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1600 John F. Kennedy Boulevard
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File No. 4862.10

Re: Response to USEPA's October 13, 2022 and December 15, 2022 Comments Concerning the September 2022 IM Monthly Progress Report for AOI 7 in MHT

Dear Mr. Bilash:

1.0 INTRODUCTION

The objective of this letter is to respond to the United States Environmental Protection Agency's (USEPA) October 13, 2022 and December 15, 2022 correspondences, both of which are included in Attachment A, regarding the Marcus Hook Terminal (MHT) Area of Interest (AOI) 7 September Interim Measures (IM) Monthly Progress Report dated September 30, 2022 (referred to as "September Progress Report" throughout this document) and October 26, 2022 and November 9, 2022 meetings between USEPA and Evergreen.

Sanborn Head prepared a technical memorandum summarizing the Porewater Sampling Plan for additional porewater sampling at select locations that was provided in an attachment to the September 2022 Monthly Progress Report. On October 13, 2022, USEPA provided comments to Evergreen on the proposed Porewater Sampling Plan. On October 26, 2022, USEPA, Evergreen, and Sanborn Head met to discuss the USEPA comments and the overall scope of work for the Porewater Sampling Plan.

Based on the outcomes of that discussion, the additional porewater sampling event was postponed to a December 5, 2022 start date. A draft response to USEPA comments were verbally provided in a follow-up call with USEPA, Evergreen, and Sanborn Head on November 9, 2022 in relation to the scope of work for the additional porewater sampling activities. On November 14, 2022, the written details of the additional calculations were provided to the USEPA to address comments from the November 9, 2022 meeting. USEPA indicated on November 22, 2022 that they had additional comments to the draft response to comments/calculations provided. These additional comments were provided to Evergreen on December 15, 2022. Based on the USEPA having additional comments, the planned December 2022 porewater sampling event has tentatively been moved to February 2023 to allow time for Evergreen to provide this response to comments.

The following provides additional information to address USEPA's October 13, 2022 and December 15, 2022 questions concerning the proposed sampling in AOI 7.

1.1 Site Description

The MHT is located on the north bank of the Delaware River (River) in the Borough of Marcus Hook, Delaware County, Pennsylvania, with portions of the facility in Lower Chichester Township, Pennsylvania and Claymont, New Castle County, Delaware (see Figure 1 in Attachment B). AOI 7, which is located within MHT, is located in Delaware and consists of approximately 50 acres of land bounded on the southeast by the Delaware River, the southwest by a property boundary with Honeywell's Delaware Valley Works (DVW) and by the Pennsylvania-Delaware state line/AOI 5 on the northeast. Middle Creek runs east-west then turns and runs north-south through AOI 7, as shown in Figure 2 in Attachment B.

Honeywell's DVW property, is a former chemical manufacturing plant located in Claymont, Delaware and Marcus Hook, PA. The DVW consists of approximately 100 acres, which is divided by Route 13 into two separate plants, referred to as the "North Plant" and "South Plant". The South Plant includes Solid Waste Management Unit 9 (SWMU 9) which was used for disposal of pesticides and related wastes, arsenic, materials from DDT and DDD production, and laboratory samples disposal. SWMU 9 is located adjacent to the MHT AOI 7 site. A drainage channel referred to as "the sluiceway" traverses the southern portion of the South Plant and discharges to the Delaware River approximately 2,500 feet downstream of Middle Creek. The location of the South Plant and SWMU 9 is shown on Figure 3 in Attachment B.

1.2 Historical Site Use

AOI 7 is part of the MHT facility that has a long history of petroleum transportation, storage, and refining of fuels and petrochemicals. Operations began in 1902, and the facility was owned and operated by Sunoco since its inception as Sun Oil in 1901. AOI 7 was generally undeveloped until the late 1950s. Prior to development, AOI 7 generally consisted of a low-lying floodplain and marsh area, as shown by the 1898 historical topographical map included in Attachment C. The surface of AOI 7 was significantly modified by filling and Middle Creek was relocated several times during development between 1930s to late 1950s. Figure 4 in Attachment B presents a summary of these changes over time to the shoreline and orientation of Middle Creek in AOI 7. Attachment C presents the 1898 historical topographical map and historical aerial photographs of AOI 7 and SWMU 9 in 1937, 1953, 1958 and 1965, which are described below. This discussion is included in this letter since it is helpful to understand depositional patterns related to potential source areas and former surface water features that may influence current day groundwater flow through preferential pathways. Specifically, this discussion will help inform the Response to Comment 7 in Section 2.0 and Response to Comments 2, 9, and 10 in Section 3.0.

1898 Topographical Map

The outline of the MHT AOIs, with AOI 7 outlined in black is shown overlain on the 1898 historical topographic map, which was first presented in the AOI RFI (GHD, 2017). This map shows that approximately half of AOI 7 is open water or marsh land and that Middle Creek (Walkers Run) is located on the eastern edge of AOI 7. This figure also shows that the marsh area existed in the majority of SWMU 9 at this time.

1937 Aerial Photo

- *AOI 7* - The marsh area shown on the 1898 topographical map is not shown on the 1937 aerial, but Middle Creek has been shown to be slightly re-routed and be present on the eastern side of AOI 7. The southwest portion of AOI 7 where the elevated arsenic detections in groundwater have been observed was not made land in the 1937 aerial photo, but rather was still part of the Delaware River. Apparent outwash/sedimentation from SWMU 9 on the adjacent DVW into surface water at AOI 7 are shown in the 1937 aerial photo, as evidenced by the white material migrating from SWMU 9 along the shoreline and towards AOI 7.
- *SWMU 9* – Approximately half of the current extent of SWMU 9 was still surface water in 1937. Waste deposition on the land surface is apparent in SWMU 9, based on the white areas in the 1937 aerial photo. As mentioned above, materials also appear to be migrating from SWMU 9 to AOI 7 and deposited in the sediments along the shoreline of AOI 7.

1953 Aerial Photo

- *AOI 7* – The shoreline has been straightened in the 1953 aerial photo since the 1937 photo. Middle Creek is more channelized and now crosses the center of AOI 7. There is an additional area of made land along the southwestern boundary of AOI 7, in the general area where the deposition from SWMU 9 was observed in 1937 and current elevated arsenic detections are observed. The newly made land also appears to have overland depositions from SWMU 9.
- *SWMU 9* –A bulkhead further out in the Delaware River is apparent in the 1953 aerial, which is assumed to be used to form an expansion of the impoundment for the alum mud settling. As mentioned above, overland materials also seem to be migrating from SWMU 9 to AOI 7.

1958 Aerial Photo

- *AOI 7* – In the 1958 aerial photo, there is additional made land in the southwestern portion of AOI 7 and Middle Creek has been completely channelized and re-routed through the center of AOI 7 and along the western AOI 7 boundary to its current configuration.
- *SWMU 9* – The 1958 aerial photo shows that the impoundment had more deposition than shown in the 1953 aerial photo. The remainder of SWMU 9 also appears to have more materials placed than shown in the 1953 aerial photo, but drainage channels into the impoundment were also clearly present.

1965 Aerial Photo

- *AOI 7* – The 1965 aerial photo shows the build out of the ethylene and ethylene oxide units and the remainder of the riverfront margin of AOI 7 filled to the current bulkhead line. Materials were placed to bring the elevation of the area to 15 feet above mean sea level (AMSL) and then eventually to the current elevation of approximately 19 feet AMSL in the southern portion of AOI 7.

- *SWMU 9* – Continued deposition is apparent in the alum mud impoundment in the 1965 aerial photo. There is a large white area in SWMU 9 that may be gypsum waste being stockpiled.

2. USEPA'S OCTOBER 13, 2022 COMMENTS AND EVERGREEN RESPONSES

This section includes each of the comments from the USEPA's October 13, 2022 correspondence as well as Evergreen's response to these comments.

Comment 1: *Section 4.5: Preferential pathways for contaminant migration should consider fluvial channels associated with middle creek and anthropogenic features like the bulkhead and old/degraded dock pilings (if present). Anthropogenic features have the potential to create a pathway of upward vertical flow. Fluvial channels have the potential to create a pathway through granular sediments beneath the former location of Middle Creek. EPA suggests that Section 5.0, supplemental porewater sampling, include: 1) collecting a porewater sample in the historic fluvial channel of Middle Creek, near the shoreline, at a depth that would be anticipated to intercept or be within creek bottom sediment; 2) collecting a porewater sample adjacent to the southwest terminus of the bulkhead and, if possible, adjacent to or between the bulkhead and riprap; and 3) if old and degraded pilings exist (as observed in aerial 1953), an additional porewater sample collected adjacent to a subset of the pilings.*

Response to Comment 1:

(1) Historic Middle Creek (as shown on Exhibits 1 and 2 in Attachment D) does not extend to the current AOI 7 shoreline. Rather, historic Middle Creek is located approximately 540 feet inland from the current AOI 7 shoreline. Therefore, Evergreen cannot collect a porewater sample from the historic fluvial channel of Middle Creek.

(2) Location PW-01B is located at the southwest terminus of the bulkhead. See picture of the area between the bulkhead and the riprap (Exhibit 3 in Attachment D). This area is located on a steep slope between large boulders, therefore another sample cannot be collected closer to the shoreline than PW-01B.

(3) The bulkhead and dock pilings are located on Exhibit 4 in Attachment D. The dock pilings are not currently present and would be in the filled land, therefore a porewater sample cannot be collected at these locations.

In addition, the USEPA, Evergreen, and Sanborn Head met on November 9, 2022 and discussed the USEPA's concerns with potential preferential pathways based on Site geology and Site features. Based on that discussion, Evergreen prepared a technical memorandum with additional information concerning the potential for porewater discharge from the southwest corner of AOI 7, which was submitted to the USEPA on November 14, 2022. This technical memorandum, which is included in Attachment E, documents that even if a preferential pathway existed it would not result in porewater concentrations above the

porewater PRG or arsenic deposition above the sediment PRG. Evergreen has included additional supporting information from this analysis in response to further USEPA questions, later in this response to comments.

Comment 2: *Section 5.1 Porewater Sampling Methodology: There is no mention of number of attempts to be made to collect a porewater sample before attempting the additional actions described. Please discuss whether, similarly to previous sampling, two attempts will be made or an alternative number. EPA is extremely interested in retrieving sample results from proposed locations PW-01B, PW-02B, PW-07B, and PW-13B.*

Response to Comment 2: Consistent with the activities completed during the March 2022 porewater sampling event, 10 to 15 attempts will be completed to collect porewater using the standard push point sampler method at each location before taking one or more of the following actions:

- Sampling at varying depths within a 0.2 to 0.8 ft interval,
- Sampling within a 20-ft radius of the original proposed location,
- Using up to five 0.45 micron filters per sample, since these locations are expected to have silt-laden porewater recovery that will clog the filters,
- Taking out the screen in the push point sampling port, and/or
- Allowing for very slow porewater recovery (up to 20 minutes).

Evergreen will prioritize previous sample locations PW-01B, PW-02B, PW-07B, and PW-13B in order to maximize the efforts to collect a porewater sample at these locations.

Comment 3: *Section 5.1.2: Every attempt should be made to reduce sample aeration, including:*

- *If possible, sampling using more than one filter should be avoided.*
- *Prior to filling the bottle ware, the initial aliquot should be discarded (to help remove aeration introduced during the filtration) or utilized to measure water quality parameters, and the actual sample collected during a steady flow of effluent.*
- *If air or bubbles are observed within the tubing, adjusted procedures to remove air.*
- *Avoid exposing the sample to air during extended sample collection periods.*

EPA requests that procedures associated with the use of multiple filters, observation of air bubbles created by the peristaltic pump, and start and stop times of sample collection should be documented on the sample form or field logbook at each location.

Response to Comment 3: The following steps will be taken during sample collection to reduce sample aeration.

- Porewater quality will be compared to surface water quality prior to sampling.
- Porewater will not be sampled if air/bubbles are present in the tubing.
- Air exposure of the sample will be limited as much as possible by using low flow sampling techniques and taking care to prevent aeration when filling the sample bottles.

- More than one filter will be used only if the 5-6 attempts are made without porewater recovery using one filter and if the filter is being clogged within seconds of retrieval on the final attempt.
- If any of the actions listed above are taken, they will be documented along with sample collection duration and the initial aliquot (assuming it does not have air bubbles in the sample container) will be held until another sample is able to be collected. If additional volume is not available for sampling, then the initial aliquot will be sent to the laboratory for analysis.

Comment 4: *Section 5.1.2:*
• Variation in sample depths and potentially collecting a deeper porewater sample may be necessary to evaluate fluvial channel pathways.
• Water quality parameter readings should be compared against background surface water.

Response to Comment 4:

- See response to Comment 1 regarding fluvial channel pathways.
- At each location, surface water quality readings will be collected and compared to porewater quality readings to ensure the sample is representative of porewater, using the same procedures as those followed for the March 2022 porewater sampling.

Comment 5: *Please specify which EPA analytical methods will be used for porewater and sediment samples. EPA Method 6010 was used to analyzed porewater and sediment samples collected at MHT. The US Army Corps of Engineers (USACE) utilized EPA Method 6020. At least one duplicate sediment and porewater sample duplicate should be analyzed using 6020 for comparison to the USACE results.*

Response to Comment 5: All arsenic data at the MHT site collected by Evergreen has been analyzed using USEPA Method 6010 per the QA/QC Plan provided in Appendix H in the 2017 RCRA Facility Investigation Report. None of the porewater or sediment samples collected in March 2022, using Method 6010, had QA/QC issues that resulted in reporting limits to be elevated above either the porewater or sediment PRG. Since previous samples did not identify issues with matrix interferences, the arsenic results from Method 6010 and Method 6020 are expected to be very similar. Therefore, if the USEPA requires that one sample be analyzed with Method 6020, then Evergreen suggests that all samples during the proposed field activities be completed with Method 6020.

Comment 6: *Figures 16-18: Revise sample identifiers from ND to NS.*

Response to Comment 6: Figures 16-18 have been revised (see Attachment F) to reflect any porewater locations that were not sampled to be designated as “NS” instead of “ND”.

Comment 7: *Additionally, in the conference call referenced in the Report, EPA and Evergreen discussed the sediment results that exceeded its PRG. Evergreen proposed including supporting information on its position that tidal transport and deposition (after AOI7 area was filled) is the cause of the sediment in front of AOI7 as opposed to on-site arsenic impacts attributed to historic deposition. To assist in confirming the source (tidal fluctuations, historic deposition, precipitation from pore water, or a combination of the above), EPA requests vertical delineation of sediment. In terms of scope, EPA recommends collecting samples from at least two locations with the highest reported concentrations of arsenic in sediment. Soil stratigraphy should be documented during sample collection and sediment samples should be collected at every 1-to-2-foot interval or change in lithology. Sediment samples should be analyzed for Arsenic. Speciation analysis may be warranted to understand if arsenic in sediment has accumulated from metal precipitation from porewater.*

Response to Comment 7:
In addition to the historic deposition of fill (discussed in detail in Section 1.2) and tidal transport, Evergreen and the USEPA had a video conference on November 9, 2022 that discussed geochemical conditions and fate and transport calculations to show that porewater is not the cause of arsenic in sediment at the site. The information included in Attachment E, discussed in the Response to Comment 1 above, provided additional detail in relation to the USEPA's Comment 7.

Because the source of arsenic in sediment is not due to deposition from porewater but rather historic deposition from the former DVW site, vertical delineation sampling for arsenic will not be beneficial in identifying the source. However, to address the USEPA's concerns, Evergreen is proposing sampling sediment at the seven locations that are proposed for porewater collection for selective sequential extraction (SSE) in the 0 to 1 foot below grade interval which will indicate the relationship between sediment and porewater concentrations. Evergreen would collect these samples during the second mobilization when the peeper samplers would be retrieved from the sediment (see Response to Comment 8 below regarding peepers). Evergreen will provide an updated Scope of Work for the SSE sampling methodology if this additional sediment sampling work has been agreed upon by the USEPA.

Comment 8: *Lastly, it was discussed on the call that Peeper porewater samplers would be considered to remove the variable associated with sample aeration. EPA suggests that at least one sample location utilize a peeper duplicate sample be collected in conjunction with a pushpoint sampler.*

Response to Comment 8: The passive samplers that were used in the March 2022 porewater sampling event (the DGT samplers) addressed sample aeration by deoxygenating for at least 24 hours in trace metal-clean 0.01M NaCl that was gently bubbled with nitrogen gas and sealed in plastic covering prior to use. Therefore, additional sampling with peepers is not needed to address potential sample aeration.

In addition, previous comments to the IM Workplan provided by the USEPA on October 26, 2021 stated the following regarding use of peepers: *"The proposed pore water sampling methodology in this section is again using a non- standardized research-style technique, which cannot be directly compared to other pore water results for the DVW project. The peeper equipment and technique is so investigative that there is not even a standardized equilibrium period, with researchers using periods ranging from a single day to well over a month. These results will not be accepted by EPA."* Additionally, the US Army Corp of Engineers (USACE) review of Evergreen's May 2022 IM Progress Report summarizing Evergreen March 2022 porewater sampling methods and results concluded that Evergreen's findings were valid, so passive sampling is not necessary to remove variability in the data set.

Although previous USEPA comments suggested against using peepers as a sampling method and the other sampling methods and results were deemed valid by USACE, Evergreen will collect porewater samples via peepers for each location that is going to be sampled in the next porewater sampling event (PW-01B, PW-02B, PW-04B, PW-07B, PW-10B, PW-13B, and PW-16B) to address EPA comments. Please note that adding peepers to the sampling plan (as discussed in Section 4.1.4 below) may change the porewater sampling start date based on peeper availability and will require a second mobilization to retrieve peepers.

3. USEPA'S DECEMBER 15, 2022 COMMENTS AND EVERGREEN RESPONSES

This section includes each of the comments from the USEPA's December 15, 2022 correspondence as well as Evergreen's response to these comments.

Comment 1: *Discussion 2.1. Equation 1 table As groundwater conc. CGW and Area show value "based on cross section" but no actual value reported. Please provide input values and supporting calculations. Back calculating using a presumed Area of 18 ft2 yields a CGW of approximately 113 mg/L. If correct, this value appears low and would not support the statement that calculated arsenic mass discharge represents the highest Arsenic concentrations across the plume or that it represents a worst-case estimate.*

Response to Comment 1:

(A) The mass discharge calculations (including input values and supporting calculations) are provided in Attachment G. The mass discharge calculations provided in Discussion 2.1 Equation 1 table utilizes the average arsenic concentrations of the entire plume near the bulkhead and the area of the sandy silt layer as shown in Figure 1 in Attachment G. The results of these calculations indicate that the mass discharge would be approximately 0.039 g/d, which show that arsenic in groundwater discharging from the sandy silt layer near the bulkhead will not accumulate in sediment to the arsenic in sediment PRG within a 5,000 year timeframe.

(B) If we used the highest arsenic concentration found near the bulkhead (at MW-609D with a concentration of 636,000 ug/L) instead of the average concentrations across the entire plume, the mass discharge would be approximately 0.070 g/d. Continuing with the calculations discussed through Discussion 2, the time to reach the arsenic in sediment PRG value (170 mg/kg) is greater than 2,900 years. The calculations for the mass discharge and time to reach the sediment arsenic PRG using the highest concentration found near/at the bulkhead is provided in Attachment G. The results of these calculations show that even using the highest arsenic in groundwater concentration found near the bulkhead and assuming that this concentration discharges from the sandy silt layer to the porewater, that it will not result in an arsenic sediment deposition rate greater than 0.000159 mg/kg, which would result in it taking over 2,900 years to achieve the sediment PRG.

Comment 2: *Discussion 2.2. A second discharge volume should be calculated for the riverfront area near MW-531L and MW-531U. The request is being made because: 1) collectively the dissolved arsenic plume is observed extending beyond the bulkhead in this area and sediment PRG exceedances are located immediately downgradient; and 2) the sediment, represented by samples SED-13 and SED-16 is not currently planned to be addressed.*

Response to Comment 2: Attachment G includes the calculations for arsenic mass discharge from the MW-531U/L area to the closest sediment sample above the sediment PRG (SED-13). Figure 2 in Attachment G shows the cross-sectional area of mass discharge for this calculation and Figure 3 in Attachment G shows the width of the plume/area of discharge. Note that the mass discharge was calculated using the highest concentration found at MW-531L (202,000 ug/L arsenic) and the area used for the mass discharge considered the sandy silt layer as an area of mass discharge in addition to the clay layer beneath as a conservative estimate. This mass discharge was used to calculate the time for porewater discharge in the MW-531U/L area to potentially accumulate in sediment and reach the sediment concentration found at SED-13 (198 mg/kg). The arsenic mass discharge from the MW-531U/L area would take over 1,300 years to accumulate in sediment to the SED-13 arsenic sediment concentration of 198 mg/kg. Because SED-13 and SED-16 are already above the arsenic in sediment PRG and the calculations show that arsenic in groundwater near the MW-531U/L area would not cause arsenic concentrations in sediment to accumulate above the arsenic in sediment PRG, the historic deposition of arsenic in sediment due to SWMU 9 historic operations as discussed in Section 1.2 above is the cause of exceedances of the arsenic in sediment PRG.

Comment 3: *Discussion 2.3. EPA is in the process of reviewing dilution inputs (CorMIX memorandum) and notes the high sensitivity of the parameter on the calculation. Pending this review, additional inputs to calculations and/or verification of data may be requested.*

Response to Comment 3: Note that the calculations provided in Attachment G used a dilution factor of 100 whereas the CorMix models uses a dilution factor of 10,000. Therefore, the dilution factor used in these calculations are conservative.

Comment 4: *Discussion 2.5. Calculating the "Time to reach sediment PRG from the sediment arsenic accumulation rate" does not incorporate existing in place contaminated sediment. Specifically the EPA requests that this analysis be expanded to answer:*

a. *Based on the time to reach sediment PRG, could porewater discharge from Sunoco be the cause of or a contributor to current sediment exceedances at SED-13 and SED 16? This would need to account for conservative estimates of maximum arsenic concentrations and river dilution.*
b. *At what timeframe would the PRG be exceeded, at locations that do not currently exceed the PRG, considering the potential for arsenic precipitation to accumulate at locations with previously reported arsenic concentrations?*

Response to Comment 4: Incorporating existing sediment data is not appropriate for this calculation because this calculation is estimating what the accrued sediment concentration would be over time from AOI 7 groundwater only. Because the calculations show that it would take thousands of years to accumulate arsenic in sediment to the sediment PRG from AOI 7 groundwater, this demonstrates that current arsenic in sediment concentrations are from previous impacts (i.e., from historic SWMU 9 fill that spread onto the current AOI 7 land).

a. Attachment G provides the calculations for the time to reach SED-13 arsenic sediment concentrations (higher than the sediment PRG) from groundwater discharge from the nearest upgradient wells MW-531U/L according to the groundwater flow direction. The time to reach the arsenic in sediment concentration at SED-13 (198 mg/kg) is greater than 1,300 years as discussed in the Response to Comment 2 above.
b. SED-07 and SED-10 are the two locations that do not exceed the arsenic in sediment PRG and are located downgradient of the arsenic in groundwater plume. Attachment G provides the calculations for the timeframe the PRG would be exceeded at these locations. Figure 4 in Attachment G demonstrates the cross-sectional area of mass discharge to this area and the concentrations used for the mass discharge calculations. The time to reach the arsenic in sediment PRG (170 mg/kg) is approximately 900 years. In the last 50 years, up to 10 mg/kg of arsenic could have potentially been deposited to the sediment. The current arsenic in sediment concentrations at SED-07 and SED-10 are higher than the accumulation rate would calculate these concentrations to be since the beginning of AOI 7 made land to present day. This also demonstrates that current arsenic in sediment concentrations, even in the area of highest arsenic concentrations at the site, is not due to discharge from groundwater but due to previous impacts from historic SWMU 9 operations/activities.

Comment 5: *Discussion 3. Where is the location of the USGS NWIS sample station that was utilized for cation/anion inputs? If this station is not in the immediate vicinity of the site, the analysis should consider collection and use of site specific data.*

Response to Comment 5: The closest Delaware River USGS NWIS sample station with the most recent data for surface water quality was utilized for these inputs, which was monitoring location 01463500 in Trenton, NJ. Evergreen can collect surface water quality data for calcium, magnesium, iron, and potassium to represent the cations and chloride, sulfate, and bicarbonate to represent the anions near the toe of slope at the AOI 7 shoreline to confirm the inputs to the Geochemist Workbench model, these data will not be evaluated as potential COCs. This data will inform the arsenic solubility diagram for AOI 7 surface water to confirm that arsenic in porewater is in the dissolved phase and will not precipitate/accumulate in the sediment.

Comment 6: *Discussion 3. Please incorporate site specific surface water pH/eh measurements plotted on the Arsenic and Iron pe-pH diagram, similar to Exhibit 1, into the evaluation.*

Response to Comment 6: Exhibit 5 in Attachment D shows the arsenic and iron pe-pH diagram. The yellow box placed on the graph are the site-specific surface water pe/pH measurements that were collected during the March 2021 porewater sampling event. The site-specific pe/pH measurements fall within the dissolved phase of the arsenic-iron pe-pH diagram, demonstrating that arsenic at the surface water interface will not precipitate and accumulate in sediment. Note that the arsenic solubility diagram presented in Exhibit 6 of Attachment E is more representative of arsenic solubility in surface water conditions at the site because this graph factors in multiple anions/cations that would affect solubility of arsenic rather than iron only (as depicted in the arsenic-iron pe-pH diagram).

Comment 7: *Discussion 3. The evaluation suggests that current geochemical parameters will not facilitate arsenic precipitation at the sediment/surface water boundary. For future consideration the evaluation should incorporate future geochemical conditions that may result from climate change. For example, future climate change adaptation should consider dilution of anion and cations based on more frequent rainfall and flooding events. EPA is acceptable to this scenario being addressed in a future Cleanup Plan.*

Response to Comment 7: Additional dilution due to climate change would increase the dilution factor and lower the predicted porewater to surface water concentrations (which are currently below the porewater PRG).

Comment 8: *In the October 26, 2022 meeting EPA and Evergreen discussed the use of the colloidal borescope to evaluate the potential for preferential pathway within the silty sand strata and direction of groundwater flow in this zone. Has this data been evaluated and what are the results. Does it support the potential for preferential pathways as being evaluated in the draft arsenic precipitation calculations?*

Response to Comment 8: The pressure transducer data collected in September 2022 in both the shallow and deep groundwater wells provided a unique point in time where all the water levels in these wells were measured during high and low tide to be able to generate representative groundwater flow direction to support the evaluation of potential preferential pathways at the site. Specifically, the pressure transducers were deployed in deep monitoring wells MW-56D, MW-509D, MW-530U, MW-531L, MW-532L, MW-534L, MW-558D, MW-559D, MW-560D, MW-606D, MW-607D, MW-608D, and MW-609D in the southern portion of AOI 7 to evaluate this potential preferential pathway. This approach was selected over the borescope because the borescope cannot collect groundwater flow direction data in multiple wells at the same time for a comprehensive data set. Because of the tidal influence at the site, the groundwater flow evaluation needs to be performed across multiple wells (shallow and deep) over a tidal cycle at the same time, which is not possible with one borescope, but was achieved with the pressure transducers.

Comment 9: *The revised CSM presented in the 20220930_AOI 7 Monthly USEPA Report suggests the source of arsenic was "deposited onto the Delaware River Sediment from Honeywell's DVW properties before this portion of AOI 7 was made land." EPA notes that Honeywell DVW SWMU-9 was not present during this time and the mechanism for source and deposition onto AOI-7 is not entirely clear. Are there additional lines of evidence (facility operations, documented transport mechanisms like outfalls, etc) that suggest Honeywell DVW is the source of arsenic deposited onto river sediment?*

Response to Comment 9: As summarized in Section 1.2. above, the property for the DVW South Plant historically generated products that contained arsenic including phosphoric acid, hydrofluoric acid, aluminum sulfate, alum, sulfuric acid, and various chemical products. The General Chemical site additionally contained pyritic ore, a waste-product generated during the production of sulfuric acid and is a known source of arsenic. Specifically, SWMU 9 is a former settling pond used for the dewatering of alum mud (used to bind arsenic from wastewater treatment processes) from the 1950s to the late 1980s.

Historic aerials of the site from 1937 to 1965, as discussed in detail in Section 1.2, show consistent material deposition from the DVW South Plant to the western portion of AOI 7 which was filled 1937 and 1965 and along the current Delaware River shoreline during this same period. In summary, the historic operations at the DVW site included arsenic in its generated products, historic deposition over time was demonstrated in the historic aerials from SWMU 9 to AOI 7, and no source of arsenic is identified at the AOI 7 property (based on historical operations and extensive subsurface investigations) that would result in the observed concentrations. Based on these lines of evidence, the Honeywell DVW site is the former source for arsenic in the subsurface and shoreline of AOI 7.

Comment 10: *Evergreen previously discussed a multiple lines of evidence approach to support that sediment contamination in front on the AOI-7 is not related to arsenic precipitation from porewater. Lines of evidence that would be considered included: 1) preferential pathway for discharge and precipitation (being evaluated in the Draft for Discussion, Arsenic in Sediment and Porewater Calculations and subsequent comments - ongoing); and 2) review of and comparison between the ratios of arsenic to iron (and potentially DDX and other anion/cations) from AOI-7 and Honeywell DVW (has the been evaluated). Based on the results, EPA believes there would be value in collecting supplemental sediment samples to fill any necessary data gaps for the evaluation and/or confirm conclusions of the multiple lines of evidence approach.*

Response to Comment 10: Collecting additional sediment data (for iron or other anion/cation data) at locations where arsenic was previously collected in sediment will not be useful to evaluate potential fingerprinting of arsenic transport. As discussed in Section 1.2 and throughout the calculations provided in Section 3.0, arsenic in sediment is due to historic deposition of materials from DVW South Plant onto the portion of AOI 7 that was later filled and along the shoreline. Collecting sediment samples for fingerprinting is not useful because the source of the arsenic impacts in the southwestern area of AOI 7 and the former Honeywell site are the same.

Comment 11: *What is Evergreen's plan on how to incorporate EPA's comments on porewater sampling methodology and analysis from October 13, 2022 comment letter?*

Response to Comment 11: The details of the porewater sampling methodology and analysis is provided in Section 3.0 of this letter.

Comment 12: *I wanted to again offer the option for you to move forward to not continue to delay the contractor sampling scheduling. EPA notes there would be value in collecting sediment samples and surface water (site specific anion and cation) to address any data gaps (As/Fe ratios, speciation, and other supporting information) to support the conclusions presented in the calculations. So, you could opt to collect and hold if you prefer pending the outcome of this calculation submittal. I will note thought that some aspects of the sampling methodology and analysis comments still need to be addressed if you decide to attempt sampling.*

Response to Comment 12: The porewater sampling field event has been postponed until the scope of this event has been agreed upon between Evergreen and USEPA to ensure that the data collected will be acceptable by the USEPA and useable by Evergreen to complete the remedial design for AOI 7.

4. SUPPLEMENTAL POREWATER SAMPLING PLAN

Seven supplemental porewater sampling locations are proposed based on the results of the previous porewater sampling results and the conceptual site model. The proposed locations are shown in Figure 18 (Attachment F) and are:

- PW-01B – a confirmatory location for USACE 2 (LOC-002),
- PW-02B – a step out location from PW-01B (and confirmatory location for USACE 7),
- PW-04B – a confirmatory location for PW-04,
- PW-07B – a confirmatory location for USACE 3 (LOC-003),
- PW-10B – a confirmatory location for PW-10,
- PW-13B – a confirmatory location for USACE 4 (LOC-004), and
- PW-16B - a confirmatory location for PW-16.

Locations PW-01B, PW-04B, PW-07B, PW-10B, PW-13B, and PW-16B are located immediately downgradient of the area of arsenic mass discharge across the AOI 7 shoreline. Additionally, locations PW-01B and PW-07B are co-located with USACE porewater sampling locations that could not be collected during the Evergreen porewater sampling event in March 2022. PW-02B is a step-out location for PW-01B that also could not be collected in March 2022 by Evergreen and is located downgradient of the highest arsenic in porewater concentration from the USACE porewater sampling event. Evergreen will prioritize previous sample locations PW-01B, PW-02B, PW-07B, and PW-13B in order to maximize the efforts to collect a porewater sample at these locations

4.1 October 2022 Porewater Sampling Methodology

The following porewater sampling methodology is consistent with the Evergreen March 2022 porewater sampling event methodology that was provided in the IM Workplan and documented in the May 27, 2022 Sediment and Porewater Sampling technical memorandum, with enhancements made in response to USEPA comments as summarized above in the response to comments and below in Section 4.1.2.

4.1.1 Mobilization

The Evergreen sampling team will travel by an 18-foot Jon boat equipped with a davit and winch (used as the sampling platform for all locations) to the AOI 7 shoreline area from a docking area located underneath the Commodore Barry Bridge near Subaru Park in Chester, Pennsylvania. The Jon boat drafts less than one foot of water which allows for access to shallow areas during low tide. The boat will be positioned as close as possible (within 2 feet) to the proposed location coordinates (as shown on Figure 18 in Attachment F) using an on-board survey instrumentation (Trimble GeoXH) and the GPS-determined coordinates recorded for each location. For the first row of samples (PW-01B, PW-04B, PW-07B, PW-10B, PW-13B, PW-16B), each location will be evaluated by navigating to the coordinates for each location and then physically verifying with one of the samplers walking on the sediment surface to identify the rip rap and the toe of slope (and a soft bottom sediment area) to ensure that the sample is located immediately at the toe of the slope. If the sample location is not located at the toe of the slope, its distance from the toe of the slope will be noted. After positioning the boat and documenting the coordinates, the boat bow will anchor, and the sampling will take place off the side on the aft deck. As discussed above, sample locations PW-01B, PW-02B, PW-07B, and PW-13B will be prioritized for porewater collection.

A stability plate will be used as part of the push point sampler so that the push point sampler will not move when deployed from the boat, since the tubing and wave action could potentially pull it loose. High and low tides hours will be researched and conveyed to the sampling team before the event. During areas of low tide, the first row of samples may not be reachable due to no standing water present. Sampling during high tide conditions (between five and six feet of standing water) can be conducted at any of the sampling locations because the push point sampler is able to reach these depths easily.

4.1.2 Porewater Sampling Methodology – Push Point Sampling Methodology

Six-foot long push point samplers (used during the Evergreen, USACE, and Delaware Valley Works (DVW) sampling events) will be used for sample collection due to the anticipated tidal range. The porewater sampler will attach to a stability plate at approximately 0.5 ft from the bottom of the sampling probe. A retrieval line will be attached to the plate and the top of the probe so the sampler can be pulled aboard after the sampling. The probe will be lowered to the bottom and relocated as necessary to permit the stability plate to rest firmly on the bottom sediment. The interior probe placement rod is then removed and replaced with flexible tubing at the top of the probe and connected to the peristaltic pump for porewater collection. New tubing will be used at each location and the push point will be decontaminated using water, nitric acid and acetone followed by a final water rinse.

Evergreen will attempt to collect the porewater samples during low to mid-tide cycles when the surface water elevation in the Delaware River is lower than groundwater elevations along AOI 7 shoreline. In addition, 10 to 15 attempts will be completed to collect porewater using the standard push point sampler method at each location before taking one or more of the following actions:

- Sampling at varying depths within a 0.2 to 0.8 ft interval,
- Sampling within a 20-ft radius of the original proposed location,
- Using up to five 0.45 micron filters per sample, since these locations are expected to have silt-laden porewater recovery that will clog the filters,
- Taking out the screen in the push point sampling port, and/or
- Allowing for very slow porewater recovery (up to 20 minutes).

Additionally, the following steps will be taken during sample collection to reduce sample aeration.

- Porewater quality will be compared to surface water quality prior to sampling.
- Porewater will not be sampled if air/bubbles are present in the tubing.
- Air exposure of the sample will be limited as much as possible by using low flow sampling techniques and taking care to prevent aeration when filling the sample bottles.
- More than one filter will be used only if the 5-6 attempts are made without porewater recovery using one filter and if the filter is being clogged within seconds of retrieval on the final attempt.

If any of the actions listed above are taken, they will be documented along with sample collection duration and the initial aliquot (assuming it does not have air bubbles in the sample container), will be held until another sample is able to be collected. If additional volume is not available for sampling, then the initial aliquot will be sent to the laboratory for analysis.

The first step of the porewater sampling process will be to measure water quality parameters using a Myron Ultrameter Model 6P meter (Myron) to obtain field readings for conductivity, oxidation-reduction potential (ORP), pH, and temperature. These water quality parameters will be collected at least once for every location to verify that the sample represents porewater, not surface water. The Myron meter will be calibrated each morning of the sampling event.

A 0.45 micron filter will be attached to the end of the tubing after water quality parameters are assessed, and a new filter will be used for each location. The dissolved arsenic porewater samples will be preserved in 250 mL nitric acid preserved bottles. During this sampling process, the steps outlined above will be taken to reduce sample aeration.

Porewater samples will be sent to SGS North America, Inc. (SGS) of Dayton, New Jersey for analysis of dissolved arsenic via USEPA SW-846 method 6020. One rinsate equipment blank will be collected for dissolved arsenic analysis following the decontamination process of the push point sampler. Additional field Quality Assurance/Quality Control (QA/QC) samples will include one field duplicate sample and one matrix spike/matrix spike duplicate (MS/MSD pair) from one of the porewater sampling locations collected. Data validation will be performed for all porewater samples collected for dissolved arsenic analysis.

4.1.3 Porewater Sampling Methodology – Peeper Sampling Methodology

The seven porewater sample locations (PW-01B, PW-02B, PW-04B, PW-07B, PW-10B, PW-13B, and PW-16B) will also collect dissolved arsenic samples using passive porewater samplers called peepers. Peepers quantify the dissolved form of constituents to provide more accurate data regarding contaminant bioavailability to environmental receptors. The peepers consist of chambers overfilled with deionized oxygen-free water (DI) that is held within the chambers by a porous membrane and the overlays. The peepers will be degassed prior to deployment. Peepers will be deployed by inserting into the sediment to a depth of 6 inches below the mudline or as deep as possible to allow the surrounding interstitial water to infiltrate the sampler. The peeper will be deployed for a 2-week period prior to retrieval. This will allow for better sample collection and to also simulate chronic conditions (which the current arsenic in groundwater PRG is based upon).

For porewater retrieval, the sample would be removed from the chamber using a syringe. While collecting porewater to fill laboratory-provided containers, the porewater pH, temperature, and conductivity should be measured from additional sample volume. Following porewater collection into the laboratory-supplied containers, the porewater samples needs to be placed in a cooler at 4 degrees Celsius for transport to the field facility where they will be packaged for shipment. The SOP for the porewater sampling at AOI 7 is provided in Attachment H.

The peeper samplers for dissolved arsenic analysis will be provided by SiREM Lab. Porewater samples will be sent to a subcontracted lab via SiREM Lab for analysis of dissolved arsenic via USEPA SW-846 method 6020 and subsequent calculation of the dissolved arsenic in porewater concentration based on the time the samplers have been deployed. Data validation will be performed for all porewater samples collected for dissolved arsenic analysis.

4.1.4 Surface Water Sampling Methodology

As discussed in Section 3.0 above, specific cations and anions will be collected in surface water as inputs to the Geochem Workbench to confirm that arsenic encountering the surface water-sediment interface will not precipitate out into the sediment. The location of the surface water collection will occur at PW-04B (the location of the highest arsenic in porewater and sediment in the March 2022 sediment and porewater sampling event to evaluate whether surface water conditions are favorable for precipitation). The surface water sample will be collected by decanting a grab surface water volume from a decontaminated collection device such as a stainless-steel scoop or other device. Cations that will be collected and analyzed in this sample include calcium via EPA 6020, magnesium via EPA 6020, iron via EPA 6020, and potassium via EPA 6020. Anions that will be collected and analyzed in this sample include chloride via SW846 9056A, sulfate via SW846 9056A, and bicarbonate via EPA Method 310.1. The surface water sample will be sent to SGS of Dayton, NJ for all analyses discussed above and data validation will not be performed on the results.

4.2 Schedule

The first mobilization for the additional porewater sampling is tentatively planned for February 6, 2022 through February 10, 2022 by Sanborn Head with their subcontractor Normandeau. This tentative schedule is contingent upon the availability and shipment of the peepers. The peepers will require a second mobilization to collect the peeper samplers after equilibrium has been reached (two weeks after deployment). After porewater sample results have been analyzed and data validated, the results of the confirmatory porewater sampling event will be provided in a subsequent IM Progress Report.

Very truly yours,
SANBORN, HEAD & ASSOCIATES, INC.

Colleen Costello, P.G.
Senior Vice President

CC/CS: cs

Encl. Attachment A – October 13, 2022 and December 15, 2022 USEPA Comments
Attachment B – Site Description Figures

Attachment C – Historic Aerials
Attachment D – Exhibits
Attachment E – Sediment and Porewater Calculations
Attachment F – Figures 16 – 18
Attachment G – Additional Mass Discharge Calculations
Attachment H – Peeper SOP

cc: Jeffrey Christopher, Tiffani Doerr, Chelsey Shepsko

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Attachment A

October 13, 2022 and December 15, 2022 USEPA Comments

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
Four Penn Center
1600 John F. Kennedy Boulevard
Philadelphia, Pennsylvania 19103-2852

October 13, 2022

Subject: Monthly Progress Report – September 2022 comments AOI7

Dear Mrs. Doerr:

The U.S. Environmental Protection Agency (EPA) has reviewed the Marcus Hook Terminal (MHT) Monthly Progress Report – September 2022 AOI7 (Report) prepared by Sanborn, Head & Associates, Inc. on behalf of Evergreen Resources Management Operations (Evergreen), dated September 30, 2022. The EPA has the following comments on the Report:

Section 4.5: Preferential pathways for contaminant migration should consider fluvial channels associated with middle creek and anthropogenic features like the bulkhead and old/degraded dock pilings (if present). Anthropogenic features have the potential to create a pathway of upward vertical flow. Fluvial channels have the potential to create a pathway through granular sediments beneath the former location of Middle Creek. EPA suggests that Section 5.0, supplemental porewater sampling, include: 1) collecting a porewater sample in the historic fluvial channel of Middle Creek, near the shoreline, at a depth that would be anticipated to intercept or be within creek bottom sediment; 2) collecting a porewater sample adjacent to the southwest terminus of the bulkhead and, if possible, adjacent to or between the bulkhead and riprap; and 3) if old and degraded pilings exist (as observed in aerial 1953), an additional porewater sample collected adjacent to a subset of the pilings.

Section 5.1 Porewater Sampling Methodology: There is no mention of number of attempts to be made to collect a porewater sample before attempting the additional actions described. Please discuss whether, similarly to previous sampling, two attempts will be made or an alternative number. EPA is extremely interested in retrieving sample results from proposed locations PW-01B, PW-02B, PW-07B, and PW-13B.

Section 5.1.2: Every attempt should be made to reduce sample aeration, including:

- If possible, sampling using more than one filter should be avoided.
- Prior to filling the bottleware, the initial aliquot should be discarded (to help remove aeration introduced during the filtration) or utilized to measure water quality parameters, and the actual sample collected during a steady flow of effluent.
- If air or bubbles are observed within the tubing, adjusted procedures to remove air.
- Avoid exposing the sample to air during extended sample collection periods.

EPA requests that procedures associated with the use of multiple filters, observation of air bubbles created by the peristaltic pump, and start and stop times of sample collection should be documented on the sample form or field logbook at each location.

Section 5.1.2:

- Variation in sample depths and potentially collecting a deeper porewater sample may be necessary to evaluate fluvial channel pathways.
- Water quality parameter readings should be compared against background surface water.

Please specify which EPA analytical methods will be used for porewater and sediment samples. EPA Method 6010 was used to analyzed porewater and sediment samples collected at MHT. The US Army Corps of Engineers (USACE) utilized EPA Method 6020. At least one duplicate sediment and porewater sample duplicate should be analyzed using 6020 for comparison to the USACE results.

Figures 16-18: Revise sample identifiers from ND to NS.

Additionally, in the conference call referenced in the Report, EPA and Evergreen discussed the sediment results that exceeded its PRG. Evergreen proposed including supporting information on its position that tidal transport and deposition (after AOI7 area was filled) is the cause of the sediment in front of AOI7 as opposed to on-site arsenic impacts attributed to historic deposition. To assist in confirming the source (tidal fluctuations, historic deposition, precipitation from pore water, or a combination of the above), EPA requests vertical delineation of sediment. In terms of scope, EPA recommends collecting samples from at least two locations with the highest reported concentrations of arsenic in sediment. Soil stratigraphy should be documented during sample collection and sediment samples should be collected at every 1-to-2-foot interval or change in lithology. Sediment samples should be analyzed for Arsenic. Speciation analysis may be warranted to understand if arsenic in sediment has accumulated from metal precipitation from porewater.

Lastly, it was discussed on the call that Peeper porewater samplers would be considered to remove the variable associated with sample aeration. EPA suggests that at least one sample location utilize a peeper duplicate sample be collected in conjunction with a pushpoint sampler.

If you have any questions or concerns, please contact me at 215-814-2796 or bilash.kevin@epa.gov upon receipt and review of this letter.

Sincerely,

_____

Kevin Bilash
Land, Chemicals & Redevelopment Division
US Environmental Protection Agency, Region III

cc: file

Chelsey Shepsko

From: Colleen Costello
Sent: Thursday, December 15, 2022 3:01 PM
To: Chelsey Shepsko
Subject: FW: AOI7 As calculation comments

From: Bilash, Kevin <Bilash.Kevin@epa.gov>
Sent: Thursday, December 15, 2022 2:10 PM
To: Colleen Costello <ccostello@sanbornhead.com>; DOERR, TIFFANI L <TLDOERR@evergreenresmgt.com>
Cc: Christopher, Jeffrey <Christopher.Jeffrey@epa.gov>
Subject: AOI7 As calculation comments

Tiffani and Colleen,

The EPA offers the following comments and questions for the AOI7 Calculations PDF submitted 11/14/2022.

1. Discussion 2.1. Equation 1 table As groundwater conc. C_{GW} and Area show value "based on cross section" but no actual value reported. Please provide input values and supporting calculations. Back calculating using a presumed Area of 18 ft^2 yields a C_{GW} of approximately 113 mg/L. If correct, this value appears low and would not support the statement that calculated arsenic mass discharge represents the highest Arsenic concentrations across the plume or that it represents a worst-case estimate.
2. Discussion 2.2. A second discharge volume should be calculated for the riverfront area near MW-531L and MW-531U. The request is being made because: 1) collectively the dissolved arsenic plume is observed extending beyond the bulkhead in this area and sediment PRG exceedances are located immediately downgradient; and 2) the sediment, represented by samples SED-13 and SED-16 is not currently planned to be addressed.
3. Discussion 2.3. EPA is in the process of reviewing dilution inputs (CorMIX memorandum) and notes the high sensitivity of the parameter on the calculation. Pending this review, additional inputs to calculations and/or verification of data may be requested.
4. Discussion 2.5. Calculating the "Time to reach sediment PRG from the sediment arsenic accumulation rate" does not incorporate existing in place contaminated sediment. Specifically the EPA requests that this analysis be expanded to answer:
    a. Based on the time to reach sediment PRG, could porewater discharge from Sunoco be the cause of or a contributer to current sediment exceedances at SED-13 and SED 16? This would need to account for conservative estimates of maximum arsenic concentrations and river dilution.
    b. At what timeframe would the PRG be exceeded, at locations that do not currently exceed the PRG, considering the potential for arsenic precipitation to accumulate at locations with previously reported arsenic concentrations?
5. Discussion 3. Where is the location of the USGS NWIS sample station that was utilized for cation/anion inputs? If this station is not in the immediate vicinity of the site, the analysis should consider collection and use of site specific data.
6. Discussion 3. Please incorporate site specific surface water pH/eh measurements plotted on the Arsenic and Iron pe-pH diagram, similar to Exhibit 1, into the evaluation.
7. Discussion 3. The evaluation suggests that <u>current</u> geochemical parameters will not facilitate arsenic precipitation at the sediment/surface water boundary. For future consideration the evaluation should incorporate future geochemical conditions that may result from climate change. For example, future climate change adaptation should consider dilution of anion and cations based on more frequent rainfall and flooding events. EPA is acceptable to this scenario being addressed in a future Cleanup Plan.

In addition, EPA is providing input below to follow-up on meetings from 10/26/2022 and 11/9/2022 and comment letter dated October 13, 2022:

In the October 26, 2022 meeting EPA and Evergreen discussed the use of the colloidal borescope to evaluate the potential for preferential pathway within the silty sand strata and direction of groundwater flow in this zone. Has this data been evaluated and what are the results. Does it support the potential for preferential pathways as being evaluated in the draft arsenic precipitation calculations?

The revised CSM presented in the 20220930_AOI 7 Monthly USEPA Report suggests the source of arsenic was *"deposited onto the Delaware River Sediment from Honeywell's DVW properties before this portion of AOI 7 was made land."* EPA notes that Honeywell DVW SWMU-9 was not present during this time and the mechanism for source and deposition onto AOI-7 is not entirely clear. Are there additional lines of evidence (facility operations, documented transport mechanisms like outfalls, etc) that suggest Honeywell DVW is the source of arsenic deposited onto river sediment?

Evergreen previously discussed a multiple lines of evidence approach to support that sediment contamination in front on the AOI-7 is not related to arsenic precipitation from porewater. Lines of evidence that would be considered included: 1) preferential pathway for discharge and precipitation (being evaluated in the *Draft for Discussion, Arsenic in Sediment and Porewater Calculations* and subsequent comments - ongoing); and 2) review of and comparison between the ratios of arsenic to iron (and potentially DDX and other anion/cations) from AOI-7 and Honeywell DVW (has the been evaluated). Based on the results, EPA believes there would be value in collecting supplemental sediment samples to fill any necessary data gaps for the evaluation and/or confirm conclusions of the multiple lines of evidence approach.

What is Evergreen's plan on how to incorporate EPA's comments on porewater sampling methodology and analysis from October 13, 2022 comment letter?

I wanted to again offer the option for you to move forward to not continue to delay the contractor sampling scheduling. EPA notes there would be value in collecting sediment samples and surface water (site specific anion and cation) to address any data gaps (As/Fe ratios, speciation, and other supporting information) to support the conclusions presented in the calculations.
So, you could opt to collect and hold if you prefer pending the outcome of this calculation submittal. I will note thought that some aspects of the sampling methodology and analysis comments still need to be addressed if you decide to attempt sampling.

Once you review this information, please let us know if you would like to discuss.

Thank you,
Kevin Bilash
US Environmental Protection Agency Region III
Land, Chemicals & Redevelopment Division 3LD20
Four Penn Center
1600 John F. Kennedy Boulevard
Philadelphia, PA 19103-2852
Tel: 215-814-2796

Attachment B

Site Description Figures

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Last Edited By: hlapointe

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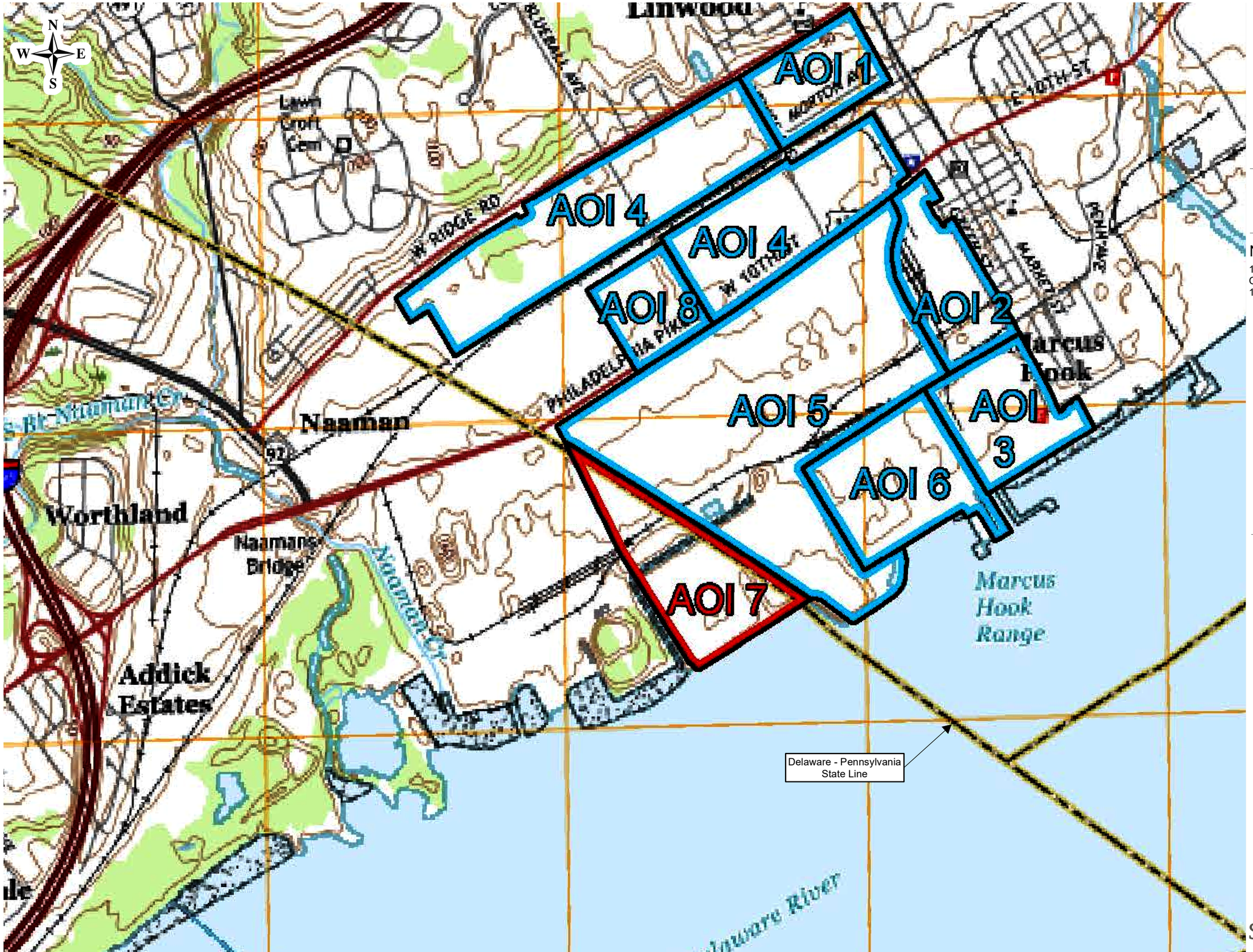

Figure 1

Site Location Map

Evergreen

Marcus Hook, Pennsylvania

Drawn By:	H. Pothier
Designed By:	A. Buchy
Reviewed By:	C. Costello
Project No:	4862.00
Date:	December 2021

Notes

1. Figure topography and features modified from GHD's RCRA Facility Investigation Report, Figure 1, May 2017 (Revised 2019).

Legend

- AOI 7
- Remaining AOIs
- MHIC Boundary

SANBORN HEAD

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Last Edited By: ewright

Figure 2

Updated AOI 7 Site Plan

Evergreen

Marcus Hook, Pennsylvania

Drawn By:	M. Fuerte / E. Wright
Designed By:	C. Costello
Reviewed By:	C. Costello
Project No:	4862.00
Date:	September 2022

Notes

1. AOI 7 well locations provided by Stanport data portal, August 2021.

2. Aerial imagery Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community.

3. SWMU 9 located based on SWMU 9 Data Summary Report, Wood, 2020.

4. The bulkhead, remedial systems, sheet pile wall and well locations were provided by Stantec in Figure I-3 "Phillips Island Remediation System Site Plan" from July 2019.

Legend

- Monitoring Well
- Recovery Well
- Remediation Well
- Soil Boring
- Staff Gauge
- 2022 Monitoring Well
- 2022 Soil Boring
- Existing Location for PDI Sampling and Pressure Transducer
- Existing Location for PDI Sampling Only
- Sunoco Pipeline
- Bulkhead
- Sheet Pile Wall
- Remediation Systems
- AOI-7 Boundary
- SWMU 9 Boundary

137.568.75 0 137.5 275 Feet

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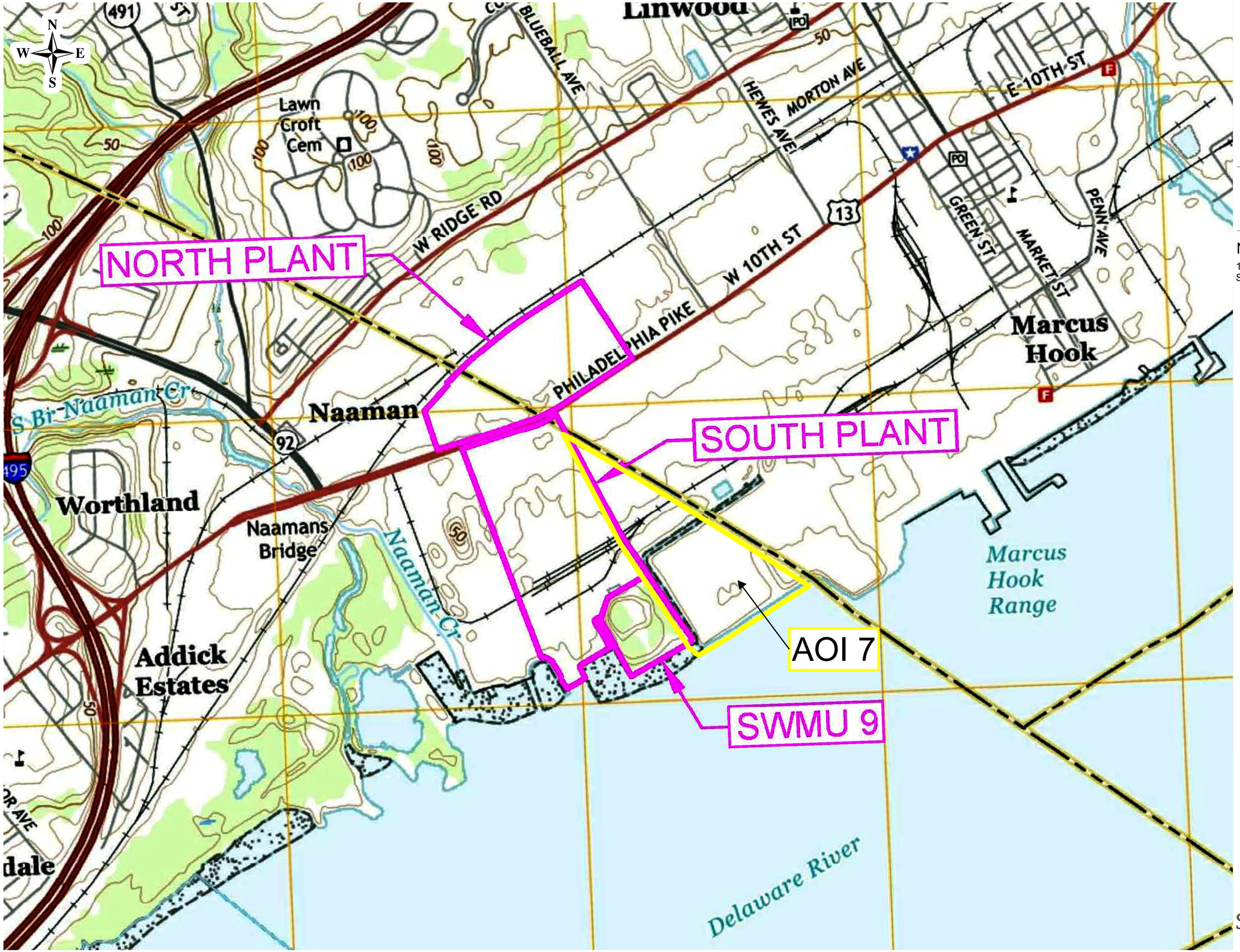

Figure 3

Honeywell DVW South Plant and SWMU 9

Evergreen

Marcus Hook, Pennsylvania

Drawn By:	H. Pothier
Designed By:	A. Buchy
Reviewed By:	C. Costello
Project No:	4862.00
Date:	September 2021

Notes

1. Figure modified from the 2020 SWMU 9 Data Summary Report (Wood, 2020).

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Last Edited By: hlapointe

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Figure 4

Changes to Middle Creek and Historic Shorelines

Evergreen

Marcus Hook, Pennsylvania

Drawn By:	H. Pothier
Designed By:	A. Buchy
Reviewed By:	C. Costello
Project No:	4862.00
Date:	September 2021

Notes

1. Figure modified from the AOI 7 RFI (GHD, 2017/Revised 2019).

2. Historic topographic maps and aerials supporting this figure are included in Appendix B of the IM Workplan, 2021.

Legend

- Area Of Interest
- Bear Creek 1898
- Middle Creek Walkers Run 1898
- 1937 Middle Creek
- 1951 Middle Creek
- 1937 Shoreline
- 1951 Shoreline
- 1958 Shoreline
- 1960 Shoreline
- 1962 Shoreline
- Fill on Geology Map
- Marsh Area 1898

150 75 0 150 300 Feet

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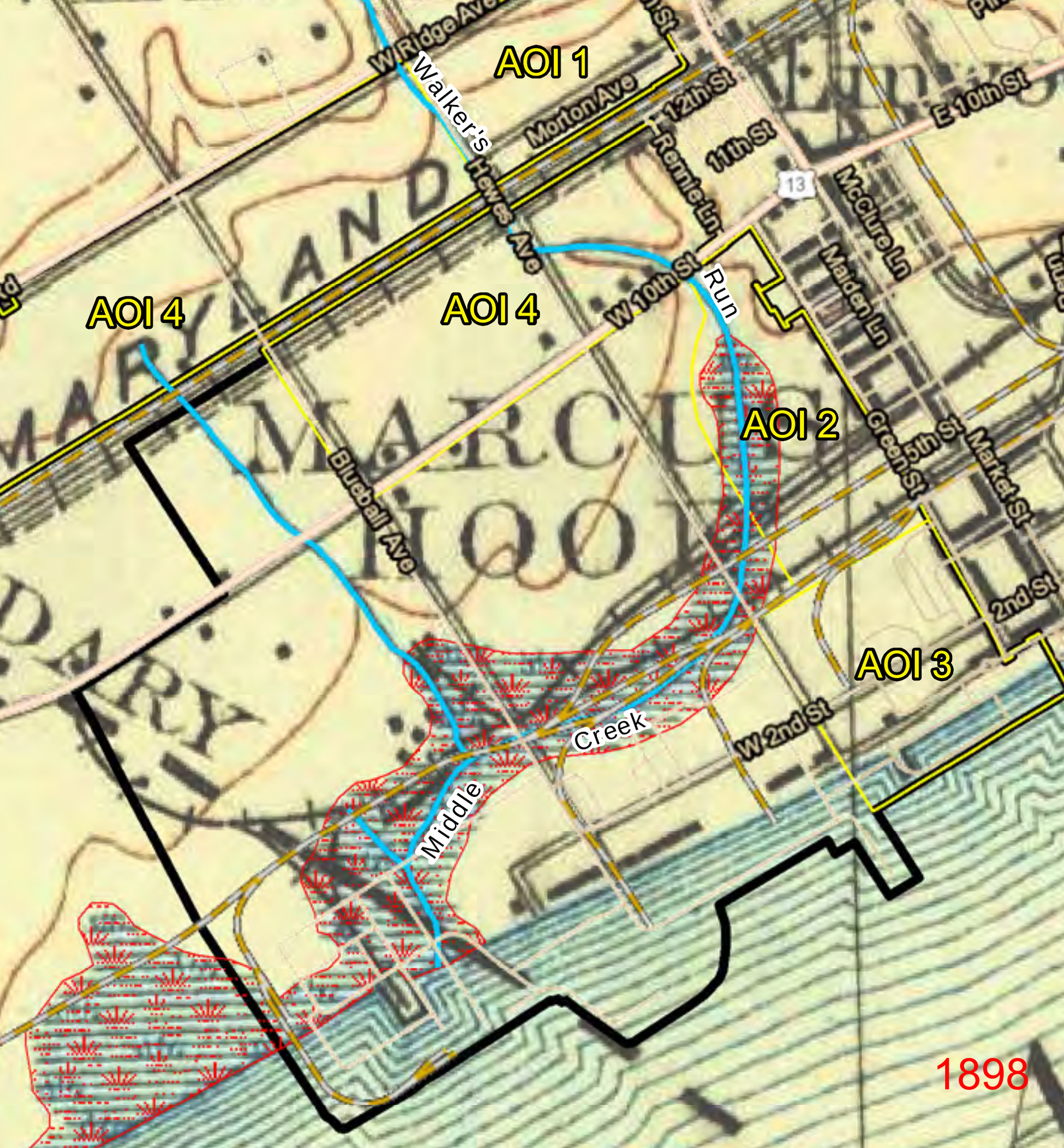
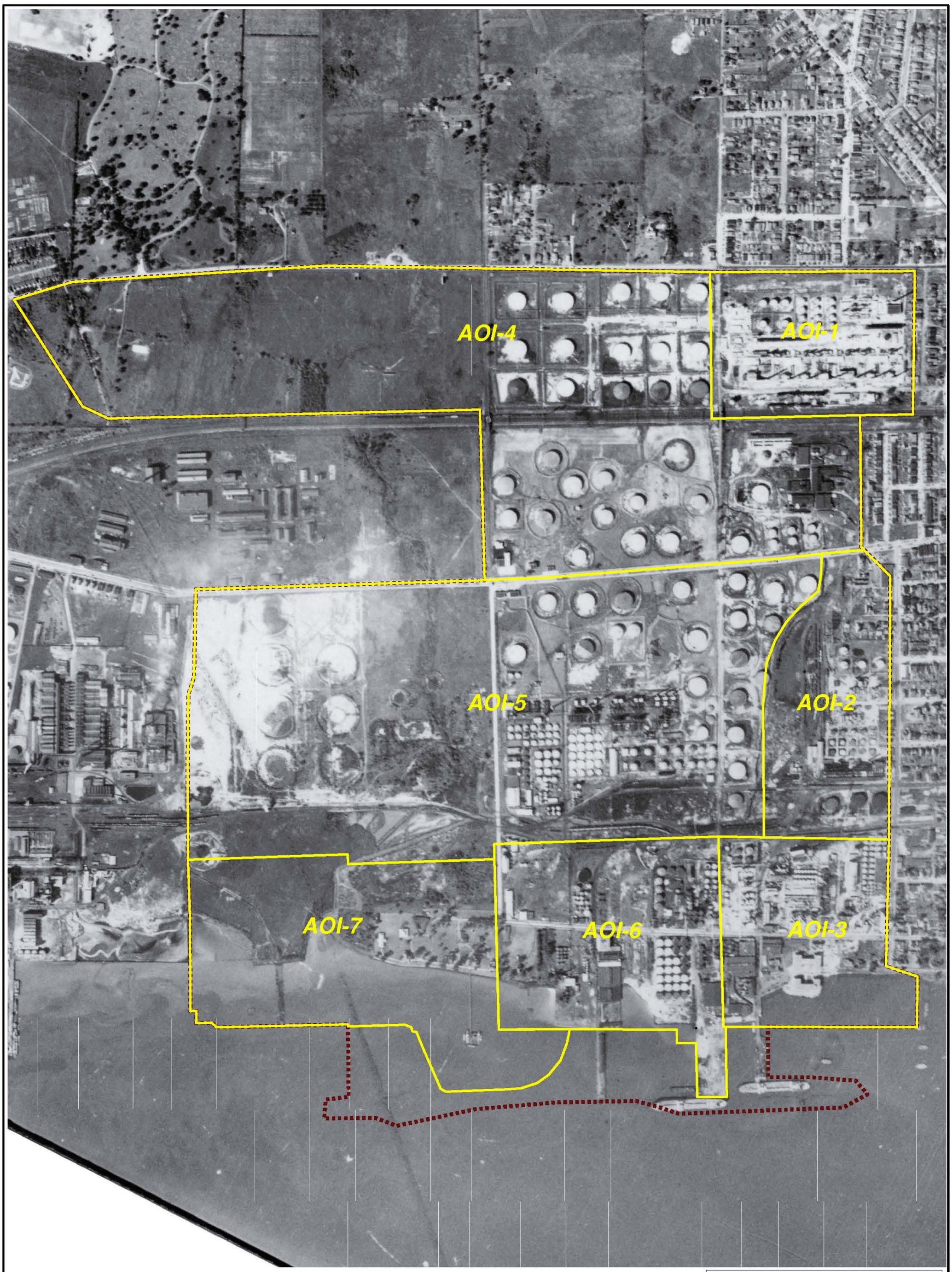
Attachment C

Historic Aerials


AOI 1
AOI 4
AOI 4
AOI 2
AOI 3
W Ridge Ave
Walker's
Morton Ave
12th St
11th St
E 10th St
Hewes Ave
Rennie Ln
13
McClure Ln
Marden Ln
W 10th St
Run
Green St
5th St
Market St
Blueball Ave
2nd St
W 2nd St
Creek
Middle
1898



Legend

Approximate Areas of Interest (AOIs)

Approximate Property Boundary

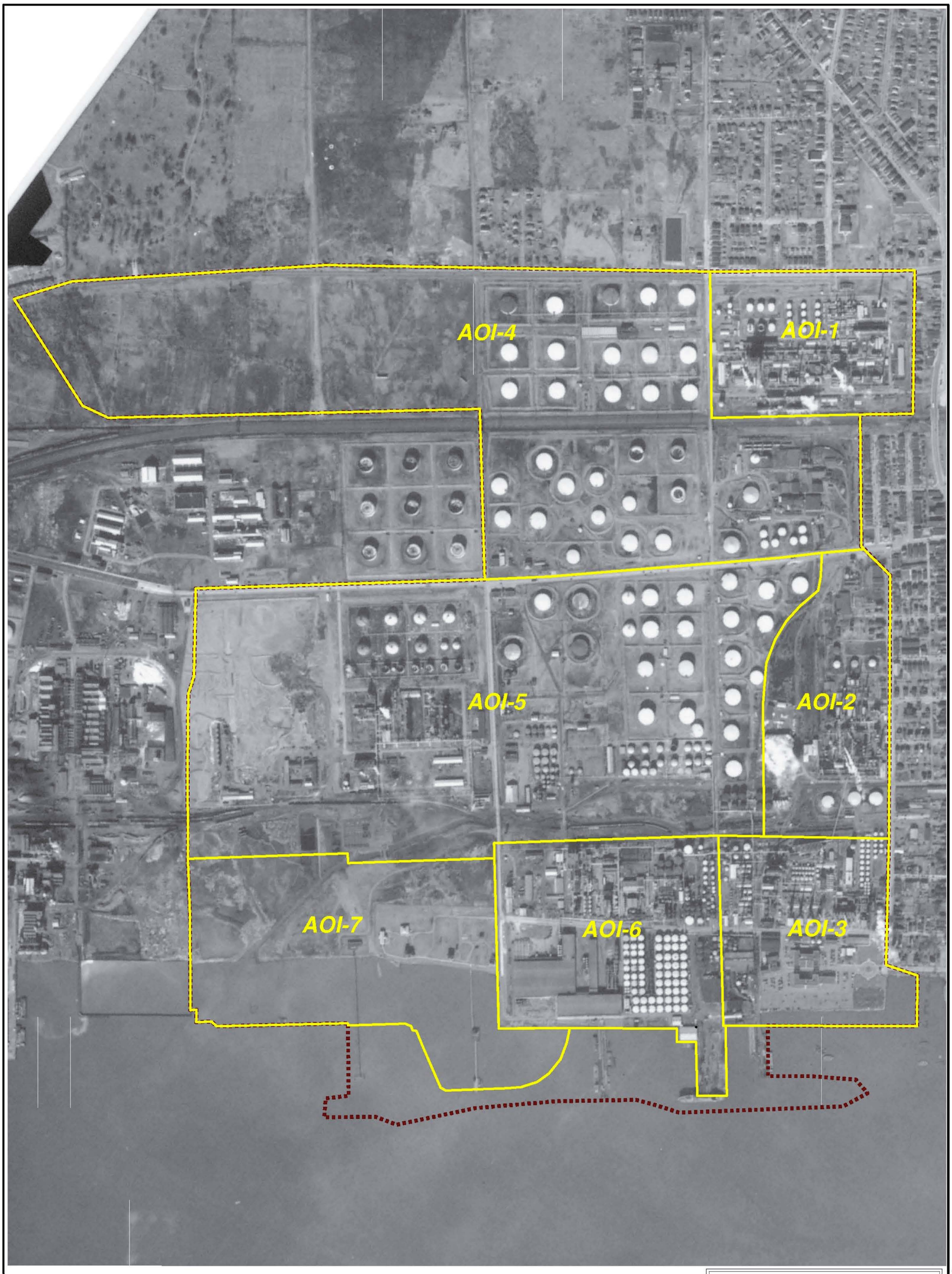
NOTES:
1. Aerial photograph dated September 18, 1937.

1937 Aerial Photograph
Current Conditions Report
Sunoco Marcus Hook Refinery
Marcus Hook, Pennsylvania

Sunoco, Inc.
Marcus Hook Refinery
Philadelphia, PA

0 140 280 560 Feet

1937



N
W
E
S

Legend

Approximate Areas of Interest (AOIs)

Approximate Property Boundary

NOTES:
1. Aerial photograph dated February 18, 1951.

1951 Aerial Photograph
Current Conditions Report
Sunoco Marcus Hook Refinery
Marcus Hook, Pennsylvania

SUNOCO

Sunoco, Inc.
Marcus Hook Refinery
Philadelphia, PA

0 140 280 560 Feet

SCALE: 1" = 280
DATE: June 17, 2011
DRN BY: MR
CKD BY: BW
JOB # 70100281

1953

1954

1958

AOI-4

AOI-1

AOI-5

AOI-2

AOI-7

AOI-6

AOI-3

Legend

Approximate Areas of Interest (AOIs)

Approximate Property Boundary

NOTES:
1. Aerial photograph dated January 13, 1962

1962 Aerial Photograph
Current Conditions Report
Sunoco Marcus Hook Refinery
Marcus Hook, Pennsylvania

Sunoco, Inc.
Marcus Hook Refinery
Philadelphia, PA

0 140 280 560 Feet

1965

Legend

Approximate Areas of Interest (AOIs)

Approximate Property Boundary

NOTES:
1. Aerial photograph dated April 8, 1970.

1970 Aerial Photograph
Current Conditions Report
Sunoco Marcus Hook Refinery
Marcus Hook, Pennsylvania

Sunoco, Inc.
Marcus Hook Refinery
Philadelphia, PA

0 140 280 560 Feet

SCALE: 1" = 280
DATE: June 17, 2011
DRN BY: MR
CKD BY: BM
JOB # 70002081

Legend

Approximate Areas of Interest (AOIs)

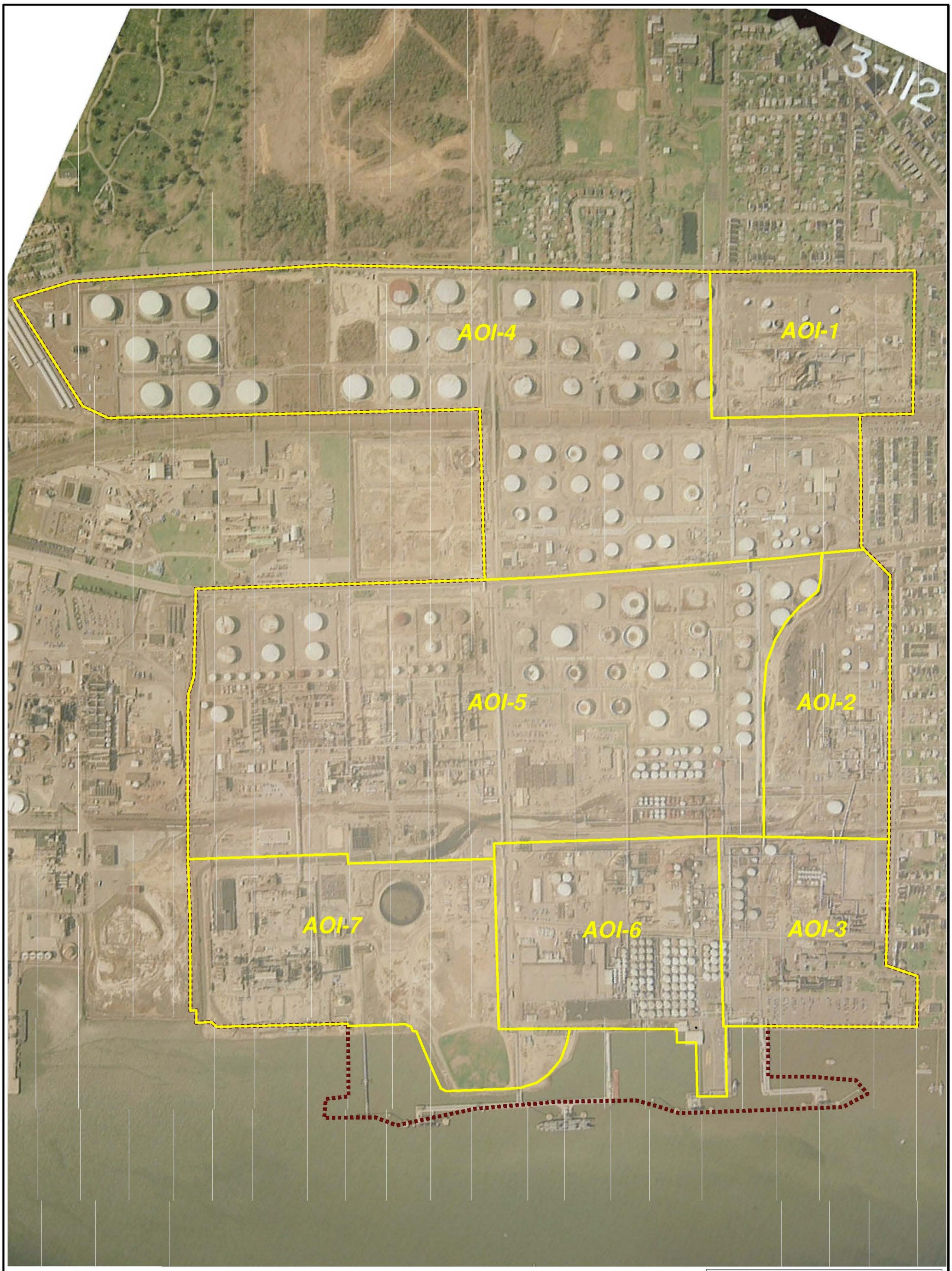
Approximate Property Boundary

NOTES:
1. Aerial photograph dated March 28, 1982.

1982 Aerial Photograph
Current Conditions Report
Sunoco Marcus Hook Refinery
Marcus Hook, Pennsylvania

Sunoco, Inc.
Marcus Hook Refinery
Philadelphia, PA.

0 140 280 560 Feet



Legend

Approximate Areas of Interest (AOIs)

Approximate Property Boundary

NOTES:
1. Aerial photograph dated April 20, 1989

1989 Aerial Photograph
Current Conditions Report
Sunoco Marcus Hook Refinery
Marcus Hook, Pennsylvania

Sunoco, Inc.
Marcus Hook Refinery
Philadelphia, PA

0 140 280 560 Feet

Legend

Approximate Areas of Interest (AOIs)

Approximate Property Boundary

NOTES:
1. Aerial photograph dated September 24, 1999.

1999 Aerial Photograph
Current Conditions Report
Sunoco Marcus Hook Refinery
Marcus Hook, Pennsylvania

Sunoco, Inc.
Marcus Hook Refinery
Philadelphia, PA

0 140 280 560 Feet

Attachment D

Exhibits

Exhibit 1. 1953 Aerial with Historic Middle Creek Highlighted

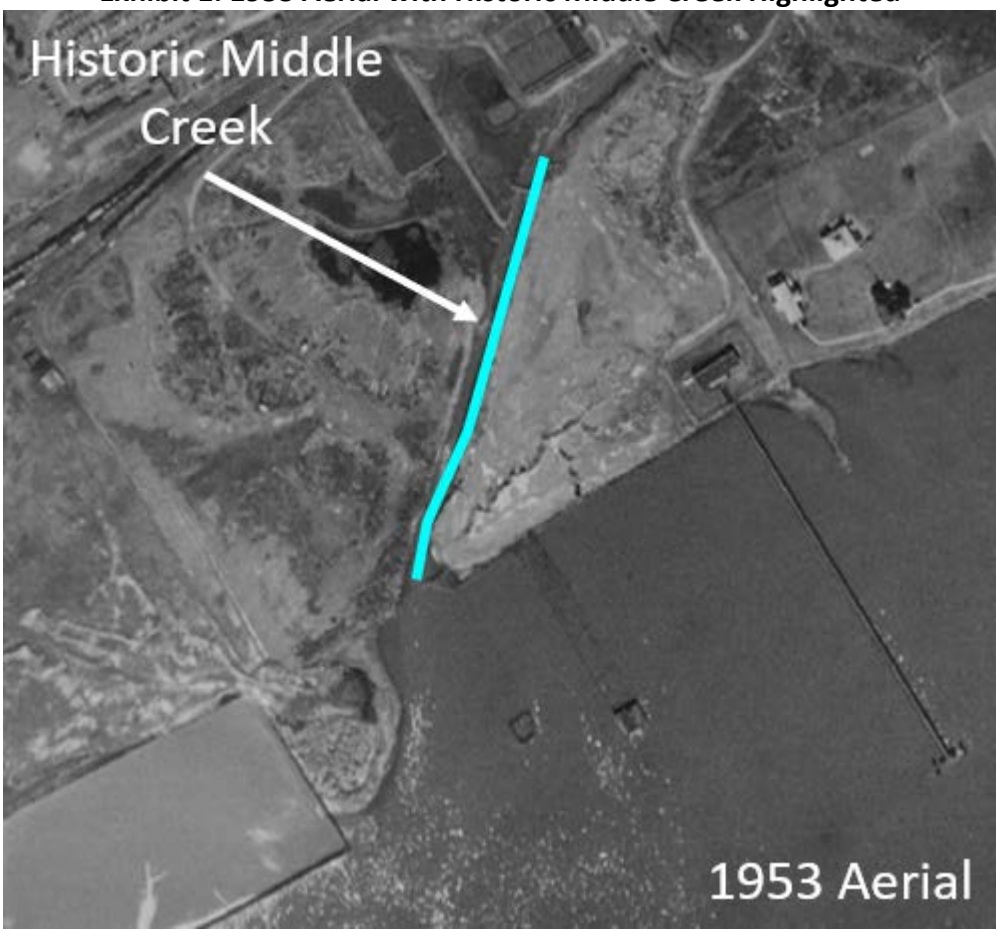


Exhibit 2. Historic Middle Creek Overlaid on Current Aerial Map

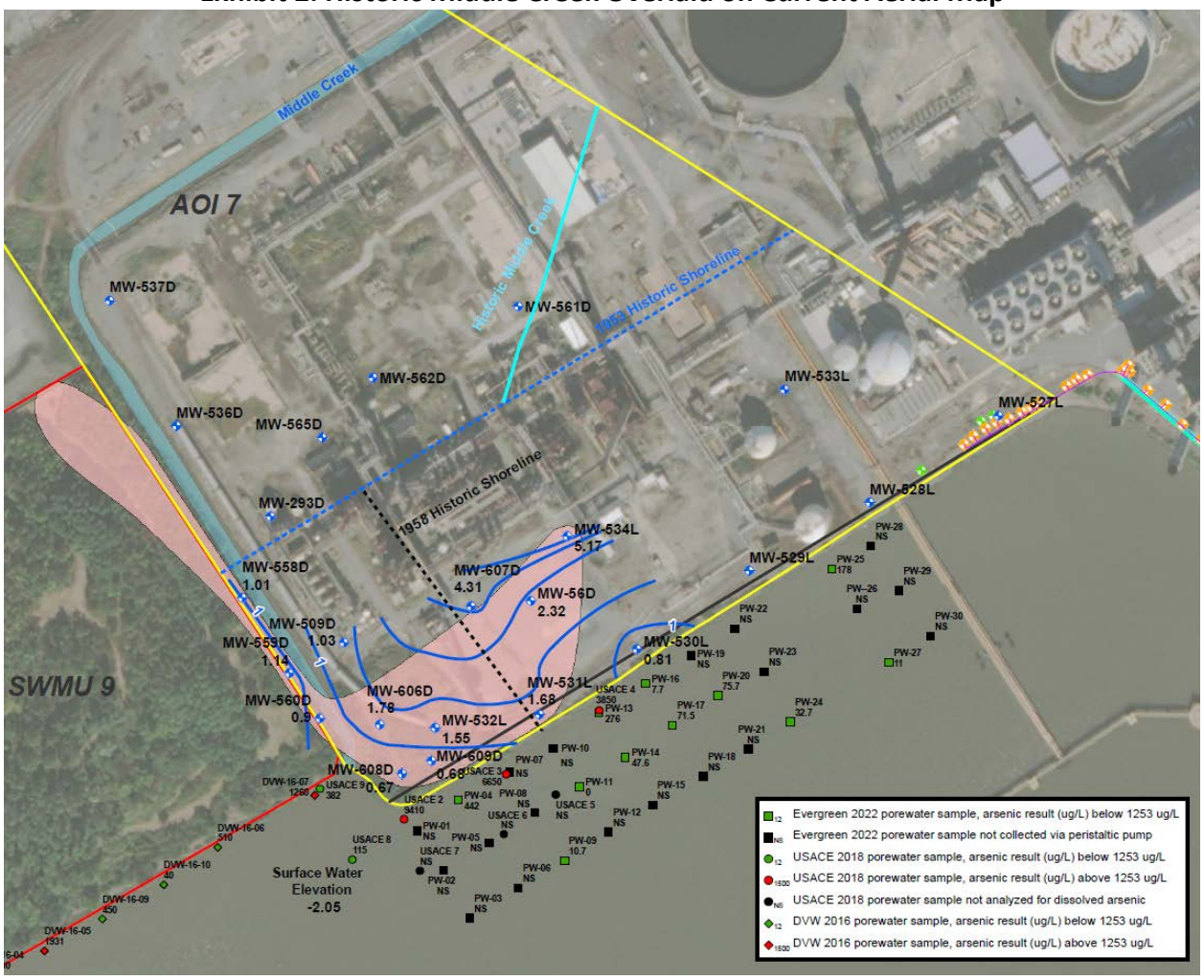


Exhibit 3. Area Between the Bulkhead and Riprap

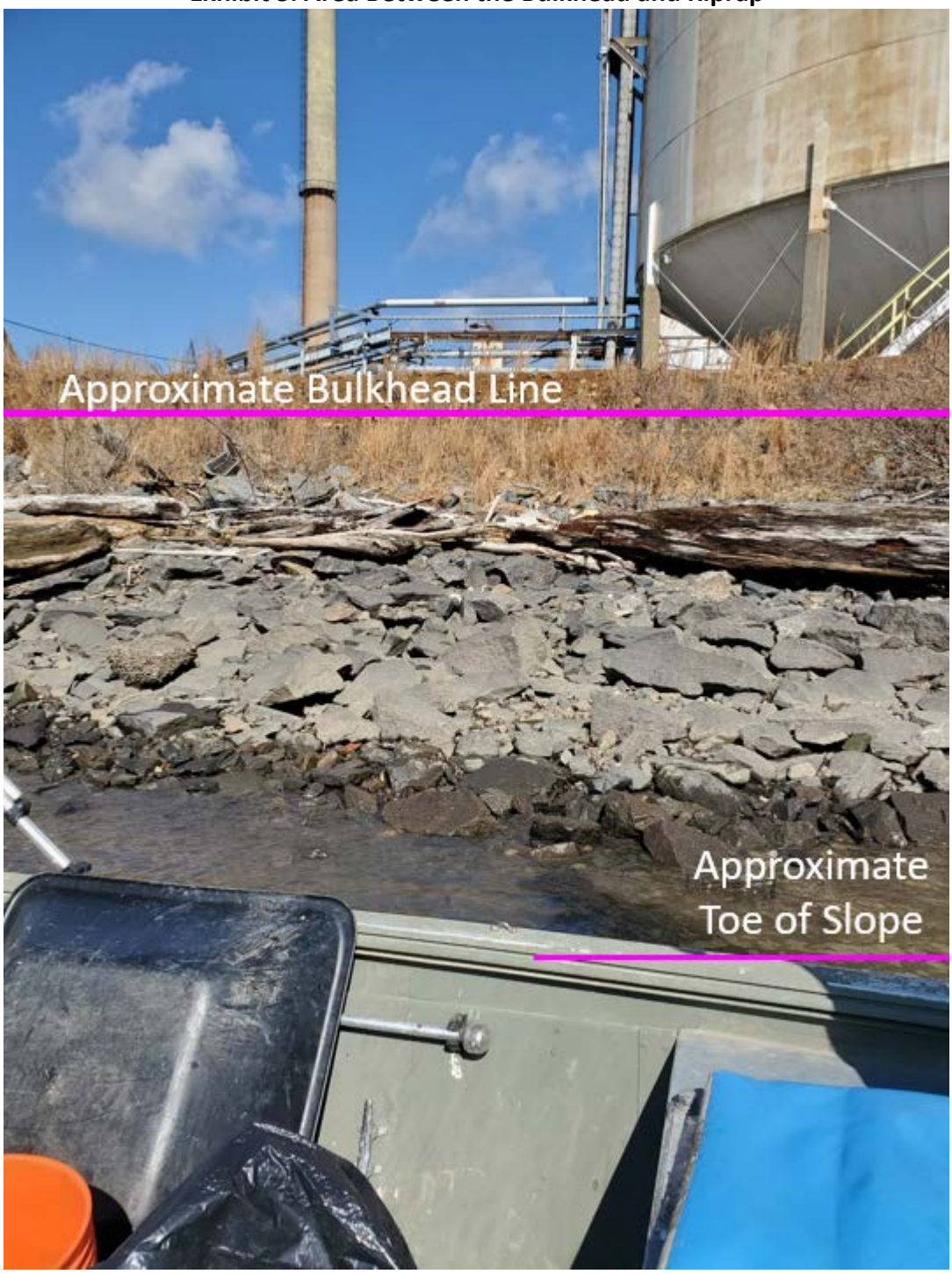


Exhibit 4. Location of Bulkhead and Dock Pilings

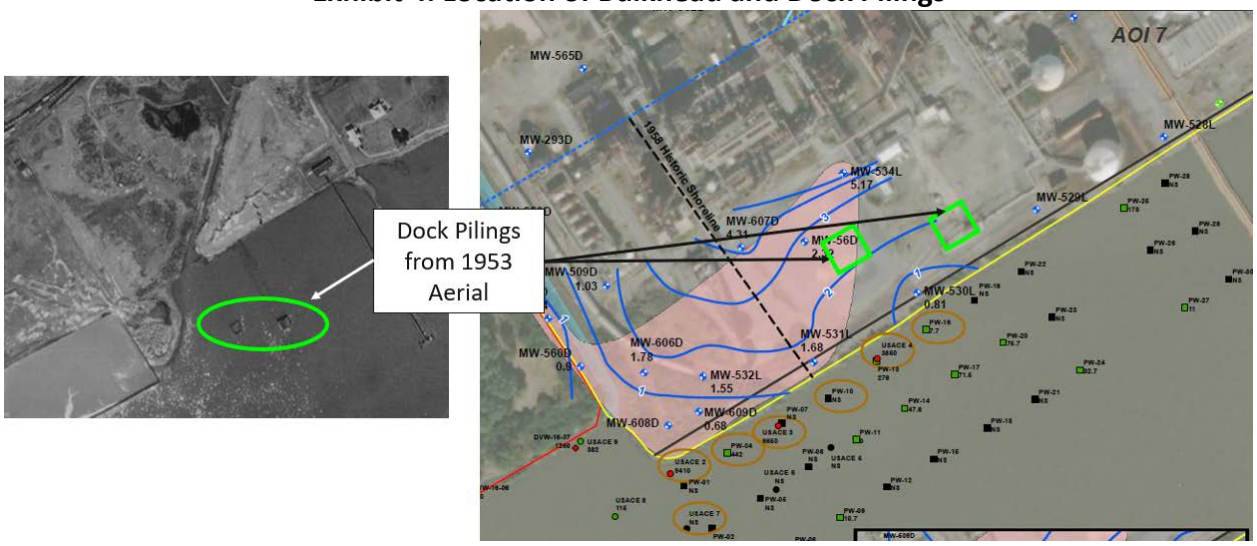
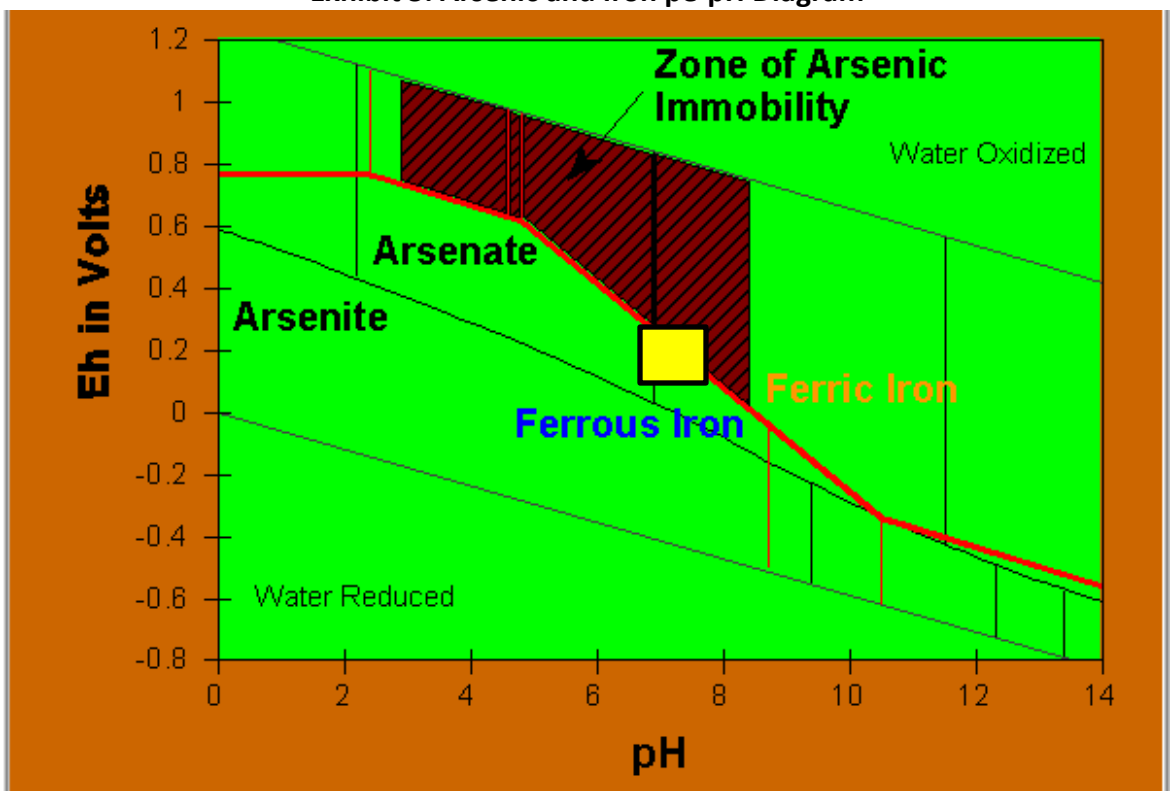


Exhibit 5. Arsenic and Iron pe-pH Diagram



Attachment E

Sediment and Porewater Calculations

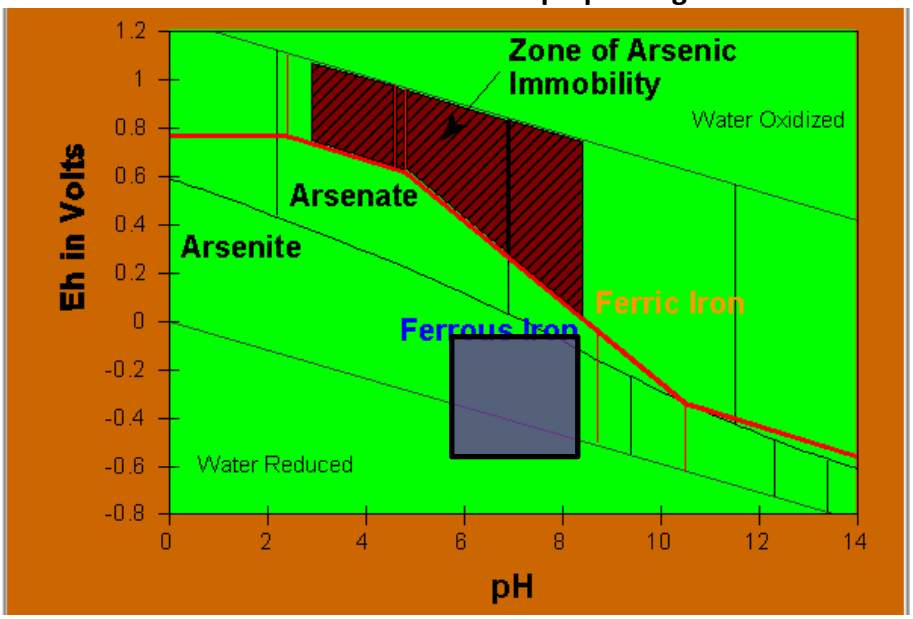
Attachment C
Sediment and Porewater Calculations
AOI 7, MHT

<u>Discussion 1:</u> Geochemical conditions in porewater from the March 2022 event

Sample Location	ORP (mV)	pH
PW-04	-149	6.73
PW-09	-122	6.82
PW-11	-91	7.47
PW-13	-115	6.61
PW-14	-155	6.49
PW-16	-166	7.46
PW-17	-117	6.62
PW-20	-66	7.31
PW-24	-78	6.68
PW-25	-102	7.39
PW-27	-163	6.54

Looking at the Eh-pH diagram for arsenic and iron speciation below (Exhibit 1), the geochemical conditions in porewater fall in the dissolved phase in the diagram (see purple shaded box) and would not precipitate within the sediment (i.e., "zone of arsenic immobility").

Exhibit 1 – Arsenic and Iron pe-pH Diagram



Source: Vance, David B. "Arsenic chemical behavior and treatment." National Environmental Journal 5.3 (1995): 60-64.

<u>Discussion 2:</u> Worst-case estimate for arsenic accumulation from the sandy silt layer at the sediment-surface water interface

1. **Arsenic mass discharge from AOI 7 plume (shoreline cross section using highest concentrations) into sandy silt layer at the bulkhead**

Equation 1: $\boldsymbol{Q_{GW} = KiA}$

Equation 2: $\boldsymbol{M = d\,\Sigma Q_{GW} C_w}$

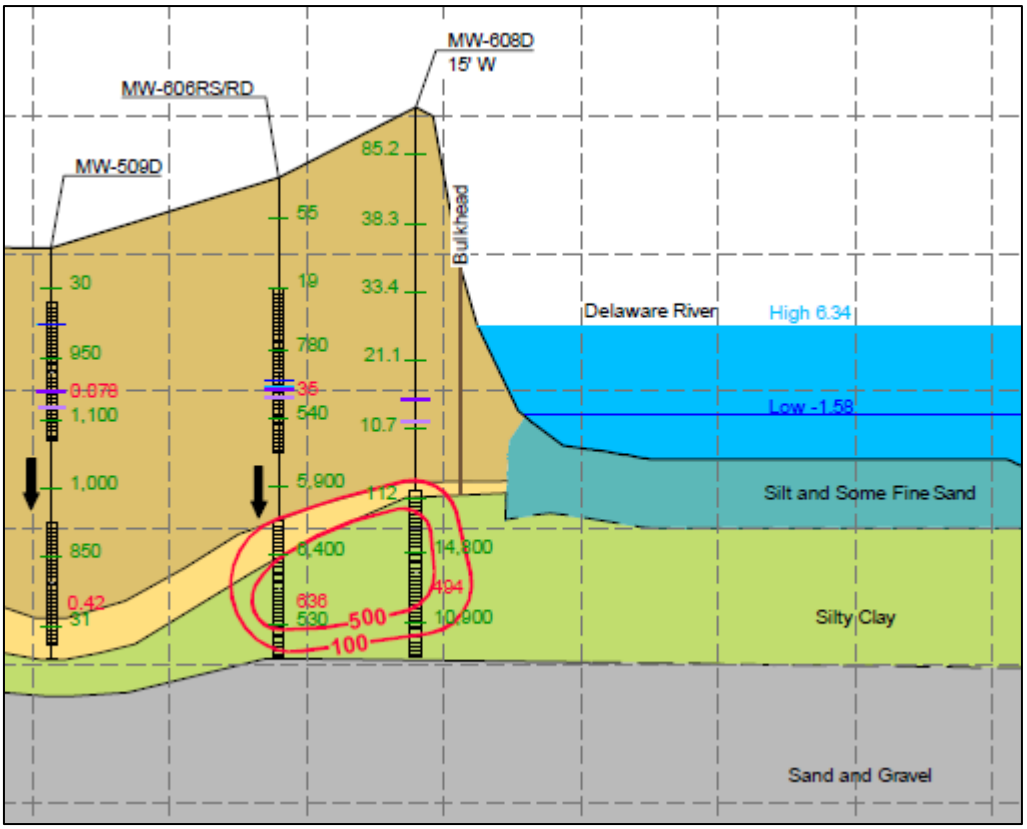
Parameter	Value	Reference
As Groundwater (GW) Concentration, C_w	Based on Cross Section	Based on Cross Section B-B' shown in Exhibit 2
Area of GW Flow, A	Based on Cross Section	Based on Cross Section B-B' shown in Exhibit 2
Hydraulic Conductivity, K	0.125 ft/d	See note 1
Hydraulic Gradient, i	0.00697	See note 2
GW Flow Rate, Q_{GW} (calculated)	0.493 L/d	Calculated from Equation 1
%Time of Discharge to Surface Water, d	70%	See note 2
As Mass Discharge, M (calculated)	**0.039 g/d**	**Calculated from Equation 2**

<u>Notes:</u>

1. The hydraulic conductivity value used represents a conservative estimated value for silty clay to represent the flux from the highest concentrations in the silty clay layer to the sandy silt layer. The estimated hydraulic conductivity value was taken from a range of hydraulic conductivity values from Duffield, G. (2019, June 06). Aquifer testing 101: Hydraulic properties representative values of hydraulic properties. Retrieved from http://www.aqtesolv.com/aquifer-tests/aquifer_properties.htm.
2. % Time of Discharge and hydraulic gradient is based on pressure transducer data collected in September as discussed in the September 2022 IM Progress Report.
3. Note that Cross Section B-B' was provided as Figure 14 in the September 2022 IM Progress Report.

The arsenic mass discharge calculated above assumes the highest arsenic concentrations across the plume. The estimate provided below assumes the highest arsenic groundwater concentrations across the plume is discharging in this sandy silt layer as a "worst-case" estimate.

Exhibit 2: Cross Section B-B'



2. **Groundwater concentration discharge throughout the sandy silt layer from the bulkhead to the shoreline**

Equation 3: $V = DLW$

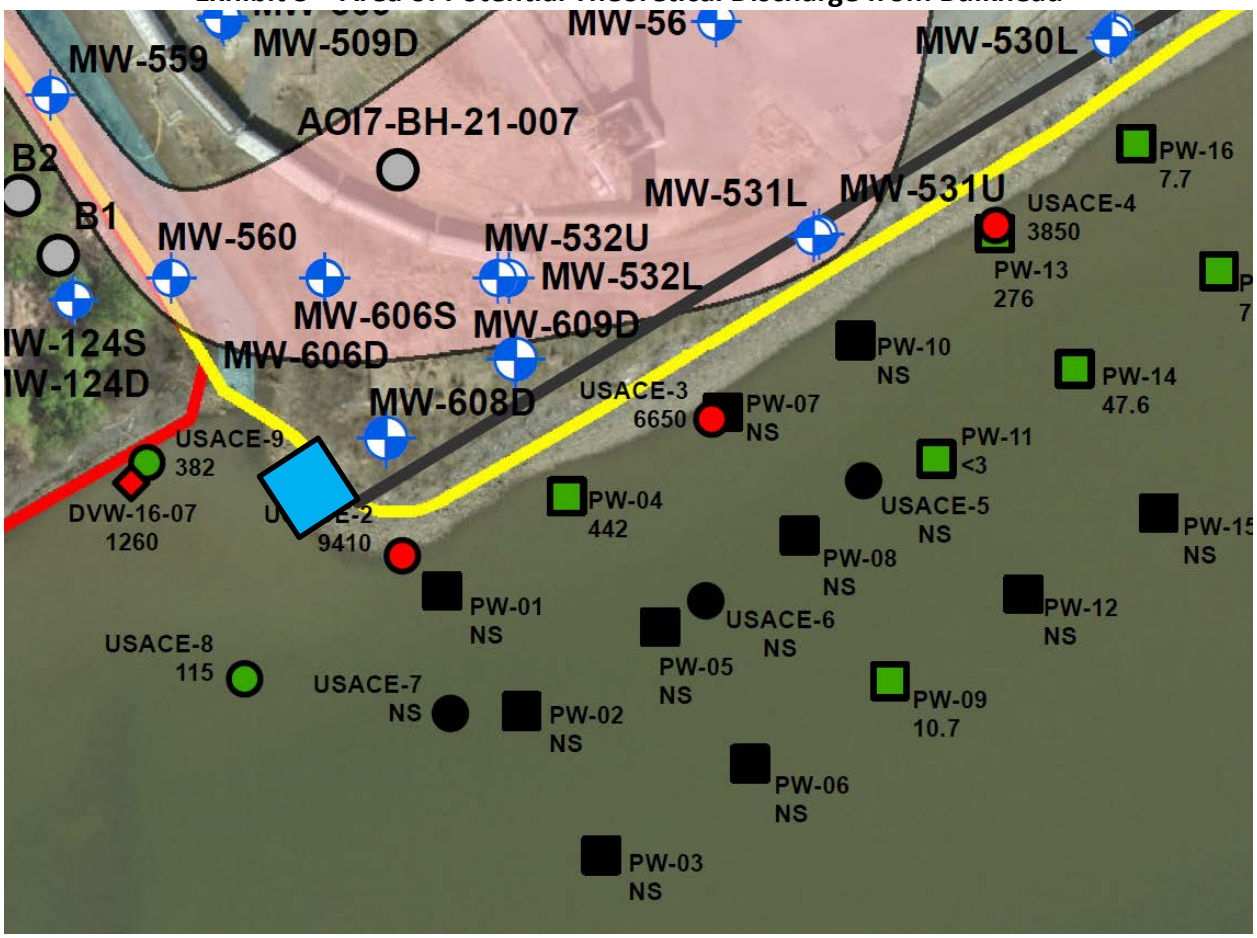
Equation 4: $C_{PW} = \frac{M}{V}$

Parameter	Value	Reference
As Mass Discharge, M (calculated)	0.039 g/d	Calculated from Equation 2
Depth of sandy silt layer, D	1 ft	See note 1 below
Width of discharge, L	30 ft	See note 1 below
Length of discharge, W	45 ft	See note 1 below
Volume of discharge, V	1350 ft^3	Calculated from Equation 3
Groundwater As Concentration discharge, C_{PW}	**0.00102 mg/L/d**	**Calculated from Equation 4**

Notes:

1. Assumed theoretical discharge volume shown in areal below (Exhibit 3) as blue box. The blue box was bounded based on Cross Section B-B' (Figure 14 in the September 2022 IM Progress Report). This includes the depth of the silty sand layer, the width of discharge in the MW-608D/bulkhead area, and the length of discharge to the shoreline/sediment interface from sandy silt layer.

Exhibit 3 – Area of Potential Theoretical Discharge from Bulkhead



3. **Potential theoretical porewater concentration discharge from the shoreline to the toe of slope, and resulting concentration discharge at sediment-surface water interface**

   Equations 5 – 9 below reflect the components to the general advection-dispersion equation (Equation 10) for solute transport. Equation 11 reflects the porewater concentration discharge to surface water concentration. Each term is defined in the table below.

   Equation 5: $a_x = 0.83(logx)^{2.414}$

   Equation 6: $a_y = \frac{a_x}{10}$

   Equation 7: $a_z = \frac{a_x}{100}$

   Equation 8: $u = \frac{Ki}{nR_f}$

   Equation 9: $R_f = 1 + \frac{K_d \rho_b}{n}$

Equation 10:

$$C_{TS} = \frac{C_{PW}}{2} exp\{\frac{x}{2a_x}\left(1 - \sqrt{1 + \frac{4\lambda a_x}{u}}\right)\} \cdot erfc\{\frac{1}{2\sqrt{a_x ut}}\left(x - ut\sqrt{1 + \frac{4\lambda a_x}{u}}\right)\} \cdot erf\{\frac{S_y}{2\sqrt{a_y x}}\} \cdot erf\{\frac{S_z}{2\sqrt{a_z x}}\}$$

Equation 11: $C_W = DF \cdot C_{TS}$

Parameter	Value	Reference
Groundwater As Concentration discharge, C_{PW}	0.00102 mg/L/d	Calculated from Equation 4
Distance from source, x	30 ft	Distance from shoreline to estimated toe of slope
Longitudinal dispersivity, a_x	2.13 ft	See Equation 5 from EPA On-Line Tools for Site Assessment Calculation (see note 1 for reference)
Lateral dispersivity, a_y	0.213 ft	See Equation 6 based on Quick Domenico Manual (see note 2 for reference)
Vertical dispersivity, a_z	0.0213 ft	See Equation 7 based on Quick Domenico Manual (see note 2 for reference)
Decay constant, λ	0	Assumed no decay for arsenic
Rate of contaminant transport, u	5.69E-05 ft/d	See Equation 8 as part of the general advection-dispersion equation
Time, t	9E99 d	See note 3 below
Hydraulic conductivity, K	0.482 ft/d	See note 4 below
Hydraulic gradient, i	0.00697	Calculated from September 2022 pressure transducer data collection
Porosity, n	0.40	See December 14, 2020 AOI 7 Letter to the USEPA
Retardation factor, R_f	148	See Equation 9 based on Quick Domenico Manual
Partition Coefficient, K_d	39.18 L/kg	See note 5 below
Sediment bulk density, ρ_b	1.5 kg/L	EPA On-Line Tools for Site Assessment Calculation estimated value (see note 1)
Thickness of discharge, S_y	1 ft	Based on sediment thickness
Width of discharge, S_z	74 ft	Dispersion width from shoreline to toe of slope (see note 6)
Porewater As Concentration discharge at toe of slope, C_{TS}	**0.000225 mg/L/d**	**Calculated, Equation 10**
Dilution Factor, DF	100	See note 7 below
As Concentration at Sediment-Surface Water Interface, Cw	**2.25E-6 mg/L/d**	**Calculated, Equation 11**

Notes:

1. EPA On-Line Tools for Site Assessment Calculation: https://www3.epa.gov/ceampubl/learn2model/part-two/onsite/.
2. User's Manual for the Quick Domenico Groundwater Fate-and-Transport Model: https://files.dep.state.pa.us/EnvironmentalCleanupBrownfields/LandRecyclingProgram/LandRecyclingProgramPortalFiles/GuidanceTechTools/QD_manual_v3b%2002-28-2014.pdf.
3. Note that the time value is at infinity to assume steady state.
4. Hydraulic conductivity value based on the 2017 AOI 7 RCRA Facility Investigation Report based on slug tests from the MW-532 area.

5. Partition coefficient for arsenic in sediment from Literature: Allison, Jerry D., and Terry L. Allison. "Partition coefficients for metals in surface water, soil, and waste." Rep. EPA/600/R-05 74 (2005).
6. See Figure 2 from the September 2022 IM Progress Report for estimated width.
7. Dilution factor is a conservative estimate/minimum expected dilution compared to the 10,000 dilution factor calculated in the CorMIX model from the 2017 AOI 7 RCRA Facility Investigation (RFI) Report.

4. **Theoretical maximum As sediment accumulation based on As porewater encountering surface water geochemical conditions and attenuating on the sediment**

Equation 12: $C_{sed} = C_w \cdot [K_d + \frac{P_w + (P_a \cdot H_d)}{P_b}]$

Parameter	Value	Reference
Porewater As Concentration Discharge, C_w	2.25E-6 mg/L/d	Calculated above in Equation 11
Partition Coefficient, K_d	39.18 L/kg	See note 1 below
Water-filled porosity, P_w	0.23	See December 14, 2020 AOI 7 Letter to the USEPA
Air-filled porosity, P_a	0.18	See December 14, 2020 AOI 7 Letter to the USEPA
Dimensionless Henry's constant, H_d	0	Assumed for arsenic
Sediment bulk density, P_b	1.5 kg/L	EPA On-Line Tools for Site Assessment Calculation (note 2) estimated value for silty clay
Sediment As Concentration Accumulation, C_{sed} (calculated)	**8.84E-5 mg/kg/d**	**Calculated, Equation 12**

Notes:

1. Partition coefficient for arsenic in sediment from Literature: Allison, Jerry D., and Terry L. Allison. "Partition coefficients for metals in surface water, soil, and waste." Rep. EPA/600/R-05 74 (2005).
2. EPA On-Line Tools for Site Assessment Calculation: https://www3.epa.gov/ceampubl/learn2model/part-two/onsite/.

This is the maximum/theoretical amount since it assumes that the appropriate geochemical conditions exist to allow for complete reaction to occur, minimum expected dilution of porewater, instantaneous reactions, and conservative attenuation.

5. **Time to reach sediment PRG from the sediment As accumulation rate**

Equation 13: $$T = \frac{Sediment\ PRG}{Potential\ Maximum\ Sediment\ Accumulation\ Rate}$$

$$T = \frac{170\ mg/kg}{0.0000884 \frac{mg}{kg}/d}$$

$$T > 5,000\ years$$

<u>Discussion 3:</u> Geochemical conditions for porewater discharge at the sediment-surface water interface.

Geochemist Workbench™ 2022 was used to simulate the results of arsenic in porewater and sediment when encountering geochemical conditions in the Delaware River and sediment systems. All cation/anion inputs for the model (except for arsenic) was collected from the USGS surface water quality database (National Water Information System - https://waterdata.usgs.gov/nwis/sw) for the Delaware River and are shown below in Exhibits 4 and 5. Arsenic data is reflective of the arsenic conditions in sediment and porewater that was collected during the March 2022 event, which is summarized in the September 2022 IM Progress Report.

Exhibit 4 – Input Table for Reagent Reactivity

Basis | Medium | Command | Results

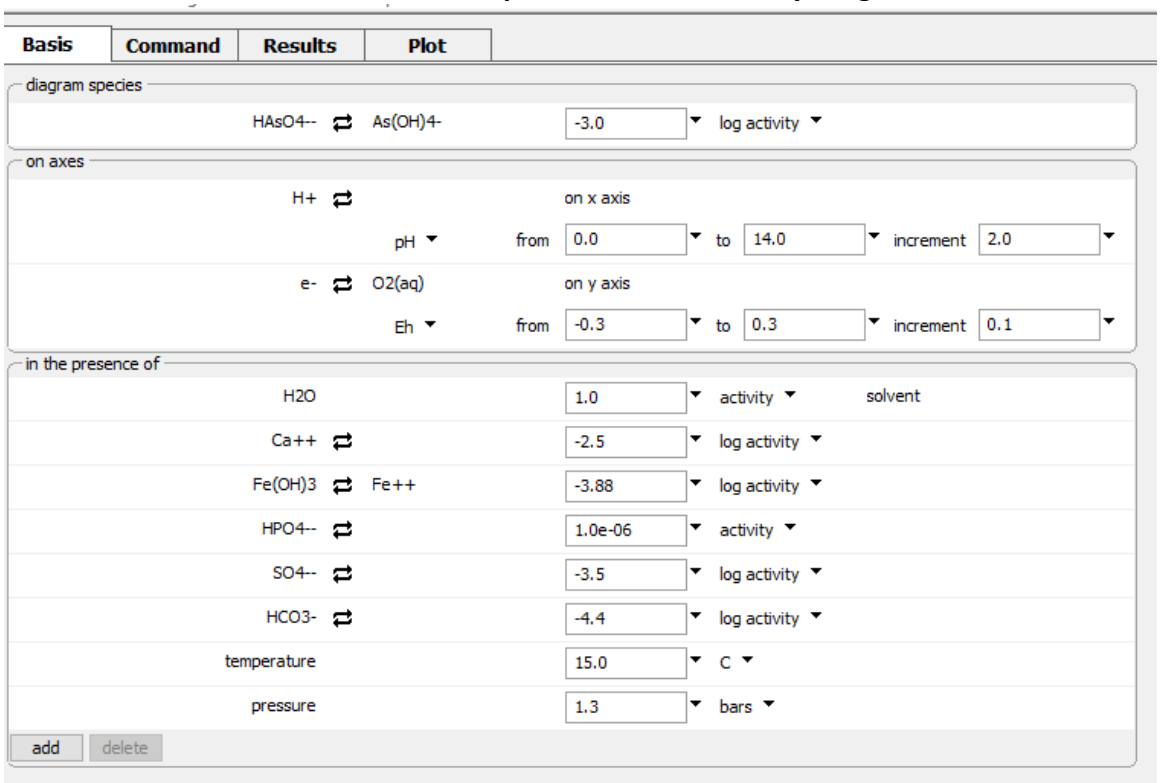
constraints on initial system

H2O			1.0	free kg	solvent
Cl-	⇄		8.0	mg/kg	
Ca++	⇄		80.0	mg/l	
Mg++	⇄		7.4	mg/l	
Na+	⇄		5.4	mg/l	
K+	⇄		5.0	mg/l	
SO4--	⇄		50.0	mg/l	
HCO3-	⇄		59.0	mg/l	charge balance
SiO2(aq)	⇄		6.0	mg/l	
CO2(g)	⇄	H+	-3.5	log fugacity	
O2(g)	⇄	O2(aq)	0.2	fugacity	
As(OH)4-	⇄		341.0	mg/kg	
Fe++	⇄		20.0	mg/l	
temperature			15.0	C	

+ advanced

add | delete

Exhibit 5 – Input Table for Solubility Diagram



Basis | Command | Results | Plot

diagram species

HAsO4--	As(OH)4-	-3.0	log activity	

on axes

H+		on x axis						
	pH	from	0.0	to	14.0	increment	2.0	
e-	O2(aq)	on y axis						
	Eh	from	-0.3	to	0.3	increment	0.1	

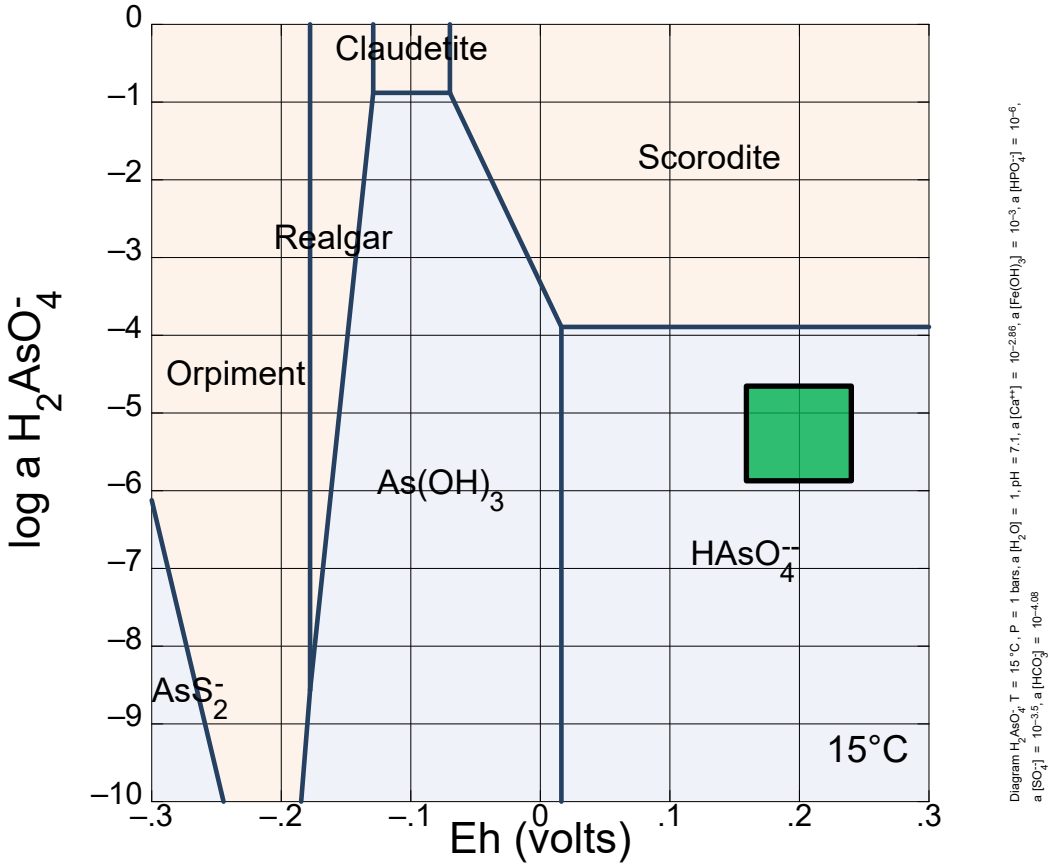
in the presence of

H2O		1.0	activity	solvent
Ca++		-2.5	log activity	
Fe(OH)3	Fe++	-3.88	log activity	
HPO4--		1.0e-06	activity	
SO4--		-3.5	log activity	
HCO3-		-4.4	log activity	
temperature		15.0	C	
pressure		1.3	bars	

add | delete

The resulting solubility diagram is presented below (Exhibit 6) as a function of arsenic concentrations and ORP values. Note that the y-axis has units of mmol/L. The peach shaded regions are areas where arsenic will be in the solid phase, and the blue shaded regions are areas where arsenic will remain in the dissolved form. The green box below shows the porewater concentration values from the March 2022 event diluted 100 times (conservative estimate from the CorMIX model results of 10,000 times dilution discussed in the previous calculation) into surface water and the geochemical conditions in surface water. These porewater concentrations remain in the dissolved phase and will not precipitate onto sediment at the sediment-surface water interface.

Exhibit 6 – Arsenic Solubility Diagram based on Delaware River Surface Water/Sediment Conditions



Attachment F

Figures 16 - 18

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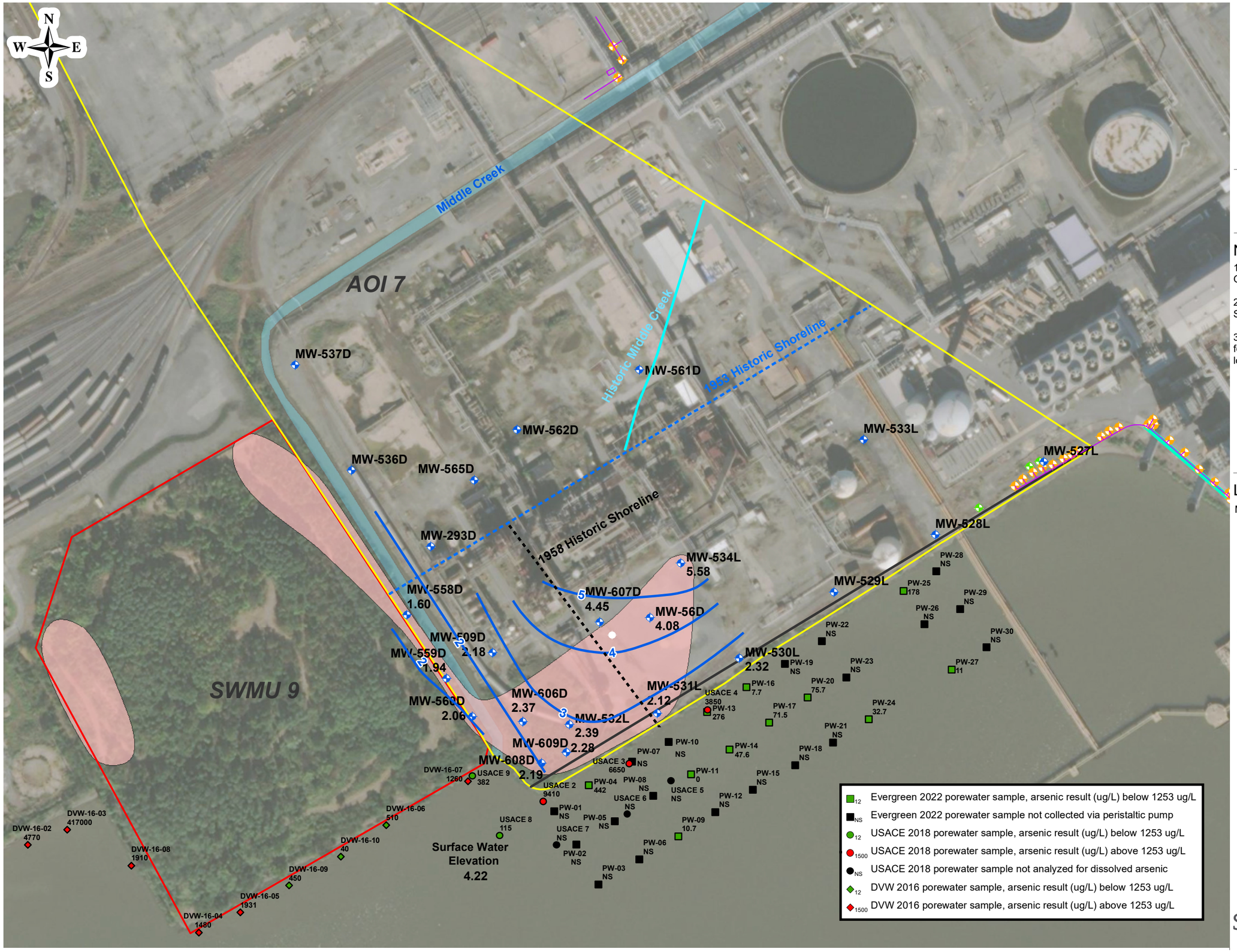

Figure 16

Conceptual Model Figure - Deep High Tide

Evergreen
Marcus Hook, Pennsylvania

Drawn By:	Z. Svoboda
Designed By:	C. Shepsko
Reviewed By:	C. Costello
Project No:	4862.00
Date:	September 2022

Notes

1. Aerial Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community.

2. Groundwater elevations were taken on September 19, 2022.

3. The stilling well location depicted in this figure is for evaluation purposes. The actual stilling well location is on the Dock off the AOI 7 shoreline.

Legend

MW-531L — Location Name
1.68 — Water Elevation (ft amsl)

- Monitoring Well
- Recovery Well
- Remediation Well
- Bulkhead
- Sheet Pile Wall
- Remediation Systems
- AOI-7 Boundary
- SWMU 9 Boundary
- Groundwater Elevation Contour
- Current and Historic Arsenic in Groundwater Above 1,253 µg/L

100 50 0 100 200 Feet

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Last Edited By: zsvoboda

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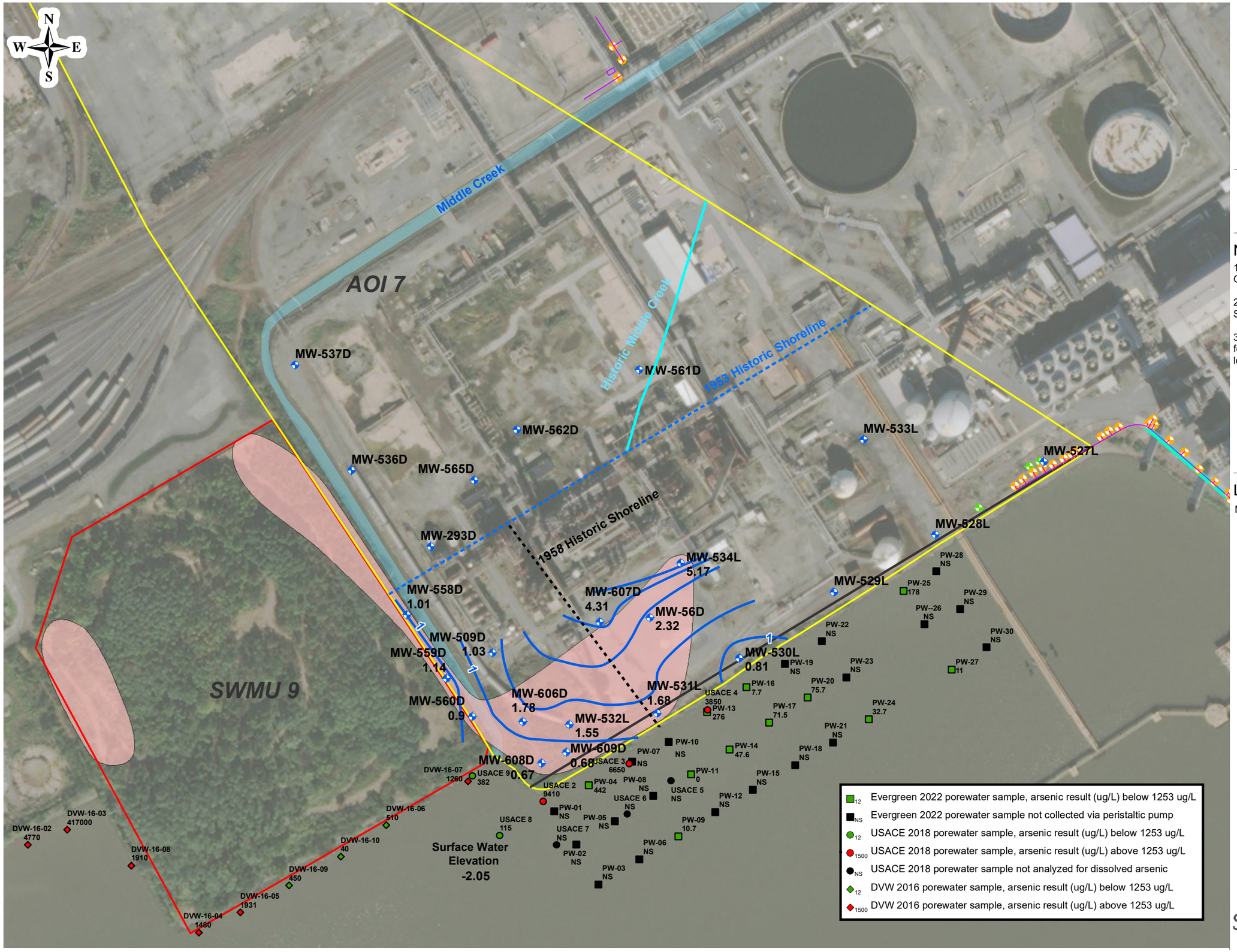

Figure 17

Conceptual Model Figure - Deep Low Tide

Evergreen
Marcus Hook, Pennsylvania

Drawn By:	Z. Svoboda
Designed By:	C. Shepsko
Reviewed By:	C. Costello
Project No:	4862.00
Date:	September 2022

Notes

1. Aerial Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community.

2. Groundwater elevations were taken on September 19, 2022.

3. The stilling well location depicted in this figure is for evaluation purposes. The actual stilling well location is on the Dock off the AOI 7 shoreline.

Legend

MW-531L Location Name
1.68 Water Elevation (ft amsl)

- Monitoring Well
- Recovery Well
- Remediation Well
- Bulkhead
- Sheet Pile Wall
- Remediation Systems
- AOI-7 Boundary
- SWMU 9 Boundary
- Groundwater Elevation Contour
- Current and Historic Arsenic in Groundwater Above 1,253 µg/L

100 50 0 100 200 Feet

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Last Edited By: zsvoboda

Path: P:\4800s\4862.00\Graphics Files\ArcGIS\Figures\202209 GW Contours\ConceptualSiteModel.mxd

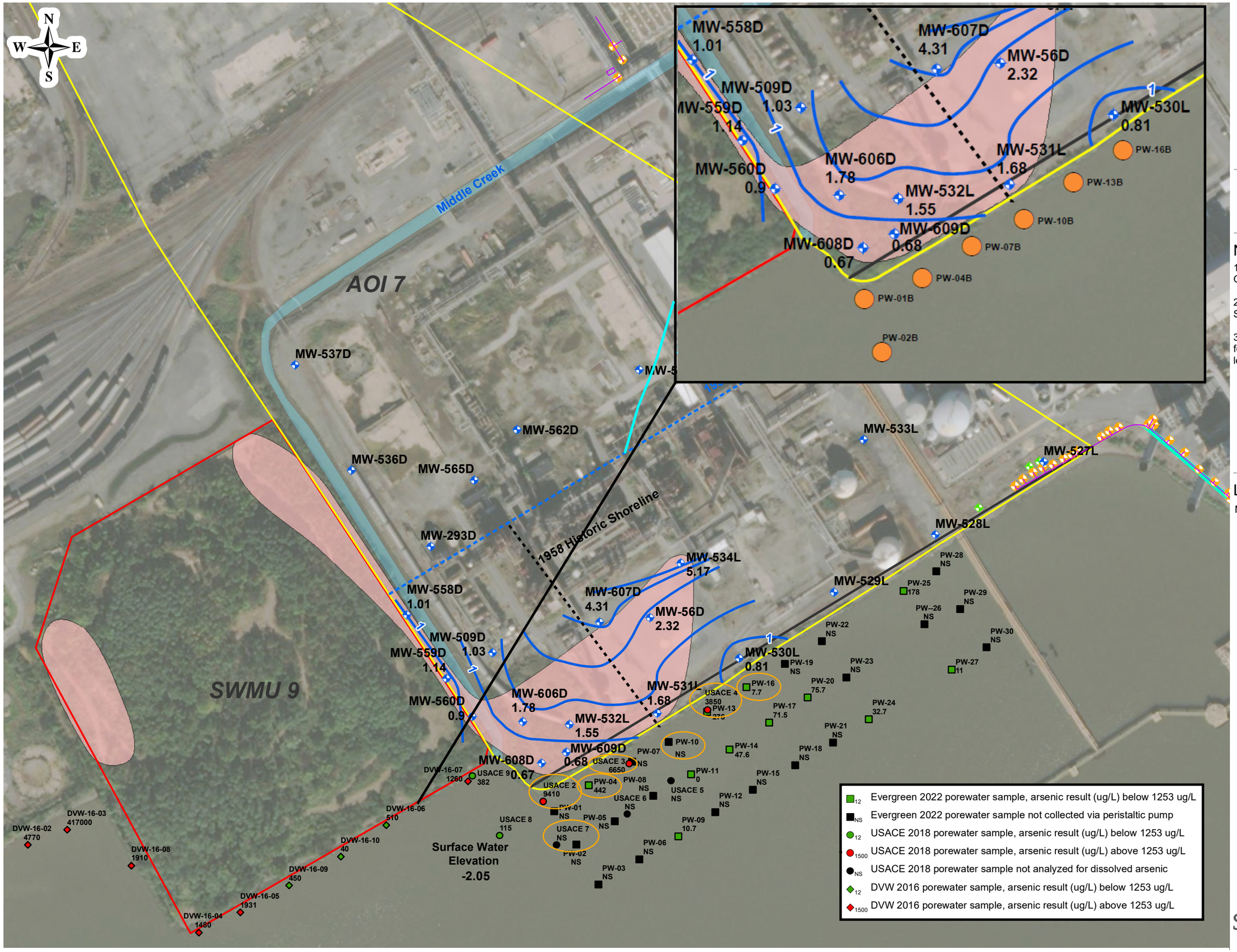

Figure 18

Proposed Supplemental Porewater Sampling Locations

Evergreen
Marcus Hook, Pennsylvania

Drawn By:	Z. Svoboda
Designed By:	C. Shepsko
Reviewed By:	C. Costello
Project No:	4862.00
Date:	September 2022

Notes

1. Aerial Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community.

2. Groundwater elevations were taken on September 19, 2022.

3. The stilling well location depicted in this figure is for evaluation purposes. The actual stilling well location is on the Dock off the AOI 7 shoreline.

Legend

MW-531L 1.68 — Location Name, Water Elevation (ft amsl)

- Monitoring Well
- Recovery Well
- Remediation Well
- Bulkhead
- Sheet Pile Wall
- Remediation Systems
- AOI-7 Boundary
- SWMU 9 Boundary
- Groundwater Elevation Contour
- Current and Historic Arsenic in Groundwater Above 1,253 µg/L
- Proposed Porewater Sample Locations

100 50 0 100 200 Feet

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Attachment G

Additional Mass Discharge Calculations

Calculations for Response to Comment 1A:

1. **Arsenic mass discharge from AOI 7 plume into sandy silt layer at the bulkhead using the average arsenic groundwater concentration shown in the plume in Figure 1.**

Equation 1: $$Q_{GW} = KiA$$

Equation 2: $$M = d\,\Sigma Q_{GW} C_w$$

Mass Discharge								
	Average As GW concentration (C_w) (ug/L)	Area (A) (ft^2)	Hydraulic Conductivity (K) (ft/d)	i (ft/ft)	Qgw (L/d)	Mass Discharge (M) (g/d)	% Time of Discharge to SW	Corrected Mass Discharge (M) (g/d)
Inner Contour	564000	2.5	0.125	0.00697	0.0617	0.035	70%	0.024
Outer Contour	224000	3.9	0.125	0.00697	0.0962	0.022	70%	0.015
							TOTAL	0.039

Notes:

1. The Average As GW concentration is the average of As concentrations in the red plume in Figure 1.
2. The area of mass discharge is depicted in Figure 1 and is located in the immediate area near bulkhead in the sandy silt layer.
3. The hydraulic conductivity value used represents a conservative estimated value for silty clay to represent the flux from the highest concentrations in the silty clay layer to the sandy silt layer. The estimated hydraulic conductivity value was taken from a range of hydraulic conductivity values from Duffield, G. (2019, June 06). Aquifer testing 101: Hydraulic properties representative values of hydraulic properties. Retrieved from http://www.aqtesolv.com/aquifer-tests/aquifer_properties.htm.
4. % Time of Discharge and hydraulic gradient is based on pressure transducer data collected in September as discussed in the September 2022 IM Progress Report.
5. ug - micrograms
   L - liter
   ft - feet
   d - day
   g – grams
   SW – surface water

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Last Edited By: zsvoboda

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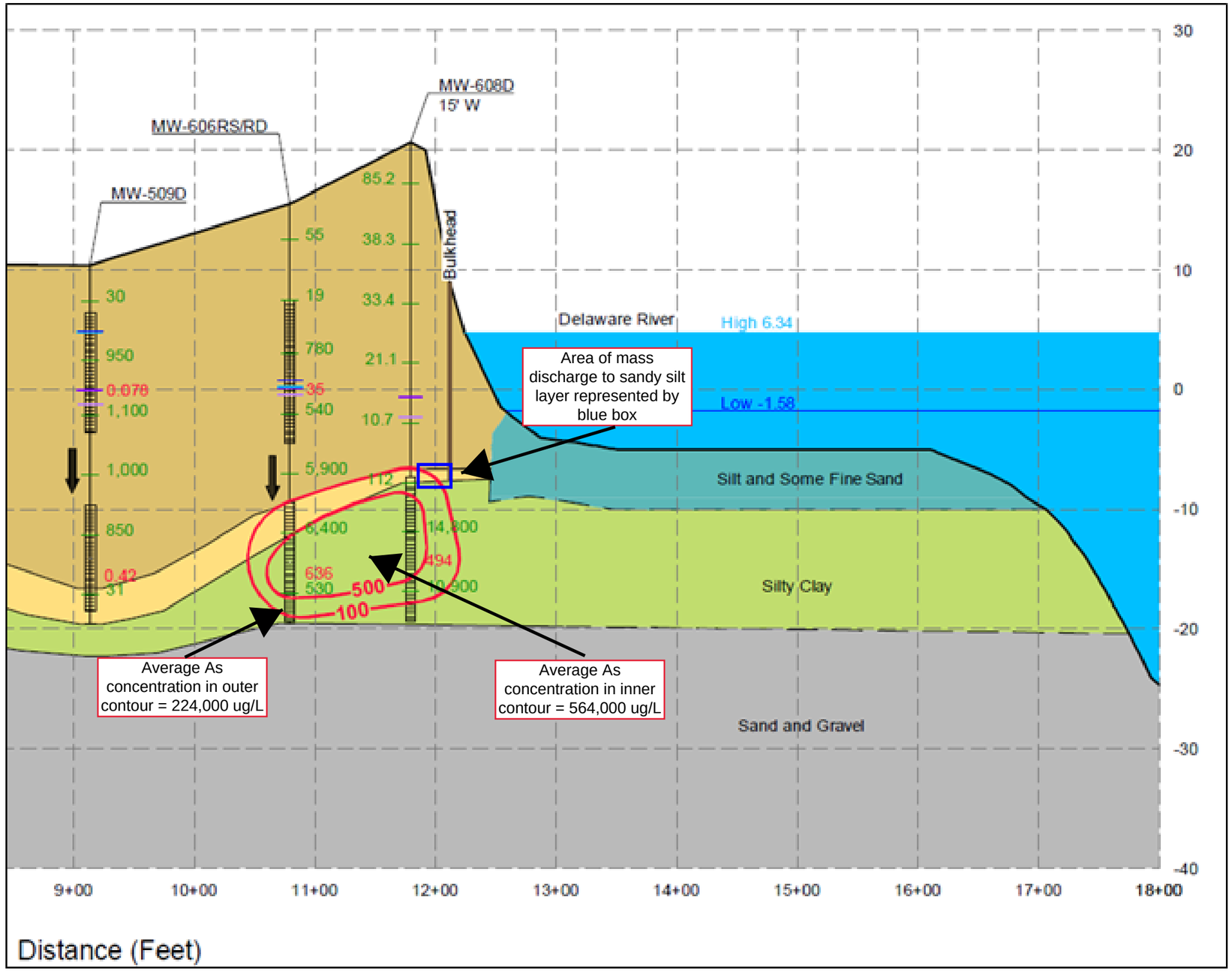
Figure 1

AOI 7 Cross Section B-B'

Evergreen

Marcus Hook, Pennsylvania

Drawn By:	Z. Svoboda
Designed By:	C. Shepsko
Reviewed By:	C. Costello
Project No:	4862.04
Date:	January 2023



Notes

1. 2021 boring logs provided in Appendix D of the 2021 IM Work Plan. RFI boring logs are in the RFI (GHD 2017, revised 2019). Logs for the 2022 borings will be provided in a future submittal.

2. Bottom elevation of Middle Creek surveyed in May 2021 by Vargo Associates using the NAVD 1988 vertical datum in US Feet.

3. Groundwater elevations shown with the triangle symbology are from August 18, 2021. Updated high and low tide groundwater elevations denoted by the purple and blue lines in the legend are from September 19, 2022.

4. Water elevations shown for the Delaware River were taken from the USGS Station # 01482170 for the Delaware River at New Castle, DE for August 18, 2021.

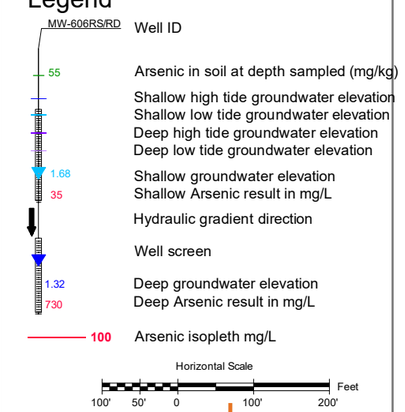
5. Water elevations shown for Middle Creek were taken from the staff gauge in Middle Creek on September 19, 2022 at high tide and low tide conditions.

6. The Delaware River sediment lithology in the 0 to 5 ft below grade interval is based on sediment core logs from the January 17, 2020 Marcus Hook Industrial Complex Water Quality Certificate: January 2020 Sediment Sampling Results letter from Weston Solutions, Inc. The lithology below 5 ft below grade is projected from the lithology in AOI 7 and should be considered approximate.

7. The location of bulkhead is based on the Figure I-3 "Phillips Island Remediation System Site Plan" provided by Stantec from July 2019.

8. Soil arsenic concentrations are from the 2017 RFI (GHD, 2017), July 2021, and April/May 2022 results. Groundwater concentrations are from the August 2021 and May 2022 results.

Legend



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Calculations for Response to Comment 1B:

1. **Arsenic mass discharge from AOI 7 plume into sandy silt layer at the bulkhead using the highest arsenic concentration in the area (636,000 ug/L).**

Equation 1: $Q_{GW} = KiA$

Equation 2: $M = d\,\Sigma Q_{GW} C_w$

Mass Discharge							
As GW concentration (C_w) (ug/L)	Area (A) (ft^2)	Hydraulic Conductivity (K) (ft/d)	i (ft/ft)	Qgw (L/d)	Mass Discharge (M) (g/d)	% Time of Discharge to SW	Corrected Mass Discharge (M) (g/d)
636000	6.4	0.125	0.00697	0.1579	0.100	70%	0.0703
						TOTAL	0.070

Notes:
1. The As GW concentration is the highest arsenic concentration in the red plume in Figure 1 at MW-606D.
2. The area of mass discharge is depicted in Figure 1 and is located in the immediate area near bulkhead in the sandy silt layer.
3. The hydraulic conductivity value used represents a conservative estimated value for silty clay to represent the flux from the highest concentrations in the silty clay layer to the sandy silt layer. The estimated hydraulic conductivity value was taken from a range of hydraulic conductivity values from Duffield, G. (2019, June 06). Aquifer testing 101: Hydraulic properties representative values of hydraulic properties. Retrieved from http://www.aqtesolv.com/aquifer-tests/aquifer_properties.htm.
4. % Time of Discharge and hydraulic gradient is based on pressure transducer data collected in September as discussed in the September 2022 IM Progress Report.
5. ug - micrograms
   L - liter
   ft - feet
   d - day
   g – grams
   SW – surface water

The arsenic mass discharge calculated above assumes the highest arsenic concentrations across the plume. The estimate provided below assumes the highest arsenic groundwater concentrations across the plume is discharging in this sandy silt layer as a “worst-case” estimate.

2. **Groundwater concentration discharge throughout the sandy silt layer from the bulkhead to the shoreline**

Equation 3: $V = DLW$

Equation 4: $C_{PW} = \frac{M}{V}$

Groundwater concentration discharge from the bulkhead to the shoreline		
Parameter	**Value**	**Unit**
As Mass Discharge (M)	0.070	g/d
Depth of Plume (D)	1	ft
Width of Discharge (W)	30	ft
Length of Discharge (L)	45	ft
Volume of Discharge in cubic feet (V)	1350	ft^3
Volume of Discharge in liters (V)	38300	L
GW Concentration Discharge (C_{PW})	**0.00184**	**mg/L per d**

Notes:

1. The volume (V) of discharge includes the depth (D) of the sandy silt layer, the width (W) of discharge in the MW-608D/bulkhead area, and the length (L) of discharge to the shoreline/sediment interface from the sandy silt layer as shown in Figure 1.
2. mg - milligrams

3. **Potential theoretical porewater concentration discharge from the shoreline to the toe of slope, and resulting concentration discharge at sediment-surface water interface**

Equations 5 – 9 below reflect the components to the general advection-dispersion equation (Equation 10) for solute transport. Equation 11 reflects the porewater concentration discharge to surface water concentration. Each term is defined in the table below.

Equation 5: $a_x = 0.83(logx)^{2.414}$

Equation 6: $a_y = \frac{a_x}{10}$

Equation 7: $a_z = \frac{a_x}{100}$

Equation 8: $u = \frac{Ki}{nR_f}$

Equation 9: $R_f = 1 + \frac{K_d \rho_b}{n}$

Equation 10:

$$C_{TS} = \frac{C_{PW}}{2} exp\{\frac{x}{2a_x}\left(1 - \sqrt{1 + \frac{4\lambda a_x}{u}}\right)\} \cdot erfc\{\frac{1}{2\sqrt{a_x ut}}\left(x - ut\sqrt{1 + \frac{4\lambda a_x}{u}}\right)\} \cdot erf\{\frac{S_y}{2\sqrt{a_y x}}\} \cdot erf\{\frac{S_z}{2\sqrt{a_z x}}\}$$

Equation 11: $C_W = DF \cdot C_{TS}$

Parameter	Value	Reference
Groundwater As Concentration discharge, C_{PW}	0.00184 mg/L/d	Calculated from Equation 4
Distance from source, x	30 ft	Distance from shoreline to estimated toe of slope
Longitudinal dispersivity, a_x	2.13 ft	See Equation 5 from EPA On-Line Tools for Site Assessment Calculation (see note 1 for reference)
Lateral dispersivity, a_y	0.213 ft	See Equation 6 based on Quick Domenico Manual (see note 2 for reference)
Vertical dispersivity, a_z	0.0213 ft	See Equation 7 based on Quick Domenico Manual (see note 2 for reference)
Decay constant, λ	0	Assumed no decay for arsenic
Rate of contaminant transport, u	5.7E-05 ft/d	See Equation 8 as part of the general advection-dispersion equation
Time, t	9E99 d	See note 3 below
Hydraulic conductivity, K	0.482 ft/d	See note 4 below
Hydraulic gradient, i	0.00697	Calculated from September 2022 pressure transducer data collection
Porosity, n	0.40	See December 14, 2020 AOI 7 Letter to the USEPA
Retardation factor, R_f	148	See Equation 9 based on Quick Domenico Manual
Partition Coefficient, K_d	39.18 L/kg	See note 5 below
Sediment bulk density, ρ_b	1.5 kg/L	EPA On-Line Tools for Site Assessment Calculation estimated value (see note 1)
Thickness of discharge, S_y	1 ft	Based on sediment thickness
Width of discharge, S_z	74 ft	Dispersion width from shoreline to toe of slope (see note 6)
Porewater As Concentration discharge at toe of slope, C_{TS}	**0.000405 mg/L/d**	**Calculated, Equation 10**
Dilution Factor, DF	100	See note 7 below
As Concentration at Sediment-Surface Water Interface, Cw	**4.05E-6 mg/L/d**	**Calculated, Equation 11**

Notes:

1. EPA On-Line Tools for Site Assessment Calculation: https://www3.epa.gov/ceampubl/learn2model/part-two/onsite/.
2. User's Manual for the Quick Domenico Groundwater Fate-and-Transport Model: https://files.dep.state.pa.us/EnvironmentalCleanupBrownfields/LandRecyclingProgram/LandRecyclingProgramPortalFiles/GuidanceTechTools/QD_manual_v3b%2002-28-2014.pdf.
3. Note that the time value is at infinity to assume steady state.
4. Hydraulic conductivity value based on the 2017 AOI 7 RCRA Facility Investigation Report based on slug tests from the MW-532 area.
5. Partition coefficient for arsenic in sediment from Literature: Allison, Jerry D., and Terry L. Allison. "Partition coefficients for metals in surface water, soil, and waste." Rep. EPA/600/R-05 74 (2005).
6. See Figure 1 attached for estimated width.
7. Dilution factor is a conservative estimate/minimum expected dilution compared to the 10,000 dilution factor calculated in the CorMIX model from the 2017 AOI 7 RCRA Facility Investigation (RFI) Report.
8. kg - kilograms

4. **Theoretical maximum As sediment accumulation based on As porewater encountering surface water geochemical conditions and attenuating on the sediment**

Equation 12: $C_{sed} = C_w \cdot [K_d + \frac{P_w + (P_a \cdot H_d)}{P_b}]$

Parameter	Value	Reference
Porewater As Concentration Discharge, C_w	4.05E-6 mg/L/d	Calculated above in Equation 11
Partition Coefficient, K_d	39.18 L/kg	See note 1 below
Water-filled porosity, P_w	0.23	See December 14, 2020 AOI 7 Letter to the USEPA
Air-filled porosity, P_a	0.18	See December 14, 2020 AOI 7 Letter to the USEPA
Dimensionless Henry's constant, H_d	0	Assumed for arsenic
Sediment bulk density, P_b	1.5 kg/L	EPA On-Line Tools for Site Assessment Calculation (note 2) estimated value for silty clay
Sediment As Concentration Accumulation, C_{sed} (calculated)	**1.59E-4 mg/kg/d**	**Calculated, Equation 12**

Notes:

1. Partition coefficient for arsenic in sediment from Literature: Allison, Jerry D., and Terry L. Allison. "Partition coefficients for metals in surface water, soil, and waste." Rep. EPA/600/R-05 74 (2005).
2. EPA On-Line Tools for Site Assessment Calculation: https://www3.epa.gov/ceampubl/learn2model/part-two/onsite/.

This is the maximum/theoretical amount since it assumes that the appropriate geochemical conditions exist to allow for complete reaction to occur, minimum expected dilution of porewater, instantaneous reactions, and conservative attenuation.

5. **Time to reach sediment PRG from the sediment As accumulation rate**

Equation 13: $$T = \frac{Sediment\ PRG}{Potential\ Maximum\ Sediment\ Accumulation\ Rate}$$

$$T = \frac{170\ mg/kg}{0.000159\frac{mg}{kg}/d}$$

$$T > 2,900\ years$$

Calculations for Response to Comment 2:

1. **Arsenic mass discharge from the MW-531U/L area.**

Equation 1: $Q_{GW} = KiA$

Equation 2: $M = d\,\Sigma Q_{GW} C_w$

Mass Discharge							
As GW concentration (C_w) (ug/L)	Area (A) (ft^2)	Hydraulic Conductivity (K) (ft/d)	i (ft/ft)	Qgw (L/d)	Mass Discharge (M) (g/d)	% Time of Discharge to SW	Corrected Mass Discharge (M) (g/d)
202000	784	0.125	0.00638	17.7	3.58	70%	2.50
202000	84	0.482	0.00638	7.31	1.48	70%	1.03
						TOTAL	**3.53**

Notes:

1. The As GW concentration is the highest arsenic concentration in the red plume in Figure 2 at MW-531L.
2. The area of mass discharge is depicted in Figure 2 and is located in the immediate area near MW-531L (inclusive of the sandy silt layer as a conservative estimate). This area is the length of the plume as shown in the planar map in Figure 3 based on groundwater flow direction to the SED-13 area.
3. The hydraulic conductivity value of 0.125 ft/d is used to represent a conservative estimated value for silty clay to represent the flux from the highest concentrations in the silty clay layer to the sandy silt layer. The estimated hydraulic conductivity value was taken from a range of hydraulic conductivity values from Duffield, G. (2019, June 06). Aquifer testing 101: Hydraulic properties representative values of hydraulic properties. Retrieved from http://www.aqtesolv.com/aquifer-tests/aquifer_properties.htm.
4. Hydraulic conductivity value of 0.482 ft/d is based on the 2017 AOI 7 RCRA Facility Investigation Report based on slug tests from the MW-532 area for sandy silt.
5. % Time of Discharge and hydraulic gradient is based on pressure transducer data collected in September as discussed in the September 2022 IM Progress Report.
6. ug - micrograms
   L - liter
   ft - feet
   d - day
   g – grams
   SW – surface water

The arsenic mass discharge calculated above assumes the highest arsenic concentrations in the clay and sandy silt layers at the MW-531U/L area as a conservative estimate.

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Last Edited By: zsvoboda

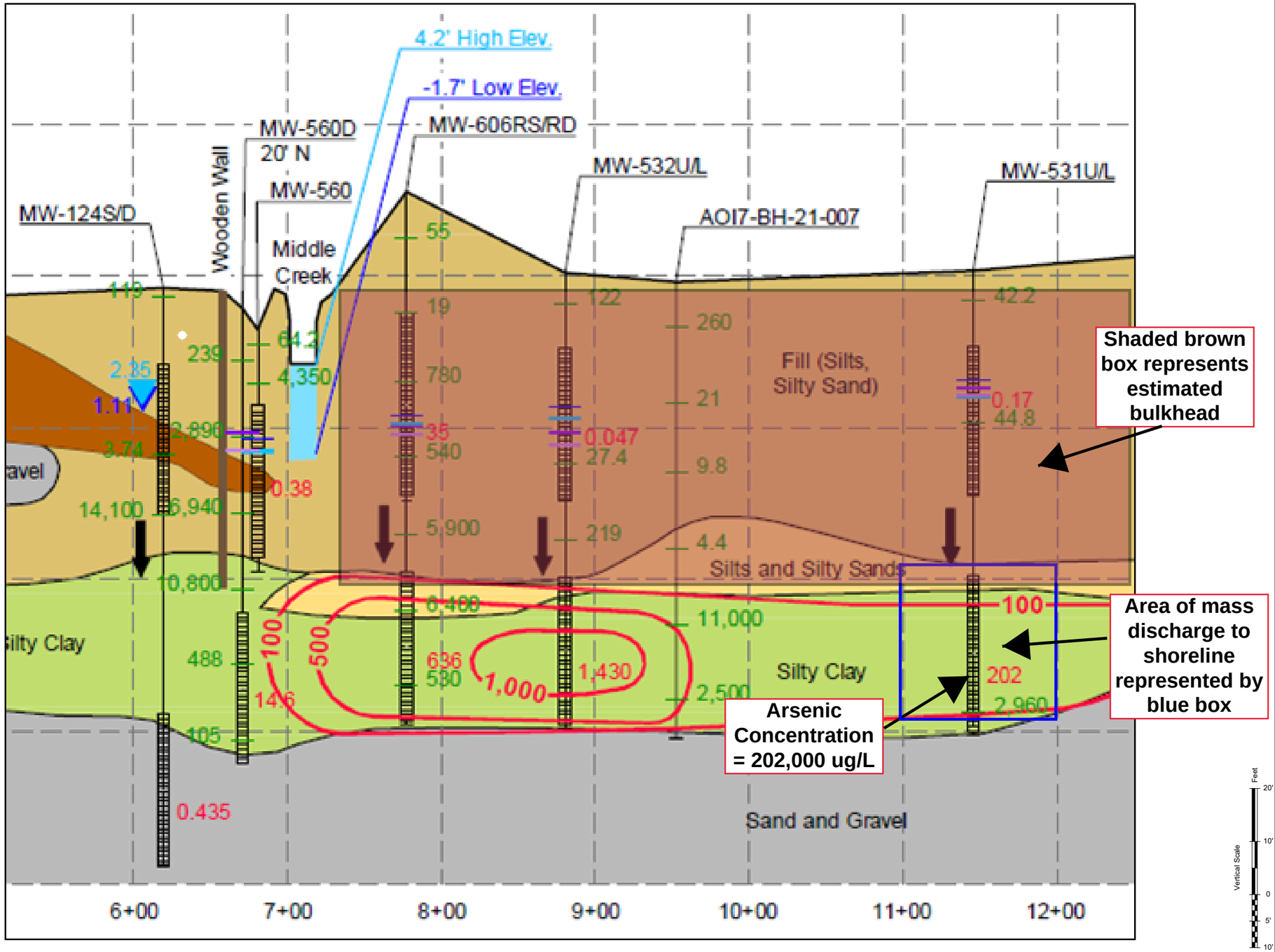
Figure 2

AOI 7 Cross Section A-A'

Evergreen

Marcus Hook, Pennsylvania

Drawn By:	Z. Svoboda
Designed By:	C. Shepsko
Reviewed By:	C. Costello
Project No:	4862.04
Date:	January 2023



Notes

1. 2021 boring logs provided in Appendix D of the 2021 IM Work Plan. RFI boring logs are in the RFI (GHD 2017, revised 2019). Logs for the 2022 borings will be provided in a future submittal.

2. Bottom elevation of Middle Creek surveyed in May 2021 by Vargo Associates using the NAVD 1988 vertical datum in US Feet.

3. Groundwater elevations shown with the triangle symbology are from August 18, 2021. Updated high and low tide groundwater elevations denoted by the purple and blue lines in the legend are from September 19, 2022.

4. Water elevations shown for the Delaware River were taken from the USGS Station # 01482170 for the Delaware River at New Castle, DE for August 18, 2021.

5. Water elevations shown for Middle Creek were taken from the staff gauge in Middle Creek on September 19, 2022 at high tide and low tide conditions.

6. The Delaware River sediment lithology in the 0 to 5 ft below grade interval is based on sediment core logs from the January 17, 2020 Marcus Hook Industrial Complex Water Quality Certificate: January 2020 Sediment Sampling Results letter from Weston Solutions, Inc. The lithology below 5 ft below grade is projected from the lithology in AOI 7 and should be considered approximate.

7. The location of bulkhead is based on the Figure I-3 "Phillips Island Remediation System Site Plan" provided by Stantec from July 2019.

8. Soil arsenic concentrations are from the 2017 RFI (GHD, 2017), July 2021, and April/May 2022 results. Groundwater concentrations are from the August 2021 and May 2022 results.

Legend

MW-606RS/RD	Well ID
55	Arsenic in soil at depth sampled (mg/kg)
	Shallow high tide groundwater elevation
	Shallow low tide groundwater elevation
	Deep high tide groundwater elevation
	Deep low tide groundwater elevation
1.68	Shallow groundwater elevation
35	Shallow Arsenic result in mg/L
	Hydraulic gradient direction
	Well screen
1.32	Deep groundwater elevation
730	Deep Arsenic result in mg/L
100	Arsenic isopleth mg/L

Vertical Scale: Feet 20', 10', 0, 5', 10'

Horizontal Scale: 100' 50' 0 100' 200' Feet

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Last Edited By: zsvoboda

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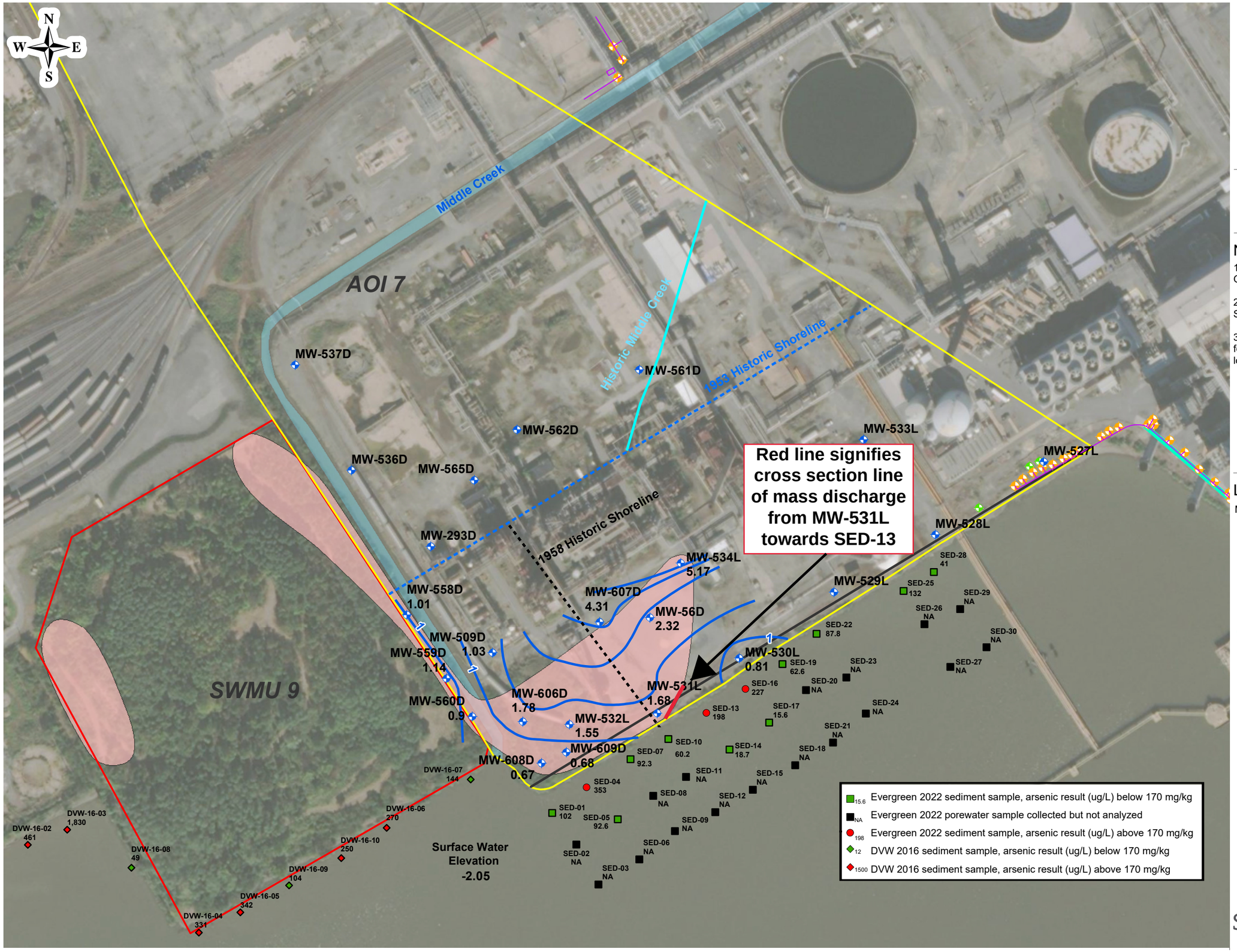

Figure 3

Site Conceptual Model

Evergreen
Marcus Hook, Pennsylvania

Drawn By:	Z. Svoboda
Designed By:	C. Shepsko
Reviewed By:	C. Costello
Project No:	4862.00
Date:	January 2022=3

Notes

1. Aerial Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community.

2. Groundwater elevations were taken on September 19, 2022.

3. The stilling well location depicted in this figure is for evaluation purposes. The actual stilling well location is on the Dock off the AOI 7 shoreline.

Legend

MW-531L Location Name
1.68 Water Elevation (ft amsl)

- Monitoring Well
- Recovery Well
- Remediation Well
- Bulkhead
- Sheet Pile Wall
- Remediation Systems
- AOI-7 Boundary
- SWMU 9 Boundary
- Groundwater Elevation Contour
- Current and Historic Arsenic in Groundwater Above 1,253 µg/L

100 50 0 100 200 Feet

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2. **Groundwater concentration discharge from MW-531U/L to the shoreline**

Equation 3: $V = DLW$

Equation 4: $C_{PW} = \frac{M}{V}$

Groundwater concentration discharge from MW-531L to the shoreline		
Parameter	**Value**	**Unit**
As Mass Discharge (M)	3.53	g/d
Depth of Plume (D)	7	ft
Width of Discharge (W)	100	ft
Length of Discharge (L)	30	ft
Volume of Discharge in cubic feet (V)	21000	ft 3
Volume of Discharge in liters (V)	59460	L
GW Concentration Discharge	**0.00595**	**mg/L per d**

Notes:

1. The volume (V) of discharge includes the depth (D) of the plume near MW-531L, the width (W) of discharge in the MW-531L area, and the length (L) of discharge to the shoreline/sediment interface towards SED-13 (see Figures 2 and 3).
2. mg - milligrams

3. **Potential theoretical porewater concentration discharge from the shoreline to the toe of slope, and resulting concentration discharge at sediment-surface water interface**

Equations 5 – 9 below reflect the components to the general advection-dispersion equation (Equation 10) for solute transport. Equation 11 reflects the porewater concentration discharge to surface water concentration. Each term is defined in the table below.

Equation 5: $a_x = 0.83(logx)^{2.414}$

Equation 6: $a_y = \frac{a_x}{10}$

Equation 7: $a_z = \frac{a_x}{100}$

Equation 8: $u = \frac{Ki}{nR_f}$

Equation 9: $R_f = 1 + \frac{K_d \rho_b}{n}$

Equation 10:

$$C_{TS} = \frac{C_{PW}}{2} exp\{\frac{x}{2a_x}\left(1 - \sqrt{1 + \frac{4\lambda a_x}{u}}\right)\} \cdot erfc\{\frac{1}{2\sqrt{a_x ut}}\left(x - ut\sqrt{1 + \frac{4\lambda a_x}{u}}\right)\}$$
$$\cdot erf\{\frac{S_y}{2\sqrt{a_y x}}\} \cdot erf\{\frac{S_z}{2\sqrt{a_z x}}\}$$

Equation 11: $C_W = DF \cdot C_{TS}$

Parameter	Value	Reference
Groundwater As Concentration discharge, C_{PW}	0.00595 mg/L/d	Calculated from Equation 4
Distance from source, x	40 ft	Distance from shoreline to estimated toe of slope
Longitudinal dispersivity, a_x	2.59 ft	See Equation 5 from EPA On-Line Tools for Site Assessment Calculation (see note 1 for reference)
Lateral dispersivity, a_y	0.259 ft	See Equation 6 based on Quick Domenico Manual (see note 2 for reference)
Vertical dispersivity, a_z	0.0259 ft	See Equation 7 based on Quick Domenico Manual (see note 2 for reference)
Decay constant, λ	0	Assumed no decay for arsenic
Rate of contaminant transport, u	1.3E-05 ft/d	See Equation 8 as part of the general advection-dispersion equation
Time, t	9E99 d	See note 3 below
Hydraulic conductivity, K	0.125 ft/d	See note 4 below
Hydraulic gradient, i	0.00638	Calculated from September 2022 pressure transducer data collection
Porosity, n	0.40	See December 14, 2020 AOI 7 Letter to the USEPA
Retardation factor, R_f	148	See Equation 9 based on Quick Domenico Manual
Partition Coefficient, K_d	39.18 L/kg	See note 5 below
Sediment bulk density, ρ_b	1.5 kg/L	EPA On-Line Tools for Site Assessment Calculation estimated value (see note 1)
Thickness of discharge, S_y	1 ft	Based on sediment thickness
Width of discharge, S_z	100 ft	Dispersion width from shoreline to toe of slope (see note 6)
Porewater As Concentration discharge at toe of slope, C_{TS}	**0.00103 mg/L/d**	**Calculated, Equation 10**
Dilution Factor, DF	100	See note 7 below
As Concentration at Sediment-Surface Water Interface, Cw	**1.03E-5 mg/L/d**	**Calculated, Equation 11**

Notes:

1. EPA On-Line Tools for Site Assessment Calculation: https://www3.epa.gov/ceampubl/learn2model/part-two/onsite/.
2. User's Manual for the Quick Domenico Groundwater Fate-and-Transport Model: https://files.dep.state.pa.us/EnvironmentalCleanupBrownfields/LandRecyclingProgram/LandRecyclingProgramPortalFiles/GuidanceTechTools/QD_manual_v3b%2002-28-2014.pdf.
3. Note that the time value is at infinity to assume steady state.

4. The hydraulic conductivity value used represents a conservative estimated value for silty clay to represent the flux from the highest concentrations in the silty clay layer to the sandy silt layer. The estimated hydraulic conductivity value was taken from a range of hydraulic conductivity values from Duffield, G. (2019, June 06). Aquifer testing 101: Hydraulic properties representative values of hydraulic properties. Retrieved from http://www.aqtesolv.com/aquifer-tests/aquifer_properties.htm.Partition coefficient for arsenic in sediment from Literature: Allison, Jerry D., and Terry L. Allison. "Partition coefficients for metals in surface water, soil, and waste." Rep. EPA/600/R-05 74 (2005).
5. See Figures 2 and 3 attached for estimated width.
6. Dilution factor is a conservative estimate/minimum expected dilution compared to the 10,000 dilution factor calculated in the CorMIX model from the 2017 AOI 7 RCRA Facility Investigation (RFI) Report.
7. kg - kilograms

4. **Theoretical maximum As sediment accumulation based on As porewater encountering surface water geochemical conditions and attenuating on the sediment**

Equation 12: $C_{sed} = C_w \cdot [K_d + \frac{P_w + (P_a \cdot H_d)}{P_b}]$

Parameter	Value	Reference
Porewater As Concentration Discharge, C_w	1.03E-5 mg/L/d	Calculated above in Equation 11
Partition Coefficient, K_d	39.18 L/kg	See note 1 below
Water-filled porosity, P_w	0.23	See December 14, 2020 AOI 7 Letter to the USEPA
Air-filled porosity, P_a	0.18	See December 14, 2020 AOI 7 Letter to the USEPA
Dimensionless Henry's constant, H_d	0	Assumed for arsenic
Sediment bulk density, P_b	1.5 kg/L	EPA On-Line Tools for Site Assessment Calculation (note 2) estimated value for silty clay
Sediment As Concentration Accumulation, C_{sed} (calculated)	**4.07E-4 mg/kg/d**	**Calculated, Equation 12**

Notes:

1. Partition coefficient for arsenic in sediment from Literature: Allison, Jerry D., and Terry L. Allison. "Partition coefficients for metals in surface water, soil, and waste." Rep. EPA/600/R-05 74 (2005).
2. EPA On-Line Tools for Site Assessment Calculation: https://www3.epa.gov/ceampubl/learn2model/part-two/onsite/.

This is the maximum/theoretical amount since it assumes that the appropriate geochemical conditions exist to allow for complete reaction to occur, minimum expected dilution of porewater, instantaneous reactions, and conservative attenuation.

5. **Time to reach arsenic sediment concentration at SED-13 from the sediment As accumulation rate**

Equation 13: $$T = \frac{SED{-}13\ As\ Concentration}{Potential\ Maximum\ Sediment\ Accumulation\ Rate}$$

$$T = \frac{198\ mg/kg}{0.000407\,\frac{mg}{kg}/d}$$

$$T > 1,300\ years$$

Calculations for Response to Comment 4:

1. ***Arsenic mass discharge from area upgradient of SED-07 and SED-10.***

Equation 1: $Q_{GW} = KiA$

Equation 2: $M = d\,\Sigma Q_{GW} C_w$

Mass Discharge							
Average As GW concentration (C_w) (ug/L)	Area (ft^2)	Hydraulic Conductivity (K) (ft/d)	i (ft/ft)	Qgw (L/d)	Mass Discharge (M) (g/d)	% Time of Discharge to SW	Corrected Mass Discharge (g/d)
708000	160	0.125	0.00638	3.61	2.56	70%	1.79
224000	1520	0.125	0.00638	34.3	7.69	70%	5.38
						TOTAL	7.17

Notes:

1. The As GW concentration is the average arsenic concentration in the red plume in Figure 4.
2. The area of mass discharge is depicted in Figure 4 and is located immediately upgradient of SED-07 and SED-10 as shown in Figure 5.
3. The hydraulic conductivity value used represents a conservative estimated value for silty clay to represent the flux from the highest concentrations in the silty clay layer to the sandy silt layer. The estimated hydraulic conductivity value was taken from a range of hydraulic conductivity values from Duffield, G. (2019, June 06). Aquifer testing 101: Hydraulic properties representative values of hydraulic properties. Retrieved from http://www.aqtesolv.com/aquifer-tests/aquifer_properties.htm.
4. % Time of Discharge and hydraulic gradient is based on pressure transducer data collected in September as discussed in the September 2022 IM Progress Report.
5. ug - micrograms
   L - liter
   ft - feet
   d - day
   g – grams
   SW – surface water

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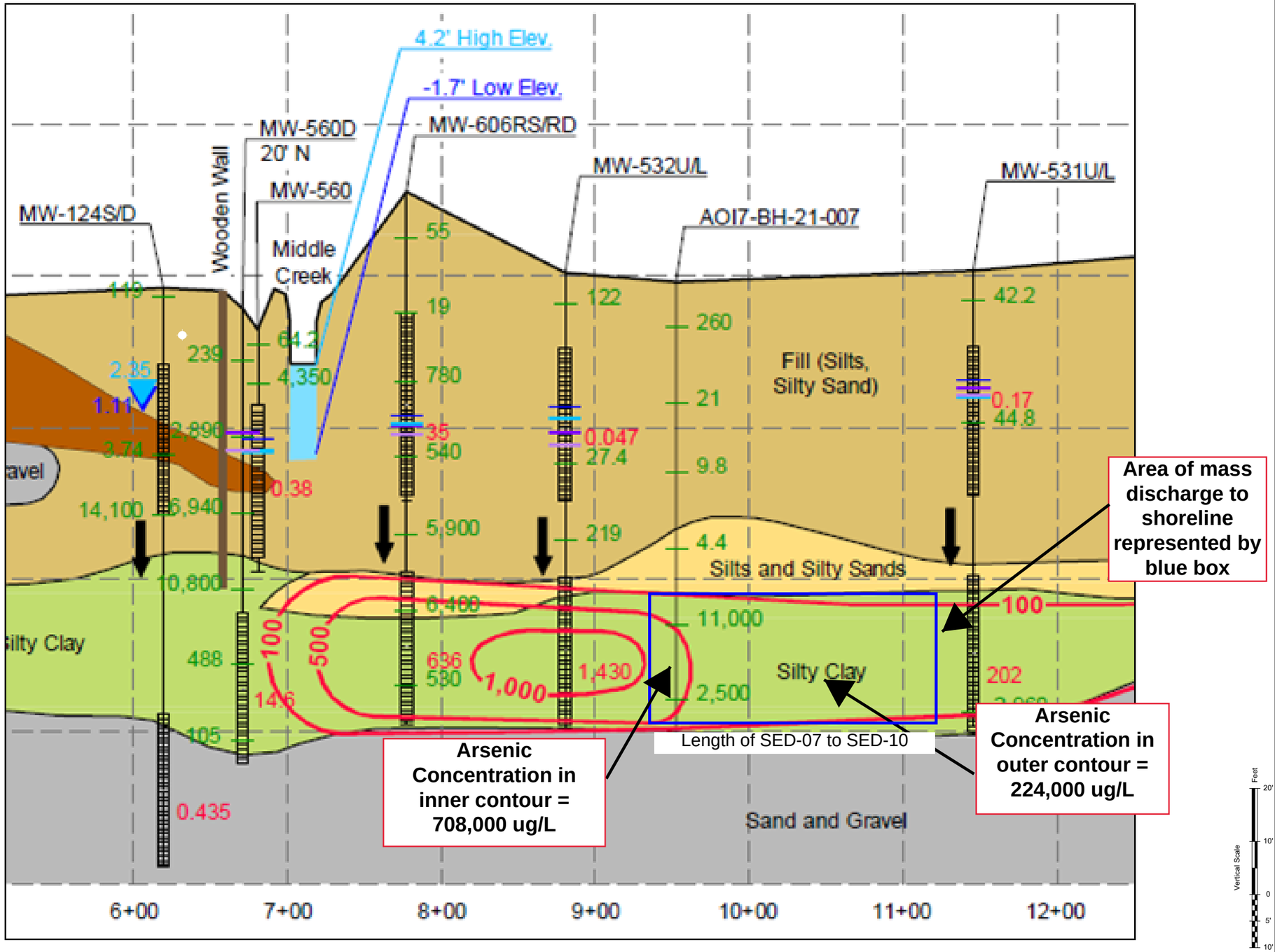
Figure 4

AOI 7 Cross Section A-A'

Evergreen

Marcus Hook, Pennsylvania

Drawn By:	Z. Svoboda
Designed By:	C. Shepsko
Reviewed By:	C. Costello
Project No:	4862.04
Date:	January 2023



Notes

1. 2021 boring logs provided in Appendix D of the 2021 IM Work Plan. RFI boring logs are in the RFI (GHD 2017, revised 2019). Logs for the 2022 borings will be provided in a future submittal.

2. Bottom elevation of Middle Creek surveyed in May 2021 by Vargo Associates using the NAVD 1988 vertical datum in US Feet.

3. Groundwater elevations shown with the triangle symbology are from August 18, 2021. Updated high and low tide groundwater elevations denoted by the purple and blue lines in the legend are from September 19, 2022.

4. Water elevations shown for the Delaware River were taken from the USGS Station # 01482170 for the Delaware River at New Castle, DE for August 18, 2021.

5. Water elevations shown for Middle Creek were taken from the staff gauge in Middle Creek on September 19, 2022 at high tide and low tide conditions.

6. The Delaware River sediment lithology in the 0 to 5 ft below grade interval is based on sediment core logs from the January 17, 2020 Marcus Hook Industrial Complex Water Quality Certificate: January 2020 Sediment Sampling Results letter from Weston Solutions, Inc. The lithology below 5 ft below grade is projected from the lithology in AOI 7 and should be considered approximate.

7. The location of bulkhead is based on the Figure I-3 "Phillips Island Remediation System Site Plan" provided by Stantec from July 2019.

8. Soil arsenic concentrations are from the 2017 RFI (GHD, 2017), July 2021, and April/May 2022 results. Groundwater concentrations are from the August 2021 and May 2022 results.

Legend

MW-606RS/RD	Well ID
55	Arsenic in soil at depth sampled (mg/kg)
	Shallow high tide groundwater elevation
	Shallow low tide groundwater elevation
	Deep high tide groundwater elevation
	Deep low tide groundwater elevation
1.68	Shallow groundwater elevation
35	Shallow Arsenic result in mg/L
	Hydraulic gradient direction
	Well screen
1.32	Deep groundwater elevation
730	Deep Arsenic result in mg/L
100	Arsenic isopleth mg/L

Vertical Scale: Feet 20', 10', 0, 5', 10'

Horizontal Scale: 100' 50' 0 100' 200' Feet

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Last Edited By: zsvoboda

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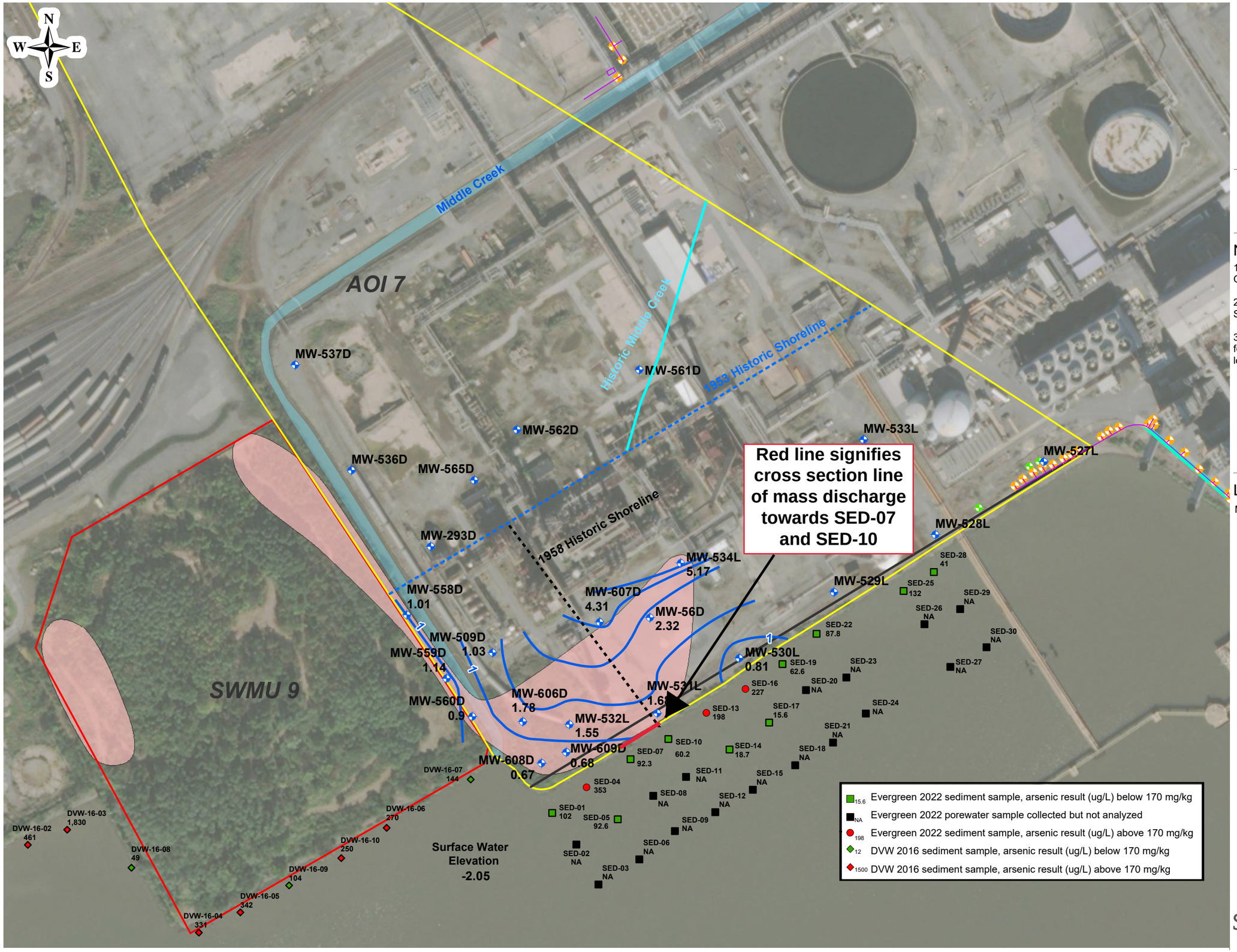

Figure 5

Site Conceptual Model

Evergreen
Marcus Hook, Pennsylvania

Drawn By:	Z. Svoboda
Designed By:	C. Shepsko
Reviewed By:	C. Costello
Project No:	4862.00
Date:	January 2022=3

Notes

1. Aerial Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community.

2. Groundwater elevations were taken on September 19, 2022.

3. The stilling well location depicted in this figure is for evaluation purposes. The actual stilling well location is on the Dock off the AOI 7 shoreline.

Legend

MW-531L Location Name
1.68 Water Elevation (ft amsl)

- Monitoring Well
- Recovery Well
- Remediation Well
- Bulkhead
- Sheet Pile Wall
- Remediation Systems
- AOI-7 Boundary
- SWMU 9 Boundary
- Groundwater Elevation Contour
- Current and Historic Arsenic in Groundwater Above 1,253 µg/L

100 50 0 100 200 Feet

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2. **Groundwater concentration discharge from upgradient plume to the shoreline**

Equation 3: $V = DLW$

Equation 4: $C_{PW} = \frac{M}{V}$

Groundwater concentration discharge to the shoreline		
Parameter	**Value**	**Unit**
As Mass Discharge (M)	7.17	g/d
Depth of Plume (D)	7	ft
Width of Discharge (W)	150	ft
Length of Discharge (L)	30	ft
Volume of Discharge in cubic feet (V)	31500	ft 3
Volume of Discharge in liters (V)	892000	L
GW Concentration	**0.00804**	**mg/L per d**

Notes:

1. The volume (V) of discharge includes the depth (D) of the upgradient plume, the width (W) of discharge in this area, and the length (L) of discharge to the shoreline/sediment interface towards SED-07/SED-10 (see Figures 4 and 5).

3. **Potential theoretical porewater concentration discharge from the shoreline to the toe of slope, and resulting concentration discharge at sediment-surface water interface**

Equations 5 – 9 below reflect the components to the general advection-dispersion equation (Equation 10) for solute transport. Equation 11 reflects the porewater concentration discharge to surface water concentration. Each term is defined in the table below.

Equation 5: $a_x = 0.83(logx)^{2.414}$

Equation 6: $a_y = \frac{a_x}{10}$

Equation 7: $a_z = \frac{a_x}{100}$

Equation 8: $u = \frac{Ki}{nR_f}$

Equation 9: $R_f = 1 + \frac{K_d \rho_b}{n}$

Equation 10:

$$C_{TS} = \frac{C_{PW}}{2} exp\{\frac{x}{2a_x}\left(1 - \sqrt{1 + \frac{4\lambda a_x}{u}}\right)\} \cdot erfc\{\frac{1}{2\sqrt{a_x ut}}\left(x - ut\sqrt{1 + \frac{4\lambda a_x}{u}}\right)\}$$
$$\cdot erf\{\frac{S_y}{2\sqrt{a_y x}}\} \cdot erf\{\frac{S_z}{2\sqrt{a_z x}}\}$$

Equation 11: $C_W = DF \cdot C_{TS}$

Parameter	Value	Reference
Groundwater As Concentration discharge, C_{PW}	0.00804 mg/L/d	Calculated from Equation 4
Distance from source, x	43 ft	Distance from shoreline to estimated toe of slope
Longitudinal dispersivity, a_x	2.71 ft	See Equation 5 from EPA On-Line Tools for Site Assessment Calculation (see note 1 for reference)
Lateral dispersivity, a_y	0.271 ft	See Equation 6 based on Quick Domenico Manual (see note 2 for reference)
Vertical dispersivity, a_z	0.0271 ft	See Equation 7 based on Quick Domenico Manual (see note 2 for reference)
Decay constant, λ	0	Assumed no decay for arsenic
Rate of contaminant transport, u	1.4E-05 ft/d	See Equation 8 as part of the general advection-dispersion equation
Time, t	9E99 d	See note 3 below
Hydraulic conductivity, K	0.125 ft/d	See note 4 below
Hydraulic gradient, i	0.00638	Calculated from September 2022 pressure transducer data collection
Porosity, n	0.40	See December 14, 2020 AOI 7 Letter to the USEPA
Retardation factor, R_f	148	See Equation 9 based on Quick Domenico Manual
Partition Coefficient, K_d	39.18 L/kg	See note 5 below
Sediment bulk density, ρ_b	1.5 kg/L	EPA On-Line Tools for Site Assessment Calculation estimated value (see note 1)
Thickness of discharge, S_y	1 ft	Based on sediment thickness
Width of discharge, S_z	150 ft	Dispersion width from shoreline to toe of slope (see note 6)
Porewater As Concentration discharge at toe of slope, C_{TS}	**0.00132 mg/L/d**	**Calculated, Equation 10**
Dilution Factor, DF	100	See note 7 below
As Concentration at Sediment-Surface Water Interface, Cw	**1.32E-5 mg/L/d**	**Calculated, Equation 11**

Notes:

1. EPA On-Line Tools for Site Assessment Calculation: https://www3.epa.gov/ceampubl/learn2model/part-two/onsite/.
2. User's Manual for the Quick Domenico Groundwater Fate-and-Transport Model: https://files.dep.state.pa.us/EnvironmentalCleanupBrownfields/LandRecyclingProgram/LandRecyclingProgramPortalFiles/GuidanceTechTools/QD_manual_v3b%2002-28-2014.pdf.
3. Note that the time value is at infinity to assume steady state.

4. The hydraulic conductivity value used represents a conservative estimated value for silty clay to represent the flux from the highest concentrations in the silty clay layer to the sandy silt layer. The estimated hydraulic conductivity value was taken from a range of hydraulic conductivity values from Duffield, G. (2019, June 06). Aquifer testing 101: Hydraulic properties representative values of hydraulic properties. Retrieved from http://www.aqtesolv.com/aquifer-tests/aquifer_properties.htm.Partition coefficient for arsenic in sediment from Literature: Allison, Jerry D., and Terry L. Allison. "Partition coefficients for metals in surface water, soil, and waste." Rep. EPA/600/R-05 74 (2005).
5. See Figures 4 and 5 attached for estimated width.
6. Dilution factor is a conservative estimate/minimum expected dilution compared to the 10,000 dilution factor calculated in the CorMIX model from the 2017 AOI 7 RCRA Facility Investigation (RFI) Report.
7. kg - kilograms

4. **Theoretical maximum As sediment accumulation based on As porewater encountering surface water geochemical conditions and attenuating on the sediment**

Equation 12: $C_{sed} = C_w \cdot [K_d + \frac{P_w + (P_a \cdot H_d)}{P_b}]$

Parameter	Value	Reference
Porewater As Concentration Discharge, C_w	1.32E-5 mg/L/d	Calculated above in Equation 11
Partition Coefficient, K_d	39.18 L/kg	See note 1 below
Water-filled porosity, P_w	0.23	See December 14, 2020 AOI 7 Letter to the USEPA
Air-filled porosity, P_a	0.18	See December 14, 2020 AOI 7 Letter to the USEPA
Dimensionless Henry's constant, H_d	0	Assumed for arsenic
Sediment bulk density, P_b	1.5 kg/L	EPA On-Line Tools for Site Assessment Calculation (note 2) estimated value for silty clay
Sediment As Concentration Accumulation, C_{sed} (calculated)	**5.19E-4 mg/kg/d**	**Calculated, Equation 12**

Notes:

1. Partition coefficient for arsenic in sediment from Literature: Allison, Jerry D., and Terry L. Allison. "Partition coefficients for metals in surface water, soil, and waste." Rep. EPA/600/R-05 74 (2005).
2. EPA On-Line Tools for Site Assessment Calculation: https://www3.epa.gov/ceampubl/learn2model/part-two/onsite/.

This is the maximum/theoretical amount since it assumes that the appropriate geochemical conditions exist to allow for complete reaction to occur, minimum expected dilution of porewater, instantaneous reactions, and conservative attenuation.

5. **Time to reach sediment PRG from the sediment As accumulation rate**

Equation 13: $$\boldsymbol{T = \frac{Sediment\ PRG}{Potential\ Maximum\ Sediment\ Accumulation\ Rate}}$$

$$\boldsymbol{T = \frac{170\ mg/kg}{0.000519\frac{mg}{kg}/d}}$$

$$\boldsymbol{T \sim 900\ years}$$

Attachment H

Peeper Sop

SPEEPER (PASSIVE POREWATER SAMPLER)
STANDARD OPERATING PROCEDURE

1.0 INTRODUCTION

As part of the AOI7 porewater sampling, field porewater samples will be screened for metal/metalloid contamination. The following procedures will be followed while utilizing SPeeper pore water sampling devices.

REQUIRED EQUIPMENT

A list of required equipment is provided below.

DEPLOYMENT

- Small volume peeper sampling device
- Appropriate membrane material
- 0.45-micron polypropylene
- Deionized water
- Waterproof marker
- Sampling vessel
- Differential global positioning system
- Waterproof sample tags, waterproof marker, and cable ties
- Personal protective equipment (PPE) for field team (e.g., rain gear, steel-toed boots, nitrile gloves)

RETRIEVAL

- Suprapur HNO3
- ** glass containers with HNO3 as preservative for metals/metalloids selenium, arsenic, cadmium, lead, zinc, iron, boron, and magnesium.
- Sample coolers and ice
- 20-mL glass syringe
- Disposable stainless-steel needles

2.0 INSTRUMENT METHODS

The following general guidelines should be followed in all the procedures and in all studies with peepers:

- Always wear clean nitrile gloves to handle the sampling device.
- Sampling should be done in a way to minimize the amount of time peepers are exposed to air to minimize the chance of cross contamination.

2.1 PRE-DEPLOYMENT PREPARATION

- Prior to deployment, the sampler body should be laid flat and the chambers overfilled with deionized oxygen-free water (DI). The DI is held within the chambers by a porous membrane and the overlays.
  - **Care** must be taken during assembly to avoid trapping air bubbles under the membrane in the sample chambers.
- Place the membrane on the sampler body.
- Place the sampler cover over the membrane.
- Install screws into cover holes and tighten cover against sampler body to keep membrane in place so that there is no air in the sample chambers.
- The cover containing the elongated openings should be spaced exactly opposite the compartments of the peeper body.
  - Following construction, peepers should be degassed to remove any oxygen present in the chambers that could markedly impact the concentration of reduction-oxidation sensitive constituents within the peeper chamber after deployment. The oxygen should be removed from the chambers and from the plastic by aerating the entire peeper assembly with nitrogen or argon gas for 24 hours in a large water bath prior to installation.
  - Peepers should be carried into the field in the degassed water bath and removed just prior to installation.

2.2 DEPLOYMENT

- The sampling device should be deployed by inserting into the sediment to a depth of 15 cm (or 6 inches) below the mudline or as deep as possible to allow the surrounding interstitial water to infiltrate the sampler.
- If multiple peeper assemblies are needed to provide adequate sample volume, each assembly should be spaced approximately 1 foot apart.
- If the sediment is soft, the peepers should be pressed into the sediment by hand or with a weighted frame.
- The sampling device should be deployed for a minimum of 28 days prior to retrieval.

2.3 RETRIEVAL

- The sampling device should be retrieved by pulling it by hand.
- Recovered peepers should be lightly rinsed with deionized water to remove any trapped sediment.
- Porewater should be removed from the chamber using a 20-mL glass syringe and sterile, one-time use stainless-steel needles.
- The syringes will be used to fill laboratory-provided sample containers.
- While collecting porewater to fill laboratory-provided containers, the porewater pH, temperature, and conductivity should be measured from additional sample volume.

  Following porewater collection into the laboratory-supplied containers, the porewater samples need to be placed in a cooler at 4 degrees Celsius for transport to the field facility where they will be packaged for shipment.

3.0 HANDLING, PACKING, AND SHIPPING

- Samples will be double wrapped and labeled with water-proof labels.
- Samples will be placed immediately on ice and will be stored on ice or in a refrigerator until shipment to the laboratory.
- Samples will be maintained via Chain of Custody until shipment via overnight express to the analytical laboratory as deemed appropriate to meet hold times.