APTIM
150 Royall Street
Canton, MA 02021
Tel: +1 617 589 5111
Fax: +1 617 589 5495

March 12, 2018

Ms. Rodene Lamkin
Bureau of Waste Site Cleanup
Massachusetts Department of Environmental Protection
205B Lowell St.
Wilmington, MA 01887

Subject: Focused Remedy Evaluation – General Chemical Corporation Site
133 Leland Street, Framingham, MA
TAD #101847, RTN: 3-19174

Dear Ms. Lamkin:

On Behalf of the Massachusetts Department of Environmental Protection (MassDEP), Aptim Environmental & Infrastructure, Inc., (APTIM) is pleased to submit this Focused Remedy Evaluation Letter Report for the General Chemical Corporation (GCC) site located at 133-135 Leland Street, Framingham, Massachusetts (**Figure 1**). This letter report includes an evaluation of the remedial approaches that can be implemented and recommends a remedy for the source area given the current funding available.

INTRODUCTION AND BACKGROUND

Statement of Purpose

The purpose of this letter report is to evaluate potential remedial approaches that can be implemented for predominant chlorinated solvents in the source area with a goal of maximizing contaminant removal given the 1.8 million dollars of funding available. This evaluation includes a review by our most experienced national experts familiar with the applicable remedial technologies including our leading thermal and bioremediation experts. Our leading thermal expert (David Cacciatore, P.E., PhD) has been included in this review since our preliminary review indicates that thermal treatment of the source may be the most effective remedial approach. Our leading bioremediation expert (Paul Hatzinger, PhD) was also included since enhanced bioremediation might also be an effective remedial technology to be used as a follow on treatment of the targeted area to help prevent the thermally treated area from being re-impacted and to promote downgradient bioremediation.

This remedy evaluation utilizes a technology screening matrix that evaluates the effectiveness, reliability, difficulty, cost, risk, timeliness and green benefits of each technology. We utilized the information included in the Draft *Phase III Remedial Action Plan,* prepared by Groundwater Environmental Services, Inc. (GES) dated February 15, 2016 as well as other applicable reports and site data. As requested by MassDEP, this evaluation is not an updated Remedial Action Plan and does not re-create the evaluation that was conducted previously by GES, but rather is a streamlined, unbiased evaluation of the technologies by our leading experts that focuses on the most effective remedial approach for the source area to ensure that a technically sound and cost effective solution is selected. This evaluation also includes an estimate of pounds of contamination that will be removed and defines the three dimensional area that could be addressed using a remedial budget of 1.8 million dollars. This evaluation also identifies and discusses limitations and challenges in implementing the selected remedial approach.

Site History

The General Chemical Corporation property was originally an oil terminal dating back to the 1920s. The GCC facility began operations in the 1960s through the 1970s as a halogenated solvent reclamation, recycling, and distribution center. The site became a treatment, storage, and disposal facility (TSDF) in 1986 and ceased operations in March 2012.

Based on previous subsurface investigations, the groundwater at the site has been found to be highly impacted by chlorinated volatile organic compounds (VOCs) due to historical operations at the site. The primary chlorinated solvents detected in groundwater at the site include: trichloroethylene (TCE), tetrachloroethylene (PCE), 1-1-1 trichloroethane (1,1,1-TCA), methylene chloride and 1,4-dioxane, plus breakdown products such as cis-1,2-dichloroethene (cis-1,2-DCE). Based on previous site investigations, impacted groundwater from the site discharges to a drainage ditch south of the site that runs southeast and flows into Course Brook. Additionally, impacted groundwater has been determined to seep into the Massachusetts Water Resources Authority (MWRA) Sudbury aqueduct located to the south of the property and ultimately discharges into Course Brook via a weir in Sherborn. Due to the historic operations at the site, soil at the General Chemical Property is highly contaminated from historical spills. Indoor air was also impacted at nearby residences that have since been acquired by GCC and abandoned.

This site is an active Public Involvement Plan site. Local officials and the public are concerned about any possible exposures (including potential future exposure) of VOC compounds associated with the site. Potential exposure pathways that have been evaluated include the Wilson School via vapor intrusion or direct contact, infiltration of contaminants to the MWRA aqueduct, migration of impacted water to farm ponds and private wells, possible vapor intrusion at other nearby residences, and potential migration of impacted water to Town of Natick public water supply wells.

Residential areas and the Woodrow Wilson School are located on properties that abut the GCC site. In the Town of Framingham, the GCC site is not located in a current or potential drinking water resource area. The nearby Sudbury Aqueduct is considered by the MWRA to be a primary standby drinking water transmission conduit for the Metropolitan Boston area. In the Town of Sherborn, with just a few exceptions, properties are served by private wells. The nearest private drinking water supply wells to the GCC site in Sherborn are located along Kendall Avenue, Coolidge Street, Meadowbrook Road, and Prospect Road. Surface water features in Framingham in the vicinity of the GCC site include a drainage ditch that flows to Course Brook. From Framingham, Course Brook passes though farmland in the Town of Sherborn into the Town of Natick. Following a pathway from the GCC facility property to the drainage ditch to Course Brook, the nearest public water supply wells to the GCC facility are situated near Lake Cochituate in Natick approximately 3.7 miles away.

The GCC site encompasses several properties or portions of properties where site-related impacts are located. In addition to the GCC facility, the GCC site includes:

- Portion of the downgradient CSX railroad property
- Vacant former residential properties (owned by GCC) at 91, 91A, 119, and 125 Leland Street
- Portion of the property occupied by the Woodrow Wilson School
- Portion of the property at 155 Leland Street
- Portion of the Century Estates Condominium property

- Portion of the downgradient MWRA property on which the Sudbury Aqueduct is located, extending to Sherborn
- Land and wetlands to the south and southeast of the GCC facility, owned by Exelon Corporation (Exelon), which is occupied by an electrical substation and an unnamed drainage ditch that discharges to Course Brook
- Course Brook from the Exelon property in Framingham onto the Massachusetts Department of Conservation and Recreation (DCR) property located in Sherborn/Natick.

DETAILED EVALUATION OF REMEDIAL ALTERNATIVES

This section evaluates and rescores the technologies presented in the GES draft Phase III report and retained as potentially applicable to treat source area contamination in the two on-site areas presented as AOC#1 (Shallow Soil 0-10' bgs) and AOC#2 (Shallow Groundwater and Soil 10-20'bgs), in **Figure 2** and **Figure 3**, respectively.

The following available technologies were identified in the initial screening as potentially applicable remedial alternatives for the treatment of CVOCs in soil and groundwater, as either a stand-alone technology or as part of an integrated remedial strategy.

- Institutional controls (e.g., activity and use limitation)
- Containment (e.g., physical barrier)
- Excavation (e.g., soil removal and off-site disposal)
- Hydraulic control (e.g., pump and treat)
- Mechanical treatment (e.g., soil vapor extraction)
- In-situ chemical oxidation
- In-situ bioremediation
- In-situ thermal treatment
- Monitored Natural Attenuation (MNA)

Institutional controls, containment, hydraulic control and MNA were not retained for further consideration in this evaluation as they either do not remove contamination or are not anticipated to remove significant contamination in a reasonable period of time. Applicable remaining technologies capable of treatment as a stand-alone remedial alternative to reduce the concentration of CVOCs in each treatment area were carried forward for comparative detailed screening.

The methodology used for conducting the detailed evaluations is described below.

Remedial Evaluation Methodology

Detailed evaluations of remedial alternatives for the treatment areas were conducted in three steps:

Step 1. Review short-listed remedial alternatives from initial screening and eliminate or retain for further consideration;

Step 2. Evaluate and score retained stand-alone alternatives using a detailed evaluation process; and

Step 3. Rank and select a remedial alternative using an evaluation scoring matrix.

A detailed evaluation was performed on the short-listed remedial alternatives for AOC#1 and AOC#2. The following factors were used in this evaluation: effectiveness, short and long term reliability, difficulty in implementation, comparative cost, relative risk associated with implementation, treatment time, and green benefits.

APTIM developed a detailed alternative evaluation scoring matrix based on the categories listed above. Using this matrix, potential alternatives were evaluated, consistent with MCP requirements (310 CMR 40.0858), and a score was calculated to rank each potential remediation alternative for this site. To rank the alternatives in terms of effectiveness (E), a score of 1 (least effective) to 5 (most effective) was assigned to each alternative under consideration. A score of 5 was assigned to only those alternatives that have been demonstrated to be a successful remediation tool at sites with similar compounds and geologic characteristics.

To receive a rating of 5, the alternatives should reuse, recycle, destroy, detoxify, or treat the oil or hazardous material and have a high probability of achieving a Permanent or Temporary Solution. Decreasing scores were assigned to alternatives which are less proven or not readily available and do not reduce levels of untreated oil or hazardous material to concentrations that achieve or approach background or properly control residues or wastes or discharges to the environment.

The comparative short-term and long-term reliability (R1) of the alternatives was evaluated. A score of 1 (least reliable) to 3 (most reliable) was assigned to each alternative under consideration. Those alternatives which provided a higher degree of certainty of being successful were given a higher score. In addition, a higher score indicates a greater effectiveness in managing wastes, controlling emissions or discharges to the environment.

To rank alternatives in terms of difficulty (D) of implementation or technical complexity, a score of 1 (most difficult) to 3 (least difficult) was assigned to each alternative under consideration. A score of 3 was assigned to those alternatives that are anticipated to have the least delay due to permitting and equipment procurement and the materials and resources are readily available for implementation. A score of 3 also indicates that the technology has a low technical complexity. Decreasing scores were assigned to alternatives that are anticipated to have difficulties with permitting, access agreements, interruption to present operations, availability of necessary off-site treatment, storage and disposal facilities, and increased complexity requiring a higher level of training for operators.

The alternatives were further ranked from 1 to 5 according to relative cost (C). Alternatives with the lowest relative costs were assigned a score of 5. The scores decrease to a minimum of 1 as relative costs increase.

The alternatives were also ranked from 1 to 3 based on the potential relative short- and long-term risk (R2) of harm to human health, safety, public welfare or the environment associated with their implementation. The implementation risks should also consider on-site and off-site risks associated with excavation, transport, disposal, containment, construction, operation or maintenance activities, or discharges to the environment. A score of 3 was assigned to alternatives that expect to incur minimal risks. Decreasing scores were assigned as risk associated with implementation increased.

In addition, each alternative was ranked on a scale of 1 to 3 based on the estimated time (T) required to achieve the desired remediation goal. Alternatives that will achieve the goal the quickest were assigned a value of 3. Alternatives that will take longer but result in an acceptable treatment time were assigned value of 2. Alternatives with treatment times longer than desired were assigned a value of 1.

Finally, each alternative was ranked on a scale of 1 to 4 based on the green benefits (B) related to that alternative. Alternatives which are expected to minimize energy use or use renewable energy and resources, minimize air pollution or greenhouse gas emissions, reduce, reuse and recycle waste, protect land and ecosystems and minimize adverse visual and aesthetic impacts would receive a score of 4. Alternatives that will not meet these objectives were assigned a lower score.

The following equation was used to calculate the overall score of each alternative:

$$E+R1+D+C+R2+T+B = score$$

Where:

E = effectiveness
R1 = reliability
D = difficulty score
C = estimated relative cost score
R2 = risk associated with implementation score
T = estimated time score required to meet the project goal, and
B = green benefits

The scores may range from 7 to 26. The alternative evaluation indices were developed based upon the above described matrix system, literature review, professional judgement, and APTIM's remediation experience. The selected remedial action alternative was based on the results of the scoring matrix unless otherwise stated.

Evaluation and Selection of Remedial Alternatives

AOC#1 (Shallow Soil 0-10' bgs)

The following text box summarizes remedial alternatives for CVOC soil impacts in AOC#1 that were retained and further evaluated in a detailed evaluation and alternative scoring matrix. Results of the detailed evaluation are presented in **Table 1** and **Table 2**.

Retained Remedial Alternatives for AOC#1 (Shallow Soil 0-10' bgs)
Remedial Alternative 1 – Soil Vapor Extraction and Air Sparging *Remedial Alternative 2 – In-situ Thermal Treatment* *Remedial Alternative 3 – Excavation with Off-Site Disposal*

Alternative 1 (Soil Vapor Extraction and Air Sparging) and In-situ Thermal Treatment scored highest of the stand-alone remedial alternatives evaluated for AOC#1. SVE/AS scored high because it is a proven technology with a comparatively lower cost and risks. The score for SVE/AS would have been higher but there is some risk of off-site groundwater plume migration to the school property due to potential mounding of groundwater from the air sparging component. Thermal treatment also scored high as it too is a proven effective technology and has the highest certainty of success and in a short period of time, but its score was tempered by higher cost of implementation and perceived risk associated with vapor capture/migration close to receptors (school) and system complexity. Note that this risk can be effectively addressed through the design and O&M of a thermal treatment system. Excavation was not selected primarily due to exposure

risks from vapor emissions to workers and surrounding community and high cost for transportation and disposal of soil as hazardous waste. As this AOC pertains mainly to unsaturated soils in the source areas, bioremediation was not considered due to a majority of the contaminants being in the unsaturated zone. While AS/SVE seems like a reasonable solution, if thermal treatment will be performed in these source areas to remediate contaminants associated with AOC#2, there is no longer a need for an additional treatment alternative, as the thermal treatment will include SVE from the vadose zone to capture vapors.

AOC#2 (Shallow Groundwater and Soil 10-20' bgs)

The following text box summarizes remedial alternatives for CVOC shallow groundwater and soil impacts in AOC#2 that were retained and further evaluated in a detailed evaluation and alternative scoring matrix. Results of the detailed evaluation are presented in **Table 3** and **Table 4**.

Retained Remedial Alternatives for AOC#2 (Shallow Groundwater and Soil 10-20' bgs)
Remedial Alternative 1 – Soil Vapor Extraction and Air Sparging
Remedial Alternative 2 – In-situ Thermal Treatment
Remedial Alternative 3 – In-situ Chemical Oxidation

Alternative 2 (In-situ Thermal Treatment) scored highest of the stand-alone remedial alternatives evaluated for AOC#2. In-situ Thermal Treatment scored the highest because it is a proven technology with the highest certainty of success in the shortest period of time. As with AOC#1, perceived risk of fugitive vapors can be effectively addressed through proper design and field implementation of a thermal treatment system. Though costly relative to the other alternatives, thermal treatment in AOC#2 has the added benefit of also treating AOC#1 shallow soil (0-10') in the prescribed treatment area. In-situ Chemical Oxidation (ISCO) did not rank as well due to uncertainty of sustained reduction of OHM in areas of high contaminant mass and lower permeability. Additional injections may be required, adding to the cost and extending treatment duration. As noted in the Draft Phase III report, there is some doubt that post-injection sampling would be favorable, and that another strategy would have to be developed. Further, the addition of SVE wells to capture liberated vapors provides little system complexity advantage over the other alternatives. AS/SVE received a lower score for certainty of success in reducing OHM due to soil heterogeneities and extended time to reach remedial goals compared to thermal remediation.

While bioremediation was not considered as a primary remedial technology for this AOC due to the toxicity of high CVOC concentrations in the source areas to microbes, bioremediation is a viable low-risk and low cost remedial approach for both post-treatment of the thermal treatment zone ("biopolishing"), and treatment of lower concentration areas outside the thermal treatment zone.

Selected Remedial Alternatives

The Selected Remedial Alternative for the treatment of CVOCs in shallow soil in AOC#1 and CVOCs in shallow groundwater and soil in AOC#2 is In-situ Thermal Treatment. SVE/AS and In-situ Thermal Treatment tied for the highest score for AOC#1 and In-situ Thermal Treatment scored the highest for AOC#2 based on the detailed evaluations completed and described above. However please note that as In-situ Thermal Treatment also includes SVE to capture vapors from the vadose zone, there is no longer a need for an additional treatment technology. Further, there is economy in scale in consolidating thermal treatment infrastructure to treat multiple areas, so a lower combined cost will be realized over implementing thermal treatment in the two areas separately.

DISCUSSION AND DEVELOPMENT OF SELECTED REMEDY IMPLEMENTATION

Discussion of In-Situ Thermal Treatment

In-situ Thermal Treatment is the optimal technology to achieve the goal of removing as much contaminant mass as quickly as possible given a limited budget. The technology is capable of removing DNAPL concentrations and is not limited by multiple volatile contaminants or complex lithology. Benefits of thermal treatment for the General Chemical site include:

- elevated concentrations of chlorinated ethenes, including dense non-aqueous phase liquid (DNAPL), can be effectively removed
- expedited treatment time, which can result in reduced overall cost due to less long-term monitoring
- difficult lithology including clays can be effectively treated
- negligible rebound is expected using this technology (other than from untreated upgradient areas)

There are limitations to the technology that could adversely affect achieving the project goal. Specifically, the fixed price cost for the thermal treatment is based upon a specified energy input. Often the treatment goal has not quite been achieved when that energy input limitation is reached. Continued operation on a weekly rate is engaged at additional cost, which may not be budgeted to the extent required. Also, hydraulic control of the site groundwater, if required, could affect the overall project goal. This operation would remove resources (budget and labor) from the actual thermal treatment which could limit the goals achieved within the limited budget. Other limitations of thermal treatment include:

- demanding O&M to effectively deal with condensate
- likely to have limited effect on 1,4-dioxane, although remediation of this contaminant is not the main driver
- high cost precludes cost-effectiveness for complete site-wide treatment down to regulatory levels, so a polishing technology application is usually necessary (e.g., biopolishing)

Concerns regarding vapor migration can be effectively addressed in the design and operation and maintenance (O&M) of a thermal treatment system. A vapor recovery system with a surface cap that maintains an overlapping, vacuum radius of influence (ROI) across and extends an ROI beyond the surface expression of the treatment area will be effective at capturing all of the vapors generated provided the system is properly maintained and any conduits are identified and blocked. The maintenance of the vapor extraction system associated with thermal treatment is largely focused on condensate draining and removal. The extracted vapors are saturated and cool as they are drawn to the system for treatment. This cooling promotes condensation, which can impede vacuum influence at the recovery wells. Low points along the vapor recovery system should be connected to a central condensate collection system. Any subsurface conduits and surrounding backfill should be evaluated and blocked as necessary to prevent unanticipated vapor escape.

Part of the system's O&M vacuum monitoring points inside and outside the treatment area should be routinely checked to ensure influence. Minimal vacuum should be observable at all monitored locations during operations. Also the capability of independent vacuum control at the wellheads should be installed using globe valves. This will allow for throttling at individual wells especially the horizontal wells while maintaining the overall system vacuum.

Installation of additional vapor recovery wells along the radial direction outside the treatment area and toward the school is an extra safeguard that could be implemented. This system should be routed separately to the vapor extraction system so as not to be impacted by any condensate issues. This is not needed if the O&M is maintained properly, but would provide an additional safeguard installation, at additional cost, if required.

Implementation of In-Situ Thermal Treatment

Thermal heater wells and vapor extraction wells should be installed in separate, regular grids across the site. The spacing is based upon overlapping thermal and vacuum radii of influence which covers the treatment area and extends below and outside the area to ensure complete treatment. If required by MassDEP, monitoring wells in the treatment area will need to be re-installed using temperature compatible materials – fiberglass or stainless steel, with sealing caps, dedicated tubing, and a valve to allow for safe sampling under boiling conditions. Alternatively, the replacement of monitoring wells in the treatment zone could be installed at a later date for post treatment monitoring once the groundwater and soil temperatures have cooled. Other installations include temperature and vacuum monitoring points which are distributed across the area and outside to monitor progress and operations, respectively. All vapor recovery plumbing should be constructed of thermally compatible materials (CPVC) and be sloped for condensate drainage.

Ideally, groundwater and soil concentrations should be collected from a number of locations and/or depths for baseline, intermediate (approximately 70% and 90% design energy input), at completion, and 2-3 months post completion. Monitoring during operations will also include extracted vapor stream monitoring, daily using a photoionization detector or other field instrument, and regularly using Summa canister collection and analytical laboratory analysis (e.g., EPA TO-15), as required. These data will support mass removal approximations and treatment efficiency assurance.

The largest O&M effort related to thermal operations is the effective removal of condensate. The extracted vapors are saturated and the water vapor condenses in the lines as it cools. The water must be drained at all low points otherwise vacuum and extraction will be reduced. As the thermal heating commences, maintaining uptime will be critical because the treatment area will lose heat almost twice as fast as it increases. Thus, any extended downtime has a compounded effect on the schedule.

The site will be at an elevated temperature, greater than ambient, for up to a year after treatment. To reduce the potential for VOC rebound in groundwater, the thermal treatment application would be implemented in coordination with a follow up technology, such as in-situ bioremediation, that capitalizes upon the site wide elevated temperatures. The injection of microbes and substrate in the treatment area and ahead of the declining heat front will support continued and extended contaminant reduction in situ at a limited additional cost.

Estimation of the Expectations of Contaminant Mass Removal Goal

To further support the development of the conceptual strategy for implementation of thermal remediation, APTIM reviewed thermal treatment options with TerraTherm, a recognized leader and specialist in thermal remediation.

TerraTherm prepared a Budgetary Proposal for the purposes of evaluating the viability of thermal treatment at the General Chemical site with the goal of maximizing contaminant removal from the source area(s) given the limited available funding. Additional costs common to remedy implementation (e.g., planning, permitting, oversight, confirmatory monitoring and sampling, restoration) would be incurred and are not included in TerraTherm's Budgetary Proposal. The budgetary proposal focuses on two source areas: the Former

Loading Rack Area of AOC#1 (Treatment Area 1) and a portion of the Area Southeast of the Former Production Area of AOC#2 (Treatment Area 2), as shown on **Figure 4**.

Note that high contaminant groundwater concentrations indicate likely potential for DNAPL presence in areas outside the identified thermal treatment areas (e.g., MW-100M, MW-22, MW-110S in Area South of Warehouse, remainder of Area Southeast of Former Production Area and Former AST/Containment Area). While we understand that there is a limited budget for this project, the expansion of the thermal treatment program to remediate these additional high concentration areas would increase short-term mass removal, and greatly decrease the site-wide remediation time frame. Additionally, leaving these areas untreated could have long-term negative impacts (i.e., recontamination) on the areas where thermal treatment is currently planned, as well as provide continuing contaminant sources for downgradient portions of the plume

TerraTherm modeled mass removal, including estimated surface area, treated volume and respective costs using Thermal Conduction Heating (TCH) for three treatment scenarios:

Treatment Scenario 1: Loading Rack Area (Treatment Area 1)
Treatment Scenario 2: Portion of Area Southeast of Former Production Area (Treatment Area 2)
Treatment Scenario 3: Treatment Area 1 and Treatment Area 2 combined

Results are detailed in the attached **TerraTherm Budgetary Proposal for In-Situ Thermal Remediation** and are summarized in the table below:

Treatment Scenario	**Treatment Areas (ft^2)**		**Target Depth (ft bgs)**	**Target Volume (cy)**	**Estimated Mass (lbs)**	**Estimated Treatment Cost ($)**	**Cost per Pound Removed ($/lbs)**	**Pounds Removed per $1000 (lbs/$1000)**
1	**Area 1**	**1,500**	**0-10**	**556**	**334**	**1,138,000**	**3,407**	**0.29**
2	**Area 2**	**2,500**	**0-30**	**2,778**	**1,401**	**1,394,100**	**995**	**1.00**
3	**Area 1**	**4,000**	**0-10**	**3,333**	**1,735**	**1,516,700**	**874**	**1.14**
	Area 2		**0-30**					

TerraTherm estimated that 99% of the estimated CVOC mass and 30% to 50% of the 1,4-dioxane mass present within each given treatment area will be removed from the subsurface. Note, however, that the presence of 1,4-dioxane is not a significant contributor to the overall mass and does not change the mass estimate. As such, the TerraTherm proposal does not include specific above ground treatment equipment to address 1,4-dioxane removal. Also, a more reasonable CVOC estimate is probably greater than 95%, as measured by concentration reductions in soil and groundwater. Note it is unlikely that the vapor treatment (i.e., Summa canisters) and condensate sampling will confirm this mass removal. We have found in several applications that the measured physical mass removal by vapor extraction to be up to an order of magnitude less than that supported by soil and groundwater concentration changes post treatment.

Based upon a 95% CVOC removal efficiency, and the assumed mass numbers per treatment area that TerraTherm estimated, which are reasonable estimates, the pounds of contaminant removed per $1,000 of cost are:

Treatment Scenario 1: **0.28 lbs/$1000**
Treatment Scenario 2: **0.95 lbs/$1000**
Treatment Scenario 3: **1.1 lbs/$1000**

Note that this media is considered as treated and not as cleaned-up as there will be residual contaminants in both soil and water. As noted above, biopolishing is recommended for post treatment of the thermal treatment zone and for treatment of lower concentration areas outside the thermal treatment zone.

Implementation of In-Situ Bioremediation

Upon completion of the thermal remediation strategy, APTIM recommends treating the remaining impacted groundwater in the source areas, including the Former Loading Rack Area, the Area Southeast of the Former Production Area, and the Former AST Containment Area via an *in situ* bioremediation approach that includes bioaugmentation with a mixed anaerobic microbial consortium. The portions of the aquifer in these source areas considered to be within AOC#2 (top 15 feet of saturated zone within the sand unit) would be the targeted treatment zone.

APTIM has developed a microbial consortium (SDC-9®) containing a high density of DHC capable of performing complete and rapid dechlorination of PCE and TCE to ethene without accumulation of the intermediates DCE or VC. This culture, which is grown at commercial scale along with several others in our Lawrenceville, NJ facility, has been widely applied in the US over the past decade. In addition, SDC-9 is capable of degrading other contaminants of concern found at the GCC site, including 1,1-DCE, carbon tetrachloride (CT), and Freon 113. The degradation of CT by SDC-9, however, produces an accumulation of dichloromethane (DCM). Therefore, to degrade CT/DCM, APTIM has developed another bacterial culture (MDB-1) which can be added to the SDC-9 consortium for injection at the GCC site. Finally, 1,1,1-TCA and 1,1-DCA are also present at elevated concentrations at the GCC site, and are not substantially degraded by either SDC-9 or MDB-1. Therefore, a third culture (TCA-20) would be added to the injected consortium at the site for degradation of these compounds. These three cultures would be grown by APTIM and pre-mixed at desired densities onsite prior to injection as a single inoculum.

Implementation of bioaugmentation requires that amendments (fermentable substrate and nutrients) and microorganisms are properly delivered and distributed to the subsurface. The pH of the aquifer must also be within the desired range for successful biologic degradation of the target contaminants. The three cultures listed above require a pH in the range of approximately 6.0 to 8.0 standard units to be effective. Available data show that the pH of the site is within this range, thus pH adjustment should not be required.

Note that the proposed bioaugmentation consortium (which are anaerobes) will not degrade 1,4-dioxane. 1,4-dioxane has not been shown to degrade under anaerobic conditions. An in situ bioremediation approach that has been shown to be effective in treating 1,4-dioxane, should it be required, is aerobic cometabolic biosparging. APTIM successfully implemented this approach at Vandenberg AFB. It generally involves sparging air (or oxygen) and an alkane gas (propane, ethane, isobutane) to grow organisms that also degrade 1,4-dioxane. This approach could be accomplished via biosparging, or recirculating groundwater amended with the gases. The addition of nutrients may be necessary as well. These approaches can be difficult in heterogeneous aquifers, and would require pre-treatment (e.g., thermal treatment or anaerobic bioaugmentation) to reduce the high concentrations of PCE and degradation intermediates at the site that are toxic to the aerobic microbes. Also, as this is an aerobic approach, it would therefore need to be performed after the completion of the anaerobic treatment. Several CVOCs can also be degraded via this approach, should there be residual CVOC contamination.

A description of anaerobic bioremediation technologies, conceptual implementation strategy, and budgetary cost estimates are provided in the attached document, **In-Situ Bioremediation for the General Chemical Site**.

Conclusion

It is APTIM's opinion that In-situ Thermal Treatment is the optimal technology to achieve the goal of removing as much contaminant mass as possible given a limited budget of $1.8 Million. This includes the thermal treatment of Area's 1 and 2 in TerraTherm's Budgetary Proposal. The thermal treatment of Areas 1 and 2 will likely consume over 85% ($1,5M) of the $1.8M available for this project. The remaining budget will need to be utilized for a remedy implementation plan (that includes the remedial system design), permitting, system implementation oversight, replacement of site monitoring wells, site monitoring, system performance tracking and project reporting by APTIM. However, there are additional high concentration source areas not addressed in TerraTherm's Budgetary Proposal given the limited budget available for remediation. Leaving these areas untreated could have long-term negative impacts (i.e., recontamination) on some of the areas where thermal treatment is currently planned, as well as provide continuing contaminant sources for downgradient portions of the plume. Should additional funding become available to MassDEP for this site in the near future, it is strongly recommended that expansion of the thermal treatment program and/or implementation of a post thermal treatment bioremediation program be implemented. Coupling thermal treatment with a post thermal treatment biopolishing step will support continued and extended contaminant reduction in situ at a limited additional cost.

If you have any questions regarding this proposal, please feel free to contact me directly at 617-589-4008 or Brian Cote at (617) 589-6175 or via e-mail at james.collins@aptim.com or brian.cote@aptim.com.

Respectfully submitted,
Aptim Environmental & Infrastructure, Inc.

Eric Vining
Project Engineer

David Cacciatore, P.E., PhD
Project Engineer

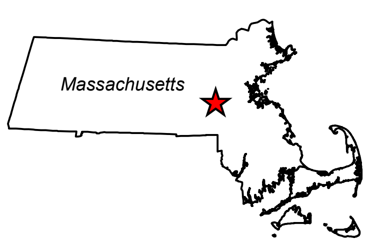
James J. Collins, LSP, LEP
SARSS Program Manager

Brian Cote, P.G., LSP
Senior Project Manager

Attachments:
- Figure 1 – Site Location Map
- Figure 2 – AOC#1 – Shallow Soil
- Figure 3 – AOC#2 – Shallow Groundwater
- Figure 4 – Conceptual Treatment Areas #1 and #2
- Table 1 – Detailed Evaluation of Remedial Alternatives – AOC#1
- Table 2 – Detailed Technology Evaluation Matrix – AOC#1
- Table 3 – Detailed Evaluation of Remedial Alternatives – AOC#2
- Table 4 – Detailed Technology Evaluation Matrix – AOC#2
- Attachment A – TerraTherm Budgetary Proposal for In-Situ Thermal Remediation
- Attachment B – In-Situ Bioremediation for the General Chemical Site

cc: John Miano – MassDEP NERO

FIGURES



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0 1,000 2,000 4,000
Feet

REFERENCE:
Topographic source provided by ESRI ArcGIS Online and data partners including USGS and © 2007 National Geographic Society

GENERAL CHEMICAL CORPORATION
133-135 LELAND STREET
FRAMINGHAM, MASSACHUSETTS

SEMI-ANNUAL SAMPLING REPORT
JULY 2017

FIGURE NUMBER	
1	**SITE LOCATION MAP**

APTIM

150 Royall Street
Canton, Massachusetts 02021
www.APTIM.com

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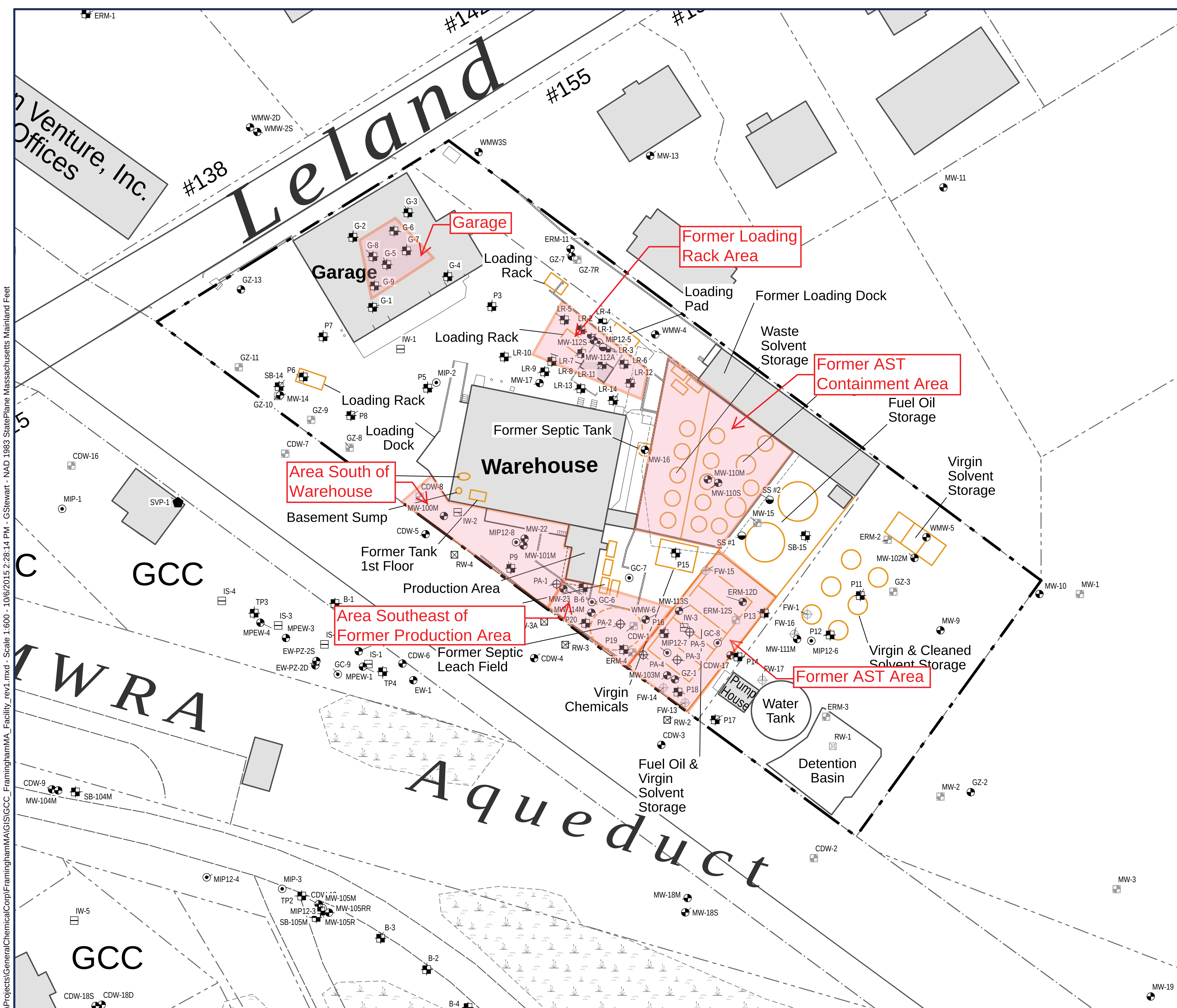


Legend

- Monitoring Well
- Monitoring Well, Destroyed
- Piezometer
- Piezometer, Destroyed
- Injection Well
- Recovery Well
- Recovery Well, Destroyed
- MIP Boring
- Soil Boring
- Surface Soil
- Aqueduct
- Surface Water
- Soil Vapor
- Water Well
- Sediment Sample
- GCC Facility Property
- Former Storage and Handling Areas (Approximate)
- Rail Road Tracks
- Roads
- Access Road
- Drainage Brook (Approximate)
- Buildings
- Fence
- Parcel Boundary
- Parcel Division
- Right of Way
- Wetlands (Surveyed)
- AOC#1 is comprised of shaded areas shown

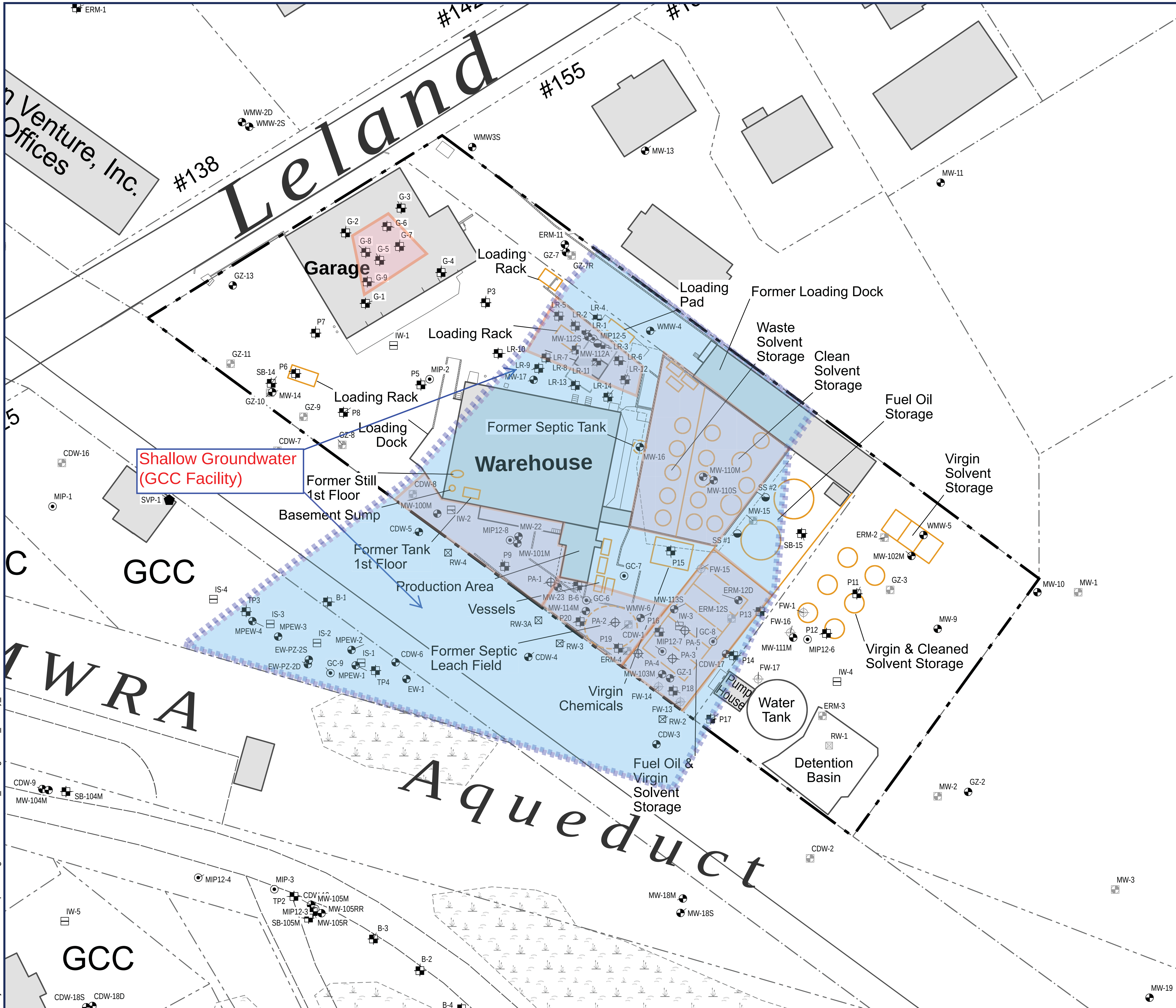
GES

DRAFT

Note:
Historical solvent storage and handling features obtained from multiple sources. There are no chemical storage tanks remaining on the GCC facility property following the 2012 RCRA closure activities.

DRAFTED BY: GKS	AOC#1: SHALLOW SOIL - GCC FACILITY
CHECKED BY: DMC	GENERAL CHEMICAL CORPORATION 133-135 LELAND STREET FRAMINGHAM, MASSACHUSETTS
REVIEWED BY: SS	
NORTH	Groundwater & Environmental Services, Inc. 364 LITTLETON ROAD, SUITE 4, WESTFORD, MA 01886

SCALE IN FEET	DATE	FIGURE
0 50	1-29-16	2



Legend

- Monitoring Well
- Monitoring Well, Destroyed
- Piezometer
- Piezometer, Destroyed
- Injection Well
- Recovery Well
- Recovery Well, Destroyed
- MIP Boring
- Soil Boring
- Surface Soil
- Aqueduct
- Surface Water
- Soil Vapor
- Water Well
- Sediment Sample
- GCC Facility Property
- Former Storage and Handling Areas (Approximate)
- Rail Road Tracks
- Roads
- Access Road
- Drainage Brook (Approximate)
- Buildings
- Fence
- Parcel Boundary
- Parcel Division
- Right of Way
- Wetlands (Surveyed)
- Limit of Wetlands Survey Delineation
- AOC#2 is comprised of shaded area shown

GES

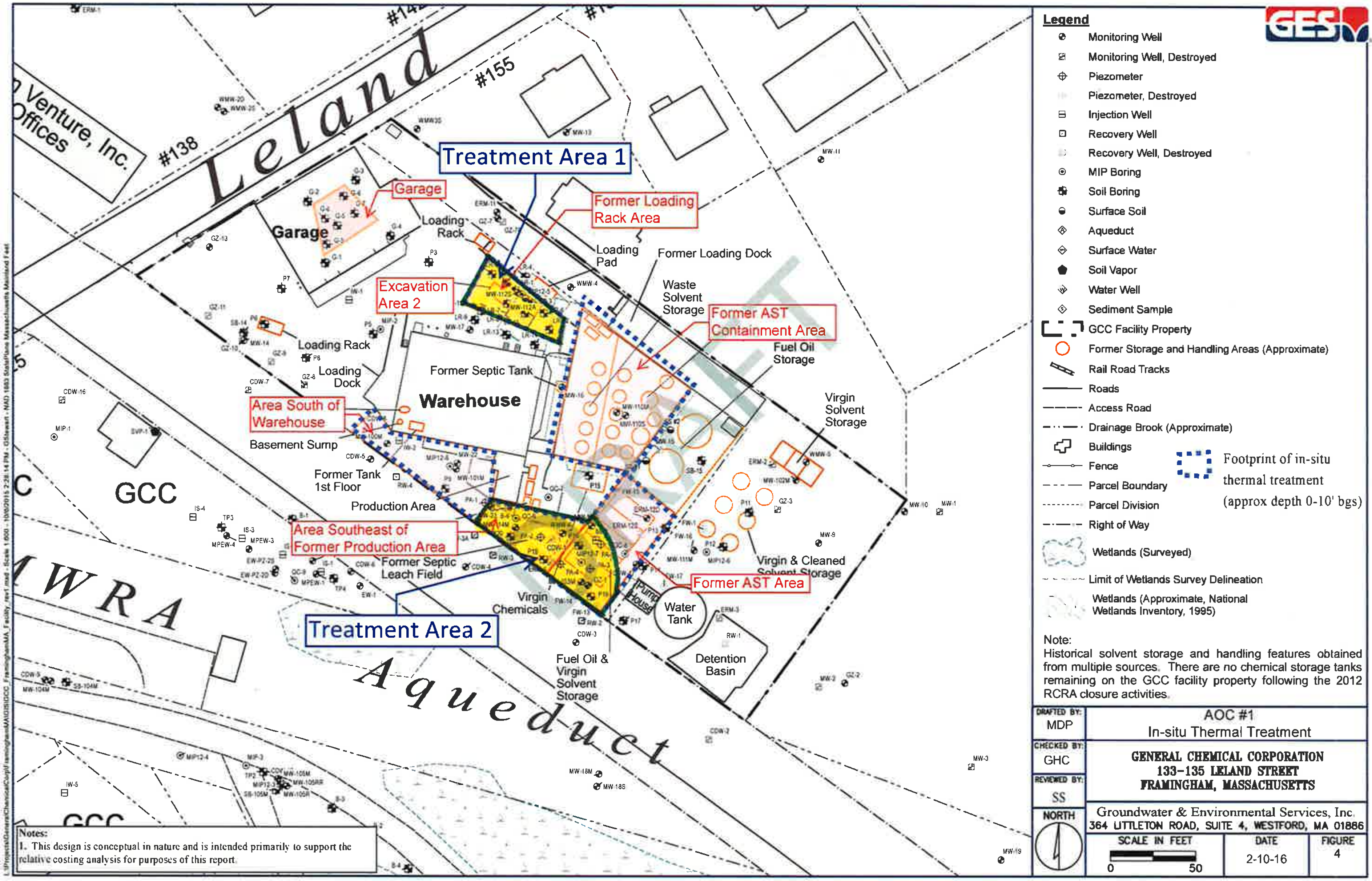
DRAFT

Note:
Historical solvent storage and handling features obtained from multiple sources. There are no chemical storage tanks remaining on the GCC facility property following the 2012 RCRA closure activities.

DRAFTED BY: GKS	AOC#2: SHALLOW GROUNDWATER – GCC FACILITY
CHECKED BY: DMC	GENERAL CHEMICAL CORPORATION 133-135 LELAND STREET FRAMINGHAM, MASSACHUSETTS
REVIEWED BY: SS	
NORTH	Groundwater & Environmental Services, Inc. 364 LITTLETON ROAD, SUITE 4, WESTFORD, MA 01886

SCALE IN FEET	DATE	FIGURE
0 – 50	1-29-16	3

L:\Projects\GeneralChemicalCorp\FraminghamMA\GIS\GCC_FraminghamMA_Facility_rev1.mxd - GStewart - NAD 1983 StatePlane Massachusetts Mainland Feet - Scale 1:600 - 10/6/2015 2:28:14 PM



Legend
Monitoring Well
Monitoring Well, Destroyed
Piezometer
Piezometer, Destroyed
Injection Well
Recovery Well
Recovery Well, Destroyed
MIP Boring
Soil Boring
Surface Soil
Aqueduct
Surface Water
Soil Vapor
Water Well
Sediment Sample
GCC Facility Property
Former Storage and Handling Areas (Approximate)
Rail Road Tracks
Roads
Access Road
Drainage Brook (Approximate)
Buildings
Fence
Parcel Boundary
Parcel Division
Right of Way
Wetlands (Surveyed)
Limit of Wetlands Survey Delineation
Wetlands (Approximate, National Wetlands Inventory, 1995)
Footprint of in-situ thermal treatment (approx depth 0-10' bgs)
Note:
Historical solvent storage and handling features obtained from multiple sources. There are no chemical storage tanks remaining on the GCC facility property following the 2012 RCRA closure activities.
Leland
Aqueduct
MWRA
GCC
#138
#155
Venture, Inc. Offices
Treatment Area 1
Treatment Area 2
Garage
Former Loading Rack Area
Excavation Area 2
Former AST Containment Area
Area South of Warehouse
Area Southeast of Former Production Area
Former AST Area
Loading Rack
Loading Pad
Former Loading Dock
Waste Solvent Storage
Fuel Oil Storage
Loading Dock
Former Septic Tank
Warehouse
Basement Sump
Former Tank 1st Floor
Production Area
Former Septic Leach Field
Virgin Chemicals
Virgin Solvent Storage
Virgin & Cleaned Solvent Storage
Pump House
Water Tank
Detention Basin
Fuel Oil & Virgin Solvent Storage
Notes:
1. This design is conceptual in nature and is intended primarily to support the relative costing analysis for purposes of this report.
DRAFTED BY: MDP
CHECKED BY: GHC
REVIEWED BY: SS
AOC #1
In-situ Thermal Treatment
GENERAL CHEMICAL CORPORATION
133-135 LELAND STREET
FRAMINGHAM, MASSACHUSETTS
Groundwater & Environmental Services, Inc.
364 LITTLETON ROAD, SUITE 4, WESTFORD, MA 01886
NORTH
SCALE IN FEET
0
50
DATE
2-10-16
FIGURE
4

TABLES

Table 1
DETAILED EVALUATION OF REMEDIAL ALTERNATIVES
AOC#1 (Shallow Soil 0-10' bgs)

General Chemical Corporation Site
Framingham, MA

Evaluation Criteria	Alternative 1 Soil Vapor Extraction and Air Sparging	Alternative 2 In-Situ Thermal Treatment	Alternative 3 Excavation with Off-Site Disposal
1. Effectiveness			
a) Ability to Achieve a Permanent or Temporary Solution	• This alternative may achieve a Temporary Solution.	• This alternative may achieve a Temporary Solution.	• This alternative may achieve a Temporary Solution.
b) Ability to Reuse, Recycle, Destroy, Detoxify, or Treat	• SVE/AS processes destroy OHM by catalytic oxidizer and/or off-site during carbon regeneration.	• Captured dissolved and vapor contamination destroyed off-site during carbon regeneration.	• Excavated soil disposed off-site as hazardous waste.
c) Ability to Achieve or Approach Background Conditions	• This alternative is not anticipated to achieve or approach background in the near term.	• This alternative is not anticipated to achieve or approach background in the near term.	• This alternative is not anticipated to achieve or approach background in the near term.
Effectiveness Rating	**3**	**5**	**4**
2. Reliability (Short-Term & Long-Term)			
a) Certainty of Success	• This alternative has a lower chance of success in reducing soil concentrations in the near term.	• This alternative has a high certainty of success in reducing soil concentrations in the near term.	• This alternative has a high certainty of success in reducing soil concentrations for accessible soils.
b) Measures to Manage Residues	• No residues requiring special treatment are anticipated with SVE/AS.	• No residues requiring special management are anticipated with thermal treatment.	• Minimal residues left to manage; pockets of inaccessible soils may remain.
c) Measures to Control Emissions or Discharges	• Emissions or discharges controlled by extraction and catalytic oxidizer and/or vapor phase carbon.	• Emissions or discharges controlled by extraction and liquid and vapor phase carbon.	• No discharges are anticipated. Disturbed soil will generate vapor emissions.
Reliability Rating	**2**	**3**	**2**

Table 1 (continued)
DETAILED EVALUATION OF REMEDIAL ALTERNATIVES
AOC#1 (Shallow Soil 0-10' bgs)

General Chemical Corporation Site
Framingham, MA

Evaluation Criteria	Alternative 1 Soil Vapor Extraction and Air Sparging	Alternative 2 In-Situ Thermal Treatment	Alternative 3 Excavation with Off-Site Disposal
3. Difficulty			
a) Technical Complexity	• Moderate system complexity.	• Higher system complexity.	• Excavation has moderate complexity due to subsurface obstacles.
b) Integration with Facility Operations	• Inactive facility.	• Inactive facility.	• Inactive facility.
c) Operation, Maintenance and Monitoring (OM&M) or Site Access Requirements/Limitations	• Site access for OM&M and groundwater monitoring will be required for longer period of time.	• Site access for OM&M and groundwater monitoring will be required for period of time.	• No OM&M anticipated other than periodic well gauging.
d) Availability of Services, Materials, Equipment or Specialists.	• The services, materials, equipment, and specialists needed are readily available.	• The services, materials, equipment, and specialists needed are readily available.	• The services, materials, equipment, and specialists needed are readily available.
e) Availability, Capacity and Location of Off-Site Treatment, Storage, and Disposal Facilities	• Facilities are readily available for handling spent activated carbon.	• Facilities are readily available for handling spent activated carbon.	• Facilities are readily available for handling contaminated soil.
f) Permits	• No special permits are anticipated to be required.	• No special permits are anticipated to be required.	• No permits are anticipated to be required.
Difficulty Rating	**2**	**1**	**2**
4. Cost			
a) Estimated Cost of Implementation	• Lowest initial investment. • Moderate annual O&M. • Lowest total present worth.	• High initial investment. • Moderate short-term O&M. • Highest total present worth.	• High initial investment. • Low annual O&M. • High total present worth due to due to T&D of hazardous materials.
b) Cost of Environmental Restoration and Potential Damages to Natural Resources	• No further environmental restoration is anticipated to be necessary.	• No further environmental restoration is anticipated to be necessary.	• No further environmental restoration is anticipated to be necessary.
c) Cost of Energy Consumption	• This alternative requires moderate energy consumption for O&M.	• This alternative requires the highest energy consumption during short-term implementation.	• This alternative does not require energy costs associated with system operation.
Cost Rating	**3**	**1**	**2**
5. Risk			
a) Relative Risk During Implementation	• Moderate risk associated with installation activities.	• Moderate risk associated with installation activities.	• Higher risk associated with excavation near above- and below-grade structures/obstacles and fugitive vapor emissions.
b) Relative Risk During Operations	• Lower system complexity. Risk of vapor migration can be effectively controlled through system design and O&M. Mounding of groundwater and potential for off-site plume migration is a risk for the air sparging component.	• Higher system complexity. Risk of vapor migration can be effectively controlled through system design and O&M.	• No operational risks anticipated after excavation as no on-going O&M.
c) Relative Risk Associated with Remaining Oil and Hazardous Materials	• Minor risk associated with remaining OHM.	• Minimal residual impacts anticipated after treatment.	• Minor risk associated with remaining OHM.
Risk Rating	**2**	**2**	**1**
6. Timeliness			
a) Time to Achieve Remedial Objective	• Longer time to achieve remedial objective (>2 years)	• Short time to achieve remedial objective (<1 year)	• Shortest time to achieve remedial objective (<1 year)
Timeliness Rating	**1**	**2**	**3**

Table 1 (continued)
DETAILED EVALUATION OF REMEDIAL ALTERNATIVES
AOC#1 (Shallow Soil 0-10' bgs)

General Chemical Corporation Site
Framingham, MA

Evaluation Criteria	Alternative 1 Soil Vapor Extraction and Air Sparging	Alternative 2 In-Situ Thermal Treatment	Alternative 3 Excavation with Off-Site Disposal
7. Green Benefits			
a) Minimizes energy use or uses renewable energy and resources	• Moderate longer-term energy use (electricity) during course of system operation.	• Higher short-term energy use (electricity) during system operation.	• Moderate energy use (fuel consumption during implementation).
b) Minimizes air pollution or greenhouse gas emissions	• Minimal air pollution from fuel consumption during well installation.	• Minimal air pollution from fuel consumption during well installation.	• Moderate air pollution from fuel consumption during implementation.
c) Reduce, reuse and recycle waste	• Waste generated during well installation. Spent carbon can be regenerated.	• Waste generated during well installation. Spent carbon can be regenerated.	• Excavated soil disposed off-site as hazardous waste.
d) Protects land and ecosystem	• Most protective due to lack of land disturbance.	• Potential for impact to some biota in treatment area due to elevated temperatures.	• Significant disturbance to native soils.
e) Minimizes adverse visual and aesthetic impacts on receptors outside of the property	• Proposed alternative is not anticipated to adversely affect aesthetics of the site.	• Proposed alternative is not anticipated to adversely affect aesthetics of the site.	• Proposed alternative is not anticipated to adversely affect aesthetics of the site.
Green Benefits Rating	**4**	**3**	**1**

Table 1 (continued)
DETAILED EVALUATION OF REMEDIAL ALTERNATIVES
AOC#1 (Shallow Soil 0-10' bgs)

General Chemical Corporation Site
Framingham, MA

Evaluation Criteria	Alternative 1 Soil Vapor Extraction and Air Sparging	Alternative 2 In-Situ Thermal Treatment	Alternative 3 Excavation with Off-Site Disposal

Notes:

E Effectiveness
1 = Not widely used and probably not effective
2 = Widely used but probably not effective, or not widely used and may not be effective
3 = Widely used but may not be effective, or not widely used but probably effective
4 = Widely used and probably effective, or not widely used but proven and effective
5 = Widely used, proven, and effective

R1 Reliability (short and long term)
1 = Low reliability and/or high maintenance
2 = Average reliability and/or average maintenance
3 = High reliability and/or low maintenance

D Difficulty (comparative technical complexity, permitting, and disruptions to current operations)
1 = Most difficult to implement
2 = Moderate difficulty to implement
3 = Easiest to implement

C Cost
1 = Highest relative cost compared to other alternatives
5 = Lowest relative cost compared to other alternatives

R2 Risk (relative risk associated with implementation)
1 = Highest risks associated with implementation
2 = Moderate risk associated with implementation
3 = Lowest risk associated with implementation

T Time (comparative timeliness to eliminate uncontrolled sources and achieve a level of No Significant Risk)
1 = Extended treatment time
2 = Acceptable treatment time
3 = Rapid treatment

G Green Benefits (B)
1 = Low benefits
2 = Low to moderate benefits
3 = Moderate to high benefits
4 = High benefits

Score = E + R1 + D + C + R2 + T + B; Possible scores are 7 to 26

Table 2
DETAILED TECHNOLOGY EVALUATION MATRIX
AOC#1 (Shallow Soil 0-10' bgs)

General Chemical Corporation Site
Framingham, MA

Alternative #	Alternative Description	E	R1	D	C	R2	T	B	Score	Overall Ranking
1	Soil Vapor Extraction and Air Sparging	3	2	2	3	2	1	4	17	1
2	In-Situ Thermal Treatment	5	3	1	1	2	2	3	17	2
3	Excavation with Off-Site Disposal	4	2	2	2	1	3	1	15	3

Notes:
E Effectiveness
1 = Not widely used and probably not effective
2 = Widely used but probably not effective, or not widely used and may not be effective
3 = Widely used but may not be effective, or not widely used but probably effective
4 = Widely used and probably effective, or not widely used but proven and effective
5 = Widely used, proven, and effective

R1 Reliability (short and long term)
1 = Low reliability and/or high maintenance
2 = Average reliability and/or average maintenance
3 = High reliability and/or low maintenance

D Difficulty (comparative technical complexity, permitting, and disruptions to current operations)
1 = Most difficult to implement
2 = Moderate difficulty to implement
3 = Easiest to implement

C Cost
1 = Highest relative cost compared to other alternatives
5 = Lowest relative cost compared to other alternatives

R2 Risk (relative risk associated with implementation)
1 = Highest risks associated with implementation
2 = Moderate risk associated with implementation
3 = Lowest risk associated with implementation

T Time (comparative timeliness to eliminate uncontrolled sources and achieve a level of No Significant Risk)
1 = Extended treatment time
2 = Acceptable treatment time
3 = Rapid treatment

G Green Benefits (B)
1 = Low benefits
2 = Low to moderate benefits
3 = Moderate to high benefits
4 = High benefits

Score = E + R1 + D + C + R2 + T + B; Possible scores are 7 to 26

Table 3
DETAILED EVALUATION OF REMEDIAL ALTERNATIVES
AOC#2 (Shallow Groundwater and Soil 10-20' bgs)
General Chemical Corporation Site
Framingham, MA

Evaluation Criteria	Alternative 1 Soil Vapor Extraction and Air Sparging	Alternative 2 In-Situ Thermal Treatment	Alternative 3 In-Situ Chemical Oxidation
1. Effectiveness			
a) Ability to Achieve a Permanent or Temporary Solution	• This alternative may achieve a Temporary Solution.	• This alternative may achieve a Temporary Solution.	• This alternative may achieve a Temporary Solution.
b) Ability to Reuse, Recycle, Destroy, Detoxify, or Treat	• SVE/AS processes destroy OHM by catalytic oxidizer and/or off-site during carbon regeneration.	• Captured dissolved and vapor contamination destroyed off-site during carbon regeneration.	• Chemical oxidation processes would destroy OHM *in-situ* on contact with oxidant. Captured vapor contamination from SVE component destroyed off-site during carbon regeneration.
c) Ability to Achieve or Approach Background Conditions	• This alternative is not anticipated to achieve or approach background in the near term.	• This alternative is not anticipated to achieve or approach background in the near term.	• This alternative is not anticipated to achieve or approach background in the near term.
Effectiveness Rating	**2**	**5**	**3**
2. Reliability (Short-Term & Long-Term)			
a) Certainty of Success	• This alternative has a lower chance of success in reducing OHM concentrations in the near term due to soil heterogeneities.	• This alternative has a high certainty of success in reducing OHM concentrations in the near term.	• This alternative would have a higher certainty of success where oxidant contact is established. However, a low certainty of success is anticipated for sustained reduction of OHM concentrations in areas of high contaminant mass.
b) Measures to Manage Residues	• No residues requiring special treatment are anticipated with SVE/AS.	• No residues requiring special management are anticipated with thermal treatment.	• No residues requiring special management are anticipated with oxidation.
c) Measures to Control Emissions or Discharges	• Emissions or discharges controlled by extraction and catalytic oxidizer and/or vapor phase carbon.	• Emissions or discharges controlled by extraction and liquid and vapor phase carbon.	• No emissions are anticipated. Injection rate control and monitoring required to protect against oxidant daylighting.
Reliability Rating	**1**	**3**	**1**

Table 3 (continued)
DETAILED EVALUATION OF REMEDIAL ALTERNATIVES
AOC#2 (Shallow Groundwater and Soil 10-20' bgs)

General Chemical Corporation Site
Framingham, MA

Evaluation Criteria	Alternative 1 Soil Vapor Extraction and Air Sparging	Alternative 2 In-Situ Thermal Treatment	Alternative 3 In-Situ Chemical Oxidation
3. Difficulty			
a) Technical Complexity	• Moderate system complexity.	• Higher system complexity.	• This alternative would have a low complexity for oxidation alone. System complexity increases with addition of SVE.
b) Integration with Facility Operations	• Inactive facility.	• Inactive facility.	• Inactive facility.
c) Operation, Maintenance and Monitoring (OM&M) or Site Access Requirements/Limitations	• Site access for OM&M and groundwater monitoring will be required for longer period of time.	• Site access for OM&M and groundwater monitoring will be required for period of time.	• Site access for OM&M and groundwater monitoring will be required for longer period of time.
d) Availability of Services, Materials, Equipment or Specialists.	• The services, materials, equipment, and specialists needed are readily available.	• The services, materials, equipment, and specialists needed are readily available.	• The services, materials, equipment, and specialists needed are readily available.
e) Availability, Capacity and Location of Off-Site Treatment, Storage, and Disposal Facilities	• Facilities are readily available for handling spent activated carbon.	• Facilities are readily available for handling spent activated carbon.	• Facilities are readily available for handling spent activated carbon.
f) Permits	• No special permits are anticipated to be required.	• No special permits are anticipated to be required.	• No permits are anticipated to be required.
Difficulty Rating	**2**	**2**	**3**
4. Cost			
a) Estimated Cost of Implementation	• Lower initial investment and moderate annual O&M. • Moderate total present worth.	• Higher initial investment and short-term O&M. • Highest total present worth.	• Moderate initial investment and lowest annual O&M. • Moderate total present worth.
b) Cost of Environmental Restoration and Potential Damages to Natural Resources	• No further environmental restoration is anticipated to be necessary.	• No further environmental restoration is anticipated to be necessary.	• No further environmental restoration is anticipated to be necessary.
c) Cost of Energy Consumption	• This alternative requires moderate energy consumption for O&M.	• This alternative requires the highest energy consumption during short-term implementation.	• This alternative requires lowest energy consumption for O&M.
Cost Rating	**2**	**1**	**3**
5. Risk			
a) Relative Risk During Implementation	• Moderate risk associated with installation activities.	• Moderate risk associated with installation activities.	• Moderate risk associated with installation activities.
b) Relative Risk During Operations	• Lower system complexity. Risk of vapor migration can be effectively controlled through system design and O&M.	• Higher system complexity. Risk of vapor migration can be effectively controlled through system design and O&M.	• Moderate risk associated with potential for daylighting and handling of oxidants.
c) Relative Risk Associated with Remaining Oil and Hazardous Materials	• Minor risk associated with remaining OHM.	• Minimal residual impacts anticipated after treatment.	• Minor risk associated with remaining OHM.
Risk Rating	**3**	**2**	**3**
6. Timeliness			
a) Time to Achieve Remedial Objective	• Longer time to achieve remedial objective (>2 years)	• Short time to achieve remedial objective (<1 year)	• Longer time to achieve remedial objective (>2 years)
Timeliness Rating	**1**	**3**	**1**

Table 3 (continued)
DETAILED EVALUATION OF REMEDIAL ALTERNATIVES
AOC#2 (Shallow Groundwater and Soil 10-20' bgs)

General Chemical Corporation Site
Framingham, MA

Evaluation Criteria	Alternative 1 Soil Vapor Extraction and Air Sparging	Alternative 2 In-Situ Thermal Treatment	Alternative 3 In-Situ Chemical Oxidation
7. Green Benefits			
a) Minimizes energy use or uses renewable energy and resources	• Moderate energy use (fuel consumption during implementation and electricity during course of system operation).	• Higher short-term energy use (electricity) during system operation.	• Moderate energy use (fuel consumption during implementation).
b) Minimizes air pollution or greenhouse gas emissions	• Minimal air pollution from fuel consumption during well installation.	• Minimal air pollution from fuel consumption during well installation.	• Minimal air pollution from fuel consumption during well installation.
c) Reduce, reuse and recycle waste	• Waste generated during well installation. Spent carbon can be regenerated.	• Waste generated during well installation. Spent carbon can be regenerated.	• Waste generated during well installation. Spent carbon can be regenerated.
d) Protects land and ecosystem	• Most protective due to lack of land disturbance.	• Potential for impact to some biota in treatment area due to elevated temperatures.	• Potential for impact to ecosystem from contact sterilization.
e) Minimizes adverse visual and aesthetic impacts on receptors outside of the property	• Proposed alternative is not anticipated to adversely affect aesthetics of the site.	• Proposed alternative is not anticipated to adversely affect aesthetics of the site.	• Proposed alternative is not anticipated to adversely affect aesthetics of the site.
Green Benefits Rating	**4**	**3**	**2**

Table 3 (continued)
DETAILED EVALUATION OF REMEDIAL ALTERNATIVES
AOC#2 (Shallow Groundwater and Soil 10-20' bgs)

General Chemical Corporation Site
Framingham, MA

Evaluation Criteria	Alternative 1 Soil Vapor Extraction and Air Sparging	Alternative 2 In-Situ Thermal Treatment	Alternative 3 In-Situ Chemical Oxidation

Notes:

E Effectiveness
- 1 = Not widely used and probably not effective
- 2 = Widely used but probably not effective, or not widely used and may not be effective
- 3 = Widely used but may not be effective, or not widely used but probably effective
- 4 = Widely used and probably effective, or not widely used but proven and effective
- 5 = Widely used, proven, and effective

R1 Reliability (short and long term)
- 1 = Low reliability and/or high maintenance
- 2 = Average reliability and/or average maintenance
- 3 = High reliability and/or low maintenance

D Difficulty (comparative technical complexity, permitting, and disruptions to current operations)
- 1 = Most difficult to implement
- 2 = Moderate difficulty to implement
- 3 = Easiest to implement

C Cost
- 1 = Highest relative cost compared to other alternatives
- 5 = Lowest relative cost compared to other alternatives

R2 Risk (relative risk associated with implementation)
- 1 = Highest risks associated with implementation
- 2 = Moderate risk associated with implementation
- 3 = Lowest risk associated with implementation

T Time (comparative timeliness to eliminate uncontrolled sources and achieve a level of No Significant Risk)
- 1 = Extended treatment time
- 2 = Acceptable treatment time
- 3 = Rapid treatment

G Green Benefits (B)
- 1 = Low benefits
- 2 = Low to moderate benefits
- 3 = Moderate to high benefits
- 4 = High benefits

Score = E + R1 + D + C + R2 + T + B; Possible scores are 7 to 26

Table 4
DETAILED TECHNOLOGY EVALUATION MATRIX
AOC#2 (Shallow Groundwater and Soil 10-20' bgs)

General Chemical Corporation Site
Framingham, MA

Alternative #	Alternative Description	E	R1	D	C	R2	T	B	Score	Overall Ranking
1	Soil Vapor Extraction and Air Sparging	2	1	2	2	3	1	4	15	3
2	In-Situ Thermal Treatment	5	3	2	1	2	3	3	19	1
3	In-Situ Chemical Oxidation	3	1	3	3	3	1	2	16	2

Notes:

E Effectiveness
- 1 = Not widely used and probably not effective
- 2 = Widely used but probably not effective, or not widely used and may not be effective
- 3 = Widely used but may not be effective, or not widely used but probably effective
- 4 = Widely used and probably effective, or not widely used but proven and effective
- 5 = Widely used, proven, and effective

R1 Reliability (short and long term)
- 1 = Low reliability and/or high maintenance
- 2 = Average reliability and/or average maintenance
- 3 = High reliability and/or low maintenance

D Difficulty (comparative technical complexity, permitting, and disruptions to current operations)
- 1 = Most difficult to implement
- 2 = Moderate difficulty to implement
- 3 = Easiest to implement

C Cost
- 1 = Highest relative cost compared to other alternatives
- 5 = Lowest relative cost compared to other alternatives

R2 Risk (relative risk associated with implementation)
- 1 = Highest risks associated with implementation
- 2 = Moderate risk associated with implementation
- 3 = Lowest risk associated with implementation

T Time (comparative timeliness to eliminate uncontrolled sources and achieve a level of No Significant Risk)
- 1 = Extended treatment time
- 2 = Acceptable treatment time
- 3 = Rapid treatment

G Green Benefits (B)
- 1 = Low benefits
- 2 = Low to moderate benefits
- 3 = Moderate to high benefits
- 4 = High benefits

Score = E + R1 + D + C + R2 + T + B; Possible scores are 7 to 26

ATTACHMENT A
TERRATHERM BUDGETARY PROPOSAL FOR IN-SITU THERMAL REMEDIATION

TERRATHERM
a Cascade Company
151 Suffolk Lane
Gardner, MA 01440
Phone: (978) 730-1200
Fax: (978) 632-3422
www.terratherm.com

March 12, 2018

Mr. Eric Vining
APTIM
150 Royall Street
Canton, MA 02021

RE: Revision 2 - TerraTherm Budgetary Proposal for In Situ Thermal Remediation
General Chemical Corporation - Framingham, MA

Dear Eric:

Thank you for your interest in TerraTherm and our technologies for In Situ Thermal Remediation (ISTR). We are pleased to enclose our Revision 2 budgetary proposal to implement an ISTR solution via electric Thermal Conduction Heating (TCH) at the General Chemical site.

TerraTherm is offering APTIM and the client a veteran team of management, technical, and field service professionals to ensure the success of this important project. We have successfully executed several projects with similar geology/hydrogeology, target contaminants, and site characteristics, and we are confident in our ability to meet APTIM's and the client's performance objectives for this site.

As a member of the Cascade family of companies, TerraTherm is part of a nationwide network of experts with equipment and technologies to help our clients delineate and remediate complex and technically challenging sites. Incorporating TerraTherm into the project team will provide APTIM with a single point of contracting to access Cascade's 1,100 trained field crews and technical experts along with our suite of drilling, high-resolution site characterization, and in situ remediation technologies.

In summary, TerraTherm is proposing a safe, reliable, proven, and cost-effective thermal remediation solution for the site, and we are confident that our approach will lead to a successful project outcome. We understand that our performance on the project will have a direct impact on your success and as such, we are extremely committed to ensuring the successful completion of your project.

After reviewing our proposal, please feel free to call me with any questions and/or if you need additional information. Our technical experts will be available to collaborate with your project team to jointly develop the best-value solution to achieve the desired endpoint for the project at the lowest possible price.

Thank you for considering TerraTherm for this important project. We look forward to working with the APTIM team.

Sincerely,

John Haas

John Haas
Technical Sales Specialist

TERRATHERM

The Leader in Thermal Remediation

REVISION 2 BUDGETARY PROPOSAL FOR:

APTIM

General Chemical Corporation
Framingham, Massachusetts

March 12, 2018

TERRATHERM OFFERS:

- A variety of thermal treatment options
- Consistency in meeting project clean up goals
- Designs optimized to reach clean up goals

Advise
Design
Build
Operate

Table of Contents

ABBREVIATIONS

CSM:
Conceptual Site Model

TCH:
Thermal Conductive Heating

ISTR:
In Situ Thermal Remediation

ISTD:

In Situ Thermal Desorption

ERH:
Electrical Resistance Heating

MPE:
Multi Phase Extraction

SEE:
Steam Enhanced Extraction

VALUE PROPOSITION

TerraTherm, Inc. (TerraTherm), a division of Cascade Technical Services (Cascade) is pleased to present this Revision 1 budgetary proposal for In Situ Thermal Remediation (ISTR) at the General Chemical Corporation Site (the Site). Our proposed technical approach is based on the data received from APTIM.

TerraTherm's proposed approach offers APTIM and the client the following benefits:

Technical Expertise. Our design and implementation teams include some of the most knowledgeable experts in the thermal remediation industry with experience and success on thermal sites similar to this site. We are unique among thermal contractors by having a perfect performance record on all ISTR sites; every completed site to date has been remediated and all remedial goals have been met upon completion. We proactively plan for potential uncertainties, and are prepared to manage them before they become a problem. Our state-of-the-art data management system ensures that we monitor and adjust to site conditions, optimizing performance in real time.

Why Choose TerraTherm?

- **Only ETL-certified heaters in the industry**
- **Patented electric heaters and heating system**
- **Unique track record of successfully completed thermal projects**
- **Proven, simple, and robust heating approach**
- **Rapid well installation**
- **Ability to optimize systems in response to real-time site conditions**

Technology Selection. TerraTherm is the only thermal contractor who offers all three major forms of in situ heating **in-house under one roof:** Thermal Conduction Heating (TCH); Electrical Resistance Heating (ERH); and Steam Enhanced Extraction (SEE). As such, we are not motivated to direct any project towards a particular thermal technology and can provide APTIM with an unbiased assessment of the best balance of technology effectiveness and cost. We have successfully completed more than 80 in situ thermal remediation projects by choosing the most suitable technology for each individual site. Our technology experts did a thorough evaluation of site conditions and thermal remedy options, and have selected our patented electric TCH technology to remediate this site.

Technical Overview. We have designed a system where heat is added to the subsurface from electrically powered TCH heater borings. Vertical and horizontal extraction wells will be equipped with an extraction screen to ensure a robust extraction of vapors generated in the subsurface. Temperatures will be monitored from various temperature monitoring points. All vapors and liquids will be treated above ground with TerraTherm's Tier-One based treatment system.

Project Schedule. TerraTherm plans to utilize mostly equipment that is currently in stock from our extensive fleet of systems and hardware. Much of our success is due to our ability to be flexible both during initial design and implementation, and to adapt to changing conditions in the field. We have streamlined our design and implementation approaches in order to provide competitive pricing and plan to adhere to a project schedule that meets APTIM's needs. If APTIM or the client wishes to expedite the schedule, TerraTherm's depth of resources and staff will allow us to meet the demands of such an expedited schedule by: mobilizing additional drill rigs to a project site; dedicating additional engineering and/or field staff to a project; performing multiple tasks in parallel with one another; and other schedule enhancing activities.

One of TerraTherm's primary goals is to provide APTIM with a competitive project cost, while still maintaining high quality and safety standards that have contributed to our success and reputation in the industry.

Proximity. The site is located 60 minutes from TerraTherm's headquarters, equipment yard, and shop. At this location, TerraTherm has a 25 person engineering and procurement team with a 65,000 square foot indoor fabrication shop and warehouse facility with maintenance and troubleshooting personnel. This close proximity will allow us to service the needs of APTIM and the client more expeditiously than any other thermal remediation contractor.

Cost Effectiveness. TerraTherm recognizes that the cost of your project is a very important decision factor. Therefore, one of our primary goals is to provide you with a competitive project cost while still maintaining the standards and quality that have built our reputation in the industry. TerraTherm's project teams are known for effective and timely execution of thermal projects, with attention to detail and constant follow-up on activities to maintain schedules and budgets, leading to outstanding client satisfaction.

CONCEPTUAL SITE UNDERSTANDING

TerraTherm's Conceptual Site Model (CSM) is based upon information[1] provided by APTIM on December 23, 2017. Based on this information, the following sections document our understanding of the target treatment zone (TTZ).

Site Background

- Site Name: General Chemical Corporation
- Site Location: Framingham, Massachusetts
- Objective: Obtain a preliminary cost to implement thermal remediation at the site

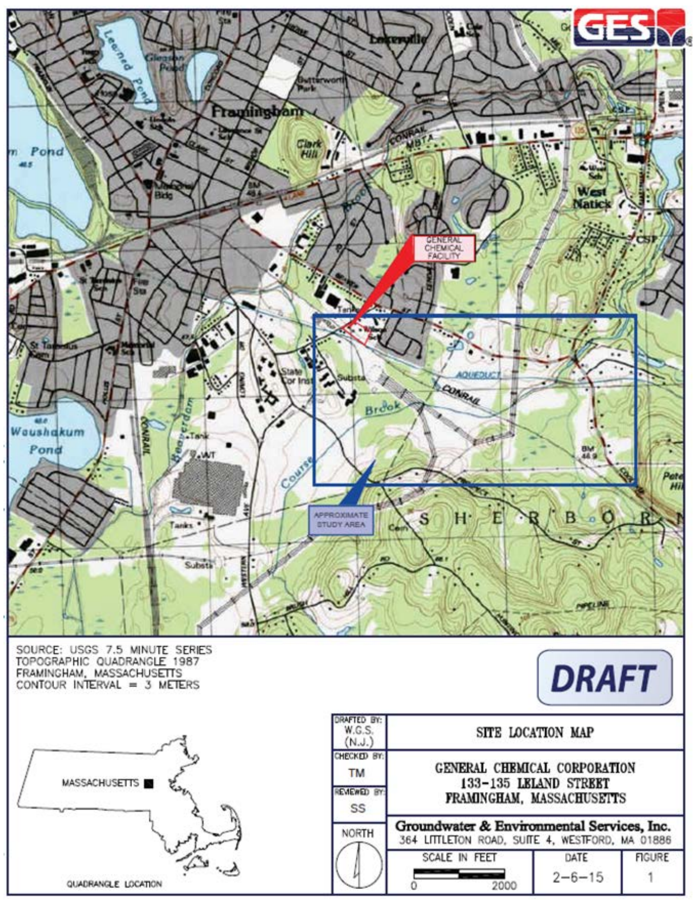


Figure 1. Site Location Map

[1] Request for Preliminary Design and Cost Estimate for ISTR Design and Implementation - General Chemical Corporation. Date: December 23, 2017.

Geology and Hydrogeology

The geology for the site is described as follows,

- 0-25 ft bgs: Fill Material
- 25-45 ft bgs: Silt and fine sand
- 45-70 ft bgs: Till

Per data provided, groundwater surface elevations at monitoring wells MW-112S (Area 1) and MW-23 (Area 2) were approximately 3 and 4.5 ft bgs respectively. Groundwater in surrounding wells was deeper and generally found at 5 ft bgs. A groundwater level of 5 feet bgs was conservatively used for this evaluation.

A hydraulic conductivity value of 3.8 feet/day ($1.34x10^{-3}$ cm/sec) was obtained from the provided Slug Tests and used for this evaluation, while a hydraulic gradient of 0.01 ft/ft was estimated and used for this evaluation[2]. Based on the hydraulic conductivity and gradient assumed for the site, the water velocity is expected to be less than 12 to 15 ft/year.

Figure 2 shows a plan view and cross sections for the site treatment areas. Cross sections are presented in **Figure 7** and **Figure 8** of this budgetary proposal.

[2] Groundwater elevations from wells MW-112S (3.32 ft bgs) and MW-23 (4.54 ft bgs), which are approximately 144 ft from each other. A hydraulic gradient of 0.0085 ft/ft was calculated and used for this evaluation.

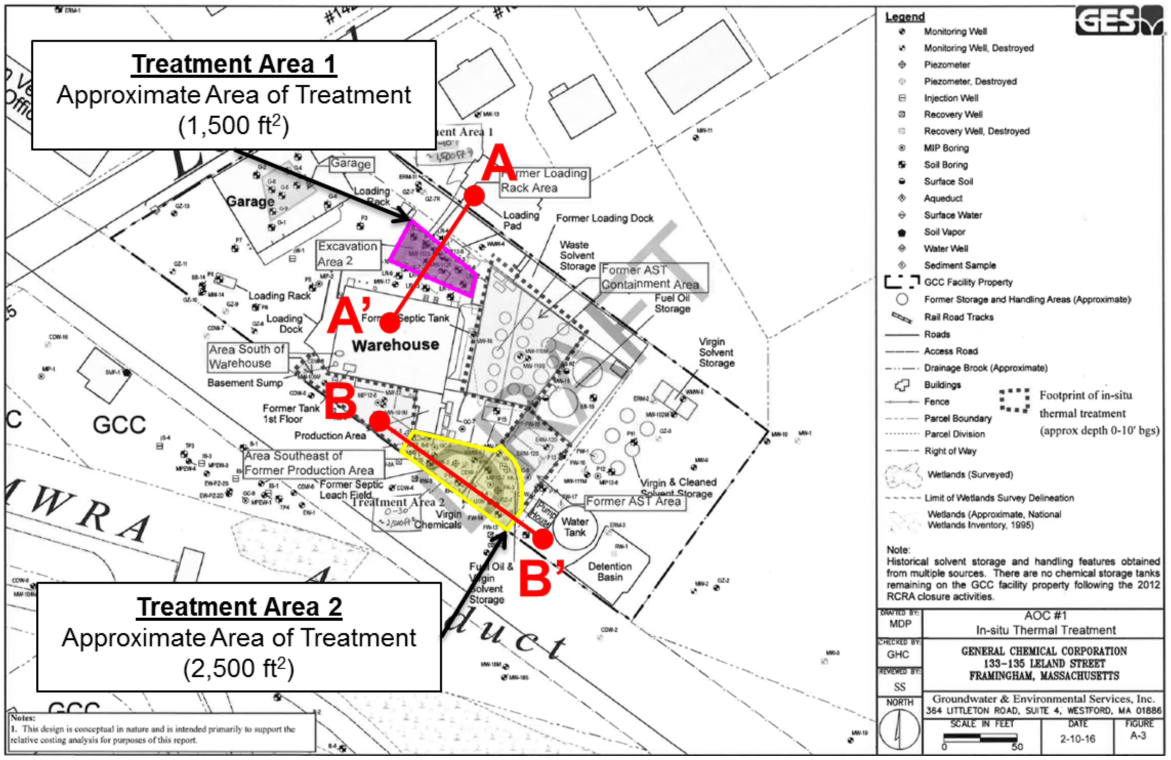


Figure 2. Treatment Areas 1 & 2 (Cross Sections A-A' and B-B')

Conceptual Treatment Scenarios

Scenarios evaluated for this proposal are summarized in **Table 1**. Since we are heating to the surface in both treatment areas, an insulated vapor cap is required to provide a vapor seal which improves the radius of influence of each of the extraction points and thereby the capture of vapors from the vadose zone during treatment.

Table 1. Summary of Conceptual Treatment Scenarios

Treatment Scenario	Treatment Areas (ft^2)		Target Depth (ft bgs)	Target Volume (cy)	
1	Area 1	1,500	0 – 10	556	
2	Area 2	2,500	0 – 30	2,778	
3	Area 1	1,500	0 – 10	556	3,333
	Area 2	2,500	0 – 30	2,778	

Contaminants of Concern, Mass Estimate, and Remediation Goals

Contaminants of Concern for the site consist of 1,1,1-TCA, PCE, TCE, 1,1-DCA, chloroethane, 1,1-DCE, cis-1,2-DCE, VC, 1,4-dioxane, and some petroleum hydrocarbons. Values of 1,4-dioxane were detected in groundwater; however not necessarily in soil in the two areas of concern. For this site, note that the presence of 1,4-dioxane does not change the mass estimate determined as it is not a significant contributor to the overall mass. In addition, please note that this proposal does not include specific above ground treatment equipment to address 1,4-dioxane removal.

Thermal treatment has shown the potential to reduce concentrations of 1,4-dioxane in groundwater. The challenge with thermal treatment of 1,4-dioxane is that it is completely miscible in water and has a very low Henry's Law Constant (HLC), even at elevated temperatures. So it behaves very much like water in the subsurface during a thermal remedy. We are designing for boiling off approximately 30% of the pore water (enough to meet the goals for the remaining COCs at the site), so 1,4-dioxane removal from the subsurface is expected to be minimum 30% and based on field observations possibly greater (up in the 50% to 60% range).

A mass estimate was not provided for the site. Per the data[3] provided by APTIM, average VOC concentrations of 210 mg/kg and 176 mg/kg were calculated for Treatment Scenario 1 and 2 respectively, and used to determine the amount of mass for all treatment scenarios. The calculated mass estimates for the treatment scenarios are as follows:

- Treatment Scenario 1: Approximately 334 lbs
- Treatment Scenario 2: Approximately 1,401 lbs
- Treatment Scenario 3: Approximately 1,735 lbs

The main overall remediation goal is mass removal. Please note that as currently designed, the thermal system is expected to remove greater than 99% of the CVOC mass present and approximately 30% of the 1,4-dioxane mass present within each of the treatment areas described above.

[3] Historical Soil Analytical Database (Prior to 2014) and Summary of Soil Analytical Data for the Former Loading Rack Area (2011-2015).

ISTR SYSTEM DESCRIPTION AND PROPOSED APPROACH

ISTR offers highly predictable remedial results in virtually all soil types. At this site, TCH heaters will be used to heat the subsurface to the boiling point of water (100 degrees Celsius [°C]); by doing this, virtually all volatile organic compounds can be remediated from the soil. In addition to the heaters, the ISTR system will be equipped with a network of SVE and horizontal extraction wells to ensure pneumatic and hydraulic control is maintained throughout the Target Treatment Zone (TTZ). Heaters in the shallow Treatment Area 1 will be equipped with a sand pack, to allow steam and contaminants to migrate up to and be capture by the horizontal wells. In the deeper Treatment Area 2, the combination of vertical extraction wells and horizontal extraction wells will capture both deep and shallow vapors.

Based on the hydraulic conductivity and gradient assumed for the site, the water velocity is expected to be less than 12 to 15 ft/year. The thermal remedy will extract a substantial amount of water as steam, and thereby maintain hydraulic control during the remedy. Therefore, no active water extraction is planned in the two treatment areas. However, the extraction wells in the deeper Area 2 will be prepared for liquid extraction, such that pumps can be installed during operation, should site data indicate that active water extraction would be beneficial during the remedy.

The ISTR system will also be equipped with a simple vapor and liquid organic carbon treatment system for vapor and liquid effluent treatment. The effluent treatment system will be designed to meet any applicable vapor and liquid discharge permit requirements for the Site. **Figure 3** presents a general ISTR system schematic.

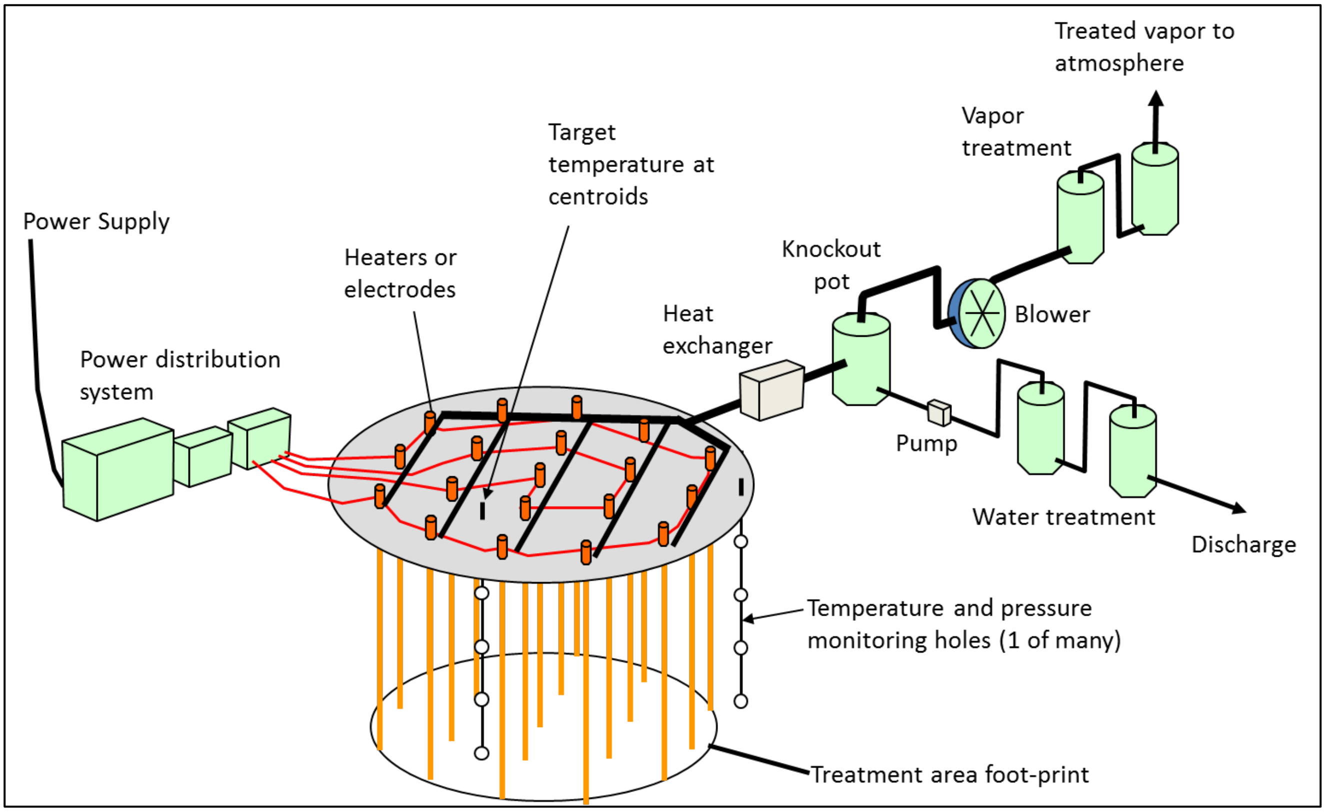


Figure 3. ISTR Remediation Process (not specific to the actual site)

The major ISTR equipment proposed to be used includes:

- Thermal wells and borings: heater wells, SVE wells, horizontal wells and temperature monitoring points (TMPs);
- Manifold and conveyance piping for extracted vapor and liquids;
- Effluent treatment system for extracted fluids (vapor and liquids); and,
- Miscellaneous valves, metering, controls and instrumentation.

The ISTR process is automated, with system operators overseeing the system and collecting data and samples as needed. As the subsurface is heated, fluids are extracted, separated, and treated. The subsurface process is monitored using temperature sensors and sampling and analysis of recovered subsurface fluids.

Figure 4 shows additional detail of the proposed process design for the Site. TerraTherm will use vapor carbon vessels in series to optimize the mass loading and thereby minimize the waste generated and cost associated with vapor carbon change-outs and disposal/regeneration. In addition, to minimize vapor carbon usage, the vapors will be cooled, steam condensed, and the non-condensable air will be dried prior to treatment.

Process liquids will be routed to a gravity separator capable of removing both Light Non-Aqueous Phase Liquid (LNAPL) and Dense Non-Aqueous Phase Liquid (DNAPL), and then treated using liquid-phase carbon. TerraTherm has pre-built skid mounted equipment packages that can be deployed for effluent treatment at the Site. Please note that the system will be prepared for active water extraction as previously stated.

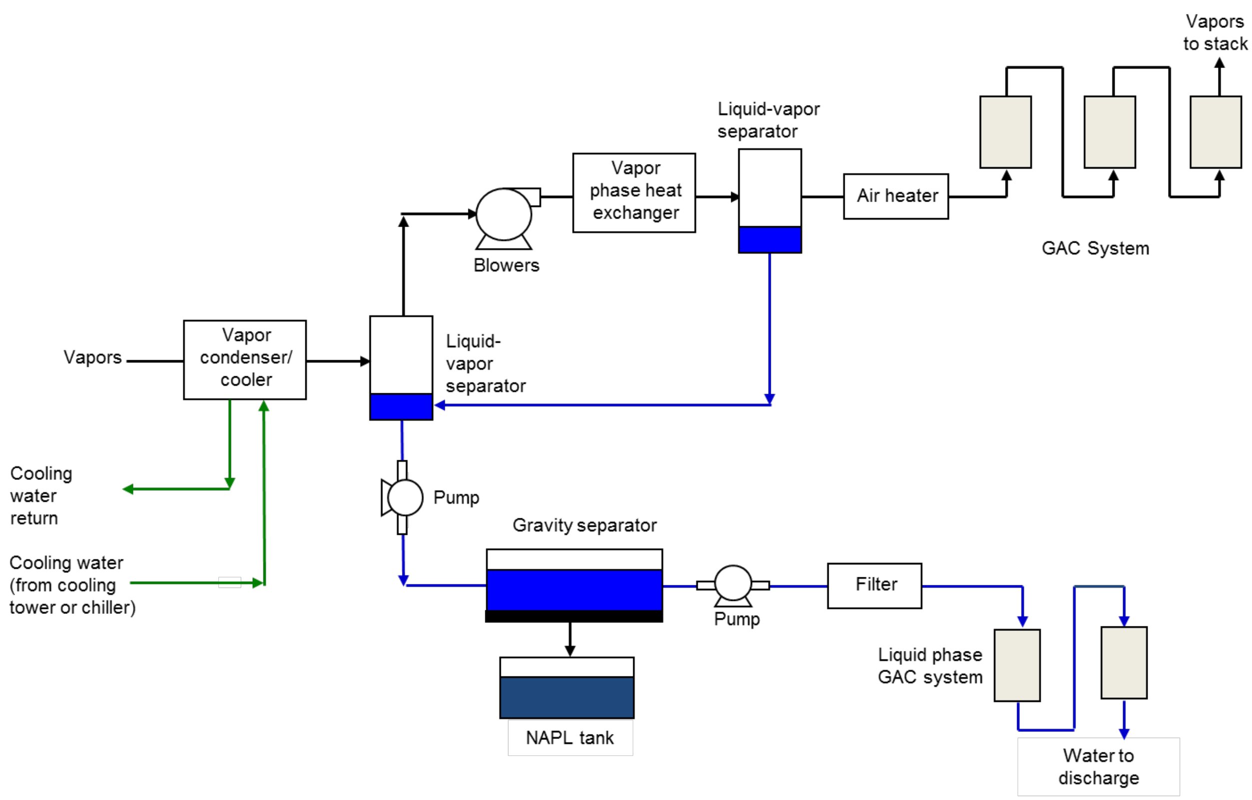


Figure 4. Effluent Treatment System Schematic

We consider the TCH approach, when coupled with an extraction system (also known as In-Situ Thermals Desorption - ISTD), to be the most robust thermal solution for the site.

Tier-One ISTD Implementation

TerraTherm proposes to use our Tier-One ISTD implementation model. TerraTherm Tier-One is a simplified and streamlined approach for routine thermal remediation sites that is well suited for this Site.

Through continuous improvement in our processes, application of extensive value engineering and use of sustainable methodologies, TerraTherm has developed an expedited project delivery approach. Intended for use at smaller or more routine thermal sites, the Tier-One approach is based on simplified design deliverables, standardized heating systems, and modular preengineered vapor/liquid treatment systems. The essential data are collected, and the thermal process is optimized so the time and energy needed for reaching remedial goals is minimized. TerraTherm's Tier-One service offering gives you TerraTherm quality and results at a reduced price, with the benefit of TerraTherm's proven track record, knowledge base, and range of heating technologies. With TerraTherm's Tier-One solution, you get all of the technology, expertise and finely-honed implementation skills that we apply to the most complex projects; and at a highly competitive price.

Conceptual Wellfield Layout and Cross Section

Figure 5 and **Figure 6** show a conceptual wellfield layout using a heater spacing of approximately 14 to 15 ft. Please note that the heaters shown extend 5 ft deeper than the bottom of the TTZ for complete heating and COC reduction in the bottom of the contaminated zone.

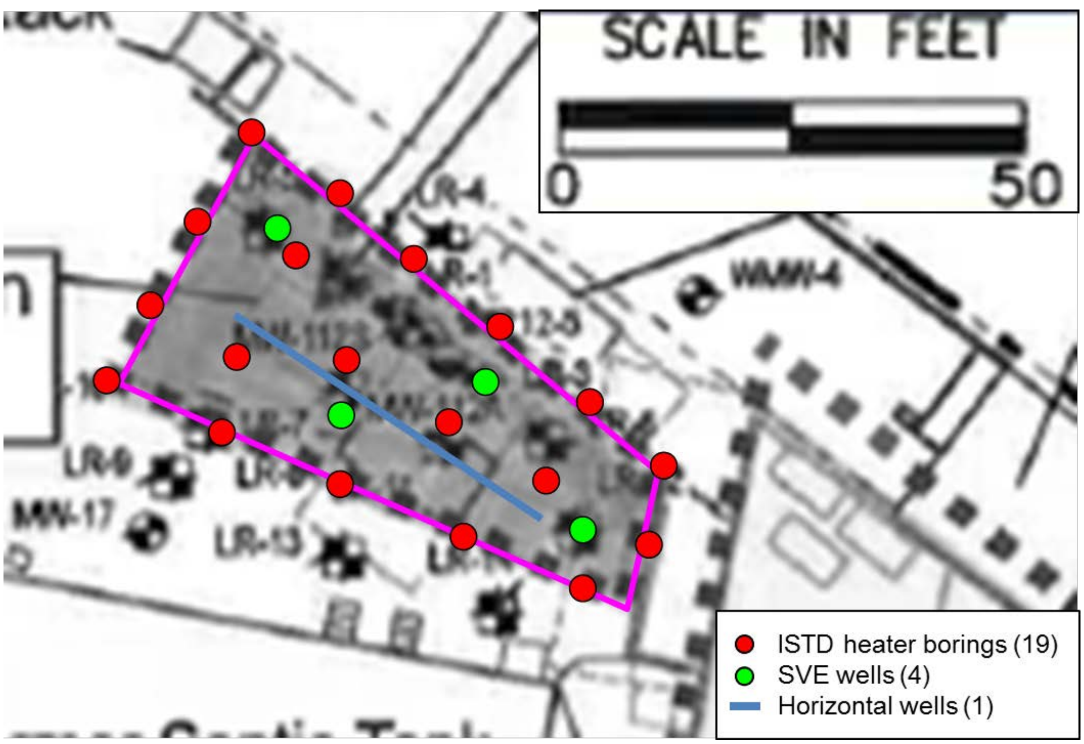


Figure 5. Conceptual Wellfield Layout – Treatment Area 1

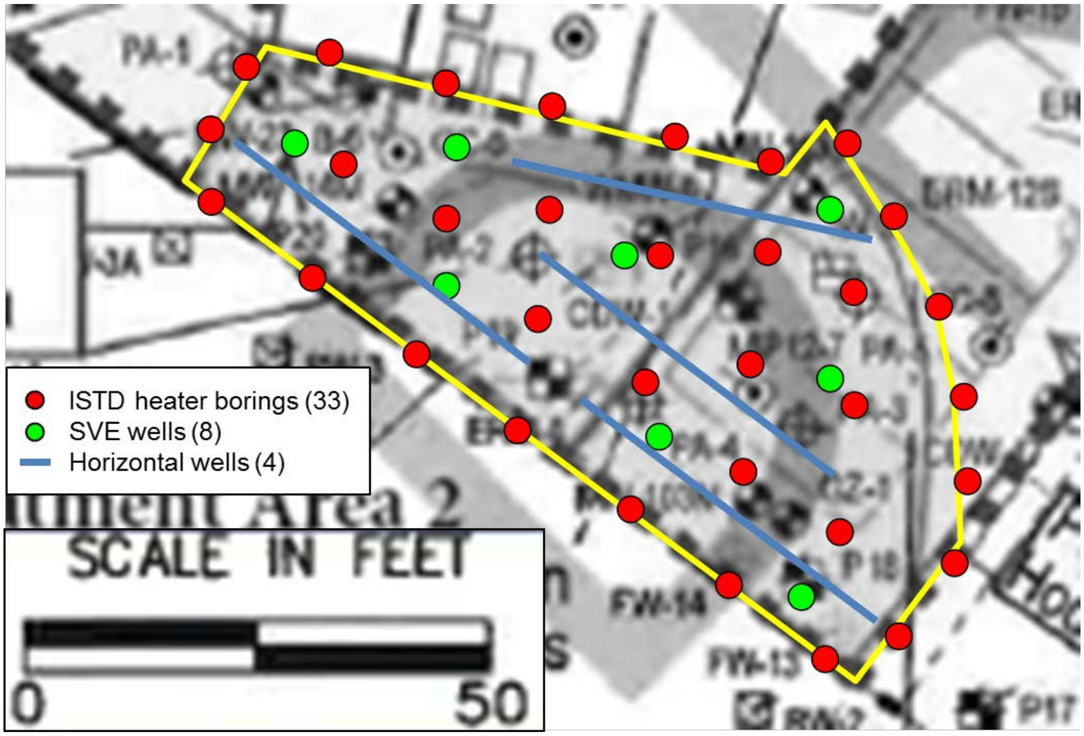


Figure 6. Conceptual Wellfield Layout – Treatment Area 2

Figure 7 and **Figure 8** show conceptual cross sections of the TTZ and the operational wells for the treatment scenarios.

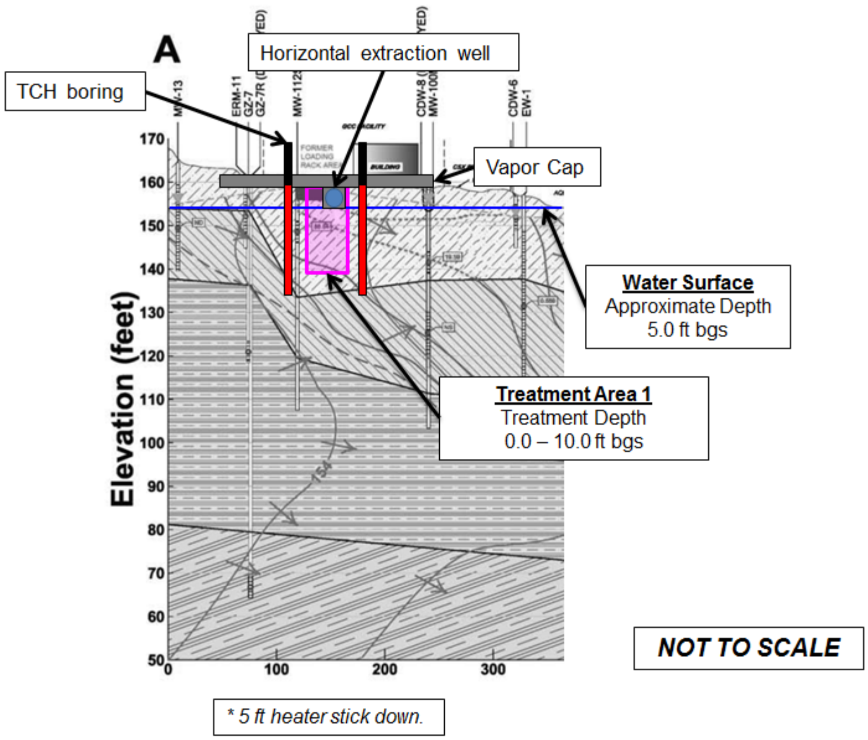


Figure 7. Conceptual Cross Section A – A' – Treatment Area 1

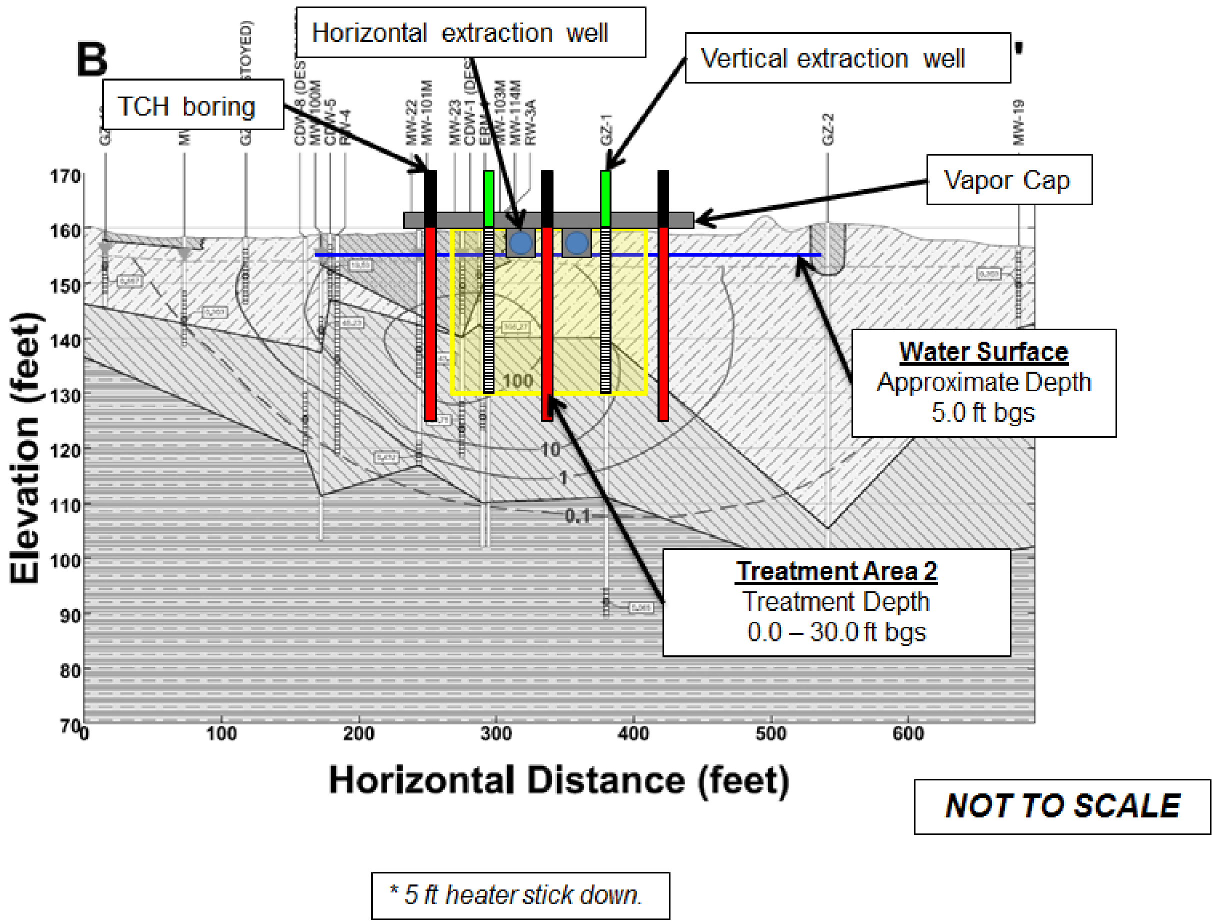


Figure 8. Conceptual Cross Section B – B' – Treatment Area 2

Conceptual Design Parameters, Treatment Outputs, and Utility Requirements

Detailed site specific features will be addressed during the detailed design phase (e.g., buried utilities etc.).

Results and Specifications

The following tables (**Table 2, Table 3, Table 4**, **Table 5**, and **Table 6**) summarize the major modeling results and specifications for the ISTD system for all scenarios evaluated.

Table 2. Volume and Heat Capacity (All Treatment Scenarios)

General Chemical Corporation				**APTIM**
Volume and heat capacity	***T. Scenario 1 (Treatment Area 1)***	***T. Scenario 2 (Treatment Area 2)***	***T. Scenario 3 (Treatment Area 1 & 2)***	***Unit***
Treatment area	1,500	2,500	4,000	ft^2
Upper depth of treatment	0	0	0	ft bgs
Lower depth of treatment	10	30	-	ft bgs
Volume, TTZ	556	2,778	3,333	yd^3
Solids volume	361	1,806	2,167	yd^3
Porosity	0.35	0.35	-	-
Porosity volume	194	972	1,167	yd^3
Initial saturation	85	95	-	percent
Soil weight	1,612,472	8,062,362	9,674,835	lbs soil
Water weight	278,883	1,558,463	1,837,346	lbs water
Soil heat capacity	403,118	2,015,591	2,418,709	BTU/F
Water heat capacity	278,883	1,558,463	1,837,346	BTU/F
Total heat capacity, whole TTZ	682,001	3,574,054	4,256,055	BTU/F

Table 3. Energy Balance and Operating Time (All Treatment Scenarios)

General Chemical Corporation				APTIM
Energy balance	***T. Scenario 1 (Treatment Area 1)***	***T. Scenario 2 (Treatment Area 2)***	***T. Scenario 3 (Treatment Area 1 & 2)***	***Unit***
TCH power input rate	78	318	396	kW
Water extraction rate during heatup	0.3	0.4	0.7	gpm
Average extracted water temperature	190	190	190	F
Percent of injected energy extracted as steam	30	30	30	%
Steam extracted, average	83	335	417	lbs/hr
Energy flux into treatment volume	267,370	1,083,550	1,350,920	BTU/hr
Energy flux in extracted groundwater	19,192	27,049	46,241	BTU/hr
Energy flux in extracted steam	80,211	325,065	405,276	BTU/hr
Net energy flux into treatment volume	167,967	731,436	899,404	BTU/hr
Heating per day	5.9	4.9	-	F/day
Start temperature	50	50	50	F
Target temperature	212	212	212	F
Estimated heat loss, worst case	111	61	-	%
Operating time				
Shake-down	5	5	5	days
Heating to boiling point	58	53	58	days
Boiling and drying	60	61	60	days
Sampling/analysis phase	5	5	5	days
Post treatment vapor extraction	7	7	7	days
Total operating time	135	131	135	days

Table 4. Number of Wells (All Treatment Scenarios)

General Chemical Corporation			APTIM
Numbers of wells	***T. Scenario 1 (Treatment Area 1)***	***T. Scenario 2 (Treatment Area 2)***	***T. Scenario 3 (Treatment Area 1 & 2)***
Heater borings, regular application	19	33	52
Vertical SVE well (prepared for water extraction)	4	8	12
Horizontal SVE wells	1	4	5
Temperature monitoring holes	3	3	6

Table 5. Process Equipment (All Treatment Scenarios)

General Chemical Corporation				APTIM
Process equipment	***T. Scenario 1 (Treatment Area 1)***	***T. Scenario 2 (Treatment Area 2)***	***T. Scenario 3 (Treatment Area 1 & 2)***	***Unit***
ISTD power supply, average	80	320	400	kW
Treatment system power supply, average	50	50	50	kW
Total power need to site	160	460	560	kW
Estimated total electric load	200	600	700	kVA
Vapor extraction rate, total	60	240	300	scfm
Non-condensable vapor	30	120	150	scfm
Estimated steam extraction	30	120	150	scfm
Liquid extraction rate	0.3	0.4	0.7	gpm
Condensed liquid rate	0.2	0.7	0.8	gpm
Water treatment rate	0.4	1.1	1.5	gpm
Vapor treatment type	GAC w/ gas conditioning	GAC w/ gas conditioning	GAC w/ gas conditioning	-
Dominant contaminant of concern	Tetrachloroethene (PCE)	Tetrachloroethene (PCE)	Tetrachloroethene (PCE)	-
Estimated COC mass	334	1,401	1,735	lbs
Estimated COC mass treated by vapor system	328	1,373	1,700	lbs
Estimated COC mass treated by water system	7	28	35	lbs
Estimated max mass removal rate, vapor system	6	24	29	lbs/day

Table 6. Utility Estimates (All Treatment Scenarios)

General Chemical Corporation				APTIM
Utility estimates	***T. Scenario 1 (Treatment Area 1)***	***T. Scenario 2 (Treatment Area 2)***	***T. Scenario 3 (Treatment Area 1 & 2)***	***Unit***
Power usage, in ground	234,000	924,000	1,158,000	kWh
Power usage, treatment system	131,000	151,000	155,000	kWh
Power usage, total	365,000	1,075,000	1,313,000	kWh

Site Specific Considerations

Power Drop

Based on the current design basis, each treatment scenario will require the following:

- Treatment Scenario 1 will require a 200 kVA, 480V, 3 Phase electrical service
- Treatment Scenario 2 will require a 600 kVA, 480V, 3 Phase electrical service
- Treatment Scenario 3 will require a 700 kVA, 480V, 3 Phase electrical service

Site and Building Access

Depending upon any access constraints at the site and inside of the buildings during construction and operations, TerraTherm will accommodate any necessary thermal design changes to continue to ensure that all areas of the TTZ are heated to the target temperature.

Vapor Cover

The vapor cover will serve the following purposes:

- Provide a vapor seal which improves the radius of influence of each of the extraction wells and thereby the capture of vapors from the vadose zone during treatment;
- Facilitate surficial runoff of precipitation so infiltration is minimized, which prevents cooling of the TTZ and helps with the hydraulic control;
- Insulate the surface such that heat losses from the TTZ are reduced; and,
- Allow foot and light vehicle traffic on the TTZ before, during, and after ISTR treatment.

The vapor cover that TerraTherm plans on constructing for this Site will provide an insulating value of minimum R-12 insulation.

The vapor cover will extend approximately 5 ft beyond the limits of the two treatment areas.

Waste Generation

Wastes generated during the thermal remediation system installation and operational process may include the following types. Quantities will be determined during the next and more detailed stage of the project.

- Drill cuttings and trenching spoils from the well installation;
- Well development and purge water;
- Spent media (e.g., vapor/liquid carbon, filter bags);
- Decontamination fluids;

- Impacted personal protective equipment (PPE); and,
- Normal construction debris and non-impacted PPE.

PRELIMINARY COST, ASSUMPTIONS AND PROJECT SCHEDULE

Cost Estimate

All prices include sales tax, but exclude tax on TerraTherm's services. Costs have been generated based on TerraTherm's proprietary cost model, and should be considered accurate within +/- 10%. **Table 7** summarizes cost estimates for all treatment scenarios.

The cost estimate is based on the division of responsibilities presented in the Responsibility Matrix included as Attachment 1.

Table 7. Cost Estimate (All Treatment Scenarios)

Task	Scenario 1	Scenario 2	Scenario 3
Design	$ 36,300	$ 36,300	$ 36,300
Premobilization	$ 146,400	$ 173,000	$ 186,900
Construction	$ 339,900	$ 421,200	$ 471,800
Operations Support	$ 405,400	$ 419,400	$ 425,800
Demobilization	$ 117,100	$ 142,600	$ 157,300
Final Report	$ 22,100	$ 22,100	$ 22,100
Contingency	$ 16,000	$ 18,200	$ 19,500
Total without power	**$ 1,083,200**	**$ 1,232,800**	**$ 1,319,700**
Power	$ 54,800	$ 161,300	$ 197,000
Total with power	**$ 1,138,000**	**$ 1,394,100**	**$ 1,516,700**

Table 8 below provides some key cost parameters for the project, indicated with respect to cost per volume treated and cost per mass of contaminants removed, based on the assumed mass estimate for the site.

Table 8. Key Cost Numbers

Treatment Scenario	Treatment Areas (ft^2)		Target Volume (cy)	Estimated Mass (lbs)	Project Cost with utilities ($)	Cost per Volume with utilities ($/cy)	Cost per lbs mass removed with utilities ($/lbs)
1	Area 1	1,500	556	334	1,138,000	2,047	3,407
2	Area 2	2,500	2,778	1,401	1,394,100	502	995
3	Area 1 and 2	4,000	3,333	1,735	1,516,700	455	874

Notes and Assumptions

TerraTherm's conceptual approach, technical description, calculations, and pricing are all proprietary to TerraTherm and shall not be shared outside the recipient's organization or project team without express written approval of TerraTherm.

Turn-Key Services

Attachment 1 includes an ISTR Responsibility Matrix that details TerraTherm's understanding of the division of the scope of work related to ISTR implementation at the Site. The Responsibility Matrix provides a specific breakdown of proposed tasks to be performed by TerraTherm and proposed tasks to be performed APTIM and/or others. The Responsibility Matrix serves as the basis for TerraTherm's price proposal and implementation schedule.

Please note that the information within the proposed Responsibility Matrix provided here aligns the Responsibility Matrix provided by APTIM. The Responsibility Matrix is completely flexible, and can be modified to meet any specific project needs as requested by APTIM and the client.

Permitting

We understand that TerraTherm and APTIM will share lead roles with respect to permitting efforts (lead roles specific to individual permitting tasks) and that TerraTherm will provide design documentation to APTIM to support APTIM's permitting tasks as needed.

Construction, Operations, Demobilization, and Reporting

TerraTherm assumes that the site information provided is representative of actual site conditions.

TerraTherm estimated the contaminant mass for all scenarios evaluated based on the information provided by APTIM, and therefore selected a GAC system as the preferred vapor treatment technology for the site.

No backup generator has been included in the estimate.

Construction

All electrical and mechanical connections assumed to be above grade.

It was assumed that the existing wells can either be left in place or overdrilled and be replaced with one of the operational wells needed for the remediation.

Vapor Phase GAC cost of 2,000 lbs, 8,000 lbs, and 10,000 lbs including disposal was included for Scenarios 1, 2, and 3 respectively. A total of 1,000 lbs of LGAC cost including disposal was included for each of the scenarios.

TerraTherm has not yet been able to obtain costs from the electric utility power company related to the power drop and transformer. A power drop allowance of $20,000 has been included in the cost estimates provided in this proposal. This allowance assumes that adequate power capacity is available in the street. Additional information may be available for the next detailed design stage of the project.

Site Security

Construction of a site security fence was not included as part of this proposal per the responsibility matrix.

Operations

One full-time operator housed within a 30 minute drive to the site was included for all Treatment Scenarios evaluated. The full-time operator was included in order to ensure rapid response time during system upsets and to maintain the highest possible system up-time.

Office support includes Project Management and Engineering at approximately 40 hours/week total.

The costs of electricity were estimated and included as a separate line item in the cost proposal. TerraTherm has assumed an electricity cost of $0.15/kWh. No natural gas is needed for the proposed approach. The costs of utilities are assumed to be paid directly by the client. Please note that for all treatment scenarios, water treatment rates shown in Table 5 are peak rates and do not apply for the entire duration of the thermal remedy (for example in Treatment Scenario 3, the peak water treatment rate of 1.5 gpm is a combination of 0.7 gpm liquid extraction rate and an estimated 0.8 gpm condensed liquid rate during peak operation). In the beginning of operations, only limited steam will be extracted and the combined liquid rate will therefore be lower than 1.5 gpm. It is assumed that generated liquids can be discharged to the local POTW.

Demobilization

Restoring the site to as near starting condition has been included in the cost estimate, and includes:

- Grouting up wells
- Removal of all equipment

Preliminary Project Duration

The schedules shown below are based on a standard project scope. **Figure 9, Figure 10,** and **Figure 11** show a tentative project duration for all treatment scenarios evaluated.

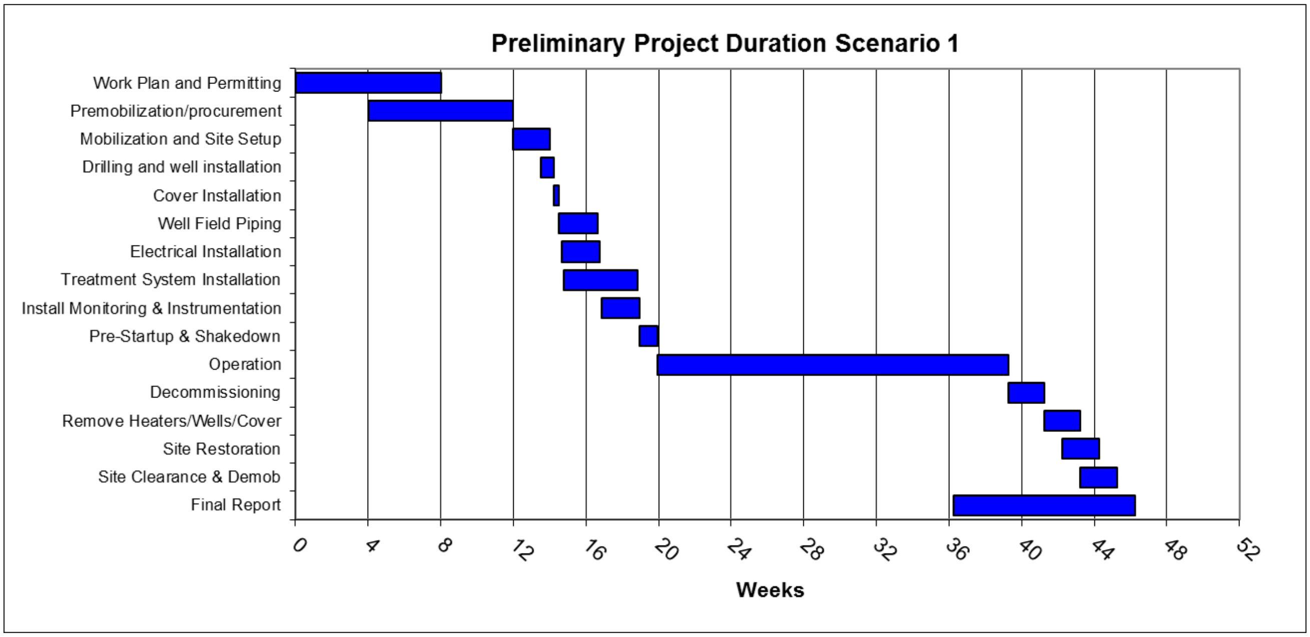


Figure 9. Project Duration (Treatment Scenario 1)

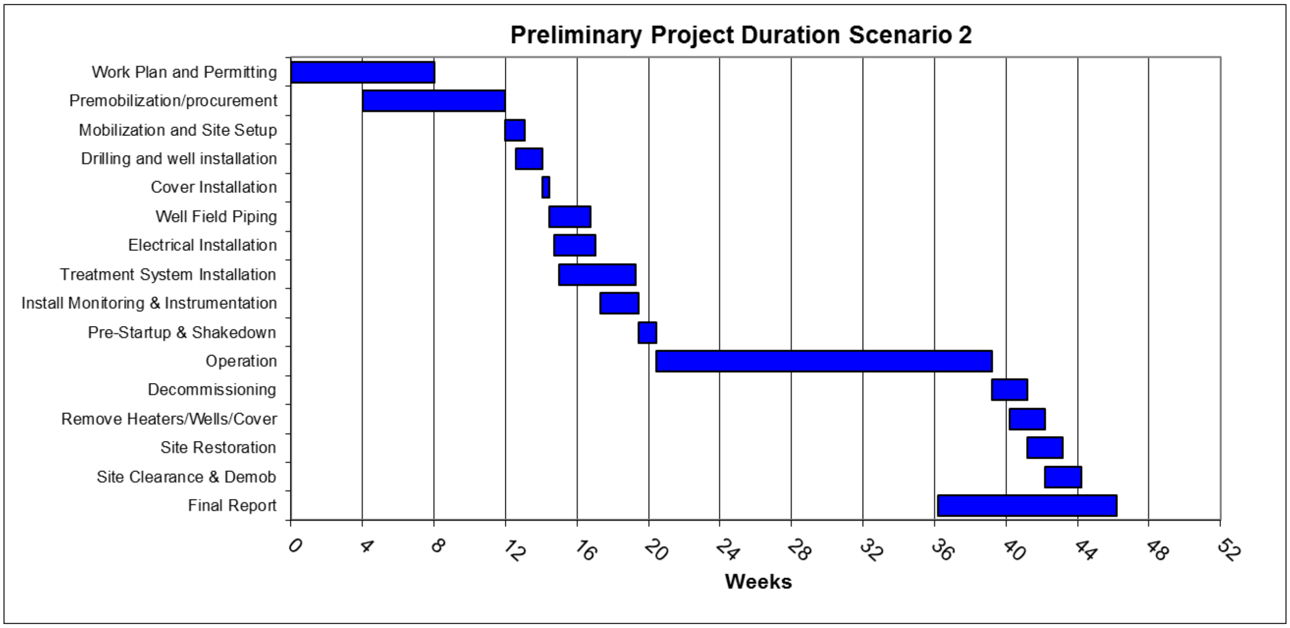


Figure 10. Project Duration (Treatment Scenario 2)

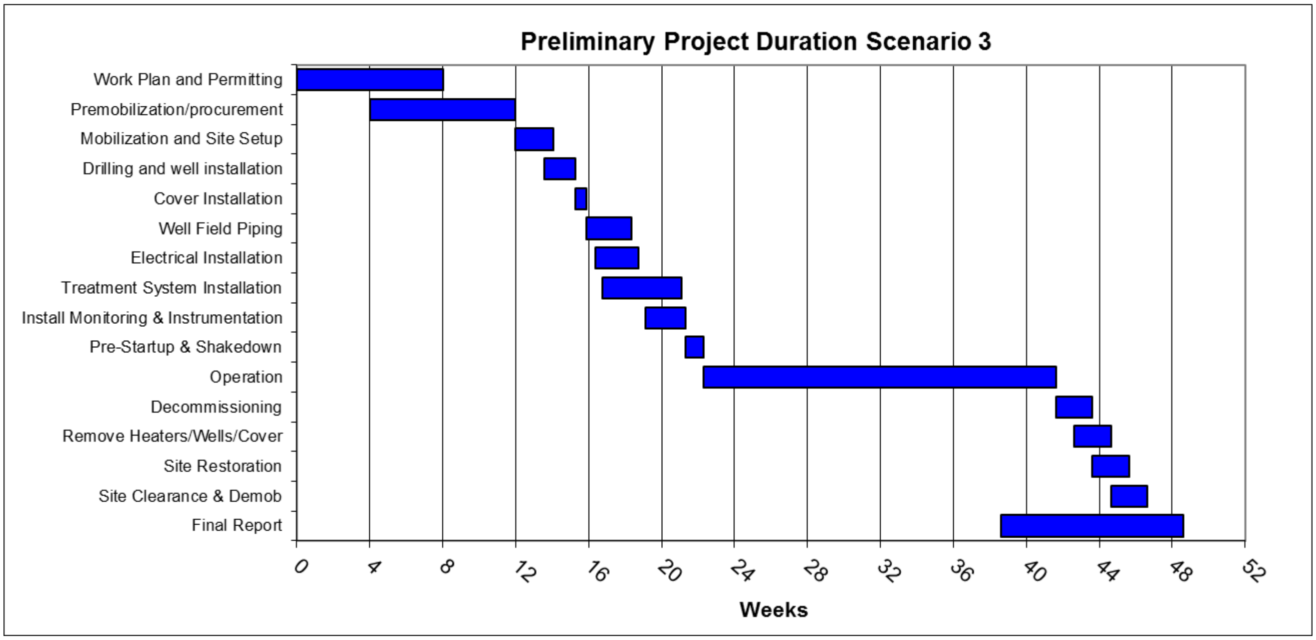


Figure 11. Project Duration (Treatment Scenario 3)

As shown above, the total project duration is estimated to be 46 weeks for Treatment Scenario 1, 46 weeks for Treatment Scenario 2, and 49 weeks for Treatment Scenario 3 from project kick-off to final report submittal. However, these preliminary schedules can be compressed if desired. For example, for Scenario 3; we are estimating that the timeframe from project kick-off to beginning of operation can be reduced to approximately 3 months as shown in **Figure 12** below, assuming that permitting can be approved within that timeframe. Please note that actual schedules are dependent on timing of contracting, availability of resources, and availability of equipment. The schedules presented are flexible and can be adjusted to meet the overall project schedule, through application of additional resources, and/or implementation of multiple tasks in parallel, if required.

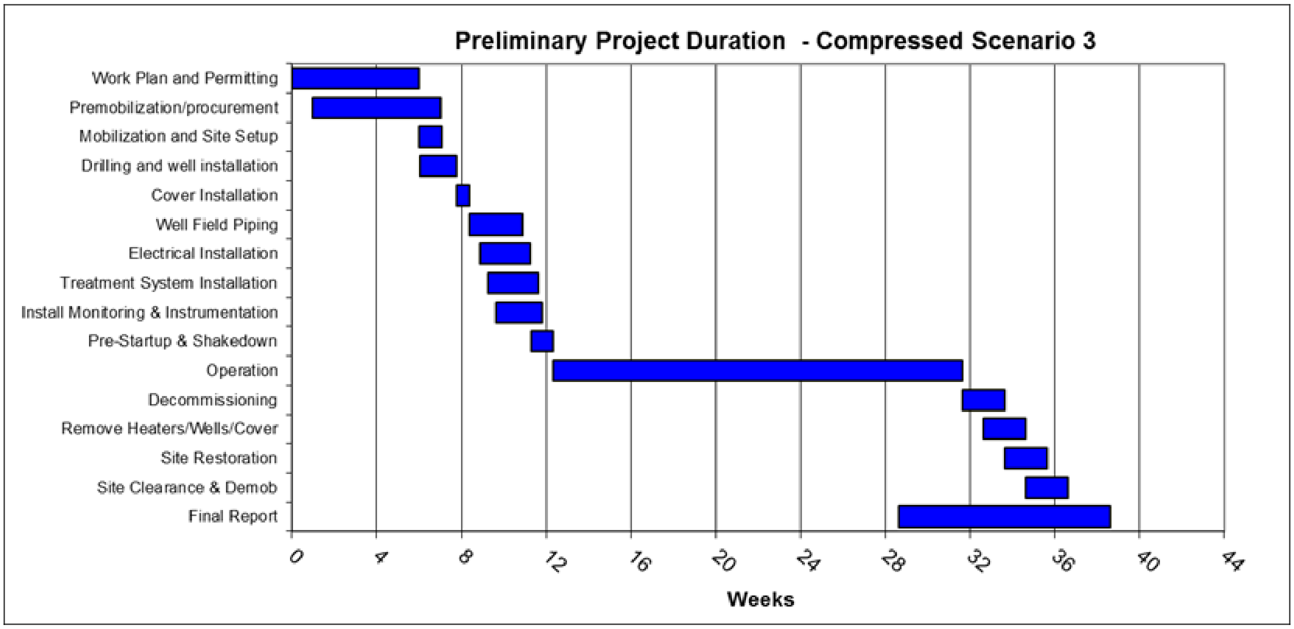


Figure 12. Compressed Project Duration (Treatment Scenario 3)

ATTACHMENT B

IN-SITU BIOREMEDIATION FOR THE GENERAL CHEMICAL SITE

IN-SITU BIOREMEDIATION FOR THE GENERAL CHEMICAL SITE

The predominant biodegradation pathway for chlorinated ethenes and ethanes under anaerobic conditions is via microbially mediated reductive dechlorination. During this process, the chlorinated compounds are used as electron acceptors, not as a source of carbon, and chlorine atoms are removed and replaced with hydrogen atoms, ultimately resulting in the production of ethane and/or ethene and chloride as terminal products. These are non-toxic species. An appropriate source of carbon and energy for microbial growth is required for this process to occur. Carbon sources (also called electron donors) that are often added to aquifers to promote reductive dechlorination include vegetable oil, lactate, and molasses, among others. The carbon sources must first be fermented by indigenous organisms in the aquifer, or by bacterial cultures that are injected into the aquifer (bioaugmentation) to yield molecular hydrogen (H_2) and acetate, each of which are required by many dehalorespiring bacteria. The hydrogen is used as an energy source, the acetate as a carbon source, and the chlorinated ethene/ethane as the electron acceptor (respiratory substrate) in the process. *Dehalococcoides ethenogenes* (DHC) is the only microbial species that is currently known to be capable of completely dechlorinating PCE and TCE to ethene. Incomplete reductive dechlorination of PCE and TCE results in an accumulation of *cis*-1,2-DCE and VC, indicating that the carbon source is depleted and/or that microorganisms capable of complete anaerobic reductive dechlorination are not present.

The highest rates and greatest extent of anaerobic dechlorination occurs under sulfate-reducing and methanogenic conditions. An oxidation-reduction potential (ORP) between -100 and -300 mV is typically considered optimal for this process. Prevailing redox conditions are largely a result of the relative amount of organic carbon (electron donor) and electron acceptors present. Thus, dissolved oxygen (DO), nitrate, and bioavailable iron and manganese must be depleted before sulfate-reducing conditions or methanogenic conditions can be induced. Therefore, sufficient organic carbon (electron donor) must be present in order to deplete native inorganic electron acceptors. In general, DO less than 0.5 mg/L, nitrate less than 1.0 mg/L, sulfate less than 20 mg/L, and total organic carbon (TOC) greater than 20 mg/L are favorable for the anaerobic dechlorination process. In addition, ferrous iron and methane concentrations greater than 1 mg/L and 0.5 mg/L, respectively, can be indicative of favorable reducing conditions.

In-Situ Bioremediation Technology Descriptions

Biostimulation

In-situ anaerobic biostimulation involves stimulating the degradation of contaminants by the indigenous microbial populations through the introduction of electron donor (substrate) and/or nutrients into the subsurface. These materials can be delivered to the subsurface using direct-push injection points, treatment walls, soil mixing, pneumatic fracturing, or vertical or horizontal wells. The assumption with this approach is that the indigenous microbial population contains DHC and other dehalogenating bacteria capable of degrading chlorinated ethenes and ethanes, but that the native bacteria are unable to maintain sufficiently high levels of contaminant degradation due to limiting conditions within the aquifer. Factors that can limit the effectiveness of indigenous bacteria to degrade chlorinated compounds include unfavorable ORP, low pH (<6), insufficient inorganic nutrient (e.g., nitrogen, phosphorus) levels, insufficient microbial cell density, and/or a lack of electron donor/fermentable substrate. The amendments provided to the aquifer will depend on the limiting condition, but most often include a fermentable substrate with or without inorganic nutrients. Buffers have also been successfully applied to small areas to increase groundwater pH to an optimal range. As such, the success of a biostimulation approach is dependent upon the ability to distribute amendments in the subsurface, create favorable oxidation-reduction conditions, create or maintain a favorable groundwater pH, and ultimately stimulate bacterial growth and microbially-enhanced reductive dehalogenation.

Bioaugmentation

Bioaugmentation is similar to biostimulation, except that it involves the delivery of halorespiring microorganisms (in addition to substrate and nutrients) to the subsurface to stimulate biological degradation of chlorinated ethenes and ethanes. These specialized organisms are available from several vendors of bioremediation products in quantities necessary for field application. A bioaugmentation approach is often more cost-effective for the treatment of sites than biostimulation alone, due to the relatively low cost of the bacterial cultures and the higher degradation rates associated with the increased microbial activity. Bioaugmentation is suggested for specific areas of the GCC site as noted below.

APTIM has developed a microbial consortium (SDC-9®) containing a high density of DHC capable of performing complete and rapid dechlorination of PCE and TCE to ethene without accumulation of the intermediates DCE or VC. This culture, which is grown at commercial scale along with several others in our Lawrenceville, NJ facility, has been widely applied in the US over the past decade. In addition, SDC-9 is capable of degrading other contaminants of concern found at the GCC site, including 1,1-DCE, carbon tetrachloride (CT), and Freon 113. The degradation of CT by SDC-9, however, produces an accumulation of dichloromethane (DCM). Therefore, to degrade CT/DCM, APTIM has developed another bacterial culture (MDB-1) which can be added to the SDC-9 consortium for injection at the GCC site. Finally, 1,1,1-TCA and 1,1-DCA are also present at elevated concentrations at the GCC site, and are not substantially degraded by either SDC-9 or MDB-1. Therefore, a third culture (TCA-20) will be added to the injected consortium at the site for degradation of these compounds. These three cultures will be grown by APTIM and pre-mixed at desired densities onsite prior to injection as a single inoculum.

Implementation of bioaugmentation requires that amendments (fermentable substrate and nutrients) and microorganisms are properly delivered and distributed to the subsurface. The pH of the aquifer must also be within the desired range for successful biologic degradation of the target contaminants. The three cultures listed above require a pH in the range of approximately 6.0 to 8.0 standard units to be effective. Available data show that the pH of the site is within this range, thus pH adjustment should not be required.

Source Area In-Situ Groundwater Bioremediation

Upon completion of the thermal remediation strategy, APTIM recommends treating the remaining impacted groundwater in the source areas, including the Former Loading Rack Area, the Area Southeast of the Former Production Area, and the Former AST Containment Area via an *in situ* bioremediation approach that includes bioaugmentation with a mixed consortium as described in the previous section. The portions of the aquifer in these source areas considered to be within AOC#2 (top 15 feet of saturated zone within the sand unit) will be the target treatment zone.

The limited budget remaining after thermal treatment would necessitate the use of a direct push technology (DPT; e.g., Geoprobe) versus groundwater recirculation or installation of multiple injection wells for bioremediation amendment distribution. One of the potential disadvantages of the direct injection approach is that subsequent injections (if needed) would be more costly due to a lack of permanent injection wells. Based on the available site hydrogeologic data, a conservative injection point spacing of 15 feet was determined to be appropriate.

The amendments to be injected will be comprised of the bacterial consortium blend detailed above (SDC-9, TCA-20, and MDB-1), with an emulsified vegetable oil and nutrients (e.g., EOS-Pro). To perform the injection activities, APTIM will mobilize to the site with a DPT drilling and injection subcontractor to mix and inject the amendments. DPT injection tooling will be advanced to the target depths for the injection of amendments into the subsurface. A bottom-up injection approach will be used, meaning the injection tooling, consisting of a 3-4 ft injection screen, will be advanced to the bottom of the treatment zone (approximately 20 ft below grade at the base of the sand unit). Injection of a pre-determined volume of amendments will be performed within the bottom interval, before the tooling is lifted to the next target interval, where additional amendment is injected. This process is continued until injections have been completed across the entire treatment zone. Mixing and pumping equipment will be used on site to prepare and inject the solution. It is recommended that anaerobic water be used for all injection solutions. Therefore, a commercially available oxygen-scavenger will be used to create batches of anaerobic water prior to amendment injections. This will insure that the injection solution will not contain high levels of dissolved oxygen that can inhibit the activity of the dehalogenating bacteria. Upon completion of each of the DPT injection locations, the boring will be grouted as per MassDEP regulations.

Former Loading Rack Area (proposed thermal treatment area)
The Former Loading Rack Area treatment area is approximately 1,500 ft^2, with a saturated thickness of 15 ft and an effective pore volume of approximately 25,245 gal (based on an estimated effective porosity of 15%). The injection program will consist of approximately 12 injection points, as presented on the attached figure. Based on design software from the EOS Remediation, approximately 5,000 lbs of EOS-Pro (12 drums, 660 gal) will be required for this area. Based on an injection volume equal to 25% of the effective pore volume, the total volume of diluted EOS be injected in this area is 6,311 gal (526 gal per injection point, 35 gal per vertical foot). Upon injection of the diluted EOS within each one-foot vertical interval, a diluted volume of the bacteria consortium will be injected (50 gal per 5-foot vertical interval), resulting in an additional 1,800 gal of bacteria/water injected over the entire treatment zone. This treatment area requires 18 liters each of APTIM's SDC-9, MDB-1 and TCA-20 bacterial consortiums.

Area Southeast of Former Production Area (proposed thermal treatment area)
The Area Southeast of Former Production Area (portion proposed for thermal treatment) is approximately 2,400 ft^2, with a saturated thickness of 15 ft and an effective pore volume of approximately 40,392 gal (based on an estimated effective porosity of 15%). The injection program will consist of approximately 16 injection points, as presented on the attached figure. Based on design software from the EOS Remediation, approximately 6,700 lbs of EOS-Pro (16 drums, 880 gal) will be required for this area. Based on an injection volume equal to 25% of the effective pore volume, the total volume of diluted EOS be injected in this area is 10,098 gal (631 gal per injection point, 42 gal per vertical foot). Upon injection of the diluted EOS within each one-foot vertical interval, a diluted volume of the bacterial consortium will be injected (50 gal per 5-foot vertical interval), resulting in an additional 2,400 gal of bacteria/water injected over the entire treatment zone. This treatment area requires 30 liters (7.9 gal) of APTIM's SDC-9, MDB-1 and TCA-20 bacterial consortiums. These cultures will be provided in individual kegs and mixed on-site so that they can be added to the aquifer as a single amendment.

Area Southeast of Former Production Area (portion where thermal treatment is not proposed)
The Area Southeast of Former Production Area (the portion where thermal treatment is not proposed) is approximately 2,125 ft^2, with a saturated thickness of 15 ft and an effective pore volume of approximately 35,764 gal (based on an effective porosity of 15%). The injection program will consist of approximately 14 injection points, as presented on the attached figure. Based on design software from the EOS Remediation, approximately 7,000 lbs of EOS-Pro (17 drums, 935 gal) will be required for this area. Based

on an injection volume equal to 25% of the effective pore volume, the total volume of diluted EOS be injected in this area is 8,941 gal (639 gal per injection point, 43 gal per vertical foot). Upon injection of the diluted EOS within each one-ft vertical interval, a diluted volume of the bacterial consortium will be injected (50 gal per 5-foot vertical interval), resulting in an additional 2,100 gal of bacteria/water injected over the entire treatment zone. This treatment area requires 26 liters (6.9 gal) each of APTIM's SDC-9, MDB-1 and TCA-20 bacterial consortiums.

Former AST Containment Area

The Former AST Containment Area is approximately 3,600 ft^2, with a saturated thickness of 15 ft and an effective pore volume of approximately 60,588 gal (based on an effective porosity of 15%). The injection program will consist of approximately 29 injection points, as presented on the attached figure. Based on design software from the EOS Remediation, approximately 7,900 lbs of EOS-Pro (19 drums, 1,045 gal) will be required for this area. Based on an injection volume equal to 25% of the effective pore volume, the total volume of diluted EOS be injected in this area is 15,147 gal (522 gal per injection point, 35 gal per vertical foot). Upon injection of the diluted EOS within each one-ft vertical interval, a diluted volume of the bacteria consortium will be injected (50 gal per 5-foot vertical interval), resulting in an additional 4,350 gal of bacteria/water injected over the entire treatment zone. This treatment area requires 44 liters (11.6 gal) each of APTIM's SDC-9, MDB-1 and TCA-20 bacterial consortiums.

Source Area 1: Former Loading Rack Area (aka TerraTherm Thermal Treatment Area #1)

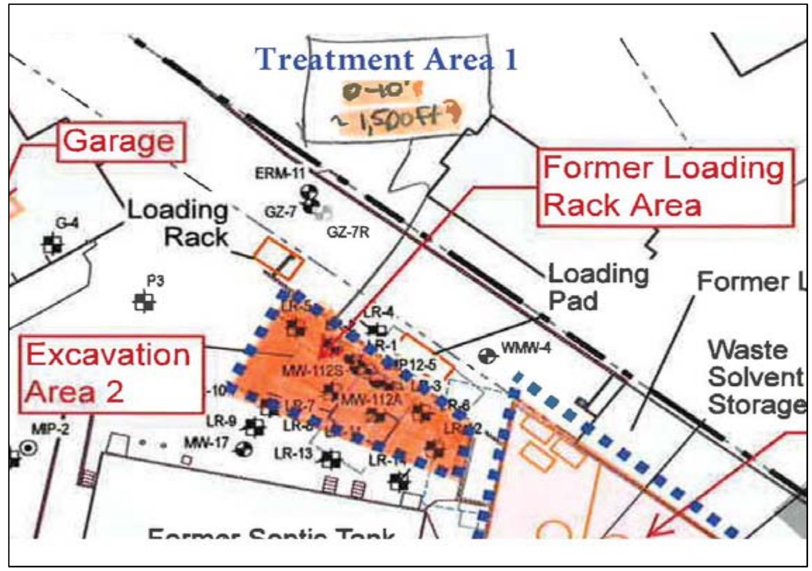
Treatment Depth ~0-10 ft-bgs
Area ~1,500 SF
Groundwater Table ~ 3-5 ft-bgs (based on MW-112S)
Soil Description: Sand 0-23 ft-bgs, Silt-Fine Sand 23-40 ft-bgs, Till 40-80 ft-bgs (based on x-section)
Porosity = 0.35 (based on TerraTherm estimate)

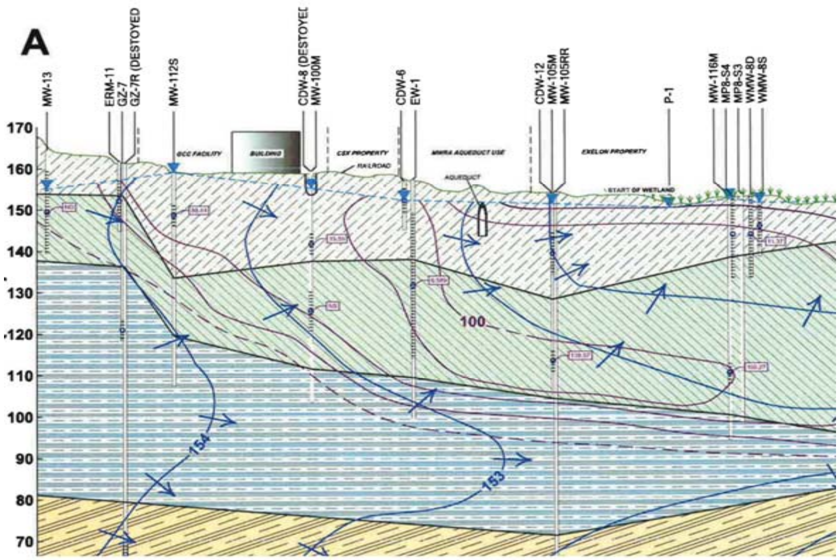
Significant Soil Hits (mg/kg, PCE+TCE+TCA, mostly PCE)

	0-2'	2-4'	4-5'	5-7.5'	5-10'	7.5-10'	10-12.5'	12.5-15'
LR-1	7464							
LR-2	1150							
LR-3	14911		2300					
LR-4			271					
LR-5	44							
LR-6	12463	4982				294		
LR-7							22	
LR-8		123			2			
LR-9				14				
LR-11	5044							
LR-12		2178						41
LR-13		173					17	
LR-14		89						80
MW-112S	9535						23	
MW-17			39					

<u>MW-112S</u>: Screen 8-13 ft-bgs, no LNAPL (screen submerged), flush-mount

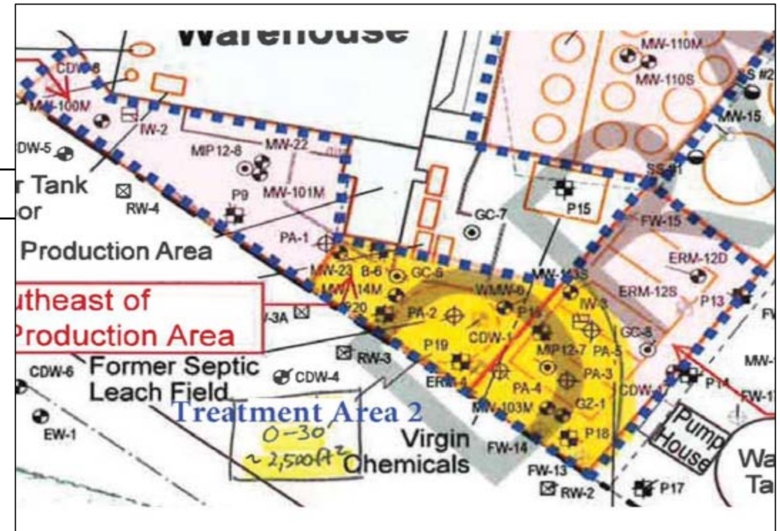
Analyte	Unit / Date:	1/17/13	9/26/14	5/14/15	11/13/15	5/13/16	11/10/16
1,1,1-TCA	µg/L	14,900	8,140	5,990	6,620	4,370	3,900
Freon 113	µg/L	629	717	<1,000	1,050	925	839
1,1-DCA	µg/L	100	131	<1,000	<250	<500	<500
1,1-DCE	µg/L	282	78.4	<1,000	<250	<500	<500
cis-1,2-DCE	µg/L	4,890	10,200	5,430	8,890	4,460	6,920
PCE	µg/L	74,500	65,700	66,900	74,100	70,100	52,300
TCE	µg/L	4,390	4,090	4,590	5,650	4,290	4,210
Vinyl Chloride	µg/L	170	301	<1,000	295	<500	<500
1,4-Dioxane	µg/L	---	0.480	0.486	0.274	0.251	0.770
pH	SU	6.45	6.01	6.38	6.15	6.36	6.25
Temp	deg C	10.63	19.27	11.85	16.92	13.81	18.30
DO	mg/L	2.73	0.42	0.44	0.89	1.07	0.40
ORP	mV	52.4	17.8	21.0	55.4	52.3	-1.9
Cond	uS/cm	846	1,538	707	2,390	1,198	1,554
Turbidity	NTU	8.8	3.8	0.2	2.3	0.1	0.0
DTW	ft-btoc	3.32	4.47	2.31	4.50	2.54	4.85





Source Area 2: Area Southeast of Former Production Area (a portion of which is TerraTherm Thermal Treatment Area #2

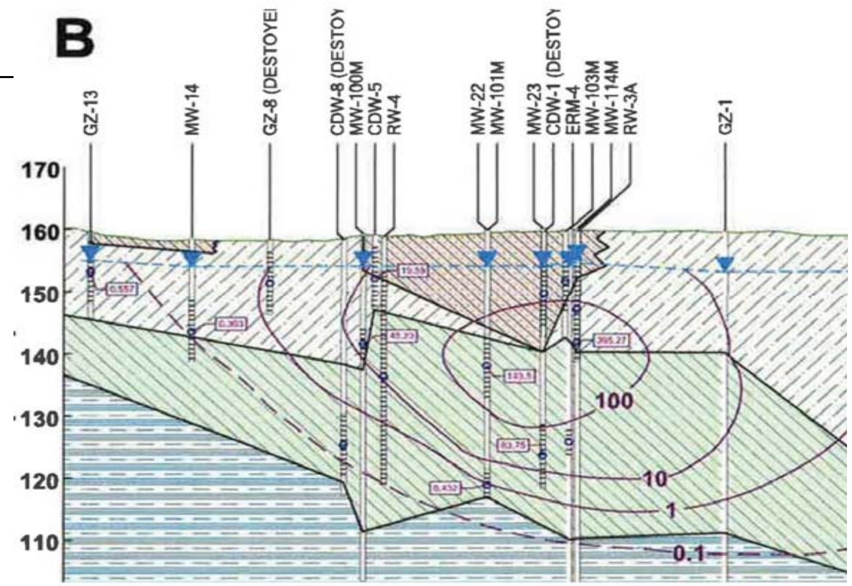
Treatment Depth ~0-10 ft-bgs
Area ~1,500 SF
Groundwater Table ~ 3-5 ft-bgs (based on MW-112S)
Soil Description: Fill 0-15 ft-bgs, Sand 5-15 ft-bgs, Silt-Fine Sand 15-50 ft-bgs, Till 50+ ft-bgs (based on x-section)
Porosity = 0.35 (based on TerraTherm estimate)



Significant Soil Hits (mg/kg, PCE+TCE+TCA, mostly PCE)

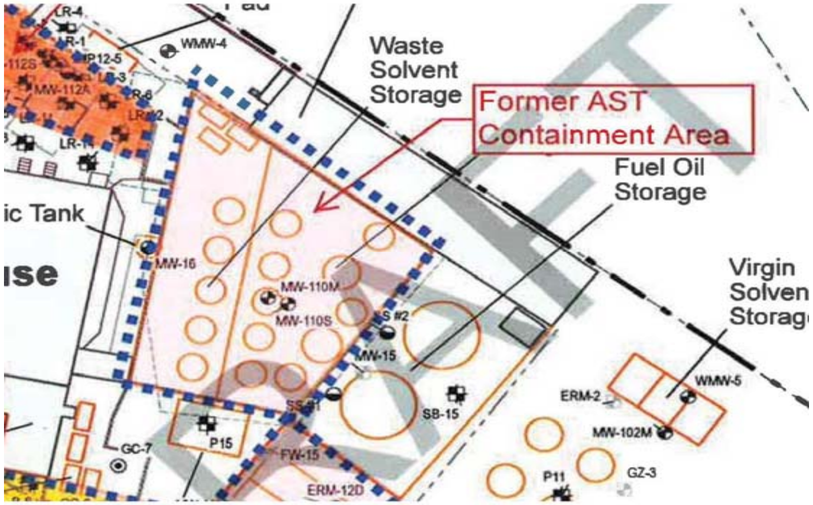
	0-2'	2-4'	3-7'	4-4'	4-6'	6-6'	5-10'	7-11'	8-10'	10-10'	10-12.5'	12.5-15'
B-6										73		
CDW-1											9 (10-12')	
GZ-1					88							
MW-22						0.8						
MW-23						158						
MW-100M						75						
MW103M				202					58			
MW-13S						466						
MW-114M				128								
PA-1	29											
PA-2							54					
PA-3	1013											
PA-4	236											
PA-5		1940										59
P9	<.1 (0-3')											
P16								10				
P18			4.4									
P19								5				
P20								17				

Analyte	Unit	MW-100M (15-20 ft-bgs)			MW-22 (17-27 ft-bgs)	MW-23 (31-41 ft-bgs)	MW-114M (16-21 ft-bgs)	MW-113S (12-17 ft-bgs)	MW-103M (31-36 ft-bgs)		
		11/13/15	5/13/16	11/10/16	10/1/14	10/1/14	10/1/14	10/1/14	11/13/15	5/12/16	11/9/16
1,1,1-TCA	µg/L	18,200	11,600	29,900	29,500	18,500	168,000	93,600	155,000	46,600	72,900
Freon 113	µg/L	12,700	9,520	17,100	5,520	2,750	24,700	58,500	9,230	1,980	5,700
1,1-DCA	µg/L	746	598	933	1,100	290	1,270	1,470	2,360	916	2,070
1,1-DCE	µg/L	1,490	1,110	2,190	3,050	1,280	18,000	9,000	5,430	1,640	3,700
cis-1,2-DCE	µg/L	46,900	32,600	55,600	44,200	19,700	133,000	56,800	87,400	23,300	47,700
PCE	µg/L	11,800	9,370	13,300	52,000	37,000	18,800	35,100	309	6,680	519
TCE	µg/L	59,200	38,000	86,000	13,400	6,980	56,200	136,000	64.8	<250	297
Vinyl Chloride	µg/L	1,160	1,070	1,690	264	< 50.0	< 200	< 200	51.4	<250	<250
1,4-Dioxane	µg/L	36.6	43.0	39.4	---	120.0	95.0	130.0	198.0	110.0	70.6
pH	SU	6.25	6.13	6.03	---	---	---	---	6.60	6.23	6.50
Temp	deg C	14.40	13.25	13.95	---	---	---	---	13.25	14.22	12.78
DO	mg/L	2.05	1.23	0.26	---	---	---	---	3.35	4.76	0.00
ORP	mV	21.9	67.5	-3.0	---	---	---	---	-80.6	167.2	-144.0
Cond	uS/cm	739	818	681	---	---	---	---	824	222	848
Turbidity	NTU	1.5	0.3	0.0	---	---	---	---	2.1	1.7	0.0
DTW	ft-btoc	5.50	3.41	5.25	---	5.87	6.13	---	5.30	3.67	5.75



Source Area 3: Former AST Containment Area

Treatment Depth ~0-15 ft-bgs (maybe more, don't have data deeper except soil at 63')
Area ~3,600 SF
Groundwater Table ~ 8-11 ft-bgs (based on MW-110S)
Soil Description: no description found, though likely similar to other areas (not on any x-section)
Porosity = 0.35 (based on TerraTherm estimate)



Soil Monitoring Results

		MW-110S		MW-110M		
Analyte	**Unit**	**1-2'**	**63-64'**	**2-5'**	**5-7.5'**	**45-47'**
1,1,1-TCA	mg/kg	54.7	< 0.117	3.07	1.52	1.04
1,1-DCA	mg/kg	< 0.151	< 0.117	< 0.0783	< 0.0711	< 0.0709
1,1-DCE	mg/kg	< 0.151	< 0.117	< 0.0783	< 0.0711	< 0.0709
cis-1,2-DCE	mg/kg	3.22	< 0.117	0.341	0.467	0.107
PCE	mg/kg	188	< 0.117	7.22	0.686	0.399
TCE	mg/kg	59.8	< 0.117	2.39	1.23	0.741
Vinyl Chloride	mg/kg	< 0.151	< 0.117	< 0.0783	< 0.0711	< 0.0709

<u>MW-110S</u>: Screen 5-15 ft-bgs, flush mount

	Date:	**2/13/13**	**9/26/14**	**10/2/14**	**5/14/15**	**11/13/15**	**5/12/16**	**11/9/16**
Analyte	**Unit**							
1,1,1-TCA	µg/L	92,800	1,120	2,740	88,200	87,100	124,000	44,600
Freon 113	µg/L	1,180	418	33.0	1,210	2,120	1,160	2,840
1,1-DCA	µg/L	2,230	65.1	77.8	2,510	3,680	3,200	2,560
1,1-DCE	µg/L	748	77.5	38.5	959	713	<1,000	<1,000
CT	µg/L	< 1.00	< 1.00	< 1.00	<100	<500	<1,000	7,120
cis-1,2-DCE	µg/L	31,900	2,050	1,220	45,400	24,700	64,100	18,700
PCE	µg/L	5,130	80.0	209	8,690	4,920	7,450	1,420
TCE	µg/L	45,400	279	331	25,500	24,000	23,500	6,350
Vinyl Chloride	µg/L	64.1	< 1.00	< 1.00	<100	<500	<1,000	<1,000
1,4-Dioxane	µg/L	---	25.0	0.860	308	13.5	160	12.0
pH	SU	7.26	---	---	5.92	6.45	5.52	6.56
Temp	deg C	9.94	---	---	9.76	16.20	13.91	15.79
DO	mg/L	0.47	---	---	0.57	1.81	1.18	0.00
ORP	mV	-23.9	---	---	14.7	2.9	35.3	-120.0
Cond	uS/cm	501	---	---	393	429	518	400
Turbidity	NTU	22.6	---	---	4.9	2.4	8.4	0.0
DTW	ft-btoc	9.52	10.65	10.80	8.37	10.57	8.62	11.06
Product Thickness	ft	---	0.03	0.03	---	---	---	---

Budgetary Cost Estimate - Bioaugmentation
General Chemical Corporation, Framingham, MA

Task 1 - Design/Workplan/Procurement

Description	Quantity	Unit	Revenue	Comments
EH&S Specialist	10	hour	$1,020.80	
Subcontract Administrator	12	hour	$1,286.21	
Cost Scheduler	12	hour	$918.72	
Scientist 3	80	hour	$7,553.92	
Engineer 4	40	hour	$5,614.40	
Project Manager 2	20	hour	$3,062.40	
		Labor Subtotal	$19,456.45	
No ODCs			$0.00	
		ODCs Subtotal	$0.00	
		Task 1 Total	**$19,456.45**	

Task 2A - Bioaugmentation Application Activities (Former Loading Rack Area)

Description	Quantity	Unit	Revenue	Comments
EH&S Specialist	30	hour	$3,062.40	
Subcontract Administrator	4	hour	$428.74	
Cost Scheduler	4	hour	$306.24	
Scientist 3	30	hour	$2,832.72	
Engineer 4	16	hour	$2,245.76	
Project Manager 2	20	hour	$3,062.40	
		Labor Subtotal	$11,938.26	
Utility Clearance (GPR)	1	day	$2,901.25	
Driller Mobilization	1	ea	$2,321.00	
Geoprobe Rig/Crew	3	day	$10,444.50	assumes 6 gpm, so 22.5 hrs to inject
Injection Trailer	3	day	$6,963.00	
EVO	12	drum	$9,124.32	
EVO Shipping	1	ea	$1,137.29	
SDC-9/TCA-20/MDB-1	54	liter	$3,275.60	
Materials/Supplies	1	ea	$580.25	
		ODCs Subtotal	$36,747.21	
		Task 2A Total	**$48,685.47**	

Task 2B - Bioaugmentation Application Activities (Area Southeast of Former Production Area - portion previously treated with thermal)

Description	Quantity	Unit	Revenue	Comments
EH&S Specialist	50	hour	$5,104.00	
Subcontract Administrator	4	hour	$428.74	
Cost Scheduler	4	hour	$306.24	
Scientist 3	50	hour	$4,721.20	
Engineer 4	20	hour	$2,807.20	
Project Manager 2	20	hour	$3,062.40	
		Labor Subtotal	$16,429.78	
Utility Clearance (GPR)	1	day	$2,901.25	
Driller Mobilization	1	ea	$0.00	
Geoprobe Rig/Crew	5	day	$17,407.50	assumes 6 gpm, so 35 hrs to inject
Injection Trailer	5	day	$11,605.00	
EVO	16	drum	$12,165.75	
EVO Shipping	1	ea	$1,392.60	
SDC-9/TCA-20/MDB-1	90	liter	$5,459.34	
Materials/Supplies	1	ea	$580.25	
		ODCs Subtotal	$51,511.69	
		Task 2B Total	**$67,941.47**	

Task 2C - Bioaugmentation Application Activities (Area Southeast of Former Production Area - portion not previously treated with thermal)

Description	Quantity	Unit	Revenue	Comments
EH&S Specialist	40	hour	$4,083.20	
Subcontract Administrator	4	hour	$428.74	
Cost Scheduler	4	hour	$306.24	
Scientist 3	40	hour	$3,776.96	

Engineer 4	20	hour	$2,807.20	
Project Manager 2	20	hour	$3,062.40	
		Labor Subtotal	$14,464.74	
Utility Clearance (GPR)	1	day	$2,901.25	
Driller Mobilization	1	ea	$0.00	
Geoprobe Rig/Crew	4	day	$13,926.00	assumes 6 gpm, so 31 hrs to inject
Injection Trailer	4	day	$9,284.00	
EVO	17	drum	$12,926.11	
EVO Shipping	1	ea	$1,392.60	
SDC-9/TCA-20/MDB-1	78	liter	$4,731.43	
Materials/Supplies	1	ea	$580.25	
		ODCs Subtotal	$45,741.64	
		Task 2C Total	**$60,206.38**	

Task 2D - Bioaugmentation Application Activities (Former AST Containment Area)

Description	Quantity	Unit	Revenue	Comments
EH&S Specialist	60	hour	$6,124.80	
Subcontract Administrator	4	hour	$428.74	
Cost Scheduler	4	hour	$306.24	
Scientist 3	60	hour	$5,665.44	
Engineer 4	24	hour	$3,368.64	
Project Manager 2	20	hour	$3,062.40	
		Labor Subtotal	$18,956.26	
Utility Clearance (GPR)	1	day	$2,901.25	
Driller Mobilization	1	ea	$0.00	
Geoprobe Rig/Crew	6	day	$20,889.00	assumes 6 gpm, so 54 hrs to inject
Injection Trailer	6	day	$13,926.00	
EVO	19	drum	$14,446.83	
EVO Shipping	1	ea	$1,740.75	
SDC-9/TCA-20/MDB-1	132	liter	$8,007.03	
Materials/Supplies	1	ea	$580.25	
		ODCs Subtotal	$62,491.11	
		Task 2D Total	**$81,447.37**	

Task 3 - Groundwater Monitoring (assumes 10 wells to be sampled quarterly for 2 years)

Description	Quantity	Unit	Revenue	Comments
EH&S Specialist	32	hour	$3,266.56	4 hrs/event
Subcontract Administrator	12	hour	$1,286.21	
Cost Scheduler	24	hour	$1,837.44	
Scientist 3	240	hour	$22,661.76	24 hrs/event (inc. mobilization)
Project Manager 2	16	hour	$2,449.92	2 hrs/event
		Labor Subtotal	$31,501.89	
GW Sampling Equip. Rent.	16	day	$9,284.00	
Analytical	80	well	$46,420.00	
Cooler Shipping	8	ea	$464.20	
Company Vehicle	16	day	$928.40	
Materials/Supplies	8	ea	$2,321.00	
		ODCs Subtotal	$59,417.60	
		Task 3 Total	**$90,919.49**	

Task 4 - Semi-Annual Reporting (assumes 4 reports over 2 years)

Description	Quantity	Unit	Revenue	Comments
Scientist 3	160	hour	$15,107.84	40 hrs/report
Engineer 4	40	hour	$5,614.40	10 hrs/report
Project Manager 2	16	hour	$2,449.92	4 hrs/report
		Labor Subtotal	$23,172.16	
No ODCs			$0.00	
		ODCs Subtotal	$0.00	
		Task 4 Total	**$23,172.16**	

TOTAL (ALL TASKS)	**$391,829**
TOTAL (DESIGN/FIELD APPLICATION)	**$277,737**