period of exposure. The sampling flow rate should always be less than 200 mL/min.

With near-source or sub-slab soil gas sampling, the sample duration should be determined by sample volume, but it is recommended to be at least 15 minutes.

If water is observed in the sample tubing during sampling, then sampling should be discontinued. Commonly, when water is encountered during sampling an effort is made to evacuate the water from the soil gas sampling point and then allow a minimum of 48 hours before reattempting purging and sampling.

viii) Sample Recordation

The field sampling team should maintain a sample log sheet summarizing the following:

- Sample identification;
- Date and time of sample collection;
- Sample location;
- Identity of sampler;
- Sampling methods and devices;
- Volume and duration of sample;
- Canister vacuum before and after sample is collected; and
- Chain of custody protocols and records used to track samples from sampling point to analysis.

b) Data Quality Objective (DQO) Process, Sampling and Data Quality Assessment Process

The DQO process (U.S. EPA, 2006) allows a person to define the data requirements and acceptable levels of decision errors prior to data collection. The DQO process should be considered in developing the sampling and analysis plan, including the QA plan. The implementation phase includes sampling execution and sample analysis. The assessment phase includes Data Quality Assessment (DQA). (See 25 Pa. Code § 250.702(a) of the regulations and Section III.F.1.)

c) QA/QC Samples

Prior to using a canister, the integrity of the canister should be examined for damage due to shipping. The canisters should be received in the field with the laboratory-measured pressure as part of the documentation. Field check the pressure of the canister before collecting the sample. The field-measured pressure should be within 10% of the laboratory recorded value. If this is not the case, the canister should be rejected and another canister used. There may be some minor difference in measured pressures (for instance with changes in altitude and barometric pressure) of less than 5% that does not reflect a canister integrity problem.

On completion of sample collection, the final pressure reading should be recorded. This should be about 5 inches mercury (70 inches water or 20,000 Pascals). The reading should be recorded on the chain of custody or other field documentation. If the final pressure is zero (atmospheric), it should still be recorded and sent to the laboratory for verification.

A field duplicate sample may be collected by using a “T” fitting at the point of collection to divide the sample stream into two separate sample containers.

Trip blanks for canisters are not typically required.

Dependent on the sampling equipment it may be desirable to perform an equipment blank. The sample collection media should be certified clean. Materials used in setting up a sampling train should be VOC-free and stored and transported in a VOC-free environment.

Field method blanks can be used to verify the effectiveness of decontamination procedures and to detect any possible interference from ambient air. If samples are collected using sorbent media, it is recommended that a blank media sample accompany the batch of sample media to the field and be returned to the laboratory for analysis. This demonstrates the media is free from compounds of concern from preparation through shipping and handling.

d) Analytical Methods

A variety of analytical methods are available to measure vapor samples (subsurface vapor, indoor and ambient air), all of which can provide useable data when reported with QA/QC (Table IV-C-3). The laboratory QA/QC will include blanks, calibration, and system performance samples that define and verify the quality of the data reported. The laboratory engaged for air and vapor analysis should have NELAC or similar accreditation for the methods reported. There may be cases where certification for the method that will be used is not available. In this case, a laboratory standard operating procedure should be available and appropriate QA/QC should be reported with the results.

Communicate with the laboratory during the planning stages of the investigation to ensure the appropriate analytical method is used. For the data assessment process, it is suggested at a minimum for the laboratory to provide summary QA/QC results with the data reported. A full validated data package can be requested if necessary.

Table IV-C-3: Analytical Methods for VOCs in Soil Gas, Indoor and Ambient Air Samples

Parameter	Method	Sample Media/Storage	Description	Method Holding Time
Polar & non-polar VOCs	TO-15	canister / ambient temperature	GC/MS	30 days
Low level VOCs	TO-15 SIM	canister / ambient temperature	GC/MS	30 days
Polar & non-polar VOCs and SVOCs to C-28	TO-17	sorbent tube/ chilled < 4°C	GC/MS	30 days
Fixed gases (methane, helium, nitrogen, oxygen, carbon dioxide, carbon monoxide)	USEPA 3C or ASTM 1946	canister or Tedlar bag / ambient temperature	GC/TCD/FID GC/FID	3 days for Tedlar bag 30 days for canister

Key elements for choosing the appropriate method are:

- The contaminants of concern;
- The concentrations that may be encountered during sampling and source strength;
- Screening levels/detection levels and other DQOs;
- Sampling considerations;
- Cost of sampling and analysis.

For U.S. EPA Method TO-15 VOCs the passivated canister is the only container allowed by the method; any other containers (e.g., Tedlar bags) are considered a modification. There is no standard list for TO-15. As a performance-based method, any compound that has sufficient volatility and recoveries may be validated for accreditation and reporting, provided a demonstration of capability is performed. TO-15 is the preferred method used for VI investigations.

Method TO-17 is a sister method to TO-15. Samples are collected with active sampling onto absorbent media. This method offers lower reporting limits and extends the compound list to include semi-volatile compounds. However, this media has a limited capacity, which is further limited if screening is done for a broad range of compounds, and sampling with sorbent media requires more field expertise.

Fixed gases, typically defined as O_2, nitrogen, CH_4, CO_2, and CO, can readily be analyzed using laboratory-based methods that use a thermal conductivity detector for detection, and using field monitoring devices (landfill gas monitors). ASTM D1946 (ASTM, 2015a) and U.S. EPA Method 3C are two of the more common analytical methods and can typically detect concentrations as low as 0.1%. They can also be used to analyze for helium, which is often used as a tracer gas during leak check procedures in subsurface sampling. Analysis for these gases can be run from the same canister as VOCs.

Contact your laboratory for analyte lists and reporting levels applicable to these methods, and reference Section III.G.3 for information regarding PQLs.

e) Data Evaluation

If the project was planned using the DQO process or another standard project planning process, the quantity and quality of data, including the measurement quality objectives, will have been specified in the sampling and analysis plan. All of the data should be examined for these types of issues to ensure the data set is of adequate quality prior to use in evaluating the VI pathway.

9. Active Sub-Slab Depressurization System Testing

Details regarding the application, design, installation, and performance testing of SSD systems and other VI mitigation systems are available in the following references: U.S. EPA (1991, 1993, 1994a, 1994b, 2001, 2008), Massachusetts DEP (1995), Pennsylvania DEP (1997), California EPA (2011b), and ASTM (2008, 2011b, 2013b, 2015b).

a) Description

This section applies to recommended performance testing procedures for active sub-slab depressurization systems installed as engineering controls on buildings where the VI pathway is a potential concern. For existing buildings, active SSD systems are the VI mitigation method preferred by DEP. However, the performance and testing requirements described below may also apply for other active VI mitigation technologies such as sub-membrane depressurization, sub-slab pressurization, and building pressurization systems.

Installation of SSD systems includes the sealing of potential soil vapor infiltration points combined with the use of a fan or blower that creates a continuous negative pressure field (vacuum) beneath the concrete floor slab of the lowest level of the building (basement or first floor). The fan or blower pulls the soil vapor from beneath the slab and vents it to the atmosphere at a height well above the outdoor breathing zone (ITRC, 2014, Appendix J). The presence of a continuous negative pressure field beneath the slab results in the movement of indoor air down into the subsurface, thereby eliminating the VI pathway as a potential concern.

Installation of SSD systems in existing buildings should be performed by qualified professionals, and it is generally completed in the following three steps:

Step 1: Inspection and Design-Support Diagnostic Testing – This step typically includes visual inspection of the lowest level of the building to assess the condition of the foundation, to identify potential soil vapor entry points that require sealing, and to review building-specific design considerations such as the location and type of construction of extraction points, possible discharge piping routes, and exhaust fan locations. This step also includes diagnostic testing to support siting of extraction points, sizing of the exhaust fan/blower and piping, and evaluation of stack effects and the potential for back-drafting of heating systems. The results of the diagnostic tests or communication tests are used to confirm the ability of the SSD to depressurize beneath the entire building.

Step 2: Design and Construction of the SSD System – The mitigation contractor prepares a design applicable to the building characteristics and results of diagnostic testing. Elements of the construction include installation of extraction point(s), exhaust piping, exhaust fans/blowers, and sealing of potential soil vapor entry points.

Step 3: Commissioning of the SSD System – The commissioning step includes post-construction performance testing consisting of pressure differential measurements to demonstrate the system is working as designed. During this step, smoke testing is also performed to confirm operation of the SSD system does not result in back-drafting of combustion appliances (heating systems). Adjustments to or augmentation of the SSD system may be completed during this final installation step. Post-construction performance testing methods completed as part of commissioning of active SSD systems are described below.

b) Performance Testing Methods

The remediator should test the mitigation system after its installation. At a minimum, the testing should follow the manufacturer's or vendor's recommendations. The mitigation system should also be tested if a significant modification or repair is made, after a change in ownership, or upon request by the Department.

The primary method of performance testing of active sub-slab depressurization systems consists of differential pressure field extension tests that provide confirmation of a continuous negative pressure field (vacuum) beneath the concrete floor slab of the lowest level of the building. If the differential pressure field extension tests demonstrate the operating SSD system is providing depressurization throughout the sub-slab, the remediator is not required to perform indoor air confirmation sampling.

Differential pressure field extension tests are performed by operating the SSD system and simultaneously measuring the sub-slab pressure at different locations across the floor slab including, if accessible, building corners and building perimeters. The pressure measurements should be performed by drilling a small hole through the slab (e.g., 3/8-inch diameter) and measuring the differential pressure using a digital micromanometer. In general, for active SSD systems a pressure differential of at least 0.01 inches water (2 Pascals) should be achieved when the heating system is operating and 0.025 inches water (6 Pascals) otherwise (U.S. EPA, 1993). The minimum pressure of 6 Pascals is a guideline that applies mostly to residential structures, but use of a lower threshold may be considered (e.g. for larger commercial structures) on a case-by-case basis if proper justification is provided. As such, a digital micromanometer with sufficient sensitivity is necessary. Smoke testing can be performed as a qualitative test, but it may not be as reliable with low vacuums.

As an alternative to differential pressure testing, the remediator may collect one or more indoor air samples.

Appendix IV-D: OSHA Program Vapor Intrusion Checklist

List the chemical(s) of concern that the facility uses:

Chemical:	CAS Registry Number:
______________________________	______________________________
______________________________	______________________________
______________________________	______________________________
______________________________	______________________________
______________________________	______________________________
______________________________	______________________________

☐ Facility provided Material Safety Data Sheet(s) (MSDS) or Safety Data Sheet(s) (SDS) for the chemical(s) of concern listed above that they have identified as using.

☐ Facility identified where the chemical(s) are used in the facility and how they are used.

☐ The facility has performed air monitoring (industrial hygiene) of the identified chemical(s) of concern.

☐ The facility has provided the results of the air monitoring to the Department.

☐ The air monitoring has been conducted in all areas of the plant or facility.

☐ The facility has provided documentation showing that all employees in the facility have completed safety training associated with the chemicals of concern.

☐ Pictures provided by the facility show PPE and signage use associated with the chemicals of concern. (Items shown below are examples of equipment associated with use of PPE, and may not be the exact items used by the facility.)

Dip Tanks

Lab or process hoods with documentation of annual assessments

Canopy hoods with documentation of annual assessments


Local ventilation with documentation of annual assessments

Use of respirators with employee medical clearances



PPE such as chemical gloves, aprons, Tyvek coverall or clothing




Occupational Exposure Values for Chemicals of Concern

Occupational Safety and Health Administration Permissible Exposure Limits (OSHA PEL) or American Conference of Governmental Industrial Hygienist Threshold Limit Values (ACGIH TLV).

Chemical of Concern	OSHA PEL	ACGIH TLV

OSHA exposure limits are available at: 29 CFR Subpart Z; 29 CFR 1910.1000–1052

https://www.osha.gov/dsg/annotated-pels/index.html

ACGIH TLVs are available from the purchased publication. All of these values should be available from the MSDS/SDS.

Status: (All of the above items must be included for the facility to qualify to use an OSHA program to address VI.)

☐ Qualified: OSHA implementation is documented and can be used to address VI

☐ Not Qualified: OSHA implementation is NOT documented

Consultant or Reviewer:

(Print)____

(Signature)__________________________________ Date:__________________

From: Daniel Scholnick
To: Philly Refinery Cleanup; cdbrown@pa.gov; rapatel@pa.gov
Subject: Please reject RIR’s for Evergreen’s AOI 4 and 9.
Date: Saturday, October 30, 2021 10:17:48 PM

To DEP Officials:

I am writing out of grave concern for the insufficiency of the RIR submitted by Evergreen regarding areas close to my home, “AOI” number 4 and number 9.

I am urging you to **reject** these reports at this time, because they do not provide the information the DEP requested, and they simply do not go far enough to protect our air and groundwater as Pennsylvania residents living close by.

Just today, I walked next to the Schuylkill River, over debris from the flooded roadway at 51st Street, the second time since the summer I’ve witnessed a flood. I walked past people fishing in the river, and embarrassingly, I tripped on a root and fell in the mud. My daughter is wary of the river there, because she’d gotten stuck in the silty smelly muck last spring at low tide, and we both fell in when I worked to free her. This is all good fun. But when I think of how Evergreen is shirking their obligation to assess groundwater flow beneath contaminated soils in these nearby areas of study, my sense grows increasingly fearful of the river and what it carries with it.

Please look out for us neighbors, and send Evergreen back to do a better job with their RIR report.

Daniel Scholnick
267-481-3044
Daniel.Scholnick@gmail.com