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September 30, 2020

Mr. Joshua P. Cook, P.E.
Environmental Engineer
New York State Department of Environmental Conservation
Division of Environmental Remediation
615 Erie Boulevard West
Syracuse, New York 13204

Subject: Former GE Farrell Road, NYSDEC Site No. 734055
Response to Submittal of Draft Building #2 Remedial System Optimization Study

Dear Mr. Cook:

On behalf of Lockheed Martin Corporation (Lockheed Martin), AECOM Technical Services, Inc. (AECOM) has addressed comments received from the New York State Department of Environmental Conservation (NYSDEC) dated July 27, 2020 regarding the draft submittal of the Building #2 Remedial System Optimization (RSO) Study.

In the draft submittal, Lockheed Martin and AECOM recommended selection of the dual phase extraction (DPE) technology utilizing horizontal wells. Since the draft submittal in June 2020, Lockheed Martin, AECOM, and the property owner (Widewaters) have had a few communications to discuss the recommended technology and the conceptual layout. As a result of these discussions, detailed evaluation of an additional technology, soil vapor extraction with air sparge, was added to the RSO study, as well as the addition of an alternate conceptual layout for the DPE approach. Applicable sections were added to the RSO Study in Sections 4 and 6.

The NYSDEC comments received in July 2020 are repeated below in bulleted, italic font and followed by Lockheed Martin's response in regular font.

1. *Section 2.2.5, 3rd Paragraph (1,4-dioxane) – "SB-114" should be "SB-115", "west" should be "east", and it seems "downgradient" should be "upgradient" (SB-138). It might be better to say the locations were generally at the periphery of the plume.*

This comment is acknowledged and the text in Section 2.2.5 has been revised to indicate that the 1,4-dioxane concentrations were identified at the periphery of the plume.

2. *Section 3.2.1, 1st Paragraph and Section 3.2.3 – Revise to read "…(NYSDEC, 1998) as updated in January 1999, April 2000 and June 2004."*

This comment is acknowledged and the text has been revised in Section 3.2.1 as suggested.

3. *Section 3.2.1, Final Paragraph – 1,4-dioxane will be evaluated based on a screening value of 1 microgram per liter (µg/L).*

This comment is acknowledged and the text has been revised in Section 3.2.1 as suggested.

4. *Section 3.2 – Include a list of standards, criteria and guidance (SCGs) that would be applicable to the implementation of the RSO. See http://www.dec.ny.gov/regulations/61794.html.*

This comment is acknowledged and additional reference to applicable SCGs have been included in Section 3.2.

5. *Section 4.0, 1st Bullet – Here it says the No Further Action (NFA) remedial alternative would include the continued operation of the existing sub-slab depressurization systems (SSDS), but elsewhere it says the SSDS would not continue to be operated.*

This comment is acknowledged and the text in Section 4.0 has been revised to correspond with language in the remainder of the report that operation of the sub-slab depressurization system will not be considered as part of the NFA remedial alternative.

6. *Section 4.0 Table – While there would certainly be obstacles and limitations, it is not accurate to say that excavation is "Not Implementable".*

This comment is acknowledged and the text in the table under Section 4 has been revised as suggested. Additional clarification, in line with NYSDEC Comment #9, is provided in Section 4.5.

7. *Section 4.1 and Section 6.1.1 – Here and in any other locations, when referring to the SSDS, delete voluntary.*

The word "voluntary" has been removed from the text in Sections 4.1 and 6.1.1. There are no other occurrences of this word in the document.

8. *Sections 4.3.1, 6.2.1, 6.4.1, 6.5.1, Table 1 (Implementability Column) – The site is already subject to a deed restriction and Interim Site Management Plan. It does not seem an additional deed restriction(s) would be necessary.*

This comment is acknowledged and reference to pursuing a deed restriction has been removed from the RSO Study, recognizing that the Interim Site Management Plan adequately addresses issues such as soil and groundwater use at the site.

9. *Section 4.5, 2nd Paragraph – Please evaluate whether some amount of excavation could be conducted without demolishing the building. It is noted an excavation was conducted within the building (at the north end) as part of the building modifications implemented in 2019 for the new truck bays. It seems a limited, targeted excavation would not impact site operations nor require the building to be vacated to a greater extent than most of the other remedial alternatives (unless any amount of excavation would require the building be demolished, but that seems unlikely).*

Additional detail has been included in Section 4.6 (previously Section 4.5) to clarify why excavation is not evaluated beyond initial screening. It is Lockheed Martin's and AECOM's understanding that excavation activities conducted by Widewaters as part of the building modifications implemented in 2019 were to a total depth of 8 feet below grade (ftbg) located entirely within the vadose zone. If excavation was to be conducted for remedial efforts, even if only to target removal of source material, shoring would need to be installed to access depths of up to 27 to 28 ftbg which would require demolition of all or part of Building #2. Screening level cost estimates were conducted that suggested costs in exceedance of $20,000,000.

In consideration of these factors, Lockheed Martin and AECOM have not completed any further evaluation of excavation as part of an optimized remedial approach at this site.

10. *Sections 5, 6 and 7 – In order to be consistent with 6 NYCRR 375-1.8(f), these sections should include community acceptance as one of the evaluation criteria.*

Lockheed Martin and AECOM note that community acceptance was not identified during development of the Table of Contents and as a result was not included in the draft submittal of the Building #2 RSO Study. Based on conversations with the NYSDEC it was established that incorporation of the community acceptance evaluation criteria would be met by preparing an information release that will be distributed to neighboring properties to the east, west, and south of the subject site. A draft information release will be provided to the NYSDEC for review in advance of circulation and separate from this document submittal. Section 5 of the RSO Study has been updated to include a reference to community involvement as described above.

11. *Section 6.0 – At the end of this section, include a statement that while the Remediation Evaluation Model for Chlorinated Solvents (REMChlor) model and Johnson-Ettinger model are useful for comparing the predicted outcomes for the various alternatives, future decisions regarding the remediation and/or operation or discontinuance of the remedial system(s) will be based on future data.*

This comment is acknowledged and the Section 6 text has been updated as suggested.

12. *Section 6.0, 5th Paragraph – Since MW-115 is a deeper well, it may be better to utilize SB-137 at 400 feet for the model input for toluene.*

As described in an email correspondence from AECOM to NYSDEC on July 14, 2020, in order to obtain concentrations from the REMChlor model that correspond with recent centerline transect data, the starting year for the simulation was adjusted. The REMChlor model assumes that the mass is immediately available in the subsurface to be transported by groundwater at the time of simulation (not a long-term release) and does not account for other types of processes (comingling/cosolvency, etc) occurring amongst the compounds. Adjusting the starting years provided the model output simulate concentrations for each compound that were similar to the centerline concentration data that we recently observed at the site.

When conducting this “calibration” of the REMChlor model, a toluene concentration for MW-115 was used (observed to be less than laboratory detection limits). The NYSDEC comment suggests instead using the toluene concentration from SB-137 (6.8 µg/L) to “calibrate” the model. In AECOM’s experience, conducting such an adjustment at this point in the evaluation would require a high level of effort and the difference in these two concentrations would not register any significant change in output concentrations from the REMChlor model. Therefore, no adjustments have been made to the text or to the model input.

13. *Section 6.0, 5-7th Paragraphs – At the end of each paragraph there is a statement as to what the model output was for each contaminant. Based on a discussion with AECOM it is understood the model was run with a start date in the past (simulating the release of the contaminants), run through the present (and/or beyond) and then checked versus existing conditions. Clarify that was done because the model does not allow inputting current plume conditions, then running it into the future from there.*

This comment is acknowledged and an additional paragraph has been included in Section 6 to explain this aspect of the REMChlor model.

14. *Section 6.0, 7th Paragraph – 1,1-dichloroethene was detected at 6 µg/L at MW-115 in February 2020, not 93 µg/L.*

This comment is acknowledged and the text in Section 6.0 has been revised.

15. *Section 6.2.6, 2nd Paragraph, Final Bullet – Revise to read, "…and, preferably, adjacent to the southwest corner of Building." The final location of remedial equipment will be coordinated, to the extent possible, with the site owner.*

This comment is acknowledged and the text in Section 6.2.6 has been revised as suggested. In addition, the text has been revised to reflect communications with the property owner and identify areas of flexibility during final design communications.

16. *Section 6.2.6, Final Paragraph, Final Bullet – Revise to read, "…Building #2, preferably to the southwest…".*

This comment is acknowledged and the text in Section 6.2.6 has been revised. The text has been revised to reflect communications with the property owner and identifies areas of flexibility during final design communications.

17. *Section 6.3 – Provide an estimate of how long the system would operate; after the 7-month installation period.*

The estimated duration of operation for the thermal treatment system is approximately four months. Section 6.3.6 has been updated to include this information.

18. *Section 6.3 – It seems the length of time for which the SSDS would be required after completion of remediation should be less for the in-situ thermal remediation (ISTR) alternative than for the recommended alternative, dual-phase extraction (DPE), given that the mass of contamination remaining after ISTR will be less than after DPE operation. If it is assumed the SSDS would be needed in perpetuity under any alternative, then costs should be projected for a 30-year timeframe, as per convention.*

It has been assumed that the SSD system operation would continue for approximately 10 years following cessation of the DPE system operation to allow for post-mitigation indoor air sampling to support deactivation of the SSD systems. A total timeframe of SSD system operation under a DPE approach is estimated to be 20 years for the purpose of cost evaluation.

It has been assumed that the SSD system operation would continue for approximately 10 years following cessation of the thermal system operation to allow for post-mitigation indoor air sampling to support deactivation of the SSD systems. A total timeframe of SSD system operation under a thermal approach is estimated to be 10 years for the purpose of cost evaluation.

The text in Sections 6.2.7 and 6.3.7 is now consistent with the above statements.

19. *Section 6.4.6 – Provide further explanation of the difficulties associated with conducting in-situ chemical oxidation (ISCO) via horizontal injection wells.*

To address this comment, clarification has been added to Section 6.4.6.

20. *Section 6.5 – This alternative (Monitored Natural Attenuation [MNA] with Enhanced Reductive Dechlorination [ERD]) does not address the source area to the greatest extent feasible, and therefore, it does not comply with the SCGs. See 6 NYCRR 375-1.8(c). Further, ERD would not address 1,4-dioxane which, given its high solubility, is more likely to migrate than the other contaminants of concern.*

This comment is acknowledged and Lockheed Martin and AECOM agree. For an MNA approach to be implemented, it would need to be subject to strict monitoring of contaminant plume migration. In addition, the downgradient use of ERD that is evaluated as part of an MNA approach is not expected to have any impact on 1,4-dioxane concentrations, or BTEX concentrations should they migrate. A sentence has been added to Section 6.5 to clearly acknowledge this position.

21. *Section 6 – It is the Department's understanding that, at the current time, electricity is supplied to the site by National Grid, but that it could be supplied by Solvay Electric, and that electricity rates from Solvay Electric would be much lower. Include costs for both supply scenarios for the ISTR alternative. It is understood there would be initial costs associated with changing from one supplier to the other, however, depending on what the costs are and the difference in rates, it could still be less expensive to switch. It may be worthwhile to conduct the same analysis for the DPE alternative.*

The logistics of having two electric service providers to the site or switching the electricity service provider from National Grid to Solvay Electric have previously been explored during initial SSD system design activities. Lockheed Martin agrees with the information referred to in email correspondence dated July 28, 2020 from Marco Marzocchi of Widewaters, in that Solvay Power does not have the capacity to match the power supply currently provided by National Grid. In addition, there is a contract clause that prohibits more than one utility company servicing a property. There have been no revisions to the final RSO Study in relation to comment #21.

22. *Section 6 – Incorporate concepts of green remediation as part of the evaluation of the alternatives, consistent with the Department's guidance document DER-31 – Green Remediation (DER-31). It seems the two technologies most likely to be implemented are DPE and ISTR. Both are energy intensive, but without evaluation, it is not clear which would result in greater greenhouse gas (GHG) emissions. As part of the evaluation, if possible (if information is available), consider the GHG footprint associated with the two electrical supply options (National Grid vs. Solvay) based on their power source(s) (i.e., hydroelectric, nuclear, fossil fuels, etc.).*

Lockheed Martin and AECOM note that conducting an evaluation in accordance with DER-31 was not identified during development of the Table of Contents and as a result was not included in the draft submittal of the Building #2 RSO Study. Based on conversations with the NYSDEC, Lockheed Martin requested that AECOM conduct a green and sustainable remediation assessment in response to NYSDEC comment #22. AECOM completed the assessment for thermal treatment and the recommended DPE optimized remedial alternatives. Narrative has been added to Section 5 and a new Section 7.8 has been added as well. The assessment is included with the RSO Study as Appendix C.

23. *Section 7 – This should provide a comparison of the extent to which each alternative would achieve/comply with each criterion, including a comparison of the extent to which each alternative would reduce the potential for soil vapor intrusion. The comparison for each criterion as a whole can be relative/qualitative, but would benefit from the quantitative measures to the extent possible (e.g., length of time for implementation; number of vehicle trips; volume of clean, imported soil required; total energy usage over the expected operating period [especially for ISTR and DPE]; etc.).*

The narrative in Section 7 references Table 2 which provides a comparison of the extent to which each alternative complies or does not comply with each criterion. A statement has been added to Table 2 for each alternative under each criterion to clearly state the position of the RSO Study on whether compliance would be met based on the evaluation conducted. In addition, reference to the estimated length of ongoing SSD system operation has been added under discussion of the long-term effectiveness and permanence criterion in both Section 7 and Table 2.

24. *Section 7.6 – In section 6.4.6, the text indicated implementation of ISCO using horizontal wells could be a challenge. That should be discussed here.*

This comment is acknowledged and the text in Section 7.6 has been revised.

25. *Section 7.6, 5th Sentence – Provide timeframes for the operating periods. Both Alternatives 2 (DPE) and 3 (ISTR) would require periodic access for operation and maintenance; however, the operational period for ISTR would be much shorter than for DPE.*

This comment is acknowledged and the text in Section 7.6 has been revised.

26. *Section 8.1 – The remedial design package should include an outline for a schedule for submitting an updated Site Management Plan, including an Operation, Maintenance and Monitoring Plan for the remedial system (if DPE is the approved alternative).*

This comment is acknowledged and a submittal schedule for an updated Site Management Plan and an Operation, Maintenance, and Monitoring Plan has been included in Section 8.2.

27. *Section 8.2 – Include a schedule for submission of the remedial design, which can be relative to approval by the Department.*

This comment is acknowledged and a proposed schedule has been included in Section 8.2 for the NYSDEC's consideration and ultimate approval.

28. *Figure 12 – Include the location of known utilities (including the SSDS) and evaluate whether it would be possible to install the horizontal wells as shown, including if temporary or permanent relocation of some utilities might be necessary and/or a realignment of the proposed path, or if the DPE wells would be deep enough so as to not conflict with the known utilities.*

The conceptual drawings that are provided in the RSO Study provide the general layout of each proposed technology. In consideration of DPE being the recommended technology, additional narrative has been included Section 6.2.6 to expand on the flexibility the design offers to adjust for utilities and/or property developments. Should DPE move forward as the optimized remedial approach, the detailed engineering design will address locations of utilities and provide cross-sectional drawings that show the locations of the horizontal well installations.

29. *Table 1, Coupled ERD and Aerobic Biodegradation of BTEX, Implementability, Last Sentence – I believe the first barrier should be to generate anaerobic conditions. Please review and revise.*

This comment is acknowledged and the text in Table 1 has been revised.

30. *Table 1, ERD and ISCO, Screening Comments – I believe this option was not retained.*

This comment is acknowledged and the text in Table 1 has been revised.

31. *Table 2, DPE, Long-Term Effectiveness – Why does this say DPE would not be effective for 1,4-dioxane? Treatment technologies are available that could treat 1,4-dioxane in the groundwater effluent.*

The intent of the narrative was to relay that the act of groundwater extraction and standard treatment using an air stripper would not effectively treat 1,4-dioxane. The intent was to subsequently include a selected means of groundwater treatment to address 1,4-dioxane in extracted groundwater in the detailed engineering design, should DPE be approved as the selected alternative.

In response to the NYSDEC's comment, the narrative for long-term effectiveness and permanence for Alternatives 2A and 2B in Table 2 have been clarified to reflect this stance.

32. *Table 2 – The present worth for each alternative should be based on 30 years of costs. The cost for ISTR is listed as over 10 years. If annual costs are expected to be zero after 10 years, please add a note to that effect.*

This comment is acknowledged and the cost for each alternative in Table 2 is now based on 30 years of cost.

33. *Attachments - Include a breakdown of the costs for each alternative, including the operation, maintenance and monitoring costs.*

It is Lockheed Martin and AECOM's position that the costs presented in the draft RSO study meet guidance outlined in DER-10 Section 4.3(a).5.(iii). The costs outlined in the final RSO study remain as originally presented.

34. *Appendix A – Here or in the text of the report, please explain why different starting years were used for each contaminant (1970 for 1,1,1-trichloroethane; 1980 for toluene; and 1990 for 1,1-dichloroethene).*

This comment is acknowledged and text has been added in Section 6, and a footnote has been added to each page of Appendix A.

35. *Appendix A, A-8 – The title for this page should be for "1,1,1-TCA Thermal Inputs".*

This comment has been confirmed and the title on Page A-8 has been revised.

Sincerely, AECOM

Carey Letts

Carey Letts
Project Manager

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Attachments: Building #2 Remedial System Optimization Study

BUILDING #2 - REMEDIAL SYSTEM OPTIMIZATION STUDY FORMER GE FARRELL ROAD SITE SITE ID NO. 734055 241 FARRELL ROAD, SYRACUSE, NEW YORK

Prepared for:
Lockheed Martin Corporation

Prepared by:
AECOM

September 2020

Approved by:
Lockheed Martin, Inc.

Revision: 0

Dustin Bytautas, Senior Engineer

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Nickcole M. Evans

Nickcole Evans, P.E., Project Director

Certification Statement

I, Nickcole M. Evans, certify that I am currently a New York State registered professional engineer as defined in 7 NYCRR Part 375 and that this *Remedial System Optimization Study* was prepared in accordance with all applicable statutes and regulations and in substantial conformance with the Division of Environmental Remediation (DER) Technical Guidance for Site Investigation and Remediation dated 2010.

STATE OF NEW YORK
NICKCOLE M. EVANS
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LICENSED PROFESSIONAL ENGINEER

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Date

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ACRONYMS AND ABBREVIATIONS

AECOM	AECOM Technical Services, Inc.
AOC	area of concern
AS	air sparge
BTEX	benzene, toluene, ethylbenzene, and xylenes
cm/s	centimeters per second
COC	chemical of concern
Cr^{6+}	hexavalent chromium
CVOC	chlorinated volatile organic compound
1,1-DCA	1,1-dichloroethane
1,1-DCE	1,1-dichloroethene
DER	New York State Department of Environmental Conservation, Division of Environmental Remediation
DNAPL	dense non-aqueous phase liquid
DPE	Dual Phase Extraction
EC	Engineering Control
ERD	enhanced reductive dechlorination
ERH	electrical resistance heating
EVO	emulsified vegetable oil
ft	feet
ftbg	feet below grade
FRP	Farrell Road Property
GAC	granular activated carbon
GHG	greenhouse gases
GWETS	groundwater extraction system
IC	Institutional Control
ISCO	In-Situ Chemical Oxidation
IRM	interim remedial measure

ISMP	Interim Site Management Plan
J&E model	Johnson and Ettinger Vapor Intrusion Model
K	potassium
KP	potassium persulfate
LNAPL	light non-aqueous phase liquid
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
µg/m^3	micrograms per cubic meter
mg/L	milligrams per liter
MNA	Monitored Natural Attenuation
MIP	membrane interface probe
Na	sodium
NAPL	non-aqueous phase liquid
NFA	No Further Action
NYCRR	New York Code of Rules and Regulations
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
O&M	Operation and Maintenance
OM&M	Operation Maintenance & Monitoring
OWS	oil-water separator
PCU	power control unit
PDI	Pre-Design Investigation
PFAS	per- and polyfluoroalkyl substances
P&IDs	Process and Instrumentation Diagrams
ppb	parts per billion
ppm	parts per million
PRB	permeable reactive barrier
PVC	polyvinyl chloride

PWB	printed wire board
RAO	Remedial Action Objective
REMChlor	Remediation Evaluation Model for Chlorinated Solvents
RI	remedial investigation
ROD	Record of Decision
ROI	radius of influence
SCGs	Standards, Criteria and Guidance
SP	sodium persulfate
sq. ft.	square feet
SSD	sub-slab depressurization
SSSV	sub-slab soil vapor
SVE	soil vapor extraction
1,1,1-TCA	1,1,1-trichloroethane
TCE	trichloroethene
UST	underground storage tank
VI	vapor intrusion
VOC	volatile organic compound

SECTION 1
INTRODUCTION

On behalf of Lockheed Martin Corporation, AECOM Technical Services Inc. (AECOM) has prepared this Building #2 Remedial System Optimization Study for the Former General Electric Farrell Road site located in the Town of Geddes, New York (Figure 1). This study considers historical investigation data, historical remedial efforts, and the updated site conceptual model to evaluate progress made toward the site's cleanup goals and conducts an evaluation of remedial technologies to optimize the remedial approach in the vicinity of Building #2. The objective of this study is to alter the current remedial strategy and enhance the ability to achieve Remedial Action Objectives.

This report is organized into the following sections: (1) Introduction, (2) Site Background, History, and Conceptual Site Model, (3) Interim Site Management Plan, (4) Development and Screening of Optimized Remedial Alternatives in the Vicinity of Building #2, (5) Evaluation Criteria for Optimized Remedial Alternatives, (6) Detailed Evaluation of Optimized Remedial Alternatives, (7) Comparative Analysis of Optimized Remedial System Alternatives, (8) Optimized Remedial Alternative Implementation, and (9) References. Tables, Figures and Appendices that are referenced are included at the end of the report body following Section 9.

SECTION 2
SITE BACKGROUND, HISTORY AND CONCEPTUAL SITE MODEL

The site consists of 16.6 acres located in an industrial setting on Farrell Road in the Town of Geddes, New York and is bounded to the north by wetlands and the Seneca River, a shipping operation to the west, Farrell Road to the south, and a vacant lot to the east (Figure 2). The site includes an industrial building (Building #2) that is approximately 310,500 square feet (sq. ft.) in size, a garage that is approximately 8,000 sq. ft. in size, and Class I wetlands on the north side of the site (Figure 3). Further to the north of the site, the Class I wetland area continues into the Seneca River. Currently, the site is classified as Class 4 on the New York State Department of Environmental Conservation (NYSDEC) Registry of Inactive Hazardous Waste Disposal Sites (Site #734055).

The following sections provide a timeline of the site remedial history and a brief summary of the available project records to document key investigative and remedial milestones for the site. Many of these sections were originally presented in the Interim Site Management Plan (ISMP) (AECOM, 2017), first approved by NYSDEC in 2017, and most recently revised on June 3, 2019.

2.1 SITE BACKGROUND AND HISTORY

The Farrell Road Property (FRP) was developed in the early 1960’s by GE and was used as a design, manufacturing, and assembly center for radar and sonar equipment until December of 1992 when GE moved all operations to other locations. The FRP was divided into two parcels, designated as FRP-1 and FRP-2, with separate ownership histories. Building #1, formerly located on FRP-1, was used as a design center for sonar equipment, and Building #2, located on FRP-2, was used as an assembly center for radar and sonar units.

Remedial investigations (RIs) conducted in the 1990s identified 16 areas of concern (AOCs) at the site. Historical activities associated with each AOC are summarized in the NYSDEC-approved

ISMP. The sections below focus on AOC #5, which includes Building #2 and is managed through an interim remedial measure (IRM), and the overarching remedial approach for groundwater remediation identified in the Record of Decision (ROD).

2.1.1 Sources and Remedial Activities - Area of Concern #5

Up to nine 275-gallon underground storage tanks (USTs) containing both chlorinated and non-chlorinated solvents and a paint drippings drywell were located along the west wall of Building #2. The USTs were reportedly removed in 1986, and the drywell was removed in 1992. This area was identified as AOC #5. The approximate locations of the former USTs and former drywell are illustrated on Figure 4.

In 1992, a soil boring investigation was conducted in the vicinity of AOC #5 and throughout the interior of Building #2 to determine the extent of impacted soil and groundwater beneath the building. Light, non-aqueous phase liquids (LNAPL) were observed at the approximate depth of the water table in borings and test pits installed near the location of the former USTs. A soil gas survey indicated the presence of volatile organic compounds (VOCs) and was followed by sampling and analysis which identified VOC concentrations, including chlorinated and aromatic hydrocarbons, in the soil. Downgradient of the former USTs, beneath the building, a suite of dissolved VOCs was detected which closely resemble those detected in the vicinity of the former USTs. Analytes detected in the vicinity of AOC #5 and at the downgradient locations illustrated on Figure 4, that exceeded NYSDEC cleanup objectives included:

1,1,1-Trichloroethane	1,1-Dichloroethane	1,1-Dichloroethene
1,2-Dichloroethane	Benzene	Ethylbenzene
Methyl isobutyl ketone	Toluene	Xylenes

Various remedial options were evaluated for AOC #5 and soil vapor extraction (SVE) was chosen as the IRM to manage soil impacts. The NYSDEC approved the selection of SVE and the remedial system was installed between October and December 1994.

Following the installation of the SVE system wells in October 1994, free-phase LNAPL and dense non-aqueous phase liquid (DNAPL) was observed at a number of system wells. Approximate locations of the historical system wells are illustrated on Figure 5. A follow-up investigation assessed the horizontal and vertical extent of LNAPL and DNAPL in AOC #5 and the phases were determined to be chemically similar (i.e., multi-component non-aqueous phase liquids [NAPLs]). A NAPL monitoring and removal program was approved by the NYSDEC in October 1995. During the program (September 1995 through August 1996 with periods of monitoring only), approximately 7.76 gallons of DNAPL were removed from well VRW-203 and 1.7 gallons of LNAPL were removed from well VRW-207. The SVE remedial system was activated on November 13, 1995 and operated until 2002.

A confirmatory soil sampling program was conducted at AOC #5 in September 2002. A total of 18 soil samples were collected from a depth of 6 to 8 feet below grade (ftbg), corresponding to the depth at which the most affected pre-remedial samples had been collected. The concentrations of VOCs in confirmatory samples were less than laboratory detection limits, except for 1,1,1-trichloroethane (1,1,1-TCA) which was detected at CSB-504 at a concentration of 0.269 parts per million (ppm), which was less than its unrestricted use soil cleanup objective of 0.68 ppm. The confirmatory samples were collected from a depth of 6 to 8 ftbg and the approximate locations are shown on Figures 4 and 5. On November 1, 2002, Lockheed Martin requested approval to permanently shut down and decommission the SVE system at AOC #5 (Lockheed Martin, 2002), which was approved by the NYSDEC in correspondence dated December 9, 2002.

In August 2016, a membrane interface probe (MIP) investigation was conducted at the site to assess soil conditions at the base of the surficial geologic unit and to determine whether there were residual soil and groundwater impacts in the vicinity of Building #2 (AECOM, 2017a). During the investigation activities, a monitoring well was identified on the west side of Building #2 in the vicinity of former AOC #5; the identification of the well could not be determined through a historical file review, so it was designated as monitoring well MW-27. During the investigation, a soil sample was collected from a soil boring near MW-27 with a benzene, toluene, ethylbenzene, and xylenes (BTEX) concentration of 66,000 micrograms per kilogram (µg/kg) between 9 and 10 ftbg and ethylbenzene and xylenes exceeded their corresponding cleanup objectives. Monitoring well MW-27 was included in the third quarter 2016 groundwater gauging and sampling and a

BTEX concentration of 13,450 micrograms per liter (µg/L) was reported with ethylbenzene and xylenes exceeding their corresponding cleanup objectives.

In 2017, an In-Situ Chemical Oxidation (ISCO) pilot test was conducted in the vicinity of MW-27 which included the collection of additional soil and groundwater samples from a location within the Building #2 footprint. This data confirmed the presence of residual soil and groundwater impacts in this area prompting additional investigation activities discussed below in Section 2.2.3.

In November/December 2017, an ISCO field pilot test was conducted near the west side of Building #2 to evaluate its potential to address residual soil and groundwater impacts in this area. In general, it was difficult to draw a decisive conclusion about the effectiveness of ISCO in this area due to surface breakthrough and lack of knowledge regarding remaining impacts in soil. A summary of the field pilot test titled *In-Situ Chemical Oxidation Pilot Test Summary Report* (AECOM, 2018) was submitted to the NYSDEC on April 26, 2018.

2.1.2 Sources and Remedial Activities - Groundwater Extraction and Treatment System

Based on the results of the February 1997 *Feasibility Study* (Parsons, 1997) and the criteria identified for the evaluation of alternatives, NYSDEC selected hydraulic containment as the remedial action. The hydraulic containment alternative employed the use of groundwater recovery wells and treatment of the contaminated groundwater by air stripping in combination with continued operation of the source control IRMs already in place at the site (ex. at AOC #5 discussed in Section 2.1.1). This selection was documented in the ROD.

A Phase I Pre-Design Investigation (PDI) was conducted in October 1997 to assess the soil and groundwater characteristics along the northern border of FRP-2 where implementation of the proposed remedial action was planned. The Phase I PDI consisted of characterization of soil from soil borings and chemical characterization of groundwater from temporary and permanent monitoring wells.

A Phase II PDI was conducted in May 1998. The purpose of the Phase II PDI was to estimate groundwater extraction well capture zones; to determine the pumping rate necessary to achieve hydraulic containment, thereby determining the expected resulting flow to the site-wide groundwater extraction system (GWETS); and to collect groundwater samples to verify the groundwater characteristics upon which to base the site-wide GWETS. On December 8, 1998, Parsons Engineering Science, Inc. (Parsons), on behalf of LMC, submitted a Remedial Design Report (Parsons, 1998) that was approved by the NYSDEC on January 6, 1999

Remedial construction of the site-wide GWETS was initiated on January 11, 1999 and completed on February 19, 1999. The site-wide GWETS consisted of four additional groundwater extraction wells (RW-4, RW-5, RW-6, and RW-7) along the northern edge of the developed portion of FRP-2. These wells were added to the groundwater recovery system already in operation at AOC #16 to intercept and remove contaminated groundwater. In November 2001, modifications were made to the site-wide GWETS including installation of four additional recovery wells (RW-8 through RW-11) with associated piping and miscellaneous system upgrades that were intended to enhance groundwater hydraulic control and treatment system operation and maintenance.

The GWETS was operated pursuant to the NYSDEC-approved Operation and Maintenance (O&M) Plan dated 1999, prepared by Parsons Engineering, and a revised O&M Plan was developed by Plumley Engineering in 2013.

In 2014, a subsurface investigation was conducted on the north side of the site to document current soil and groundwater conditions. This investigation included the installation of six monitoring well clusters (PMW-1 through PMW-6). Based on the results, on September 17, 2014, NYSDEC approved the temporary shutdown of the groundwater treatment system that had been integrated into the AOC #16 treatment system. A permanent system shutdown was pursued due to asymptotic recovery levels. The system was shut down on October 15, 2014. During the shutdown of the groundwater treatment system, all of the interior system equipment was dismantled and removed from the former maintenance garage building. Dismantling of the equipment began on October 23, 2014 and concluded the week of November 10, 2014; however, much of the infrastructure for the groundwater extraction and treatment system remains at the site.

In 2015, additional monitoring well clusters (PMW-9 through PMW-13) were installed throughout the wetland area to evaluate groundwater conditions. The analytical data from these well clusters identified VOC concentrations that exceeded the cleanup objectives. Steps toward remedial system optimization began in March 2017 with the initiation of a laboratory bench scale study that used site-specific soil and groundwater to evaluate ISCO, aerobic cometabolic bioremediation, and anaerobic bioremediation. The goal of these optimization activities was to select a remedy to address remaining groundwater impacts in the wetland area; the results of these activities are reported under separate cover (AECOM, 2017b; AECOM, 2017c).

2.1.3 Sources and Remedial Activities – Soil Vapor Intrusion

In response to a request by the NYSDEC in August 2006, Lockheed Martin retained O'Brien & Gere Engineers, Inc., a Ramboll company (Ramboll), to assess the potential for vapor intrusion (VI) in Building #2. A historical summary of VI and indoor air monitoring was summarized in Ramboll's 2019 *Nested Subslab Soil Vapor Technical Memorandum* (Ramboll, 2019a).

Sampling results from soil vapor monitoring has shown that chlorinated volatile organic compounds (CVOCs) (1,1,1-TCA, 1,1-dichloroethene [1,1-DCE], 1,1-dichloroethane [1,1-DCA], tetrachloroethane, trichloroethene [TCE] and Freon-11) are consistently present in soil vapor under Building #2; however, BTEX compounds have not been identified at appreciable levels in soil vapor.

The extent of sub-slab soil vapor (SSSV) has been well-delineated as summarized in the *2016-2018 Vapor Intrusion Activities Report* (Ramboll, 2019). As of May 2020, three sub-slab depressurization (SSD) systems are operating beneath Building #2 to mitigate the potential for VI; a fourth SSD system installation is being completed.

2.2 SITE CONCEPTUAL MODEL

2.2.1 Site Geology

The site is located within the Ontario Lowland geological province of central New York State. The lowlands are characterized by large areas of low relief interrupted by streamlined hills called drumlins. Surficial geology at the site is composed of modern and glacial lake sediments underlain by Silurian (>400 million years old) shales and evaporates (ERM, 1992).

The relative uniformity of the soils is supported by data collected during the 2016 MIP investigation (AECOM, 2017a) which indicated little variability in conductivity, hydraulic pressure, and flow rates into the formation. It is noted that a coarse sand and gravel unit on top of the red clay layer was documented in the eastern and western areas beneath Building #2. Based on halogen-specific detector, photoionization and flame ionization readings collected by the MIP, it does not appear that there are seams and/or layers of relatively fine grain sediment that have adsorbed and/or concentrated contaminant mass.

The overburden material generally consists of fine sand and silts with traces of clay that coarsen downward with depth to a fine to medium grain sand with traces of fine gravel. This surficial unit transitions to an underlying dense red clay glacial till at depths ranging between approximately 12.5 ftbg at SB-129, SB-130, and SB-133 to 33.5 ftbg at MW-101D and MW-3D in the vicinity of Building #2. The red clay till unit is at least 104 ft thick in the vicinity of Building #2 (ERM, 1995), and is believed to represent a relatively impermeable boundary that restricts downward contaminant migration.

2.2.2 Site Hydrogeology Summary

A shallow unconfined aquifer was mapped in the area by Kantrowitz (1970) and Winkley (1989). The shallow aquifer is composed of glacial sand and gravel and has been reported to produce usable quantities of water. Bedrock beneath the site is likely to produce low-yielding wells with salty water (ERM, 1992).

Depth to groundwater measured and recorded in February 2020 in the vicinity of Building #2 ranged from approximately 6.61 to 11.54 ftbg. Based on the groundwater elevation data, the direction of groundwater flow across the site is generally to the north with an easterly component from the west side to beneath Building #2.

Hydraulic conductivity was calculated by ERM after completing slug tests on four of the site monitoring wells. Hydraulic conductivity in the saturated overburden ranged from 4.9×10^{-2} centimeters per second (cm/s) to 6.63×10^{-4} cm/s across the site. The higher conductivities are associated with the wells completed in the coarse sand and gravel on the top of the red clay. The lower permeabilities are associated with the fine sand and silt material that is more common in the overburden (ERM, 1992).

According to the Onondaga County Water Authority, the public water supply for Onondaga County originates from Otisco Lake, Lake Ontario, and Skaneateles Lake. There are no private water wells on the site and the Onondaga County Health Department indicated that there are no documented private water wells in the vicinity of the site.

2.2.3 Nature and Extent of Contamination – Vicinity of Building #2

As discussed in Section 2.1.1, an SVE remediation system operated in the vicinity of Building #2 between 1995 and 2002, and in accordance with NYSDEC approval, was permanently deactivated in December 2002.

Residual soil and groundwater impacts were encountered in the vicinity of Building #2 in 2016. In July 2018, six monitoring wells were discovered within Building #2 during a ground penetrating radar survey for private utilities and a seventh was discovered in January 2019. These wells were part of historical investigation activities completed in 1992 and were previously believed to have been decommissioned. Groundwater samples collected from these wells showed elevated BTEX and CVOC concentrations further supporting the preparation and submittal of the document titled *Subsurface Investigation Work Plan in the Vicinity of Building #2* (AECOM, 2019). Investigation activities conducted in accordance with this work plan were completed in June through September 2019; soil and groundwater data collected during the investigation are shown on Figure 6 and are further summarized in the *Subsurface Investigation Summary Report* (AECOM, 2019a).

The primary chemicals of concern in the vicinity of Building #2 are:

1,1,1-Trichloroethane	1,1-Dichloroethane	1,1-Dichloroethene
1,4-Dioxane	Benzene	Ethylbenzene
Trichloroethene	Toluene	Xylenes

Monitoring data for emerging contaminants 1,4-dioxane and per- and polyfluoroalkyl substances (PFAS) has been collected and evaluated in the vicinity of Building #2. 1,4-Dioxane concentrations are monitored on a quarterly basis as part of the ISMP monitoring program via

United States Environmental Protection Agency Method (USEPA) 8270 SIM ID. PFAS concentrations are monitored every five quarters in accordance with NYSDEC correspondence dated March 6, 2020 via modified USEPA Method 537.

2.2.4 Impacted Soil Summary

Based on soil data collected during the 2019 subsurface investigation, both vertical and horizontal cross sections were generated that depicted elevated concentrations of BTEX and CVOCs compounds in soil. The cross sections showed that impacts were not consistently encountered at the same depth interval. BTEX concentrations greater than 10,000 µg/kg were observed at depths ranging from 10-11 ftbg to 23-24 ftbg (approximate elevations of 370.21 feet to 357.25 feet) and CVOC concentrations greater than 10,000 µg/kg were observed at depths ranging from 10-11 ftbg to 17-18 ftbg (approximate elevations of 370.21 feet and 363.20 feet). The depth of BTEX and CVOC impacts in soil occur primarily in the saturated zone.

BTEX concentrations were noted to be greater than 10,000 µg/kg at soil sample locations SB-134, SB-126, SB-121, SB-108/MW-112, SB-128, SB-118, and SB-114/MW-110 (moving west to east). These locations are bounded by soil samples where there were no soil cleanup objective exceedances (SB-139, SB-106, SB-131, SB-105, SB-124, SB-138, SB-101, SB-112, SB-117, SB-116, SB-111, and SB-113).

CVOC concentrations were noted to be greater than 10,000 µg/kg at soil sample locations SB-108/MW-112, SB-121, and SB-126. Similar to BTEX, these locations are bounded by soil samples where there are no soil cleanup objective exceedances. Based on the soil concentration cross sections and horizontal plume maps (AECOM, 2019a), soil conditions in the vicinity of Building #2 have been fully delineated.

1,4-Dioxane was observed at concentrations greater than the soil cleanup objective of 100 µg/kg at SB-109 (160 µg/kg), SB-110 (200 µg/kg), and SB-114 (130 µg/kg); locations are shown on Figure 6.

Two areas of soil impacts are defined on Figure 7. The first is identified as the source area which includes the greatest density of soil sample locations with total VOC concentrations greater than

10,000 µg/kg. The second is identified as the downgradient plume where, in general, total VOC concentrations in soil are less than 10,000 µg/kg and are located downgradient of the source area.

2.2.5 Impacted Groundwater Summary

Based on groundwater data collected from permanent well installations immediately following the 2019 subsurface investigation, the highest BTEX concentrations (>1,000 µg/L) are observed in groundwater monitoring wells MW-27, MW-31, MW-102S/D, MW-103R, MW-104R, MW-107R, MW-109, MW-110, MW-111D, and MW-112.

The highest CVOC concentrations (> 1,000 µg/L) are observed in groundwater monitoring wells MW-31, MW-102S/D, MW-103R, MW-107R, MW-109, MW-110, MW-111D, and MW-112.

Based on groundwater data collected from temporary well installations during the 2019 subsurface investigation, concentrations of 1,4-dioxane in groundwater were observed at locations SB-109, SB-110, SB-111, SB-114, SB-117; SB-135, and SB-138. 1,4-Dioxane concentrations at these locations ranged from 89 µg/L at SB-135 to 4,500 µg/L (estimated value) at SB-115. In general, these locations are primarily identified at the periphery of the groundwater plume shown on Figure 7.

Based on groundwater collected from permanent well installations during the 2019 subsurface investigation, a 1,4-dioxane concentration of 1,400 µg/L was detected at MW-109 via USEPA Method 8260C. During the first quarter 2020 groundwater sampling event, the analytical method was revised to USEPA Method 8270SIM ID with a lower reporting limit. 1,4-Dioxane concentrations ranged from less than the laboratory detection limits at MW-27 and MW-101I to 190 µg/L at MW-110. During the second quarter 2020 groundwater sampling event, draft laboratory analytical reports show that 1,4-dioxane concentrations ranged from less than laboratory detection limits at MW-101D, MW-108, and MW-113 to 1,100 µg/L at MW-109.

Two areas of groundwater impacts are defined on Figure 7. The first is defined as the source area where, in general, the greatest density of groundwater sample locations have total VOC concentrations greater than 50,000 µg/L. The second is identified as the downgradient plume where, in general, total VOC concentrations in groundwater are greater than 1,000 µg/L and downgradient of the source area.

2.2.6 Impacted Soil Vapor Summary

During subsurface investigation activities completed by AECOM in 2019, four sets of nested soil vapor sampling points were installed to evaluate sources of soil vapor at varying depths through the vadose zone (vapor profiling). This profiling was conducted at locations with the greatest historical soil vapor concentrations and differing chemical profiles. The objective of this profiling was to aid in determining whether soil vapor concentrations were attributable to soil and groundwater concentrations as confirmed/delineated by the AECOM 2019 subsurface investigation or whether a secondary source was contributing to the soil vapor concentrations.

Ramboll completed soil vapor sampling at the nested locations in accordance with the approved work plan (AECOM, 2019) and reported the results to the NYSDEC in a technical memorandum (Ramboll, 2019). The results showed that CVOC concentrations were generally found to be highest in the deep vapor points and rapidly decreased/degraded through the vadose zone, confirming that a secondary source contributing to soil vapor was not identified. It is noted that of the BTEX compounds, only benzene was detected at relatively low concentrations at two of the four nested soil vapor locations and is not identified as a chemical of concern in soil vapor.

In subsequent sections of this report, the Johnson Ettinger model will be used to estimate sub-slab vapor and indoor air concentrations following the completion of various remedial technologies that are evaluated.

SECTION 3
INTERIM SITE MANAGEMENT PLAN

The *Interim Site Management Plan* (ISMP) was first drafted in 2017 to manage remaining contamination at the site until the control documents are extinguished. The ISMP has been approved by the New York State Department of Environmental Conservation (NYSDEC) and compliance with the ISMP is required of Lockheed Martin, its successors and the property owner. The ISMP may only be revised with the approval of the NYSDEC.

The ISMP details site-specific implementation procedures that are required by the Record of Decision (ROD) and Order on Consent (Index #A7-0001-97-08). Failure to comply with the ISMP is a violation of Environmental Conservation Law Title 6 of the New York Code of Rules and Regulations (6 NYCRR) Part 375 and the Order on Consent for the site, and potentially subject to penalties.

3.1 REMEDIAL ACTION OBJECTIVES

The Remedial Action Objectives (RAOs) for the site, as defined in the ROD, are listed below.

- Mitigate the potential threat to the Class I wetland biotic community resulting from the continued migration of contaminated groundwater to the wetland from the developed portion of the FRP-2 property;
- Protect potential future on-site workers;
- Achieve groundwater standards, where practicable;
- Provide for attainment of Standards, Criteria and Guidance (SCGs) for Class I wetlands by eliminating the discharge of contaminated groundwater into the wetland; and
- Protect human health by preventing the migration of contaminants in groundwater towards the Seneca River.

In accordance with the NYSDEC-approved ISMP, the RAOs are defined as follows (with discussion of how the objectives are being addressed in the vicinity of Building #2):

1. *Mitigate the potential threat to the Class I wetland biotic community resulting from the continued migration of contaminated groundwater to the wetland from the vicinity of Building #2 area.*

Groundwater SCGs identified for the site were and will continue to be based on NYSDEC Ambient Water Quality Standards and Guidance Values.

The groundwater plume comprised of benzene, toluene, ethylbenzene and xylenes (BTEX), chlorinated volatile organic compounds (CVOCs), and 1,4-dioxane has been identified in the vicinity of Building #2. A plume of CVOCs and 1,4-dioxane located in the wetland is suspected to have originated in the vicinity of Building #2.

There are two groups of monitoring well networks between Building #2 and the wetland; the first group includes MW-115, MW-3S/D, PMW-14S/I/D, PMW-15S/I/D, and PMW-24S/I/D, which is located immediately downgradient of Building #2; the second group includes PMW-1S/I/D, PMW-2S/I/D, PMW-3S/I/D, MW-26S/D, MW-29, and MW-30 located nearest the pavement/wetland boundary. Based on the current well network at the site and historical groundwater contour plots, these two groups of monitoring wells offer the best reference to evaluate and track potential further migration of contaminated groundwater towards the wetland. Based on the analytical data from these two groups of monitoring wells, the plume currently identified in the vicinity of Building #2 appears to be isolated and stable. The current site data suggests that this plume does not currently present a risk pathway to wetlands and surface water (Seneca River).

2. *Protect potential future on-site workers.*

The potential for soil vapor intrusion to Building #2 is an active risk pathway and is currently being addressed by the operation of three sub-slab depressurization systems (SS-05, SS-06, and SS-08).

SS-05 is centrally located along the easternmost wall; SS-06 is located on the south side of the partitioning wall that separates the high-bay portion of the building; and SS-08 is centrally located along the westernmost wall. O'Brien & Gere Engineers, Inc., a Ramboll company (Ramboll) and Lockheed Martin have worked to expand the coverage of these systems, including the addition of a new system.

There is a potential for construction activities to be conducted at the site; therefore, the possibility of contact between construction workers and impacted soil and groundwater exists.

3. *Achieve groundwater standards, where practicable.*

The subsurface investigation activities completed in 2019 fully delineated the current extent of groundwater impacts that remain in the vicinity of Building #2. This information provides a baseline from which to evaluate the potential timeframe required to achieve groundwater standards.

4. *Provide for attainment of SCGs for Class I wetlands by eliminating the discharge of contaminated groundwater into the wetland.*

Optimization of the remedial approach in the vicinity of Building #2 is evaluated in this study in an effort to achieve the above-defined RAO.

5. *Protect human health by preventing the migration of contaminants in groundwater towards the Seneca River.*

As demonstrated by current groundwater analytical data in the wetland area, CVOCs remain at concentrations greater than groundwater SCGs. A remedial approach was implemented in the wetland area in the summer of 2018 (AECOM, 2018a) and is currently being evaluated in a separate work plan. An optimized remedial approach for addressing groundwater in the vicinity of Building #2 is evaluated in this document with intent to achieve the above-defined RAO.

3.2 NEW YORK STATE STANDARDS, CRITERIA AND GUIDELINES

3.2.1 Groundwater

Groundwater SCGs identified for the site were and will continue to be based on NYSDEC Ambient Water Quality Standards and Guidance Values and Groundwater Effluent Limitations (NYSDEC, 1998) as updated in January 1999, April 2000, and June 2004.

Groundwater in the vicinity of Building #2 is currently monitored on a quarterly basis and analytical data has shown that CVOC and benzene, toluene, ethylbenzene, and xylenes (BTEX) analytes in the source area and downgradient plume (Figure 7) currently exceed groundwater SCGs.

The emerging contaminant, 1,4-dioxane has been detected in groundwater in the vicinity of Building #2. 1,4-Dioxane will be evaluated based on a screening value of 1 microgram per liter (µg/L).

3.2.2 Soil

Soil SCGs identified for the site are based on the NYSDEC Commissioner Policy 51: Soil Cleanup Guidance Policy which became effective December 3, 2010, and references Tables 375-6.8(b) Restricted Use Soil Cleanup Objectives of Title 6 NYCRR Part 375 for sites that are part of the Inactive Hazardous Waste Disposal Site Remedial Program. The site is under that program and is listed as Site #734055.

Soil in the vicinity of Building #2 was sampled in a 2019 subsurface investigation (AECOM, 2019a). Analytical data has shown that CVOC and BTEX analytes in the source area (Figures 6 and 7) currently exceed soil SCGs.

3.2.3 Treatment System Water Effluent

Groundwater that has been extracted from the subsurface and subject to treatment by an above-grade remedial system will be discharged back to groundwater in accordance with Title 6 NYCRR Part 703.6 NYSDEC Groundwater Effluent Limitations for Class GA (6 NYCRR Part 701) waters. A compilation of the groundwater effluent limitations is available in the NYSDEC Ambient Water

Quality Standards and Guidance Values and Groundwater Effluent Limitations (NYSDEC, 1998) as updated in January 1999, April 2000, and June 2004.

3.2.4 Treatment System Air Effluent

Vapor that has been extracted from the subsurface and subject to treatment by an above-grade remedial system will be discharged to the atmosphere in accordance with Title 6 NYCRR Part 212 Process Operations and Division of Air Resources (DAR)-1 Guidelines for the Evaluation and Control of Ambient Air Contaminants under Part 212 (NYSDEC, 2016).

3.2.5 Surface Water

Surface water SCGs identified for the site were and will continue to be based on NYSDEC Ambient Water Quality Standards and Guidance Values and Groundwater Effluent Limitations (NYSDEC, 1998).

3.2.6 Sediment

Sediment SCGs for the site are based on the NYSDEC Technical Guidance for Screening Contaminated Sediments dated November 1993, which has since been replaced by the guidance document *Screening and Assessment of Contaminated Sediments* dated June 2014 (NYSDEC, 2014).

3.2.7 Soil Vapor Intrusion

Soil vapor intrusion in Building #2 is evaluated pursuant to New York State Department of Health (NYSDOH) *Guidance for Evaluating Soil Vapor Intrusion in the State of New York* dated October 2006, as updated (NYSDOH, 2006).

3.2.8 Waste Disposal

As outlined in the ISMP, all transport of materials will be performed by licensed haulers in accordance with appropriate local, State, and Federal regulations, including 6 NYCRR Part 364. Haulers will be appropriately licensed and trucks properly placarded.

All material excavated and removed from the site will be treated as contaminated and regulated material and will be transported and disposed in accordance with all local, State (including 6

NYCRR Part 360) and Federal regulations. Environmental media proposed for off-site disposal will be characterized in accordance with Table 5.4(e)10 of DER-10. Samples will be analyzed for USEPA Target Compound List VOCs by USEA Method 8260C, and Toxicity Characteristic Leaching Procedure (TCLP for VOCs by USEPA Method 1311. Analytical data will be compared against the "Contained-In" Criteria identified in NYSDEC Technical and Guidance Memorandum (TAGM) 3028 for any media contaminated by a listed hazardous waste. Any wastes determined to be hazardous waste, or environmental media contaminated by hazardous waste, will be handled and disposed off-site in accordance with 6 NYCRR Parts 370 – Hazardous Waste Management System; 6 NYCRR 371 – Identification and Listing of Hazardous Wastes; 6 NYCRR 372 - Hazardous Waste Manifest System and Related Standards for Generators, Transporters and Facilities; and 6 NCYRR 376 – Land Disposal Restrictions.

3.2.9 Imported Materials

Soil imported to the site for use as backfill will be tested for PFAs in accordance with NYSDEC Guidelines for Sampling and Analysis of PFAS (NYSDEC, 2020) and as required by the ISMP and DER-10 section 5.4(e).

3.2.10 Wetlands

If activities are necessary within or adjacent to freshwater wetlands, they will be conducted in accordance with the permit requirements under 6 NYCRR 663 – Freshwater Wetlands Permit Requirements. When applicable, those activities would also be conducted in accordance with federal wetland permitting requirements under 33 CFR Parts 320-330 and 40 CFR Part 230. If a federal wetland permit is required, the requirements for a NYSDEC Section 401 water quality certification would also be evaluated.

SECTION 4
DEVELOPMENT AND SCREENING OF OPTIMIZED REMEDIAL ALTERNATIVES IN THE VICINITY OF BUILDING #2

This section presents general response actions which are broad response categories capable of satisfying the Remedial Action Objectives (RAOs) for the site:

- No Further Action (NFA). An NFA response provides a baseline for comparison with other alternatives and excludes operation of the existing sub-slab depressurization (SSD) systems in Building #2 that mitigates vapor intrusion.

- Institutional Controls (ICs) and Engineering Controls (ECs). These actions use physical, legal, or administrative mechanisms to restrict the use of, and limit access and exposure to, contaminants in soil and groundwater.

- Monitored Natural Attenuation (MNA). These actions apply to contaminated groundwater and rely on natural attenuation processes to reduce mass, toxicity, mobility, volume, and/or the concentration of contaminants in a carefully monitored site cleanup approach.

- Removal. These actions comprise removal (extraction) and transport of impacted soil, soil gas, or groundwater above ground for treatment or discharge.

- In Situ Treatment. These actions treat impacted soil and groundwater in place to reduce the toxicity, mobility, and/or volume of contamination.

Remedial technologies and process options associated with each general response action were evaluated based on a qualitative and comparative evaluation of effectiveness and implementability. Process options and technologies were screened out if they were deemed less effective or less implementable compared to similar options. As presented in Section 2.2.4, the majority of remaining soil impacts are located in the saturated zone, thus requiring an optimized remedial approach that addresses both soil and groundwater impacts.

The table included below provides an overview of the optimized remedial alternatives evaluated for the treatment of groundwater impacts. At the end of this document, Table 1 provides a detailed description of the technologies and process options subject to screening.

Technology/Process Option	Effectiveness	Implementability	Screening
No Further Action	Not Effective	Implementable	Retained as baseline for comparison
Monitored Natural Attenuation	Less Effective[1]	Implementable [in combination with another technology/process option]	Retained for evaluation in a combined remedial approach
Institutional and Engineering Controls	Effective	Implementable [in combination with another technology/process option]	Retained for evaluation in a combined remedial approach
Removal – Dual Phase Extraction	Effective	Implementable	Retained
Removal – Soil Vapor Extraction	Effective	Implementable	Retained
Removal – Excavation	Effective	Implementable	Not Retained
In Situ Treatment – Chemical Oxidation	Effective	Implementable	Retained
In Situ Treatment – Biological Treatment	Effective	Implementable [in combination with another technology/process option]	Retained for evaluation in a combined remedial approach
In Situ Treatment/Removal – Thermal Treatment	Effective	Implementable	Retained

[1] Less effective when compared to the other process options

4.1 NO FURTHER ACTION

Using an NFA approach, no remedial measures would be conducted. In this scenario evaluation, environmental impacts associated with the contaminated soil and groundwater plumes would not be eliminated or reduced. The operation of the existing SSD systems would cease, and the potential for migration of impacted groundwater located in the vicinity of Building #2 towards the wetland and Seneca River would remain. NFA is technically implementable because no remedial actions would be required; however, it would not be possible to obtain regulatory approval since the RAOs defined in the 1997 ROD would not be achieved.

The remedial approach of NFA is not retained for evaluation as a primary means of response but is retained as a baseline for comparison with other remedial options.

4.2 MONITORED NATURAL ATTENUATION

MNA relies on naturally occurring processes to reduce groundwater contaminant concentrations. Natural attenuation processes include non-destructive processes such as volatilization, adsorption, dilution, and dispersion, as well as destructive processes such as biodegradation and abiotic degradation. The combined effects of these processes result in a concentration reduction in the groundwater plume over time that will result in a restorative trend. Natural attenuation of site chemicals of concern (COCs) has historically been shown to occur in groundwater downgradient of the current plume (PES, 1997). In many cases, recent (2019) soil and groundwater concentrations have remained stable or have increased, when compared to historical (1992) concentrations. MNA involves long-term groundwater monitoring to confirm the effectiveness of the natural attenuation and to quantify the reductions in COC concentrations. Long-term groundwater monitoring is readily implementable at the site; however, based on the recent groundwater analytical data, natural attenuation as a standalone option does not appear to be an effective long-term measure for the volatile organic compound (VOC) plume beneath Building #2. Over the long-term, MNA may be effective for the treatment of groundwater contamination and reaching site RAOs if the technology is used in conjunction with or following source area remediation.

4.3 INSTITUTIONAL CONTROLS AND ENGINEERING CONTROLS

4.3.1 Institutional Controls

Institutional Controls (ICs) are a means of enforcing a restriction on the site that limits exposure to impacted materials and prevents actions that would interfere with the remedial program. The industrial building on site is utilized by a number of tenants, some who are actively working and some who are using the building primarily for storage, and the site RAOs include protection of these and future on-site workers. Four ICs exist for this site and will be implemented accordingly to protect future on-site human exposure to contamination and ensuring the continued operation and maintenance of any engineering controls that may be part of the optimized remedy. The ICs at the site are listed as follows:

- Interim Site Management Plan (ISMP);
- Fully Executed Agreement of Purchase and Sale dated September 2, 1993;
- License Agreement dated December 17, 1993; and
- Respondent obligations as defined in the March 27, 1998 *Order on Consent*.

4.3.2 Engineering Controls

Engineering Controls (ECs) are any physical barrier or method employed to actively or passively contain, stabilize, or monitor contamination, restrict the movement of contamination to ensure the long-term effectiveness of a remedial program, or eliminate potential pathways of exposure to contamination. Sub-slab depressurization (SSD) systems are a type of Engineering Control that has already been implemented at the site. An SSD system is analogous to a common radon system, which generates a vacuum immediately beneath the slab of a building and extracts soil gas from that area to prevent the build-up and potential intrusion of vapors into the overlying building. Extracted vapors are exhausted above the building roofline. SSD systems have been in operation at Building 2 since 2016. In addition, the current building foundation and exterior paved surface at the site serve as ECs by acting as physical barriers between site personnel and areas of impacted soil and groundwater. These ECs environmentally isolate the impacted soil to prevent infiltration of precipitation that could mobilize contaminants to the underlying groundwater. Both ECs are existing controls currently in place at the site and will need to be combined with ICs to ensure that the controls are maintained. The ECs implemented at the site have proven effective at limiting exposure; however, they do not address the contaminant mass currently present in soil and groundwater. The use of ECs as part of the optimized remediation strategy is further evaluated in Section 6.

4.4 REMOVAL – DUAL PHASE EXTRACTION

Dual Phase Extraction (DPE) includes the extraction of contaminated groundwater and vapors to physically remove contaminant mass from the vadose and saturated zones. From 1995 to 2002, soil vapor extraction (SVE) and groundwater extraction served as interim remedial measures at area of concern (AOC) #5 and AOC #16 for the removal of VOCs from the unsaturated soil within these areas. This evaluation considers both vertical and horizontal extraction well installation throughout the source area to draw down the water table, exposing the saturated zone using down-well pumps, thereby making currently inaccessible soil impacts accessible to vacuum extraction. Pumped groundwater and extracted soil vapor would be treated at an above-grade location on site. Following treatment, vapors would be discharged to the atmosphere and groundwater would be discharged to either the sanitary sewer, the facility outfall to the wetland, or back into the aquifer. Impacted groundwater and soil with contaminant concentrations in excess of Standards, Criteria and Guidance (SCGs), as defined in the ISMP, would be targeted for removal from the subsurface by extraction and volatilization with treatment of water and vapor occurring above grade.

SVE was previously shown to be effective at removing VOCs from unsaturated soil at AOC #5, in the vicinity of Building #2, and groundwater extraction was previously shown to be effective at removing VOCs from groundwater at AOC #16. Air emissions from the SVE system that historically operated in AOC #5 were less than the NYSDEC criteria for the site COCs and air treatment was not required (Rust, 1995). This evaluation considers the installation of a new extraction well network and an enhanced treatment system in the vicinity of Building #2 to effectively decrease the contaminant mass in soil and treat the groundwater plume to meet the site RAOs.

The installation of a DPE system within Building #2 would be challenging due to issues related to building access. Therefore, this approach also includes evaluation of horizontal extraction well installations in order to limit the impact of system installation and operation on the current building operations. This alternative form of DPE utilizes directional drilling methods to install extraction wells horizontally across the area of impacted soil. Horizontal extraction wells enhance DPE system performance by laterally expanding the radius of influence for both groundwater and soil vapor extraction compared to traditional vertical extraction wells. Horizontal extraction wells have not been installed or pilot-tested at the site.

A DPE system using vertical or horizontal wells is implementable at the site and has been retained for further evaluation in Section 6 of this RSO Study. Similar technologies were proven to be effective for AOC#5 and AOC #16. Historical pilot testing and system operations data from the site can be used to support the design of the DPE system. Additional site data would need to be collected in order to implement the system with horizontal wells. The use of traditional vertical extraction wells may be more cost effective than horizontal wells; however, the method using vertical wells requires extended access within Building #2 for the installation of extraction wells and infrastructure. The use of horizontal wells would reduce the need for access within Building #2; however, it may increase the required staging footprint outside of the building during well installation. Additionally, the horizontal well installation costs may be greater, when compared to the cost per area treated. These aspects are further evaluated in Section 6.

4.5 REMOVAL – SOIL VAPOR EXTRACTION AND AIR SPARGING

An SVE system with Air Sparge (AS) includes the injection of air into the saturated zone that volatilizes contaminants and carries the vapors upward into the vadose zone paired with extraction of vapors to physically remove contaminant mass from the vadose zones. As described in Section 4.4, an SVE system previously operated for seven years at AOC #5 in the vicinity of Building #2 and was effective at removing VOCs from unsaturated soil. Enhancing an SVE system design with AS would target treatment of impacted soil within the saturated zone and groundwater. This evaluation considers the installation of a new horizontal extraction and injection well network and an enhanced treatment system in the vicinity of Building #2 to effectively decrease the contaminant mass in soil and treat the groundwater plume to meet the site RAOs.

This alternative utilizes directional drilling methods to install treatment wells horizontally across the area of impacted soil and groundwater, while limiting the impact of system installation and operation on the current building operations. Horizontal extraction wells enhance SVE system performance by laterally expanding the radius of influence for soil vapor extraction compared to traditional vertical extraction wells. Horizontal extraction wells have not been installed or pilot-tested at the site.

An SVE and AS system using horizontal wells is implementable at the site and has been retained for further evaluation in Section 6 of this RSO Study. Similar technologies were proven to be effective for AOC#5 and AOC #16. Historical pilot testing and system operations data from the site can be used to support the design of the SVE system. Additional site data would need to be collected in order to implement the SVE and AS system with horizontal wells.

4.6 REMOVAL - EXCAVATION

Excavation would include the removal of impacted soil exceeding the specified SCGs and transportation of the soils to a Lockheed Martin approved off-site facility for reuse, recycling, disposal, and/or treatment, followed by the replacement of excavated material with clean fill, and restoration of the site to current conditions. Excavation is considered to be effective because it would eliminate source materials contributing to continuous groundwater impacts and site RAOs would be achieved.

While excavation in general is implementable, it is deemed unreasonably difficult to implement at this site. Average depth to water beneath Building #2 ranges from 9 to 11 feet below grade (ftbg). The majority of soil exhibiting exceedances of SCGs beneath Building #2 is located at or below the water table ranging from depths of 10 to 11 ftbg and 27 to 28 ftbg and is comprised mainly of fine sand and silt. Excavation of soil below the water table would require shoring to maintain the safety of the excavation sidewalls, dewatering to depress the water table to access soils that are excavated from beneath the groundwater table, the treatment of dewatering effluent, and discharge of treated effluent to the nearby wetland or sanitary sewer. Excavation would limit site operations; the building would need to be vacated and at a minimum, partially demolished and a large portion of the site would have to remain inaccessible throughout these activities. Due to the challenges of implementing an excavation remedial approach, this alternative is not retained.

4.7 IN SITU REMEDIATION – CHEMICAL OXIDATION

In-Situ Chemical Oxidation (ISCO) is a remedial approach used to treat chlorinated VOCs, 1,4-dioxane, and petroleum-based contaminants, such as benzene, toluene, ethylbenzene, and xylenes (BTEX), in soils and groundwater via the injection of chemical oxidants (i.e., permanganate, persulfate, peroxide, or ozone) into the subsurface. As the oxidants come into contact with the COCs, they are broken down into less-harmful byproducts. An ISCO treatment approach can be designed to target the comingled BTEX and chlorinated volatile organic compound (CVOC) source plumes that are present beneath Building #2.

The application of ISCO at the site was previously evaluated in a bench-scale treatability study; the results of this study are summarized in the *In-Situ Chemical Oxidation Treatability Study Summary Report and Pilot Test Work Plan* (AECOM, 2017b). Based on the results of the study, pilot testing was performed at the site in two treatment areas: the wetlands and AOC #5 (west of Building #2). Decreases in VOC concentrations in groundwater were observed in both treatment areas; however, a rebound in VOC concentrations was observed in groundwater collected from MW-27 in AOC #5. Pilot test results were summarized in the *In-Situ Chemical Oxidation Pilot Test Summary Report* (AECOM, 2018). A full-scale ISCO remedy was performed in the wetland in fall 2018 as summarized in the *Injection Summary and Baseline Groundwater Monitoring Report* (AECOM, 2018a). The implementation of ISCO in the vicinity of Building #2 would include the injection of chemical oxidant to target source materials in the saturated zone.

The effectiveness of this option may be challenged by pockets of non-aqueous phase liquid (NAPL) that are potentially present (based on VOC concentrations) and could act as sources for rebound. Multiple rounds of injections would be necessary to target and sufficiently treat source materials contributing to rebound. Effectiveness may also be impacted if chemical amendments migrate into preferential pathways in the subsurface. Historical activities in the vicinity of Building #2 include backfilling of a former underground storage tank (UST) pit, and the presence of below-grade polyvinyl chloride (PVC) piping associated with the former SVE system in AOC#5 could present an increased opportunity for the development of preferential pathways for migration of chemical amendments. Migration of chemical amendments through preferential pathways could limit oxidant contact with target source areas and may result in amendment daylighting at the Building #2 floor slab.

ISCO is implementable; however, it may require access to Building #2 for extended periods of time during active injection and to a lesser extent for post-injection monitoring, depending on whether vertical or horizontal well infrastructure would be employed. ISCO is considered both effective and implementable; it is retained and evaluated in further detail in Section 6.

4.8 IN SITU REMEDIATION – BIOLOGICAL TREATMENT

Biological remediation using enhanced reductive dechlorination (ERD) is a remedial approach used to treat CVOCs in groundwater via the injection of electron donor/carbon source substrates such as emulsified vegetable oil into the subsurface. Bench-scale testing of biological treatment was performed in 2017 (AECOM, 2017c) using a combined approach of ERD and aerobic cometabolic bioremediation; CVOCs were treated using ERD and 1,4-dioxane and BTEX were treated using aerobic cometabolic bioremediation. The results of the bench-scale treatability studies demonstrated that biological treatment was not effective at the site in treating the comingled CVOC and 1,4-dioxane plume present in the wetland area. Treatment of BTEX-contaminated groundwater was not evaluated as part of the laboratory testing. Bench-scale results for the CVOC destruction using only ERD demonstrated decreasing concentrations; however, the aerobic cometabolic bioremediation treatment had no effect on the 1,4-dioxane. Based on these bench-scale results, the combined ERD and aerobic cometabolic bioremediation is not being retained for further evaluation. However, based on the success of ERD to decrease CVOC concentrations, ERD will be retained for further evaluation as a component of an optimized remedial approach. Due to the presence of BTEX compounds in vicinity of Building #2, a secondary approach would be needed to generate aerobic conditions to decrease the concentrations of petroleum-related compounds.

Similar to other in-situ remedies, biological treatment relies heavily on obtaining a successful distribution of the amendments. Heterogeneous subsurface conditions could pose difficulties for obtaining the needed distribution. Effectiveness at this site would be challenged by contaminant mass bound to soil and pockets of NAPL potentially present (based on VOC concentrations) that could act as sources for rebound. Based on the extent of COC mass present throughout the Building

#2 area, COC mass within the soil, and the difficulties associated with applying combined injection remedies across the large remediation area of Building #2, biological treatment will be retained as part of a downgradient groundwater control remedy combined with aerobic treatment and is further evaluated in Section 6.

4.9 IN SITU REMEDIATION – THERMAL TREATMENT

In-situ thermal treatment is the application of heat to soil and groundwater through a variety of methods to volatilize, mobilize, or degrade contaminants. Electrical resistance heating (ERH) is a type of thermal treatment commonly utilized to remediate VOCs, including CVOC and BTEX compounds, in soil and groundwater with relatively low permeability. ERH consists of installing electrodes and vapor recovery wells in soil and groundwater. Electricity is conducted through the electrodes and the matrix resists the electricity and produces heat in the soil and groundwater, volatilizing the contaminants. Generated steam acts as a carrier gas that transports the vapor phase contaminants to the vadose zone. Negative pressure is maintained in the treatment area throughout system operation to capture steam and contaminant vapors which are treated with vapor-phase granular activated carbon (GAC) prior to discharge into the atmosphere.

Thermal treatment has not been implemented at the site but is a proven industry standard that, in AECOM's experience, has been effective in remediating VOC compounds in soil and groundwater. ERH can reduce BTEX and CVOC concentrations below the SCGs for the site and has the potential to reduce contaminant concentrations by up to 99% after one remedial event, not requiring multiple mobilizations. Treatment of soil and groundwater impacts utilizing thermal treatment is implementable. This alternative consists of installing electrodes and vapor recovery wells throughout the treatment area within Building 2, installing a vapor extraction system with GAC filters to treat air discharge, installing a power control unit to operate the system, and operating the system for a period of up to four to twelve months. Implementation of an ERH system at the site would be challenging due to issues related to access to the building and securing a footprint on the property to house the power control unit and vapor recovery and treatment system. Thermal treatment typically has higher capital costs when compared to other remedial alternatives; however, it is very effective in reducing contaminant concentrations. Thermal treatment via ERH has been retained for further evaluation as discussed in Section 6.

SECTION 5
EVALUATION CRITERIA FOR OPTIMIZED REMEDIAL ALTERNATIVES

5.1 DESCRIPTION

In accordance with 6 NYCRR 375-1.8(f) and technical guidance in the New York State Department of Environmental Conservation (NYSDEC) *DER-10, Technical Guidance for Site Investigation and Remediation* (NYSDEC, 2010) a remedy shall be selected upon consideration of evaluation criteria that are comprised of two threshold criteria and seven primary balancing criteria. The threshold criteria must be satisfied for a remedial alternative to be selected. The threshold and primary balancing criteria are outlined below. Section 6 provides a detailed evaluation of each retained remedial alternative with respect to these criteria.

5.2 THRESHOLD CRITERIA

5.2.1 Overall Protection of Human Health and the Environment

This criterion is an assessment of whether the remedial alternative meets requirements that are protective of human health and the environment. The overall assessment is based on a series of factors assessed under other evaluation criteria, particularly long-term effectiveness and permanence, short-term impact and effectiveness, and compliance with Standards, Criteria and Guidance (SCGs). This evaluation focuses on how a specific alternative achieves protection over time and how site risks are reduced. The analysis includes how the source of contamination is to be eliminated, reduced, or controlled.

5.2.2 Compliance with Standards, Criteria and Guidance

This criterion determines whether each alternative and the proposed remedial technologies comply with applicable environmental laws and SCGs pertaining to the chemicals detected in contaminated media as well as the location of the site.

5.3 PRIMARY BALANCING CRITERIA

5.3.1 Long-Term Effective and Permanence

This criterion addresses the performance of a remedial action in terms of its permanence and the quantity/nature of waste or residuals remaining at the site after implementation. The evaluation considers the extent and effectiveness of controls required to manage residuals remaining at the site and the operation and maintenance systems necessary for the remedy to remain effective. The factors that are evaluated include permanence of the remedial alternative, magnitude of the remaining risk, and the adequacy and reliability of controls used to manage residual contamination.

5.3.2 Reduction of Toxicity, Mobility, or Volume with Treatment

This criterion assesses the remedial alternative's use of technologies that permanently and significantly reduce toxicity, mobility, or volume of the contamination as their principal element. Preference is given to remedies that permanently and significantly reduce the toxicity, mobility, or volume of the contaminants at the site.

5.3.3 Short-Term Impact and Effectiveness

This criterion assesses the effects of the alternative during the construction and implementation phase with respect to the effect on human health and the environment. The factors that are assessed include protection of the site workers and the community during remedial activities, environmental impacts that result from remediation, and the time required until the Remedial Action Objectives are achieved.

5.3.4 Implementability

This criterion addresses the technical and administrative feasibility of implementing the alternative and the availability of various services and materials required during implementation. The evaluation includes the feasibility of construction and operation; the reliability of the technology; the ease of undertaking additional remedial action; monitoring considerations; activities needed to coordinate with regulatory agencies; and the availability of adequate equipment, services and materials, offsite treatment, and storage and disposal services.

5.3.5 Land Use

This criterion addresses the current, intended, and reasonably anticipated future land use of the site and surroundings. For the purpose of this evaluation, it is assumed that the site will not undergo major zoning modifications in the future, such as development as a residential/recreational area. It is anticipated that industrial construction activities will be conducted in the future.

As outlined in Section 3.2.2, Title 6 NYCRR Part 375 Restricted Use Soil Cleanup Objectives are utilized for this site, since it is part of the Inactive Hazardous Waste Disposal Site Remedial Program.

5.3.6 Cost

Capital costs and operation, maintenance, and monitoring costs (OM&M) are estimated for each alternative and are presented as existing for the duration of future activities.

5.3.7 Community Involvement

An information release will be provided to neighboring property owners for parcels to the east, west, and south of the subject site. The information release will include a brief project summary including direction to access project documentation that has been submitted to the NYSDEC and contact information at Lockheed Martin for any direct inquiries. A draft information release separate from this document will be provided to the NYSDEC for review prior to distribution.

5.4 GREEN AND SUSTAINABLE REMEDIATION ASSESSMENT

A green and sustainable remediation assessment was conducted for two of the evaluated optimized alternatives: dual phase extraction and thermal treatment. These two technologies were included in the evaluation based on input from the NYSDEC and given that both of these alternatives are equally protective of human and environmental health. In this case, the green and sustainable remediation assessment was primarily used to compare the greenhouse gas emissions generated, the total energy consumption, electricity use and water consumption, total emissions of criteria air pollutants (sulfur oxides, nitrous oxides and PM_{10}), and accident risk.

SECTION 6
DETAILED EVALUATION OF OPTIMIZED REMEDIAL ALTERNATIVES

Based on the screening discussion presented in Section 4, six remedial alternatives were retained for further evaluation, including:

- Remedial Alternative 1: No Further Action (NFA)
- Remedial Alternative 2: Dual Phase Extraction (DPE)
  - Remedial Alternative 2A: DPE – Vertical Well Design
  - Remedial Alternative 2B: DPE – Horizontal Well Design
- Remedial Alternative 3: Thermal Treatment
- Remedial Alternative 4: In-Situ Chemical Oxidation (ISCO)
  - Remedial Alternative 4A: ISCO – Vertical Well Design
  - Remedial Alternative 4B: ISCO – Horizontal and Vertical Well Design
- Remedial Alternative 5: Monitored Natural Attenuation (MNA) and Enhanced Reductive Dechlorination (ERD)
- Remedial Alternative 6: Soil Vapor Extraction (SVE) with Air Sparge (AS)

In this section, each remedial alternative is compared against the evaluation criteria presented in Section 5. To aid in the evaluation and comparison of the remedial alternatives, the Remediation Evaluation Model for Chlorinated Solvents (REMChlor) analytical modeling software was used to simulate plume degradation over time based on the remedial alternative. The model structure was populated with a variety of input parameters that are summarized and presented in Appendix A.

The REMChlor model framework was designed to report and predict concentrations for toluene, 1,1,1-trichloroethane (1,1,1-TCA), and 1,1-dichloroethene (1,1-DCE) at setpoint distances along the centerline of the groundwater plume (Figure 7). Toluene was selected because it had the greatest concentration of the benzene, toluene, ethylbenzene, and xylenes (BTEX) compounds in the source area. Similarly, 1,1,1-TCA was selected because it had the greatest concentration of the chlorinated volatile organic compounds (CVOC) in the source area and is a primary compound detected in soil vapor. A third REMChlor model was generated to report and predict concentrations for 1,1-DCE because it is one of the main components in the breakdown pathway of 1,1,1-TCA, is present in soil vapor, and is also present in groundwater in the wetland area, whereas toluene and 1,1,1-TCA are not. The cleanup objective for toluene, 1,1,1-TCA, and 1,1-DCE is 5 micrograms per liter (µg/L).

As illustrated on Figure 7, the starting distance of 0 feet (ft) is located at the downgradient edge of the source area. The modeled concentration outputs are presented on Figures 8, 9, and 10, for MNA, DPE, ISCO, thermal, and SVE/AS remedial alternatives. Each graph includes concentration modeling for a series of timeframes including pre-remediation, post-remediation (2-year mark for thermal and 6-year mark for MNA/DPE/ISCO/SVE with AS), 20-years post-remediation, and 50-years post remediation.

The REMChlor model is not structured to accept the input of current plume conditions, but instead is based on simulating the release of contaminants from a start year. Since the exact start year of release to the subsurface is not known, the REMChlor model was refined by adjusting the start year for each compound until model outputs matched current groundwater concentrations as much as possible. Comparisons between actual groundwater concentrations and modeled outputs are provided for the three compounds (toluene, 1,1,1-TCA, and 1,1-DCE) in the following paragraphs.

To validate the modeling structure, actual groundwater concentrations are compared to modeled outputs at select locations along the plume centerline. Current groundwater concentrations for toluene are 35,000 parts per billion (ppb) at 100 ft (MW-110 on February 27, 2020), 13,000 ppb at 300 ft (MW-109 on July 22, 2019), 1,400 ppb at 300 ft (MW-109 on August 28, 2019), and less than laboratory detection limits at 500 ft (MW-115 on February 26, 2020). Corresponding model outputs for toluene are 5,685 ppb at 100 ft, 97 ppb at 300 ft, and 1.9 ppb at 500 ft.

Current groundwater concentrations for 1,1,1-TCA are 6,300 ppb at 100 ft (MW-110 on February 27, 2020), less than laboratory detection limits at 300 ft (MW-109 on July 22, 2019 and August 28, 2019), and less than laboratory detection limits at 500 ft (MW-115 on February 26, 2020). Corresponding model outputs for 1,1,1-TCA are 364 ppb at 100 ft, 4 ppb at 300 ft, and 0.06 ppb at 500 ft.

Current groundwater concentrations for 1,1-DCE are 7,100 ppb at 100 ft (MW-110 on February 27, 2020), 5,700 ppb at 300 ft (MW-109 on July 22, 2019), 2,600 ppb at 300 ft (MW-109 on August 28, 2019), and 6.0 ppb at 500 ft (MW-115 on February 26, 2020). Corresponding model outputs for 1,1-DCE are 4,266 ppb at 100 ft, 719 ppb at 300 ft, and 165 ppb at 500 ft. The three model structures indicate some variation between actual and modeled data when compared to current groundwater concentrations at the site. However, the model is intended as a tool to aid in decision making and is not being relied upon to recommend a specific remedial alternative. The variation between actual and modeled concentrations is deemed to be sufficient for the objective.

The detailed evaluation for each remedial alternative, with the exception of Alternative 1, also considers the continued operation of the sub-slab depressurization (SSD) systems. In scenarios other than alternative 1, the SSD systems remain in operation throughout remedial treatment of the soil and groundwater plume in order to achieve the Remedial Action Objective to protect potential on-site workers. The continued operation of the SSD systems following remediation is evaluated by the Johnson and Ettinger Vapor Intrusion Model (J&E model). Based on the current SSD system operations, BTEX has not been observed in historical vapor intrusion samples collected from Building #2. Additionally, results from the REMChlor model demonstrated that 1,1,1-TCA was not anticipated to persist in the subsurface for an extended time period; therefore, 1,1-DCE was used as the primary contaminant modeled with the J&E model. The J&E model integrates 1,1-DCE concentrations modeled by REMChlor to estimate indoor air and sub-slab vapor concentrations for Building #2. The J&E model outputs are used to predict when operation of the SSD systems might cease, to select the appropriate optimized remedial approach, and to estimate the duration of remediation at the site. The J&E model structure was populated with a variety of input parameters that are summarized and presented in Appendix B.

The REMChlor model and J&E model are used solely for the purpose of predicting and comparing outcomes for the various alternatives. All future decisions regarding the remediation and/or operation or discontinuance of the remedial approach will be based on future data.

6.1 REMEDIAL ALTERNATIVE 1: NO FURTHER ACTION

As discussed in Section 4.1, NFA is not considered to be an effective optimization alternative for remediation at the site, but it will be used as a baseline of comparison for the effectiveness of other remedial alternatives.

The NFA alternative would not utilize any remedial technologies for the treatment of soil and groundwater and no monitoring would be conducted. Additionally, operation of the SSD system, that was implemented based on NYSDOH Guidance, would be discontinued. The following existing Institutional Controls (ICs) would remain in place:

- Institutional Controls on future site use;
- Maintenance of the current Building #2 foundation and floor slab;
- Maintenance of the paved surface exterior to Building #2; and
- Site security via perimeter fencing.

The REMChlor model has been used to integrate current groundwater analytical data for the site, specifically in the vicinity of Building #2. Model outputs have been generated that represent current and future groundwater concentrations of toluene, 1,1,1-TCA, and 1,1-DCE if an MNA approach was implemented, and the same outputs are applicable to an NFA approach. These outputs are presented on Figures 8, 9, and 10 in comparison to the other evaluated remedial alternatives.

6.1.1 Overall Protection of Human Health and the Environment

Vapor mitigation within Building #2 and groundwater monitoring would not be conducted under an NFA approach and it would be unlikely that human health and the environment would be adequately protected. An NFA approach does not prevent the potential for future discharge of impacted groundwater into the wetlands, does not mitigate the potential threat to the Class I wetland biotic community from the continued migration of impacted groundwater to the wetland,

and does not protect human health by preventing the migration of contaminants in groundwater toward the Seneca River.

This alternative would not achieve site Remedial Action Objectives (RAOs).

6.1.2 Compliance with Standards, Criteria and Guidance

With an NFA approach, REMChlor model outputs on Figures 8, 9, and 10 depict/predict the following outcomes:

- Toluene concentrations would remain beneath the building for at least 50 years and would not be expected to migrate downgradient towards the wetland.
- 1,1,1-TCA concentrations would remain beneath the building for approximately 10 years and would not be expected to migrate downgradient towards the wetland.
- 1,1-DCE concentrations would remain beneath the building for at least 50 years and would be expected to continue to migrate downgradient towards the wetland, under current conditions, for 20 years and 50 years into the future. The model predicts that the concentration of 1,1-DCE migrating towards the wetland at 700 ft along the plume centerline would be approximately 13 micrograms per liter (µg/L) under current conditions.

6.1.3 Long-Term Effectiveness and Permanence

This alternative is not effective in the long term.

6.1.4 Reduction of Toxicity, Mobility, or Volume of Contamination

Any natural processes which are currently active in soil and groundwater would continue to reduce contaminant levels over time. However, based on a comparison of historical and current data, it is expected that any existing natural processes are slow-acting and would not destroy the majority of the contamination within the foreseeable future.

6.1.5 Short-Term Impact and Effectiveness

There is no construction associated with this alternative, there would be no short-term impacts to workers or the community during construction. Any existing risks at the site would remain for the foreseeable future. This alternative would not be expected to achieve any of the RAOs.

6.1.6 Implementability Evaluation

This alternative would be difficult to implement due to administrative issues, specifically New York State Department of Environmental Conservation (NYSDEC) approvals. The RAOs would not be met and groundwater contamination would remain at concentrations greater than the Standards, Criteria and Guidance (SCGs).

6.1.7 Cost Evaluation

There are no capital costs associated with an NFA approach.

6.2 REMEDIAL ALTERNATIVE #2: DUAL PHASE EXTRACTION

DPE is a combined remedial approach that involves extraction of both groundwater and soil vapor. A groundwater extraction and treatment system operated in the northern portion of the developed site from 1999 to 2014 to hydraulically control site-wide groundwater from discharging into the wetland. Extracted groundwater was treated utilizing an air stripper prior to discharge into the wetland.

An SVE and air venting system operated from 1995 to 2002 in area of concern (AOC) #5 located on the west side of Building #2. The SVE system targeted the vadose zone and the extracted air effluent stream was treated using granular activated carbon (GAC) vessels prior to discharge to the atmosphere.

Both systems have since been shut-down and decommissioned. Following soil and groundwater sampling activities in 2017, it was determined that residual contamination may exist in the vicinity of Building #2. In 2019, a subsurface investigation conducted in the vicinity of Building #2 confirmed the presence of residual contamination and aided the contaminant plume delineation in soil and groundwater. As stated, the SVE system operated in this area and confirmatory soil samples in the vadose zone showed that concentrations less than laboratory detection limits were achieved following system operation. The success of SVE in this area warrants a detailed evaluation of vapor extraction paired with groundwater extraction in an effort to target impacts in the saturated zone that remain in the vicinity of Building #2.

This optimized remedial alternative extracts groundwater to allow for the treatment of impacted groundwater and creates water-table drawdown that facilitates the application of vacuum to target impacted soil beneath the static water table. The extracted groundwater and vapors would be treated in an onsite treatment system, reducing volatile organic compound (VOC) concentrations to the applicable discharge criteria prior to discharge. Soil vapor would be passed through vapor-phase GAC units prior to discharge to the atmosphere. Groundwater would be passed through an oil-water separator (OWS), post-extraction treatment units such as GAC, an ultraviolet system, an ozone system, and/or an air stripper. Air effluent analysis would be conducted during the system startup to confirm that annual and short-term guidelines for ambient air contaminants set forth in the NYSDEC policy Division of Air Resources' (DAR)-1 (NYSDEC, 2016) are met prior to discharge to the atmosphere. Groundwater effluent analysis would be conducted during the system startup to confirm that the cleanup objectives (NYSDEC, 1998) are met prior to discharge.

For the purpose of evaluating feasibility, a DPE conceptual design was developed that focused on extraction of groundwater impacted with CVOCs, BTEX, and 1,4-dioxane and treatment of CVOCs and BTEX using vertical extraction wells or horizontal extraction wells in both the source area and the downgradient plume area. Figure 11 shows the conceptual drawing for the vertical extraction well approach, and two conceptual drawings are provided in Figures 12A and 12B for the horizontal extraction well approach.

Groundwater conditions would be monitored during remediation on a quarterly basis and post-remediation for an estimated 5 years to monitor for potential migration and attenuation of any remaining concentrations following DPE operation. It is assumed that the existing SSD systems would operate for an estimated 10 years post-DPE operation to allow for time to conduct post-mitigation indoor air monitoring to demonstrate acceptable air quality conditions within Building #2 without using the SSD systems.

The ICs and ECs already in place for the site will be maintained during the full extent of this program.

6.2.1 Overall Protection of Human Health and the Environment

The extraction of groundwater and soil vapor will remove contaminant mass from beneath Building #2 over time, resulting in a reduced potential for vapor intrusion into the building, and protecting current and future on-site workers from potential exposure. This exposure pathway is currently being controlled by the SSD systems installed in Building #2, as further described in Section 2.1.3, which are anticipated to continue operation throughout the DPE system operation.

Applying the modeled indoor air and sub-slab concentrations for 1,1-DCE against the NYSDOH Soil Vapor/Indoor Air Matrix A (NYSDOH, 2006), continued use of the SSD systems as an engineering control would be recommended. There is conservatism built into the two modeling software programs used to generate the estimated indoor air and sub-slab concentrations; therefore, it is possible that indoor air and sub-slab concentrations could be less than those predicted by the J&E model. Follow-up indoor air and sub-slab concentration monitoring would be recommended following DPE system operation to confirm actual conditions. Additionally, the maintenance of the current Building #2 foundation and paved surface exterior to Building #2 is recommended.

In addition to contaminant mass reduction in groundwater and soil, groundwater extraction would hydraulically control the flow of contaminated groundwater from migrating further north towards the wetland and the Seneca River. This alternative would achieve all site RAOs by removing and treating contaminated groundwater in an effort to achieve SCGs and hydraulically prevent further migration of contaminated groundwater to the wetland and the Seneca River.

The initial depth to impacted saturated soil is approximately 8 to 10 feet below grade (ftbg). It is unlikely that these soils would be disturbed during future construction activities; however, institutional controls are in place to ensure that they would be handled in a manner consistent with protection of human health and the environment.

6.2.2 Compliance with Standards, Criteria and Guidance

With a DPE approach, REMChlor model outputs on Figures 8, 9, and 10 depict/predict the following outcomes:

- Toluene concentrations would remain beneath the building at concentrations greater than the cleanup objectives following remediation; however, the remaining average concentration following remediation is an approximately 94% reduction in existing concentrations and would not migrate downgradient towards the wetland.
- 1,1,1-TCA concentrations would remain beneath the building at concentrations greater than the cleanup objectives following remediation; however, the remaining average concentration following remediation would be an approximately 91% reduction in existing concentrations and would not migrate downgradient towards the wetland.
- 1,1-DCE concentrations would remain beneath the building at concentrations greater than the cleanup objectives following remediation; however, the remaining average concentration is an approximately 91% reduction in existing concentrations. It is noted that following remediation, concentrations of 1,1-DCE migrating towards the wetland at 700 ft along the plume centerline are modeled to be approximately 8 µg/L, compared to the cleanup objective of 5 µg/L.

The primary analytes identified in sub-slab and indoor air samples in Building #2 are CVOCs. The REMChlor model estimates that the greatest concentration of 1,1-DCE remaining beneath Building #2 following DPE remediation would be 1,390 ppb. Using that concentration, the J&E model estimates that, following DPE treatment, indoor air concentrations would be approximately 3.4 $\mu g/m^3$ and sub-slab concentrations would be approximately 1,100 $\mu g/m^3$. Post-remediation indoor air and sub-slab concentration monitoring would be recommended following DPE system operation to confirm actual conditions.

6.2.3 Long-Term Effectiveness and Permanence

Groundwater extraction and SVE have been successfully implemented at this site for an extended period (i.e., longer than 5 years) showing the long-term effectiveness of this treatment alternative. When SVE previously operated in AOC #5, targeting unsaturated soil, confirmatory soil sampling demonstrated that soil SCGs were met and, based on recent soil investigations, the long-term efficacy was confirmed. The long-term effectiveness of this Remedial Alternative #2, while targeting groundwater and soil in the saturated zone, would be most effective when it is well-monitored and maintained.

6.2.4 Reduction of Toxicity, Mobility, or Volume of Contamination

SVE has been shown to reduce soil concentrations of BTEX and CVOC compounds in the vadose zone soil in AOC #5 and AOC #16. Groundwater extraction will remove contaminated groundwater from the plume, reducing the mobility and volume of site chemicals of concern (COCs) in groundwater beneath Building #2. Groundwater extraction will also dewater a portion of the saturated zone with the objective of making impacted soil accessible to SVE, reducing the soil contaminant mass. If there are any pockets of non-aqueous phase liquid (NAPL) remaining in the subsurface that are liberated during application of DPE, the NAPL will be extracted from system wells and will be separated in the OWS.

6.2.5 Short-Term Impact and Effectiveness

Potential short-term impacts from installation and implementation of Remedial Alternative #2 include:

- Disruption to tenant operations within Building #2 for an estimated 3 months if a vertical well approach would be utilized;
- Limited disruption to tenant operations within Building #2 for an estimated 1 to 3 months if a horizontal well approach would be utilized;
- Potential exposure of field staff to contaminated media (i.e., soil, soil vapor, groundwater);
- Noise exposure during well installations inside Building #2 if a vertical well approach would be utilized; and
- Remedial contractor and onsite worker safety.

Safety measure planning, monitoring, and the use of appropriate levels of personal protective equipment would be required during the installation of the treatment system. An exclusion zone would be established and any tenant operations within that zone would have to be shut down for the period of system installation. This would aid in the protection of tenants from short-term exposure to contaminated media and noise during system installation activities.

Indoor air monitoring for dust and VOCs would be conducted in accordance with the site-specific health and safety plan in order to safeguard remedial workers during system installation. Impact to tenant operations would depend on what tenants are in place inside of Building #2, and at the site overall, at the time of system installation. If a vertical extraction well design is implemented for the DPE remedial approach, system installation activities would be conducted across a large area within Building #2, as depicted in Figure 11. If a horizontal extraction well design is implemented for the DPE remedial approach, significantly less work would be conducted within Building #2 and the primary activity footprint would be outside to the west of Building #2, as depicted in Figures 12A and 12B.

The length of time required to install a DPE system utilizing vertical and/or horizontal extraction wells would be an estimated six months. It is expected that the system operation and maintenance would extend for an approximate duration of 5 to 10 years in order to achieve RAOs (as described in Section 3.1) #1, 3, 4, and 5. It is expected that operation of the SSD systems would extend for a duration of up to 20 years in order to achieve RAO #2.

6.2.6 Implementability Evaluation

Experienced remedial contractors are readily available to implement drilling and construction activities required for a DPE system installation. The necessary mechanical equipment is also readily available for effective system operation. The use of groundwater and vapor extraction wells is a standard industry practice.

The DPE system installation using vertical extraction wells would involve the following:

- Detailed full-scale system design;
- Installation of approximately 50 extraction wells within the Building #2 footprint;

- Trenching within Building #2 for sub-slab completion of system conveyance piping;
- Attainment of all necessary permits to operate the system;
- Continued operation of existing SSD systems; and
- Construction of a remediation equipment enclosure outside of and, preferably adjacent to the southwest corner of Building #2.

Historical site data associated with the former site-wide groundwater extraction and treatment system and the former AOC #5 system can support the development of a detailed system design. SVE pilot testing in the former AOC #5 demonstrated a radius of influence (ROI) of 20 ft. The DPE conceptual design using vertical wells is presented in Figure 11 and uses the 20 ft ROI design parameter to target treatment in the source and downgradient plume areas.

Construction of vertical recovery wells, sub-slab conveyance piping, and the above-ground treatment system would require extended access to Building #2, disrupting building operations that are in place at the time.

The installation of horizontal extraction wells is an option to minimize the impact on tenants that occupy space in Building #2. Using a horizontal well approach, drilling activities for well installation and associated system trenching would occur outside of Building #2, allowing tenant operations to continue with minimal interruption during system installation. Two DPE conceptual drawings using horizontal wells are presented in Figures 12A and 12B. The conceptual drawing in Figure 12A would employ two sets of horizontal groundwater extraction and SVE wells. The conceptual drawing in Figure 12B would employ an estimated six individual horizontal groundwater extraction wells and an estimated seven individual horizontal groundwater extraction wells. The conceptual layout in Figure 12B would benefit from the more consistent elevation of the confining till layer, specifically as it relates to installation of the deeper groundwater extraction wells. Based on field observations (AECOM, 2019a) the confining till layer is present at more consistent elevations from west to east when compared to south to north where the elevation changes by up to 12 ft.

The timeline and scope of future property developments at this site were unknown at the time of report submittal. However, the conceptual drawing shown in Figure 12B considers the potential for property development on the west side of Building #2. Specifically, the setback of each horizontal well from the west side of Building #2 assumes that excavation may take place up to a depth of 8 ftbg while providing a 3 foot buffer between the bottom of the excavation and any horizontal well that passes at that location. It is recognized that this may result in a "sump" type effect for SVE wells that need to slope down and then slope back up into the vadose zone for vapor collection, however this would be addressed during the detailed engineering design should DPE be selected as the optimized remedial approach. In addition, Figure 12B conceptual drawing shows the remedial equipment enclosure in the vicinity of the former remediation shed in the northwest corner of the site. Locating the equipment enclosure in this area is understood to be preferred by the property owner when compared to a location that has greater visibility from Farrell Road.

The DPE system installation using horizontal extraction wells would involve the following:

- Detailed full-scale system design;
- Installation of an estimated six horizontal groundwater extraction wells beneath the Building #2 footprint;
- Installation of an estimated seven horizontal vapor extraction wells beneath the Building #2 footprint;
- Trenching outside of Building #2 to connect the horizontal wells with the equipment enclosure;
- Attainment of all necessary permits to operate the system;
- Continued operation of existing SSD systems; and
- Construction of a new or retrofitted remediation equipment enclosure at the northwest corner of the site where the former remediation shed for AOC#16 was located.

6.2.7 Cost Evaluation

A detailed cost evaluation was performed for the installation, operation and monitoring of a DPE system utilizing a vertical extraction well network as well as a combined horizontal/vertical extraction well network. It was assumed that quarterly performance monitoring would continue leading up to installation and throughout a 10-year period of operation. It is assumed that the DPE system would operate for a period of 10 years and operation of the SSD system would continue for an estimated 20 years to allow for post-mitigation indoor air sampling to support deactivation of the SSD systems. The following tables provide a summary of the costs:

Description	**Cost**
Capital Cost of System Installation Using Vertical Well Network (Year 1)	$ 1,410,000
Operation, Monitoring & Maintenance Costs (Years 2 - 11)	$ 5,770,000
Closure Monitoring & Decommissioning	$ 620,000
SSD Systems Operation (Years 1 – 20)	$ 2,520,000
Total Project Cost	**$ 10,320,000**

Description	**Cost**
Capital Cost of System Installation Using Horizontal Conceptual Drawing #2 (Year 1)	$ 1,890,000
Operation, Monitoring & Maintenance Costs (Years 2 - 11)	$ 5,770,000
Closure Monitoring & Decommissioning	$ 500,000
SSD Systems Operation (Years 1 – 20)	$ 2,520,000
Total Project Cost	**$ 10,680,000**

6.3 REMEDIAL ALTERNATIVE 3: THERMAL TREATMENT

In-situ thermal treatment is the application of heat to soil and groundwater through a variety of methods to volatilize, mobilize, or degrade contaminants. Electrical resistance heating (ERH) is typically used to remediate VOCs, including CVOCs and BTEX compounds, in soil and groundwater. The majority of these compounds have boiling points ranging between 100 and 200 degrees Celsius and will volatilize when exposed to temperatures in this range. ERH consists of installing vertical or horizontal electrodes and vapor recovery wells in the subsurface. Electricity is conducted through the electrodes and the matrix resists the electricity and produces heat in the soil and groundwater, volatilizing the contaminants. The vapor acts as a carrier gas that transports the vapor phase contaminants to the vadose zone. Negative pressure is maintained in the treatment area throughout the system operation to capture steam and contaminant vapors which are treated with vapor-phase GAC prior to discharge to the atmosphere.

With the exception of benzene, CVOCs have lower boiling point temperatures than BTEX compounds, thus requiring less energy for treatment. For the purpose of evaluating feasibility, an ERH design was developed that focused on treatment of CVOCs using vertical electrodes and recovery wells in the source area and downgradient plume area. In this scenario, VOC concentrations greater than 1,000 μg/L are targeted, achieving 99.99% treatment of CVOCs and 80% treatment of BTEX compounds. ERH at the site would include the installation of approximately 170 electrodes across the two treatment areas, co-located with vapor recovery wells. Vapor recovery piping would be trenched to remediation equipment housed outside of Building #2. Subsurface temperatures would be monitored during system operation and extracted vapors would be treated using GAC vessels. Recovered condensate would be treated using liquid phase carbon vessels prior to off-site disposal. Alternative treatment options may be evaluated as part of a full-scale design.

To monitor post-treatment groundwater conditions and potential migration and attenuation of the remaining BTEX compounds following ERH treatment, 2 years of compliance monitoring and 8 years of MNA would be implemented as part of this optimized remedial alternative. It is assumed that the existing SSD systems would operate for up to 10 years post-ERH implementation to allow for time to conduct post-mitigation indoor air monitoring to demonstrate acceptable air quality conditions within Building #2 without using the SSD systems.

6.3.1 Overall Protection of Human Health and the Environment

Thermal treatment would reduce or eliminate existing or potential human health exposure and environmental impacts associated with the soil and groundwater plumes in the vicinity of Building #2. The application of ERH would be designed to reduce CVOC concentrations by up to 99.99% and BTEX compounds by up to 80% of the mass currently present beneath Building #2. The

99.99% reduction of CVOC concentrations will eliminate the potential for further CVOC migration north towards the wetlands and the Seneca River. After the completion of treatment, the remaining BTEX concentrations in soil and groundwater are expected to remain relatively stable and to attenuate over time. A monitoring program would be implemented to determine if any residual BTEX and CVOC concentrations remain following thermal treatment.

6.3.2 Compliance with SCGs

With a thermal approach, REMChlor model outputs on Figures 8, 9, and 10 depict/predict the following outcomes:

- Toluene concentrations beneath the building would remain greater than the cleanup objectives following remediation; however, the remaining average concentration following remediation is an approximately 80% reduction in existing concentrations and would not migrate downgradient towards the wetland.
- 1,1,1-TCA concentrations beneath the building would remain greater than the cleanup objectives following remediation; however, the remaining average concentration following remediation is an approximately 99% reduction in existing concentrations and would not migrate downgradient towards the wetland.
- 1,1-DCE concentrations beneath the building would remain greater than the cleanup objectives following remediation; however, the remaining average concentration following remediation is an approximately 99% reduction in existing concentrations. It is noted that following remediation, concentrations of 1,1-DCE migrating towards the wetland at 700 ft along the plume centerline are modeled to be approximately 13 µg/L, compared to the cleanup objective of 5 µg/L.

The primary analytes identified in sub-slab and indoor air samples in Building #2 are CVOCs. The REMChlor model estimates that the greatest concentration of 1,1-DCE remaining beneath Building #2 following remediation would be 235 ppb. Using that concentration, the J&E model estimates that, following thermal treatment, indoor air concentrations would be approximately 0.58 $\mu g/m^3$ and sub-slab concentrations would be approximately 190 $\mu g/m^3$.

6.3.3 Long-Term Effectiveness and Permanence

Thermal treatment is expected to significantly and permanently reduce CVOC and BTEX concentrations in soil and groundwater in the treated areas in a relatively short timeframe. Any residual contamination, especially petroleum-related, is expected to naturally attenuate over the long-term.

6.3.4 Reduction of Toxicity, Mobility, or Volume of Contamination

The use of ERH has been shown to reduce soil and groundwater concentrations of CVOCs by 99.99% and BTEX concentrations by 80%. This will result in an overall reduction in toxicity, mobility, and volume of contamination in the subsurface beneath Building #2. There is little evidence to support the migration of BTEX compounds from the source area to the downgradient wetland area on the north side of the site. Following treatment, any remaining COC concentrations will be monitored with an MNA program.

6.3.5 Short-Term Impact and Effectiveness

Potential short-term impacts from installation and implementation of Remedial Alternative #3 include:

- Disruption to tenant operations inside of Building #2 for approximately 7 months;
- Potential exposure of field staff to contaminated media (i.e., soil, soil vapor, groundwater);
- Noise exposure during well installations inside Building #2;
- Electrical hazards associated with operating the ERH system; and
- Remedial contractor and onsite worker safety.

Safety measure planning, monitoring, and the use of appropriate levels of personal protective equipment would be required during the installation of the treatment system. An exclusion zone would be established and any tenant operations within that zone would have to be shut down for the period of system installation. This would aid in the protection of tenants from short-term exposure to contaminated media and noise during system installation activities.

The length of time required to install an ERH system utilizing vertical electrodes and vapor recovery wells would be an estimated seven months. It is expected that the system operation would extend for an approximate duration of 4 months in order to achieve RAOs (as described in Section 3.1) #1, 3, 4, and 5. It is expected that operation of the SSD systems would extend for a duration of up to 10 years in order to achieve RAO #2.

6.3.6 Implementability Evaluation

Experienced remedial contractors are readily available to implement the remedial activities associated with this alternative. The necessary equipment is also available for system operation; however, it can be somewhat specialized and requires a detailed engineering design. The use of ERH is a standard industry practice.

The ERH system installation would involve the following:

- Detailed full-scale system design;
- Decommissioning the existing monitoring wells within the Building #2 footprint;
- Acquiring the necessary permits to operate the system;
- Installing approximately 170 co-located electrodes and vapor extraction wells within the Building #2 footprint;
- Trenching within Building #2 for sub-slab completion of system conveyance piping;
- Constructing a power control unit (PCU) connected to the local electrical utility; and
- Constructing a remediation equipment shed outside of and adjacent to the southwest corner of Building #2.

The co-located electrodes and vapor recovery wells are anticipated to be spaced approximately 17.5 ft apart to an average depth of 24 ftbg. The construction of the system would require unlimited access to Building #2 for approximately seven months to accommodate drilling and trenching operations and connection to the PCU and vapor treatment system. Operation of the ERH treatment system would occur for a duration of approximately four months and would include operating the

PCU to conduct the required amount of electricity through the electrodes to heat the subsurface to the required design temperature. Approximately 19 temperature monitoring points would be installed throughout the treatment area to monitor subsurface temperatures at varying depths. Building #2 operations would not be impacted during system operation and access for Lockheed Martin and its subcontractors to Building #2 during operation would only be required for regular monitoring and maintenance. After the system operation timeframe is complete and satisfactory confirmatory sampling has been conducted, the ERH system would be decommissioned. Decommissioning consists of disconnecting and demobilizing the vapor recovery system and power control units, abandoning the vapor recovery wells and electrodes, and replacing the building floor slab disturbed during system installation/decommissioning activities. Decommissioning is anticipated to last approximately three months and would require unlimited access to Building #2.

A conceptual design overview showing the proposed thermal treatment areas and equipment housing is provided on Figure 13. The required footprint(s) for staging areas will be evaluated if Remedial Alternative #3 is recommended for implementation.

6.3.7 Cost Evaluation

A detailed cost evaluation was performed for installation, operation, and monitoring of an ERH system utilizing a vertical electrode/SVE network. It is assumed that the ERH system would operate for a period of four months and operation of the SSD system would continue for a period of 10 years while post-mitigation indoor air sampling is completed.

Description	**Cost**
Capitol Cost System Installation (Year 1)	$ 8,990,000
Operation, Monitoring & Maintenance (Year 2)	$ 405,000
Closure Monitoring & Decommissioning (Year 3)	$ 560,000
SSD System Operation (Year 1 – 10)	$ 1,200,000
Total Project Cost	**$ 11,115,000**

As shown in the cost evaluation, installation and operation of the ERH has higher capital costs than other alternatives. There are other scenarios for implementation of an ERH system that could decrease the initial capital costs. This would include applying ERH only to the source zone and applying a separate treatment technology, such as a permeable reactive barrier (PRB) to the downgradient plume where VOC concentrations are greater than 1,000 µg/L. Alternately, the cost of ERH would increase if the system was designed to treat 99.99% of the BTEX mass.

6.4 REMEDIAL ALTERNATIVE 4: IN-SITU CHEMICAL OXIDATION

In-Situ Chemical Oxidation (ISCO) as a remedial alternative would include injection of the chemical oxidant persulfate into the subsurface, targeting contact with contaminated soil and groundwater in the saturated zone. As the oxidant contacts the contaminants, they are broken down into less harmful or innocuous byproducts. Bench-scale and pilot testing previously performed at the site determined that, when contact could be achieved, persulfate was effective in reducing CVOC and BTEX concentrations in groundwater. Various oxidant delivery mechanisms are available including direct-push injections, injections using permanent vertical or horizontal wells, PRBs, and recirculation systems which utilize a combination of injection and extraction wells. For the purpose of evaluating feasibility, an ISCO design was developed that includes permanent vertical injection wells to deliver Klozur® sodium persulfate (SP) in the source area and PRBs installed by direct push to deliver Klozur® potassium persulfate (KP) in the downgradient plume. Alternative delivery mechanisms may be evaluated as part of a full-scale design.

During remediation, groundwater monitoring would be performed on a quarterly basis for approximately 5 years, and post-remediation for an estimated 5 years to monitor for potential migration and attenuation of any remaining concentrations following ISCO treatment. It is assumed that the existing SSD systems would operate for up to 10 years post-ISCO treatment to allow for time to conduct post-mitigation indoor air monitoring to demonstrate acceptable air quality conditions within Building #2 without using the SSD systems.

The ICs and ECs already in place for the site will be maintained during the full extent of this program.

6.4.1 Overall Protection of Human Health and the Environment

The application of ISCO will be designed to reduce or eliminate CVOC and BTEX concentrations in the source area and downgradient plume beneath Building #2 in order to decrease contaminant concentrations and achieve cleanup goals. Data collected during a laboratory bench scale study, conducted in 2017 using groundwater from the site, showed that 1,4-dioxane and other VOC concentrations were treated to over 99% reduction using alkaline activated Klozur® SP when contact was achieved.

It is expected that this remedial alternative would meet the RAOs for mitigating the potential threat to the Class I wetland biotic community and for mitigating discharge of contaminated groundwater to the wetland and Seneca River. The potential for migration of contaminated groundwater from the vicinity of Building #2 to the wetland would be greatly reduced (although groundwater would not be hydraulically contained). Similarly, by reducing the migration of contaminated groundwater, protection of human health and the environment could be achieved.

The initial depth to impacted saturated soil is approximately 8 to 10 ftbg. It is unlikely that these soils would be disturbed during future construction activities; however, institutional controls are in place to ensure that they would be handled in a manner consistent with protection of human health and the environment.

The continued use of the SSD systems as an Engineering Control is recommended for this remedial alternative pending the results of post-mitigation indoor air monitoring. Additionally, maintenance of the current Building #2 foundation and paved surface exterior to Building #2 is recommended.

6.4.2 Compliance with SCGs

With an ISCO approach, REMChlor model outputs on Figures 8, 9, and 10 depict/predict the following outcomes:

- Toluene concentrations beneath the building would remain greater than the cleanup objectives following remediation; however, the remaining average concentration following remediation is an approximately 84% reduction in existing concentrations and would not migrate downgradient towards the wetland.

- 1,1,1-TCA concentrations beneath the building would remain greater than the cleanup objectives following remediation; however, the remaining average concentration following remediation is an approximately 88% reduction in existing concentrations and would not migrate downgradient towards the wetland.
- 1,1-DCE concentrations beneath the building would remain greater than the cleanup objectives following remediation; however, the remaining average concentration following remediation is an approximately 81% reduction in existing concentrations. It is noted that following remediation, concentrations of 1,1-DCE migrating towards the wetland at 700 ft along the plume centerline are modeled to be approximately 8 μg/L, compared to the cleanup objective of 5 μg/L.

The primary analytes identified in sub-slab and indoor air concentrations in Building #2 are CVOCs. The REMChlor model estimates that the greatest concentration of 1,1-DCE remaining beneath Building #2 following remediation is 2,990 μg/L. Using that concentration, the J&E model estimates that following thermal treatment, indoor air concentrations would be approximately 7.4 $\mu g/m^3$ and sub-slab concentrations would be approximately 2,400 $\mu g/m^3$.

6.4.3 Long-Term Effectiveness and Permanence

The effectiveness of ISCO depends upon contact between the oxidant and the contaminants. The lithology of the targeted saturated zone is relatively homogeneous and even reagent distribution is expected. Given the limited impacts to soil in the vadose zone, ISCO chemical reactions will be promoted in the saturated zone. Following oxidation reactions in the dissolved phase, BTEX compounds readily desorb from soil and dissolve into groundwater while CVOCs dissolve more slowly into groundwater. The presence of added sulfate associated with the breakdown of sodium persulfate may enhance the populations of sulfate-reducing bacteria which, in turn, could biodegrade some of the site COCs.

The bench scale treatability study performed in 2017 reported that Klozur® persulfate effectively reduced 1,4-dioxane concentrations in groundwater (AECOM, 2017b). Although 1,4-dioxane is not considered a primary COC in the vicinity of Building #2, during the second quarter groundwater monitoring event in 2020, concentrations ranged from less than laboratory detection limits to 1,100 µ/L in monitoring wells within the Building #2 footprint. ISCO would be effective for the treatment of 1,4-dioxane concentrations if contact could be achieved.

Multiple rounds of injections would be performed as part of Remedial Alternative #4 in order to effectively treat the source area and limit the potential for concentration rebound in groundwater. Following injection events, groundwater post-injection performance monitoring followed by groundwater compliance monitoring will be conducted to ensure that groundwater SCGs have been achieved.

The vertical and horizontal extents of the BTEX and CVOC plumes in the vicinity of Building #2 have been adequately delineated; however, investigations have not been performed at the site to identify if, and to what extent, NAPL is present. According to the NYSDEC *DER-10, Technical Guidance for Site Investigation and Remediation* (NYSDEC, 2010), NAPL is suspected to be present in groundwater where the concentration of a contaminant is equal to or greater than 1% of the water solubility of that contaminant. Based on concentrations detected during the 2019 subsurface investigation, both DNAPL and LNAPL are potentially present in groundwater. The maximum and average concentrations of 1,1,1-TCA (solubility = 1,290 mg/L) are 240 mg/L and 11.67 mg/L, respectively, in groundwater samples collected from permanent and temporary monitoring wells. The maximum and average concentrations of toluene (solubility = 530 mg/L) are 200 mg/L and 18.64 mg/L, respectively, in groundwater samples collected from permanent and temporary monitoring wells. While concentrations indicate that NAPL may be present in groundwater, NAPL has not been detected during recent groundwater monitoring events. NAPL was not observed in soil or groundwater during 2019 drilling activities; however, in 1992, NAPL was observed at the approximate depth of the water table during investigation activities and LNAPL and DNAPL were observed and subject to a removal program following the installation of the SVE system wells in 1994.

If NAPL is present in the subsurface, it would impact the effectiveness of ISCO. Remaining NAPL mass could provide a source for concentration rebound in groundwater. ISCO treatment of NAPL is possible; however, the effective treatment of NAPL would require larger quantities of chemicals than those that are currently considered in this evaluation.

Post-injection performance monitoring would be performed over a period of 5 years to confirm that VOC concentrations decrease after injections and do not rebound. If rebound is observed, the ISCO injection program would be modified based on collected data.

6.4.4 Reduction of Toxicity, Mobility, or Volume of Contamination

Persulfate has been shown to effectively reduce site contaminants. The ISCO remediation would be designed to primarily treat BTEX and CVOC compounds found in the source area. Chemical amendments injected into the saturated zone would degrade contaminants into less toxic or non-toxic compounds. PRBs containing Klozur® SP and KP would be installed in the plume area located immediately downgradient of the source area. As the COCs in groundwater migrate through the PRBs, their concentrations would be reduced, thus limiting further migration of contaminants in groundwater towards the northern portion of the site.

It is possible for byproduct production from reactions between persulfate and contaminants and for persulfate to resolubilize metals in soil. Total chromium has been detected in soil and groundwater near the former printed wire board (PWB) assembly area (AOC #6), which is located in the southwest corner of Building #2. Based on information in the Interstate Technology & Regulatory Council (ITRC) publication *Technical and Regulatory Guidance for In Situ Chemical Oxidation of Contaminated Soil and Groundwater* (ITRC, 2005), it is possible for trivalent chromium to be converted to hexavalent chromium under oxidizing conditions. Hexavalent chromium (Cr^{6+}) was analyzed in groundwater as part of the baseline and post-injection monitoring during the 2017 pilot tests in Treatment Area #1 (south of the wetland) and Treatment Area #2 (AOC #5). Post-injection monitoring showed increases in Cr^{6+} concentrations in monitoring wells situated 5- and 10-feet downgradient of injection locations in Treatment Area #1. Post-injection monitoring for Cr^{6+} has been ongoing since the August 2018 full scale ISCO application in the wetland area. Based on post-injection groundwater results, Cr^{6+} has not mobilized downgradient of the treatment zones.

6.4.5 Short-Term Impact and Effectiveness

Potential short-term impacts from installation and implementation of Remedial Alternative #4 include:

- Disruption to tenant operations inside of Building #2 for approximately 4 months during infrastructure installation and 4-6 weeks during each injection event;
- Potential exposure of field staff to contaminated media (i.e., soil, soil vapor, groundwater);
- Noise exposure during well installations inside Building #2;
- Remedial contractor and onsite worker safety;
- Direct contact with chemical oxidants during the mixing and injection processes; and
- Direct contact with chemical mixtures if daylighting occurs.

Safety measure planning, monitoring, and the use of appropriate levels of personal protective equipment would be required during infrastructure installation and active injections. An exclusion zone would be established during infrastructure installation and any tenant operations within that zone would have to be shut down during the installation timeframe. This would aid in the protection of tenants from short-term exposure to contaminated media and noise during system installation activities. A site-specific health and safety plan would be in place with standard operating procedures for conducting chemical mixing and injection processes and a required protocol to address daylighting should it occur.

It is expected that this remedial approach would extend for an approximate duration of three years in order to achieve RAOs (as defined in Section 3.1) #1, 3, 4, and 5. It is expected that the operation of the SSD systems would extend for a duration of up to 20 years in order to achieve RAO #2. However, when targeting soil impacts, there is a possibility that not all sorbed contaminants would be treated with injected oxidant which could result in groundwater concentration rebound following treatment thereby increasing the time required to achieve RAOs #1, 3, 4, and 5.

The *Technical and Regulatory Guidance for In Situ Chemical Oxidation of Contaminated Soil and Groundwater* (ITRC, 2005) states that ISCO should not be implemented at sites with NAPL under an occupied building unless the design includes adequate collection of gases. It is possible that NAPL is indeed present in the subsurface; however, no observations have been documented in monitoring wells within the Building #2 footprint. As a precautionary measure, indoor air monitoring would be performed during active injections and continued operation of the existing SSD systems would be in place.

6.4.6 Implementability Evaluation

Experienced remedial contractors are readily available to implement drilling and injection activities required for an ISCO treatment approach. The necessary oxidants and equipment are also readily available. The use of chemical oxidation to remediate soil and groundwater concentrations is a standard industry practice.

The ISCO treatment approach using vertical injection wells and PRBs would involve the following:

- Detailed full-scale oxidant dosing design;
- Attainment of all necessary permits to operate the system;
- Installation of approximately 40 permanent injection wells within the Building #2 footprint;
- Installation of approximately 500 ft of direct-push PRBs within the Building #2 footprint;
- Continued operation of existing SSD systems; and
- Uninterrupted access during injection events within Building #2.

ISCO implementation would depend primarily on the oxidant delivery mechanism employed. To remediate the entirety of the source and downgradient plume areas, the ISCO approach in the vicinity of Building #2 would require installation of an extensive injection well network and PRBs made up of direct-push injection locations (Figure 14). The installation of the oxidant delivery mechanisms and the first injection event would require unlimited access to Building #2 for a period of approximately six months. Each subsequent injection event would require unlimited access to Building #2 for approximately one to two months each.

The oxidants can also be delivered to the subsurface using horizontal injection wells. For this approach, a footprint approximately 100 foot by 100 foot would be required outside of Building

#2 to the southwest (Figure 15). Horizontal installations can be completed under two scenarios: the first approach installs the injection well with both an entry and an exit point; the second approach installs the injection well with only an entry point (i.e., a blind entry). If the horizontal well is installed using an entry and exit point (i.e, continuous drilling), the exit point would be on the north side of Building #2 and would require a footprint of approximately 10 ft by 10 ft. Injection well installation using continuous drilling involves advancing the augers through the borehole and then at the exit point, pulling the sleeve that contains the discrete nested wells, back through the borehole while the borehole is supported by the drilling equipment. Injection well installation using a blind entry involves advancing the augers through the borehole, but instead of daylighting at an exit point, the drilling equipment is extracted from the borehole. During extraction of the drilling equipment, some contractors will place a proprietary mixture into the borehole to support it against collapse, others use a carrier casing. The sleeve of discrete nested wells is then pushed back through the supported borehole.

In either the case of continuous drilling or blind entry, once the discrete nested wells have been put into place, grout is installed between each injection screen to isolate treatment of a targeted zone. The installation of these targeted injection zones can be challenging and time-consuming due to the level of precision necessary to ensure the wells operate as designed and carries the risk of multiple attempts to achieve the correct installation.

The ISCO treatment approach using a combination of horizontal and vertical injection wells would involve the following:

- Detailed full-scale oxidant dosing design;
- Attainment of all necessary permits to operate the system;
- Installation of an estimated 2 permanent horizontal injection wells beneath the Building #2 footprint;
- Installation of an estimated seven permanent vertical injection wells within the Building #2 footprint and approximately three permanent vertical injection wells outside of Building #2;

- Continued operation of existing SSD systems; and
- Uninterrupted access during injection events within Building #2.

Chemical amendments including Klozur® SP and KP are commercially available and the dosing design for the ISCO injections would be based on recommendations from the chemical manufacturer. For both the vertical injection well and horizontal injection well approaches, a staging area would be required outside of Building #2 during injection events to store and mix the chemical amendments. The required footprints for staging areas will be evaluated if Remedial Alternative #4 is recommended for implementation.

Regardless of the delivery system employed, baseline and quarterly post-injection monitoring would be conducted and uninterrupted access to all monitoring wells inside Building #2 would be required on a quarterly basis.

6.4.7 Cost Evaluation

A detailed cost evaluation was performed for the installation of permanent vertical injection wells in the source area, five PRBs in the downgradient plume, one initial injection event, two optimized scope injection events, and performance monitoring; these costs are summarized in the table below. Additionally, a detailed cost evaluation was performed for installation of horizontal injection wells in the source area and downgradient plume, one initial injection event, two optimized scope injection events, and performance monitoring; these costs are summarized in the second table that follows. For both installations, it was assumed that quarterly performance monitoring would continue throughout ISCO treatment events, the ISCO treatment approach would be applied over a period of three years, and operation of the SSD system would continue for a period of 20 years. It was also assumed that annual monitoring for closure would be conducted for a duration of 5 years.

Description	Cost
Capital Cost Injection Delivery System Installation Using Vertical Wells and Permeable Reactive Barriers (Year 1)	$ 660,000
First Injection (Year 1)	$ 830,000
Performance Monitoring (Years 1 – 5)	$ 1,020,000
Two Follow-Up Injections (Years 2 and 3)	$ 1,040,000
Closure Monitoring & Decommissioning (Years 5 – 10)	$ 810,000
SSD System Operation (Year 1 – 20)	$ 2,520,000
Total Project Cost	**$ 6,880,000**

Description	Cost
Capital Cost Injection Delivery System Installation Using Horizontal Wells (Year 1)	$ 790,000
First Injection (Year 1)	$ 920,000
Performance Monitoring (Years 1 – 5)	$ 1,000,000
Two Follow-Up Injections (Years 2 and 3)	$ 1,120,000
Closure Monitoring & Decommissioning (Years 5 – 10)	$ 690,000
SSD System Operation (Year 1 – 20)	$ 2,520,000
Total Project Cost	**$ 7,040,000**

6.5 REMEDIAL ALTERNATIVE 5: MONITORED NATURAL ATTENUATION AND ENHANCED REDUCTIVE DECHLORINATION OF CVOCS

This alternative evaluates a combined remedial approach of MNA and enhanced reductive dechlorination (ERD) of CVOCs in a PRB design located downgradient of Building #2. The MNA program would monitor the mobility and attenuation of the contaminant plume beneath Building #2 and if data is indicative of CVOC groundwater plume migration, the installation of the downgradient PRB would be implemented. It is anticipated that maintenance injections to rehabilitate the PRB would be conducted every 3-5 years, depending on the monitoring data.

The ICs and ECs already in place for the site would be maintained during the full extent of this program.

This alternative does not contemplate treatment of BTEX given that a comparison of historical and current groundwater data at the site suggests that BTEX compounds have not migrated from beneath Building #2 towards the wetland to the same extent as CVOCs. During the first quarter groundwater sampling event in 2020, a maximum BTEX concentration of 3.2 µg/L was observed in wetland monitoring well PMW-10S, whereas a maximum CVOC concentration of 950.4 µg/L was observed in wetland monitoring well PMW-12S. Additionally, the REMChlor model as shown in Figure 8, suggests that under an MNA scenario, migration of toluene along the plume centerline would not occur at concentrations that exceed cleanup objectives beyond Building #2.

The ERD barrier would consist of mulch which would act as the primary electron donor to facilitate the reduction of CVOCs. Emulsified vegetable oil (EVO) would be mixed in with the mulch during barrier installation to supplement biological activity within the barrier. The PRB would need to be rehabilitated periodically throughout operation; this would include injections of EVO into the barrier. It is assumed that rehabilitation would need to occur once every 3 to 5 years based on groundwater monitoring data.

6.5.1 Overall Protection of Human Health and the Environment

This alternative involves a passive remedial approach using MNA for the contaminant plume beneath Building #2. The plume would be monitored for migration from beneath Building #2. If an increasing trend of CVOC concentrations is observed during the MNA program, implementation of the ERD PRB would be initiated. For purpose of this evaluation, it is assumed that it would take approximately 15 years for the plume to migrate from beneath Building #2. Protection of human health would be maintained during the MNA program and PRB operation because the impacted soil and groundwater are inaccessible beneath the building foundation and the continued operation of the SSD systems would control the potential for vapor intrusion into Building #2.

The initial depth to impacted saturated soil is approximately 8 to 10 ftbg. It is unlikely that these soils would be disturbed during future construction activities; however, institutional controls are in place to ensure that they would be handled in a manner consistent with protection of human health and the environment.

The continued use of the SSD systems as an Engineering Control is recommended for this remedial alternative. Additionally, the maintenance of the current Building #2 foundation and paved surface exterior to Building #2 is recommended.

6.5.2 Compliance with SCGs

With an MNA approach, REMChlor model outputs on Figures 8, 9, and 10 depict/predict the following outcomes:

- Toluene would remain beneath the building at concentrations greater than the cleanup objectives for at least 50 years and would not migrate downgradient towards the wetland.
- 1,1,1-TCA would remain beneath the building at concentrations greater than the cleanup objectives for approximately 12 years and would not migrate downgradient towards the wetland.
- 1,1-DCE would remain beneath the building at concentrations greater than the cleanup objectives for at least 50 years and would continue to migrate downgradient toward the wetland under current conditions, 20 years and 50 years into the future. The model predicts that concentrations of 1,1-DCE migrating from beneath Building #2 at 500 ft along the plume centerline between 6 and 20 years in the future would be approximately 145 to 162 µg/L.

The MNA with ERD approach is not expected to meet SCGs for BTEX, CVOCs, and/or 1,4-dioxane in the source area groundwater beneath Building #2. The REMChlor model was not used to evaluate concentrations downgradient of the ERD PRB should it be installed.

The primary analytes identified in sub-slab and indoor air concentrations in Building #2 are CVOCs. The REMChlor model estimates that the highest concentration of 1,1-DCE remaining beneath Building #2 after 6 years is approximately 13,300 µg/L. Using that concentration, the J&E model estimates that at 50 years, indoor air concentrations would be approximately 33 µg/m^3 and sub-slab concentrations would be approximately 11,000 µg/m^3.

6.5.3 Long-Term Effectiveness and Permanence

MNA is not expected to significantly reduce CVOC and BTEX concentrations in groundwater beneath Building #2 within a short time frame. MNA is estimated to continue for approximately 15 years prior to installation of the downgradient ERD PRB if it is demonstrated that the CVOC plume is migrating beyond the Building #2 footprint. The installation of the PRB would be expected to take approximately two weeks to install using DeWind trenching technology. Multiple rounds of injections are assumed to be required to rehabilitate the PRB on a schedule of once every 3 to 5 years. The ERD barrier is expected to create anaerobic conditions in groundwater and reduce CVOC concentrations in groundwater prior to migration of the plume to the northern wetlands. Bench-scale testing of ERD at the site was shown to be effective in reducing CVOC concentrations in site groundwater (AECOM, 2017b). Performance monitoring of the ERD PRB would be conducted to ensure that VOC concentrations decrease as a result of passing through the PRB. Operation and maintenance of the current SSD system is assumed to continue throughout implementation of Remedial Alternative #5.

6.5.4 Reduction of Toxicity, Mobility, or Volume of Contamination

The groundwater plume would be monitored during the MNA program until it has been shown that the plume has migrated beyond the Building #2 footprint, at which point PRBs would be installed to treat the groundwater as the plume continues to migrate towards the northern wetlands. The PRBs would reduce the volume of contamination downgradient of the current source area and reduce contaminant concentrations prior to reaching the northern wetland. This approach would not reduce the current toxicity or volume of VOC contamination within the source area beneath Building #2.

6.5.5 Short-Term Impact and Effectiveness

MNA is expected to occur for a period lasting up to 15 years before an active remediation technology is installed at the site. Potential short-term impacts of the PRB installation include disruption to tenant operations outside of Building #2 in the northern loading area (as shown in Figure 16), potential exposure of field staff to contaminated media (i.e., soil, soil vapor, groundwater), and noise exposure to remedial and site workers. Safety measure planning, monitoring and the use of appropriate levels of personal protective equipment would be required during the installation of the ERD PRB. Installation of the ERD PRB trench is expected to take approximately 2 weeks followed by restoration of the asphalt in this area. Subsequent rounds of injection would be performed in the ERD PRB once every 3 to 5 years.

Assuming that the MNA approach is implemented for a duration of 15 years followed by installation of the ERD PRB trench, it is expected that the remedial approach would extend for an estimated 27 years in order to achieve RAOs (as described in Section 3.1) #1, 3, and 5. It is expected that operation of the SSD systems would extend for a duration greater than 30 years in order to achieve RAO #2 and that RAO #3 may be achieved in greater than 30 years.

6.5.6 Implementability Evaluation

MNA would be implemented using a long-term groundwater monitoring plan that would be developed in communication with the NYSDEC. Experienced remedial contractors are readily available to implement trenching and injection activities required for the downgradient PRB treatment approach. The necessary materials and equipment are also readily available. The use of a PRB to remediate groundwater concentrations is a standard industry practice.

The combined MNA and PRB treatment approach would involve the following:

- Development of a long-term groundwater monitoring plan for MNA;
- Installation of supplemental monitoring wells inside of Building #2 and to the north of Building #2 to support the MNA program and future performance monitoring of the PRB;
- Detailed full-scale PRB and rehabilitating injection design;
- Attainment of the necessary permits to install the PRB;
- Continued operation of the SSD systems;
- Installation of one 400-foot-long PRB trench consisting of mulch mixed with EVO;
- Performance groundwater monitoring;
- Re-mobilization every 3 to 5 years for PRB rehabilitation via direct-push injections; and

- Uninterrupted access during installation and injection events to the north of Building #2.

An estimated four groundwater monitoring wells would be installed approximately 20 ft downgradient of MW-109 and an additional four would be installed approximately 70 ft upgradient of MW-115. These wells would be spaced approximately 8 foot apart to support the MNA program and to monitor potential plume migration towards the downgradient side of the Building #2 footprint. In addition, a slug test would be conducted to confirm the estimated hydraulic conductivity in this area of the site. Results from the slug test would be used in comparison with tests historically completed at MW-3 in order to estimate the time in which the plume could be expected to migrate towards the downgradient edge of Building #2. These results in combination with monitoring data collected from the additional monitoring wells would be used to prepare for installation of the ERD PRB if required. This evaluation assumes a timeframe of up to 15 years for MNA prior to the installation of the ERD PRB. If the plume is observed to begin migrating, activities will be initiated related to installation of a 400-foot-long trench approximately one year in advance of planned installation to allow for coordination with the property owner and tenant activities. The trench would be installed to the north of MW-115 perpendicular to the groundwater flow path in order to treat the contaminant plume migrating towards the northern wetlands. As discussed in Section 6.5, it is anticipated that the migrating plume would consist primarily of CVOC compounds. The PRB would consist of mulch mixed with EVO to promote ERD of the CVOCs in groundwater. BTEX compounds are expected to remain stable beneath the building foundation. Approximately three monitoring wells would be installed upgradient and downgradient of the PRB, respectively, as shown on Figure 16, and would be used for performance monitoring of the PRB. As groundwater passes through the PRB over time, reduction in CVOC concentrations would be expected. It is anticipated that injections of EVO would need to occur within the PRB to rehabilitate the barrier once every 3 to 5 years. This would occur until groundwater concentrations upgradient of the PRB have attained groundwater standards as practicable. For purposes of this evaluation, it is assumed there would be three rounds of injections.

A conceptual design showing the proposed PRB location and proposed monitoring well locations is presented in Figure 16.

6.5.7 Cost Evaluation

A detailed cost evaluation was performed for a long-term MNA program (up to 15 years), installation of a PRB for ERD treatment of CVOCs, three subsequent rounds of injections, performance monitoring, and continued operation and maintenance of the current SSD systems on site. All monitoring was assumed to occur on a quarterly basis. It is assumed that the MNA and ERD PRB approach would be in place for a period of 27 years and operation of the SSD systems would continue for a period of at least 30 years. The costs are presented in the following table below:

Description	**Cost**
MNA (Years 1-15)	$ 4,310,000
Capitol Cost Additional Well and Trench Installation (Year 16)	$ 820,000
Trench Rejuvenation (Years 19, 22, and 25)	$ 280,000
Performance Monitoring (Years 16 - 27)	$ 2,400,000
Closure Monitoring (Years 28 – 30)	$ 720,000
SSD System Operation (Year 1 – 30)	$ 3,970,000
Total Project Cost	**$ 12,500,000**

6.6 REMEDIAL ALTERNATIVE #6: SOIL VAPOR EXTRACTION WITH AIR SPARGE

SVE with AS is a combined remedial approach that involves injection of air into the saturated zone and the extraction of soil vapor from the vadose zone.

An SVE system operated from 1995 to 2002 at AOC #5 located on the west side of Building #2. The historic SVE system targeted the vadose zone and the extracted air effluent stream was treated using GAC vessels prior to discharge to the atmosphere. Confirmatory soil samples collected from the vadose zone after system operation showed that concentrations for chemicals of concern were less than laboratory detection limits. This system has since been shut-down and decommissioned.

Soil and groundwater sampling activities conducted in 2017 demonstrated that residual contamination may still exist in the vicinity of Building #2 below the water table. In 2019, a subsurface investigation conducted in the vicinity of Building #2 confirmed the presence of residual contamination and fully delineated the soil and groundwater contaminant plume beneath the building. Based on the success of historic SVE operation in the AOC #5 vadose zone, SVE optimized with AS is subject to a detailed evaluation in this section.

This optimized remedial alternative would inject air into the impacted saturated zone to cause a phase transfer of VOCs in impacted groundwater and soil to a vapor phase. Vapor extraction in the vadose zone must accompany operation of the sparge system in order to capture the resulting vapor. The extracted vapors would be treated through vapor-phase GAC units, reducing VOC concentrations prior to discharge. Air effluent analysis would be conducted during the system startup and initial operation to confirm that annual and short-term guidelines for ambient air contaminants set forth in the NYSDEC policy DAR-1 (NYSDEC, 2016) are met prior to discharge to the atmosphere.

For the purpose of evaluating feasibility, an SVE with AS conceptual design was developed that focused on sparging the impacted soil and groundwater plume approximately 8 ft beneath the average water table using horizontal injection wells in both the source area and the downgradient plume area.

Remediation performance monitoring would include quarterly groundwater sampling events conducted during and post-remediation for an estimated 5 years to monitor for potential contaminant migration and evaluate the attenuation of any remaining contaminant concentrations following the SVE/AS system operation. This alternative assumes the existing SSD systems would operate for an estimated 10 years post-SVE/AS operation to allow for time to conduct post-mitigation indoor air monitoring to demonstrate acceptable air quality conditions within Building #2 without using the SSD systems.

The ICs and ECs already in place for the site would be maintained during the full extent of this program.

6.6.1 Overall Protection of Human Health and the Environment

Air sparging and soil vapor extraction would remove contaminant mass from beneath Building #2 over time, resulting in a reduced potential for vapor intrusion into the building, and protecting current and future on-site workers from potential exposure. This exposure pathway is currently being controlled by the SSD systems installed in Building #2, as further described in Section 2.1.3, which are anticipated to continue operation throughout the SVE/AS system operation and for an estimated 20-years post-SVE/AS operation.

Applying the modeled indoor air and sub-slab concentrations for 1,1-DCE against the NYSDOH Soil Vapor/Indoor Air Matrix A (NYSDOH, 2006), continued use of the SSD systems as an engineering control would be recommended. There is conservatism built into the two modeling software programs used to generate the estimated indoor air and sub-slab concentrations; therefore, it is possible that indoor air and sub-slab concentrations could be less than those predicted by the J&E model. Follow-up indoor air and sub-slab concentration monitoring would be recommended following SVE and AS system operation to confirm actual conditions. Additionally, the maintenance of the current Building #2 foundation and paved surface exterior to Building #2 is recommended.

Reduction in contaminant mass in the source zone and downgradient plume area beneath Building #2 would help to limit the flow of contaminated groundwater from migrating further north towards the wetland and the Seneca River.

The initial depth to impacted saturated soil is approximately 8 to 10 ftbg. It is unlikely that these soils would be disturbed during future construction activities; however, institutional controls are in place to ensure that they would be handled in a manner consistent with protection of human health and the environment.

6.6.2 Compliance with SCGs

With an SVE and AS approach, REMChlor model outputs on Figures 8, 9, and 10 depict/predict the following outcomes:

- Toluene concentrations would remain beneath the building at concentrations greater than the cleanup objectives following remediation; however, the remaining average concentration following remediation is an approximately 84% reduction in existing concentrations and would not migrate downgradient towards the wetland.

- 1,1,1-TCA concentrations would remain beneath the building at concentrations greater than the cleanup objectives following remediation; however, the remaining average concentration following remediation would be an approximately 86% reduction in existing concentrations and would not migrate downgradient towards the wetland.
- 1,1-DCE concentrations would remain beneath the building at concentrations greater than the cleanup objectives following remediation; however, the remaining average concentration is an approximately 80% reduction in existing concentrations. It is noted that following remediation, concentrations of 1,1-DCE migrating towards the wetland at 700 ft along the plume centerline are modeled to be approximately 9 µg/L, compared to the cleanup objective of 5 µg/L.

The primary analytes identified in sub-slab and indoor air samples in Building #2 are CVOCs. The REMChlor model estimates that the greatest concentration of 1,1-DCE remaining beneath Building #2 following SVE and AS remediation would be 2,761 ppb. Using that concentration, the J&E model estimates that, following SVE and AS treatment, indoor air concentrations would be approximately 6.8 $\mu g/m^3$ and sub-slab concentrations would be approximately 2,300 $\mu g/m^3$. Post-remediation indoor air and sub-slab concentration monitoring would be recommended following system operation to confirm actual conditions.

6.6.3 Long-Term Effectiveness and Permanence

SVE has been successfully implemented at this site for an extended period (i.e., longer than 5 years) showing the long-term effectiveness of this treatment alternative. When SVE previously operated in AOC #5, targeting unsaturated soil, confirmatory soil sampling demonstrated that soil SCGs were met and, based on recent soil investigations, the long-term efficacy was confirmed. Historical and recent soil and groundwater analytical data from sample locations in close proximity were compared in the former SVE treatment area. There are two instances where groundwater concentrations decreased since system operation, for example, CVOC concentrations at B-45 decreased from 1,310 ppb to 5.79 ppb at SB-104 and CVOC/BTEX concentrations at B-44 have decreased from 34,100 ppb / 768,600 ppb to 447.7 ppb / 2,329 ppb at SB-105, respectively. A comparison of historical and recent soil samples from within the saturated zone does not suggest a decrease in soil impacts have occurred based on operation of the SVE system alone. However, there was adequate supporting analytical data in the vadose zone both pre- and post-SVE system operation to support system shutdown.

The majority of soil impacts remain below the water table in the saturated zone beneath Building #2. SVE has been shown to be effective in capturing vapors and reducing contaminant concentrations in the vadose zone. It is anticipated that optimizing an SVE system with an active AS system would reduce contaminant concentrations in saturated soil and groundwater.

6.6.4 Reduction of Toxicity, Mobility, or Volume of Contamination

SVE has been shown to reduce soil concentrations of BTEX and CVOC compounds in the vadose zone soil in AOC #5 and AOC #16. AS is anticipated to reduce saturated soil and groundwater concentrations by transitioning the contaminants to a vapor phase to be extracted by the SVE system. As a result, the volume of site chemicals of concern (COCs) would decrease in groundwater and soil beneath Building #2. The extracted vapors would be treated above ground to reduce COC concentrations prior to discharging to the atmosphere.

6.6.5 Short-Term Impact and Effectiveness

Potential short-term impacts from installation and implementation of Remedial Alternative #6 include:

- Limited disruption to tenant operations within Building #2 for an estimated three months for well installation;
- Potential exposure of field staff to contaminated media (i.e., soil, soil vapor, groundwater); and
- Remedial contractor and onsite worker safety.

Safety measure planning, monitoring, and the use of appropriate levels of personal protective equipment would be required during the installation of the treatment system. Air monitoring for dust and VOCs would be conducted in accordance with the site-specific health and safety plan in order to safeguard remedial workers during system installation. Impact to tenant operations would depend on what tenants are in place the site, at the time of system installation. Significantly less work would be conducted within Building #2 utilizing horizontal wells over traditional vertical wells. The primary activity footprint would be outside to the west of Building #2, as depicted in Figure 17.

The length of time required to install an SVE/AS system utilizing horizontal wells would be an estimated four months. It is expected that the system operation and maintenance would extend for an approximate duration of 5 to 10 years in order to achieve RAOs (as described in Section 3.1) #1, 3, 4, and 5. It is expected that operation of the SSD systems would extend for a duration of up to 20 years in order to achieve RAO #2.

6.6.6 Implementability Evaluation

Experienced remedial contractors are readily available to implement drilling and construction activities required for an SVE with AS system installation. The necessary mechanical equipment is also readily available for effective system operation. The use of vapor extraction wells and air injection wells is a standard industry practice.

The SVE and AS system installation using horizontal extraction and injection wells would involve the following:

- Detailed full-scale system design;
- Installation of an estimated six horizontal air injection wells beneath the Building #2 footprint;
- Installation of an estimated seven horizontal vapor extraction wells beneath the Building #2 footprint;
- Attainment of all necessary permits to operate the system;
- Continued operation of existing SSD systems; and
- Construction of a remediation equipment enclosure at the northwest corner of the site where the former remediation shed for AOC#16 was located.

Historical site data associated with the former AOC #5 SVE system can support the development of a detailed system design. Historic SVE pilot testing in the former AOC #5 demonstrated a ROI of 20 ft was achievable.

The installation of horizontal wells is an option to minimize the impact on tenants that occupy space in Building #2. Drilling activities for well installation and associated system trenching would occur outside of Building #2, allowing tenant operations to continue with minimal interruption during well and system installation. The SVE and AS conceptual design using horizontal wells is presented in Figure 17 and would require an estimated six horizontal air injection wells and an estimated seven soil vapor extraction wells.

6.6.7 Cost Evaluation

A detailed cost evaluation was performed for the installation, operation and monitoring of an SVE and AS system utilizing a horizontal remedial well network. It was assumed that quarterly performance monitoring would continue leading up to installation, throughout a 10-year period of operation, and for 5-years post-system operation. It is assumed that the SVE/AS system would operate for a period of 5 to 10 years and operation of the SSD system would continue for an estimated 20 years to allow for post-mitigation indoor air sampling to support deactivation of the SSD systems. The costs are presented in the following table below:

Description	Cost
Capital Cost of System Installation (Year 1)	$ 1,800,000
Operation, Monitoring & Maintenance Costs (Years 2-11)	$ 3,950,000
Closure Monitoring & Decommissioning	$ 560,000
SSD System Operation (Years 1 – 20)	$ 2,520,000
Total Project Cost	**$ 8,830,000**

SECTION 7
COMPARATIVE ANALYSIS OF OPTIMIZED REMEDIAL SYSTEM ALTERNATIVES

This section presents a comparative analysis of remedial alternatives. The alternatives are compared below on the basis of criteria defined in Section 5. The overall comparative analysis is provided on Table 2.

The optimized remedial alternatives for the site are:

- Remedial Alternative 1: No Further Action (NFA)
- Remedial Alternative 2: Dual Phase Extraction (DPE)
  - Remedial Alternative 2A: DPE – Vertical Well Design
  - Remedial Alternative 2B: DPE – Horizontal Well Design
- Remedial Alternative 3: Thermal Treatment
- Remedial Alternative 4: In-Situ Chemical Oxidation (ISCO)
  - Remedial Alternative 4A: ISCO – Vertical Well Design
  - Remedial Alternative 4B: ISCO – Horizontal and Vertical Well Design
- Remedial Alternative 5: Monitored Natural Attenuation (MNA) and Enhanced Reductive Dechlorination (ERD)
- Remedial Alternative 6: Soil Vapor Extraction (SVE) with Air Sparge (AS)

7.1 OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

Alternative 1 is not protective of human health and the environment because the contamination remains in place potentially resulting in migration of contaminants in groundwater towards the Seneca River, and it does not protect future on-site workers against vapor intrusion. Any potential future property owner would be notified of the contamination through Institutional Controls (ICs).

Alternatives 2, 3, 4, 5, and 6 provide levels of protection through operation of sub-slab depressurization (SSD) systems to mitigate vapor intrusion impacts to future on-site workers and reduce contaminant mass in groundwater thereby mitigating migration of contamination in groundwater towards the Seneca River over the duration of treatment. Alternative 2 also provides hydraulic control through groundwater extraction which would immediately mitigate migration of contamination in groundwater towards the Seneca River.

7.2 COMPLIANCE WITH STANDARDS, CRITERIA AND GUIDANCE

Alternative 1 is not expected to significantly reduce groundwater concentrations beneath Building #2. Alternatives 2, 3, and 4 may not reduce all chemical of concern (COC) concentrations to below standards, criteria, and guidance (SCGs) but are expected to significantly reduce benzene, toluene, ethylbenzene, and xylenes (BTEX), chlorinated volatile organic compound (CVOC), and 1,4-dioxane concentrations in groundwater beneath Building #2. Alternative 5, based on modeling, may reduce BTEX concentrations under MNA over time, though not necessarily below the SCGs. If the CVOC plume begins to migrate from beneath Building #2, the ERD barrier is expected to reduce CVOC groundwater concentrations as groundwater flows through the barrier. Alternative 6 is expected to significantly reduce BTEX and CVOC concentrations, however 1,-dioxane concentrations in groundwater are not expected to be significantly reduced.

7.3 LONG-TERM EFFECTIVENESS AND PERMANENCE

Alternative 1 is not expected to offer long-term effectiveness or permanence in remediation. Alternatives 2, 3, and 6 are expected to be effective and permanent in the long term with respect to reduction in CVOC and BTEX contaminant concentrations in groundwater. Alternative 2 is expected to effectively remove 1,4-dioxane concentrations with extracted groundwater, which would require treatment before discharge. Alternative 3 is expected to effectively treat 1,4-dioxane. Alternative 6 is not expected to effectively treat 1,4-dioxane. Alternative 4 may offer long-term effectiveness and permanence with respect to reduction in CVOC, BTEX, and 1,4-dioxane concentrations, but it is dependent on the injection distribution and/or potential presence of non-aqueous phase liquid (NAPL) in the subsurface. Alternative 5 may be effective and permanent in the long term for the attenuation of BTEX concentrations in groundwater and is expected to be effective for the treatment of CVOCs; however, this alternative is not expected to be effective in the long term for attenuation or treatment of 1,4-dioxane concentrations in groundwater.

Alternatives 1 and 5 are not expected to mitigate vapor intrusion to Building #2 within a 30-year period. Alternative 3 is estimated to mitigate vapor intrusion to Building #2 within a 10-year period. Alternatives 2, 4, and 6 are estimated to mitigate vapor intrusion to Building #2 within a 20-year period.

7.4 REDUCTION OF TOXICITY, MOBILITY, OR VOLUME OF CONTAMINATION

Alternatives 1 and 5 are not expected to reduce the toxicity, mobility, and volume of impacted groundwater in the foreseeable future. If the ERD barrier is implemented as part of Alternative 5, the mass of contamination in groundwater would be reduced as groundwater flows through the barrier. Alternatives 2, 3 and 6 are expected to reduce toxicity, mobility, and volume of impacted groundwater. Alternative 4 is expected to reduce the toxicity, mobility, and volume of impacted groundwater; however, mobilization of hexavalent chromium or other metals may occur in the short term.

7.5 SHORT-TERM IMPACT AND EFFECTIVENESS

Alternative 1 does not have any short-term impacts to workers or the community. Alternatives 2, 3, 4, 5, and 6 are all expected to have short-term impacts during construction activities but can be mitigated with appropriate health and safety measures.

Alternative 1 is not expected to be effective in achieving the Remedial Action Objectives (RAOs) identified for this site. Alternative 2 is expected to take an estimated duration of 5 to 10 years to achieve RAOs #1, 3, 4, and 5, and an estimated 20 years to achieve RAO #2. Alternative 3 is expected to take an estimated duration of 1 year to achieve RAOs #1, 3, 4, and 5, and an estimated 10 years to achieve RAO #2. Alternative 4 is expected to take an estimated duration of three years to achieve RAOs #1, 3, 4, and 5, and an estimated 20 years to achieve RAO #2. Alternative 5 is expected to take an estimated duration of 27 years to achieve RAOs #1, 3, and 5, and greater than 30 years to achieve RAOs #2 and #3. Alternative 6 is expected to take an estimated duration of three years to achieve RAOs #1, 3 (except for 1,4-dioxane), 4, and 5, and an estimated 20 years to achieve RAO #2.

7.6 IMPLEMENTABILITY EVALUATION

Each alternative is technically implementable with readily available methods, equipment, materials, and services. The level of disruption to Building #2 tenant operations during construction associated with Alternatives 2A, 3, and 4A is expected to be significant. If Alternative 5 requires the installation of the ERD barrier, significant, though short-term, disruption to tenant operations north of Building #2 is expected. Implementability of Alternatives 2B, 4B, and 6 would result in much less disruption to Building #2 tenant operations compared to the installation of solely vertical wells. Alternative 2A would require periodic access to Building #2 for operation and maintenance (O&M) activities for an estimated duration of 10 years, whereas Alternative 2B would not require any access to Building #2 for the same purpose. Alternative 3 would require periodic access to Building #2 for O&M activities for an estimated duration of four months. Alternative 4 would require intermittent access to Building #2 during injection events. Well installation activities for Alternative 4B may be challenging and time-consuming due to the level of precision necessary to ensure the wells operate as designed and carries the risk of multiple attempts to achieve the correct installation.

7.7 COST EVALUATION

The estimated costs associated with the implementation of each alternative are summarized in the last column on Table 2. The lowest present worth of $0 is for Alternative 1 which does not include any remedial actions or monitoring. Alternatives 2 through 6 include costs to implement the remedial alternative in addition to the operation of the SSD systems in Building #2 and estimated costs range from $6,880,000 to $11,115,000. Alternative 5 provides MNA in addition to installation of an ERD barrier, should the CVOC groundwater plume migrate from beneath Building #2, for a cost of $12,500,000.

7.8 GREEN AND SUSTAINABLE REMEDIATION ASSESSMENT

As stated in Section 5.4, the DPE and thermal treatment alternatives were subject to a green and sustainable remediation assessment in accordance with NYSDEC DER-31 provided in Appendix

C. This assessment was completed in response to input provided by NYSDEC and to aid in the comparison of these two technologies which have been assessed to be equally compliant with the threshold and primary balancing evaluation criteria.

The DPE alternative is an energy intensive treatment option with many operational components which will run 24 hours a day and seven days a week for the duration of the remedy timeframe. Overall, the DPE option has the higher environmental footprint, primarily due to the long-term operation of the system and related treatment components. The energy consumption of the thermal treatment option is not insignificant, but it is condensed to a shorter timeframe. In addition, consumption of raw materials, both to construct the remedies and to treat extracted media, contribute to the environmental footprint for both options.

SECTION 8
OPTIMIZED REMEDIAL ALTERNATIVE IMPLEMENTATION

Based on the comparison of optimized remedial alternatives, Alternative 2B, Dual Phase Extraction (DPE) utilizing horizontal wells, is the recommended approach to remediate soil and groundwater impacts in the vicinity of Building #2.

DPE utilizing horizontal wells has been selected for the following reasons:

- Previous experience with groundwater and vapor extraction technology at the site has been successful;
- Extraction of groundwater impacted with benzene, toluene, ethylbenzene and xylenes (BTEX), chlorinated volatile organic compounds (CVOCs), and 1,4-dioxane would reduce the overall contaminant mass in groundwater;
- Extraction of soil vapor impacted with BTEX and CVOCs would reduce overall contaminant mass in soil below the water table, thereby mitigating continued dissolution into groundwater;
- Horizontal well design would limit interruption to Building #2 tenant operations and property owner activities;
- Compliance with Standards, Criteria, and Guidelines, in addition to all site Remedial Action Objectives would be achieved by implementation of the DPE remedial approach; and
- Contribution to vapor intrusion from impacted soil and groundwater would be significantly reduced and potentially eliminated, resulting in deactivation of existing sub-slab depressurization systems currently in use at the site.

While the green and sustainable remediation assessment identified DPE as being a more energy intensive treatment option than thermal treatment, the distribution of cost expenditure over the lifetime of the DPE system operation is preferable from a business operations standpoint. In consideration of the green and sustainable remediation assessment, the detailed engineering design will focus on reducing the footprint of the high environmental impact items where possible.

A detailed engineering design will be undertaken pending approval from the New York State Department of Environmental Conservation (NYSDEC) to move forward with the DPE approach.

8.1 REMEDIAL DESIGN

The detailed engineering design will define elements of the recommended DPE system including:

- Number, location, and type of horizontal wells;
- Number, location, and type of vertical wells (if required);
- Location and construction of remedial equipment enclosure;
- Description and specifications of extracted groundwater remedial equipment;
- Description and specifications of extracted vapor remedial equipment;
- Process and Instrumentation Diagrams;
- Treated groundwater discharge;
- Equipment layout inside the equipment enclosure;
- Characterization and treatment of air emissions;
- System startup procedures and initial system compliance monitoring;
- Performance monitoring plan;
- Outline of the Operation, Monitoring and Maintenance Plan; and
- Schedule for an updated Interim Site Management Plan (ISMP) submittal.

8.2 SCHEDULE

The following schedule is a draft, conceptual schedule that will be refined in coordination with the property owner, subcontractors, and vendors for the design, construction, and implementation of the recommended DPE treatment system:

Task	Deliverable Dates
Develop Detailed Engineering Design in consultation with Widewaters	Estimated 20-week period following NYSDEC approval of recommended technology
Submit Detailed Engineering Design to NYSDEC	Estimated 24 weeks following NYSDEC approval of recommended technology (pending consultation with Widewaters)
Receive NYSDEC Comments on Detailed Engineering Design	4 weeks following submittal
Submit Response to NYSDEC Comments on Detailed Engineering Design	8 weeks following receipt of NYSDEC comments
Receive NYSDEC Approval of Detailed Engineering Design	4 weeks following submittal
Issue Bid Package to Installation Contractors	4 weeks following NYSDEC approval of final engineering design
Installation Contract Award	6 weeks following issuance of bid package
Initiate Remedial Construction	4 weeks following bid award
System Startup and Commissioning	To be determined in consultation with installation contractor
Submit System Install Certification Report and Operation, Monitoring & Maintenance Plan	To be determined in consultation with installation contractor
Submit Updates to the ISMP	4 weeks following completion of System Startup and Commissioning

SECTION 9 REFERENCES

AECOM, 2017. *Interim Site Management Plan*. July 25 (revised through June 3, 2019).

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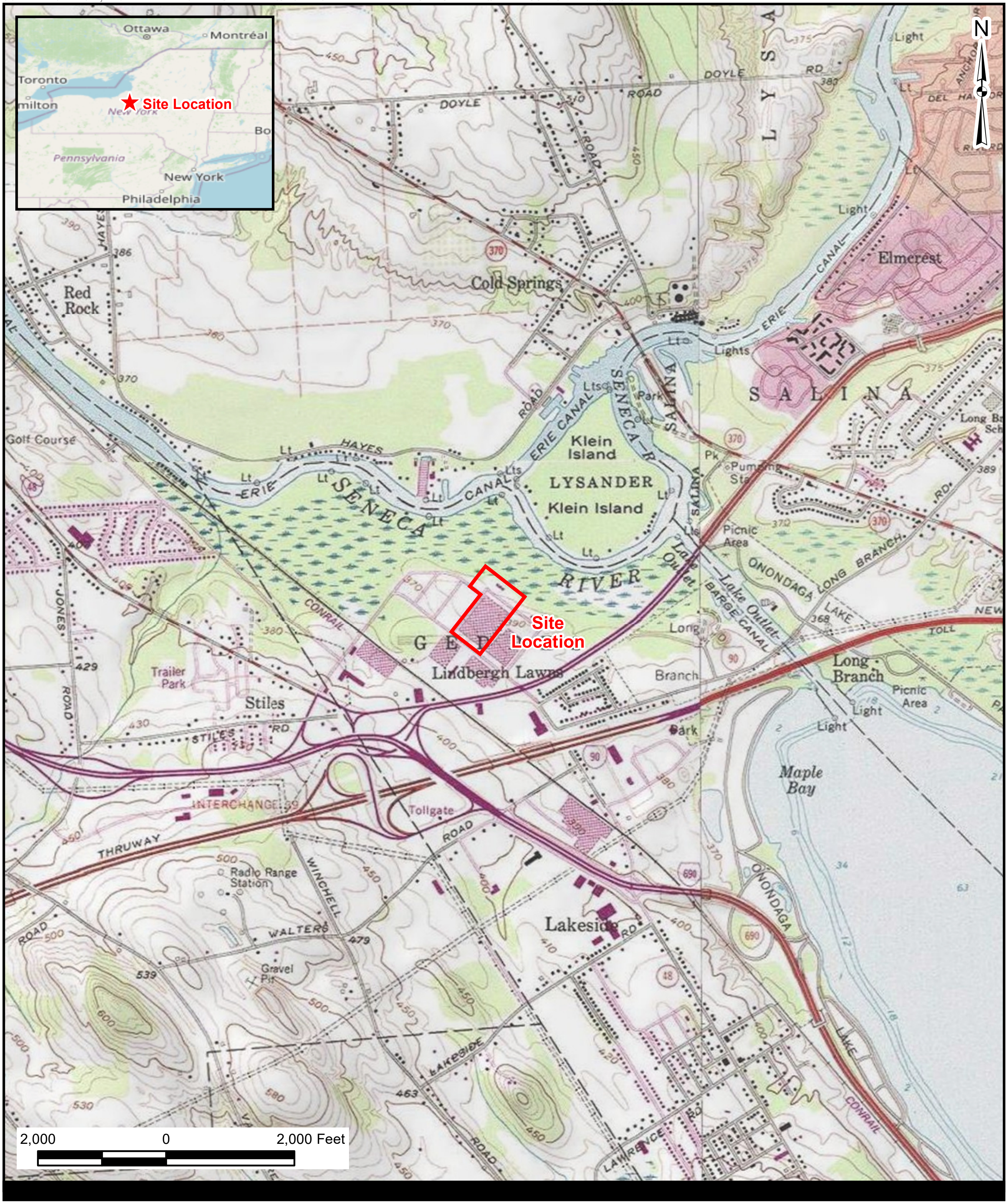
FIGURES

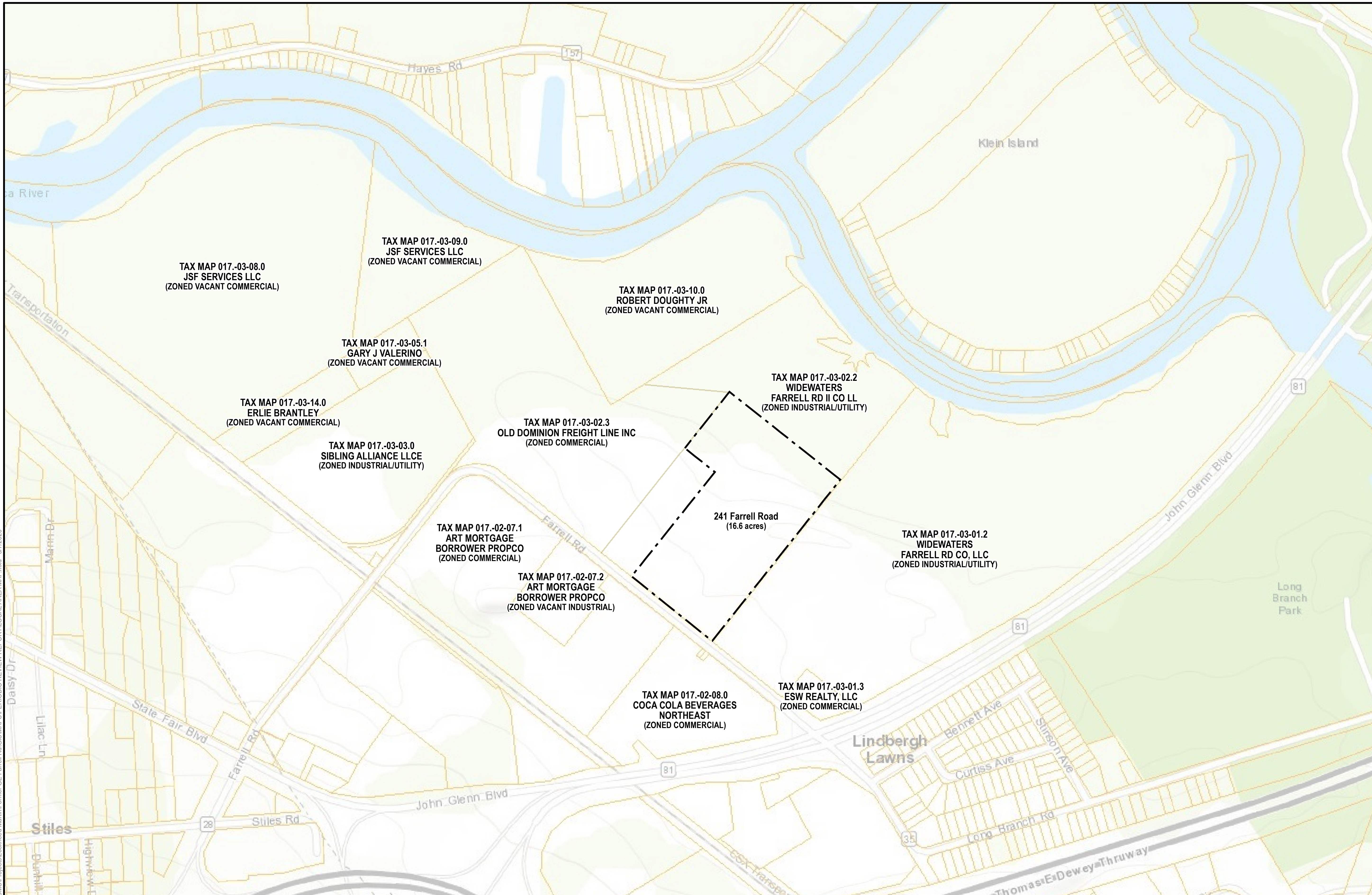
J:\Resources\RDMS\Projects\Lockheed Martin\Former GE Farrell Rd\GIS\MAPS\WETLAND REMEDIATION WORK PLAN\01 SITE LOCATION.mxd 6/10/2020



LOCKHEED MARTIN CORPORATION
FORMER G.E. FARRELL ROAD SITE
TOWN OF GEDDES, ONONDAGA COUNTY, NY
Project No.: 60624041 Date: June 10, 2020

SITE LOCATION MAP

AECOM
Figure: 1



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Reference:
Syracuse-Onondaga County GIS on the Web

500 0 500 Feet

AECOM
Figure: 2

LOCAL AREA MAP

LOCKHEED MARTIN CORPORATION
FORMER G.E. FARRELL ROAD SITE
TOWN OF GEDDES, ONONDAGA COUNTY, NEW YORK
Project No.: 60624041 Date: May 7, 2020

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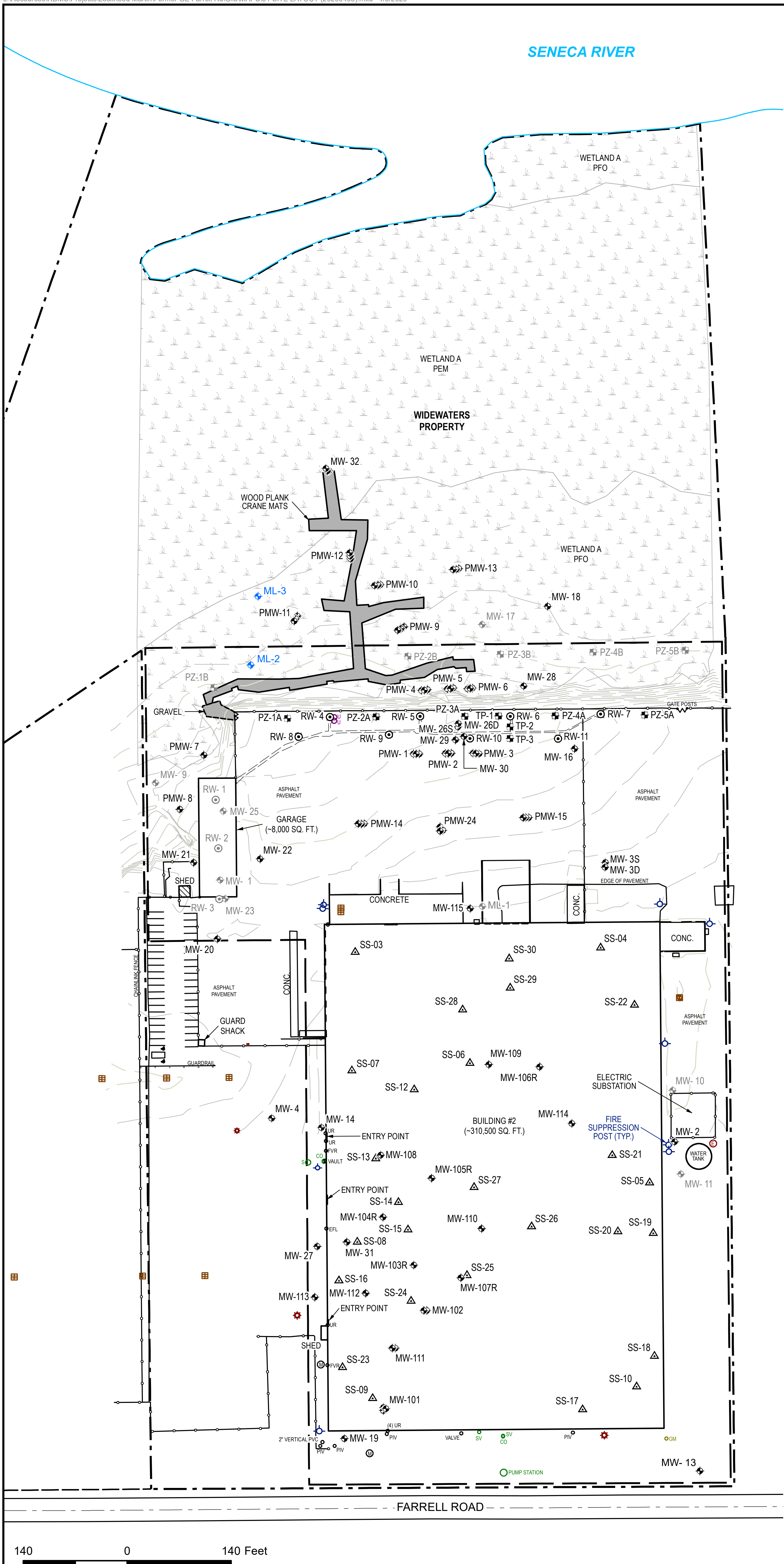


Legend

- Monitoring Well [1]
- Continuous Multichamber Tubing (CMT) Well
- Abandoned/ Decommissioned Well
- Groundwater Extraction Well
- Piezometer
- Sub-Slab Soil Vapor Sampling Point
- Unknown Manhole
- Sanitary Manhole
- SV CO — Sewer Vent/ Clean Out
- Catch Basin
- GM — Gas Marker
- Electric Manhole
- Light Pole
- Fire Hydrant/ Fire Suppression Post
- PIV — Post Indicator Valve
- Manhole
- FVR — Former Vent Riser
- UR — Utility Riser
- EFL — Sub-Slab Depressurization System Exhaust Fan Location
- 241 Farrell Road (16.6 acres) [2]
- Widewaters Property
- Trench Outline
- Topographic Contour
- Chainlink Fence
- Lockheed Martin Storage Shed
- Wetland Construction Mat Access Road
- Delineated Wetland Area [3]

Footnotes:
1. PMW- 1 through PMW- 6, PMW- 9 through PMW-15, and PMW-24 are deep, intermediate, and shallow-screened sets of wells.
2. Site boundary as defined in April 26, 2012 NYSDEC correspondence (refer to Interim Site Management Plan, dated July 25, 2017).
3. Wetland areas were delineated in May 2017.

Notes:
- PEM = Palustrine Emergent
- PFO = Palustrine Forested
- Abandoned/ decommissioned wells are shown in gray. Locations were not surveyed and are approximate.
- SS-15, SS-16, SS-24, and SS-25 represent sub-slab, 4-ft and 8-ft soil vapor sample locations.

Reference:
Site layout based on survey information provided by CNY Land Surveying drawing, Farrell Road topographic survey and monitoring well locations, dated April 2, 2016.

LOCKHEED MARTIN CORPORATION
FORMER G.E. FARRELL ROAD SITE
TOWN OF GEDDES, ONONDAGA COUNTY, NEW YORK
Project No.: 60598883 Date: April 3, 2020

SITE LAYOUT MAP

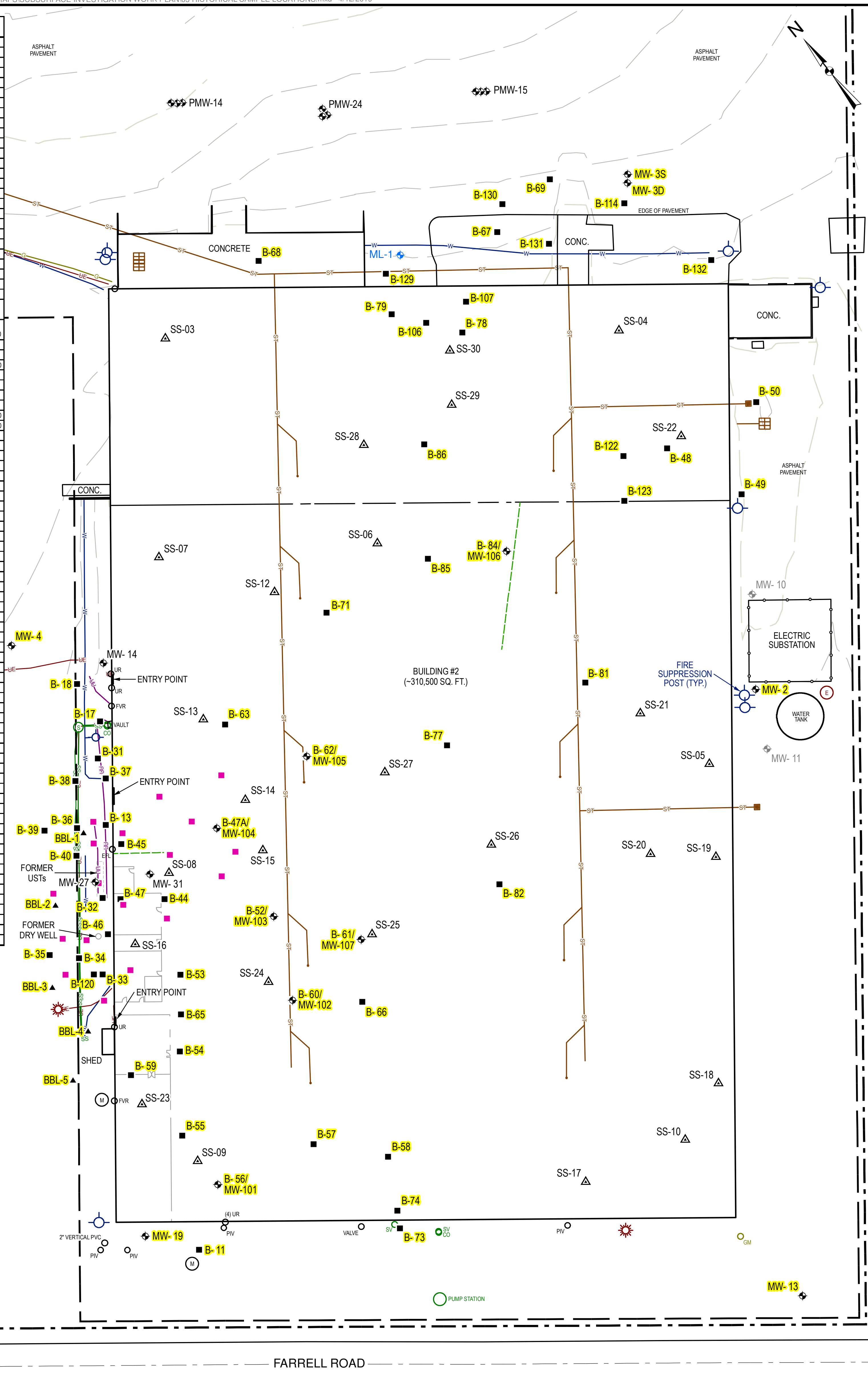
AECOM

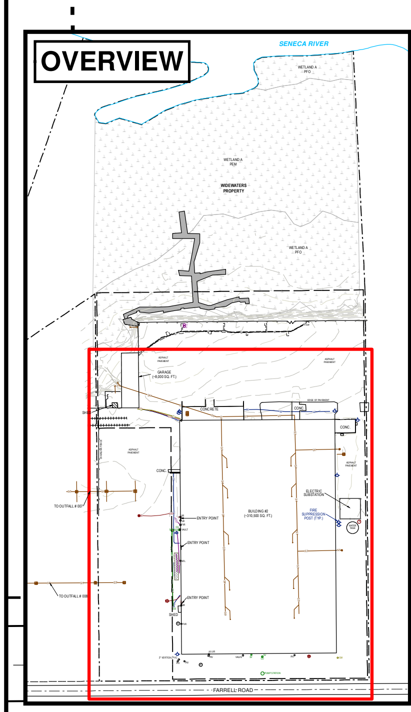
Figure: 3

J:\Resources\RDMS\Projects\Lockheed Martin\Former GE Farrell Rd\GIS\MAPS\SUBSURFACE INVESTIGATION WORK PLAN\03 HISTORICAL SAMPLE LOCATIONS.mxd 4/12/2019

Boring ID	Soil Sample Date	CVOCs (ppb)	BTEX (ppb)	Groundwater Sample Date	CVOCs (ppb)	BTEX (ppb)
BBL-1 (8-10')	9/25-27/95	ND	ND	--	--	--
BBL-1 (16-16.4')	9/25-27/95	ND	1 (J)	--	--	--
BBL-1 (22-24')	9/25-27/95	ND	2 (J)	--	--	--
BBL-2 (8-10')	9/25-27/95	3 (J)	ND	--	--	--
BBL-2 (14-16')	9/25-27/95	ND	ND	--	--	--
BBL-3 (8-10')	9/25-27/95	ND	ND	--	--	--
BBL-3 (12-14')	9/25-27/95	ND	2 (J)	--	--	--
BBL-3 (22-24')	9/25-27/95	ND	6 (J)	--	--	--
BBL-4 (12-14')	9/25-27/95	ND	889	--	--	--
BBL-4 (21-22')	9/25-27/95	17 (J)	12 (J)	--	--	--
BBL-5 (12-14')	9/25-27/95	ND	10 (J)	--	--	--
BBL-5 (24-26')	9/25-27/95	13 (J)	1 (J)	--	--	--
BBL-5 (28-30')	9/25-27/95	ND	2 (J)	--	--	--
B-11 (11')	1/22/92	26	ND	--	--	--
B-13 (6')	1/21/92	650,000	6,930,000	--	--	--
B-17 (10')	--	--	--	--	--	--
B-18 (6-8')	1/21/92	ND	6	--	--	--
B-31 (7')	2/3/92	30	ND	--	--	--
B-32	--	--	--	--	--	--
B-33 (9')	2/3/92	17,000	97,400	--	--	--
B-34	--	--	--	--	--	--
B-35 (5')	2/3/92	ND	10	--	--	--
B-36 (9')	2/3/92	140,000	2,160,000	--	--	--
B-37	--	--	--	--	--	--
B-38 (5')	2/3/92	14	5	--	--	--
B-39 (5')	2/3/92	ND	9	--	--	--
B-40 (8') B-40 (13')	2/3/92	35,600 ND	336,000 427,000	--	--	--
B-44 (6') B-44 (10')	3/16/92	23 1,300	ND ND	3/16/1992	34,100	768,600
B-45 (8')	3/12/92	80	0	3/13/92	1,310	7
B-46/MW-14 (8')	3/13/92	ND	ND	3/26/92	ND	ND
B-47 (9')	3/13/92	12,350	37,400	3/13/92	192,000	511,000
B-47A/MW-104 (9')	3/18/92	93	830	3/18/92	920	3,010
B-48 (1')	3/12/92	ND	ND	3/13/92	99	ND
B-49	--	--	--	--	--	--
B-50	--	--	--	--	--	--
B-52/MW-103 (8')	4/6/92	51	ND	4/6/92	64,220	155,880
B-53 (8')	4/25/92	6	ND	4/26/92	85,100	113,100
B-54 (4')	4/25/92	ND	ND	--	--	--
B-55 (8')	4/25/92	ND	ND	--	--	--
B-56/MW-101	--	--	--	4/30/92	37	ND
B-57 (7')	4/25/92	ND	ND	--	--	--
B-58 (4')	4/25/92	ND	ND	--	--	--
B-59 (7')	4/25/92	ND	ND	--	--	--
B-60/MW-102 (7')	4/25/92	ND	ND	4/30/92	474	ND
B-61/MW-107 (8')	4/26/92	8	ND	4/30/92	343	ND
B-62/MW-105 (7')	4/26/92	ND	ND	4/27/92	760	2,180
B-63 (8')	4/27/92	43	ND	--	--	--
B-65 (8')	4/27/92	43	ND	4/23/92	24,850	40,800
B-66 (8')	4/27/92	ND	ND	--	--	--
B-67 (1-3')	4/23/92	56	ND	4/24/92	270	ND
B-68 (8-10')	4/23/92	120	1,900	4/25/92	1,250	12,000
B-69 (8-10')	4/23/92	ND	ND	--	--	--
B-71 (15')	5/5/92	ND	ND	5/5/92	ND	ND
B-73 (4-6')	4/24/92	ND	ND	--	--	--
B-74 (7')	4/26/92	ND	ND	4/25/92	8	ND
B-75 (8-10')	4/23/92	7	74	4/23/92	50	4,860
B-76 (8-10')	4/23/92	2,855	225	4/23/92	3,530	60
B-77 (8')	4/27/92	ND	ND	4/27/92	11,900	24,700
B-78 (8')	4/27/92	ND	ND	--	--	--
B-79 (8.5')	4/27/92	ND	ND	--	--	--
B-81 (14')	5/5/92	ND	ND	5/5/92	ND	ND
B-82 (14')	5/5/92	ND	ND	5/5/92	ND	ND
B-84/MW-106	--	--	--	5/5/92	94	ND
B-85 (15')	4/29/92	ND	8	4/29/92	ND	8
B-86 (15')	5/6/92	11	ND	5/6/92	11	ND
B-106 (2-3')	11/1/93	NS	NS	--	--	--
B-106 (5-6')	11/1/93	NS	NS	--	--	--
B-107 (2-3')	10/28/94	NS	NS	--	--	--
B-107 (5-6')	10/28/94	NS	NS	--	--	--
B-114 (5-7')	5/4/94	ND	ND	--	--	--
B-114 (7-9')	5/4/94	ND	ND	--	--	--
B-120 (2-4')	4/26/94	ND	ND	--	--	--
B-122 (0-1')	10/28/93	NS	NS	--	--	--
B-123 (0-1')	10/28/93	NS	NS	--	--	--
B-129 (3-5')	5/5/94	ND	ND	--	--	--
B-129 (9-11')	5/5/94	ND	ND	--	--	--
B-130 (3-5')	5/4/94	ND	ND	--	--	--
B-130 (9-11')	5/4/94	ND	ND	--	--	--
B-131 (3-5')	5/4/94	ND	ND	--	--	--
B-131 (7-9')	5/4/94	ND	ND	--	--	--
B-132 (3-5')	5/5/94	ND	ND	--	--	--
B-132 (5-7')	5/5/94	ND	ND	--	--	--
MW-2	--	--	--	5/23/91	966	38
MW-3S	--	--	--	2/3/92	4,200	ND
MW-3D	--	--	--	3/26/92	297	ND
MW-4	--	--	--	2/3/92	4	ND
MW-13	--	--	--	5/23/91	ND	ND
MW-19	--	--	--	3/26/92	54	ND

NS - Not Sampled for Volatile Organic Compounds
-- indicates no sample date and no data
Boring locations are shown on figure highlighted in yellow





Legend

- Monitoring Well [1]
- Groundwater Extraction Well
- Continuous Multichamber Tubing (CMT) Well
- Piezometer
- Sub-Slab Soil Vapor
- Historic Soil Boring
- Historic LNAPL/DNAPL Investigation Soil Boring
- September 2002 Confirmatory Soil Sample (CSB-501 through CSB-518)
- Unknown Manhole
- Sanitary Manhole
- SV CO Sewer Vent/ Clean Out
- Catch Basin
- GM Gas Marker
- Electric Manhole
- Light Pole
- Fire Hydrant/ Fire Suppression Post
- PIV Post Indicator Valve
- Manhole
- FVR Former Vent Riser
- UR Utility Riser
- EFL Sub-Slab Depressurization System Exhaust Fan Location
- Lockheed Martin Storage Shed
- 241 Farrell Road (16.6 acres) [2]
- Widewaters Property
- Topographic Contour
- Chainlink Fence
- SSDS System
- E Subgrade System Piping for the Groundwater Extraction Treatment System
- SS Sanitary Sewer Line
- ST Storm Sewer Line
- G Underground Gas Line
- UE Underground Electric Line
- W Underground Water Line
- UU Unknown Utility Line

Notes:
1. PMW- 1 through PMW- 6, PMW- 9 through PMW-13, and PMW-24 are deep, intermediate, and shallow-screened sets of wells.
2. Site boundary as defined in April 26, 2012 NYSDEC correspondence (refer to Interim Site Management Plan, dated July 25, 2017).
3. Abandoned/ decommissioned wells are shown in gray. Locations were not surveyed and are approximate.
4. All historic locations are approximate.

Reference:
Site layout based on survey information provided by CNY Land Surveying drawing, Farrell Road topographic survey and monitoring well locations, dated April 2, 2016.

80 0 80 Feet

LOCKHEED MARTIN CORPORATION
FORMER G.E. FARRELL ROAD SITE
TOWN OF GEDDES, ONONDAGA COUNTY, NEW YORK
Project No.: 60598882 Date: April 12, 2019

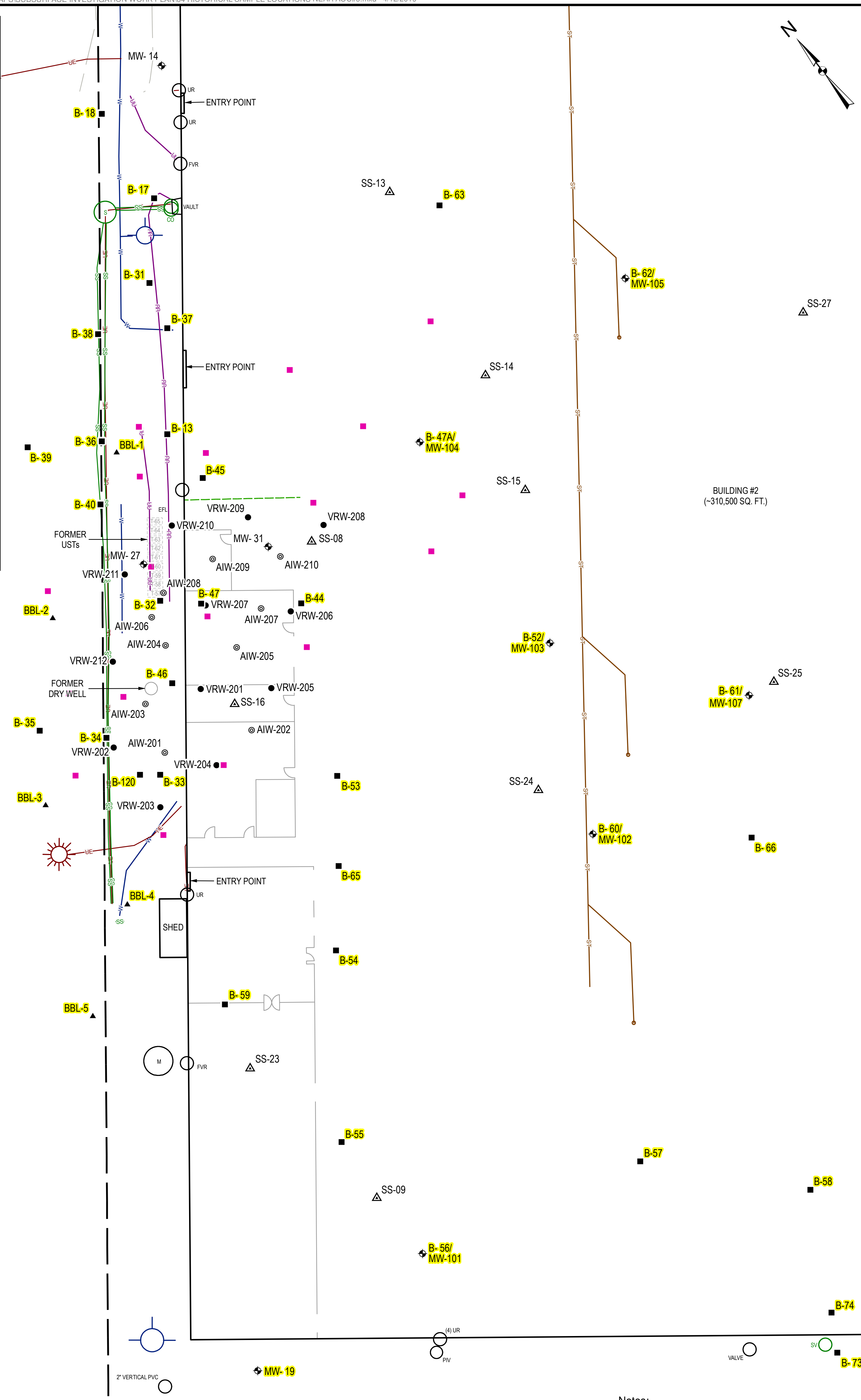
HISTORICAL SOIL AND GROUNDWATER SAMPLE LOCATIONS AND DATA IN VICINITY OF BUILDING #2

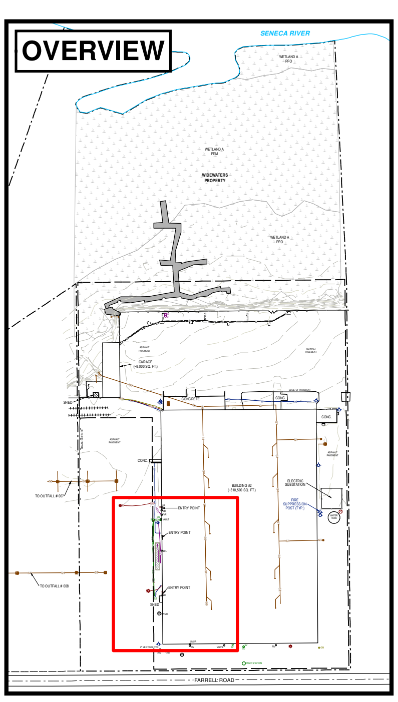
AECOM
Figure: 4

J:\Resources\RDMS\Projects\Lockheed Martin\Former GE Farrell Rd\GIS\MAPS\SUBSURFACE INVESTIGATION WORK PLAN\04 HISTORICAL SAMPLE LOCATIONS NEAR AOC#5.mxd 4/12/2019

Boring ID	Soil Sample Date	CVOCs (ppb)	BTEX (ppb)	Groundwater Sample Date	CVOCs (ppb)	BTEX (ppb)
BBL-1 (8-10')	9/25-27/95	ND	ND	--	--	--
BBL-1 (16-16.4')	9/25-27/95	ND	1 (J)	--	--	--
BBL-1 (22-24')	9/25-27/95	ND	2 (J)	--	--	--
BBL-2 (8-10')	9/25-27/95	3 (J)	ND	--	--	--
BBL-2 (14-16')	9/25-27/95	ND	ND	--	--	--
BBL-3 (8-10')	9/25-27/95	ND	ND	--	--	--
BBL-3 (12-14')	9/25-27/95	ND	2 (J)	--	--	--
BBL-3 (22-24')	9/25-27/95	ND	6 (J)	--	--	--
BBL-4 (12-14')	9/25-27/95	ND	889	--	--	--
BBL-4 (21-22')	9/25-27/95	17 (J)	12 (J)	--	--	--
BBL-5 (12-14')	9/25-27/95	ND	10 (J)	--	--	--
BBL-5 (24-26')	9/25-27/95	13 (J)	1 (J)	--	--	--
BBL-5 (28-30')	9/25-27/95	ND	2 (J)	--	--	--
B-13 (6')	1/21/92	650,000	6,930,000	--	--	--
B-17 (10')	--	--	--	--	--	--
B-18 (6-8')	1/21/92	ND	6	--	--	--
B-31 (7')	2/3/92	30	ND	--	--	--
B-32	--	--	--	--	--	--
B-33 (9')	2/3/92	17,000	97,400	--	--	--
B-34	--	--	--	--	--	--
B-35 (5')	2/3/92	ND	10	--	--	--
B-36 (9')	2/3/92	140,000	2,160,000	--	--	--
B-37	--	--	--	--	--	--
B-38 (5')	2/3/92	14	5	--	--	--
B-39 (5')	2/3/92	ND	9	--	--	--
B-40 (8') B-40 (13')	2/3/92	35,600 ND	336,000 427,000	--	--	--
B-44 (6') B-44 (10')	3/16/92	23 1,300	ND ND	3/16/1992	34,100	768,600
B-45 (8')	3/12/92	80	ND	3/13/92	1,310	7
B-46/MW-14 (8')	3/13/92	ND	ND	3/26/92	ND	ND
B-47 (9')	3/13/92	12,350	37,400	3/13/92	192,000	511,000
B-47A/MW-104 (9')	3/18/92	93	830	3/18/92	920	3,010
B-52/MW-103 (8')	4/6/92	51	ND	4/6/92	64,220	155,880
B-53 (8')	4/25/92	6	ND	4/26/92	85,100	113,100
B-54 (4')	4/25/92	ND	ND	--	--	--
B-55 (8')	4/25/92	ND	ND	--	--	--
B-56/MW-101	--	--	--	4/30/92	37	ND
B-57 (7')	4/25/92	ND	ND	--	--	--
B-58 (4')	4/25/92	ND	ND	--	--	--
B-59 (7')	4/25/92	ND	ND	--	--	--
B-60/MW-102 (7')	4/25/92	ND	ND	4/30/92	474	ND
B-61/MW-107 (8')	4/26/92	8	ND	4/30/92	343	ND
B-62/MW-105 (7')	4/26/92	ND	ND	4/27/92	760	2,180
B-63 (8')	4/27/92	43	ND	--	--	--
B-65 (8')	4/27/92	43	ND	4/23/92	24,850	40,800
B-66 (8')	4/27/92	ND	ND	--	--	--
B-73 (4-6')	4/24/92	ND	ND	--	--	--
B-74 (7')	4/26/92	ND	ND	4/25/92	8	0
B-77 (8')	4/27/92	ND	ND	4/27/92	11,900	24,700
B-120 (2-4')	4/26/94	ND	ND	--	--	--
MW-4	--	--	--	2/3/92	4	ND
MW-19	--	--	--	3/26/92	54	ND

NS - Not Sampled for Volatile Organic Compounds
-- indicates no sample date and no data
Boring locations are shown on figure highlighted in yellow





Legend

Monitoring Well [1]	Unknown Manhole	Manhole
Groundwater Extraction Well	Sanitary Manhole	FVR Former Vent Riser
Continuous Multichamber Tubing (CMT) Well	SV CO Sewer Vent/ Clean Out	UR Utility Riser
Piezometer	Catch Basin	EFL Sub-Slab Depressurization System Exhaust Fan Location
Sub-Slab Soil Vapor	GM Gas Marker	Lockheed Martin Storage Shed
Historic Soil Boring	Electric Manhole	241 Farrell Road (16.6 acres) [2]
Historic LNAPL/DNAPL Investigation Soil Boring	Light Pole	Widewaters Property
Historic Air Injection Well	Fire Hydrant/ Fire Suppression Post	Topographic Contour
Historic Vapor Recovery Well	PIV Post Indicator Valve	Chainlink Fence
September 2002 Confirmatory Soil Sample (CSB-501 through CSB-518)		

SSDS System	
E	Subgrade System Piping for the Groundwater Extraction Treatment System
SS	Sanitary Sewer Line
ST	Storm Sewer Line
G	Underground Gas Line
UE	Underground Electric Line
W	Underground Water Line
UU	Unknown Utility Line

Notes:
1. PMW- 1 through PMW- 6, PMW- 9 through PMW-13, and PMW-24 are deep, intermediate, and shallow-screened sets of wells.
2. Site boundary as defined in April 26, 2012 NYSDEC correspondence (refer to Interim Site Management Plan, dated July 25, 2017).
3. Abandoned/ decommissioned wells are shown in gray. Locations were not surveyed and are approximate.
4. All historic locations are approximate.

Reference:
Site layout based on survey information provided by CNY Land Surveying drawing, Farrell Road topographic survey and monitoring well locations, dated April 2, 2016.

35 0 35 Feet

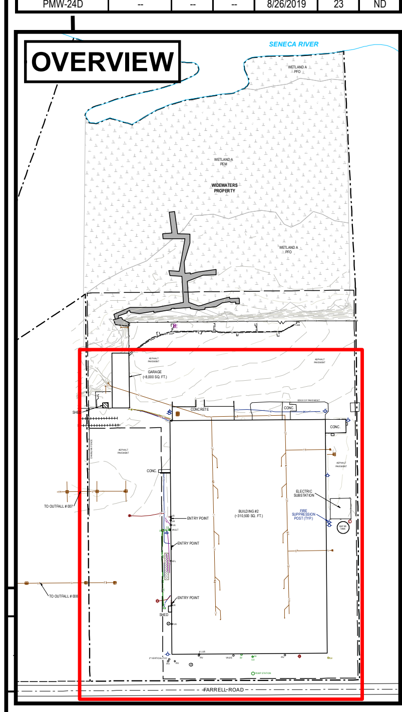
LOCKHEED MARTIN CORPORATION
FORMER G.E. FARRELL ROAD SITE
TOWN OF GEDDES, ONONDAGA COUNTY, NEW YORK
Project No.: 60598882 Date: April 12, 2019

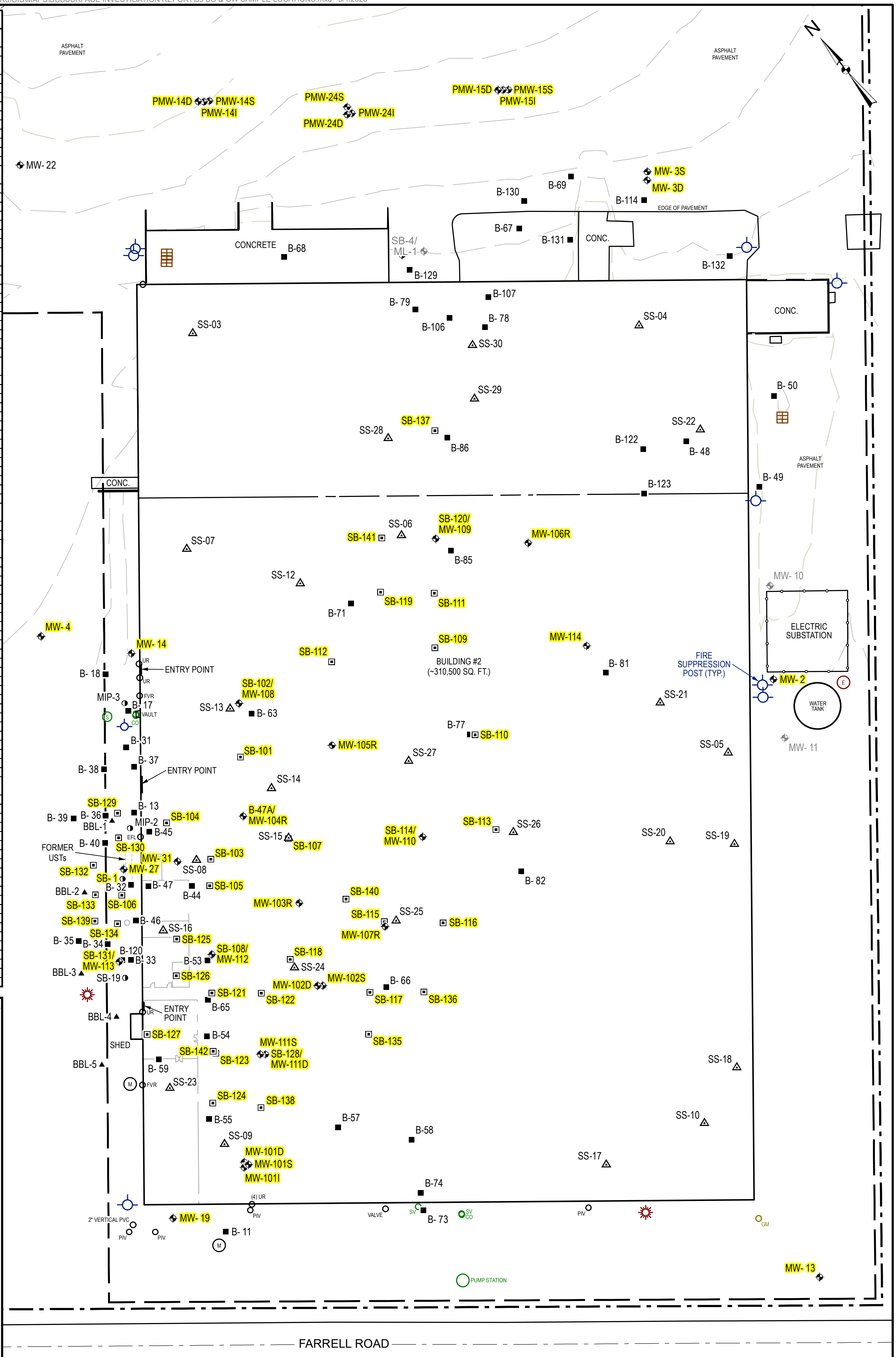
FOCUS VIEW OF HISTORICAL SOIL AND GROUNDWATER SAMPLE LOCATIONS AND DATA IN VICINITY OF AOC #5

AECOM
Figure: 5

J:\Resources\RDMS\Projects\Lockheed Martin\Former GE Farrell Rd\GIS\MAPS\SUBSURFACE INVESTIGATION REPORT\05 SO & GW SAMPLE LOCATIONS.mxd 5/1/2020

Boring ID	Soil Sample Date	CVOCs (ppb)	BTEX (ppb)	Groundwater Sample Date	CVOCs (ppb)	BTEX (ppb)
SB-1/MW-27 (9-10) SB-1/MW-27 (13-14)	9/12/2016	0 18.3	66,000 2,631	8/28/2019	15	25,610
SB-101 (7-8)	6/24/2019	ND	ND	6/24/2019	6.1	0.68
SB-102 / MW-108	--	--	--	6/25/2019 8/28/2019	0.80 5.9	0.87 5.61
SB-103 (10-11)	6/26/2019	91	1,650	--	--	--
SB-103 (14-15)	6/26/2019	8.36	14.68	6/26/2019	258.92	1,470
SB-104 (6-7)	6/27/2019	ND	ND	6/27/2019	4.76	5.79
SB-105 (11-12)	6/27/2019	86.2	368	--	--	--
SB-105 (16-17)	6/27/2019	14.63	106.3	6/27/2019	447.7	2,329
B-47A (13.5-14.5)	6/28/2019	1.42	3.4	--	--	--
SB-106 (7-8)	6/28/2019	9.9	0.18	6/28/2019	25.45	8.62
SB-107 (9-10)	7/1/2019	33	1,170	--	--	--
SB-107 (13-14)	7/1/2019	83	1,280	7/1/2019	594.7	1,176.42
SB-108 (10-11)	7/2/2019	34,666	31,829	--	--	--
SB-108 (18-19) / MW-112	7/2/2019	47.08	64	7/2/2019 8/28/2019	32,949 87,620	35,790 97,620
SB-109 (13-14)	7/8/2019	150	114.8	7/8/2019	5,503.8	3,928.9
SB-110 (14-15)	7/9/2019	99.78	263.25	7/9/2019	7,620	10,215
SB-111 (15-16)	7/9/2019	94	194.1	7/9/2019	5,106.3	4,254.8
SB-112 (9-10)	7/10/2019	9.19	ND	7/10/2019	11.2	3.52
SB-113 (7-8)	7/11/2019	9.81	ND	7/11/2019	ND	ND
SB-114 (8-9)	7/11/2019	347.8	10.18	--	--	--
SB-114 (9-10)	7/11/2019	1,130	1,544	--	--	--
SB-114 (14-15) / MW-110	7/11/2019	1,605	4,588	7/11/2019 8/28/2019	21,910 15,987	72,300 44,921
SB-114 (15-15.5)	7/11/2019	2,010	7,430	--	--	--
SB-114 (15.5-16)	7/11/2019	2,231	26,340	--	--	--
SB-115 (15-16)	7/12/2019	1,121	4,000	--	--	--
SB-115 (18-19)	7/12/2019	2,190	9,030	7/12/2019	6,668	40,703
SB-116 (9-10)	7/15/2020	2.89	ND	7/15/2019	3.92	0.71
SB-117 (19-20)	7/15/2019	68.99	0.54	7/15/2019	463.8	3.12
SB-118 (9-10)	7/16/2019	2,700	6,907	--	--	--
SB-118 (14-15)	7/16/2019	7,750	10,280	--	--	--
SB-118 (19-20)	7/16/2019	211.94	31.26	7/16/2019	11,534	2,501
SB-119	--	--	--	7/22/2019	38.4	ND
SB-120 / MW-109	--	--	--	7/22/2019 8/28/2019	10,600 5,414	17,880 2,981
SB-121 (13-14)	7/24/2019	3,690	10,970	--	--	--
SB-121 (17-18)	7/24/2019	12,870	14,330	--	--	--
SB-121 (21-22)	7/24/2019	44.68	12.1	7/24/2019	249,300	216,300
SB-122 (15-16)	7/26/2019	3,840	4,451	--	--	--
SB-122 (21-22)	7/26/2019	233.47	26.68	7/26/2019	10,309	1,614
SB-123 (17-18)	7/25/2019	6.5	ND	--	--	--
SB-123 (21-22)	7/25/2019	1,970	2,190	--	--	--
SB-123 (25-26)	7/25/2019	731	1,048	7/25/2019	26,890	53,000
SB-124 (8-9)	7/31/2019	ND	ND	7/31/2019	119.9	32.1
SB-125 (12-13)	7/29/2019	990	1,202	--	--	--
SB-125 (17-18)	7/29/2019	6.94	2.32	7/30/2019	3,648.1	5,354.7
SB-126 (10-11)	7/30/2019	39,449	44,280	--	--	--
SB-126 (17-18)	7/30/2019	96.92	92.1	7/30/2019	139,070	141,000
SB-127 (18-19)	7/31/2019	2.4	34.1	7/31/2019	60.6	234
SB-128 (23-24) / MW-111D	8/1/2019	6,450	12,530	8/1/2019 8/28/2019	42,000 6,256	90,100 10,990
SB-129 (8-9)	8/5/2019	0.27	ND	8/5/2019	0.94	ND
SB-130 (7-8)	8/5/2019	ND	ND	8/5/2019	2.1	ND
SB-131 (9-10) / MW-113	8/5/2019	0.4	3.07	8/5/2019 8/28/2019	5.12 3.96	ND 35.8
SB-132 (9-10)	8/5/2019	0.41	ND	8/5/2019	1.46	0.65
SB-133	--	--	--	8/6/2019	7.72	3.3
SB-134 (9-10)	8/6/2019	62	37,760	--	--	--
SB-134 (17-18)	8/6/2019	2.11	0.34	8/6/2019	10	8.54
SB-135	--	--	--	8/7/2019	300.51	2.08
SB-136	--	--	--	8/7/2019	3.2	0.48
SB-137	--	--	--	8/7/2019	350.72	6.8
SB-138 (9-10)	8/8/2019	0.35	ND	8/8/2019	237.54	0.68
SB-139 (9-10)	8/8/2019	1.3	ND	8/8/2019	4.9	3.1
SB-140 (10-11)	8/9/2019	2,240	3,666	--	--	--
SB-140 (17-18)	8/9/2019	830	493	--	--	--
SB-140 (18-19)	8/9/2019	440	2,840	--	--	--
SB-140 (19-20)	8/9/2019	400	1,553	8/9/2019	18,472	31,831
SB-141 (10-11)	8/9/2019	6.09	ND	8/9/2019	26.92	6.54
SB-142 (20-21)	8/23/2019	2,056	3,730	--	--	--
SB-142 (24-25)	8/23/2019	1,386	2,433	--	--	--
SB-142 (27-28)	8/23/2019	2,740	4,340	8/23/2019	9,064	10,210
MW-2	--	--	--	8/27/2019	ND	ND
MW-3S	--	--	--	8/26/2019	0.8	ND
MW-3D	--	--	--	8/26/2019	3.6	ND
MW-4	--	--	--	8/29/2019	0.6	1.5
MW-13	--	--	--	8/27/2019	ND	ND
MW-14	--	--	--	8/28/2019	ND	ND
MW-19	--	--	--	8/27/2019	14	ND
MW-31 (10-12) MW-31 (16-18)	11/28/2017	210 1.9	20600 82.5	8/27/2019	3,530	96,900
MW-101S	--	--	--	8/28/2019	ND	ND
MW-101I	--	--	--	8/28/2019	0.29	ND
MW-101D	--	--	--	8/28/2019	0.51	0.7
MW-102S	--	--	--	8/28/2019	19,454	22,587
MW-102D	--	--	--	8/28/2019	64,520	89,100
MW-103R	--	--	--	8/28/2019	10,018	12,354
MW-104R	--	--	--	8/28/2019	430	75,800
MW-105R	--	--	--	8/28/2019	196.5	21.2
MW-106R	--	--	--	8/28/2019	121.08	2.0
MW-107R	--	--	--	8/28/2019	10,112	20,351
MW-111S	--	--	--	8/28/2019	215.85	1.59
MW-114	--	--	--	9/3/2019	0.59	ND
PMW-14S	--	--	--	8/26/2019	ND	ND
PMW-14I	--	--	--	8/26/2019	0.97	ND
PMW-14D	--	--	--	8/26/2019	2.56	ND
PMW-15S	--	--	--	8/26/2019	ND	ND
PMW-15I	--	--	--	8/26/2019	0.79	ND
PMW-15D (31.4-32)	12/2/2015	11.3	ND	8/26/2019	74.3	ND
PMW-24S	--	--	--	7/30/2018	ND	ND
PMW-24I	--	--	--	8/26/2019	0.56	ND
PMW-24D	--	--	--	8/26/2019	23	ND





Legend

Monitoring Well [1]	Unknown Manhole	Manhole
Groundwater Extraction Well	Sanitary Manhole	Former Vent Riser
Continuous Multichamber Tubing (CMT) Well	Sewer Vent/ Clean Out	Utility Riser
Piezometer	Catch Basin	Sub-Slab Depressurization System Exhaust Fan Location
Sub-Slab Soil Vapor	Gas Marker	Lockheed Martin Storage Shed
Historic Soil Boring	Electric Manhole	241 Farrell Road (16.6 acres) [2]
Historic LNAPL/DNAPL Investigation Soil Boring	Light Pole	Widewaters Property
Membrane Interface Probe Location	Fire Hydrant/ Fire Suppression Post	Topographic Contour
	Post Indicator Valve	Chainlink Fence

Notes:
1. PMW- 1 through PMW- 6, PMW- 9 through PMW-13, and PMW-24 are deep, intermediate, and shallow-screened sets of wells.
2. Site boundary as defined in April 26, 2012 NYSDEC correspondence (refer to Interim Site Management Plan, dated July 25, 2017).
3. Abandoned/ decommissioned wells are shown in gray. Locations were not surveyed and are approximate.
4. All historic locations are approximate.
5. CVOC concentrations tabulated and depicted on this figure include only 1,1,1-TCA, 1,1-DCE, 1,1-DCA, TCE, and Freon-11.
6. Highlighted locations have data presented in the table.

Reference:
Site layout based on survey information provided by CNY Land Surveying drawing, Farrell Road topographic survey and monitoring well locations, dated April 2, 2016.

80 0 80 Feet

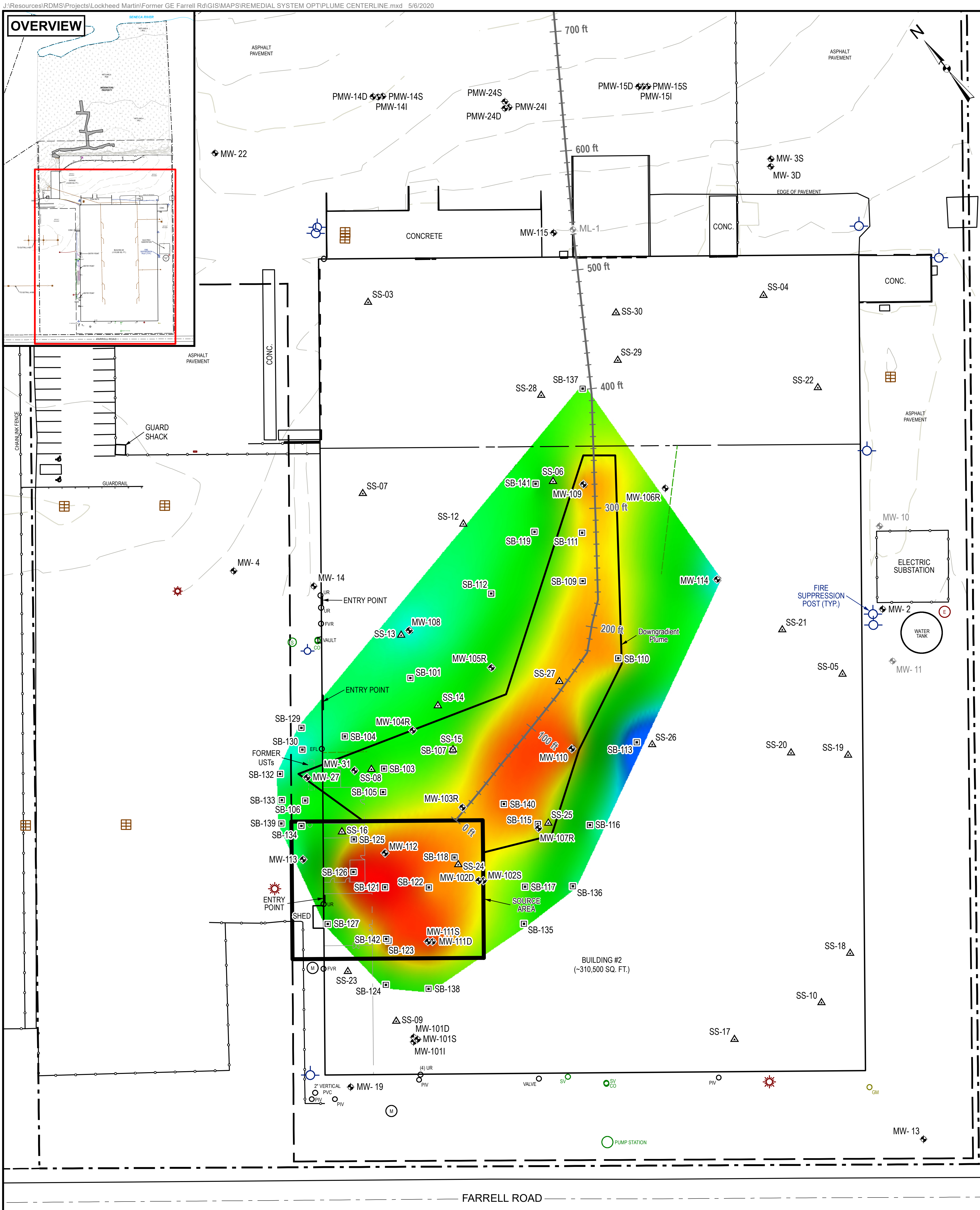
LOCKHEED MARTIN CORPORATION
FORMER G.E. FARRELL ROAD SITE
TOWN OF GEDDES, ONONDAGA COUNTY, NEW YORK
Project No.: 60598882 Date: May 1, 2020

SOIL AND GROUNDWATER SAMPLE LOCATIONS AND DATA

AECOM

Figure: 6

J:\Resources\RDMS\Projects\Lockheed Martin\Former GE Farrell Rd\GIS\MAPS\REMEDIAL SYSTEM OPT\PLUME CENTERLINE.mxd 5/6/2020



Legend

Monitoring Well [1]	Gas Marker
Continuous Multichamber Tubing (CMT) Well	Electric Manhole
Abandoned/ Decommissioned Well	Light Pole
Groundwater Extraction Well	Fire Hydrant/ Fire Suppression Post
Piezometer	Post Indicator Valve
Sub-Slab Soil Vapor	Manhole
Unknown Manhole	Former Vent Riser
Sanitary Manhole	Utility Riser
Sewer Vent/ Clean Out	Sub-Slab Depressurization System Exhaust Fan Location
Catch Basin	

SSDS System
241 Farrell Road (16.6 acres) [2]
Widewaters Property
Topographic Contour
Chainlink Fence
Groundwater Plume Centerline (Approximate)

CVOC Concentration (µg/L)
249,300
100,000
10,000
1,000
100
10
1
0.1
0.01

Footnotes:
1. PMW- 1 through PMW- 6, PMW- 9 through PMW-15, and PMW-24 are deep, intermediate, and shallow-screened sets of wells.
2. Site boundary as defined in April 26, 2012 NYSDEC correspondence (refer to Interim Site Management Plan, dated July 25, 2017).

Notes:
- Abandoned/ decommissioned wells are shown in gray. Locations were not surveyed and are approximate.
- SS-15, SS-16, SS-24, and SS-25 represent sub-slab, 4-ft and 8-ft soil vapor sample locations.
- CVOC concentrations depicted on this figure include only 1,1,1-TCA, 1,1-DCE, 1,1-DCA, TCE, and Freon-11.
- Data depicted on this figure was collected during the 2019 subsurface investigation.

Reference:
Site layout based on survey information provided by CNY Land Surveying drawing, Farrell Road topographic survey and monitoring well locations, dated April 2, 2016.

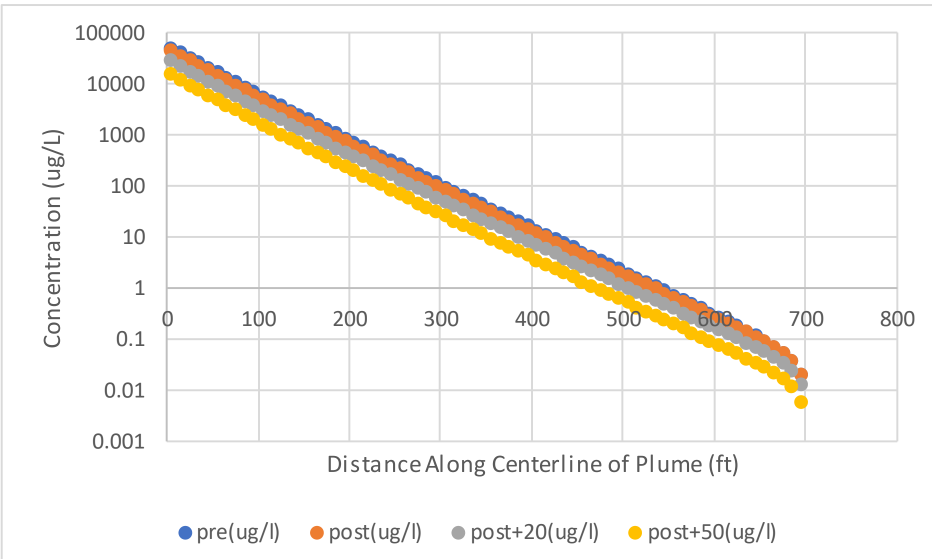
80 0 80 Feet

LOCKHEED MARTIN CORPORATION
FORMER G.E. FARRELL ROAD SITE
TOWN OF GEDDES, ONONDAGA COUNTY, NEW YORK
Project No.: 60622683 Date: May 6, 2020

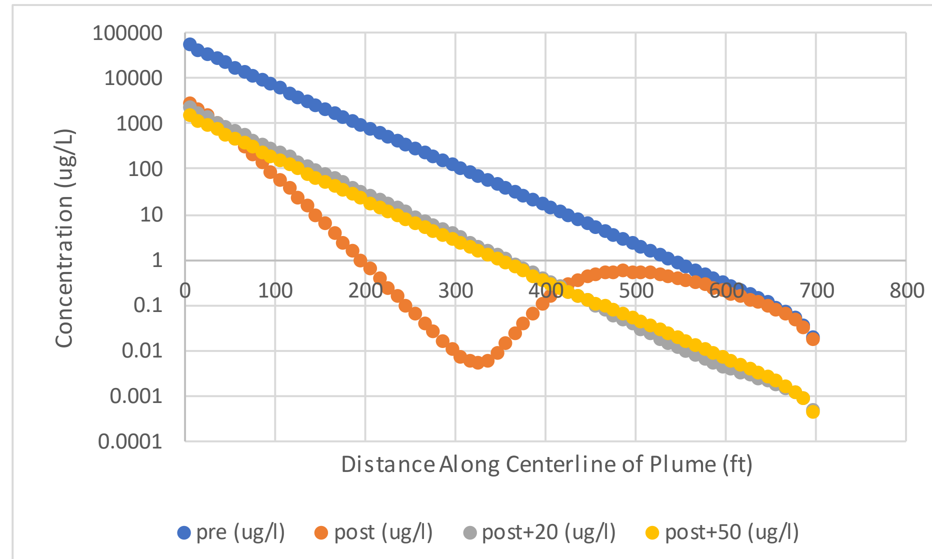
DISTANCE MARKERS ALONG GROUNDWATER PLUME CENTERLINE

AECOM
Figure: 7

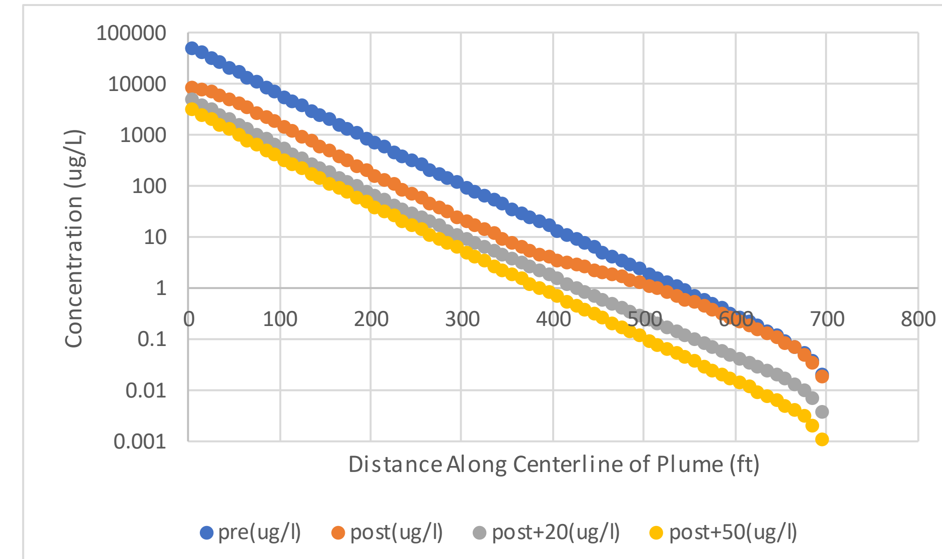
Monitored Natural Attenuation
(Logarithmic Scale)



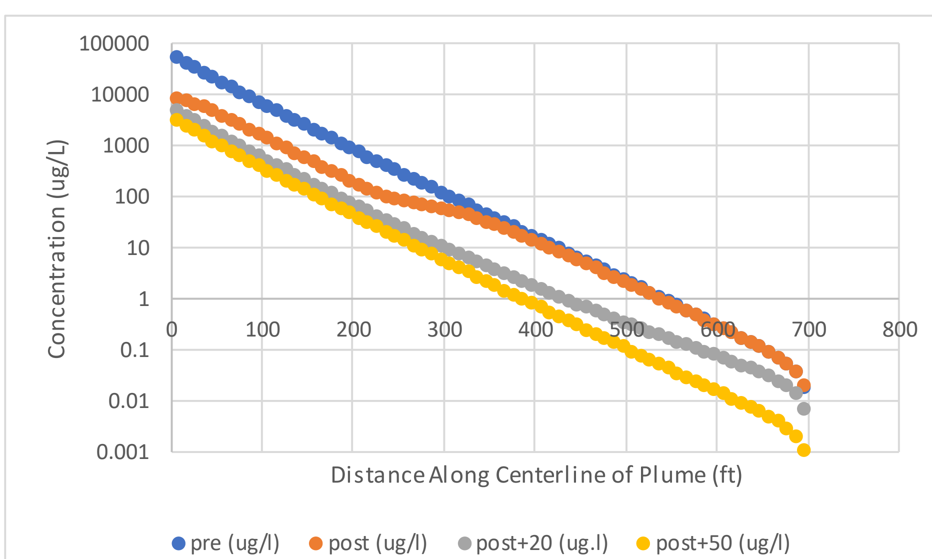
Dual Phase Extraction
(Logarithmic Scale)



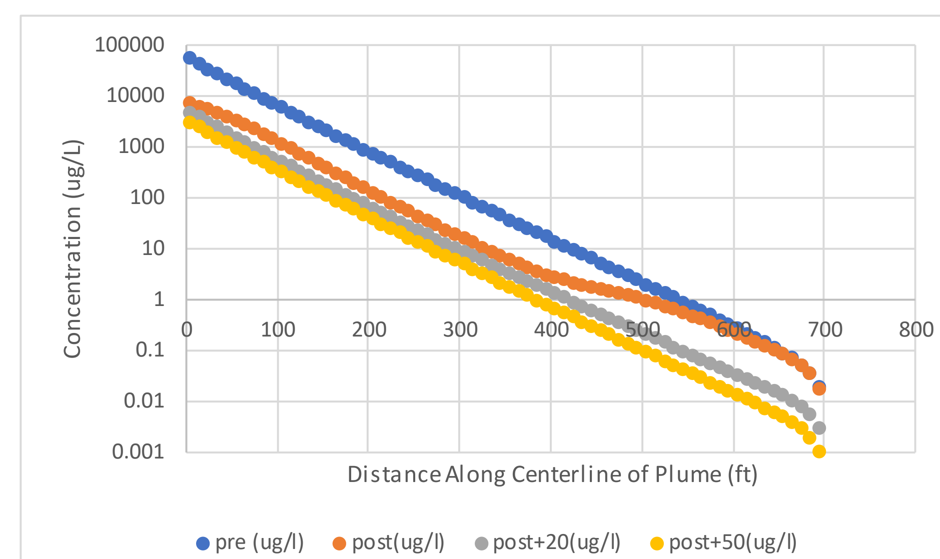
In-Situ Chemical Oxidation
(Logarithmic Scale)



Thermal
(Logarithmic Scale)



Soil Vapor Extraction with Air Sparge
(Logarithmic Scale)



AECOM

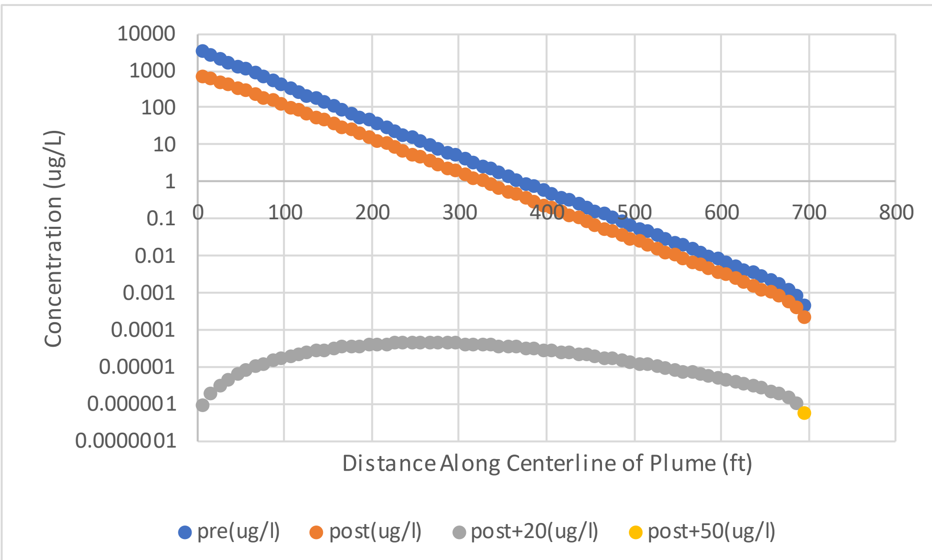
Figure: 8

REMCHLOR MODEL OUTPUTS FOR TOLUENE CONCENTRATIONS

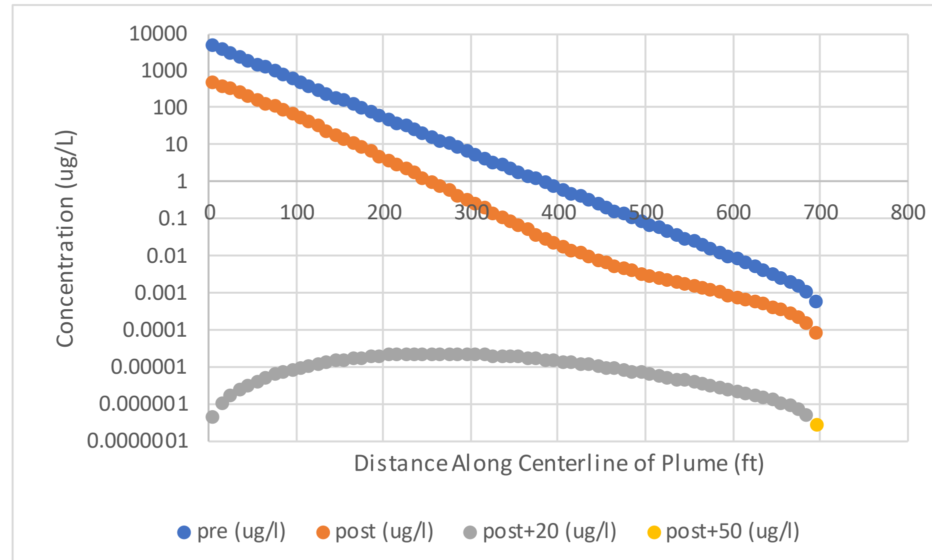
LOCKHEED MARTIN CORPORATION
FORMER G.E. FARRELL ROAD SITE
TOWN OF GEDDES, ONONDAGA COUNTY, NEW YORK
Project No.: 60622683 Date: August 24, 2020

J:\Resources\RDMS\Projects\Lockheed Martin\Former GE Farrell Rd\GIS\MAPS\REMEDIAL SYSTEM OPT\08 REMCHLOR MODEL OUTPUTS (TOLUENE).mxd 8/24/2020

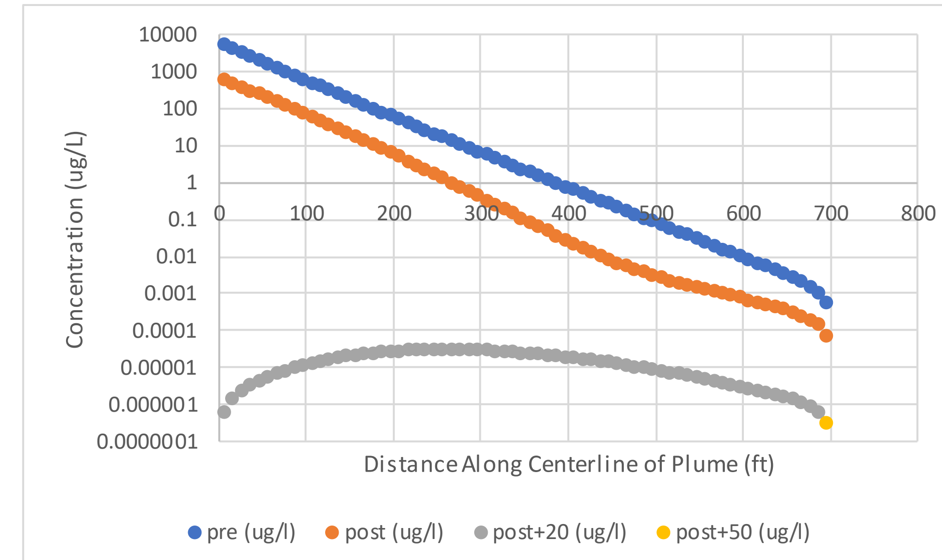
Monitored Natural Attenuation
(Logarithmic Scale)



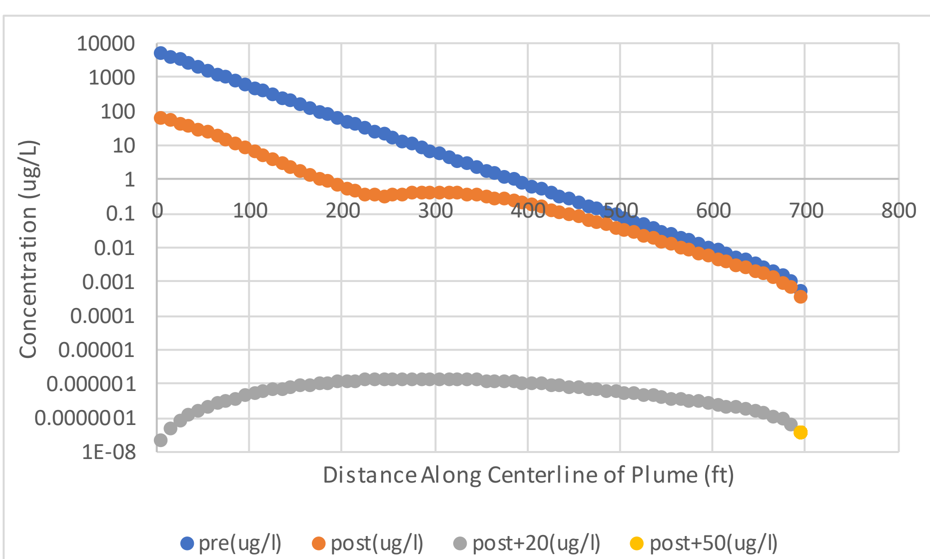
Dual Phase Extraction
(Logarithmic Scale)



In-Situ Chemical Oxidation
(Logarithmic Scale)



Thermal
(Logarithmic Scale)



Soil Vapor Extraction with Air Sparge
(Logarithmic Scale)

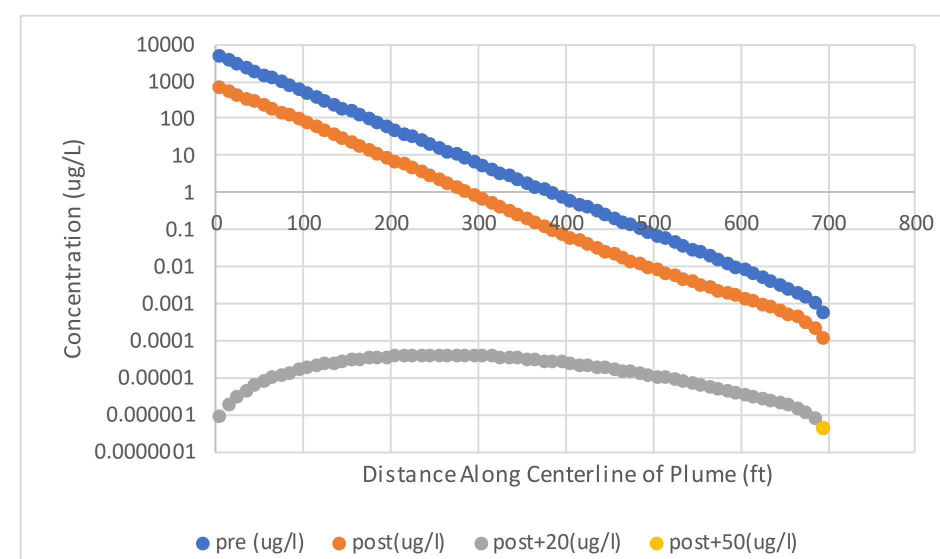
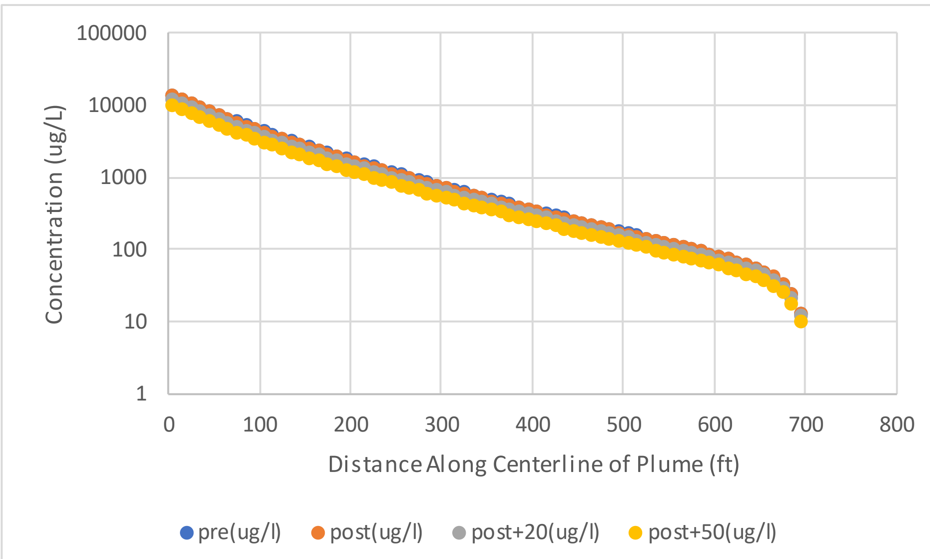


Figure: 9

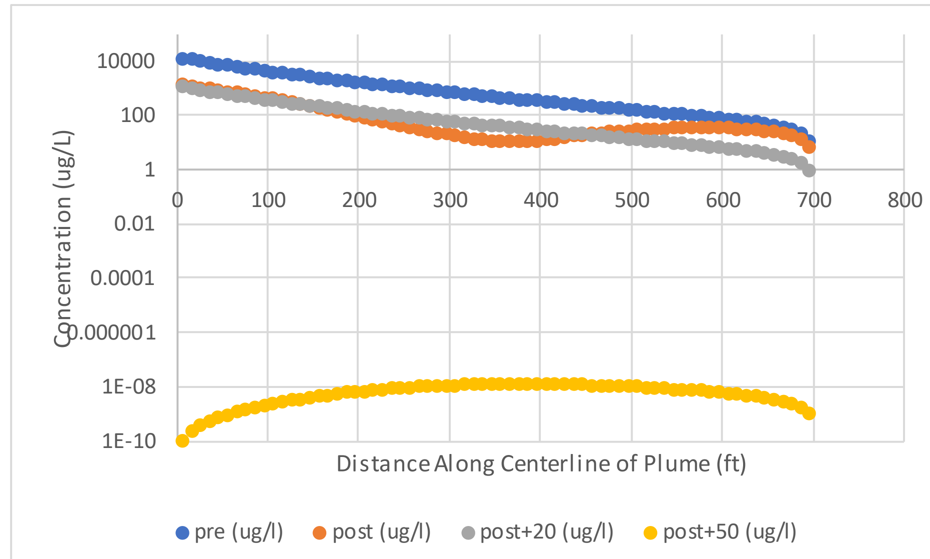
REMCHLOR MODEL OUTPUTS FOR 1,1,1-TRICHLOROETHANE CONCENTRATIONS

LOCKHEED MARTIN CORPORATION
FORMER G.E. FARRELL ROAD SITE
TOWN OF GEDDES, ONONDAGA COUNTY, NEW YORK
Project No.: 60622683 Date: August 24, 2020

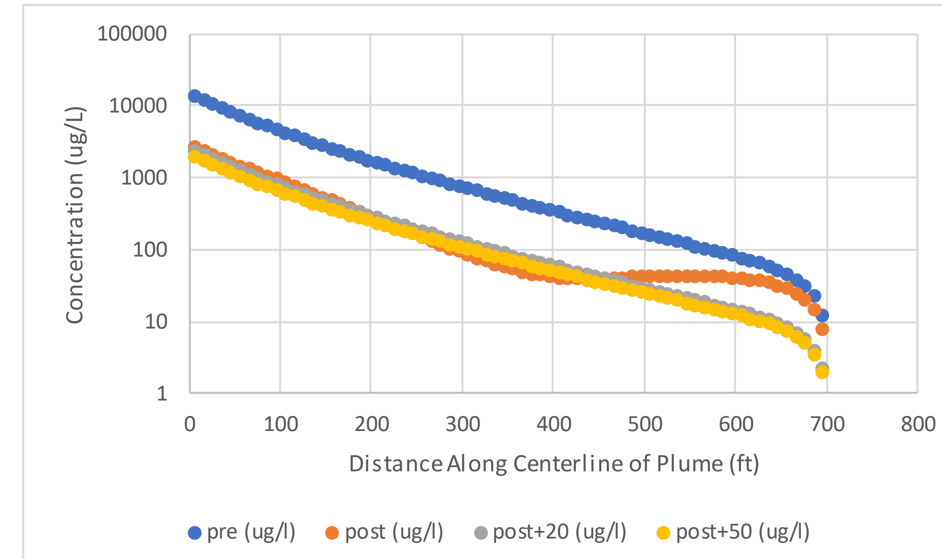
Monitored Natural Attenuation
(Logarithmic Scale)



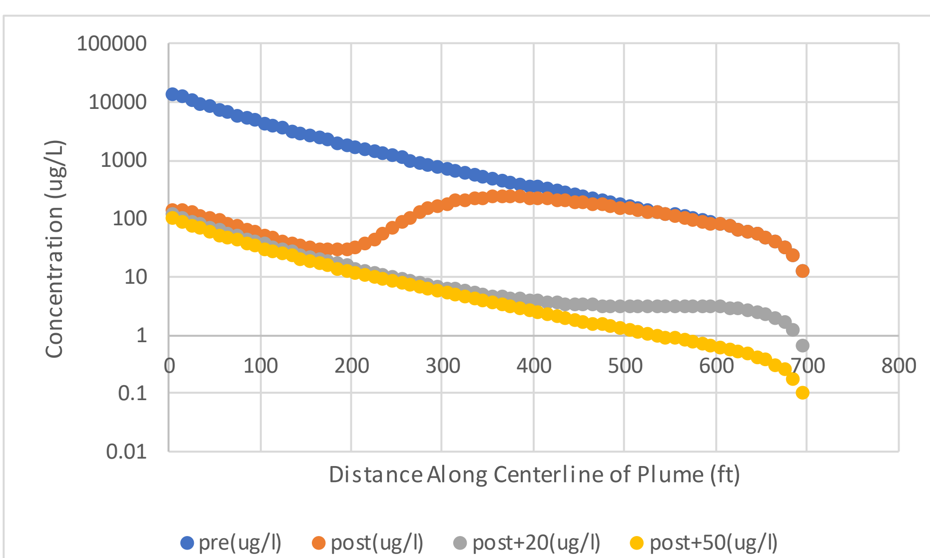
Dual Phase Extraction
(Logarithmic Scale)



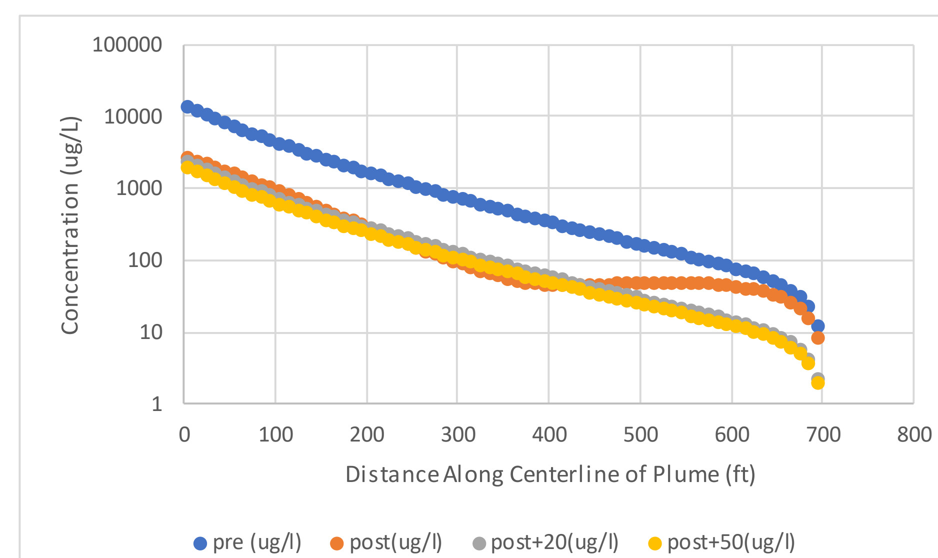
In-Situ Chemical Oxidation
(Logarithmic Scale)



Thermal
(Logarithmic Scale)



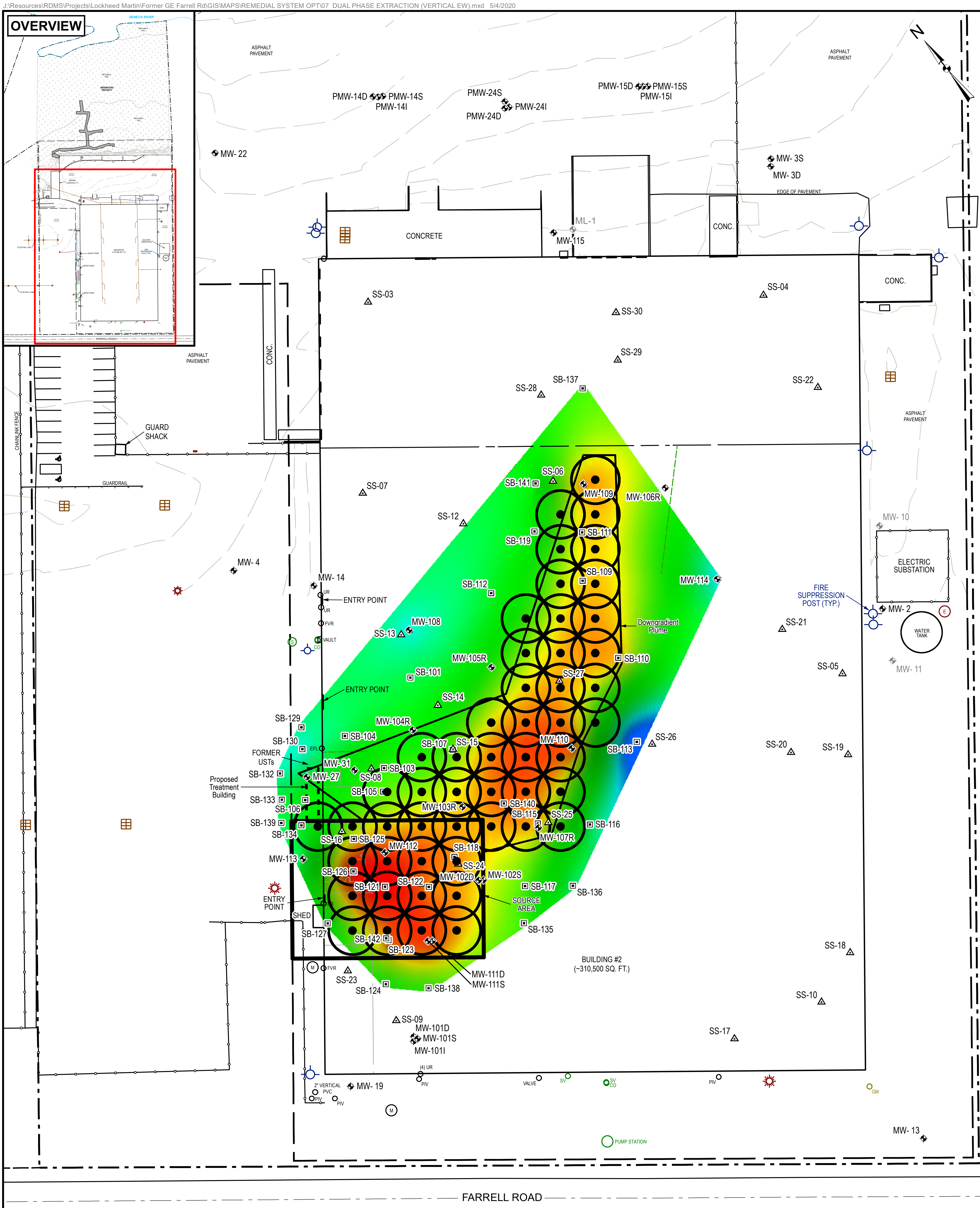
Soil Vapor Extraction with Air Sparge
(Logarithmic Scale)



AECOM
Figure: 10

REMCHLOR MODEL OUTPUTS FOR 1,1-DICHLOROETHENE CONCENTRATIONS

LOCKHEED MARTIN CORPORATION
FORMER G.E. FARRELL ROAD SITE
TOWN OF GEDDES, ONONDAGA COUNTY, NEW YORK
Project No.: 60622683 Date: August 24, 2020



Legend

Monitoring Well [1]	Gas Marker	Extraction Well
Continuous Multichamber Tubing (CMT) Well	Electric Manhole	Design Radius of Influence
Abandoned/ Decommissioned Well	Light Pole	SSDS System
Groundwater Extraction Well	Fire Hydrant/ Fire Suppression Post	241 Farrell Road (16.6 acres) [2]
Piezometer	Post Indicator Valve	Widewaters Property
Sub-Slab Soil Vapor	Manhole	Topographic Contour
Unknown Manhole	Former Vent Riser	Chainlink Fence
Sanitary Manhole	Utility Riser	
Sewer Vent/ Clean Out	Sub-Slab Depressurization System Exhaust Fan Location	
Catch Basin		

CVOC Concentration (µg/L)

249,300
100,000
10,000
1,000
100
10
1
0.1
0.01

Footnotes:
1. PMW- 1 through PMW- 6, PMW- 9 through PMW-15, and PMW-24 are deep, intermediate, and shallow-screened sets of wells.
2. Site boundary as defined in April 26, 2012 NYSDEC correspondence (refer to Interim Site Management Plan, dated July 25, 2017).

Notes:
- Abandoned/ decommissioned wells are shown in gray. Locations were not surveyed and are approximate.
- SS-15, SS-16, SS-24, and SS-25 represent sub-slab, 4-ft and 8-ft soil vapor sample locations.
- All historic locations are approximate.
- CVOC concentrations tabulated and depicted on this figure include only 1,1,1-TCA, 1,1-DCE, 1,1-DCA, TCE, and Freon-11.
- Data depicted on this figure was collected during the 2019 subsurface investigation.

Reference:
Site layout based on survey information provided by CNY Land Surveying drawing, Farrell Road topographic survey and monitoring well locations, dated April 2, 2016.

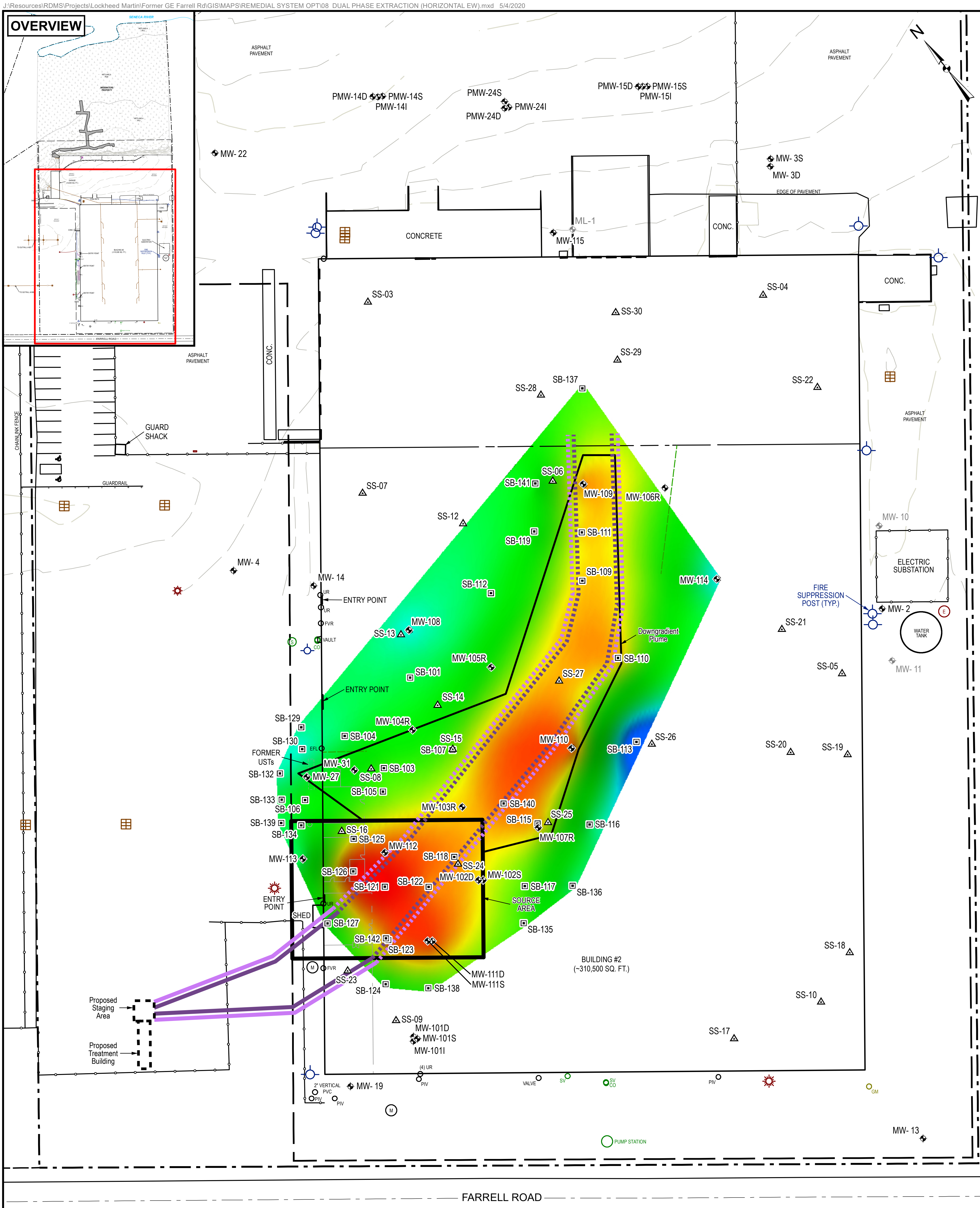
80 0 80 Feet

LOCKHEED MARTIN CORPORATION
FORMER G.E. FARRELL ROAD SITE
TOWN OF GEDDES, ONONDAGA COUNTY, NEW YORK
Project No.: 60622683 Date: May 4, 2020

DUAL PHASE EXTRACTION CONCEPTUAL DRAWING (VERTICAL EXTRACTION WELLS)

AECOM
Figure: 11

J:\Resources\RDMS\Projects\Lockheed Martin\Former GE Farrell Rd\GIS\MAPS\REMEDIAL SYSTEM OPT\08 DUAL PHASE EXTRACTION (HORIZONTAL EW).mxd 5/4/2020



Legend

- Monitoring Well [1]
- Continuous Multichamber Tubing (CMT) Well
- Abandoned/ Decommissioned Well
- Groundwater Extraction Well
- Piezometer
- Sub-Slab Soil Vapor
- Unknown Manhole
- Sanitary Manhole
- Sewer Vent/ Clean Out
- Catch Basin
- Gas Marker
- Electric Manhole
- Light Pole
- Fire Hydrant/ Fire Suppression Post
- Post Indicator Valve
- Manhole
- Former Vent Riser
- Utility Riser
- Sub-Slab Depressurization System Exhaust Fan Location
- Dual Phase Extraction Horizontal Well
- Soil Vapor Extraction Horizontal Well
- SSDS System
- 241 Farrell Road (16.6 acres) [2]
- Widewaters Property
- Topographic Contour
- Chainlink Fence

CVOC Concentration (µg/L)

249,300
100,000
10,000
1,000
100
10
1
0.1
0.01

Footnotes:
1. PMW- 1 through PMW- 6, PMW- 9 through PMW-15, and PMW-24 are deep, intermediate, and shallow-screened sets of wells.
2. Site boundary as defined in April 26, 2012 NYSDEC correspondence (refer to Interim Site Management Plan, dated July 25, 2017).

Notes:
- Abandoned/ decommissioned wells are shown in gray. Locations were not surveyed and are approximate.
- SS-15, SS-16, SS-24, and SS-25 represent sub-slab, 4-ft and 8-ft soil vapor sample locations.
- All historic locations are approximate.
- CVOC concentrations tabulated and depicted on this figure include only 1,1,1-TCA, 1,1-DCE, 1,1-DCA, TCE, and Freon-11.
- Data depicted on this figure was collected during the 2019 subsurface investigation.

Reference:
Site layout based on survey information provided by CNY Land Surveying drawing, Farrell Road topographic survey and monitoring well locations, dated April 2, 2016.

80 0 80 Feet

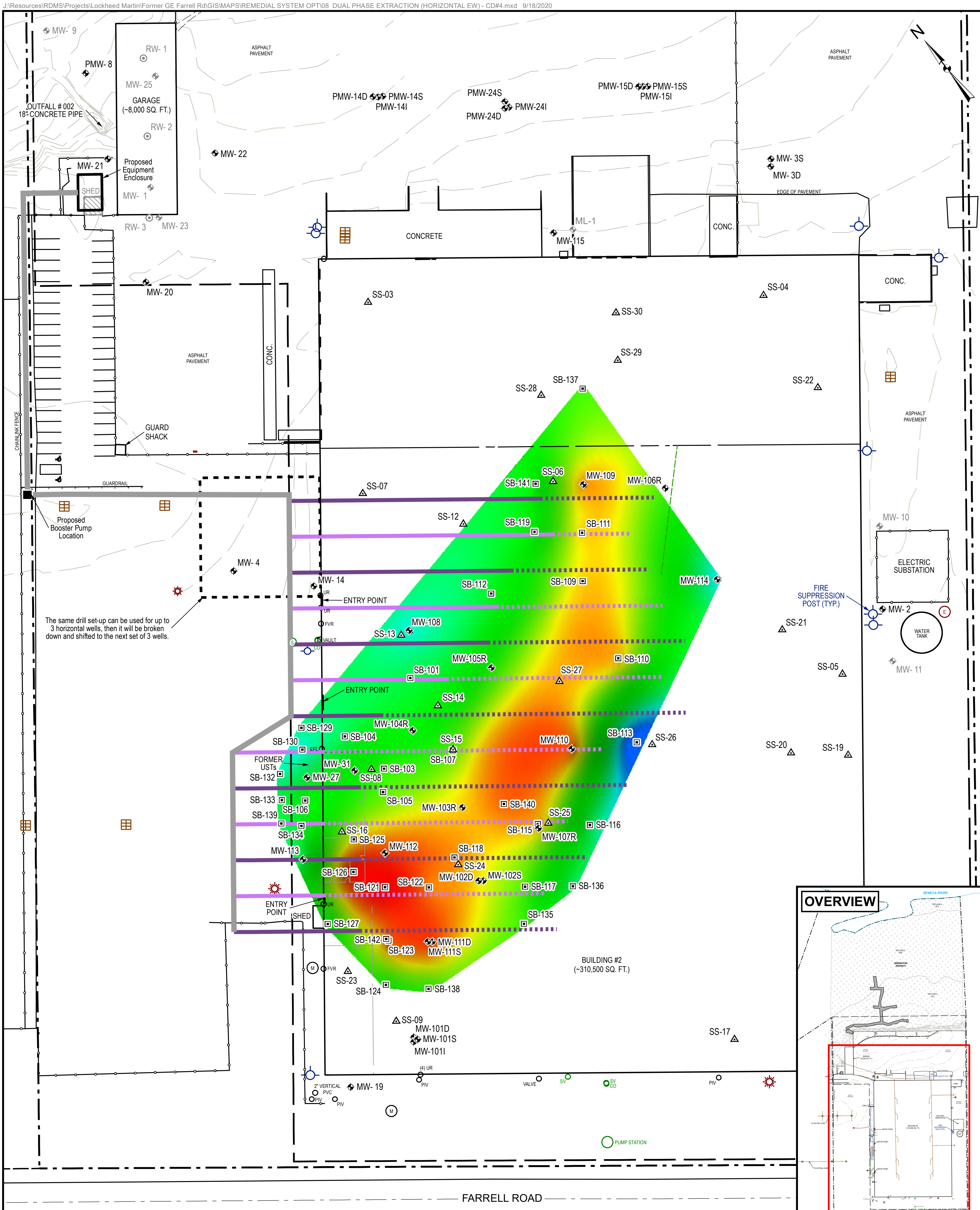
LOCKHEED MARTIN CORPORATION
FORMER G.E. FARRELL ROAD SITE
TOWN OF GEDDES, ONONDAGA COUNTY, NEW YORK
Project No.: 60622683 Date: May 4, 2020

DUAL PHASE EXTRACTION CONCEPTUAL DRAWING #1 (HORIZONTAL EXTRACTION WELLS)

AECOM

Figure: 12A

J:\Resources\RDMS\Projects\Lockheed Martin\Former GE Farrell Rd\GIS\MAPS\REMEDIAL SYSTEM OPT\08 DUAL PHASE EXTRACTION (HORIZONTAL EW) - CD#4.mxd 9/18/2020



Legend

- Monitoring Well [1]
- Continuous Multichamber Tubing (CMT) Well
- Abandoned/ Decommissioned Well
- Groundwater Extraction Well
- Piezometer
- Sub-Slab Soil Vapor
- Unknown Manhole
- Sanitary Manhole
- Sewer Vent/ Clean Out
- Catch Basin
- Gas Marker
- Electric Manhole
- Light Pole
- Fire Hydrant/ Fire Suppression Post
- Post Indicator Valve
- Manhole
- Former Vent Riser
- Utility Riser
- Sub-Slab Depressurization System Exhaust Fan Location
- System Piping Trench
- Dual Phase Extraction Horizontal Well
- Soil Vapor Extraction Horizontal Well
- SSDS System
- 241 Farrell Road (16.6 acres) [2]
- Widewaters Property
- Topographic Contour
- Chainlink Fence

CVOC Concentration (µg/L)

249,300
100,000
10,000
1,000
100
10
1
0.1
0.01

Footnotes:
1. PMW- 1 through PMW- 6, PMW- 9 through PMW-15, and PMW-24 are deep, intermediate, and shallow-screened sets of wells.
2. Site boundary as defined in April 26, 2012 NYSDEC correspondence (refer to Interim Site Management Plan, dated July 25, 2017).

Notes:
- Abandoned/ decommissioned wells are shown in gray. Locations were not surveyed and are approximate.
- SS-15, SS-16, SS-24, and SS-25 represent sub-slab, 4-ft and 8-ft soil vapor sample locations.
- All historic locations are approximate.
- CVOC concentrations tabulated and depicted on this figure include only 1,1,1-TCA, 1,1-DCE, 1,1-DCA, TCE, and Freon-11.
- Data depicted on this figure was collected during the 2019 subsurface investigation.

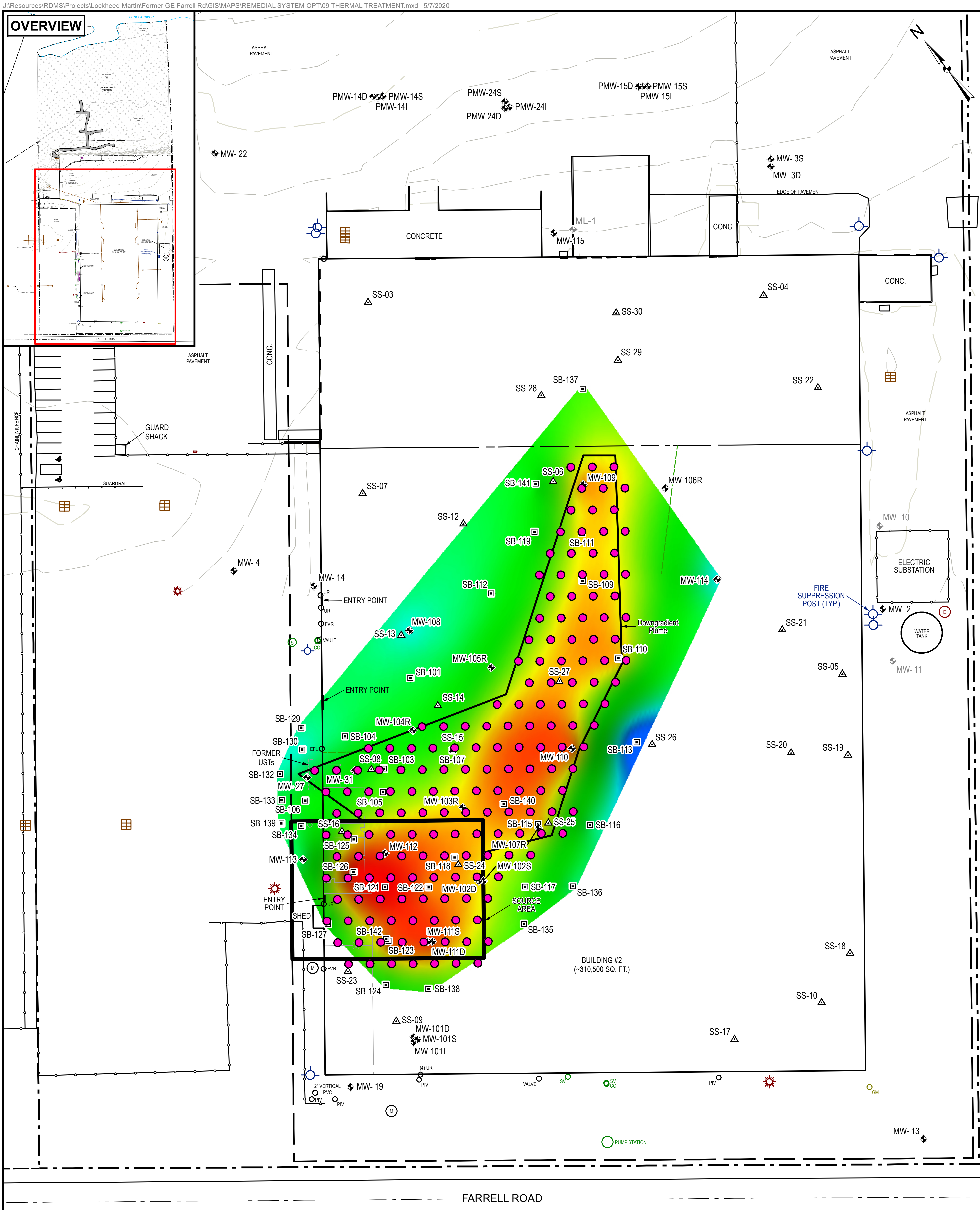
Reference:
Site layout based on survey information provided by CNY Land Surveying drawing, Farrell Road topographic survey and monitoring well locations, dated April 2, 2016.

80 0 80 Feet

LOCKHEED MARTIN CORPORATION
FORMER G.E. FARRELL ROAD SITE
TOWN OF GEDDES, ONONDAGA COUNTY, NEW YORK
Project No.: 60622683 Date: September 18, 2020

DUAL PHASE EXTRACTION CONCEPTUAL DRAWING #2 (HORIZONTAL EXTRACTION WELLS)

AECOM
Figure: 12B



Legend

	Monitoring Well [1]	GM	Gas Marker		Electrode/Vapor Recovery Well
	Continuous Multichamber Tubing (CMT) Well	E	Electric Manhole		SSDS System
	Abandoned/ Decommissioned Well		Light Pole		241 Farrell Road (16.6 acres) [2]
	Groundwater Extraction Well		Fire Hydrant/ Fire Suppression Post		Widewaters Property
	Piezometer	PIV	Post Indicator Valve		Topographic Contour
	Sub-Slab Soil Vapor		Manhole		Chainlink Fence
	Unknown Manhole	FVR	Former Vent Riser		
	Sanitary Manhole	UR	Utility Riser		
SV CO	Sewer Vent/ Clean Out	EFL	Sub-Slab Depressurization System Exhaust Fan Location		
	Catch Basin				

CVOC Concentration (µg/L)

249,300
100,000
10,000
1,000
100
10
1
0.1
0.01

Footnotes:
1. PMW- 1 through PMW- 6, PMW- 9 through PMW-15, and PMW-24 are deep, intermediate, and shallow-screened sets of wells.
2. Site boundary as defined in April 26, 2012 NYSDEC correspondence (refer to Interim Site Management Plan, dated July 25, 2017).

Notes:
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- SS-15, SS-16, SS-24, and SS-25 represent sub-slab, 4-ft and 8-ft soil vapor sample locations.
- All historic locations are approximate.
- CVOC concentrations tabulated and depicted on this figure include only 1,1,1-TCA, 1,1-DCE, 1,1-DCA, TCE, and Freon-11.
- Data depicted on this figure was collected during the 2019 subsurface investigation.

Reference:
Site layout based on survey information provided by CNY Land Surveying drawing, Farrell Road topographic survey and monitoring well locations, dated April 2, 2016.

80 0 80 Feet

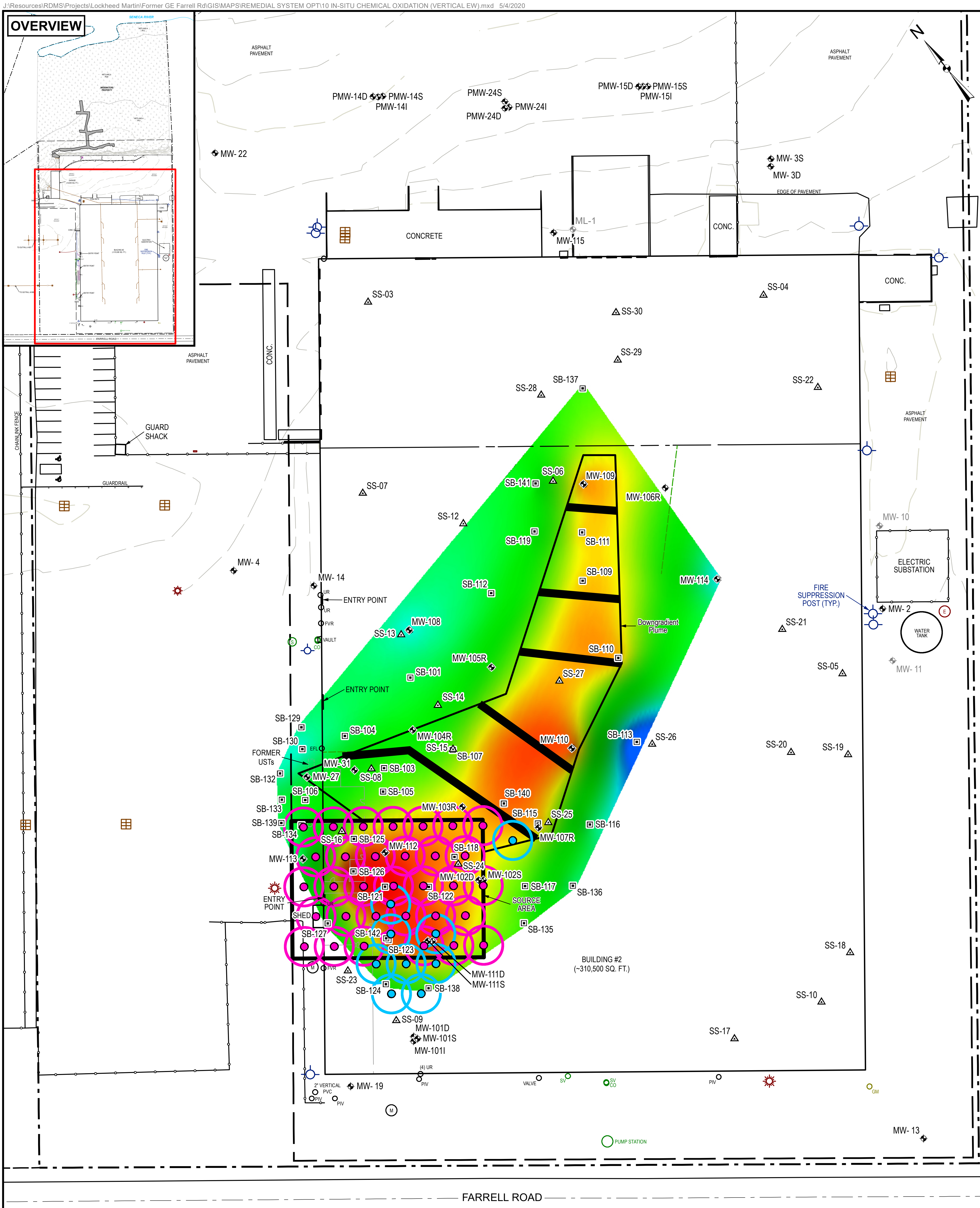
LOCKHEED MARTIN CORPORATION
FORMER G.E. FARRELL ROAD SITE
TOWN OF GEDDES, ONONDAGA COUNTY, NEW YORK
Project No.: 60622683 Date: May 7, 2020

THERMAL TREATMENT CONCEPTUAL DRAWING

AECOM

Figure: 13

J:\Resources\RDMS\Projects\Lockheed Martin\Former GE Farrell Rd\GIS\MAPS\REMEDIAL SYSTEM OPT\10 IN-SITU CHEMICAL OXIDATION (VERTICAL EW).mxd 5/4/2020



Legend

Monitoring Well [1]	Gas Marker	Shallow Injection Well
Continuous Multichamber Tubing (CMT) Well	Electric Manhole	Deep Injection Well
Abandoned/ Decommissioned Well	Light Pole	Design Radius of Influence (Shallow Injection Well)
Groundwater Extraction Well	Fire Hydrant/ Fire Suppression Post	Design Radius of Influence (Deep Injection Well)
Piezometer	Post Indicator Valve	Permeable Reactive Barrier
Sub-Slab Soil Vapor	Manhole	SSDS System
Unknown Manhole	Former Vent Riser	241 Farrell Road (16.6 acres) [2]
Sanitary Manhole	Utility Riser	Widewaters Property
Sewer Vent/ Clean Out	Sub-Slab Depressurization System Exhaust Fan Location	Topographic Contour
Catch Basin		Chainlink Fence

CVOC Concentration (µg/L)

249,300
100,000
10,000
1,000
100
10
1
0.1
0.01

Footnotes:
1. PMW- 1 through PMW- 6, PMW- 9 through PMW-15, and PMW-24 are deep, intermediate, and shallow-screened sets of wells.
2. Site boundary as defined in April 26, 2012 NYSDEC correspondence (refer to Interim Site Management Plan, dated July 25, 2017).

Notes:
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- All historic locations are approximate.
- CVOC concentrations tabulated and depicted on this figure include only 1,1,1-TCA, 1,1-DCE, 1,1-DCA, TCE, and Freon-11.
- Data depicted on this figure was collected during the 2019 subsurface investigation.

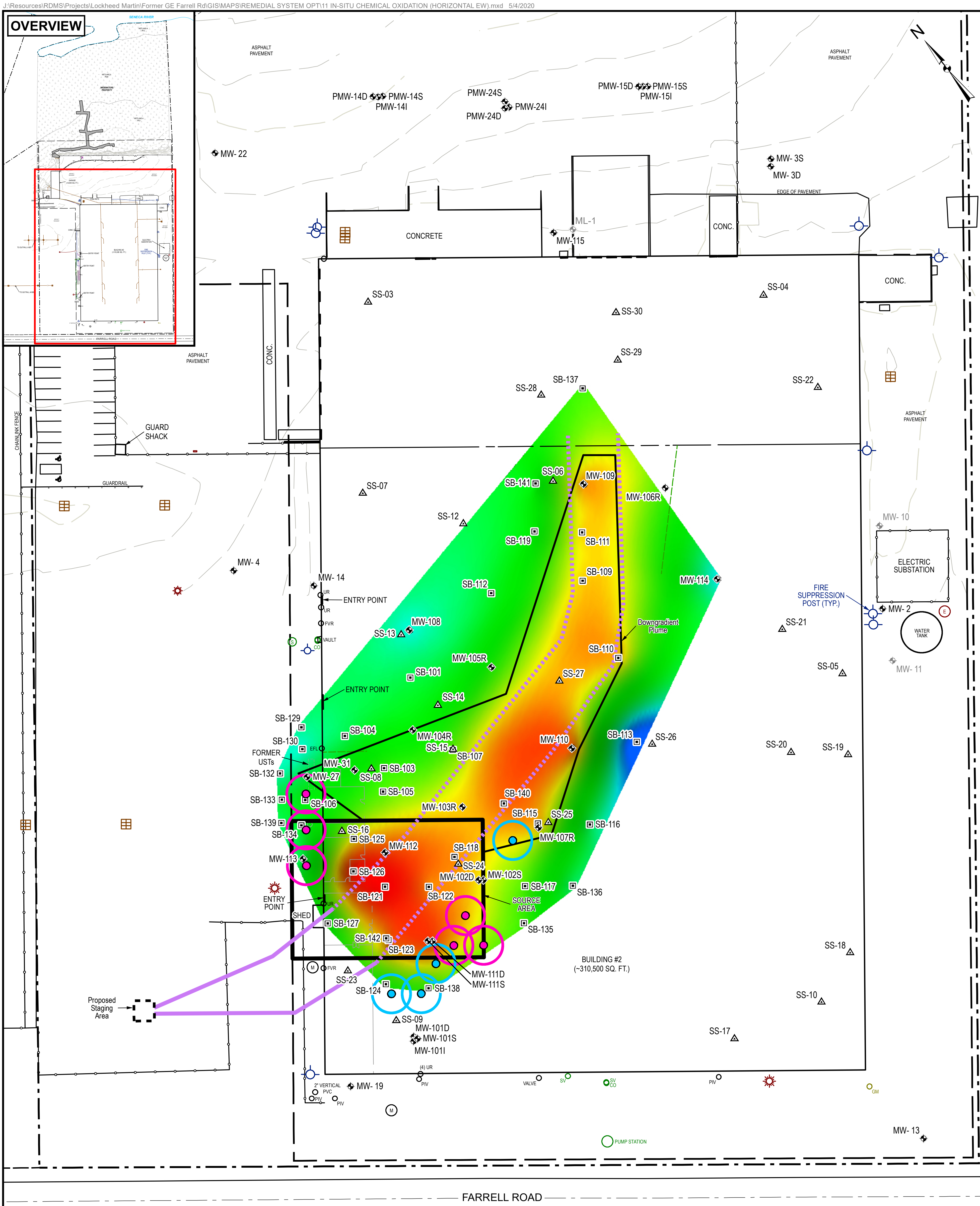
Reference:
Site layout based on survey information provided by CNY Land Surveying drawing, Farrell Road topographic survey and monitoring well locations, dated April 2, 2016.

80 0 80 Feet

LOCKHEED MARTIN CORPORATION
FORMER G.E. FARRELL ROAD SITE
TOWN OF GEDDES, ONONDAGA COUNTY, NEW YORK
Project No.: 60622683 Date: May 4, 2020

IN-SITU CHEMICAL OXIDATION CONCEPTUAL DRAWING (VERTICAL EXTRACTION WELLS)

AECOM
Figure: 14



Legend

- Monitoring Well [1]
- Continuous Multichamber Tubing (CMT) Well
- Abandoned/ Decommissioned Well
- Groundwater Extraction Well
- Piezometer
- Sub-Slab Soil Vapor
- Unknown Manhole
- Sanitary Manhole
- Sewer Vent/ Clean Out
- Catch Basin
- GMO Gas Marker
- Electric Manhole
- Light Pole
- Fire Hydrant/ Fire Suppression Post
- PIVO Post Indicator Valve
- Manhole
- FVRO Former Vent Riser
- URO Utility Riser
- EFLO Sub-Slab Depressurization System Exhaust Fan Location
- Shallow Injection Well
- Deep Injection Well
- Design Radius of Influence (Shallow Injection Well)
- Design Radius of Influence (Deep Injection Well)
- Horizontal Injection Well
- SSDS System
- 241 Farrell Road (16.6 acres) [2]
- Widewaters Property
- Topographic Contour
- Chainlink Fence

CVOC Concentration (µg/L)

249,300
100,000
10,000
1,000
100
10
1
0.1
0.01

Footnotes:
1. PMW- 1 through PMW- 6, PMW- 9 through PMW-15, and PMW-24 are deep, intermediate, and shallow-screened sets of wells.
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- Data depicted on this figure was collected during the 2019 subsurface investigation.

Reference:
Site layout based on survey information provided by CNY Land Surveying drawing, Farrell Road topographic survey and monitoring well locations, dated April 2, 2016.

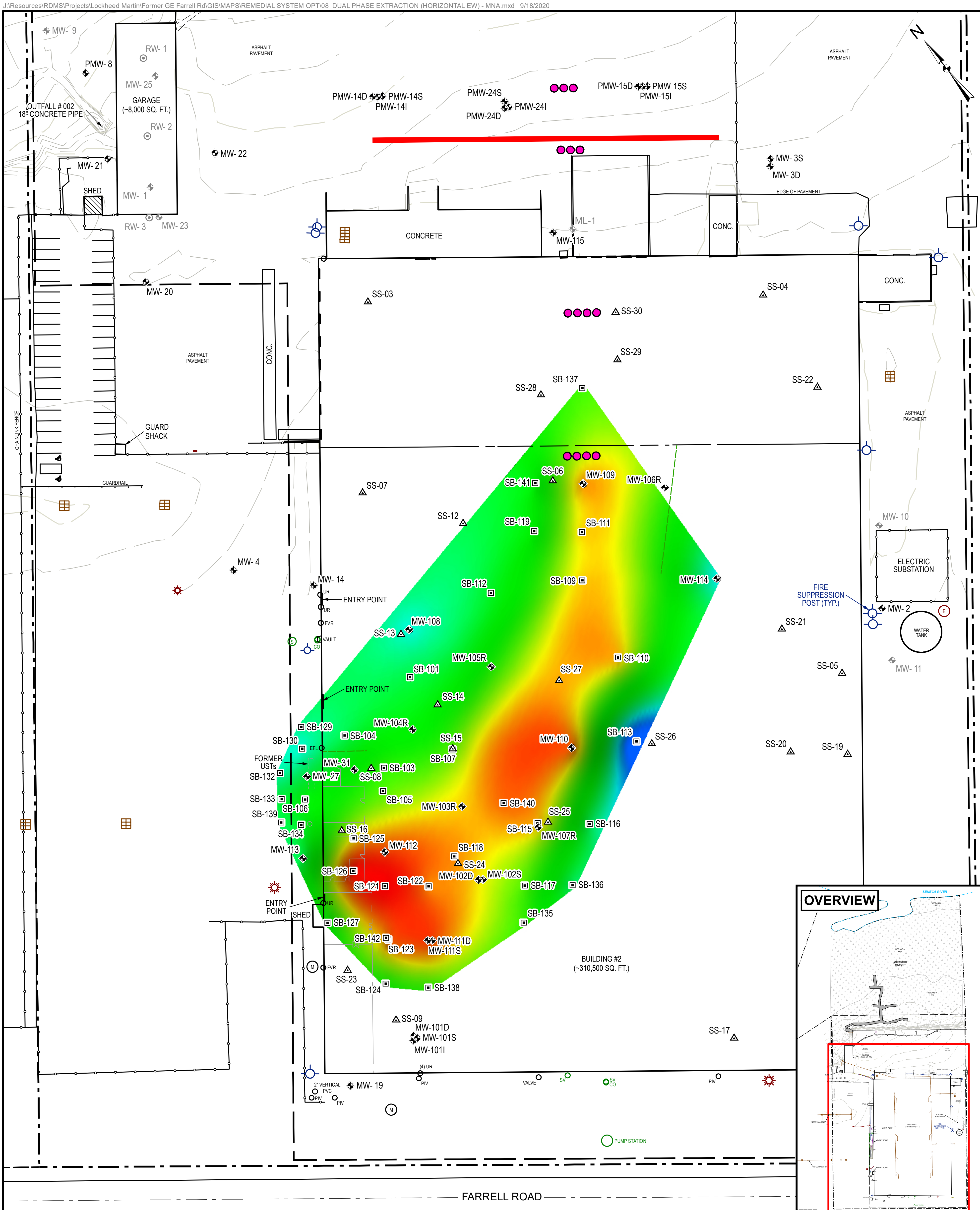
80 0 80 Feet

LOCKHEED MARTIN CORPORATION
FORMER G.E. FARRELL ROAD SITE
TOWN OF GEDDES, ONONDAGA COUNTY, NEW YORK
Project No.: 60622683 Date: May 4, 2020

IN-SITU CHEMICAL OXIDATION CONCEPTUAL DRAWING (HORIZONTAL EXTRACTION WELLS)

AECOM
Figure: 15

J:\Resources\RDMS\Projects\Lockheed Martin\Former GE Farrell Rd\GIS\MAPS\REMEDIAL SYSTEM OPT\08 DUAL PHASE EXTRACTION (HORIZONTAL EW) - MNA.mxd 9/18/2020



Legend

- Monitoring Well [1]
- Continuous Multichamber Tubing (CMT) Well
- Abandoned/ Decommissioned Well
- Groundwater Extraction Well
- Piezometer
- Sub-Slab Soil Vapor
- Unknown Manhole
- Sanitary Manhole
- Sewer Vent/ Clean Out
- Catch Basin
- GMO Gas Marker
- Electric Manhole
- Light Pole
- Fire Hydrant/ Fire Suppression Post
- PIVO Post Indicator Valve
- Manhole
- FVRO Former Vent Riser
- URO Utility Riser
- EFLO Sub-Slab Depressurization System Exhaust Fan Location
- Proposed Monitoring Well
- Enhanced Reductive Dechlorination Permeable Reactive Barrier
- SSDS System
- 241 Farrell Road (16.6 acres) [2]
- Widewaters Property
- Topographic Contour
- Chainlink Fence

CVOC Concentration (µg/L)

249,300
100,000
10,000
1,000
100
10
1
0.1
0.01

Footnotes:
1. PMW- 1 through PMW- 6, PMW- 9 through PMW-15, and PMW-24 are deep, intermediate, and shallow-screened sets of wells.
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- Data depicted on this figure was collected during the 2019 subsurface investigation.

Reference:
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80 0 80 Feet

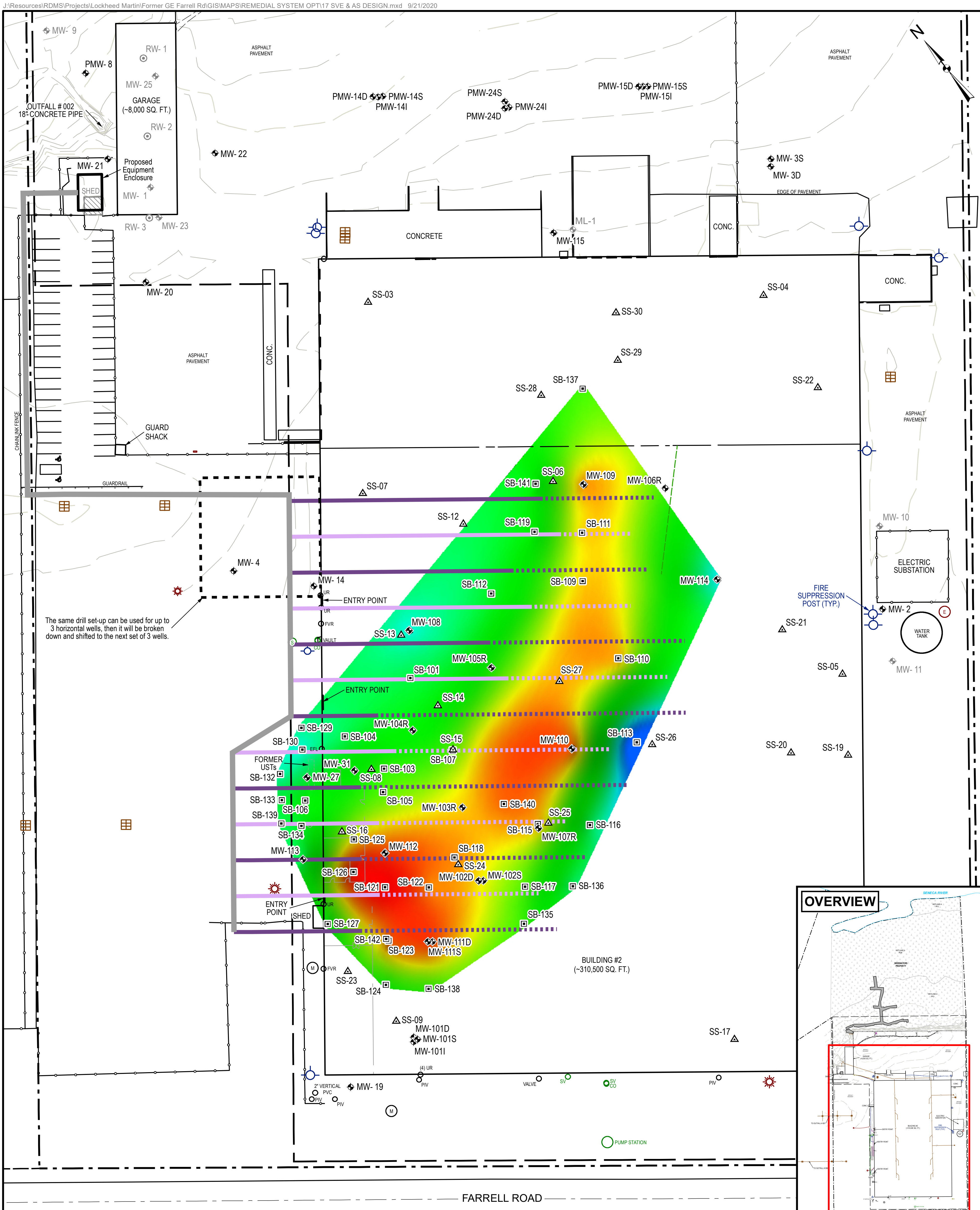
LOCKHEED MARTIN CORPORATION
FORMER G.E. FARRELL ROAD SITE
TOWN OF GEDDES, ONONDAGA COUNTY, NEW YORK
Project No.: 60622683 Date: September 18, 2020

MONITORED NATURAL ATTENUATION AND ENHANCED REDUCTIVE DECHLORINATION PERMEABLE REACTIVE BARRIER CONCEPTUAL DRAWING

AECOM

Figure: 16

J:\Resources\RDMS\Projects\Lockheed Martin\Former GE Farrell Rd\GIS\MAPS\REMEDIAL SYSTEM OPT\17 SVE & AS DESIGN.mxd 9/21/2020



Legend

Monitoring Well [1]	Gas Marker
Continuous Multichamber Tubing (CMT) Well	Electric Manhole
Abandoned/ Decommissioned Well	Light Pole
Groundwater Extraction Well	Fire Hydrant/ Fire Suppression Post
Piezometer	Post Indicator Valve
Sub-Slab Soil Vapor	Manhole
Unknown Manhole	Former Vent Riser
Sanitary Manhole	Utility Riser
Sewer Vent/ Clean Out	Sub-Slab Depressurization System Exhaust Fan Location
Catch Basin	

- System Piping Trench
- Air Sparge Horizontal Well
- Soil Vapor Extraction Horizontal Well
- SSDS System
- 241 Farrell Road (16.6 acres) [2]
- Widewaters Property
- Topographic Contour
- Chainlink Fence

CVOC Concentration (µg/L)

249,300
100,000
10,000
1,000
100
10
1
0.1
0.01

Footnotes:
1. PMW- 1 through PMW- 6, PMW- 9 through PMW-15, and PMW-24 are deep, intermediate, and shallow-screened sets of wells.
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- Data depicted on this figure was collected during the 2019 subsurface investigation.

Reference:
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80 0 80 Feet

LOCKHEED MARTIN CORPORATION
FORMER G.E. FARRELL ROAD SITE
TOWN OF GEDDES, ONONDAGA COUNTY, NEW YORK
Project No.: 60622683 Date: September 21, 2020

SOIL VAPOR EXTRACTION / AIR SPARGE CONCEPTUAL DRAWING (HORIZONTAL EXTRACTION / INJECTION WELLS)

AECOM
Figure: 17

TABLES

Table 1 – Detailed Screening of Optimized Remedial System Alternatives

Table 2 – Evaluation Criteria Comparison of Optimized Remedial System Alternatives

Table 1 – Detailed Screening of Optimized Remedial System Alternatives

General Response	Technology Option	Process Option	Description	Effectiveness	Implementability	Screening Comments
No Further Action (NFA)	None	None	No further remedial measures to reduce contaminant concentrations in soil and groundwater beneath Building #2 and no monitoring would be conducted.	Not effective. NFA would not eliminate, reduce, or control any existing or potential human health exposures or environmental impacts associated with the contaminated soil and/or groundwater beneath Building #2. Site RAOs would not be achieved.	NFA is technically implementable because no active treatment would be required. However, NFA is not administratively implementable because it would not be likely to receive regulatory approval since site RAOs would not be achieved.	Retained for evaluation as a baseline for comparison with the use of other remedial approaches.
Monitored Natural Attenuation (MNA)	Controlled Environmental Monitoring	Reliance on Physical and/or Biological Attenuation Processes to Reduce Contaminant Concentrations	Site data and a long-term groundwater monitoring plan are used to evaluate the role and effectiveness of physical attenuation and biodegradation processes towards achieving RAOs and plume stability.	The 1997 feasibility study suggested that natural attenuation of site-wide groundwater contaminants may be effective in the long-term for reduction of groundwater concentrations. Based on recent groundwater analytical data, natural attenuation does not appear to be an effective long-term measure for the VOC plume beneath Building #2. In many cases, recent (2019) soil and groundwater concentrations when compared to historical (1992) concentrations have remained stable or increased. MNA may be effective on the treatment of groundwater contamination when the technology is used in conjunction with other source remedial technologies.	MNA is implementable because no active treatment would be required. MNA would require the development and execution of a long-term monitoring plan. MNA alone is unlikely to achieve site RAOs and would require deliberation with the regulatory agency.	Retained for evaluation as part of a combined remedial approach.
Institutional Controls (ICs)	Land Use Restrictions	Site Management Plan (SMP)	Details the institutional and engineering controls required for a site and any physical components of the remedy required to be operated, maintained and monitored to assure continued effectiveness.	Provides an effective and enforceable means of continual and proper operation, maintenance, and monitoring of any engineering controls in place at the site.	A NYSDEC-approved Interim SMP is in place for the site and will be implemented accordingly to protect future on-site human exposure to contamination and ensuring the continued operation and maintenance of any engineering controls that may be part of the optimized remedy.	Retained for use as part of a combined remedial approach.
Engineering Controls (ECs)	Physical Barriers	Sub-slab depressurization (SSD) systems	SSD systems were installed in three areas within the footprint of Building #2 in 2016; a fourth will be installed in 2020. The SSD systems induce a vacuum under portions of the floor slab and exhausts the vapors outside of the building which limits exposure of building occupants to soil vapors.	SSD systems provide effective protection of site personnel from exposure to volatized compounds entering building through soil vapor intrusion. The SSD systems are currently in use and are proven effective at limiting exposure, however, do not address the contaminant mass currently present in soil and groundwater.	Both ECs are existing controls currently in place at the site which limit exposure to contaminated soils, groundwater, and soil vapor.	Retained for evaluation as part of combined approach.
		Existing Building Foundation and Outside Paved Surface	The current building foundation and exterior paved surface present at the site serve as ECs limiting the exposure of site personnel to potentially contaminated soil or groundwater.	The use of existing building foundation as an EC is an effective technology used at many sites. The existing building foundation is effective at limiting contact between personnel and contaminated soil and groundwater. However, this EC does not address the contaminant mass currently present in those same media.		
Removal	Dual Phase Extraction (DPE)	DPE utilizing Vertical Extraction Wells and Treatment of Extracted Vapors and Groundwater	DPE includes the extraction of contaminated groundwater and vapors to physically remove contaminant mass from the vadose and saturated zones. Soil vapor extraction (SVE) and groundwater extraction served as interim remedial measures at the site for AOC #5 and AOC #16 from 1995 to 2002 for the removal of VOCs from the unsaturated soil within these areas and to provide hydraulic control. This evaluation considers vertical extraction well installation throughout the source area to dewater the saturated zone using down-well pumps thereby making currently inaccessible soil impacts available to vacuum extraction.	SVE and groundwater extraction was previously effective at removing VOCs from unsaturated soil and groundwater at multiple AOCs at the site, including AOC #5 in the vicinity of Building #2, and AOC#16. Air emissions from the SVE system historically operated in AOC #5 were below NYSDEC criteria for the site COCs. This evaluation considers installation of a new extraction well network and enhanced treatment system in the vicinity of Building #2 to effectively decrease the contaminant mass in soil and treat the groundwater plume and meet site RAOs.	A DPE system utilizing vertical or horizontal wells is implementable. Similar technologies were proven to be effective. Historic pilot testing and system operations data from the site can be used to design the DPE system. Construction of DPE extraction wells, conveyance piping, and a treatment building would be disruptive to current property use for a limited time frame. A secure footprint outside of Building #2 would be required to house remedial equipment. The use of traditional vertical extraction wells may be more cost effective however would require installation of infrastructure within building. The use of horizontal wells would limit remediation infrastructure inside the building, however, may require a significant footprint for installation of wells, along with higher well installation costs. These aspects are further evaluated in Section 6 of the Remedial System Optimization Study.	Retained for detailed evaluation.

General Response	Technology Option	Process Option	Description	Effectiveness	Implementability	Screening Comments
Removal	DPE (continued)	DPE utilizing Horizontal Extraction Wells and Treatment of Extracted Vapors and Groundwater	Pumped groundwater and extracted soil vapor would be treated at an above grade location on site. Impacted groundwater with contaminant concentrations in excess of Standards, Criteria and Guidelines (SCGs) as defined in the Interim Site Management Plan (ISMP) would be targeted for removal from the subsurface. This enhanced form of DPE utilizes directional drilling methods to install extraction wells horizontally across the area of impacted soil. DPE with horizontal extraction wells has not been implemented at the site previously, though DPE with vertical extraction wells had been utilized.	Horizontal extraction wells can enhance the effectiveness of dual phase extraction by expanding the radius of influence and reducing impact to Building #2 tenant operations.		
Removal	Soil Vapor Extraction (SVE)	SVE optimized with an air sparge (AS) system	Injection of air into impacted groundwater to cause a phase transfer of VOCs to a vapor phase. The resulting vapor would be collected in the unsaturated soil zone and treated above grade via an SVE system.	Air sparging is proven effective for the treatment of VOCs in groundwater. SVE is proven effective for the extraction of VOCs from unsaturated soil. This technology can be effective in the reduction of total contaminant mass at this site.	An SVE/AS system utilizing horizontal wells is implementable. Similar technologies were proven to be effective. Historic pilot testing and system operations data from the site can be used to design the SVE system. Construction of SVE/AS injection and extraction wells, conveyance piping, and a treatment building would be disruptive to current property use for a limited time frame. A secure footprint outside of Building #2 would be required to house remedial equipment. The use of traditional vertical extraction wells may be more cost effective however would require installation of infrastructure within building. The use of horizontal wells would minimize remediation infrastructure inside the building, however, may require a significant footprint for installation of wells, along with higher well installation costs. These aspects are further evaluated in Section 6 of the Remedial System Optimization Study.	Retained for detailed evaluation.
Removal	Excavation	Removal and disposal to Landfill	Impacted soil with contaminant concentrations in excess of SCGs as defined in the ISMP would be removed and transported to an off-site facility for reuse, recycling, disposal, and/or treatment.	Excavation is effective at removing contaminated soil from the site, eliminating health risks to future on-site workers related to dust inhalation and direct contact with impacted soil. Most of the impacted soil is in the saturated zone which would require significant and continuous dewatering activities, treatment of dewatering effluent, and removal of source materials contributing to groundwater impacts which would reduce the potential for contaminated groundwater to migrate to wetlands and surface water.	Soil remediation utilizing excavation is implementable, though in this scenario is logistically very challenging. Most of the impacted soil is at or below the water table and is located beneath Building #2. To access the material, steps would include razing of Building #2, shoring to stabilize sidewalls, soil dewatering, transport of excavated materials to an LMC-approved disposal facility, and treatment/disposal of dewatering effluent. Excavation would cause disruption to current site operations which is contingent upon agreement with the property owner. The total depth of excavation in some areas may extend to 17 ftbg, requiring dewatering of up to 11 feet of saturated soils. The cost to remove building and excavate the contaminated materials is estimated to cost >$20M.	Not Retained.

General Response	Technology Option	Process Option	Description	Effectiveness	Implementability	Screening Comments
In-Situ Remediation	Physical Treatment	Thermal Treatment	Impacted groundwater with contaminant concentrations in excess of SCGs as defined in the ISMP would be treated by the addition of heat, resulting in volatilization of chemicals of concern. Contaminant concentrations in soil would also be significantly reduced. The resulting extracted vapor would be collected and treated above grade.	Thermal treatment is proven effective for the treatment of BTEX and CVOCs. This technology can be effective in the reduction of total contaminant mass at this site.	Treatment of soil and groundwater impacts utilizing thermal treatment is implementable. Treatment steps include: identifying accessibility to Building #2, high voltage electric power supply, and secure footprint outside of Building #2 to house vapor treatment and power control unit for the duration of remediation.	Retained for detailed evaluation.
In-Situ Remediation	Chemical Treatment	Chemical Oxidation	Impacted groundwater and saturated soils with contaminant concentrations in excess of SCGs as defined in the ISMP would be targeted with chemical reagents injected into the subsurface using various delivery methods.	Bench-scale treatability studies previously completed for this site, demonstrated that Klozur® sodium persulfate (SP) and potassium persulfate (KP) can effectively treat CVOCs at the site. Pilot testing conducted in AOC #5 demonstrated that activated Klozur® SP was effective in reducing CVOC and BTEX concentrations in groundwater. Site geology including the relative uniformity of soils and lack of seams and/or layers of concentrated mass may allow for maximum contact between the oxidant and contaminants. Effectiveness may be challenged if NAPL is found present, which could act as source for rebound. Effectiveness may also be limited by achieving contact of reagents with contaminated soil and groundwater. In some areas in the vicinity of Building #2, subsurface infrastructure associated with the historic SVE system remain, presenting the increased potential for reagents to follow preferential pathways instead of achieving contact with contaminated soil and groundwater.	Groundwater treatment utilizing chemical oxidation is implementable, and historically proven effective in bench-scale and pilot tests at other areas of the site. Chemical oxidation relies heavily on obtaining a successful and even distribution of the amendments, thus requiring an extensive number of injection points. An ISCO treatment approach would be designed to target delineated BTEX and CVOC plumes beneath Building #2. The use of horizontal wells may be incorporated into the ISCO approach, minimizing disturbance within the building and limiting the number of injection points required. The ISCO remedy can be optimized with the use of a recirculation system or installed as barriers to treat the downgradient plume area.	Retained for detailed evaluation.
In-Situ Remediation	Biological Treatment	Coupled Enhanced Reductive Dechlorination (ERD) of CVOCs and Aerobic Biodegradation of BTEX	Biologically driven reduction of CVOCs in groundwater through stimulation of ERD with addition of electron donor/carbon source substrates such as emulsified vegetable oil (EVO), and bioaugmenting the aquifer with a bacteria consortium such as KB-1 Plus®, followed by introduction of oxygen. BTEX impacts would be expected to biodegrade under aerobic conditions created in the subsurface during the oxygen application	Bench-scale treatability studies previously completed for this site, demonstrated that biological treatment using ERD can effectively treat CVOCs at this site. The bench scale study included secondary treatment through the application of oxygen and propane targeting 1,4-dioxane, which is of less concern in the Building #2 area. This secondary treatment was not successful for the treatment of the 1,4-dioxane. Due to the presence of BTEX compounds in vicinity of Building #2, a similar secondary approach would be needed to generate aerobic conditions. Aerobic conditions are easily created by the injection of oxygen gas, air sparging, or chemical products (i.e. oxygen releasing compounds (ORC)).	Full scale biological treatment of the source area including ERD followed by aerobic treatment would be complex due to the extent of comingled mass located throughout the treatment area, and the requirement to apply two technologies. Due to the extent of the contaminant mass multiple treatment rounds would be required for the groundwater treatment of the comingled plume. ERD/oxygen application can be evaluated to passively treat the groundwater in a combined barrier approach. This would be implemented by the installation of two adjacent barriers installed downgradient that intersect groundwater flow. The first barrier would be blended with compounds to generate aerobic conditions followed by a second barrier where sparge wells would be used to create anaerobic conditions.	Not Retained

General Response	Technology Option	Process Option	Description	Effectiveness	Implementability	Screening Comments
In-Situ Remediation/ Control	Biological/Chemical Treatment	Enhanced Reductive Dechlorination (ERD) of CVOCs and ISCO treatment of BTEX	Biologically driven reduction of CVOCs in groundwater through stimulation of ERD with addition of electron donor/carbon source substrates such as emulsified vegetable oil (EVO), and bioaugmenting the aquifer with a bacteria consortium such as KB-1 Plus®. The addition of ISCO treatment as secondary application would provide oxidation of remaining chlorinated compounds and BTEX compounds in the groundwater.	Bench-scale treatability studies previously completed for this site, demonstrated that biological treatment using ERD can effectively treat CVOCs at this site. ISCO bench-scale testing demonstrated the success of persulfate products in the breakdown of site-specific compounds. ISCO is an industry accepted remedial approach for the treatment of BTEX related compounds.	A combined bio/ISCO source remedy would be complicated and difficult to manage, as both treatments would require extensive infrastructure, and time to implement (over which the plume could migrate). A combined bio/ISCO treatment as a passive groundwater control mechanism can be implemented. It would include the installation of two trench barriers: one backfilled with materials (mulch, vegetable oil, etc), to create anaerobic conditions, and a second supplied with long-lasting KP to create oxidative conditions. This combined remedy would be used in conjunction with a long-term groundwater monitoring program. Since the location of the groundwater plume is located beneath Building #2, the barrier installation would not be installed until groundwater monitoring demonstrates that the plume is beginning to migrate towards the northern side of the Building #2 footprint.	Not Retained.

Table 2 – Evaluation Criteria Comparison of Optimized Remedial System Alternatives

Remedial Alternative	Overall Protection of Human Health & the Environment	Compliance with SCGs and Achieves RAOs	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, and Volume	Short-term Impact and Effectiveness	Implementation	Cost (30-year period)
Alternative 1 No Further Action	Alternative 1 does not protect future on-site workers from human health risk due to vapor intrusion and does not prevent migration of contaminants in groundwater towards the Seneca River. Alternative 1 would not comply with this evaluation criterion.	Alternative 1 is not expected to mitigate the potential threat to the Class I wetland biotic community resulting from continued migration of contaminated groundwater to the wetland from the developed portion of the FRP-2 property. Alternative 1 is not expected to achieve groundwater standards nor provide for attainment of SCGs for Class I wetlands by eliminating the discharge of contaminated groundwater into the wetland. Alternative 1 is not expected to meet any of the RAOs. Alternative 1 would not comply with this evaluation criterion.	Alternative 1 is not expected to be effective in the long-term and does not offer permanence of treatment. Alternative 1 would not mitigate vapor intrusion to Building #2. Alternative 1 would not comply with this evaluation criterion.	Alternative 1 is not expected to reduce toxicity, mobility and volume within the foreseeable future. Alternative 1 would not comply with this evaluation criterion.	Alternative 1 does not have any short-term impacts to workers or the community. Alternative 1 is not expected to be effective in achieving the remedial objectives identified for this site. Alternative 1 does not comply with this evaluation criterion.	Alternative 1 requires no technical action, and therefore is implementable. Alternative 1 complies with this evaluation criterion.	The estimated cost of Alternative 1 cost for a 30-year period is: $0
Alternative 2A Dual Phase Extraction – Vertical Well Design	Alternative 2A maintains protection of on-site workers through operation of the sub-slab depressurization system until post-mitigation data supports deactivation. Alternative 2A hydraulically contains the flow of contaminated groundwater from migrating further north towards the Seneca River. Alternative 2A complies with this evaluation criterion.	Alternative 2A is expected to mitigate the potential threat to the Class I wetland biotic community resulting from continued migration of contaminated groundwater to the wetland by providing hydraulic control beneath Building #2. Alternative 2A is expected to significantly reduce BTEX, CVOC and 1,4-dioxane concentrations and eliminate the discharge of contaminated groundwater into the wetland. Alternative 2A achieves all RAOs. Alternative 2A complies with this evaluation criterion.	Alternative 2A is expected to be 90% effective for BTEX and CVOC treatment but the typical treatment design is not effective for 1,4-dioxane treatment. Effluent train options to treat 1,4-dioxane would be evaluated during the detailed engineering design phase. Alternative 2A specific technology has previously shown permanence in reduction of concentrations at this site. Alternative 2A is estimated to mitigate vapor intrusion to Building #2 within a 20-year period. Alternative 2A complies with this evaluation criterion.	Alternative 2A is expected to reduce toxicity, mobility, and volume of contamination in the subsurface beneath Building #2. Alternative 2A complies with this evaluation criterion.	Alternative 2A is expected to have short-term impacts during construction activities that can be mitigated with appropriate health and safety measures. Alternative 2A is expected to take an estimated duration of 5 to 10 years to achieve remedial objectives #1, 3, 4, and 5, and an estimated 20 years to achieve remedial objective #2. Alternative 2A complies with this evaluation criterion.	Alternative 2A is implementable with significant impact to Building #2 tenants during construction and ongoing intermittent access required during operation & maintenance. This technology was previously used at the site with success. Requires above ground treatment of groundwater and vapors. Alternative 2A complies with this evaluation criterion.	The estimated cost of Alternative 2Afor a 30-year period is: $10,320,000* * The annual costs are expected to be zero after 20 years.
Alternative 2B Dual Phase Extraction – Horizontal Well Design	Alternative 2B maintains protection of on-site workers through operation of the sub-slab depressurization system until post-mitigation data supports deactivation. Alternative 2B hydraulically contains the flow of contaminated groundwater from migrating further north towards the Seneca River. Alternative 2B complies with this evaluation criterion.	Alternative 2B is expected to mitigate the potential threat to the Class I wetland biotic community resulting from continued migration of contaminated groundwater to the wetland by providing hydraulic control beneath Building #2. Alternative 2B is expected to significantly reduce BTEX, CVOC and 1,4-dioxane concentrations and eliminate the discharge of contaminated groundwater into the wetland. Alternative 2A achieves all remedial action objectives. Alternative 2B complies with this evaluation criterion.	Alternative 2B is expected to be 90% effective for BTEX and CVOC treatment but the typical treatment design is not effective for 1,4-dioxane treatment. Effluent train options to treat 1,4-dioxane would be evaluated during the detailed engineering design phase. Alternative 2A specific technology has previously shown permanence in reduction of concentrations at this site. Alternative 2B is estimated to mitigate vapor intrusion to Building #2 within a 20-year period. Alternative 2B complies with this evaluation criterion.	Alternative 2B is expected to reduce toxicity, mobility, and volume of contamination in the subsurface beneath Building #2. Alternative 2B complies with this evaluation criterion.	Alternative 2B is expected to have short-term impacts during construction activities that can be mitigated with appropriate health and safety measures. Alternative 2B is expected to take an estimated duration of 5 to 10 years to achieve remedial objectives #1, 3, 4, and 5, and an estimated 20 years to achieve remedial objective #2. Alternative 2B complies with this evaluation criterion.	Alternative 2B is implementable with significantly reduced impact to Building #2 tenants when compared to the vertical well design during construction. Ongoing intermittent access to the site will be required during operation & maintenance. Requires above ground treatment of groundwater and vapors. Alternative 2B complies with this evaluation criterion.	The estimated cost of Alternative 2B for a 30-year period is: $10,680,000* *The annual costs are expected to be zero after 20 years.

Remedial Alternative	Overall Protection of Human Health & the Environment	Compliance with SCGs and Achieves RAOs	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, and Volume	Short-term Impact and Effectiveness	Implementation	Cost (30-year period)
Alternative 3 Thermal - Vertical Electrode Design	Alternative 3 maintains protection of on-site workers through operation of the sub-slab depressurization systems until post-mitigation supports deactivation. Alternative 3 is expected to mitigate migration of contaminants in groundwater towards the Seneca River. Alternative 3 complies with this evaluation criterion.	Alternative 3 is expected to mitigate the potential threat to the Class I wetland biotic community resulting from continued migration of contaminated groundwater to the wetland by providing short duration treatment beneath Building #2. Alternative 3 is expected to significantly reduce BTEX, CVOC, and 1,4-dioxane concentrations, eliminate the discharge of contaminated groundwater into the wetland, and achieve all remedial action objectives. Alternative 3 achieves all RAOs. Alternative 3 complies with this evaluation criterion.	Alternative 3 is expected to be 80% effective BTEX treatment, 99.99% effective for CVOC treatment, and 70% effective for 1,4-dioxane treatment. Alternative 3 is estimated to mitigate vapor intrusion to Building #2 within a 10-year period. Alternative 3 complies with this evaluation criterion.	Alternative 3 is expected to reduce toxicity, mobility, and volume of contamination in the subsurface beneath Building #2. Alternative 3 complies with this evaluation criterion.	Alternative 3 is expected to have short-term impacts during construction activities that can be mitigated with appropriate health and safety measures. Alternative 3 is expected to take an estimated duration of 1 year to achieve remedial objectives #1, 3, 4, and 5, and an estimated 10 years to achieve remedial objective #2. Alternative 3 complies with this evaluation criterion.	Alternative 3 is implementable with significant impact to Building #2 tenants during construction and ongoing intermittent access required during operation and maintenance. Potential exists to dismantle and reinstall SSDs to avoid heat damage. Requires dedicated electric service. Alternative 3 complies with this evaluation criterion.	The estimated cost of Alternative 3 for a 30-year period is: $11,115,000* *The annual costs are expected to be zero after 10 years.
Alternative 4A Chemical Oxidation – Vertical Well Design and Permeable Reactive Barriers	Alternative 4A maintains protection of on-site workers through continued operation of the sub-slab depressurization system until post-mitigation data supports deactivation. Alternative 4A is expected to reduce concentrations in groundwater migrating to the Seneca River. Alternative 4A complies with this evaluation criterion.	Alternative 4A is expected to mitigate the potential threat to the Class I wetland biotic community resulting from continued migration of contaminated groundwater to the wetland by providing treatment beneath Building #2. Alternative 4A is expected to significantly reduce BTEX, CVOC, and 1,4-dioxane concentrations in groundwater, and achieve all RAOs. Alternative 4A complies with this evaluation criterion.	Alternative 4A is expected to be 80-90% effective for treatment of BTEX, CVOCs, and 1,4-dioxane in groundwater if contact can be established. The potential that pockets of NAPL persist in the subsurface may affect the long-term permanence of Alternative 4A. Alternative 4A is estimated to mitigate vapor intrusion to Building #2 within a 20-year period. Alternative 4A complies with this evaluation criterion.	Alternative 4A is expected to reduce toxicity, mobility, and volume of contamination in the subsurface beneath Building #2, however mobilization of metals may occur and will be monitored. Alternative 4A complies with this evaluation criterion.	Alternative 4A is expected to have short-term impacts during construction activities that can be mitigated with appropriate health and safety measures. Alternative 4A is expected to take an estimated duration of three years to achieve remedial objectives #1, 3, 4, and 5, and an estimated 20 years to achieve remedial objective #2. Alternative 4A complies with this evaluation criterion.	Alternative 4A is implementable with significant impact to Building #2 tenants during construction, and ongoing intermittent access required during injection events. Alternative 4A complies with this evaluation criterion.	The estimated cost of Alternative 4A for a 30-year period is: $6,880,000* *The annual costs are expected to be zero after 20 years.
Alternative 4B Chemical Oxidation - Horizontal and Vertical Well Design	Alternative 4B maintains protection of on-site workers through continued operation of the sub-slab depressurization system until post-mitigation data supports deactivation. Alternative 4A is expected to reduce concentrations in groundwater migrating to the Seneca River. Alternative 4B complies with this evaluation criterion.	Alternative 4B is expected to mitigate the potential threat to the Class I wetland biotic community resulting from continued migration of contaminated groundwater to the wetland by providing treatment beneath Building #2. Alternative 4B is expected to significantly reduce BTEX, CVOC, and 1,4-dioxane concentrations in groundwater, and achieve all RAOs. Alternative 4B complies with this evaluation criterion.	Alternative 4B is expected to be 80-90% effective for treatment of BTEX, CVOCs, and 1,4-dioxane in groundwater if contact can be established. The potential that pockets of NAPL persist in the subsurface may affect the long-term permanence of Alternative 4B. Alternative 4B is estimated to mitigate vapor intrusion to Building #2 within a 20-year period. Alternative 4B complies with this evaluation criterion.	Alternative 4B is expected to reduce toxicity, mobility, and volume of contamination in the subsurface beneath Building #2, however mobilization of metals may occur and will be monitored. Alternative 4B complies with this evaluation criterion.	Alternative 4B is expected to have short-term impacts during construction activities that can be mitigated with appropriate health and safety measures. Alternative 4B is expected to take an estimated duration of three years to achieve remedial objectives #1, 3, 4, and 5, and an estimated 20 years to achieve remedial objective #2. Alternative 4B complies with this evaluation criterion.	Alternative 4B is implementable with moderate impact to Building #2 tenants during construction, and access required during injection events. Alternative 4B complies with this evaluation criterion.	The estimated cost of Alternative 4B for a 30-year period is: $7,040,000* *The annual costs are expected to be zero after 20 years.

Remedial Alternative	Overall Protection of Human Health & the Environment	Compliance with SCGs and Achieves RAOs	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, and Volume	Short-term Impact and Effectiveness	Implementation	Cost (30-year period)
Alternative 5 Monitored Natural Attenuation and Enhanced Reductive Dechlorination Barrier	Alternative 5 maintains protection of on-site workers through continued operation of the sub-slab depressurization system for the foreseeable future. Alternative 5 is expected to reduce CVOC concentrations in groundwater migrating to the Seneca River if the barrier phase is implemented. Alternative 5 complies with this evaluation criterion.	Alternative 5 is expected to mitigate the potential threat to the Class I wetland biotic community resulting from continued migration of contaminated groundwater to the wetland by installing an enhanced reductive dechlorination barrier north of Building #2, should the CVOC plume begin to migrate. The ERD barrier is expected to reduce CVOC concentrations in groundwater as it flows through the barrier towards the wetland. Alternative 5, based on modelling, may reduce BTEX concentrations under natural attenuation, however it is not expected to significantly reduce CVOC or 1,4-dioxane groundwater concentrations beneath Building #2. Alternative 5 is expected to achieve some of the RAOs. Alternative 5 does not comply with this evaluation criterion	Alternative 5 may be effective and permanent in the long-term for the natural attenuation of BTEX concentrations in groundwater and is expected to be effective for the treatment of CVOCs. Alternative 5 is not expected to be effective for attenuation or treatment of 1,4-dioxane. Alternative 5 is not expected to mitigate vapor intrusion to Building #2 within a 30-year period. Alternative 5 does not comply with this evaluation criterion.	Alternative 5 is not expected to reduce toxicity, mobility and volume within the foreseeable future. If the barrier is required to address migration of the CVOC plume, Alternative 5 is expected to reduce volume of contamination in groundwater as it passes through the barrier. Alternative 5 does not comply with this evaluation criterion.	Alternative 5 will not have short-term impacts during monitored natural attenuation, however, is expected to have short-term impacts during barrier installation, if required. Alternative 5 is expected to take an estimated duration of 27 years to achieve remedial objectives #1, 3, and 5, and greater than 30 years to achieve remedial objectives #2 and #3. Alternative 5 does not comply with this evaluation criterion.	Alternative 5 is implementable with significant impact to any tenant on north side of Building #2 during ERD barrier install. Alternative 5 complies with this evaluation criterion.	The estimated cost of Alternative 5 for a 30-year period is: $12,500,000
Alternative 6 Soil Vapor Extraction and Air Sparging	Alternative 6 maintains protection of on-site workers through operation of the sub-slab depressurization systems until post-mitigation supports deactivation. Alternative 6 is expected to reduce concentrations in groundwater migrating to the Seneca River. Alternative 6 complies with this evaluation criterion.	Alternative 6 is expected to mitigate the potential threat to the Class I wetland biotic community resulting from continued migration of contaminated groundwater to the wetland by providing treatment beneath Building #2. Alternative 6 is expected to reduce BTEX and CVOC concentrations in groundwater, however it is not expected to reduce 1,4-dioxane groundwater concentrations beneath Building #2. Alternative 6 is expected to achieve most of the RAOs. Alternative 6 complies with this evaluation criterion.	Alternative 6 is expected to be 80% effective for BTEX and CVOC treatment but is not effective for 1,4-dioxane treatment. Alternative 6 specific technology has previously shown permanence in reduction of concentrations at this site. Alternative 6 is estimated to mitigate vapor intrusion to Building #2 within a 30-year period. Alternative 6 complies with this evaluation criterion.	Alternative 6 is expected to reduce toxicity, mobility, and volume of contamination in the subsurface beneath Building #2. Alternative 6 complies with this evaluation criterion.	Alternative 6 is expected to have short-term impacts during construction activities that can be mitigated with appropriate health and safety measures. Alternative 6 is expected to take an estimated duration of three years to achieve remedial objectives #1, 3 (except for 1,4-dioxane), 4, and 5, and an estimated 20 years to achieve remedial objective #2. Alternative 6 complies with this evaluation criterion.	Alternative 6 is implementable with significantly reduced impact to Building #2 tenants when compared to a vertical well design during construction. Ongoing intermittent access to the site will be required during operation, maintenance & monitoring. Requires above ground treatment of vapor. Alternative 6 complies with this evaluation criterion.	The estimated cost of Alternative 6 for a 30-year period is: $ 8,830,000* *The annual costs are expected to be zero after 20 years.

APPENDICES

Appendix A – REMChlor Model Input

Appendix B – Johnson & Ettinger Model Input

Appendix C – Green and Sustainable Remediation Assessment of Optimized Remedial Alternatives

Appendix A

REMChlor Model Input

Appendix A
1,1-DCE Monitored Natural Attenuation Inputs
REMChlor-MD Model

REMChlor-MD Data Input Screen

Version 1.0

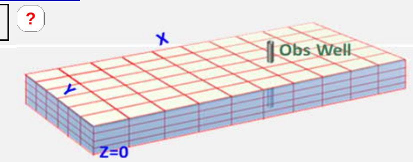
DATA INPUT INSTRUCTIONS
Enter value directly. | Toolkit default value. OK to overwrite.
Value calculated by Toolkit. Cell cannot be edited.

Site Location and ID: LMC Farrell Road

1. STARTING INFORMATION ○ SI Units ◉ English Units ◉ Unconsolidated ○ Fractured Rock/Media ?

2. MODEL CONFIGURATION

	Cell Size	Model Size	
X-Direction (in direction of groundwater flow)	10	700	(ft) ?
Y-Direction (transverse to groundwater flow)	10	400	(ft) ?
Z-Direction (vertical) (all layers have same hydrogeology)	5	25	(ft) ?

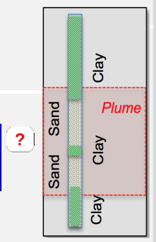


Observation Well Location: X-Value 240.0 (ft) ? Y-Value 5.0 (ft)
Obs. Well Z-Value Top of Screen (model bottom is at Z=0) 5.0 (ft) Bottom of Screen 0.0 (ft)
Starting Year of Simulation (year the source started) 1990 (YYYY year) ?
Ending Year of Simulation 2120 (YYYY year)

3. MEDIA CHARACTERISTICS (uniform for all cells)

	Soil Type	Hydr. Cond. (cm/sec)	Porosity (-)	Tortuosity (-)
Transmissive Zone (T-Zone) Fine Sand	Fine Sand	6.32E-04	0.2	0.48 ?
Low Permeability Zone (Low-k) Clay	Clay	2.17E-08	0.47	0.32
T-Zone Hydraulic Gradient	0.0067 (-)			
T-Zone Groundwater Darcy Velocity	4.38E+00 (ft/yr)			

Default Tortuosity



4. MATRIX DIFFUSION

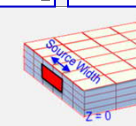
Calculate Heterogeneity ?

Average Darcy Velocity (including low-k units)	4.38E+00	(ft/yr)
Transmissive Zone Volume Fraction	1.00E+02	(%)
Average Diffusion Length	0.00E+00	(ft)
Surface Area of Low-k Interfaces	0.00E+00	(ft2)

5. CONTAMINANTS AND SOURCE TERM

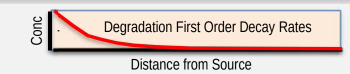
	Parent	Deg. Prod. 1	Deg. Prod. 2	Deg. Prod. 3	
Constituent (use dropdown menu)	11-DCE				?
Initial Source Concentration	1.90E+04	0.00E+00	0.00E+00	0.00E+00	(ug/L)
Source Mass at Time of Release	2.00E+02	0.00E+00	0.00E+00	0.00E+00	(kg)
Retardation Factor in T-Zone	1	1	2	2	(-) Calc R ?
Retardation Factor in Low-k	1	2	2	2	(-) Calc R' ?

Source Width (REMChlor-MD will round to nearest whole cell) 100 (ft) ?
Z-Value for Top of Source (model bottom is at Z=0) 7 (ft) ?
Z-Value for Bottom of Source 0 (ft) ?
General Molecular Diffusion Coefficient for all Constituents 1.04E-05 (cm2/sec)



Next Step: Show Graph | Show Previous Results | Return to Main Screen | New Site/Clear Data | Save/Export Data | Paste Example | Load Data | HELP

6. PLUME DEGRADATION ?
(Both T-Zone and Low-k Zone)



Enter Custom Microbial Yield Terms

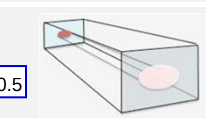
		11-DCE	Component 2	Component 3	Component 4
Model ends here →		Zone 1	Zone 2	Zone 3	
	Period 3	Decay Rate (1,3)	Decay Rate (2,3)	Decay Rate (3,3)	
		1.50E-01	1.50E-01	1.50E-01	T-Zone (1/yr)
56.00 (yrs) Time Period 2 (T2) →		0.00E+00	0.00E+00	0.00E+00	Low-k (1/yr)
	Period 2	Decay Rate (1,2)	Decay Rate (2,2)	Decay Rate (3,2)	
		1.50E-01	1.50E-01	1.50E-01	T-Zone (1/yr)
50.00 (yrs) Time Period 1 (T1) →		0.00E+00	0.00E+00	0.00E+00	Low-k (1/yr)
	Period 1	Decay Rate (1,1)	Decay Rate (2,1)	Decay Rate (3,1)	
		1.50E-01	1.50E-01	1.50E-01	T-Zone (1/yr)
Model starts here →		0.00E+00	0.00E+00	0.00E+00	Low-k (1/yr)

Time (yrs)

X1 0 X2 400
Distance From Source (ft)

7. PLUME TRANSPORT

	Longitudinal	Transverse	Vertical
Dispersivity (ft) ?	50	5	0.5



Dispersivity Calculator

8. SOURCE ZONE REMEDIATION

Percent Source Mass Removed by Remediation	0	(%) ?
Remediation Started in Year	50.00	(yrs) ?
Remediation Ended in Year	56.00	(yrs)
Mass-Flux/Remaining-Mass Term (Gamma, Γ)	1	(-) ?
Natural Source Decay Rate	0	(1/yr) ?

9. MODELING PARAMETERS

Timestep Size	1	(yr) ?
Maximum Number of Iterations	500	(-) ?
Convergence Tolerance	1.00E-02	(ug/L) ?
See Results Every	2	(yr) ?

Note:
The REMChlor model was constructed assuming that the source inputs first began in 1970. Chlorinated solvents (1,1,1-trichloroethane [1,1,1-TCA] for the purpose of this model) was released first (1970), a benzene/toluene/ethylbenzene/toluene (BTEX) source began a time thereafter (1980), and 1,1-dichloroethane (1,1-DCE) a time further thereafter (1990) to reflect breakdown to daughter products from a 1,1,1-TCA source-like condition.

REMChlor-MD Data Input Screen

Version 1.0

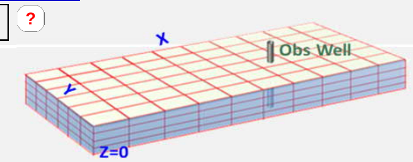
DATA INPUT INSTRUCTIONS
Enter value directly. Toolkit default value. OK to overwrite.
Value calculated by Toolkit. Cell cannot be edited.

Site Location and ID: LMC Farrell Road

1. STARTING INFORMATION ○ SI Units ◉ English Units ◉ Unconsolidated ○ Fractured Rock/Media ?

2. MODEL CONFIGURATION

	Cell Size	Model Size	
X-Direction (in direction of groundwater flow)	10	700	(ft) ?
Y-Direction (transverse to groundwater flow)	10	400	(ft) ?
Z-Direction (vertical) (all layers have same hydrogeology)	5	25	(ft) ?



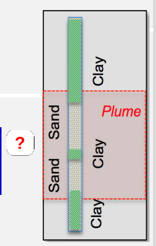
Observation Well Location: X-Value 240.0 (ft) ? Y-Value 5.0 (ft)
Obs. Well Z-Value Top of Screen (model bottom is at Z=0) 5.0 (ft) Bottom of Screen 0.0 (ft)
Starting Year of Simulation (year the source started) 1990 (YYYY year) ?
Ending Year of Simulation 2120 (YYYY year)

3. MEDIA CHARACTERISTICS (uniform for all cells)

	Soil Type		Hydr. Cond. (cm/sec)	Porosity (-)	Tortuosity (-)
Transmissive Zone (T-Zone)	Fine Sand	Fine Sand	6.32E-04	0.2	0.48 ?
Low Permeability Zone (Low-k)	Clay	Clay	2.17E-08	0.47	0.32

T-Zone Hydraulic Gradient 0.0067 (-)
T-Zone Groundwater Darcy Velocity 4.38E+00 (ft/yr)

Default Tortuosity



4. MATRIX DIFFUSION

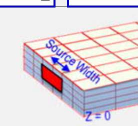
Calculate Heterogeneity ?

Average Darcy Velocity (including low-k units)	4.38E+00	(ft/yr)
Transmissive Zone Volume Fraction	1.00E+02	(%)
Average Diffusion Length	0.00E+00	(ft)
Surface Area of Low-k Interfaces	0.00E+00	(ft2)

5. CONTAMINANTS AND SOURCE TERM

	Parent	Deg. Prod. 1	Deg. Prod. 2	Deg. Prod. 3	
Constituent (use dropdown menu)	11-DCE				?
Initial Source Concentration	1.90E+04	0.00E+00	0.00E+00	0.00E+00	(ug/L)
Source Mass at Time of Release	2.00E+02	0.00E+00	0.00E+00	0.00E+00	(kg)
Retardation Factor in T-Zone	1	1	2	2	(-) Calc R ?
Retardation Factor in Low-k	1	2	2	2	(-) Calc R' ?

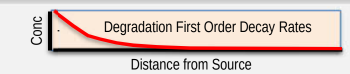
Source Width (REMChlor-MD will round to nearest whole cell) 100 (ft) ?
Z-Value for Top of Source (model bottom is at Z=0) 7 (ft) ?
Z-Value for Bottom of Source 0 (ft) ?
General Molecular Diffusion Coefficient for all Constituents 1.04E-05 (cm2/sec)



Next Step: Show Graph | Show Previous Results | Return to Main Screen | New Site/Clear Data | Save/Export Data | Paste Example | Load Data | HELP

6. PLUME DEGRADATION ?

(Both T-Zone and Low-k Zone)



Enter Custom Microbial Yield Terms

Time (yrs)

Model ends here →
34.00 (yrs) Time Period 2 (T2) →
30.00 (yrs) Time Period 1 (T1) →
Model starts here →

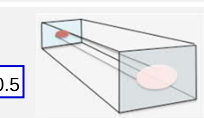
	11-DCE Zone 1	Component 2 Zone 2	Component 3 Zone 3	Component 4
Period 3	Decay Rate (1,3)	Decay Rate (2,3)	Decay Rate (3,3)	
	1.50E-01	1.50E-01	1.50E-01	T-Zone (1/yr)
	0.00E+00	0.00E+00	0.00E+00	Low-k (1/yr)
Period 2	Decay Rate (1,2)	Decay Rate (2,2)	Decay Rate (3,2)	
	1.00E+00	1.00E+00	1.50E-01	T-Zone (1/yr)
	0.00E+00	0.00E+00	0.00E+00	Low-k (1/yr)
Period 1	Decay Rate (1,1)	Decay Rate (2,1)	Decay Rate (3,1)	
	1.50E-01	1.50E-01	1.50E-01	T-Zone (1/yr)
	0.00E+00	0.00E+00	0.00E+00	Low-k (1/yr)

X1 0 X2 400

Distance From Source (ft)

7. PLUME TRANSPORT

	Longitudinal	Transverse	Vertical
Dispersivity (ft) ?	50	5	0.5



Dispersivity Calculator

8. SOURCE ZONE REMEDIATION

Percent Source Mass Removed by Remediation	80	(%)	?
Remediation Started in Year	30.00	(yrs)	?
Remediation Ended in Year	34.00	(yrs)	
Mass-Flux/Remaining-Mass Term (Gamma, Γ)	1	(-)	?
Natural Source Decay Rate	0	(1/yr)	?

9. MODELING PARAMETERS

Timestep Size	1	(yr)	?
Maximum Number of Iterations	500	(-)	?
Convergence Tolerance	1.00E-02	(ug/L)	?
See Results Every	2	(yr)	?

Note:
The REMChlor model was constructed assuming that the source inputs first began in 1970. Chlorinated solvents (1,1,1-trichloroethane [1,1,1-TCA] for the purpose of this model) was released first (1970), a benzene/toluene/ethylbenzene/toluene (BTEX) source began a time thereafter (1980), and 1,1-dichloroethane (1,1-DCE) a time further thereafter (1990) to reflect breakdown to daughter products from a 1,1,1-TCA source-like condition.

REMChlor-MD Data Input Screen

Version 1.0

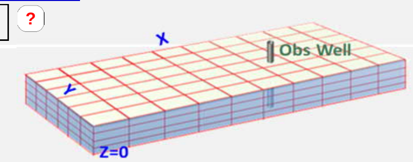
DATA INPUT INSTRUCTIONS
Enter value directly. | Toolkit default value. OK to overwrite.
Value calculated by Toolkit. Cell cannot be edited.

Site Location and ID: LMC Farrell Road

1. STARTING INFORMATION ○ SI Units ◉ English Units | ◉ Unconsolidated ○ Fractured Rock/Media ?

2. MODEL CONFIGURATION

	Cell Size	Model Size	
X-Direction (in direction of groundwater flow)	10	700	(ft)
Y-Direction (transverse to groundwater flow)	10	400	(ft)
Z-Direction (vertical) (all layers have same hydrogeology)	5	25	(ft)



Observation Well Location: X-Value	240.0 (ft)	Y-Value	5.0	(ft)
Obs. Well Z-Value Top of Screen (model bottom is at Z=0)	5.0 (ft)	Bottom of Screen	0.0	(ft)
Starting Year of Simulation (year the source started)	1990 (YYYY year)			
Ending Year of Simulation	2120 (YYYY year)			

Start Year (release yr) — T1 (Sect. 6) — T2 (Sect. 6) — Ending Year

3. MEDIA CHARACTERISTICS (uniform for all cells)

	Soil Type	Hydr. Cond. (cm/sec)	Porosity (-)	Tortuosity (-)
Transmissive Zone (T-Zone)	Fine Sand	6.32E-04	0.2	0.48
Low Permeability Zone (Low-k)	Clay	2.17E-08	0.47	0.32

T-Zone Hydraulic Gradient: 0.0067 (-)
T-Zone Groundwater Darcy Velocity: 4.38E+00 (ft/yr)
Default Tortuosity

Clay / Sand / Plume / Clay / Sand / Clay

4. MATRIX DIFFUSION

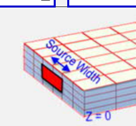
Calculate Heterogeneity

Average Darcy Velocity (including low-k units)	4.38E+00	(ft/yr)
Transmissive Zone Volume Fraction	1.00E+02	(%)
Average Diffusion Length	0.00E+00	(ft)
Surface Area of Low-k Interfaces	0.00E+00	(ft2)

5. CONTAMINANTS AND SOURCE TERM

	Parent	Deg. Prod. 1	Deg. Prod. 2	Deg. Prod. 3	
Constituent (use dropdown menu)	11-DCE				
Initial Source Concentration	1.90E+04	0.00E+00	0.00E+00	0.00E+00	(ug/L)
Source Mass at Time of Release	2.00E+02	0.00E+00	0.00E+00	0.00E+00	(kg)
Retardation Factor in T-Zone	1	1	2	2	(-) Calc R
Retardation Factor in Low-k	1	2	2	2	(-) Calc R'

Source Width (REMChlor-MD will round to nearest whole cell)	100	(ft)
Z-Value for Top of Source (model bottom is at Z=0)	7	(ft)
Z-Value for Bottom of Source	0	(ft)
General Molecular Diffusion Coefficient for all Constituents	1.04E-05	(cm2/sec)



Next Step: Show Graph | Show Previous Results | Return to Main Screen | New Site/Clear Data | Save/Export Data | Paste Example | Load Data | HELP

6. PLUME DEGRADATION
(Both T-Zone and Low-k Zone)

Degradation First Order Decay Rates (Conc vs. Distance from Source)
Enter Custom Microbial Yield Terms

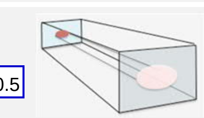
		11-DCE Zone 1	Component 2 Zone 2	Component 3 Zone 3	Component 4
Model ends here → Period 3		Decay Rate (1,3)	Decay Rate (2,3)	Decay Rate (3,3)	
		1.50E-01	1.50E-01	1.50E-01	T-Zone (1/yr)
Time Period 2 (T2): 35.00 (yrs)		0.00E+00	0.00E+00	0.00E+00	Low-k (1/yr)
Period 2		Decay Rate (1,2)	Decay Rate (2,2)	Decay Rate (3,2)	
		1.50E+00	1.50E+00	1.50E+00	T-Zone (1/yr)
Time Period 1 (T1): 30.00 (yrs)		0.00E+00	0.00E+00	0.00E+00	Low-k (1/yr)
Period 1		Decay Rate (1,1)	Decay Rate (2,1)	Decay Rate (3,1)	
		1.50E-01	1.50E-01	1.50E-01	T-Zone (1/yr)
Model starts here →		0.00E+00	0.00E+00	0.00E+00	Low-k (1/yr)

Time (yrs)

X1: 0 | X2: 400
Distance From Source (ft)

7. PLUME TRANSPORT

	Longitudinal	Transverse	Vertical
Dispersivity (ft)	50	5	0.5



Dispersivity Calculator

8. SOURCE ZONE REMEDIATION

Percent Source Mass Removed by Remediation	90	(%)
Remediation Started in Year	30.00	(yrs)
Remediation Ended in Year	35.00	(yrs)
Mass-Flux/Remaining-Mass Term (Gamma, Γ)	1	(-)
Natural Source Decay Rate	0	(1/yr)

9. MODELING PARAMETERS

Timestep Size	1	(yr)
Maximum Number of Iterations	500	(-)
Convergence Tolerance	1.00E-02	(ug/L)
See Results Every	2	(yr)

Note:
The REMChlor model was constructed assuming that the source inputs first began in 1970. Chlorinated solvents (1,1,1-trichloroethane [1,1,1-TCA] for the purpose of this model) was released first (1970), a benzene/toluene/ethylbenzene/toluene (BTEX) source began a time thereafter (1980), and 1,1-dichloroethane (1,1-DCE) a time further thereafter (1990) to reflect breakdown to daughter products from a 1,1,1-TCA source-like condition.

Appendix A
1,1-DCE Thermal Inputs
REMChlor-MD Model

REMChlor-MD Data Input Screen

Version 1.0

DATA INPUT INSTRUCTIONS
Enter value directly. Toolkit default value. OK to overwrite.
Value calculated by Toolkit. Cell cannot be edited.

Site Location and ID: LMC Farrell Road

1. STARTING INFORMATION ○ SI Units ◉ English Units ◉ Unconsolidated ○ Fractured Rock/Media

2. MODEL CONFIGURATION

	Cell Size	Model Size	
X-Direction (in direction of groundwater flow)	10	700	(ft)
Y-Direction (transverse to groundwater flow)	10	400	(ft)
Z-Direction (vertical) (all layers have same hydrogeology)	5	25	(ft)

Observation Well Location: X-Value 240.0 (ft) Y-Value 5.0 (ft)
Obs. Well Z-Value Top of Screen (model bottom is at Z=0) 5.0 (ft) Bottom of Screen 0.0 (ft)
Starting Year of Simulation (year the source started) 1990 (YYYY year)
Ending Year of Simulation 2120 (YYYY year)

Start Year (release yr) T1 (Sect 6) T2 (Sect 6) Ending Year

3. MEDIA CHARACTERISTICS (uniform for all cells)

	Soil Type		Hydr. Cond. (cm/sec)	Porosity (-)	Tortuosity (-)
Transmissive Zone (T-Zone)	Fine Sand	Fine Sand	6.32E-04	0.2	0.48
Low Permeability Zone (Low-k)	Clay	Clay	2.17E-08	0.47	0.32

T-Zone Hydraulic Gradient 0.0067 (-)
T-Zone Groundwater Darcy Velocity 4.38E+00 (ft/yr)
Default Tortuosity

Clay Sand Plume Clay Sand Clay

4. MATRIX DIFFUSION

Calculate Heterogeneity

Average Darcy Velocity (including low-k units)	4.38E+00	(ft/yr)
Transmissive Zone Volume Fraction	1.00E+02	(%)
Average Diffusion Length	0.00E+00	(ft)
Surface Area of Low-k Interfaces	0.00E+00	(ft2)

5. CONTAMINANTS AND SOURCE TERM

	Parent	Deg. Prod. 1	Deg. Prod. 2	Deg. Prod. 3	
Constituent (use dropdown menu)	11-DCE				
Initial Source Concentration	1.90E+04	0.00E+00	0.00E+00	0.00E+00	(ug/L)
Source Mass at Time of Release	2.00E+02	0.00E+00	0.00E+00	0.00E+00	(kg)
Retardation Factor in T-Zone	1	1	2	2	(-) Calc R
Retardation Factor in Low-k	1	2	2	2	(-) Calc R'

Source Width (REMChlor-MD will round to nearest whole cell) 100 (ft)
Z-Value for Top of Source (model bottom is at Z=0) 7 (ft)
Z-Value for Bottom of Source 0 (ft)
General Molecular Diffusion Coefficient for all Constituents 1.04E-05 (cm2/sec)

Next Step: Show Graph | Show Previous Results | Return to Main Screen | New Site/Clear Data | Save/Export Data | Paste Example | Load Data | HELP

6. PLUME DEGRADATION
(Both T-Zone and Low-k Zone)

Degradation First Order Decay Rates — Conc / Distance from Source
Enter Custom Microbial Yield Terms

Model ends here → Time Period 2 (T2) 31.00 (yrs) → Time Period 1 (T1) 30.00 (yrs) → Model starts here

Time (yrs)

		11-DCE	Component 2	Component 3	Component 4	
		Zone 1	Zone 2	Zone 3		
Period 3		Decay Rate (1,3)	Decay Rate (2,3)	Decay Rate (3,3)		
		1.50E-01	1.50E-01	1.50E-01		T-Zone (1/yr)
		0.00E+00	0.00E+00	0.00E+00		Low-k (1/yr)
Period 2		Decay Rate (1,2)	Decay Rate (2,2)	Decay Rate (3,2)		
		1.00E+02	1.00E+02	1.00E+02		T-Zone (1/yr)
		0.00E+00	0.00E+00	0.00E+00		Low-k (1/yr)
Period 1		Decay Rate (1,1)	Decay Rate (2,1)	Decay Rate (3,1)		
		1.50E-01	1.50E-01	1.50E-01		T-Zone (1/yr)
		0.00E+00	0.00E+00	0.00E+00		Low-k (1/yr)

X1 0 X2 250
Distance From Source (ft)

7. PLUME TRANSPORT

	Longitudinal	Transverse	Vertical
Dispersivity (ft)	50	5	0.5

Dispersivity Calculator

8. SOURCE ZONE REMEDIATION

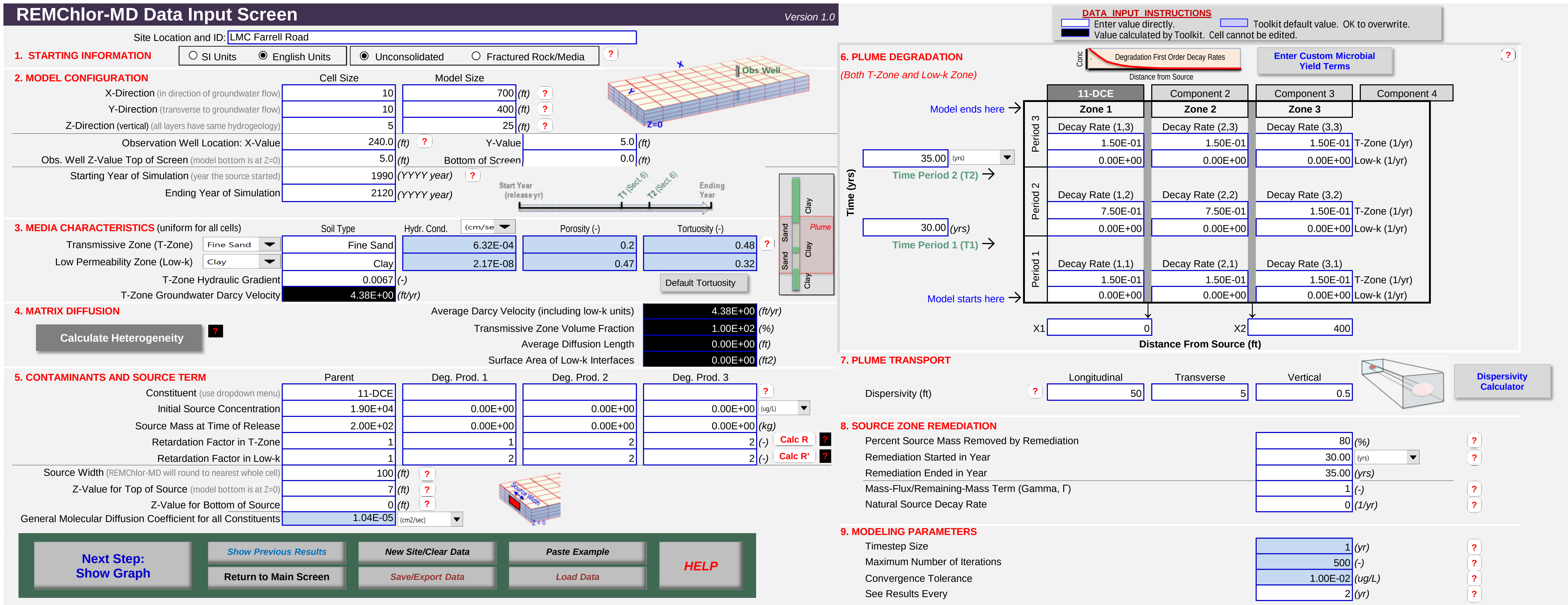
Percent Source Mass Removed by Remediation	99	(%)
Remediation Started in Year	30.00	(yrs)
Remediation Ended in Year	31.00	(yrs)
Mass-Flux/Remaining-Mass Term (Gamma, Γ)	1	(-)
Natural Source Decay Rate	0	(1/yr)

9. MODELING PARAMETERS

Timestep Size	1	(yr)
Maximum Number of Iterations	500	(-)
Convergence Tolerance	1.00E-02	(ug/L)
See Results Every	2	(yr)

Note:
The REMChlor model was constructed assuming that the source inputs first began in 1970. Chlorinated solvents (1,1,1-trichloroethane [1,1,1-TCA] for the purpose of this model) was released first (1970), a benzene/toluene/ethylbenzene/toluene (BTEX) source began a time thereafter (1980), and 1,1-dichloroethane (1,1-DCE) a time further thereafter (1990) to reflect breakdown to daughter products from a 1,1,1-TCA source-like condition.

Appendix A
1,1-DCE Soil Vapor Extraction - Air Sparge
REMChlor-MD Model



Note:
The REMChlor model was constructed assuming that the source inputs first began in 1970. Chlorinated solvents (1,1,1-trichloroethane [1,1,1-TCA] for the purpose of this model) was released first (1970), a benzene/toluene/ethylbenzene/toluene (BTEX) source began a time thereafter (1980), and 1,1-dichloroethane (1,1-DCE) a time further thereafter (1990) to reflect breakdown to daughter products from a 1,1,1-TCA source-like condition.

REMChlor-MD Data Input Screen

Version 1.0

DATA INPUT INSTRUCTIONS
- Enter value directly.
- Toolkit default value. OK to overwrite.
- Value calculated by Toolkit. Cell cannot be edited.

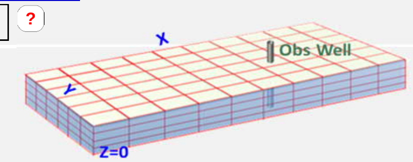
Site Location and ID: LMC Farrell Road

1. STARTING INFORMATION

○ SI Units ◉ English Units ◉ Unconsolidated ○ Fractured Rock/Media ?

2. MODEL CONFIGURATION

	Cell Size	Model Size	
X-Direction (in direction of groundwater flow)	10	700	(ft) ?
Y-Direction (transverse to groundwater flow)	10	400	(ft) ?
Z-Direction (vertical) (all layers have same hydrogeology)	5	25	(ft) ?



Observation Well Location: X-Value 240.0 (ft) ? Y-Value 5.0 (ft)

Obs. Well Z-Value Top of Screen (model bottom is at Z=0) 5.0 (ft) Bottom of Screen 0.0 (ft)

Starting Year of Simulation (year the source started) 1970 (YYYY year) ?

Ending Year of Simulation 2120 (YYYY year)

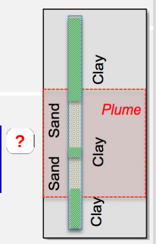
3. MEDIA CHARACTERISTICS (uniform for all cells)

	Soil Type		Hydr. Cond. (cm/sec)	Porosity (-)	Tortuosity (-)
Transmissive Zone (T-Zone)	Fine Sand	Fine Sand	6.32E-04	0.2	0.48 ?
Low Permeability Zone (Low-k)	Clay	Clay	2.17E-08	0.47	0.32

T-Zone Hydraulic Gradient 0.0067 (-)

T-Zone Groundwater Darcy Velocity 4.38E+00 (ft/yr)

Default Tortuosity



4. MATRIX DIFFUSION

Calculate Heterogeneity ?

Average Darcy Velocity (including low-k units)	4.38E+00	(ft/yr)
Transmissive Zone Volume Fraction	1.00E+02	(%)
Average Diffusion Length	0.00E+00	(ft)
Surface Area of Low-k Interfaces	0.00E+00	(ft2)

5. CONTAMINANTS AND SOURCE TERM

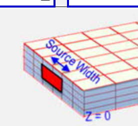
	Parent	Deg. Prod. 1	Deg. Prod. 2	Deg. Prod. 3	
Constituent (use dropdown menu)	111-TCA				?
Initial Source Concentration	2.40E+05	0.00E+00	0.00E+00	0.00E+00	(ug/L)
Source Mass at Time of Release	2.75E+02	0.00E+00	0.00E+00	0.00E+00	(kg)
Retardation Factor in T-Zone	1	1	2	2	(-) Calc R
Retardation Factor in Low-k	1	2	2	2	(-) Calc R'

Source Width (REMChlor-MD will round to nearest whole cell) 100 (ft) ?

Z-Value for Top of Source (model bottom is at Z=0) 7 (ft) ?

Z-Value for Bottom of Source 0 (ft) ?

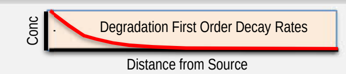
General Molecular Diffusion Coefficient for all Constituents 8.80E-06 (cm2/sec)



Next Step: Show Graph | Show Previous Results | Return to Main Screen | New Site/Clear Data | Save/Export Data | Paste Example | Load Data | HELP

6. PLUME DEGRADATION

(Both T-Zone and Low-k Zone)



Enter Custom Microbial Yield Terms ?

Time (yrs)

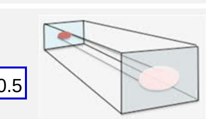
		111-TCA	Component 2	Component 3	Component 4
Model ends here →		Zone 1	Zone 2	Zone 3	
	Period 3	Decay Rate (1,3)	Decay Rate (2,3)	Decay Rate (3,3)	
		1.00E+00	1.00E+00	1.00E+00	T-Zone (1/yr)
56.00 (yrs)		0.00E+00	0.00E+00	0.00E+00	Low-k (1/yr)
Time Period 2 (T2) →	Period 2	Decay Rate (1,2)	Decay Rate (2,2)	Decay Rate (3,2)	
		1.00E+00	1.00E+00	1.00E+00	T-Zone (1/yr)
50.00 (yrs)		0.00E+00	0.00E+00	0.00E+00	Low-k (1/yr)
Time Period 1 (T1) →	Period 1	Decay Rate (1,1)	Decay Rate (2,1)	Decay Rate (3,1)	
		1.00E+00	1.00E+00	1.00E+00	T-Zone (1/yr)
Model starts here →		0.00E+00	0.00E+00	0.00E+00	Low-k (1/yr)

X1 0 X2 400

Distance From Source (ft)

7. PLUME TRANSPORT

	Longitudinal	Transverse	Vertical
Dispersivity (ft) ?	50	5	0.5



Dispersivity Calculator

8. SOURCE ZONE REMEDIATION

Percent Source Mass Removed by Remediation	0	(%)	?
Remediation Started in Year	50.00	(yrs)	?
Remediation Ended in Year	56.00	(yrs)	
Mass-Flux/Remaining-Mass Term (Gamma, Γ)	0.7	(-)	?
Natural Source Decay Rate	0	(1/yr)	?

9. MODELING PARAMETERS

Timestep Size	1	(yr)	?
Maximum Number of Iterations	500	(-)	?
Convergence Tolerance	1.00E-02	(ug/L)	?
See Results Every	2	(yr)	?

Note:
The REMChlor model was constructed assuming that the source inputs first began in 1970. Chlorinated solvents (1,1,1-trichloroethane [1,1,1-TCA] for the purpose of this model) was released first (1970), a benzene/toluene/ethylbenzene/toluene (BTEX) source began a time thereafter (1980), and 1,1-dichloroethane (1,1-DCE) a time further thereafter (1990) to reflect breakdown to daughter products from a 1,1,1-TCA source-like condition.

Appendix A
1,1,1-TCA In Situ Chemical Oxidation Inputs
REMChlor-MD Model

REMChlor-MD Data Input Screen

Version 1.0

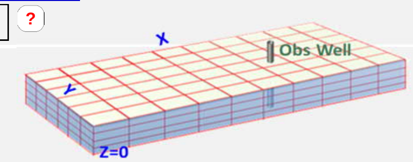
DATA INPUT INSTRUCTIONS
Enter value directly. | Toolkit default value. OK to overwrite.
Value calculated by Toolkit. Cell cannot be edited.

Site Location and ID: LMC Farrell Road

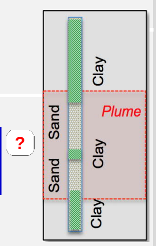
1. STARTING INFORMATION ○ SI Units ◉ English Units | ◉ Unconsolidated ○ Fractured Rock/Media ?

2. MODEL CONFIGURATION

	Cell Size	Model Size	
X-Direction (in direction of groundwater flow)	10	700	(ft) ?
Y-Direction (transverse to groundwater flow)	10	400	(ft) ?
Z-Direction (vertical) (all layers have same hydrogeology)	5	25	(ft) ?



Observation Well Location: X-Value	240.0	(ft) ?	Y-Value	5.0 (ft)
Obs. Well Z-Value Top of Screen (model bottom is at Z=0)	5.0	(ft)	Bottom of Screen	0.0 (ft)
Starting Year of Simulation (year the source started)	1970	(YYYY year) ?		
Ending Year of Simulation	2120	(YYYY year)		



3. MEDIA CHARACTERISTICS (uniform for all cells)

	Soil Type		Hydr. Cond. (cm/sec)	Porosity (-)	Tortuosity (-)
Transmissive Zone (T-Zone)	Fine Sand	Fine Sand	6.32E-04	0.2	0.48 ?
Low Permeability Zone (Low-k)	Clay	Clay	2.17E-08	0.47	0.32
T-Zone Hydraulic Gradient		0.0067 (-)			Default Tortuosity
T-Zone Groundwater Darcy Velocity		4.38E+00 (ft/yr)			

4. MATRIX DIFFUSION

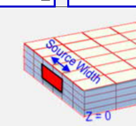
Calculate Heterogeneity

Average Darcy Velocity (including low-k units)	4.38E+00	(ft/yr)
Transmissive Zone Volume Fraction	1.00E+02	(%)
Average Diffusion Length	0.00E+00	(ft)
Surface Area of Low-k Interfaces	0.00E+00	(ft2)

5. CONTAMINANTS AND SOURCE TERM

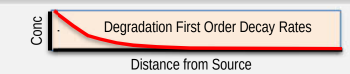
	Parent	Deg. Prod. 1	Deg. Prod. 2	Deg. Prod. 3	
Constituent (use dropdown menu)	111-TCA	11-DCA			?
Initial Source Concentration	2.40E+05	0.00E+00	0.00E+00	0.00E+00	(ug/L)
Source Mass at Time of Release	2.75E+02	0.00E+00	0.00E+00	0.00E+00	(kg)
Retardation Factor in T-Zone	1	1	2	2	(-) Calc R
Retardation Factor in Low-k	1	2	2	2	(-) Calc R'

Source Width (REMChlor-MD will round to nearest whole cell)	100	(ft) ?
Z-Value for Top of Source (model bottom is at Z=0)	7	(ft) ?
Z-Value for Bottom of Source	0	(ft) ?
General Molecular Diffusion Coefficient for all Constituents	8.80E-06	(cm2/sec)



Next Step: Show Graph | Show Previous Results | Return to Main Screen | New Site/Clear Data | Save/Export Data | Paste Example | Load Data | HELP

6. PLUME DEGRADATION (Both T-Zone and Low-k Zone)



Enter Custom Microbial Yield Terms ?

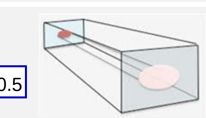
Time (yrs)		111-TCA	11-DCA	Component 3	Component 4
Model ends here →		Zone 1	Zone 2	Zone 3	
	Period 3	Decay Rate (1,3)	Decay Rate (2,3)	Decay Rate (3,3)	
		1.00E+00	1.00E+00	1.00E+00	T-Zone (1/yr)
54.00 (yrs) Time Period 2 (T2) →		0.00E+00	0.00E+00	0.00E+00	Low-k (1/yr)
	Period 2	Decay Rate (1,2)	Decay Rate (2,2)	Decay Rate (3,2)	
		2.50E+00	2.50E+00	1.00E+00	T-Zone (1/yr)
50.00 (yrs) Time Period 1 (T1) →		0.00E+00	0.00E+00	0.00E+00	Low-k (1/yr)
	Period 1	Decay Rate (1,1)	Decay Rate (2,1)	Decay Rate (3,1)	
		1.00E+00	1.00E+00	1.00E+00	T-Zone (1/yr)
Model starts here →		0.00E+00	0.00E+00	0.00E+00	Low-k (1/yr)

X1 0 | X2 400

Distance From Source (ft)

7. PLUME TRANSPORT

	Longitudinal	Transverse	Vertical
Dispersivity (ft) ?	50	5	0.5



Dispersivity Calculator

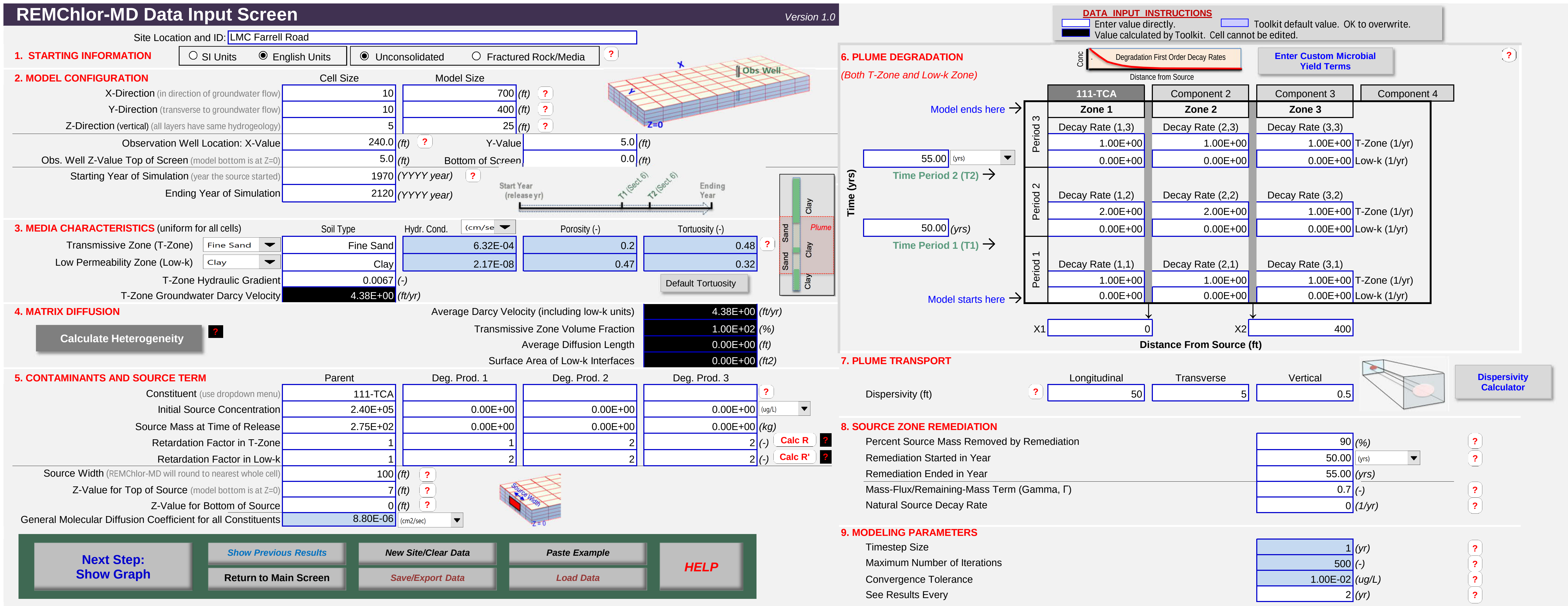
8. SOURCE ZONE REMEDIATION

Percent Source Mass Removed by Remediation	80	(%) ?
Remediation Started in Year	50.00	(yrs) ?
Remediation Ended in Year	54.00	(yrs)
Mass-Flux/Remaining-Mass Term (Gamma, Γ)	0.7	(-) ?
Natural Source Decay Rate	0	(1/yr) ?

9. MODELING PARAMETERS

Timestep Size	1	(yr) ?
Maximum Number of Iterations	500	(-) ?
Convergence Tolerance	1.00E-02	(ug/L) ?
See Results Every	2	(yr) ?

Note:
The REMChlor model was constructed assuming that the source inputs first began in 1970. Chlorinated solvents (1,1,1-trichloroethane [1,1,1-TCA] for the purpose of this model) was released first (1970), a benzene/toluene/ethylbenzene/toluene (BTEX) source began a time thereafter (1980), and 1,1-dichloroethane (1,1-DCE) a time further thereafter (1990) to reflect breakdown to daughter products from a 1,1,1-TCA source-like condition.



REMChlor-MD Data Input Screen Version 1.0

DATA INPUT INSTRUCTIONS
Enter value directly. Toolkit default value. OK to overwrite.
Value calculated by Toolkit. Cell cannot be edited.

Site Location and ID: LMC Farrell Road

1. STARTING INFORMATION SI Units ◉ English Units ◉ Unconsolidated Fractured Rock/Media

2. MODEL CONFIGURATION

	Cell Size	Model Size	
X-Direction (in direction of groundwater flow)	10	700	(ft)
Y-Direction (transverse to groundwater flow)	10	400	(ft)
Z-Direction (vertical) (all layers have same hydrogeology)	5	25	(ft)

Observation Well Location: X-Value 240.0 (ft) Y-Value 5.0 (ft)
Obs. Well Z-Value Top of Screen (model bottom is at Z=0) 5.0 (ft) Bottom of Screen 0.0 (ft)
Starting Year of Simulation (year the source started) 1970 (YYYY year)
Ending Year of Simulation 2120 (YYYY year)

3. MEDIA CHARACTERISTICS (uniform for all cells)

	Soil Type	Hydr. Cond. (cm/sec)	Porosity (-)	Tortuosity (-)
Transmissive Zone (T-Zone)	Fine Sand	6.32E-04	0.2	0.48
Low Permeability Zone (Low-k)	Clay	2.17E-08	0.47	0.32

T-Zone Hydraulic Gradient 0.0067 (-)
T-Zone Groundwater Darcy Velocity 4.38E+00 (ft/yr)
Default Tortuosity

4. MATRIX DIFFUSION

Calculate Heterogeneity

Average Darcy Velocity (including low-k units)	4.38E+00	(ft/yr)
Transmissive Zone Volume Fraction	1.00E+02	(%)
Average Diffusion Length	0.00E+00	(ft)
Surface Area of Low-k Interfaces	0.00E+00	(ft2)

5. CONTAMINANTS AND SOURCE TERM

	Parent	Deg. Prod. 1	Deg. Prod. 2	Deg. Prod. 3	
Constituent (use dropdown menu)	111-TCA				
Initial Source Concentration	2.40E+05	0.00E+00	0.00E+00	0.00E+00	(ug/L)
Source Mass at Time of Release	2.75E+02	0.00E+00	0.00E+00	0.00E+00	(kg)
Retardation Factor in T-Zone	1	1	2	2	(-) Calc R
Retardation Factor in Low-k	1	2	2	2	(-) Calc R'

Source Width (REMChlor-MD will round to nearest whole cell) 100 (ft)
Z-Value for Top of Source (model bottom is at Z=0) 7 (ft)
Z-Value for Bottom of Source 0 (ft)
General Molecular Diffusion Coefficient for all Constituents 8.80E-06 (cm2/sec)

Next Step: Show Graph | Show Previous Results | Return to Main Screen | New Site/Clear Data | Save/Export Data | Paste Example | Load Data | HELP

6. PLUME DEGRADATION (Both T-Zone and Low-k Zone)

Degradation First Order Decay Rates | Enter Custom Microbial Yield Terms

Model ends here → Time Period 2 (T2) 55.00 (yrs); Time Period 1 (T1) 50.00 (yrs); Model starts here →

	111-TCA Zone 1	Component 2 Zone 2	Component 3 Zone 3	
Period 3	Decay Rate (1,3)	Decay Rate (2,3)	Decay Rate (3,3)	
	1.00E+00	1.00E+00	1.00E+00	T-Zone (1/yr)
	0.00E+00	0.00E+00	0.00E+00	Low-k (1/yr)
Period 2	Decay Rate (1,2)	Decay Rate (2,2)	Decay Rate (3,2)	
	2.00E+00	2.00E+00	1.00E+00	T-Zone (1/yr)
	0.00E+00	0.00E+00	0.00E+00	Low-k (1/yr)
Period 1	Decay Rate (1,1)	Decay Rate (2,1)	Decay Rate (3,1)	
	1.00E+00	1.00E+00	1.00E+00	T-Zone (1/yr)
	0.00E+00	0.00E+00	0.00E+00	Low-k (1/yr)

Component 4

X1 0 X2 400 Distance From Source (ft)

7. PLUME TRANSPORT

	Longitudinal	Transverse	Vertical
Dispersivity (ft)	50	5	0.5

Dispersivity Calculator

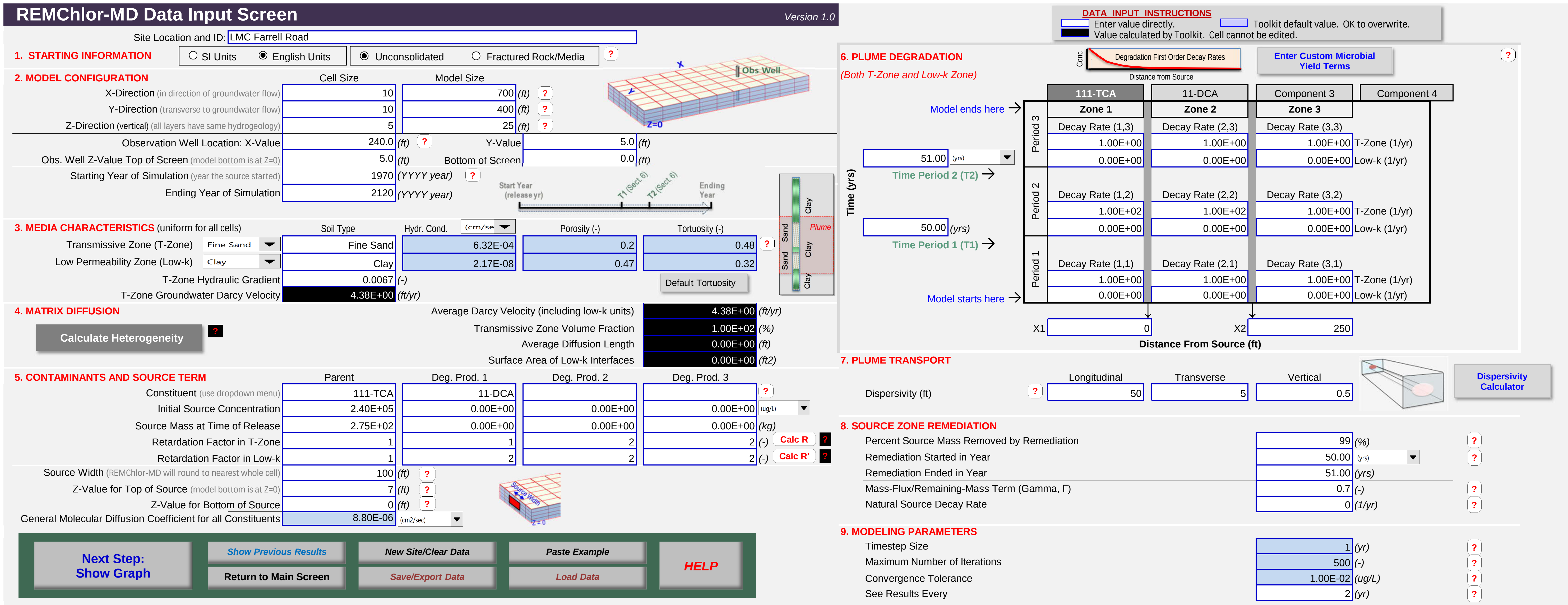
8. SOURCE ZONE REMEDIATION

Percent Source Mass Removed by Remediation	90	(%)
Remediation Started in Year	50.00	(yrs)
Remediation Ended in Year	55.00	(yrs)
Mass-Flux/Remaining-Mass Term (Gamma, Γ)	0.7	(-)
Natural Source Decay Rate	0	(1/yr)

9. MODELING PARAMETERS

Timestep Size	1	(yr)
Maximum Number of Iterations	500	(-)
Convergence Tolerance	1.00E-02	(ug/L)
See Results Every	2	(yr)

Note:
The REMChlor model was constructed assuming that the source inputs first began in 1970. Chlorinated solvents (1,1,1-trichloroethane [1,1,1-TCA] for the purpose of this model) was released first (1970), a benzene/toluene/ethylbenzene/toluene (BTEX) source began a time thereafter (1980), and 1,1-dichloroethane (1,1-DCE) a time further thereafter (1990) to reflect breakdown to daughter products from a 1,1,1-TCA source-like condition.



REMChlor-MD Data Input Screen

Version 1.0

DATA INPUT INSTRUCTIONS
Enter value directly. | Toolkit default value. OK to overwrite.
Value calculated by Toolkit. Cell cannot be edited.

Site Location and ID: LMC Farrell Road

1. STARTING INFORMATION — SI Units / (•) English Units — (•) Unconsolidated / Fractured Rock/Media

2. MODEL CONFIGURATION

	Cell Size	Model Size	
X-Direction (in direction of groundwater flow)	10	700	(ft)
Y-Direction (transverse to groundwater flow)	10	400	(ft)
Z-Direction (vertical) (all layers have same hydrogeology)	5	25	(ft)

Observation Well Location: X-Value	240.0 (ft)	Y-Value	5.0	(ft)
Obs. Well Z-Value Top of Screen (model bottom is at Z=0)	5.0 (ft)	Bottom of Screen	0.0	(ft)
Starting Year of Simulation (year the source started)	1970 (YYYY year)			
Ending Year of Simulation	2120 (YYYY year)			

Start Year (release yr) — T1 (Sect. 6) — T2 (Sect. 6) — Ending Year

3. MEDIA CHARACTERISTICS (uniform for all cells)

	Soil Type	Hydr. Cond. (cm/sec)	Porosity (-)	Tortuosity (-)
Transmissive Zone (T-Zone) — Fine Sand	Fine Sand	6.32E-04	0.2	0.48
Low Permeability Zone (Low-k) — Clay	Clay	2.17E-08	0.47	0.32

T-Zone Hydraulic Gradient: 0.0067 (-)
T-Zone Groundwater Darcy Velocity: 4.38E+00 (ft/yr)
Default Tortuosity

4. MATRIX DIFFUSION

Calculate Heterogeneity

Average Darcy Velocity (including low-k units)	4.38E+00	(ft/yr)
Transmissive Zone Volume Fraction	1.00E+02	(%)
Average Diffusion Length	0.00E+00	(ft)
Surface Area of Low-k Interfaces	0.00E+00	(ft2)

5. CONTAMINANTS AND SOURCE TERM

	Parent	Deg. Prod. 1	Deg. Prod. 2	Deg. Prod. 3	
Constituent (use dropdown menu)	111-TCA	11-DCA			
Initial Source Concentration	2.40E+05	0.00E+00	0.00E+00	0.00E+00	(ug/L)
Source Mass at Time of Release	2.75E+02	0.00E+00	0.00E+00	0.00E+00	(kg)
Retardation Factor in T-Zone	1	1	2	2	(-) Calc R
Retardation Factor in Low-k	1	2	2	2	(-) Calc R'

Source Width (REMChlor-MD will round to nearest whole cell)	100	(ft)
Z-Value for Top of Source (model bottom is at Z=0)	7	(ft)
Z-Value for Bottom of Source	0	(ft)
General Molecular Diffusion Coefficient for all Constituents	8.80E-06	(cm2/sec)

Next Step: Show Graph | Show Previous Results | Return to Main Screen | New Site/Clear Data | Save/Export Data | Paste Example | Load Data | HELP

6. PLUME DEGRADATION
(Both T-Zone and Low-k Zone)

Degradation First Order Decay Rates — Enter Custom Microbial Yield Terms

Model ends here → ; Time Period 2 (T2): 51.00 (yrs); Time Period 1 (T1): 50.00 (yrs); Model starts here →

	111-TCA Zone 1	11-DCA Zone 2	Component 3 Zone 3	Component 4
Period 3	Decay Rate (1,3)	Decay Rate (2,3)	Decay Rate (3,3)	
	1.00E+00	1.00E+00	1.00E+00	T-Zone (1/yr)
	0.00E+00	0.00E+00	0.00E+00	Low-k (1/yr)
Period 2	Decay Rate (1,2)	Decay Rate (2,2)	Decay Rate (3,2)	
	1.00E+02	1.00E+02	1.00E+00	T-Zone (1/yr)
	0.00E+00	0.00E+00	0.00E+00	Low-k (1/yr)
Period 1	Decay Rate (1,1)	Decay Rate (2,1)	Decay Rate (3,1)	
	1.00E+00	1.00E+00	1.00E+00	T-Zone (1/yr)
	0.00E+00	0.00E+00	0.00E+00	Low-k (1/yr)

X1: 0 — X2: 250
Distance From Source (ft)

7. PLUME TRANSPORT

	Longitudinal	Transverse	Vertical
Dispersivity (ft)	50	5	0.5

Dispersivity Calculator

8. SOURCE ZONE REMEDIATION

Percent Source Mass Removed by Remediation	99	(%)
Remediation Started in Year	50.00	(yrs)
Remediation Ended in Year	51.00	(yrs)
Mass-Flux/Remaining-Mass Term (Gamma, Γ)	0.7	(-)
Natural Source Decay Rate	0	(1/yr)

9. MODELING PARAMETERS

Timestep Size	1	(yr)
Maximum Number of Iterations	500	(-)
Convergence Tolerance	1.00E-02	(ug/L)
See Results Every	2	(yr)

Note:
The REMChlor model was constructed assuming that the source inputs first began in 1970. Chlorinated solvents (1,1,1-trichloroethane [1,1,1-TCA] for the purpose of this model) was released first (1970), a benzene/toluene/ethylbenzene/toluene (BTEX) source began a time thereafter (1980), and 1,1-dichloroethane (1,1-DCE) a time further thereafter (1990) to reflect breakdown to daughter products from a 1,1,1-TCA source-like condition.

REMChlor-MD Data Input Screen

Version 1.0

DATA INPUT INSTRUCTIONS
Enter value directly. Toolkit default value. OK to overwrite.
Value calculated by Toolkit. Cell cannot be edited.

Site Location and ID: LMC Farrell Road

1. STARTING INFORMATION ○ SI Units ◉ English Units ◉ Unconsolidated ○ Fractured Rock/Media ?

2. MODEL CONFIGURATION

	Cell Size	Model Size	
X-Direction (in direction of groundwater flow)	10	700	(ft)
Y-Direction (transverse to groundwater flow)	10	400	(ft)
Z-Direction (vertical) (all layers have same hydrogeology)	5	25	(ft)

Observation Well Location: X-Value 240.0 (ft) ? Y-Value 5.0 (ft)
Obs. Well Z-Value Top of Screen (model bottom is at Z=0) 5.0 (ft) Bottom of Screen 0.0 (ft)
Starting Year of Simulation (year the source started) 1970 (YYYY year) ?
Ending Year of Simulation 2120 (YYYY year)

Start Year (release yr) — T1 (Sect. 6) — T2 (Sect. 6) — Ending Year

Obs Well, X, Y, Z=0

3. MEDIA CHARACTERISTICS (uniform for all cells)

	Soil Type		Hydr. Cond. (cm/sec)	Porosity (-)	Tortuosity (-)
Transmissive Zone (T-Zone)	Fine Sand	Fine Sand	6.32E-04	0.2	0.48
Low Permeability Zone (Low-k)	Clay	Clay	2.17E-08	0.47	0.32

T-Zone Hydraulic Gradient 0.0067 (-)
T-Zone Groundwater Darcy Velocity 4.38E+00 (ft/yr)
Default Tortuosity

Clay, Sand, Plume, Clay, Sand, Clay

4. MATRIX DIFFUSION

Calculate Heterogeneity

Average Darcy Velocity (including low-k units)	4.38E+00	(ft/yr)
Transmissive Zone Volume Fraction	1.00E+02	(%)
Average Diffusion Length	0.00E+00	(ft)
Surface Area of Low-k Interfaces	0.00E+00	(ft2)

5. CONTAMINANTS AND SOURCE TERM

	Parent	Deg. Prod. 1	Deg. Prod. 2	Deg. Prod. 3	
Constituent (use dropdown menu)	111-TCA	11-DCA			
Initial Source Concentration	2.40E+05	0.00E+00	0.00E+00	0.00E+00	(ug/L)
Source Mass at Time of Release	2.75E+02	0.00E+00	0.00E+00	0.00E+00	(kg)
Retardation Factor in T-Zone	1	1	2	2	(-) Calc R
Retardation Factor in Low-k	1	2	2	2	(-) Calc R'

Source Width (REMChlor-MD will round to nearest whole cell) 100 (ft) ?
Z-Value for Top of Source (model bottom is at Z=0) 7 (ft) ?
Z-Value for Bottom of Source 0 (ft) ?
General Molecular Diffusion Coefficient for all Constituents 8.80E-06 (cm2/sec)

Source Width, Z=0

Next Step: Show Graph | Show Previous Results | Return to Main Screen | New Site/Clear Data | Save/Export Data | Paste Example | Load Data | HELP

6. PLUME DEGRADATION *(Both T-Zone and Low-k Zone)*

Degradation First Order Decay Rates (Conc vs. Distance from Source)

Enter Custom Microbial Yield Terms ?

Model ends here →
55.00 (yrs) Time Period 2 (T2) →
50.00 (yrs) Time Period 1 (T1) →
Model starts here →

Time (yrs)

		111-TCA	11-DCA	Component 3	Component 4
		Zone 1	Zone 2	Zone 3	
Period 3		Decay Rate (1,3)	Decay Rate (2,3)	Decay Rate (3,3)	
	T-Zone (1/yr)	1.00E+00	1.00E+00	1.00E+00	
	Low-k (1/yr)	0.00E+00	0.00E+00	0.00E+00	
Period 2		Decay Rate (1,2)	Decay Rate (2,2)	Decay Rate (3,2)	
	T-Zone (1/yr)	1.40E+00	1.40E+00	1.00E+00	
	Low-k (1/yr)	0.00E+00	0.00E+00	0.00E+00	
Period 1		Decay Rate (1,1)	Decay Rate (2,1)	Decay Rate (3,1)	
	T-Zone (1/yr)	1.00E+00	1.00E+00	1.00E+00	
	Low-k (1/yr)	0.00E+00	0.00E+00	0.00E+00	

X1 0 X2 400
Distance From Source (ft)

7. PLUME TRANSPORT

	Longitudinal	Transverse	Vertical
Dispersivity (ft) ?	50	5	0.5

Dispersivity Calculator

8. SOURCE ZONE REMEDIATION

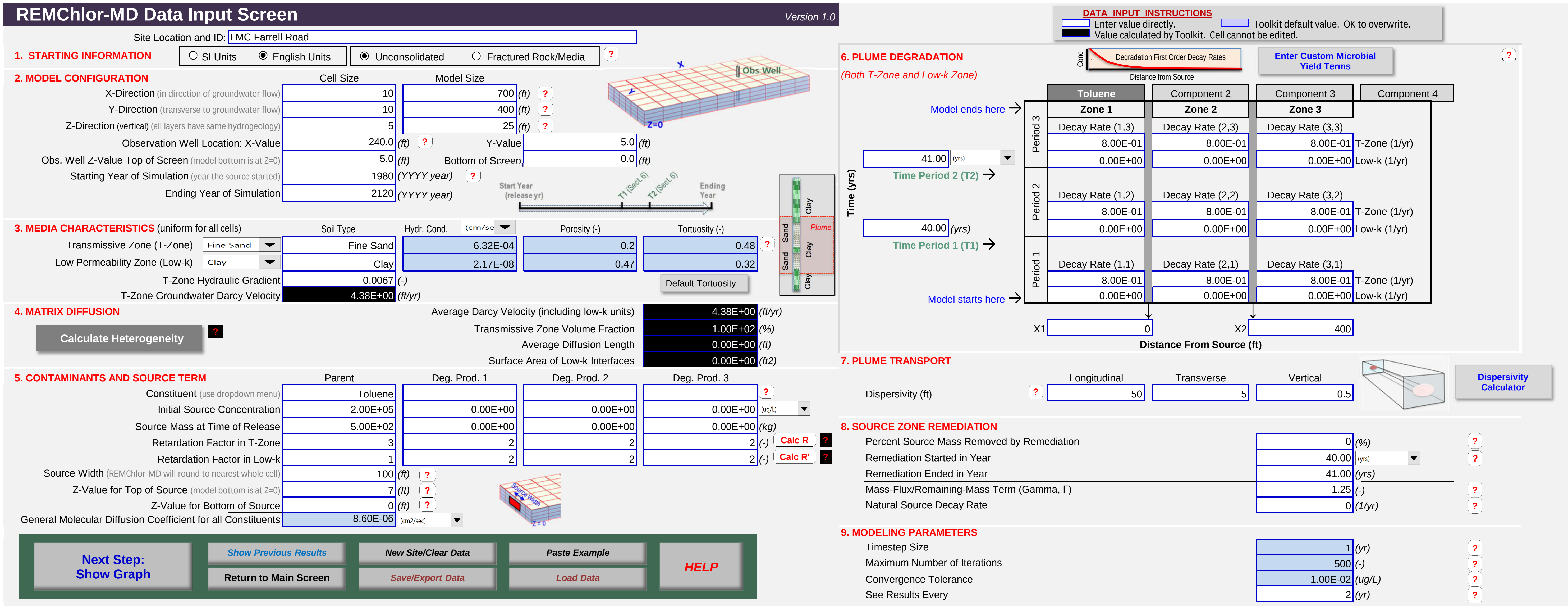
Percent Source Mass Removed by Remediation	80	(%)	?
Remediation Started in Year	50.00	(yrs)	?
Remediation Ended in Year	55.00	(yrs)	
Mass-Flux/Remaining-Mass Term (Gamma, Γ)	0.7	(-)	?
Natural Source Decay Rate	0	(1/yr)	?

9. MODELING PARAMETERS

Timestep Size	1	(yr)	?
Maximum Number of Iterations	500	(-)	?
Convergence Tolerance	1.00E-02	(ug/L)	?
See Results Every	2	(yr)	?

Note:
The REMChlor model was constructed assuming that the source inputs first began in 1970. Chlorinated solvents (1,1,1-trichloroethane [1,1,1-TCA] for the purpose of this model) was released first (1970), a benzene/toluene/ethylbenzene/toluene (BTEX) source began a time thereafter (1980), and 1,1-dichloroethane (1,1-DCE) a time further thereafter (1990) to reflect breakdown to daughter products from a 1,1,1-TCA source-like condition.

Appendix A
Toluene Monitored Natural Attenuation Inputs
REMChlor-MD Model



REMChlor-MD Data Input Screen

Version 1.0

DATA INPUT INSTRUCTIONS
Enter value directly.
Toolkit default value. OK to overwrite.
Value calculated by Toolkit. Cell cannot be edited.

Site Location and ID: LMC Farrell Road

1. STARTING INFORMATION — SI Units / ◉ English Units — ◉ Unconsolidated / Fractured Rock/Media

2. MODEL CONFIGURATION

	Cell Size	Model Size	
X-Direction (in direction of groundwater flow)	10	700	(ft)
Y-Direction (transverse to groundwater flow)	10	400	(ft)
Z-Direction (vertical) (all layers have same hydrogeology)	5	25	(ft)

Observation Well Location: X-Value 240.0 (ft); Y-Value 5.0 (ft)
Obs. Well Z-Value Top of Screen (model bottom is at Z=0) 5.0 (ft); Bottom of Screen 0.0 (ft)
Starting Year of Simulation (year the source started) 1980 (YYYY year)
Ending Year of Simulation 2120 (YYYY year)

3. MEDIA CHARACTERISTICS (uniform for all cells)

	Soil Type	Hydr. Cond. (cm/sec)	Porosity (-)	Tortuosity (-)
Transmissive Zone (T-Zone) — Fine Sand	Fine Sand	6.32E-04	0.2	0.48
Low Permeability Zone (Low-k) — Clay	Clay	2.17E-08	0.47	0.32

T-Zone Hydraulic Gradient 0.0067 (-)
T-Zone Groundwater Darcy Velocity 4.38E+00 (ft/yr)
Default Tortuosity

4. MATRIX DIFFUSION

Calculate Heterogeneity

Average Darcy Velocity (including low-k units)	4.38E+00	(ft/yr)
Transmissive Zone Volume Fraction	1.00E+02	(%)
Average Diffusion Length	0.00E+00	(ft)
Surface Area of Low-k Interfaces	0.00E+00	(ft2)

5. CONTAMINANTS AND SOURCE TERM

	Parent	Deg. Prod. 1	Deg. Prod. 2	Deg. Prod. 3	
Constituent (use dropdown menu)	Toluene				
Initial Source Concentration	2.00E+05	0.00E+00	0.00E+00	0.00E+00	(ug/L)
Source Mass at Time of Release	5.00E+02	0.00E+00	0.00E+00	0.00E+00	(kg)
Retardation Factor in T-Zone	3	2	2	2	(-) Calc R
Retardation Factor in Low-k	1	2	2	2	(-) Calc R'

Source Width (REMChlor-MD will round to nearest whole cell) 100 (ft)
Z-Value for Top of Source (model bottom is at Z=0) 7 (ft)
Z-Value for Bottom of Source 0 (ft)
General Molecular Diffusion Coefficient for all Constituents 8.60E-06 (cm2/sec)

Next Step: Show Graph | Show Previous Results | Return to Main Screen | New Site/Clear Data | Save/Export Data | Paste Example | Load Data | HELP

6. PLUME DEGRADATION
(Both T-Zone and Low-k Zone)

Degradation First Order Decay Rates — Enter Custom Microbial Yield Terms

Model ends here
Time Period 2 (T2): 41.00 (yrs)
Time Period 1 (T1): 40.00 (yrs)
Model starts here

	Toluene	Component 2	Component 3	Component 4
	Zone 1	Zone 2	Zone 3	
Period 3	Decay Rate (1,3)	Decay Rate (2,3)	Decay Rate (3,3)	
	8.00E-01	8.00E-01	8.00E-01	T-Zone (1/yr)
	0.00E+00	0.00E+00	0.00E+00	Low-k (1/yr)
Period 2	Decay Rate (1,2)	Decay Rate (2,2)	Decay Rate (3,2)	
	8.00E-01	8.00E-01	8.00E-01	T-Zone (1/yr)
	0.00E+00	0.00E+00	0.00E+00	Low-k (1/yr)
Period 1	Decay Rate (1,1)	Decay Rate (2,1)	Decay Rate (3,1)	
	8.00E-01	8.00E-01	8.00E-01	T-Zone (1/yr)
	0.00E+00	0.00E+00	0.00E+00	Low-k (1/yr)

X1 0 — X2 400
Distance From Source (ft)

7. PLUME TRANSPORT

	Longitudinal	Transverse	Vertical
Dispersivity (ft)	50	5	0.5

Dispersivity Calculator

8. SOURCE ZONE REMEDIATION

Percent Source Mass Removed by Remediation	0	(%)
Remediation Started in Year	40.00	(yrs)
Remediation Ended in Year	41.00	(yrs)
Mass-Flux/Remaining-Mass Term (Gamma, Γ)	1.25	(-)
Natural Source Decay Rate	0	(1/yr)

9. MODELING PARAMETERS

Timestep Size	1	(yr)
Maximum Number of Iterations	500	(-)
Convergence Tolerance	1.00E-02	(ug/L)
See Results Every	2	(yr)

Note:
The REMChlor model was constructed assuming that the source inputs first began in 1970. Chlorinated solvents (1,1,1-trichloroethane [1,1,1-TCA] for the purpose of this model) was released first (1970), a benzene/toluene/ethylbenzene/toluene (BTEX) source began a time thereafter (1980), and 1,1-dichloroethane (1,1-DCE) a time further thereafter (1990) to reflect breakdown to daughter products from a 1,1,1-TCA source-like condition.

Appendix A
Toluene In Situ Chemical Oxidation Inputs
REMChlor-MD Model

REMChlor-MD Data Input Screen

Version 1.0

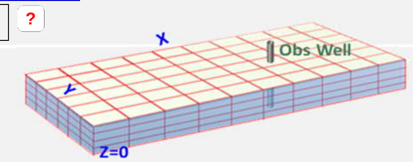
DATA INPUT INSTRUCTIONS
Enter value directly. Toolkit default value. OK to overwrite.
Value calculated by Toolkit. Cell cannot be edited.

Site Location and ID: LMC Farrell Road

1. STARTING INFORMATION ○ SI Units ◉ English Units ◉ Unconsolidated ○ Fractured Rock/Media ?

2. MODEL CONFIGURATION

	Cell Size	Model Size	
X-Direction (in direction of groundwater flow)	10	700	(ft)
Y-Direction (transverse to groundwater flow)	10	400	(ft)
Z-Direction (vertical) (all layers have same hydrogeology)	5	25	(ft)

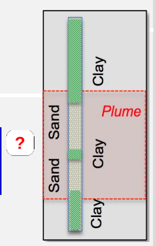


Observation Well Location: X-Value 240.0 (ft) ? Y-Value 5.0 (ft)
Obs. Well Z-Value Top of Screen (model bottom is at Z=0) 5.0 (ft) Bottom of Screen 0.0 (ft)
Starting Year of Simulation (year the source started) 1980 (YYYY year) ?
Ending Year of Simulation 2120 (YYYY year)

3. MEDIA CHARACTERISTICS (uniform for all cells)

	Soil Type	Hydr. Cond. (cm/sec)	Porosity (-)	Tortuosity (-)
Transmissive Zone (T-Zone)	Fine Sand	6.32E-04	0.2	0.48
Low Permeability Zone (Low-k)	Clay	2.17E-08	0.47	0.32

T-Zone Hydraulic Gradient 0.0067 (-)
T-Zone Groundwater Darcy Velocity 4.38E+00 (ft/yr)
Default Tortuosity



4. MATRIX DIFFUSION

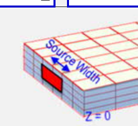
Calculate Heterogeneity

Average Darcy Velocity (including low-k units)	4.38E+00	(ft/yr)
Transmissive Zone Volume Fraction	1.00E+02	(%)
Average Diffusion Length	0.00E+00	(ft)
Surface Area of Low-k Interfaces	0.00E+00	(ft2)

5. CONTAMINANTS AND SOURCE TERM

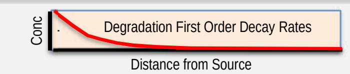
	Parent	Deg. Prod. 1	Deg. Prod. 2	Deg. Prod. 3	
Constituent (use dropdown menu)	Toluene				
Initial Source Concentration	2.00E+05	0.00E+00	0.00E+00	0.00E+00	(ug/L)
Source Mass at Time of Release	5.00E+02	0.00E+00	0.00E+00	0.00E+00	(kg)
Retardation Factor in T-Zone	3	2	2	2	(-) Calc R
Retardation Factor in Low-k	1	2	2	2	(-) Calc R'

Source Width (REMChlor-MD will round to nearest whole cell) 100 (ft) ?
Z-Value for Top of Source (model bottom is at Z=0) 7 (ft) ?
Z-Value for Bottom of Source 0 (ft) ?
General Molecular Diffusion Coefficient for all Constituents 8.60E-06 (cm2/sec)



Next Step: Show Graph | Show Previous Results | Return to Main Screen | New Site/Clear Data | Save/Export Data | Paste Example | Load Data | HELP

6. PLUME DEGRADATION ?
(Both T-Zone and Low-k Zone)



Enter Custom Microbial Yield Terms

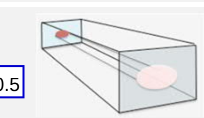
Model ends here →
44.00 (yrs) Time Period 2 (T2) →
40.00 (yrs) Time Period 1 (T1) →
Model starts here →

Time (yrs)	Toluene / Zone 1	Component 2 / Zone 2	Component 3 / Zone 3	Component 4
Period 3	Decay Rate (1,3)	Decay Rate (2,3)	Decay Rate (3,3)	
	8.00E-01	8.00E-01	8.00E-01	T-Zone (1/yr)
	0.00E+00	0.00E+00	0.00E+00	Low-k (1/yr)
Period 2	Decay Rate (1,2)	Decay Rate (2,2)	Decay Rate (3,2)	
	2.20E+00	2.20E+00	8.00E-01	T-Zone (1/yr)
	0.00E+00	0.00E+00	0.00E+00	Low-k (1/yr)
Period 1	Decay Rate (1,1)	Decay Rate (2,1)	Decay Rate (3,1)	
	8.00E-01	8.00E-01	8.00E-01	T-Zone (1/yr)
	0.00E+00	0.00E+00	0.00E+00	Low-k (1/yr)

X1 0 X2 400
Distance From Source (ft)

7. PLUME TRANSPORT

	Longitudinal	Transverse	Vertical
Dispersivity (ft) ?	50	5	0.5



Dispersivity Calculator

8. SOURCE ZONE REMEDIATION

Percent Source Mass Removed by Remediation	80	(%)
Remediation Started in Year	40.00	(yrs)
Remediation Ended in Year	44.00	(yrs)
Mass-Flux/Remaining-Mass Term (Gamma, Γ)	1.25	(-)
Natural Source Decay Rate	0	(1/yr)

9. MODELING PARAMETERS

Timestep Size	1	(yr)
Maximum Number of Iterations	500	(-)
Convergence Tolerance	1.00E-02	(ug/L)
See Results Every	2	(yr)

Note:
The REMChlor model was constructed assuming that the source inputs first began in 1970. Chlorinated solvents (1,1,1-trichloroethane [1,1,1-TCA] for the purpose of this model) was released first (1970), a benzene/toluene/ethylbenzene/toluene (BTEX) source began a time thereafter (1980), and 1,1-dichloroethane (1,1-DCE) a time further thereafter (1990) to reflect breakdown to daughter products from a 1,1,1-TCA source-like condition.

Appendix A
Toluene Dual Phase Extraction Inputs
REMChlor-MD Model

REMChlor-MD Data Input Screen

Version 1.0

DATA INPUT INSTRUCTIONS
Enter value directly. | Toolkit default value. OK to overwrite.
Value calculated by Toolkit. Cell cannot be edited.

Site Location and ID: LMC Farrell Road

1. STARTING INFORMATION ○ SI Units ◉ English Units ◉ Unconsolidated ○ Fractured Rock/Media

2. MODEL CONFIGURATION

	Cell Size	Model Size	
X-Direction (in direction of groundwater flow)	10	700	(ft)
Y-Direction (transverse to groundwater flow)	10	400	(ft)
Z-Direction (vertical) (all layers have same hydrogeology)	5	25	(ft)

Observation Well Location: X-Value 240.0 (ft); Y-Value 5.0 (ft)
Obs. Well Z-Value Top of Screen (model bottom is at Z=0) 5.0 (ft); Bottom of Screen 0.0 (ft)
Starting Year of Simulation (year the source started) 1980 (YYYY year)
Ending Year of Simulation 2120 (YYYY year)

Start Year (release yr) — T1 (Sect. 6) — T2 (Sect. 6) — Ending Year

3. MEDIA CHARACTERISTICS (uniform for all cells)

	Soil Type	Hydr. Cond. (cm/sec)	Porosity (-)	Tortuosity (-)
Transmissive Zone (T-Zone)	Fine Sand	6.32E-04	0.2	0.48
Low Permeability Zone (Low-k)	Clay	2.17E-08	0.47	0.32

T-Zone Hydraulic Gradient 0.0067 (-)
T-Zone Groundwater Darcy Velocity 4.38E+00 (ft/yr)
Default Tortuosity

4. MATRIX DIFFUSION

Calculate Heterogeneity

Average Darcy Velocity (including low-k units)	4.38E+00	(ft/yr)
Transmissive Zone Volume Fraction	1.00E+02	(%)
Average Diffusion Length	0.00E+00	(ft)
Surface Area of Low-k Interfaces	0.00E+00	(ft2)

5. CONTAMINANTS AND SOURCE TERM

	Parent	Deg. Prod. 1	Deg. Prod. 2	Deg. Prod. 3	
Constituent (use dropdown menu)	Toluene				
Initial Source Concentration	2.00E+05	0.00E+00	0.00E+00	0.00E+00	(ug/L)
Source Mass at Time of Release	5.00E+02	0.00E+00	0.00E+00	0.00E+00	(kg)
Retardation Factor in T-Zone	3	2	2	2	(-) Calc R
Retardation Factor in Low-k	1	2	2	2	(-) Calc R'

Source Width (REMChlor-MD will round to nearest whole cell) 100 (ft)
Z-Value for Top of Source (model bottom is at Z=0) 7 (ft)
Z-Value for Bottom of Source 0 (ft)
General Molecular Diffusion Coefficient for all Constituents 8.60E-06 (cm2/sec)

Next Step: Show Graph | Show Previous Results | Return to Main Screen | New Site/Clear Data | Save/Export Data | Paste Example | Load Data | HELP

6. PLUME DEGRADATION
(Both T-Zone and Low-k Zone)

Degradation First Order Decay Rates | Enter Custom Microbial Yield Terms

Model ends here →
Time Period 2 (T2): 45.00 (yrs)
Time Period 1 (T1): 40.00 (yrs)
Model starts here →

	Toluene Zone 1	Component 2 Zone 2	Component 3 Zone 3	Component 4
Period 3	Decay Rate (1,3)	Decay Rate (2,3)	Decay Rate (3,3)	
T-Zone (1/yr)	8.00E-01	8.00E-01	8.00E-01	
Low-k (1/yr)	0.00E+00	0.00E+00	0.00E+00	
Period 2	Decay Rate (1,2)	Decay Rate (2,2)	Decay Rate (3,2)	
T-Zone (1/yr)	2.50E+01	2.50E+01	8.00E-01	
Low-k (1/yr)	0.00E+00	0.00E+00	0.00E+00	
Period 1	Decay Rate (1,1)	Decay Rate (2,1)	Decay Rate (3,1)	
T-Zone (1/yr)	8.00E-01	8.00E-01	8.00E-01	
Low-k (1/yr)	0.00E+00	0.00E+00	0.00E+00	

X1 0 X2 400
Distance From Source (ft)

7. PLUME TRANSPORT

	Longitudinal	Transverse	Vertical
Dispersivity (ft)	50	5	0.5

Dispersivity Calculator

8. SOURCE ZONE REMEDIATION

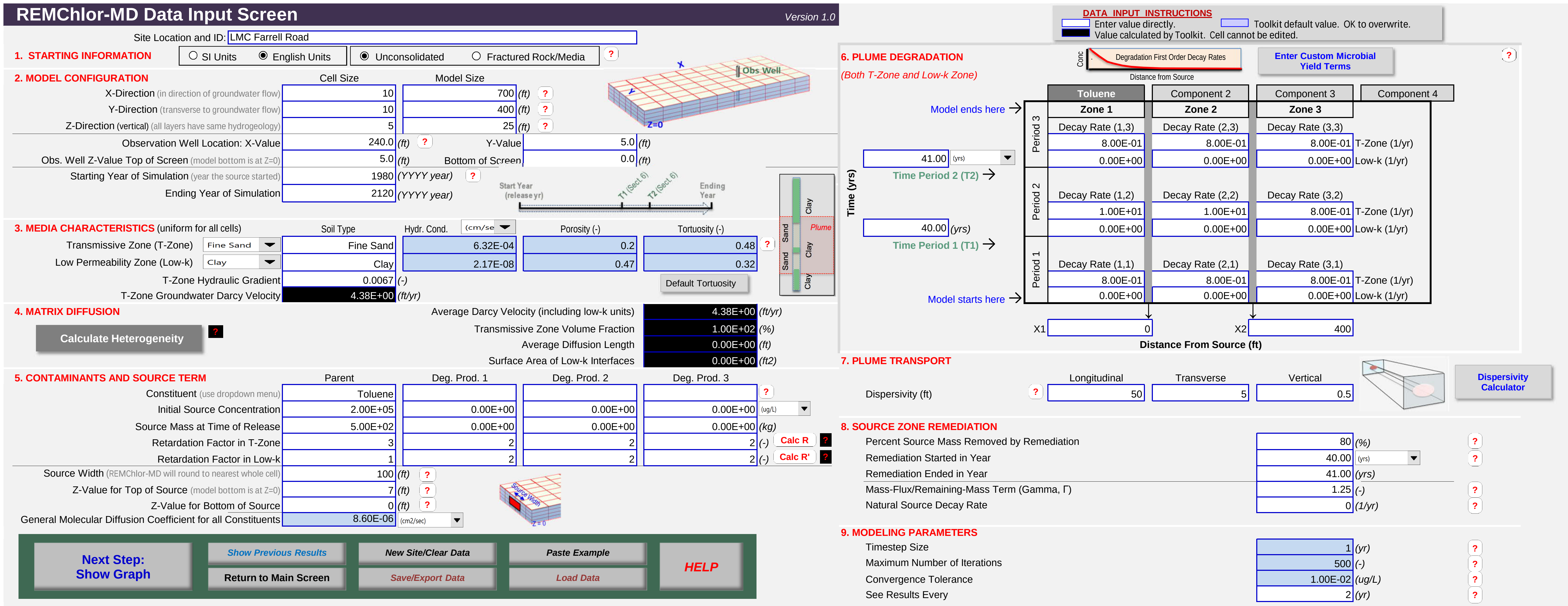
Percent Source Mass Removed by Remediation	90	(%)
Remediation Started in Year	40.00	(yrs)
Remediation Ended in Year	45.00	(yrs)
Mass-Flux/Remaining-Mass Term (Gamma, Γ)	1.25	(-)
Natural Source Decay Rate	0	(1/yr)

9. MODELING PARAMETERS

Timestep Size	1	(yr)
Maximum Number of Iterations	500	(-)
Convergence Tolerance	1.00E-02	(ug/L)
See Results Every	2	(yr)

Note:
The REMChlor model was constructed assuming that the source inputs first began in 1970. Chlorinated solvents (1,1,1-trichloroethane [1,1,1-TCA] for the purpose of this model) was released first (1970), a benzene/toluene/ethylbenzene/toluene (BTEX) source began a time thereafter (1980), and 1,1-dichloroethane (1,1-DCE) a time further thereafter (1990) to reflect breakdown to daughter products from a 1,1,1-TCA source-like condition.

Appendix A
Toluene Thermal Inputs
REMChlor-MD Model



REMChlor-MD Data Input Screen
Version 1.0

DATA INPUT INSTRUCTIONS
Enter value directly.
Toolkit default value. OK to overwrite.
Value calculated by Toolkit. Cell cannot be edited.

Site Location and ID: LMC Farrell Road

1. STARTING INFORMATION — SI Units / English Units (selected); Unconsolidated (selected) / Fractured Rock/Media

2. MODEL CONFIGURATION

	Cell Size	Model Size	
X-Direction (in direction of groundwater flow)	10	700	(ft)
Y-Direction (transverse to groundwater flow)	10	400	(ft)
Z-Direction (vertical) (all layers have same hydrogeology)	5	25	(ft)

Observation Well Location: X-Value 240.0 (ft); Y-Value 5.0 (ft)
Obs. Well Z-Value Top of Screen (model bottom is at Z=0) 5.0 (ft); Bottom of Screen 0.0 (ft)
Starting Year of Simulation (year the source started) 1980 (YYYY year)
Ending Year of Simulation 2120 (YYYY year)

Obs Well; Z=0; Start Year (release yr); T1 (Sect 6); T2 (Sect 6); Ending Year

3. MEDIA CHARACTERISTICS (uniform for all cells)

	Soil Type	Hydr. Cond. (cm/sec)	Porosity (-)	Tortuosity (-)
Transmissive Zone (T-Zone) — Fine Sand	Fine Sand	6.32E-04	0.2	0.48
Low Permeability Zone (Low-k) — Clay	Clay	2.17E-08	0.47	0.32

T-Zone Hydraulic Gradient 0.0067 (-)
T-Zone Groundwater Darcy Velocity 4.38E+00 (ft/yr)
Default Tortuosity

Clay; Sand; Plume; Clay; Sand; Clay

4. MATRIX DIFFUSION

Calculate Heterogeneity

Average Darcy Velocity (including low-k units) 4.38E+00 (ft/yr)
Transmissive Zone Volume Fraction 1.00E+02 (%)
Average Diffusion Length 0.00E+00 (ft)
Surface Area of Low-k Interfaces 0.00E+00 (ft2)

5. CONTAMINANTS AND SOURCE TERM

	Parent	Deg. Prod. 1	Deg. Prod. 2	Deg. Prod. 3	
Constituent (use dropdown menu)	Toluene				
Initial Source Concentration	2.00E+05	0.00E+00	0.00E+00	0.00E+00	(ug/L)
Source Mass at Time of Release	5.00E+02	0.00E+00	0.00E+00	0.00E+00	(kg)
Retardation Factor in T-Zone	3	2	2	2	(-) Calc R
Retardation Factor in Low-k	1	2	2	2	(-) Calc R'

Source Width (REMChlor-MD will round to nearest whole cell) 100 (ft)
Z-Value for Top of Source (model bottom is at Z=0) 7 (ft)
Z-Value for Bottom of Source 0 (ft)
General Molecular Diffusion Coefficient for all Constituents 8.60E-06 (cm2/sec)

Source Width; Z=0

Next Step: Show Graph | Show Previous Results | Return to Main Screen | New Site/Clear Data | Save/Export Data | Paste Example | Load Data | HELP

6. PLUME DEGRADATION
(Both T-Zone and Low-k Zone)

Degradation First Order Decay Rates; Conc; Distance from Source
Enter Custom Microbial Yield Terms

Toluene | Component 2 | Component 3 | Component 4

Time (yrs)		Zone 1	Zone 2	Zone 3	
Model ends here	Period 3	Decay Rate (1,3)	Decay Rate (2,3)	Decay Rate (3,3)	
41.00 (yrs)		8.00E-01	8.00E-01	8.00E-01	T-Zone (1/yr)
Time Period 2 (T2)		0.00E+00	0.00E+00	0.00E+00	Low-k (1/yr)
	Period 2	Decay Rate (1,2)	Decay Rate (2,2)	Decay Rate (3,2)	
		1.00E+01	1.00E+01	8.00E-01	T-Zone (1/yr)
40.00 (yrs)		0.00E+00	0.00E+00	0.00E+00	Low-k (1/yr)
Time Period 1 (T1)	Period 1	Decay Rate (1,1)	Decay Rate (2,1)	Decay Rate (3,1)	
		8.00E-01	8.00E-01	8.00E-01	T-Zone (1/yr)
Model starts here		0.00E+00	0.00E+00	0.00E+00	Low-k (1/yr)

X1 0; X2 400
Distance From Source (ft)

7. PLUME TRANSPORT

	Longitudinal	Transverse	Vertical
Dispersivity (ft)	50	5	0.5

Dispersivity Calculator

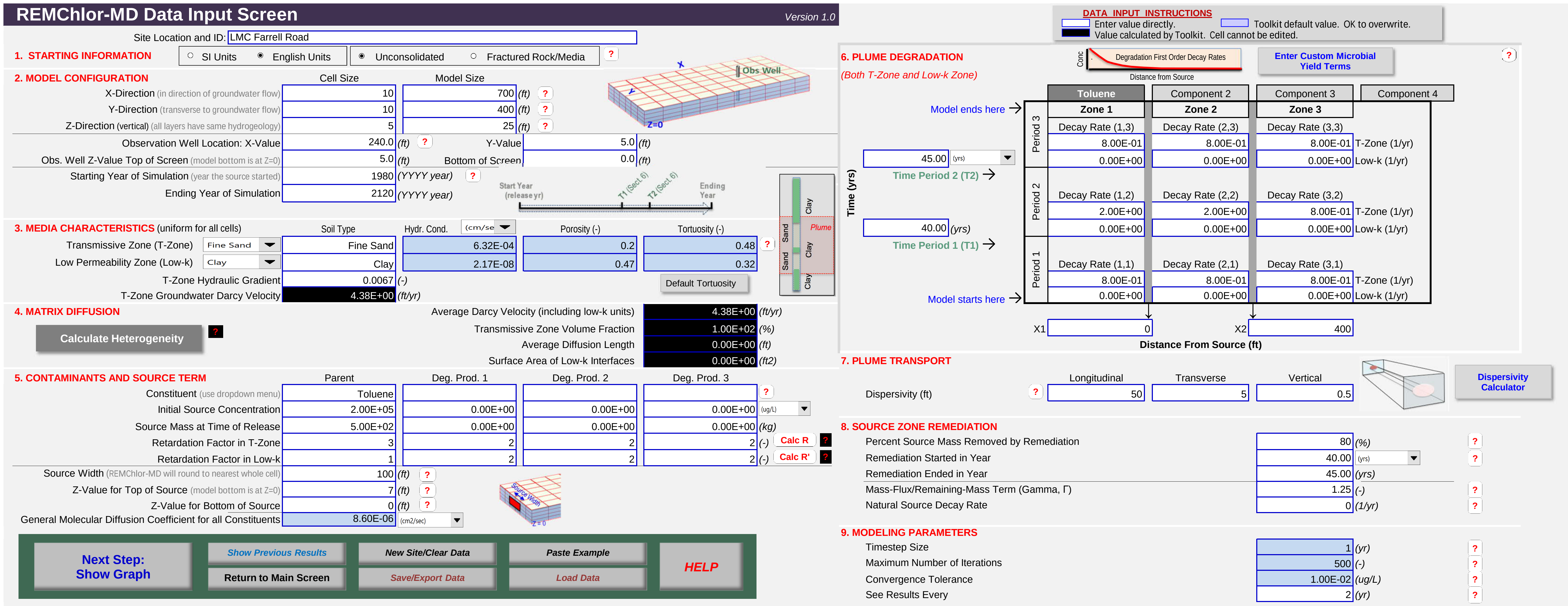
8. SOURCE ZONE REMEDIATION

Percent Source Mass Removed by Remediation 80 (%)
Remediation Started in Year 40.00 (yrs)
Remediation Ended in Year 41.00 (yrs)
Mass-Flux/Remaining-Mass Term (Gamma, Γ) 1.25 (-)
Natural Source Decay Rate 0 (1/yr)

9. MODELING PARAMETERS

Timestep Size 1 (yr)
Maximum Number of Iterations 500 (-)
Convergence Tolerance 1.00E-02 (ug/L)
See Results Every 2 (yr)

Note:
The REMChlor model was constructed assuming that the source inputs first began in 1970. Chlorinated solvents (1,1,1-trichloroethane [1,1,1-TCA] for the purpose of this model) was released first (1970), a benzene/toluene/ethylbenzene/toluene (BTEX) source began a time thereafter (1980), and 1,1-dichloroethane (1,1-DCE) a time further thereafter (1990) to reflect breakdown to daughter products from a 1,1,1-TCA source-like condition.



REMChlor-MD Data Input Screen Version 1.0

DATA INPUT INSTRUCTIONS
Enter value directly. Toolkit default value. OK to overwrite.
Value calculated by Toolkit. Cell cannot be edited.

Site Location and ID: LMC Farrell Road

1. STARTING INFORMATION ○ SI Units ◉ English Units ◉ Unconsolidated ○ Fractured Rock/Media ?

2. MODEL CONFIGURATION

	Cell Size	Model Size	
X-Direction (in direction of groundwater flow)	10	700	(ft) ?
Y-Direction (transverse to groundwater flow)	10	400	(ft) ?
Z-Direction (vertical) (all layers have same hydrogeology)	5	25	(ft) ?

Observation Well Location: X-Value 240.0 (ft) ? Y-Value 5.0 (ft)
Obs. Well Z-Value Top of Screen (model bottom is at Z=0) 5.0 (ft) Bottom of Screen 0.0 (ft)
Starting Year of Simulation (year the source started) 1980 (YYYY year) ?
Ending Year of Simulation 2120 (YYYY year)

Start Year (release yr) T1 (Sect. 6) T2 (Sect. 6) Ending Year
Obs Well X Y Z=0

3. MEDIA CHARACTERISTICS (uniform for all cells)

	Soil Type		Hydr. Cond. (cm/sec)	Porosity (-)	Tortuosity (-)
Transmissive Zone (T-Zone)	Fine Sand	Fine Sand	6.32E-04	0.2	0.48 ?
Low Permeability Zone (Low-k)	Clay	Clay	2.17E-08	0.47	0.32

T-Zone Hydraulic Gradient 0.0067 (-) Default Tortuosity
T-Zone Groundwater Darcy Velocity 4.38E+00 (ft/yr)

Clay Sand Plume Clay Sand Clay

4. MATRIX DIFFUSION

Calculate Heterogeneity ?

Average Darcy Velocity (including low-k units)	4.38E+00	(ft/yr)
Transmissive Zone Volume Fraction	1.00E+02	(%)
Average Diffusion Length	0.00E+00	(ft)
Surface Area of Low-k Interfaces	0.00E+00	(ft2)

5. CONTAMINANTS AND SOURCE TERM

	Parent	Deg. Prod. 1	Deg. Prod. 2	Deg. Prod. 3	
Constituent (use dropdown menu)	Toluene				?
Initial Source Concentration	2.00E+05	0.00E+00	0.00E+00	0.00E+00	(ug/L)
Source Mass at Time of Release	5.00E+02	0.00E+00	0.00E+00	0.00E+00	(kg)
Retardation Factor in T-Zone	3	2	2	2	(-) Calc R ?
Retardation Factor in Low-k	1	2	2	2	(-) Calc R' ?

Source Width (REMChlor-MD will round to nearest whole cell) 100 (ft) ?
Z-Value for Top of Source (model bottom is at Z=0) 7 (ft) ?
Z-Value for Bottom of Source 0 (ft) ?
General Molecular Diffusion Coefficient for all Constituents 8.60E-06 (cm2/sec)

Source Width Z=0

Next Step: Show Graph | Show Previous Results | Return to Main Screen | New Site/Clear Data | Save/Export Data | Paste Example | Load Data | HELP

6. PLUME DEGRADATION (Both T-Zone and Low-k Zone) ?

Conc Degradation First Order Decay Rates Distance from Source
Enter Custom Microbial Yield Terms

Time (yrs)		Toluene	Component 2	Component 3	Component 4
Model ends here →		Zone 1	Zone 2	Zone 3	
Period 3		Decay Rate (1,3)	Decay Rate (2,3)	Decay Rate (3,3)	
	T-Zone (1/yr)	8.00E-01	8.00E-01	8.00E-01	
45.00 (yrs) Time Period 2 (T2) →	Low-k (1/yr)	0.00E+00	0.00E+00	0.00E+00	
Period 2		Decay Rate (1,2)	Decay Rate (2,2)	Decay Rate (3,2)	
	T-Zone (1/yr)	2.00E+00	2.00E+00	8.00E-01	
40.00 (yrs) Time Period 1 (T1) →	Low-k (1/yr)	0.00E+00	0.00E+00	0.00E+00	
Period 1		Decay Rate (1,1)	Decay Rate (2,1)	Decay Rate (3,1)	
	T-Zone (1/yr)	8.00E-01	8.00E-01	8.00E-01	
Model starts here →	Low-k (1/yr)	0.00E+00	0.00E+00	0.00E+00	

X1 0 X2 400
Distance From Source (ft)

7. PLUME TRANSPORT

	Longitudinal	Transverse	Vertical
Dispersivity (ft) ?	50	5	0.5

Dispersivity Calculator

8. SOURCE ZONE REMEDIATION

Percent Source Mass Removed by Remediation	80	(%)	?
Remediation Started in Year	40.00	(yrs)	?
Remediation Ended in Year	45.00	(yrs)	
Mass-Flux/Remaining-Mass Term (Gamma, Γ)	1.25	(-)	?
Natural Source Decay Rate	0	(1/yr)	?

9. MODELING PARAMETERS

Timestep Size	1	(yr)	?
Maximum Number of Iterations	500	(-)	?
Convergence Tolerance	1.00E-02	(ug/L)	?
See Results Every	2	(yr)	?

Note:
The REMChlor model was constructed assuming that the source inputs first began in 1970. Chlorinated solvents (1,1,1-trichloroethane [1,1,1-TCA] for the purpose of this model) was released first (1970), a benzene/toluene/ethylbenzene/toluene (BTEX) source began a time thereafter (1980), and 1,1-dichloroethane (1,1-DCE) a time further thereafter (1990) to reflect breakdown to daughter products from a 1,1,1-TCA source-like condition.

RemChlorMD Inputs
References

References:

Most inputs

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Appendix B

Johnson & Ettinger Model Input

Appendix B
1,1-DCE Inputs
EPA Johnson & Ettinger Model

Model Input — Site Name/Run Number: Example, Run 1

Note:
-Yellow highlighted cells indicate parameters that typically are changed or must be inputted by the user.
-Dotted outline cells indicate default values that may be changed with justification.
-Toxicity values are taken from Regional Screening Level tables. These tables are updated semi-annually and may not reflect the most current toxicity information.

Use English/Metric Converter

Source Characteristics:	Units	Symbol	Value	Default	Potential Span	CV	Flag	Comment
Source medium		Source	Groundwater					
Groundwater concentration	(ug/L)	Cmedium	16		NA			
Depth below grade to water table	(m)	Ls	3.00		Vary - 50	NA		
Average groundwater temperature	(^{o}C)	Ts	15	25	3 - 25			
Calc: Source vapor concentration	(ug/m3)	Cs	12171					
Calc: % of pure component saturated vapor concentration	(%)	%Sat	0.000%					

Chemical:	Units	Symbol	Value	Default	Potential Span	CV	Flag	Comment
Chemical Name		Chem	Dichloroethylene, 1,1-					
CAS No.		CAS	75-35-4					
Toxicity Factors								
Unit risk factor	$(ug/m^3)^{-1}$	IUR	Not Available	Not Available	NA	NA		No IUR available for this compound.
Mutagenic compound		Mut	No	NA	NA	NA		
Reference concentration	(mg/m^3)	RfC	2.00E-01	2.00E-01	NA	NA		

Chemical Properties:	Units	Symbol	Value	Default	Potential Span	CV	Flag	Comment
Pure component water solubility	(mg/L)	S	2.42E+03	2.42E+03	NA	NA		
Henry's Law Constant @ 25^{o}C	$(atm\text{-}m^3/mol)$	Hc	2.61E-02	2.61E-02	NA	NA		
Calc: Henry's Law Constant @ 25^{o}C	(dimensionless)	Hr	1.07E+00	1.07E+00				
Calc: Henry's Law Constant @ system temperature	(dimensionless)	Hs	7.61E-01	1.10E+00				
Diffusivity in air	(cm2/s)	Dair	8.63E-02	8.63E-02	NA	NA		
Diffusivity in water	(cm2/s)	Dwater	1.10E-05	1.10E-05	NA	NA		

Building Characteristics:

Select Building Assumptions
- (●) Use ratio for Qsoil/Qbuilding (recommended if no site specific data available)
- (○) Specify Qsoil and Qbuilding separately; calculate ratio

	Units	Symbol	Value	Default	Potential Span	CV	Flag	Comment
Building setting		Bldg_Setting	Commercial	Commercial				
Foundation type		Found_Type	Slab-on-grade	Slab-on-grade				
Depth below grade to base of foundation	(m)	Lb	1.22	0.20	0.1 - 2.44	NA	WARNING	Value is different from default value; pl
Foundation thickness	(m)	Lf	0.10	0.20	0.1 - 0.25	NA	WARNING	Value is different from default value; ple
Fraction of foundation area with cracks	(-)	eta	0.000	0.001	0.00019-0.0019	1.00	WARNING	Value is different from default value; pl
Enclosed space floor area	(m2)	Abf	21739.00	1500.00	80-1000	NA	WARNING	Value is outside of reasonable range (8(
Enclosed space mixing height	(m)	Hb	5.00	3.00	2.13 - 3.05	NA	WARNING	Value is outside of reasonable range (2.
Indoor air exchange rate	(1 / hr)	ach	0.10	1.50	.3-4.1	NA	WARNING	Value is outside of reasonable range (0.
Qsoil/Qbuilding	(-)	Qsoil_Qb	0.0030	0.0030	0.0001 - 0.05	1.24		
Calc: Building ventilation rate	(m3/hr)	Qb	10869.50	6750.00	NA	0.30		
Calc: Average vapor flow rate into building	(m3/hr)	Qsoil	32.61	20.25	NA	NA		

Appendix B
1,1-DCE Inputs
EPA Johnson & Ettinger Model

Model Input — Site Name/Run Number: Example, Run 1
Chemical Name: Dichloroethylene, 1,1- CAS No. 75-35-4
Depth below grade to water table: 3.00 meters

Vadose zone characteristics:	Units	Symbol	Value	Default	Potential Span	CV	Flag	Comment
Stratum A (Top of soil profile):								
Stratum A SCS soil type		SCS_A	Sand					
Stratum A thickness (from surface)	(m)	hSA	3.00					
Stratum A total porosity	(-)	nSA	0.375	0.375	NA	0.20		
Stratum A water-filled porosity	(-)	nwSA	0.200	0.054	0.053 - 0.055	0.25	WARNING	Value is different from default value; ple
Stratum A bulk density	(g/cm^3)	rhoSA	1.660	1.660	NA	0.05		
Stratum B (Soil layer below Stratum A):								
Stratum B SCS soil type		SCS_B	Not Present					
Stratum B thickness	(m)	hSB	0.00					
Stratum B total porosity	(-)	nSB			NA	NA		
Stratum B water-filled porosity	(-)	nwSB			NA	NA		
Stratum B bulk density	(g/cm^3)	rhoSB			NA	NA		
Stratum C (Soil layer below Stratum B):								
Stratum C SCS soil type		SCS_C	Not Present					
Stratum C thickness	(m)	hSC	0.00					
Stratum C total porosity	(-)	nSC			NA	NA		
Stratum C water-filled porosity	(-)	nwSC			NA	NA		
Stratum C bulk density	(g/cm^3)	rhoSC			NA	NA		
Stratum directly above the water table								
Stratum A, B, or C		src_soil	Stratum A					
Height of capillary fringe	(m)	hcz	0.170	0.170	NA	NA		
Capillary zone total porosity	(-)	ncz	0.375	0.375	NA	0.20		
Capillary zone water filled porosity	(-)	nwcz	0.253	0.253	NA	0.14		

Exposure Parameters:	Units	Symbol	Value	Default	Potential Span	CV	Flag	Comment
Target risk for carcinogens	(-)	Target_CR	1.00E-06	1.00E-06	NA	NA		
Target hazard quotient for non-carcinogens	(-)	Target_HQ	1	1	NA	NA		
Exposure Scenario		Scenario	Commercial	Commercial				
Averaging time for carcinogens	(yrs)	ATc	70	70	NA	NA		
Averaging time for non-carcinogens	(yrs)	ATnc	25	25	NA	NA		
Exposure duration	(yrs)	ED	25	25	NA	NA		
Exposure frequency	(days/yr)	EF	250	250	NA	NA		
Exposure time	(hrs/24 hrs)	ET	8	8	NA	NA		
Mutagenic mode-of-action factor	(yrs)	MMOAF	72	72	NA	NA	NOTE	MMOAF not relevant for non-mutagenic

Appendix B
1,1-DCE Inputs
EPA Johnson & Ettinger Model

Model Output   Site Name/Run Number: Example, Run 1

Chemical Name: Dichloroethylene, 1,1-   CAS No. 75-35-4

Range is based on the reasonable range of Qsoil/Qbuilding values, as reported in the literature.

Source to Indoor Air Attenuation Factor	Units	Symbol	Value	Range	Default	Default Range	Flag
Groundwater to indoor air attenuation coefficient	(-)	alpha	5.2E-04	8.6E-05 - 6.2E-04	1.6E-04	6.2E-05 - 1.6E-04	WARNING

Predicted Indoor Air Concentration	Units	Symbol	Value	Range	Default	Default Range	Flag
Indoor air concentration due to vapor intrusion	(ug/m3)	Cia	6.4E+00	1.1E+00 - 7.6E+00	1.9E+00	7.6E-01 - 2.0E+00	
	(ppbv)		1.6E+00	2.7E-01 - 1.9E+00	4.8E-01	1.9E-01 - 5.0E-01	WARNING

Predicted Vapor Conc. Beneath Foundation	Units	Symbol	Value	Range	Default	Default Range	Flag
Subslab vapor concentration	(ug/m3)	Css	2.1E+03	1.5E+02 - 1.1E+04	6.3E+02	7.6E+03 - 2.0E+04	
	(ppbv)		5.3E+02	3.8E+01 - 2.7E+03	1.6E+02	1.9E+03 - 5.0E+03	

Diffusive Transport Upward Through Vadose Zone	Units	Symbol	Value	Range	Default	Default Range	Flag
Effective diffusion coefficient through Stratum A	(cm2/sec)	DeffA	1.9E-03	-	1.4E-02	-	
Effective diffusion coefficient through Stratum B	(cm2/sec)	DeffB		-		-	
Effective diffusion coefficient through Stratum C	(cm2/sec)	DeffC		-		-	
Effective diffusion coefficient through capillary zone	(cm2/sec)	DeffCZ	5.5E-04	-	5.5E-04	-	
Effective diffusion coefficient through unsaturated zone	(cm2/sec)	DeffT	1.5E-03	-	5.6E-03	-	

Critical Parameters		Symbol	Value	Range	Default	Default Range	Flag
α for diffusive transport from source to building with dirt floor foundation	(-)	A_Param	6.3E-04	-	1.6E-04		
Pe (Peclet Number) for transport through the foundation (advection / diffusion)	(-)	B_Param	1.1E+03	3.8E+01 - 1.9E+04	5.3E+02	1.8E+01 - 8.8E+03	
α for convective transport from subslab to building	(-)	C_Param	3.0E-03	1.0E-04 - 5.0E-02	3.0E-03	1.0E-04 - 5.0E-02	

Interpretation

Advection is the dominant mechanism across the foundation.

Diffusion through soil and advection through foundation both control intrusic

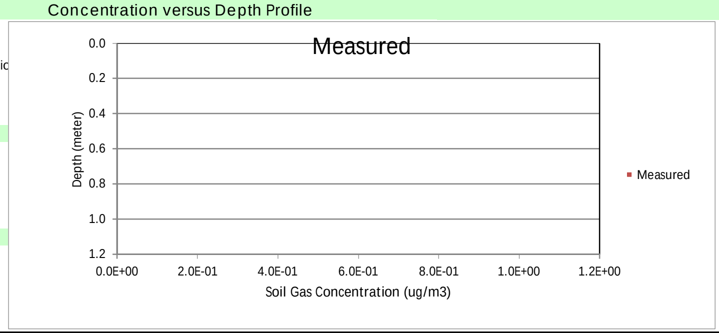
Critical Parameters

Hb, Ls, DeffT, ach, Qsoil_Qb

Non-Critical Parameters

Lf, DeffA, eta

Concentration versus Depth Profile



Please check WARNING or ERROR flags

Appendix B
1,1-DCE Inputs
EPA Johnson & Ettinger Model

Model Output Site Name/Run Number: Example, Run 1

Chemical Name: Dichloroethylene, 1,1- CAS No. 75-35-4

Risk Calculations	Units	Symbol	Value	Range	Default	Range	Flag
Risk-Based Target Screening Levels Scenario: Commercial							
Target risk for carcinogens	(-)	Target_CR	1E-06	-	1E-06	-	
Target hazard quotient for noncarcinogens	(-)	Target_HQ	1	-	1	-	
Target indoor air concentration	(ug/m3)	Target_IA	8.76E+02	-	8.76E+02	-	Target indoor air concentration based o concentration)
	(ppbv)		2.21E+02	-	2.21E+02	-	
Target groundwater concentration	(ug/L)	Target_GW	2.21E+03	1.8E+03 - 1.3E+04	5.09E+03	7.0E+03 - 1.9E+04	
Incremental Risk Estimates							
Incremental cancer risk from vapor intrusion	(-)	Cancer_Risk	No IUR	-	No IUR	No IUR - No IUR	
Hazard quotient from vapor intrusion	(-)	HQ	7.25E-03	1.2E-03 - 8.7E-03	2.17E-03	8.6E-04 - 2.3E-03	

Appendix C

Green and Sustainable Remediation Assessment of

Optimized Remedial Alternatives

GREEN AND SUSTAINABLE REMEDIATION ASSESSMENT OF OPTIMIZED REMEDIAL ALTERNATIVES
FORMER GE FARRELL ROAD SITE
SITE ID NO. 734055
241 FARRELL ROAD, SYRACUSE, NEW YORK

Prepared for:
Lockheed Martin Corporation

Prepared by:
AECOM

September 18, 2020

Approved by:
Lockheed Martin, Inc.

Revision: 0

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ACRONYMS AND ABBREVIATIONS

CH_4	methane
CO_2	carbon dioxide
NO_x	nitrogen oxides
N_2O	nitrous oxide
PM_{10}	total airborne particulate matter
SO_x	sulfur oxides
GHG	greenhouse gases
kg	kilogram
MMBTU	one million British thermal units
MWH	megawatt hours
USEPA	United States Environmental Protection Agency

SECTION 1
INTRODUCTION

AECOM has prepared this Green and Sustainability Assessment on behalf of Lockheed Martin Corporation (Lockheed Martin) with respect to two of the potential optimized remedial alternatives evaluated in the *Building #2 Remedial System Optimization Study* (RSO) for the Former General Electric Farrell Road Site located in the Town of Geddes, New York.

The two optimized remedial alternatives evaluated in this assessment are:

1. Dual Phase Extraction using Horizontal Wells

2. Thermal Treatment

Consideration of environmental, economic and social impacts of remediation is an established process, which is outlined in international guidance including the Sustainable Remediation Forum SuRF-UK framework and the International Standard ISO18504 Sustainable Remediation. Sustainable remediation is defined as the elimination and/or control of unacceptable risks in a safe and timely manner while optimizing the environmental, social and economic value of the work (ref: ISO18504, 2017).

Sustainability assessments of remedial alternatives should look at a broad range of interactions that include:

- The environmental footprint of remedial alternatives, including energy consumption, local and global emission generations and consumption of raw materials.
- Economic analysis, including cost benefit considerations.
- Social considerations, including consideration of how the remedial alternative will impact (both positively and/or negatively) the surrounding community.

The environmental impact of a remediation alternative is an important project consideration, as is outlined in the New York State Department of Environmental Remediation Green Remediation Guidance Document (DER-31). As part of the detailed alternatives evaluation conducted in the RSO this green remediation assessment was conducted to provide a quantitative evaluation to compare the environmental impact of the two optimized remedial alternatives mentioned above. Both of these potential alternatives are equally protective of human and environmental health. Specifically, the goals of this assessment were to compare the greenhouse gas emissions generation and the total energy consumption of the alternatives. The resulting estimated environmental impacts were considered as one of many balancing criteria when comparing, evaluating and recommending a remedial action for the facility.

A description of the environmental footprint assessment process and results is described below.

SECTION 2
SUSTAINABLE REMEDIATION TOOLBOX

2.1 SITEWISE™ MODEL

SiteWise™ is a series of publicly available Microsoft Excel spreadsheets used to calculate the environmental footprint of remediation activities in terms of sustainability metrics. This tool is a footprint estimator based on life cycle equivalents used to quantify common environmental metrics, as well as worker safety metrics. SiteWise™ was developed in a joint effort by Battelle Memorial Institute, the United States (US) Navy, and the US Army Corps of Engineers (NAVFAC, 2015). Use of the SiteWise™ tool involves developing a conceptual design of each remediation option and using these designs as the basis for the inputs in the tool.

The SiteWise™ tool can be used to calculate the following metrics using life cycle equivalents (i.e. published emission factors, consumption rates, and accident statistics):

- Air emissions, including:
  - Greenhouse gases, reported as the combined total of carbon dioxide methane and nitrous oxide
  - On-site and total nitrogen oxides
  - On-site and total sulfur oxides
  - On-site and total airborne particulate matter
- Energy use;
- Accident risk (injury and fatality); and
- Hazardous and non-hazardous waste quantities.

SiteWise™ quantifies metrics associated with materials production (including raw materials and other construction/treatment materials); transportation of materials, personnel, and equipment to the site; on-site construction activities (i.e., excavation and capping equipment operation); on-site labour; transportation of waste for off-site disposal; and management of landfills proportional to the quantity of waste disposed. The emissions factors in SiteWise™ are reflective of the full life cycle of materials and waste; impacts are inclusive of material production and management of waste at the landfill, even though these activities are conducted off-site.

2.2 ANALYSIS APPROACH

This sustainable remediation assessment scope involves the following principal elements:

- Development of a conceptual outline of each remediation scenario and identifying the necessary SiteWise™ inputs for each;
- Critical evaluation of the inputs of each remediation option to develop a consistent and defensible baseline for each option within the SiteWise™ domain;
- Running the SiteWise™ model for each scenario and optimizing the model parameters to generate realistic outputs, and technical review for consistency and 'real-world' practicality;
- Interpreting data and outputs in terms of sustainability metrics to evaluate the net benefits and impacts of each remediation option; and
- Compare the results of the two tools and identify the sustainability merits of each alternative.

SECTION 3
RESULTS

3.1 SITEWISE™

3.1.1 SiteWise™ – Input Values

As described above, the SiteWise™ inputs were generated based on a conceptual design of the two specified optimized remedial alternatives. The conceptual designs, including assumptions and references, are outlined in the inputs and assumptions tables.

These tables, included in Appendix A, serve as the basis for the SiteWise™ input sheets and include details regarding various components to each of the remedial scenarios. The inputs and assumptions were based on information known from previous experience and on sound engineering judgement.

3.1.2 SiteWise™ – Outputs

Once the conceptual designs and inputs and assumptions tables were generated and reviewed by the SiteWise™ assessment team, the SiteWise™ tool was run for each remedial alternative individually, and then compiled to create a final summary which compares the environmental footprint of both of the remedial alternatives. The SiteWise™ results files are included in Appendix B.

The SiteWise™ results for each alternative include a detailed breakdown of how each component of the remediation stage (construction, operation, residual handling, etc.) contributes to the environmental metrics. The individual results for each alternative provide insight as to which stages of the remedial process (equipment use, residual handling, consumables etc.) produce the most impacts and can provide insight into impacts due to raw materials consumption. The final summary comparison results from the SiteWise™ tool focus on the bigger picture and present the total environmental footprint from all components for each remedial alternative. The main outputs from the final summary results comparison are presented and described below.

Table 1 – Summary of Remedial Alternative Environmental Footprint

Environmental Factors	Remedial Alternative	
	Dual Phase Extraction (Horizontal Wells)	**Thermal Treatment**
Greenhouse Gas Emissions (metric tons)	759	177
Total Energy Used (MMBTU)	27,524	17,724
Water Consumption (gallons)	932,817	16,353
Electricity Usage (MHW)	1,829	32
Non-Hazardous Waste Landfill Space (tons)	780	213
Total NO_x Emissions (metric tons)	1.24	0.85
Total SO_x Emissions (metric tons)	1.19	0.40
Total PM_{10} Emissions (metric tons)	0.65	0.15
Accident Risk Fatality	0.000058	0.0000932
Accident Risk Injury	0.0131	0.023

Table 1 shows a comparison of the estimated environmental footprint that would be generated by the implementation of each remedial alternative. It is worth noting that the electricity required for thermal heating is represented in the tool as an energy input and therefore is included in the total energy used calculation, not the electricity usage calculation. Detailed results are included in Attachment B.

3.1.3 SiteWise™ Metric Specific Results

As shown in Table 1, of the two evaluated technologies, the dual phase extraction (DPE) alternative has the overall higher environmental footprint for each of the environmental metrics, including greenhouse gas emissions and energy consumption, while thermal treatment has the overall lower environmental footprint for all metrics. Thermal remedies are often viewed as highly energy intensive and are thought to have a large environmental impact, therefore the results of the evaluation may seem unexpected. A detailed evaluation of individual environmental metrics and the remedy components in the SiteWise™ results offer some insight as to why the DPE option output the higher of the two technologies for environmental impact.

A brief summary of the key findings specific to selected metrics is outlined below:

- Greenhouse Gas (GHG) Emissions: DPE treatment has GHG emissions that are more than 4 times higher than the GHG of the thermal treatment option. GHG emissions for the DPE option are driven by the equipment use category which is about 82% of the emissions, followed by consumables which is 17%. The 10-year operational timeframe requires long term treatment equipment use. GHG from the thermal treatment option are mainly due to consumables (58%), and equipment use (41%).
- Energy Use: Based on this estimate, thermal treatment requires approximately 17,622 one million British Thermal Units (MMBTU) and DPE requires 28,872 MMBTU. Note that for the thermal option, the electricity needed for the heating elements is captured under total energy use in SiteWise™. Therefore, most of the energy demand for the thermal option (85%) is accordingly from equipment use. For DPE, energy use is about equal between consumables (49%) and equipment use (50%). DPE requires a large amount of granular activated carbon for the treatment of extracted vapor and groundwater and is a high environmental impact material.
- Electricity Use and Water Consumption: DPE has a higher electricity use impact than thermal and therefore a higher water consumption as well. (In SiteWise™ water consumption is related to electricity generation.) For both options electricity use and water use are directly due to equipment use.
- Total SO_x, NO_x, and PM_{10} (criteria pollutants): Criteria air pollutants are calculated for on-site and off-site activities such that local emissions can be accounted for if the site is in a sensitive location. Overall, DPE has higher emissions of criteria air pollutants when considered on a

wholistic basis, however, thermal treatment has higher onsite air pollutant emissions due to more on site drilling being required for this option. Overall DPE has higher criteria air pollutant emissions which makes sense since these emissions track with overall energy use and electricity use.

- Accident risk - injury: For the safety metrics thermal treatment is estimated to be the higher risk treatment option of the two options, however both risk for both alternatives is within the same order of magnitude. Thermal treatment has more drilling time than DPE which accounts for the higher risk.

Figure 1 - SiteWise™ Results Presented on a Normalized Scale

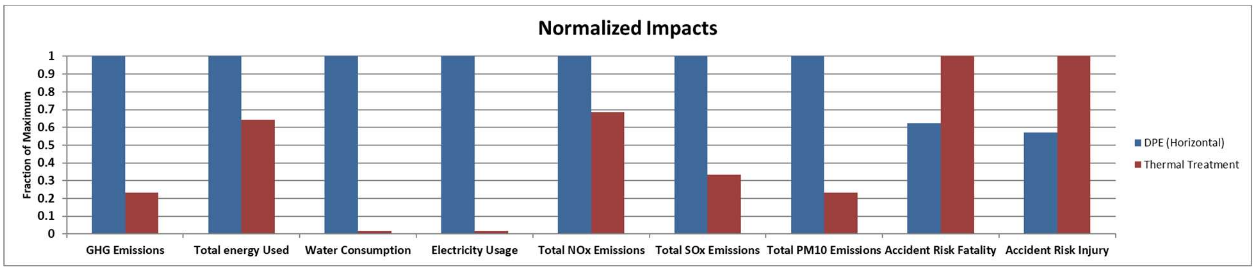

Figure 1 presents the results in a manner where the quantitative values are normalized to the highest result for each metric. The alternative with the highest result for each metric is shown as 100%, while the other four alternatives are shown as percentages of the maximum. Figure 1 illustrates that DPE has a higher impact across all environmental metrics, but thermal treatment has a safety higher risk.

SECTION 4
SUMMARY AND SUSTAINABILITY INTERPRETATION

Each remedial alternative has sustainability benefits and drawbacks and site-specific assessments are worthwhile for quantifying the environmental impact for equally protective and similarly costly remedial alternatives. The SiteWise™ assessment has highlighted that each of the active stages of remediation has an environmental impact in terms of energy, resource usage and environmental emissions. The dual phase extraction (DPE) alternative is an energy intensive treatment option with many operational components which will run for twenty-four hours a day, seven days a week for the duration of the remedy timeframe. Overall the DPE option has the higher environmental footprint mainly due to the long-term operation of the extraction system and related treatment components. The energy consumption of the thermal option is not insignificant, but it is condensed to a shorter timeframe. Thermal remediation projects are often thought of as very energy intensive and resource demanding, however, when compared to remedial alternatives that have an extended timeframe, the duration of a remedy plays an important role in the environmental impact. Consumption of raw materials, both to construct the remedies and treatment media also contribute to the environmental footprint for both options.

Regardless of the selected alternative, AECOM recommends that the chosen remedial option be thoroughly value-engineered during the design phase to minimize impacts; for example:

- Reduce the impact of consumables through close monitoring of treatment performance.
- Reduce the impact of materials through selection of lower impact materials consistent with their functional value, and considering the reuse of trenching soils on site instead of disposing of them and importing backfill.
- Reduce the impact of other significant contributors by minimizing double handling, low-emission retrofits for diesel equipment, and sourcing materials near the site when possible.

In addition, best management practices published by EPA (EPA 2012), ASTM (ASTM 2013), and ITRC (ITRC 2011) should be considered in the upcoming design and construction phases. Best management practices might consider clean fuel and emission reduction technologies, equipment idle reduction plans, among others, and can be tailored to the specific site, project, and project goals.

SECTION 5
REFERENCES

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ATTACHMENTS

Attachment A—Inputs and Assumptions

Attachment B—SiteWise™ Results

Attachment A

Inputs and Assumptions

Lockheed Martin Corporation - Farrell Road Remedial System Optimization - SiteWise Inputs and Assumptions - Dual Phase Extraction (Horizontal)

Task		Item	Quantity	Units	Quantity	Units	Assumptions	SiteWise Input Cell	References
Vapor Extraction Well Installation - HORIZONTAL	Well Install	drilling time	100	hrs/location	400	hrs total	total drilling time 40 days, assume 10 hr day	E116, E17	from cost estimate
		# of points (HSA)	4	locations				E114	
	Well Materials	depth	625	ft			2" PVC wells Assume 500ft screen	E18	
		sand	19,868	kg			Used Sitewise Well Materials Well Calculator	E21	
		gravel	-	kg				E22	
		bentonite	77	kg				E23	
		cement	3,829	kg				E24	
		concrete	162	kg				E25	
		steel	9	kg				E26	
Waste Disposal	Drilling	solids (non haz)	480	CY	528	tons	soil = 2,200lbs/cy	D309, D310	https://todayshomeowner.com/buying-materials-by-the-cubic-yard-faq/#:~:text=Soil%3A%20Weighs%20about%202%2C200%20pounds,3%2C000%20pounds%20per%20cubic%20yard.
					22	trips	assume 25' ton loads, assume waste facility is within 30 miles	D303-D306	
		liquid	6	CY	5	tons	water = 1685lbs/cy	-	
					1	trips	assume 25' ton loads, assume waste facility is within 30 miles	E303-E306	
	Trenching	solid (non Haz)	252	tons	11	trips	assume 25' ton loads, assume waste facility is within 30 miles	E310, F303-F306	
	Gac		80,000	lbs	40	tons		G303-G306	
					2	trips	assume 20' ton loads, assume regen facility is within 30 miles,	G305	
Conveyance Piping Trenching & Materials		piping	1,805	LF	1,787	lbs	assume1" hdpe (0.23lbs/ft) threaded through 2" hdpe (0.76lbs/ft)	D54-D56	https://hdpesupply.com/content/duraline_hdpe_water_pipe_spec_sheet.pdf
	Vapor Recovery Trench		1,415	LF				-	
	Trenching		142	hrs	25-40	hp	assume 100ft/day, 10 hr day	D121, D122	
System Operation	Blower	size	20	hp				D215	
		operating time	87,600	hrs			Assume 10 years operation time, 24 hrs a day.	D217	
		# of blowers	1	#				D216	
	Water Recovery Pump	size	2	hp			Assume 50 gpm Flowrate, 25 gpm for each pump.	D192	Based on general assumptions of pump efficiency, possible piping alignment, & potential head required.
		operating time	87,600	hrs			Assume 10 years operation time, 24 hrs a day.	D194	
		# of pumps	2	#				D193	
Soil Vapor Treatment	Vapor TTX	GAC	40,000	lbs			assume regenerated GAC, 2 x 1,000lb units, one unit replaced every 3 months.	E54-E56	
Extracted Water Treatment	OWS	size	1	hp			given from clean harbors quote	E192	
		operating time	87,600	hrs			Assume 10 years operation time, 24 hrs a day.	E194	
		# of pumps	1	#				E193	
	GAC		40,000				assume regenerated GAC, 2 x 2,000lb units, one unit replaced every 6 months.	F54-F56	
	Air Stripper	size	3	hp			Blower style given from clean harbors quote	F192	
		operating time	87,600	hrs			Assume 10 years operation time, 24 hrs a day.	F194	
		# of blowers	1	#				F193	
Site Restoration	Trenching	backfill	4,115	CF			assume soil	G54-G56	
		asphalt repair	900	SF	450	CF	assume 6" thickness, 1' width	H54-H56	
		concrete	515	LF	258	CF	assume 6" thickness, 1' width	I54-I56	

Lockheed Martin Corporation - Farrell Road Remedial System Optimization - SiteWise Inputs and Assumptions - Thermal Treatment

Task		Item	Quantity	Units	Quantity	Units	Assumptions	SiteWise Input Cell	References
Vapor Extraction Well Installation	Well Install	drilling time	4	hrs/location	680	hrs total	total drilling time 3.4 months, HSA method	D116	
		# of points (HSA)	170	locations				D114, D17	
	Well Materials	depth	29	ft			2" stainless steel wells - assume 6 ft screen	D18	
		sand	342	kg			Used Sitewise Well Materials Well Calculator	D21	
		gravel	0	kg				D22	
		bentonite	77	kg				D23	
		cement	547	kg				D24	
		concrete	162	kg				D25	
		steel	9	kg				D26	
Electrode Installation	Co located within extracting well, no additional drilling. Materials negligible.								
Waste Disposal	Drilling	solid (non haz)	88	drums	24	tons	1 drum = 7.35 CF, soil = 75lbs/CF	D309, D310	http://www.kylesconverter.com/volume/drums-(55-us-gal)-to-cubic-feet, https://www.engineeringtoolbox.com/earth-soil-weight-d_1349.html
		liquid	88	drums	20	tons	1 gal = 8.34 lbs.	-	
		solid			1	trips	assume 25' ton loads, assume waste facility is within 30 miles	D303-D306	
		liquid			1	trips		E303-E306	
	Trenching	solid (non haz)	189	tons	8	trips	assume 25' ton loads, assume waste facility is within 30 miles	F303-F306, E309, E310	
	Gac		10,000	lbs	5	tons	give from cost estimate, assume regenerated, assume regen facility is within 30 miles.	G303-G306	
					1	trips		G306	
	Condensate	Neglect							
Conveyance Piping Trenching & materials	Vapor Recovery Line	piping	3100	LF	8370	lbs	assume 2" stainless steel, 2.7 lbs/ft	D54-D56	
	Trenching		310	hrs	25-40	hp	assume 100ft/day, 10 hr day	D120-D122	
Soil Vapor Treatment	Blower	size	20	hp				D215	
		operating time	2150.4	hrs			Assume 3.2 months operation time, 24 hrs a day.	D217	
		# of blowers	1	#				D216	
	Vapor TTX	GAC	10,000	lbs			assume regenerated GAC	E54-E56	
Thermal Treatment	Energy	subsurface	3,950,000	kWh	13,467	MMBTU		D287	
		surface	170,000	kWh	580	MMBTU		D287	
Site Restoration	Trenching	backfill	3100	CF			assume soil	F54-F56	
		concrete repair	3100	LF	1550	CF	assume 6" thickness	G54-G56	

Attachment B

SiteWise^{TM} Results

Lockheed Martin Corporation - Farrell Road Remedial System Optimization - SiteWise Results

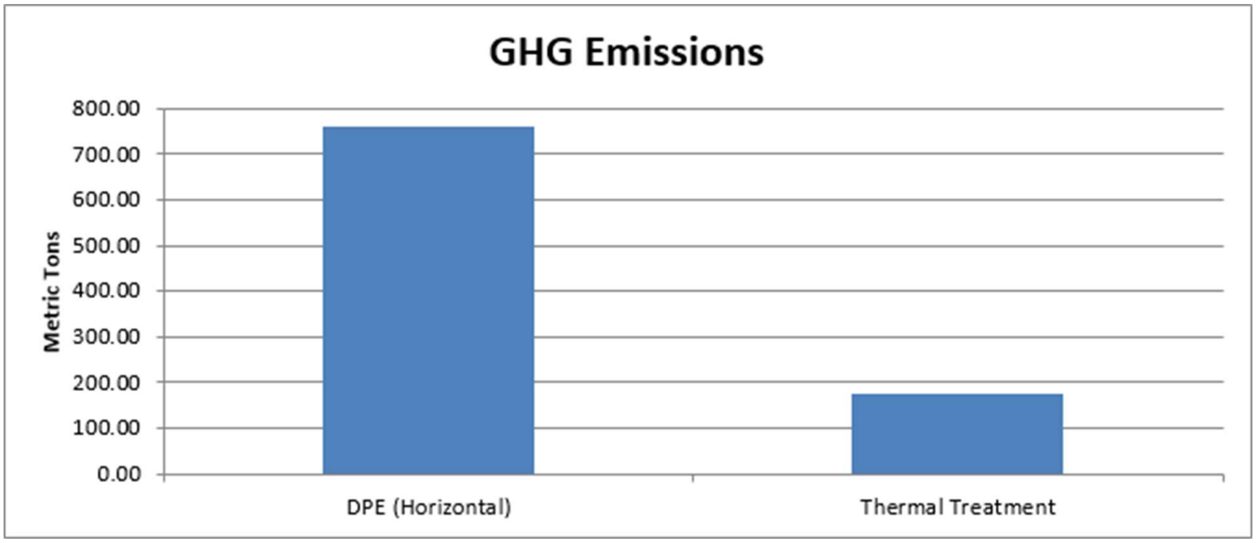
Remedial Alternatives	GHG Emissions	Total Energy Used	Water Consumption	Electricity Usage	Onsite NO_x Emissions	Onsite SO_x Emissions	Onsite PM_{10} Emissions	Total NO_x Emissions	Total SO_x Emissions	Total PM_{10} Emissions	Accident Risk Fatality	Accident Risk Injury
	metric ton	MMBTU	gallons	MWH	metric ton	metric ton	metric ton	metric ton	metric ton	metric ton		
DPE (Horizontal)	759.00	27,524	932,817	1,829	0.34	0.04	0.03	1.24	1.19	0.65	5.80E-05	1.31E-02
Thermal Treatment	177.53	17,724	16,353	32	0.58	0.06	0.05	0.85	0.40	0.15	9.32E-05	2.30E-02

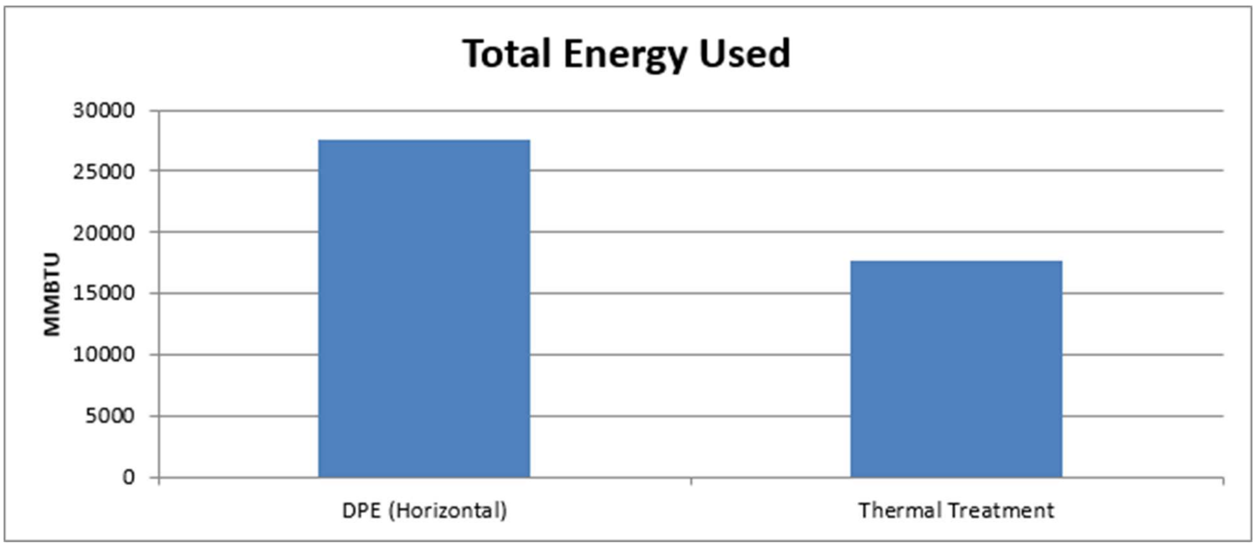
Additional Sustainability Metrics

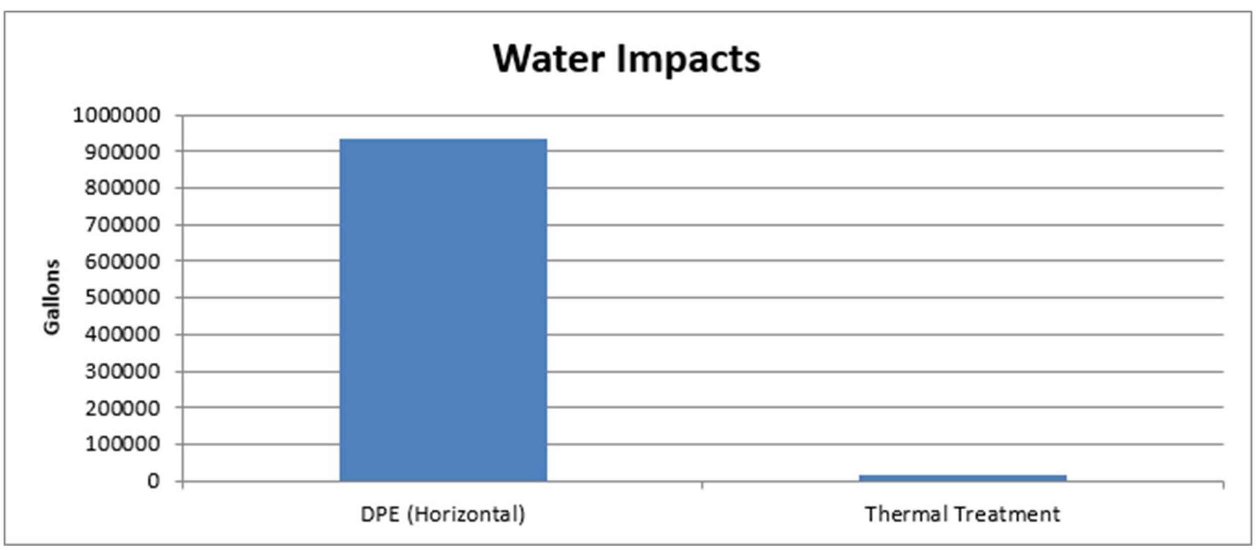
Remedial Alternatives	Non-Hazardous Waste Landfill Space	Hazardous Waste Landfill Space	Topsoil Consumption	Lost Hours - Injury	Percent Electricity from Renewable Sources
	tons	tons	cubic yards		%
DPE (Horizontal)	780	0	0	1.05E-01	6.1%
Thermal Treatment	213	0	0	1.84E-01	6.1%

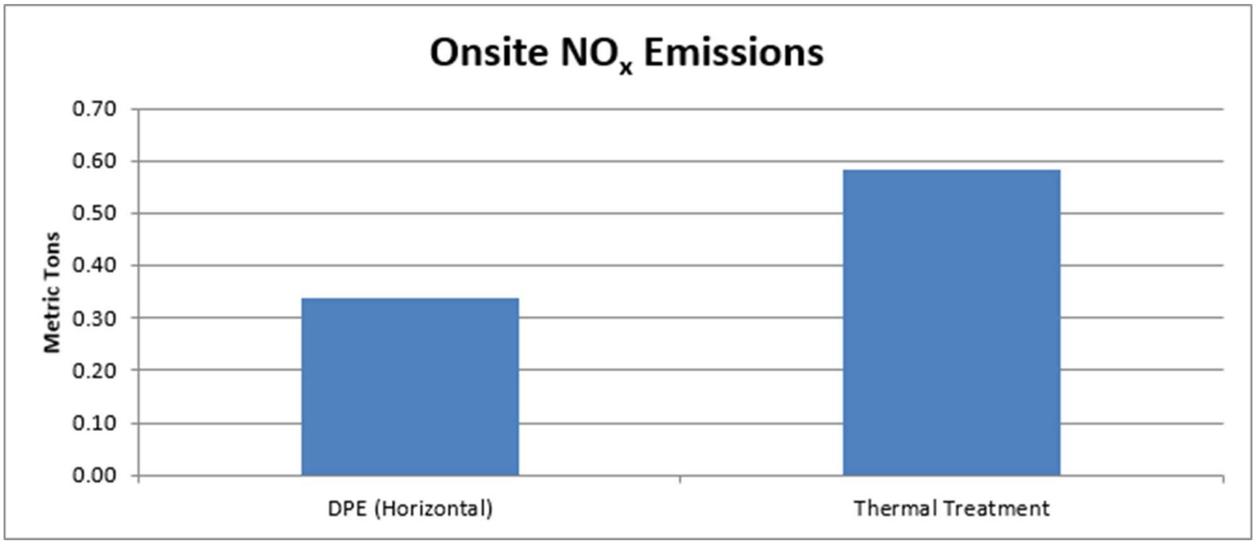
Relative Impact

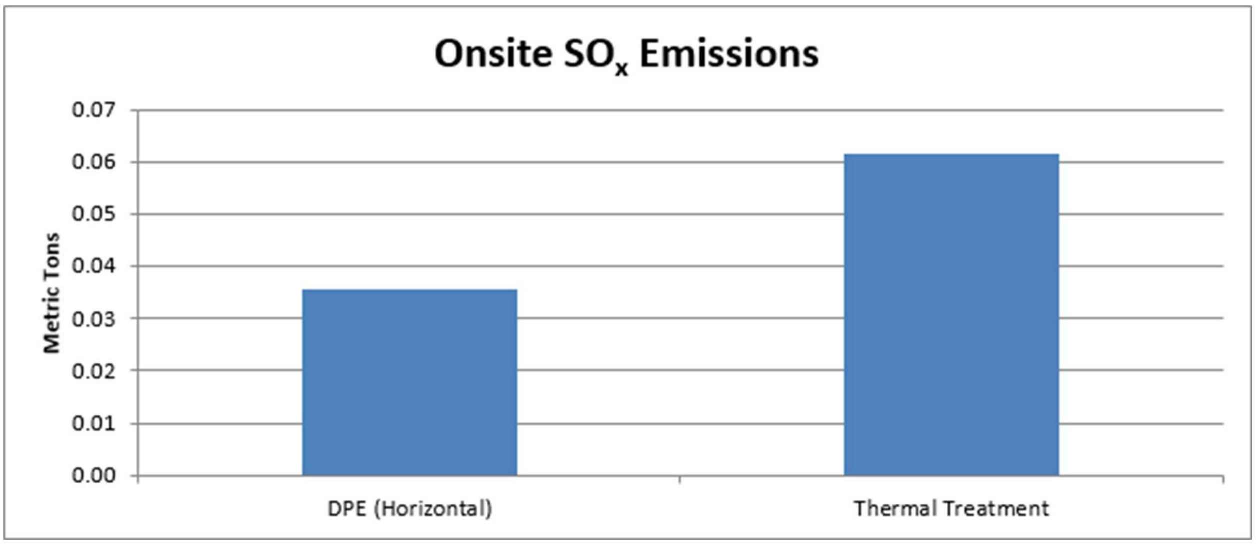
Remedial Alternatives	GHG Emissions	Energy Usage	Water Usage	Electricity Usage	Onsite NOx Emissions	Onsite SOx Emissions	Onsite PM10 Emissions	Total NOx emissions	Total SOx Emissions	Total PM10 Emissions	*Accident Risk Fatality	*Accident Risk Injury
DPE (Horizontal)	High	High	High	High	Medium	Medium	Medium	High	High	High	Low	Low
Thermal Treatment	Low	Medium	Low	Low	High	High	High	Medium	Medium	Low	Low	Low

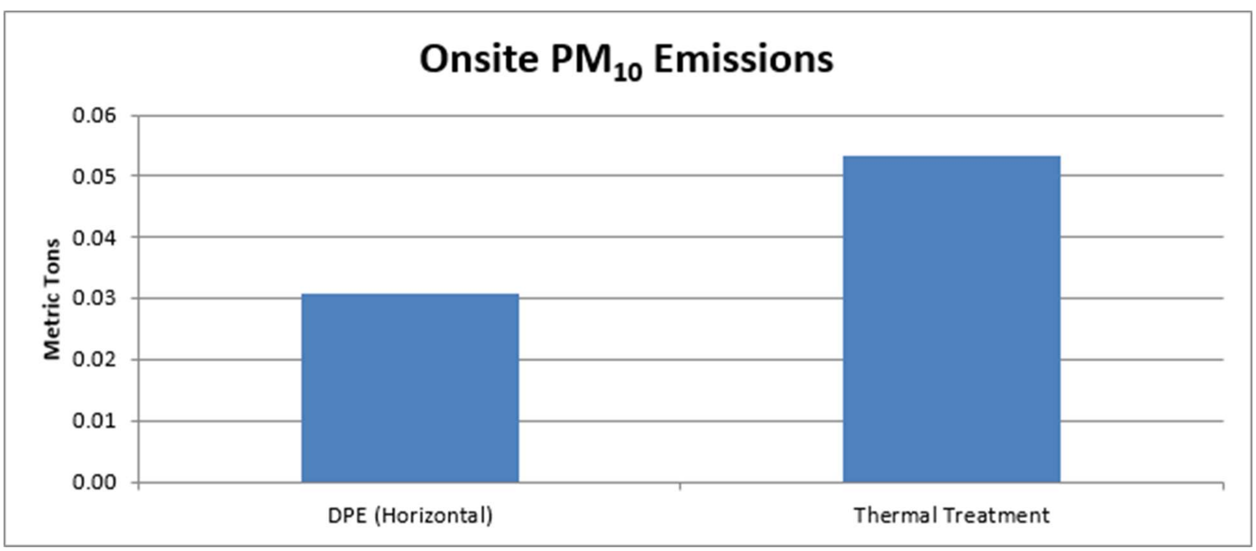

GHG Emissions
Metric Tons
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
DPE (Horizontal)
Thermal Treatment

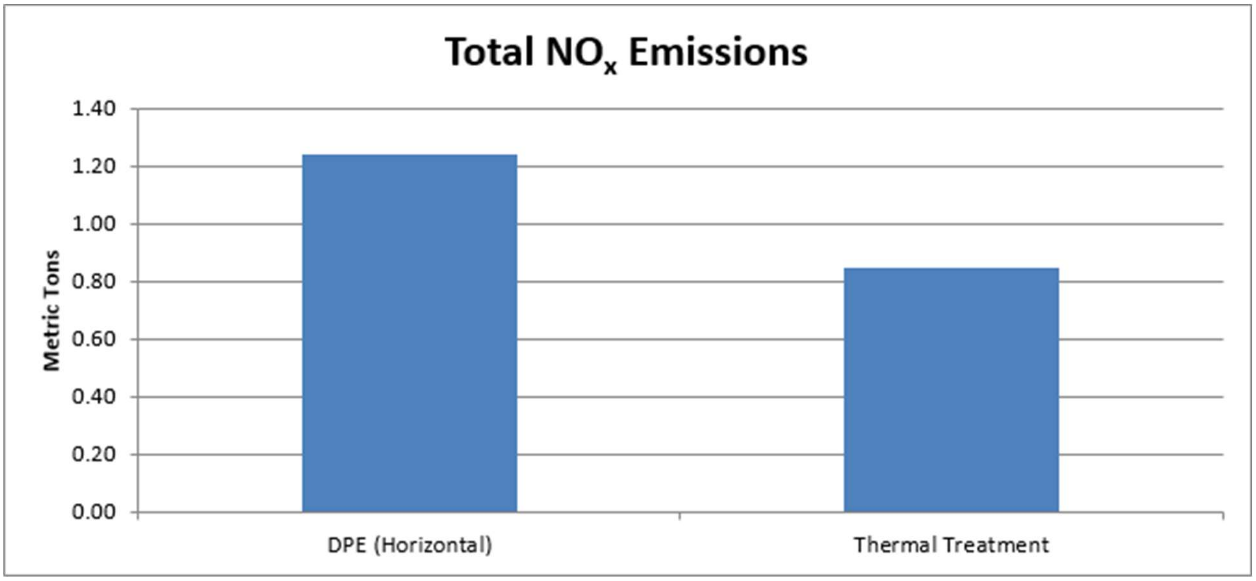

Total Energy Used
MMBTU
30000
25000
20000
15000
10000
5000
0
DPE (Horizontal)
Thermal Treatment

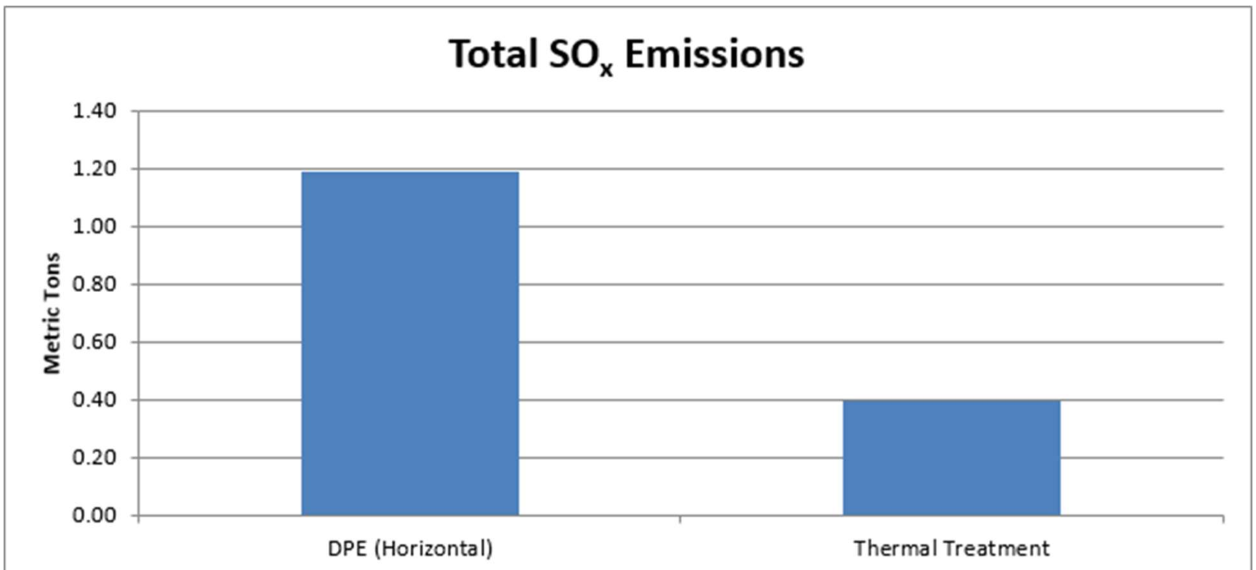

Water Impacts
Gallons
1000000
900000
800000
700000
600000
500000
400000
300000
200000
100000
0
DPE (Horizontal)
Thermal Treatment

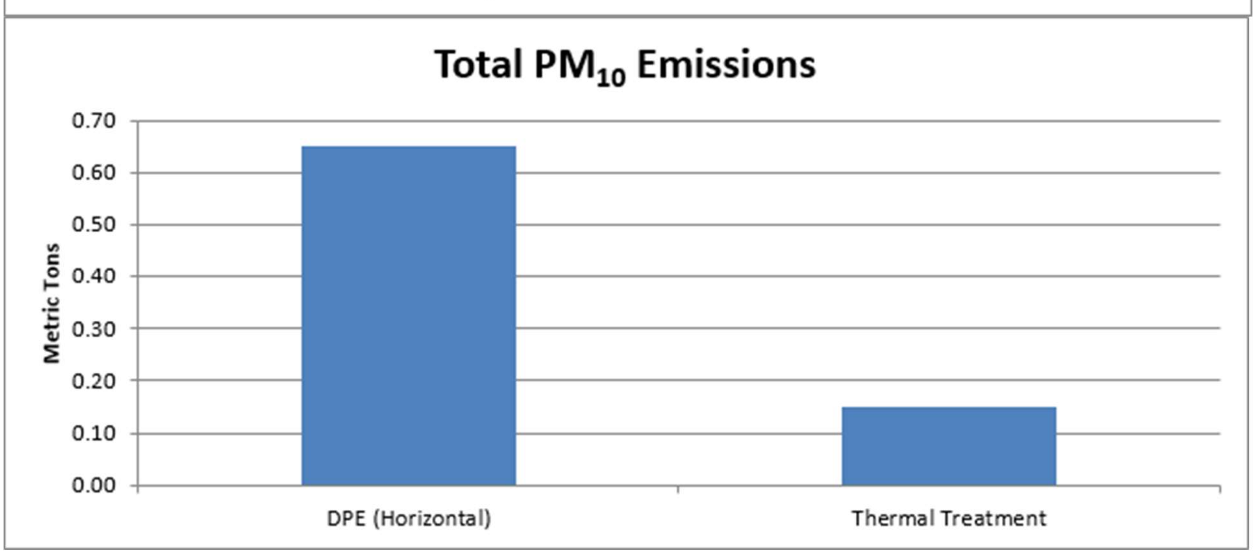

Onsite NOx Emissions
Metric Tons
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
DPE (Horizontal)
Thermal Treatment

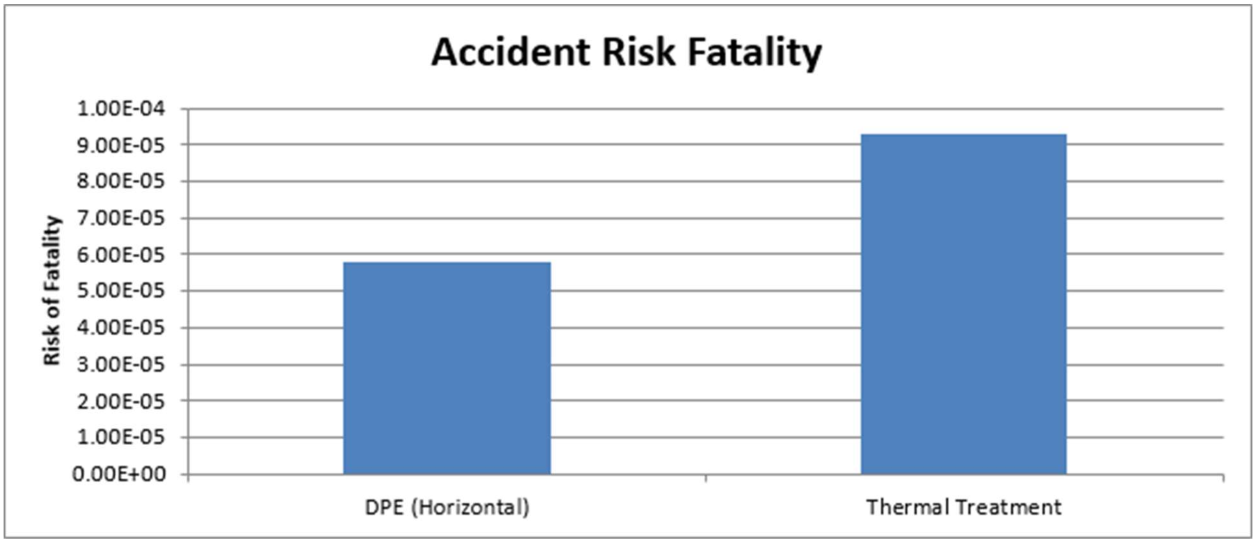

Onsite SOx Emissions
Metric Tons
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
DPE (Horizontal)
Thermal Treatment

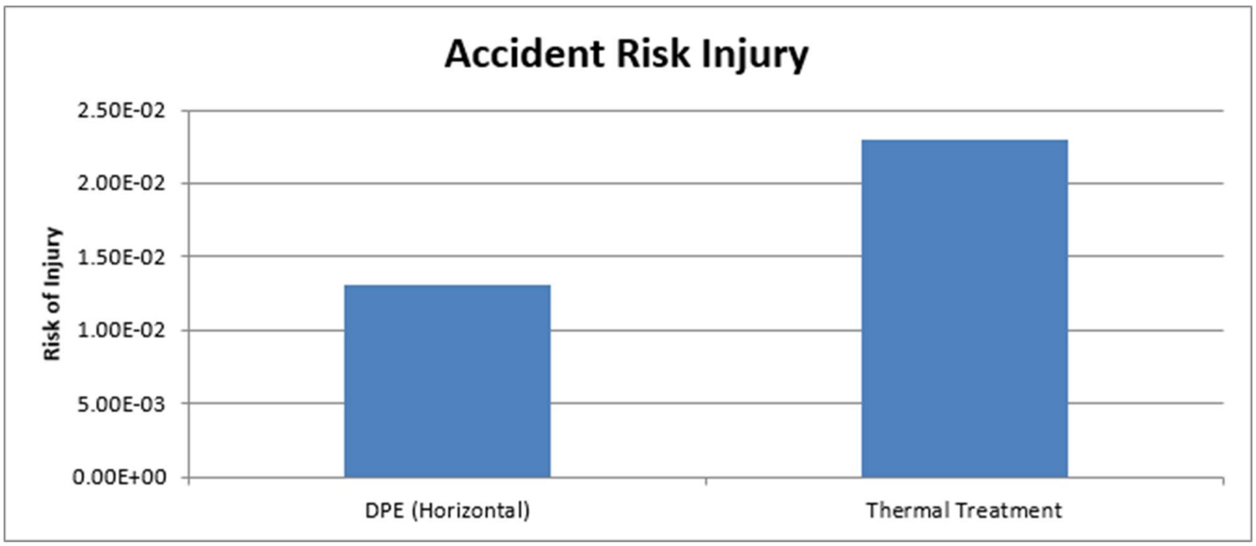

Onsite PM10 Emissions
Metric Tons
0.06
0.05
0.04
0.03
0.02
0.01
0.00
DPE (Horizontal)
Thermal Treatment

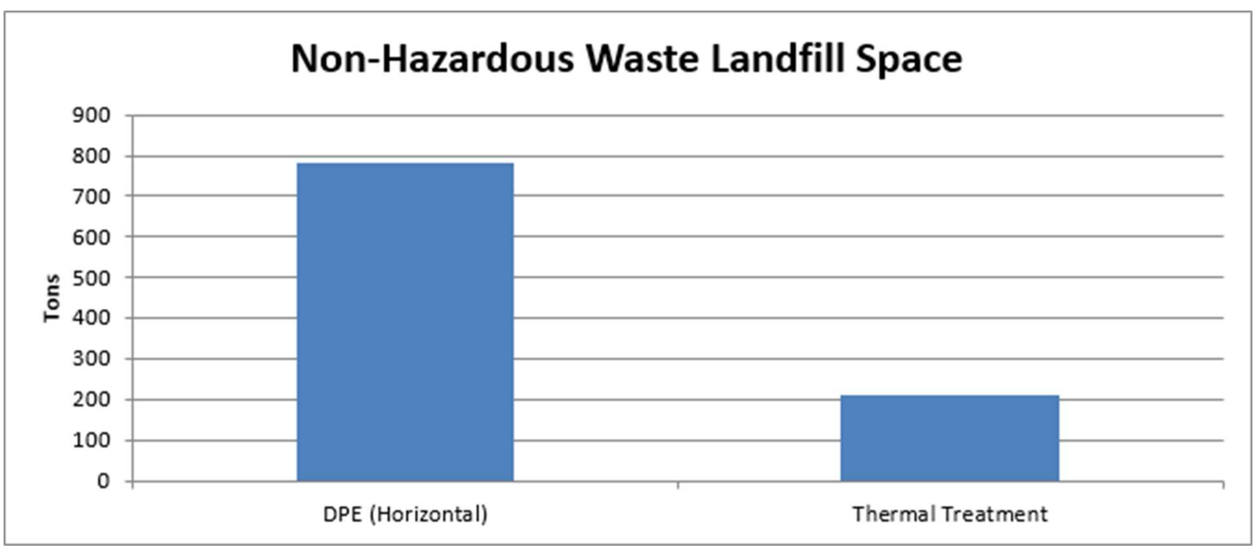

Total NO_x Emissions
Metric Tons
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
DPE (Horizontal)
Thermal Treatment

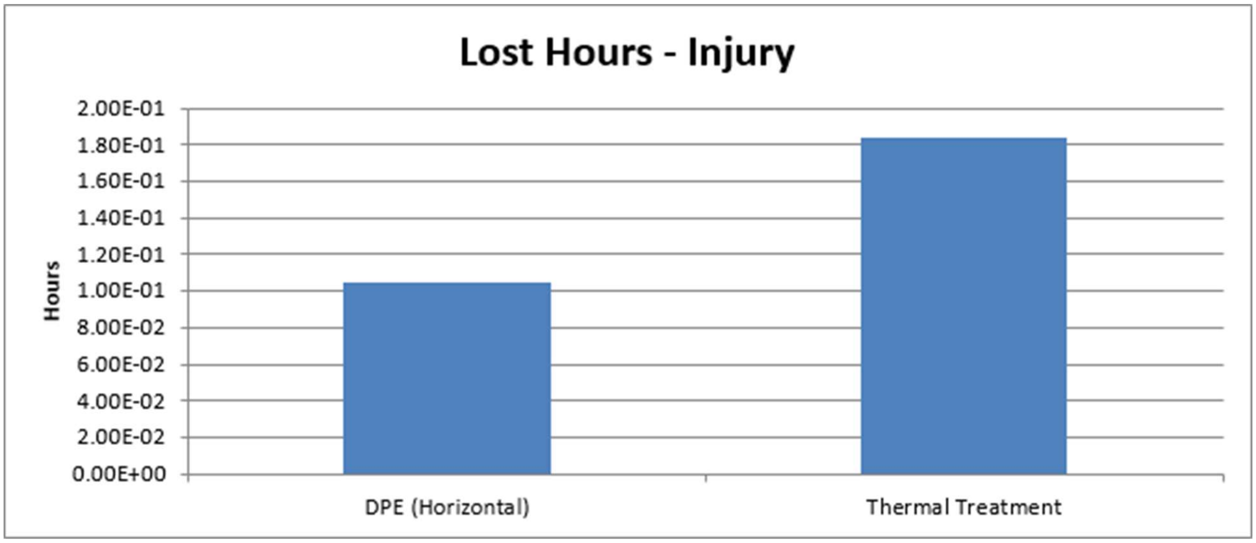

Total SO_x Emissions
Metric Tons
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
DPE (Horizontal)
Thermal Treatment

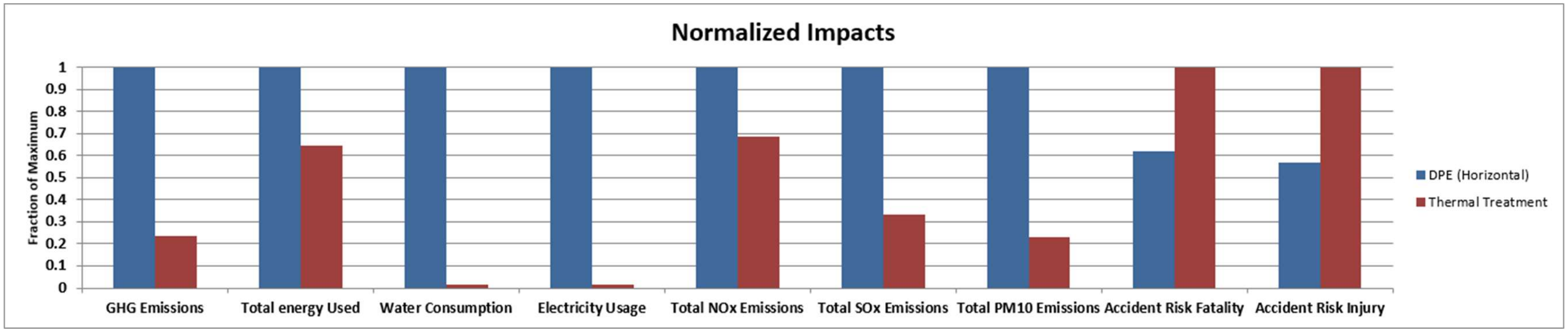

Total PM_{10} Emissions
Metric Tons
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
DPE (Horizontal)
Thermal Treatment


Accident Risk Fatality
Risk of Fatality
1.00E-04
9.00E-05
8.00E-05
7.00E-05
6.00E-05
5.00E-05
4.00E-05
3.00E-05
2.00E-05
1.00E-05
0.00E+00
DPE (Horizontal)
Thermal Treatment


Accident Risk Injury
Risk of Injury
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
DPE (Horizontal)
Thermal Treatment


Non-Hazardous Waste Landfill Space
Tons
900
800
700
600
500
400
300
200
100
0
DPE (Horizontal)
Thermal Treatment


Lost Hours - Injury
Hours
2.00E-01
1.80E-01
1.60E-01
1.40E-01
1.20E-01
1.00E-01
8.00E-02
6.00E-02
4.00E-02
2.00E-02
0.00E+00
DPE (Horizontal)
Thermal Treatment



Normalized Impacts
Fraction of Maximum
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
GHG Emissions
Total energy Used
Water Consumption
Electricity Usage
Total NOx Emissions
Total SOx Emissions
Total PM10 Emissions
Accident Risk Fatality
Accident Risk Injury
DPE (Horizontal)
Thermal Treatment