**Groundwater & Environmental Services, Inc.®**

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September 27, 2011

Ms. Maria E. Pinaud, LSP
Deputy Director for Enforcement & Audits
BWP/Business Compliance Division
Massachusetts Department of Environmental Protection
One Winter Street
Boston, Massachusetts 02108

**RE: General Chemical Corporation Site – Cost Re-Evaluation**
**133-135 Leland Street**
**Framingham, Massachusetts**

Dear Ms. Pinaud:

Counsel for General Chemical Corporation (GCC), Ms. Sarah Broughel (Choate), and representatives from Groundwater & Environmental Services, Inc. (GES) held a telephonic meeting with the Massachusetts Department of Environmental Protection (MassDEP) representatives on September 23, 2011. MassDEP requested that the following information be provided in detail within (or submitted concurrently with) the Remedy Implementation Plan (RIP) due to be submitted on September 28, 2011:

1. The number of injection wells that will be installed as part of the remedial efforts *-within the revised RIP*.
2. The details regarding the SVE system *-within the revised RIP*.
3. Contingency cost estimate for a round of In-situ Chemical Oxidation (ISCO) injections in Area 3 located beyond the CSX railroad tracks which is considered the middle plume area near well CD-6 *-addressed in this letter and attached cost spreadsheet*.
4. Contingency cost estimate for a third round of ISCO injections in Area 1 *-addressed in this letter and attached cost spreadsheet*.
5. Contingency cost estimate for 10 years of monitored natural attenuation (MNA) *-addressed in this letter and attached cost spreadsheet*.
6. Clarifications that the existing ISCO injection cost estimates include health and safety monitoring for the school *-within the revised RIP*.
7. Detailed ISCO volume calculations *-within the revised RIP*.

In addition, based on a meeting with MassDEP on September 14, 2011, with representatives from GCC and GES, the following evaluation and back-up for proposed remedial costs at the GCC site in Framingham, Massachusetts was prepared. During the meeting, the Environmental Security Technology Certification Program (ESTCP) document ER-200116 was provided to GES by MassDEP as an evaluation tool for the potential costs associated with the planned remedial activities at the GCC site. GES has evaluated the document and has provided comments on both the technical nature of the pilot study described in the ESTCP report and the overall cost analysis associated with the ISCO approach. This evaluation serves as a basis for revising costs associated with the GCC remedial program in accordance with the tasks and timelines presented in the Remedy Implementation Plan (RIP) that is currently in preparation, and due for submittal on or before September 28, 2011.

A sequential approach has been selected by GES for implementation at the GCC site. ISCO is planned for the remediation of the source area and middle plume, while enhanced anaerobic bioremediation has been selected for the downgradient portion of the chlorinated volatile organic compound (CVOC) plume, followed by MNA.

## INTRODUCTION

The ESTCP conducted a pilot study at the Launch Complex 34 (LC-34) located in Cape Canaveral, Florida. The pilot testing consisted of the remediation of dense non-aqueous phase liquids (DNAPL) through sequential in-situ chemical oxidation (ISCO), biostimulation, and bioaugmentation. The report was prepared in June 2010. Potassium permanganate ($KMnO_4$) was utilized for the ISCO pilot study.

A number of research-oriented technology demonstrations have been conducted at the LC-34 location, including the performance evaluations of ISCO using potassium permanganate, six-phase heating (SPH), steam injection, bioaugmentation, and emulsified zero-valent iron (EZVI). The treatment areas had considerable overlap. The potential effects of the different technological approaches to the indigenous microbial communities were not addressed in the report. For example, in 1999, a demonstration of ISCO using permanganate at LC-34 was completed in a 75 feet x 50 feet test plot. During the demonstration, 842,985 gallons of a $KMnO_4$ solution (typical concentration of 1.4% to 2%) was injected into the ISCO test plot through a drive-point injection system. The total mass of $MnO4^-$ used during the demonstration was 68,479 kilograms (kg). Detailed measurements of the mass of TCE in the demonstrations area were not performed. In addition, no direct measurements of oxidation-reduction potential (ORP) were conducted during the pilot study and ESTCP relied on the dissolved iron and manganese to demonstrate that groundwater ORP was generally reducing.

The main objectives of the sequential technology pilot study were to assess the technical feasibility of the sequential application of ISCO and in-situ bioremediation (ISB), to evaluate the effects of the combined treatment on overall cost and performance, and to identify the optimal timing of the transition from ISCO to ISB.

The cost-benefit of ISCO diminishes as the mass of target chemicals decreases, particularly where low permeability zones limit mass transfer. According to ESTCP, the results of a technology status review of in-situ oxidation technology demonstrations indicated that rebound of CVOC concentrations was observed at many ISCO sites, and that re-application of the oxidant or implementation of a secondary polishing technology was required. Based on the current status of the technology, it appears that the most effective application of ISCO consists of the rapid destruction of the readily accessible target chemical mass within the source area coupled with a less costly and more passive in-situ remediation approach to control the remaining mass (e.g., ISB or natural attenuation).

ESTCP noted that technical problems limited the ability of the pilot study to meet fully the set program objectives. For example, biofouling caused significant downtime during operations and a series of hurricanes limited the pilot study implementation. The pilot study demonstration was terminated earlier than planned.

## TECHNOLOGY APPROACH

According to ESTCP, bioremediation, generally thought to be of limited effectiveness in DNAPL source areas[1], results in a lower mass transfer enhancement than ISCO but requires only the addition of a dilute nutrient solution (i.e., minimal operating cost) while ISCO, which can result in a relatively large mass transfer enhancement, requires the addition of concentrated permanganate solution (i.e., high operating cost). Strategically coupling these technologies to match the rate of DNAPL mass removal from the source may be used to minimize the lifetime cost of source area remediation.

After the initial phase of ISCO, in which the rate of DNAPL removal is very high, the rate typically decreases to the point that it does not increase the rate of DNAPL removal over that expected by flushing the source area with groundwater only. Accordingly, applying a lower cost remediation technology is appropriate. The switchover point may be determined based on either the total rate of DNAPL removal (as determined by either measurement of concentrations of the parent compound or chloride, an oxidation reaction product) or by comparison to the background chloride concentration.

Although ISCO involves the comparatively high operating cost of continuous oxidant addition, this technology can result in up to 40-fold enhancements of the DNAPL removal rate[2].

Residual permanganate in the target treatment zone may directly impact ISB by inhibiting reductive dechlorination and reacting with the electron donor. Through disinfection, ISCO will reduce the microbial numbers. If the remaining biomass is not sufficient to support reductive dechlorination processes, longer periods of electron donor addition will be required. However, removal of the indigenous biomass *may* [italics added] enhance subsequent bioaugmentation of the treatment zone by decreasing the competition for electron donors.

GES Comment: Test data from a variety of ISCO applications at hazardous waste sites has shown that although microbial populations decline after the initial ISCO applications, the populations rebound after acclimatization. Research has shown that although microbial communities may potentially be adversely affected by chemical oxidation in the short term, a rebound of microbial biomass and/or bioremediation activity can be expected.[3] The above

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[1] Pankow, J.F. and J.A. Cherry. 1996. Dense chlorinated solvents and other DNAPLs in Groundwater. Waterloo Press.

[2] Schnarr, M.J., C.L Truax, G.J. Farquhar, E.D. Hood, T. Gonullu, and B. Stickney. 1998. Laboratory and field experiments using potassium permanganate to remediate trichloroethylene and perchloroethylene DNAPLs in porous media. *Journal of Contaminant Hydrology*, 29(3):205-225.

[3] Jason Sahl, Junko Munakata-Marr (2006): The effects of *in situ* chemical oxidation on microbiological processes:

ESTCP comment is a broad-sweeping generalization and does not take into account the robust nature of indigenous microbial populations, the diversity of the myriad of consortia that have established and adapted to site conditions and contaminant levels, nor their natural rebound with time or after biostimulation.

## PREVIOUS TESTING OF THE PROPOSED TECHNOLOGICAL APPROACH

According to ESTCP, to date, a limited number of laboratory investigations have evaluated the impacts of ISCO on microbial populations and dechlorinating activity. ESTCP summarized the following:

- Reductions in indigenous populations of aerobic and anaerobic heterotrophs, nitrate, nitrite, and sulfate reducers, and methanogens following permanganate treatment ranged from 47% to 99.95%[4]. Results from six months after treatment suggest that the population of heterotrophic aerobic microorganisms rebounded although anaerobic heterotrophic microorganisms had minimal regrowth.

GES Comment: The test data clearly showed that heterotrophic aerobic microorganisms rebounded while anaerobic heterotrophic organisms displayed minimal growth. While laboratory microcosm evaluations are deemed appropriate and important as a scientific investigatory tool, the maintenance of anaerobic populations is difficult to control even in a laboratory environment. Several new studies have been conducted since 2001. The data cited is a decade old.

- Azadpour-Keeley[5] reported on microbial sampling conducted to evaluate the effects of ISCO testing at the pilot testing site LC-34 in Cape Canaveral, Florida, and showed that biomass had increased markedly from pre-ISCO levels at one month post-ISCO, but then returned to pre-ISCO levels over the remainder of the monitoring period.

GES Comment: The Azadpour-Keely report clearly showed that biomass had increased markedly from pre-ISCO levels, but then returned to pre-ISCO levels over the remainder of the monitoring period. This information indicated that the diverse microbial population in the subsurface rebounded after the ISCO injections and then returned to equilibrium during the monitoring period. After the microbial populations re-established, the predator populations also re-established, including viruses, bacteriophage, and protozoa. The ESTCP study did not evaluate the predator populations prior to and after the ISCO injections. This report is seven years old.

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A review. *Remediation Journal*, Volume 16, Issue 3, pages 57–70.

[4] Klens, J., D. Pohlmann, and D. Graves. 2001. The effects of permanganate oxidation on subsurface microbial populations, in the proceedings of the *Sixth International In Situ and On-Site Bioremediation Symposium*, San Diego, CA, June 4-7, 2001.

[5] Azadpour-Keeley, A., L.A. Wood, T.R. Lee, and S.C. Mravik. 2004. Microbial responses to in situ chemical oxidation, six-phase heating, and steam injection remediation technologies in groundwater. Remediation, Autumn, 2004.

- Macbeth[6] used microbial community profiling and quantitative polymerase chain reaction (QPCR) testing to track *Dehalococcoides* (D*hc*)-like species prior to and one year following $MnO4^-$ injection. Decreases in both biomass and diversity were observed, but these partially recovered one year after residual $MnO4^-$ concentrations had decreased. *Dhc* was found to be present at low levels in the treatment area post-ISCO.

GES Comment: QPCR methods have improved since 2005. QPCR methods rely on end-point analyzes, which can be misleading due to product inhibition, enzyme instability, and a decrease of reaction components in time. Testing to track D*hc*-like species most likely resulted in weighted data. The laboratory study did show that biomass and diversity did recover after the ISCO concentrations had decreased.

- At least one microcosm study of sequential ISCO and bioremediation[7] suggests that ISCO does not intrinsically inhibit the dechlorinating activity of the microbial population.

GES Comment: This provides an argument that bioaugmentation is unnecessary following ISCO injections.

- In summary, ESTCP concluded that although there are a number of laboratory that suggest that application of ISCO may have no long-term impacts upon a follow-on ISB application. However, while these studies have shown that biomass returns post-ISCO, they have not clearly demonstrated a return of microbial activity resulting in dechlorination of chlorinated VOCs.

GES Comment: The cited laboratory studies evaluated microbial responses to ISCO injections, six-phase heating, and steam injection technologies. In addition, the laboratory studies and microbial community profiling were conducted using testing techniques shown to have limitations. The cited references did not specifically investigate the ability of rebounding microbial populations with regard to the dechlorination of chlorinated VOCs.

## TREATABILITY AND LABORATORY STUDY RESULTS

Prior to initiating the sequential technology pilot study demonstration at LC-34, a number of pre-demonstration tasks were conducted that included pre-design treatability studies. The laboratory treatability studies indicated that:

- Complete dechlorination occurred only in microcosms bioaugmented with KB-1. However, stoichiometric conversion of the amended TCE to ethane was slower in microcosms that were pretreated with permanganate.

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[6] Macbeth, T.W., L.N. Peterson, R.C. Starr, K.S. Sorenson Jr., R. Goehlert, K.S. Moor. In press. ISCO impacts on indigenous microbes in a PCE-DNAPL contaminated aquifer. In the proceedings of the *Eighth International Symposium of In-Situ and On-SiteBioremediation*, Baltimore, Maryland, June 6-9, 2005.

[7] Rowland, M.A., and G.R. Brubaker. 2001. Effects of potassium permanganate oxidation on subsurface microbial activity. In: Proceedings of the *Sixth International In Situ and On-Site Bioremediation Symposium*, San Diego, CA, June 4-7.

GES Comment: The above-mentioned laboratory study was included as Appendix C of the ER-0116 Final Report prepared by Geosyntec. The Web version of the report did not include the appendices. Laboratory microcosm studies may not be representative of field conditions due to the controls and procedures employed during the studies. Geosyntec is a known proponent of bioaugmentation methods and procedures. GES personnel are knowledgeable of the Geosyntec approach and have conducted oversight on a chlorinated solvent site in Massachusetts where bioaugmentation methods were employed by Geosyntec. The Massachusetts study was not successful.

## MICROBIAL CHARACTERIZATION

An extensive program of microbial characterization was completed using samples collected at the end of the baseline, biostimulation, and bioaugmentation phases of the demonstration. Detailed reports for each of these three studies were included in the Geosyntec Final Report, Appendix M.

GES Comment: We could not locate Appendix M in the final report or on Web.

Key results of the baseline microbial characterization study, using samples collected from the Test Plot and a background Control Plot, include:

- Biomass density in the Test Plot appears to be approximately two-fold higher than the biomass density in the Control Plot.

GES Comment: A clear delineation of the test plot and control plot was not presented. Several technologies have been applied at the LC-34 site in the past. Any potential impact to the control plot from previously implemented pilot studies and technology applications was not clearly presented.

- There were significant differences in the microbial community structure between the Test and Control Plots. The Test Plot community includes members of the *Acinitobacteria*, *Acidovorax,* and *Symbiobacterium,* which were not detected in the Control Plot. The microbial community in the Control Plot appeared to be dominated by members of the gamma subdivision of the Proteobacteria and, more specifically, Pseudomonas species, a number of which were not present in the Test Plot.

GES Comment: See previous comment. A clear delineation of the test plot and control plot was not presented. In addition, Pseudomonas is a common soil bacterial species and responds robustly to biostimulation methods, including ethanol which was injected during the sequential technology pilot study. The microbial community analytical testing methods require further scrutiny and evaluation.

- DNA from *Dhc* organisms is present in the Test Plot; however, only bacteria from Control Plot samples exhibited dechlorinating activity. Dechlorination activity in the ISCO Test Plot was strongly inhibited, even after over 276 days of incubation.

GES Comment: The DNA analysis and microbial community analytical testing methods require further scrutiny and evaluation.

- *Dhc* microorganisms were not detected; however, organisms at two thirds of the sample locations completely dechlorinated TCE to ethene, indicating that these organisms were present at an initial cell density below the detection limit of the *Dhc* PCR method.

GES Comment: ESTCP cited that D*hc* bacteria are the only dehalorespiring bacteria capable of completely dechlorinating TCE to ethene. However, although *Dhc* were not detected, organisms at two thirds of the sample locations completely dechlorinated TCE to ethane. ESTCP concluded that the initial cell density was below the detection limit of the D*hc* PCR method. However, other mechanisms may be responsible for the dechlorination including anaerobic oxidation, anaerobic cometabolic processes, or a variety of microbial consortia working in tandem on the various daughter products.

- A definitive evaluation of the ability of ISB to enhance mass flux following ISCO to achieve continued source treatment cannot be made from this demonstration. However, the increase in dechlorination product mass flux does suggest that a sequential ISCO-ISB remedy can allow plume containment, which would be beneficial in reducing plume extent and associated monitoring and remediation costs.

GES Comment: The demonstration was terminated prematurely. Mass flux quantification could not be made from the demonstration results. In addition, the survivability of the introduced microorganisms during the bioaugmentation component of the pilot testing was never adequately determined.

**COST ASSESSMENT**

Costs were tracked by project milestones that were defined at the start of the demonstration in the on-line ESTCP project financial tracking system. According to ESTCP, the unit costs incurred during the demonstration are much higher than those likely to be experienced during full-scale implementation due to (1) the small scale of the demonstration, (2) the extensive monitoring effort, and (3) the implementation of a groundwater recirculation system.

The principal cost drivers for the sequential technology include the costs of:

- Infrastructure, including injection well drilling and installation, aboveground piping, and process instrumentation; and
- O&M, including potassium permanganate injection, electron donor injection, labor required for the annual injection events, performance monitoring, and reporting.

ESTCP concluded that the unit costs of the demonstration were high as compared to that anticipated for a typical site and that costs for alternative ISCO and ISB approaches may differ from those presented in the Final Report. For example, use of batch injection approaches for both technologies may result in lower infrastructure costs as compared to recirculation approaches but provide less hydraulic control. The selection of oxidant and electron donor will also impact costs.

***Cost Comparison***

The ESTCP cost of full-scale source remediation was assessed by comparing the lifetime costs of sequential ISCO/ISB to the following technologies for a theoretical site:

- *Pump-and-treat:* Contain groundwater in the source area using groundwater extraction wells and ex-situ VOC treatment;
- *ISCO:* Remove VOC mass from the source area using the injection of a concentrated solution of permanganate followed by monitored natural attenuation (MNA); and
- *ISB:* Contain groundwater in the source area and/or remove VOC mass using rapid biodegradation (ISB).

***Cost Basis***

Costing parameters are based on a theoretical site with dimensions of 100-feet long by 100-feet wide. The corresponding source area is assumed to contain 1,500,000 gallons of TCE-impacted groundwater, with the TCE source zone present from 10 to 80 feet bgs. The geology in the source area includes a sand unit from 10 to 40 feet bgs, and a silty sand unit from 40 to 80 feet bgs. The corresponding mass of impacted soil is 35.7x106 kg (porosity 0.3, bulk density 1800 $kg/m^3$).

The total mass of TCE (dissolved, sorbed, and as DNAPL) in the source area is 12,500 pounds, and the average groundwater concentration existing in the source area is 175 mg/L.

Capital and operating costs focus on those costs associated with the implementation of the technology and do not include costs that may be site-specific and/or equal between technologies such as regulatory approvals. The operating period of each technology was evaluated by considering the time for the source zone to be removed via dissolution using the numerical solutions.

ESTCP's cost evaluation centered on four technology applications with several general assumptions and conditions:

Alternative 1: Pump-and-Treat (P&T)
Alternative 2: Enhanced ISB
Alternative 3: ISCO and Monitored Natural Attenuation (MNA)
Alternative 4: ISCO and Enhanced ISB

***Life-Cycle Costs***

The estimated life-cycle cost for the sequential ISCO/ISB technology is based on the capital cost of the infrastructure, plus operations and maintenance (including reagents, performance monitoring and reporting) over the period of technology implementation. Total life-cycle costs of each alternative were calculated as the net present value over the estimated operating period at a real discount rate of 2.8% (Office of Management and Budget, 1992). The operating period of each technology was evaluated by considering the time for the source zone to be removed via dissolution. Based on this assessment, the P&T remedy would be expected to have an operating period of 34 years, ISB 55 years, ISCO/MNA 40 years, and ISCO/ISB 10 years. Without any remedial actions, the source would take an estimated 145 years to be removed through natural attenuation processes. Should the mass flux enhancement of ISB be as high as a factor of 10, there is a predicted decrease in the operating period to 29 years. Clearly, for a site where schedule is the strongest driver for technology selection, ISCO/ISB has a strong advantage over all other technologies.

In terms of capital costs (infrastructure only), ISB has the lowest capital costs. P&T also has relatively low capital costs, primarily due to the low flow rate required to contain groundwater in the source area (5 gpm). The ISCO and ISCO/ISB options have the highest capital costs. Long-term annual O&M costs vary by alternative. ISCO is assumed to have low long-term O&M costs associated with MNA following active ISCO application. The O&M costs for Alternatives 2 and 4, which include bioremediation, are higher since they include annual ongoing electron donor addition with an aggressive dosing strategy intended to remove contaminant mass.

Overall, Alternative 2 (ISB) offers the smallest life-cycle costs, and the costs of implementing the sequential technology (Alternative 4 [ISCO/ISB]) are somewhat lower than that of implementing ISCO alone. However, the duration of the remedy is also a critical factor for most sites, and Alternative 4 clearly offers advantages as compared to all other alternatives evaluated. The cost analysis suggests that all three aggressive in situ alternatives have lower lifetime costs than pump-and-treat, providing that they have short operating durations. While the ISCO/ISB option has a higher life-cycle cost than ISB alone, the shorter lifetime of sequential approach may make it more advantageous than ISB alone.

## IN-DEPTH ANALYSIS OF ESTCP CONCLUSIONS

The following conclusions were noted by ESTCP:

- Electron donor addition (biostimulation) after ISCO) resulted in partial biodegradation of trichlorothene (TCE) to *cis*-1,2-dichloroethene (*cis*-1,2-DCE), although bioaugmentation was needed to complete biodegradation (to low levels of ethene).

GES Comment: The pilot study was designed to be completed in three operation phases: (1) baseline with groundwater circulation only, (2) biostimulation with the addition of electron donor, and (3) bioaugmentation with the addition of electron donor and bioaugmentation with KB-1™. According to the report, each phase was operated for sufficient duration to establish a near steady-state rate of TCE removal under each of the different operating conditions. Details of the operation were not provided in the final report. Although biostimulation was employed during the biostimulation and bioaugmentation phases of the pilot testing (ethanol amendments), the potential effect of the biostimulation on the indigenous microbial populations was not clearly identified. In addition, the survivability of the introduced organisms was not fully documented or demonstrated.

- The precipitated manganese dioxide ($MnO_2$) produced by permanganate reduction did not abiotically degrade any of the chloroethenes or ethane. $MnO_2$ can be dissolved by the activity of Mn(IV)-reducing bacteria that appear to preferentially utilize hydrogen and thus inhibit the activity of dechlorinating bacteria such as *Dehalococcoides* (Dhc), which use hydrogen as their sole electron donor.

GES Comment: Despite its long-term use in bioremediation, bioaugmentation of contaminated sites with microbial cells continues to be a source of controversy within the field of environmental microbiology.[8] This largely results from its notoriously unreliable performance record. Bioaugmentation has been dictated by the search for catabolically competent microorganisms, with little or no consideration given to other essential features that are required to be functionally active and persistent in target habitats. The traditional application of a particular microbial strain is an ineffective approach to enhancing bioremediation.

- The limited cost assessment indicated there was a significant cost and schedule advantage for the sequential treatment strategy when compared to P&T, or the use of ISCO alone (assuming a reasonable mass flux enhancement can be achieved during ISB).

GES Comment: The pilot study approach (sequential ISCO and ISB) was compared to P&T technology or the ISCO alone approach, which is not a valid approach. For the purposes of a cost evaluation, ISCO and ISB should be compared against a variety of remedial technologies. ESTCP also indicated that the cost assessment for the pilot study was limited. This statement also introduces uncertainty in the costing approach and evaluation.

- Unfortunately, little is known regarding impact of ISCO on groundwater chemistry and indigenous microbial populations. Specifically, the application of an aggressive oxidant such as permanganate may have adverse impacts on the indigenous microbial community such that bioremediation of the chlorinated solvents cannot be stimulated through electron donor addition alone.

- The reseeding (bioaugmentation) of the ISCO treatment area with microorganisms capable of degrading chlorinated solvents (e.g., dehalorespirers) *may* [italics added] be required to permit successful implementation of in-situ bioremediation as a polishing technology.

GES Comment: As highlighted previously, the implementation of bioaugmentation at contaminated sites with microbial cells continues to be a source of controversy within environmental microbiology. The survivability of introduced organisms remains in question at many pilot study demonstrations.

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[8] Thompson, IP and van der Gast, CJ and Ciric, L and Singer, AC (2005): Bioaugmentation for bioremediation: the challenge of strain selection. *ENVIRON MICROBIOL*, 7 (7) 909 - 915.

## COMPARISON OF THE GES APPROACH TO THE ESTCP COST AND PERFORMANCE ANALYSIS

The sequential approach has been selected by GES for implementation at the GCC site. ISCO using sodium persulfate and a hydrogen peroxide catalyst is planned for the remediation of the source area and middle plume while enhanced anaerobic bioremediation has been selected for the downgradient portion of the CVOC plume, followed by MNA.

On the basis of the understanding of site conditions at the time, GES provided a general budgetary estimate totaling $592,000. The selected remedial technology applications are expected to make significant progress toward closure. GES also recommended that a 25 percent contingency be added to address conditions that may be encountered during the progression of the proposed work. Therefore, our budgetary estimate with contingency was $740,000. As with all projects of this magnitude, the work scope and cost estimate will be evaluated, and revised as necessary, once the initial phase of the ISCO program is completed. More specifically, the 25 percent contingency included costs associated with follow-up ISCO injections and the design and implementation of an enhanced anaerobic bioremediation pilot study that will effectively address the downgradient portion of the dissolved-phase plume.

Based upon discussions with GCC and MassDEP, the overall project costs have been increased to reflect additional tasks and regulatory recommendations.

As noted in the ESTCP report, the cost-benefit of ISCO diminishes as the mass of target chemicals decreases, particularly where low permeability zones limit mass transfer. Therefore, GES estimates that only two or three ISCO injection events will be conducted in the source area and middle plume.

A direct comparison of the ESTCP cost and approach to the proposed technology implementation at the GCC site is difficult since the general assumptions and conditions inherent in the ESTCP sequential technology pilot study and the associated costs will not or do not apply. For example, the ESTCP sequential technology pilot study was based on:

- Costing performed for a theoretical site;
- TCE source zone present from 10 to 80 feet bgs;

  (GCC site source zone is approximately 20 to 40 feet bgs)
- Capital and operating costs focus on those costs associated with the implementation of the technology and do not include costs that may be site-specific and/or equal between technologies such as regulatory approvals;
- The actual contaminant mass at the GCC site may be significantly lower than the mass flux estimated for the total remedy cost evaluation provided in the ESTCP report;
- The GES-proposed ISCO technology application is more aggressive than that utilized for the ESTCP sequential technology pilot study;

- The operating period of each technology was evaluated by considering the time for the source zone to be removed via dissolution using the numerical solutions; and
- The ISCO and enhanced anaerobic bioremediation approaches at the GCC site will involve batch injections that will result in lower infrastructure costs as compared to recirculation approaches (for hydraulic control) utilized in the ESTCP pilot study.

GES originally estimated costs for two ISCO injections using persulfate in the source area at approximately $500,000. Given the size of the GCC site source area, the proposed estimate was considered reasonable and defensible. While the GES cost estimate did not include the entire life-cycle remediation costs, Massachusetts Contingency Plan (MCP)-related costs, or other associated costs at this time including full-scale anaerobic bioremediation application or long-term MNA costs, the estimate also did not include the majority of the remedial and MCP-related start-up costs, much of which has already been spent during the last two months (primarily assessment, laboratory analyses, public relations, and remediation coordination) or will be spent during the next couple of months. If weather conditions are favorable and the comment/response period for the RIP is concluded shortly after the 30-day period, GES anticipates that the first ISCO injection event will be conducted in December 2011.

The ESTCP report estimated the source area ISCO recirculation with 85% removal followed by MNA approach cost to be $2,801,206. The source area ISCO recirculation with 85% removal followed by source area bioremediation approach cost was estimated at $2,613,724.

GES not believe that these costs developed for a theoretical site and based on several general assumptions and conditions to be directly comparable to the General Chemical facility. At best, the data provides a roadmap to potential destinations, some of which are more realistic than others. Furthermore, the technology pilot study was implemented in a manner that is not consistent with typical commercial practices as pointed out by ESTCP; that is, the pilot study level of effort with regard to laboratory analyses was far greater than anticipated for a commercial remedial effort. In addition, the ESTCP cost analysis was based on the time for the source zone to be removed via dissolution using the numerical solutions.

Additional costs of approximately $85,000 will be realized for the full-scale implementation of the GES proposed enhanced anaerobic bioremediation technology. In addition, costs will be incurred for implementation and reporting for a MNA program (over a 10-year period) and for follow-up MCP submittals. Based on the Cost Re-Evaluation Table provided as an attachment the estimated costs for tasks presented in the RIP were estimated at $1,129,000.

In closing, the intent of this letter is to convey that the GCC site is not readily comparable to the ESTCP example site by the detailed rationale provided above, and the RIP to be implemented at the GCC site is based on knowledge of site-specific conditions. GES trusts that the above information provides more the detailed back-up requested by MassDEP in support of implementing the RIP.

Sincerely,

Stefan C. Sokol, LSP
Senior Project Manager

Felix A. Perriello, CHMM, CPG, LSP, LEP
Site Operations Manager

Attachment

Cost Re-Evaluation and Proposed Implementation Schedule

cc: M. Persico/GCC

**Cost Re-Evaluation and Proposed Implementation Schedule**
**General Chemical Corporation Site**
**133 - 135 Leland Street, Framingham, MA**

| **Remediation Related Costs** | | |
|---|---|---|
| **Tentative Implemenation Date** | **Task Description** | **Best-Case Cost Estimate** |
| 11/15 - 12/2/11 | Coordinate, prepare and install ISCO injection wells and SVE wells on GCC property | $ 60,000 |
| 12/6 - 12/9/11 | Pre-injection sampling | $ 6,500 |
| 12/12 - 12/23/11 | 1st two weeks of ISCO injections of Area 1 on GCC property (**17 injection wells**)# | $ 210,000 |
| 1/23/ - 1/30/12 | 30-day post-injection sampling/combine with January quarterly sampling event | $ 8,500 |
| 4/2 - 4/20/12 | Baseline prior to 2nd ISCO injection of Area 1/combine with April quarterly sampling event | $ 7,500 |
| 5/7 - 5/18/12 | 2nd two weeks of ISCO injections of Area 1 on GCC property* | $ 225,000 |
| 6/1 - 6/10/12 | Anaerobic pilot test well installation | $ 4,000 |
| 6/18 - 6/22/12 | 2nd 30-day Post-Injection Monitoring Event/combine with anaerobic test baseline sampling | $ 7,500 |
| 7/2 - 7/31/12 | Coordinate, prepare and install injection wells on CSX property, additional area sentinel wells. | $ 16,000 |
| 7/2 - 7/16/12 | Anaerobic bioremediation pilot test | $ 48,000 |
| 7/11-7/15/12 | July quarterly sampling event | $ 4,000 |
| 8/1 - 8/7/12 | Pre-injection sampling and anaerobic pilot test sampling | $ 6,000 |
| 8/13 - 8/24/12 | 3rd two weeks of ISCO injections – first time at Area 2 (railroad ROW, **10-12 injection wells**) | $ 120,000 |
| 9/26 - 10/4/12 | 3rd 30-day Post-Injection Monitoring Event/combine with October quarterly sampling event | $ 8,500 |
| 1/7 - 1/11/13 | January quarterly sampling event | $ 4,000 |
| 4/1 - 4/15/13 | Anaerobic bioremediation implementation for downgradient plume | $ 85,000 |
| 4/25 - 4/30/13 | Follow-up anaerobic sampling/combine with April quarterly event (quarterly schedule thereafter - see MCP costs below) | $ 6,000 |
| **Total Estimated Costs - Remediation**** | | **$ 826,500** |

| **MCP Compliance Related Costs** | |
|---|---|
| **Description** | |
| Comprehensive Sampling Events (4-6 events over 10 years) | $ 66,000 |
| Quarterly Sampling for key monitoring wells over an estimated 10 year period and reported in I&M status reports - Events when comprehesive sampling not performed | $ 93,500 |
| I&M Status Reports over an estimated 10 year period | $ 90,000 |
| Final Inspection Report | $ 15,000 |
| Other MCP Reporting (including RAO, Risk Characterization Updates, etc.) | $ 38,000 |
| **Total Estimated Costs - MCP Compliance** | **$ 302,500** |
| **Combined Estimated Total Costs** | **$ 1,129,000** |

**Assumptions:**

1. Does not include costs related to subsurface investigation, comprehensive sampling event and RIP preparation currently in excess of $100,000.
2. Includes 2-3 ISCO injection events and follow-up sampling.
3. Considers that ISCO will focus on source area and middle plume (potentially to the area of the MWRA aqueduct), and enhanced anaerobic bioremediation will address impacts south of the Exelon access road .
4. Schedule based on tentative RIP approval date of October 28, 2011 considering a 30-day review period following the September 28, 2011 submittal.
5. Assumes initial and post-injection monitoring can occur in winter given all initial injection locations should be accessible on the GCC property. Downgradient wells immediately beyond the GCC property will be marked in the field prior to winter.
6. Assumes effective implementation of ISCO with sodium persulfate without change in ISCO chemistry.
7. Costs are not included for DNAPL remediation should it found to be required at some future date. DNAPL was not detected in wells sampled during the recent comprehensive groundwater sampling event.
8. Costs for Activity and Use Limitations, if required as part of the closure plan, are not included.
9. Drilling costs included use of two rigs to expedite the install.
10. ISCO well screens are patented, and require 3-week lead time for order.

**Notes:**

# Schedule dependent upon weather conditions and a rapid conclusion to the comment/response period

* A third ISCO injection event, if required, in Area 1 would be an additional $225,000

** An ISCO injection event in Area 3 (near CDW-64, **4-6 injection wells**) would be an additional $55,000