AECOM Environment

Prepared for:
NYSDEC
625 Broadway
Albany, NY 12233

Prepared by:
AECOM
Latham, NY
Project 60279080
March 2013

Enhanced In-Situ Bioremediation Pilot Study Work Plan Former Duso Chemical Site Poughkeepsie, New York NYSDEC Site # 3-14-103

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Engineering Certification

I certify that I am currently a New York State registered professional engineer and that this Enhanced In-Situ Bioremediation Pilot Study Work Plan for the Former Duso Chemical Site (Site Number # 3-14-103) was prepared in accordance with all applicable statutes and regulations and in substantial conformance with the DER Technical Guidance for Site Investigation and Remediation (DER-10).

Respectfully submitted,

AECOM Technical Services Northeast, Inc.

March 27, 2013

Daniel Servetas — Date
Registered Professional Engineer
New York License No. 079068

1.0 Introduction

This Enhanced In-Situ Bioremediation (EISB) Pilot Study Work Plan has been prepared for the Former Duso Chemical site (Site), a Class 2 inactive hazardous waste disposal site, by AECOM Technical Services Northeast, Inc. (AECOM) for New York State Department of Environmental Conservation (NYSDEC). The NYSDEC reference number for the site is 3-14-103. This design document has been prepared in accordance with the Record of Decision (ROD) issued by the NYSDEC in March 2008.

1.1 Site Background

The pilot test described in this work plan will be implemented on the Former Duso Chemical property, where the site was historically occupied by the Duso Chemical Company. As a result of a chemical fire and historic site operations, releases of various volatile organic compounds (VOCs) occurred to the environment.

Goals for the remedial program were established in the ROD through the remedy selection process stated in 6 NYCRR Part 375. At a minimum, the remedy selected must eliminate or mitigate all significant threats to public health and the environment, presented by the hazardous waste disposed at the site through the proper application of scientific and engineering principles. As defined in the ROD, the remediation goals for this site are to eliminate or reduce to the extent practicable:

- Exposures of persons at or around the site to VOCs in soil and groundwater;
- The release of contaminants from the saturated soil into groundwater that may create exceedances of groundwater quality standards; and
- The release of contaminants from groundwater into indoor air through soil vapor intrusion.

Further, the remediation goals for the site include attaining to the extent practicable:

- Commercial soil criteria; and
- Ambient groundwater quality standards

1.2 Pilot Test Objectives

The objective of the pilot study described herein will be to evaluate the field-scale effectiveness of implementing EISB via reductive dechlorination for reducing concentrations of chlorinated VOCs (CVOCs) in groundwater. The pilot test will be evaluated by the following performance objectives:

- Achieve satisfactory distribution of the carbon substrate solution into the subsurface;
- Establish and maintain anaerobic (reducing) conditions in the subsurface throughout the targeted treatment area; and
- Reduce CVOC concentrations in groundwater and soils and/or observe the formation and subsequent decrease of biodegradation daughter products.

Performance data collected during implementation will be compared to historical data and evaluated against the performance objectives. EISB will be implemented with the objective of meeting the goals of the ROD.

2.0 Site History and Description

The Former Duso Chemical Site is defined as the approximately three-acre triangle-shaped property located located off of Route 9 at 33 Fulton Street, in the City of Poughkeepsie, New York . A site plan is included as **Figure 1**.

2.1 Site History and Regulatory Conditions

The site was occupied by the Duso Chemical Company, a distributor of bulk chemicals from 1950 through 1963. In 1963, a chemical fire occurred at the Duso Chemical Company warehouse and is believed to have resulted in a large scale release of various VOCs to the environment. In 1990, the Duso Chemical property was purchased and Star Gas Products, Incorporated subsequently began operating there. Immediately to the west of the Former Duso site is the Mid Hudson Business Park (MHBP), which has a long industrial past including automobile manufacturing operation by FIAT between 1910 and 1917 and various operations by West & Publishing after 1935. Elevated levels of chlorinated solvents were detected in the soil and groundwater at MHBP during an investigation in 1990. The investigation revealed the origin of the contamination to be the Former Duso Chemical property. In April of 1999, the NYSDEC listed the Former Duso Chemical property as a Class 2 site in the State's Registry of Inactive Hazardous Waste Disposal Sites. A Class 2 site is a site where hazardous waste has been deemed to pose a significant threat to the public health or the environment, and action is required.

A Remedial Investigation (RI) was initiated for the Former Duso Chemical Site in 2005 and conducted in several phases. The first phase was conducted from June to August of 2005 and a second sampling event was conducted in March of 2007. A Feasibility Study (FS) was developed in the fall of 2007. NYSDEC prepared the ROD in March 2008 based on the findings of the RI and the FS.

An Interim Remedial Measure (IRM) was conducted at the Former Duso Chemical site to address the source of contamination or exposure pathway from elevated soil vapor levels before completion of the RI/FS. The detected levels of tetrachloroethene (PCE) and trichloroethene (TCE) in the sub-slab and indoor air samples of the Star Gas building were above New York State Department of Health (NYSDOH) guidance for the protection of human health. Thus mitigation measures were undertaken in the form of a sub-slab depressurization system (SSDS) for the Star Gas facility which aimed to address current human exposures (via inhalation) to volatile organic compounds associated with soil vapor intrusion. The system was installed in February of 2006. Confirmatory samples were collected to ensure that the SSDS was operating effectively. The concentrations of all compounds of concern in indoor air were reduced to below their respective action levels.

2.2 Current Site Features and Use

The property is currently operated by Star Gas Products, Inc., a propane distribution facility. There are three buildings, a shed, and an above ground storage tank located on the site currently (**Figure 1**). The topography of the site and surrounding properties is relatively level, sloping gently to the west. A steep embankment borders the property to the east and a former railroad track bed and intermittent stream/swale border the property to the west. The site is located within a mixed neighborhood of commercial establishments and residential properties.

2.3 ROD-Selected Remedy for Former Duso Chemical Site

Goals for the remedial program were established in the ROD through the remedy selection process stated in 6 NYCRR Part 375. At a minimum, the remedy selected must eliminate or mitigate all significant threats to public health and the environment, presented by the hazardous waste disposed at the site through the proper application of scientific and engineering principles.

The remediation goals for this site are to eliminate or reduce to the extent practicable:

- Exposures of persons at or around the site to VOCs in soil and groundwater;
- The release of contaminants from the saturated soil into groundwater that may create exceedances of groundwater quality standards; and
- The release of contaminants from groundwater into indoor air through soil vapor intrusion.

Further, the remediation goals for the site include attaining to the extent practicable:

- Commercial soil criteria as defined in 6 NYCRR Part 375; and
- NYSDEC "Ambient Water Quality Standards and Guidance Values" for groundwater

Based on the Administrative Record in the ROD, NYSDEC selected EISB for the former Duso Chemical property and in-situ thermal treatment for the MHBP property, as the remedies. The selected remedy was based on the results of the RI and the evaluation of alternatives presented in the FS. These technologies were selected because they satisfy the threshold criteria, provide the best balance of the primary balancing criteria of the FS, achieve the remediation goals for the site by reducing the residual source material at the site, and creating conditions conducive to the restoration of groundwater quality to the extent practicable.

EISB via reductive dechlorination is a remediation technology applied for treating CVOCs in groundwater. Through the process of biologically-mediated reductive dechlorination, CVOCs are transformed through a series of sequential biochemical reactions where chloride atoms are replaced by hydrogen atoms by naturally occurring bacteria under reducing conditions to eventually form non-toxic ethene and less toxic chloroethane (see Appendix D, Figure 1).

PCE → TCE → cis-1,2-dichloroethene → vinyl chloride → ethene

1,1,1-trichloroethane → 1,1-dichloroethane → chloroethane

1,1-dichloroethene → vinyl chloride → ethene

These biologically-mediated reactions occur favorably in anaerobic (negligible dissolved oxygen), reducing (oxidation reduction potential or ORP is less than -75 millivolts [mV]), circum-neutral (pH between 6.0 and 8.5) groundwater. Current groundwater conditions beneath the Former Duso Chemical Site are slightly aerobic to slightly reducing (ORP between -57 and 40 mV, DO between 0.4 and 3.0 milligrams per liter [mg/L]); limited reductive dechlorination is occurring or has occurred based on the detection of dechlorination daughter products, but conditions are not ideal for reductive biodegradation. Remediation will be performed by modifying groundwater geochemistry to create reducing conditions that are conducive to the progressive dechlorination of CVOCs by bacteria through the addition of a carbon substrate, which serves as a source of an electron donor (hydrogen) and a microbial energy source. As the naturally-occurring microbial population utilizes the added carbon substrate (electron donor), dissolved oxygen in groundwater will be consumed and generation

of anaerobic reducing conditions will proceed. These reducing conditions, along with the presence of electron acceptors enable the reductive dechlorination process to occur.

Anaerobic microbial dechlorination of chloroethane is not a pathway that has been observed in bench- or field-scale studies. However, chloromethane, as well wel 1,1,1-TCA, has been observed to be biodegraded by aerobic methane-oxidizing bacteria. Methane generated as a result of addition of carbon substrate may support natural attenuation of the chloroethane as groundwater conditions return to baseline.

Per the ROD, the EISB selected remedy for the Former Duso Chemical property would be implemented using the following approach:

- Characterization of groundwater geochemistry (inorganic and organic), the oxidation-reduction (redox) conditions, and bacterial populations in site groundwater.
- Bench scale testing to evaluate biological processes for treatment of site VOCs.
- Application of soluble electron donors to the groundwater beneath the site.
- Evaluation of EISB performance by post-injection geochemical and biological groundwater monitoring as part of the Site Management Plan.

Groundwater characterization and bench scale testing was performed in 2011 through 2012. Details are provided in Sections 2.4 and 3.4, respectively.

A remedial component to treat source areas by in-situ thermal remediation will be designed for the adjacent MHBP site. In addition, institutional controls in the form of an environmental easement may be implemented as part of the selected remedy.

2.4 2012 Supplemental Investigation

In August 2012, 12 additional 2-inch PVC monitoring wells were installed at the Former Duso Chemical Site, including five multi-level pairs (BIW-1S/D, BIW-2S/D, BIW-3S/D, BIW-5S/D, and BIW-6S/D) and two singlet wells (BIW-4 and BIW-7), as shown on **Figure 1**. The new monitoring wells were developed, after at least seven days following construction, and sampled using low-flow methods in November 2012. In addition to the 12 new wells, groundwater samples were also collected from wells MHC-23, MHC-25S, and MHC-26 at the Former Duso Chemical property, and a comprehensive round of groundwater sampling was performed at the adjacent MHBP property. A summary of monitoring wells sampled and laboratory analyses for each well is presented as **Table 2-1.**

The 2012 Supplemental Investigation was conducted in order to support design and planning to implement the EISB remedy for the Former Duso Chemical site, including delineating the extents requiring treatment for CVOCs, quantification of current dechlorinating bacteria, and evaluation of nutrients and competing electron acceptors for biotic reductive dechlorination reactions. Generally nitrate was not detected, or detected at very low concentrations, but sulfate was measured between approximately 2 and 80 micrograms per liter (μg/L). This combination of observations, in conjunction with numerous ORP measurements between -50 and 0 mV, indicates that site groundwater is sufficiently reducing for nitrate-reduction but not for sulfate-reducing conditions, which are favorable for reductive dechlorination to occur. Low concentrations of bacteria capable of complete dechlorination of PCE to ethene (Dehalococcoides [Dhc]) and 1,1,1-Trichloroethane (1,1,1-TCA) to ethane (Dehalobacter [Dhb]) were quantified. Dhc cell counts ranged from 2 $x10^2$ to $7x10^2$ cells/milliliter (mL), and Dhb cell counts ranged from 1 $x10^3$ to $4x10^3$ cells/mL. Cell counts greater

than 10^6 are considered favorable for in-situ reductive dechlorination. The highest cell enumerations were observed in samples from wells MHC-23, BIW-5S, and BIW-5D.

Total VOC concentrations on the Former Duso Chemical site are shown spatially on **Figure 2**. All laboratory analytical results from the 2012 investigation are presented in tabular form in **Appendix A**, along with geologic cross-sections generated from soil borings advanced in 2012 during installation of the new monitoring wells.

3.0 Basis of Design

3.1 Primary Contaminants of Concern

Groundwater and soil sampling has been conducted at the Former Duso Chemical property as part of numerous historic investigation activities. Groundwater sampling conducted in 2011 and 2012 will be given the greatest attention for design and planning of the EISB pilot test in this work plan and will be used for pre-pilot test baseline data. CVOCs are the primary contaminants of concern at the Former Duso Chemical site; specific CVOC analytes and respective NYSDEC Ambient Water Quality Standard are presented below.

Chemical	Ambient Water Quality Standard (ug/L)	Maximum Concentration (ug/L)
1,1,1-trichloroethane (1,1,1-TCA)	5	33,000
1,1-dichloroethane (1,1-DCA)	5	80,000
1,2-dichloroethane (1,2-DCA)	0.6	6,800
chloroethane	5	1,000
tetrachloroethene (PCE)	5	56
trichloroethene (TCE)	5	340
cis-1,2-dichloroethene (cis-1,2-DCE)	5	910
1,1-dichloroethene (1,1-DCE)	5	1,900
vinyl chloride (VC)	2	210

The CVOCs measured at the highest concentrations are 1,1,1-TCA and 1,1-DCA. Within the extent of the pilot test area, 1,1,1-TCA concentration was observed to range from 1,500 to 33,000 µg/L, and 1,1-DCA ranging from 590 to 80,000 µg/L.

3.2 Hydrogeologic Considerations for Pilot Test

Based on measurements collected during the Remedial Investigation (RI) for the Former Duso Chemical site [O'Brien and Gere, 2007], Supplemental Remedial Investigation (SRI) for the MHBP site [Chazen Companies, 1998] and by AECOM, the following hydrogeologic considerations will be incorporated into the design for the EISB pilot test:

- Depth to water in monitoring wells within the EISB pilot test area generally ranges from 3 to 4 feet below ground surface (bgs).
- Groundwater in the overburden beneath the Former Duso Chemical site generally flows to the west (towards the MHBP site).
- Hydraulic conductivity testing during the RI focused on the MHBP site. The results of the hydraulic conductivity testing for the unconsolidated hydrogeologic unit ranged from $9.62x10^{-5}$ cm/sec (0.27 ft/day) in well OBG-5S to $2.18x10^{-2}$ cm/sec (61.68 ft/day) in well OBG-6S. The average hydraulic conductivity estimate for the unconsolidated hydrogeologic unit is $1.44x10^{-3}$ cm/sec (4.09 ft/day).
- Hydraulic gradients in the EISB pilot study area overburden soils is estimated to be between 0.02 and 0.04 foot per foot based on a sitewide groundwater gauging event in December 2012 **(Figures 3A and 3B)**, which is consistent with sitewide hydraulic gradient reported in the RI of 0.028 to 0.039 foot per foot [O'Brien and Gere, 2007].
- Using a hydraulic conductivity of $1.44x10^{-3}$ cm/sec (4.09 ft/day), a hydraulic gradient of 0.03 ft/ft and a porosity of 0.3 result in an average groundwater velocity of 0.41 ft/day (150 ft/year).
- Soils beneath the Former Duso Chemical site, and within the EISB pilot test area, have been generalized to consist of (in descending vertical order):
    - an uppermost layer of gravelly sands (top two to four feet);
    - silty sands, beneath the gravelly sands;
    - clayey silt, beneath the silty sands, starting at approximately 20 to 24 feet; and
    - glacial till, beneath the clayey silt, but the till was not observed in most borings within the EISB pilot test area.

3.3 Conceptual Fate and Transport of Site Contaminants

The major source of VOC contamination at the Former Duso Chemical Site was the surficial release of VOCs that occurred as a result of a warehouse fire in 1963. VOC field screen sampling and analysis during the SRI observed concentrations greater than 50,000 parts per billion of 1,1,1-TCA at a depth of 2-4 feet near well MHC-22, and the highest concentrations of 1,1,1-TCA in soil at the property were detected in the portion of the site between wells MHC-22 and BIW-2S. The VOC release impacted the shallow groundwater table. CVOCs have densities greater than water, and with groundwater flow direction from east to west, CVOCs moved west and downward over time. At the western boundary of the Former Duso Chemical property, as well as the MHBP site downgradient to the west, the highest VOC concentrations in soil and groundwater are generally observed just above the transition to clayey silt. Less impacts are currently measured in shallow groundwater, compared to deeper intervals, along the western boundary of the property. Over time due to contaminant migration, dilution, and partial biodegradation by native bacteria, concentrations have decreased at the Former Duso Chemical property.

The primary chemical released from the Former Duso Chemical operations was 1,1,1-TCA. As a result of partial reductive dechlorionaion by native bacteria in the slightly anaerobic groundwater 1,1-DCA is also currently presented in the subsurface at high concentrations. 1,1-DCE measured in groundwater is an abiotic breakdown product of 1,1,1-TCA.

3.4 Extent of Pilot Test Treatment

The pilot test described in this work plan is intended to evaluate the effectiveness of EISB for treating VOC contamination in groundwater at the Former Duso Chemical property. The identified treatment extent by the EISB pilot test is shown on **Figure 4**. This area was delineated primarily using groundwater sampling results from 2011 and 2012 where total CVOC exceeded 50 ug/L in a monitoring well (**Figure 2** and **Appendix A**); sampling results from the Remedial Investigation and Supplemental Remedial Investigation were used to refine the extents. The extent of the EISB treatment area is approximately 10,200 square feet (0.25 acres). Within the eastern portion of this area (east and between the buildings), injection will target the vertical interval between the groundwater table and approximately 16 feet bgs. In the western portion of this area, VOC contamination is observed deeper, particularly immediately above and in the upper most portion of the clayey silt (transition to clayey silt observed between 20 and 22 feet bgs). In the western portion of the pilot test, injections will focus on the vertical interval from approximately 4 to 6 feet bgs to 24 to 26 feet bgs.

No injections will be completed immediately below the active buildings on the property as the combination of the injection delivery and hydraulic will allow the substrate to treat beneath the buildings. In addition, several groundwater monitoring wells with samples that exhibited low VOC concentrations in excess of the NYSDEC "Ambient Water Quality Standards and Guidance Values" in monitoring wells are not included in the pilot test treatment zone (BIW-2D, BIW-3S, BIW-6D, MHC-24, MHC-25S/D). Treatment in adjacent areas to the building and these wells, and subsequent natural attenuation, will result in decreases in VOC concentrations at these locations over time.

3.5 Bench Scale Treatability Study

SiREM Laboratory (SiREM) was retained by AECOM to perform a laboratory biotreatability study to assess the potential for natural and stimulated in-situ bioremediation of chlorinated ethenes (PCE; TCE; cis-1,2-DCE; 1,1-DCE; and VC) and chlorinated ethanes (1,1,1-TCA; 1,2-DCA; and 1,1-DCA) in subsurface samples collected from the Former Duso Chemical site.

SiREM conducted the study using groundwater and soil collected at the site from the following locations: SGSB3, MHC-22, MHC-24, and MHC-26 (groundwater); SB-1, SB-2, SB-3, and SB-4 (soil). The study consisted of a total of nine microcosms. Three microcosms were prepared using the site soil and groundwater: an anaerobic sterile control, an anaerobic active control, and an emulsified oil substrate (EOS® 598 B42) amended and bioaugmented set of microcosms. Each microcosm set was prepared in triplicate for QA/QC purposes. **Appendix D** contains the laboratory report prepared by SiREM for AECOM. The results from the study indicate the following:

1. The rate and extent of intrinsic (natural) degradation of the chlorinated ethenes and ethanes in site groundwater is limited by the lack of available electron donors and/or nutrients at the site.
2. EOS® 598 B42 amendment promoted the appropriate geochemical conditions (i.e., sulfate reducing conditions).
3. The pH of the treatment microcosms decreased only slightly following addition of EOS® 598 B42 amendment over the incubation period, reaching an average value of 6.60 after 119 days. This maintenance of suitable pH for continued bioremediation of chlorinated ethenes and ethanes suggests that application of buffering agents is not likely to be required to support enhanced reductive dechlorination at the site. Other electron

donors may also provide the same or similar results, however no other donors were tested.

4. EOS® 598 B42 supported significant increases of indigenous populations (three orders of magnitude) at levels associated with complete dechlorination of PCE to ethene (Dhc) and 1,1,1-TCA to ethane (Dhb).
5. Indigenous bacteria present at the site appear to be capable of completely dechlorinating the chlorinated ethenes to ethene, 1,1,1-TCA and 1,1-DCA to CA and partial dechlorination of 1,2-DCA with the addition of EOS® 598 B42 as the electron donor.

3.6 Permits

Injection of remedial substrates falls under the requirements of United States Environmental Protection Agency's (USEPA) Underground Injection Control (UIC) program. Currently NYS has not requested program primacy for the federal UIC program. The Former Duso Chemical Site is a state-lead site, the NYSDEC Division of Environmental Remediation (DER), or its consultant (AECOM), is responsible for making the notification to USEPA. In accordance with DER Internal Guidance Procedure 22 (IGP-22), AECOM prepared the inventory spreadsheet, which was created by USEPA Region 2 for exclusive use by NYSDEC. The inventory spreadsheet is included as **Appendix E**. Email notification was provided to USEPA Region 2 on March 13, 2013 by AECOM on behalf of by DER. It is not necessary to wait for a response from EPA, as injections used to enhance or effect remediation are generally authorized by rule and the notification is all that is required at least 30 prior days prior to commencement of direct-push injection or well construction.

4.0 EISB Pilot Test Design

This section details the design components for planning and implementing the EISB pilot test. A summary of design parameters for the EISB Pilot Study is presented in **Table 4-1**.

4.1 EISB Amendments

Several proprietary and non-proprietary reductive amendments are available for groundwater remediation including emulsified vegetable oil (EVO), Hydrogen Release Compound®, molasses, lactate, and soluble oils. Proprietary formulations include readily available carbon as well as slow-release carbon, which allows for extended time-release availability, and nutrients required for biotic growth. Variations of these products include addition of zero valent iron or reduced (ferrous) iron complexes for promotion of abiotic, chemical dechlorination in addition to biodegradation.
EOS PRO (formerly EOS® 598 B42) is a nutrient-enriched, food-grade, oil/water emulsion and will be the primary carbon substrate for the EISB pilot test. Selection was based on the following factors:

- As an EVO, the active lifetime of EOS products is approximately three to five years, which is longer than other carbon substrates used for enhanced reductive dechlorination.
- At the bench scale this carbon substrate successfully demonstrated complete dechlorination of PCE to ethene and 1,1,1-TCA to ethane in addition to supporting significant increases of Dhc and Dhb microbial populations.
- At the bench scale, minimal decrease in pH was observed with this carbon substrate.
- This is a commonly applied EVO product that is water-miscible concentrate and relatively easy to handle in the field.
- This substrate includes Vitamin B12 Supplement that provides additional nutrients to further enhance microbial activity and the rate of reductive dechlorination.
- This specific remedial substrate has been demonstrated to be effective for enhancing bioremediation of CVOCs in-situ, including on more than 10 AECOM projects.

Other electron donors may also provide the same or similar results; however, no other donors were tested in the bench-scale study (Section 3.5). During planning for the bench-scale testing, an extensive evaluation was performed of carbon substrate options, including reviewing literature and AECOM case studies and discussions with the treatability lab and vendors, and EOS was chosen balancing the site objectives with the advantages and disadvantages of each amedment option. Following the excellent bench-scale results, other donors were evaluated; however, implementation with a substrate demonstrated to attain treatment for site materials, compared with an un-tested substrate, was a critical decision factor in selecting EOS Pro as the primary carbon substrate.

A second carbon substrate source will be applied to the portion of the pilot test area with the highest concentrations of CVOCs (greater than 100,000 µg/L, target blue injection subarea on **Figure 4**). EHC consists of a controlled-release organic carbon of fibrous organic material in addition to zero valent iron (ZVI). EHC, like EOS, has persistence after injection of three to five years. The reduced iron generates highly reducing conditions, and accelerates the creation of conditions favorable for reductive dechloration. In addition, the added ZVI reacts directly with CVOCs by an abiotic process (beta-elimination) that does not generate daughter products (i.e. cis-

1,2-DCE, vinyl chloride, 1,1-DCA, or chloroethane). In the reaction time, the bench scale testing did observe accumulation of chloroethane, from incomplete dechlorination, and the abiotic reactions would decrease the generation of this intermediate product. Therefore, the combination of ZVI and carbon substrate utilizes both abiotic and biotic processes for treatment of CVOCs in groundwater, and AECOM has successfully implemented at several sites across the United States and Canada.

Product information, including the Material Safety Data Sheets (MSDS) for EOS PRO and EHC, are presented in **Appendix B**.

The respiration of added carbon substrate by soil microbes can result in a decrease in groundwater pH, and a buffering agent (i.e., sodium bicarbonate) is sometimes injected with the carbon substrate to minimize changes in pH. However, based on the results of the bench scale test, no buffer will be applied for the pilot test.

Calculations supporting amendment dosages are presented in **Appendix C**. The *Substrate Estimating Tool for Enhanced Anaerobic Bioremediation of Chlorinated Solvents* developed for the Environmental Security Technology Certification Program (ESTCP) was used to support emulsified vegetable oil (EOS Pro) quantities for remediation.

4.2 Injection Volume

Delivery of amendments is a primary factor to achieving a successful remediation. Based on AECOM experience on other enhanced reductive dechlorination projects, carbon substrate solutions will be injected at volumes equivalent to 15 to 20 percent of the pore volume in the pilot test treatment area (injection volume calculations provided in **Appendix C**). This volume is sufficient to generate reducing conditions favorable for dechlorinating bacteria, not cause significant mounding during injections, and allow additional distribution of carbon substrates by advection of groundwater over the active lifetime of the EVO. Based on this injection volume range, and the estimated total mass of EVO specified in **Appendix C**, EVO solutions will be diluted to approximately 10 percent (v/v) to attain both the carbon loading and injection volume objectives. This percentage is within the range commonly applied by AECOM and other remediation practitioners.

The EHC product is injected as a slurry due to the presence of micron-scale iron particles. Based on manufacturer's recommendations, EHC will be injected at approximately 0.35 percent of the soil mass in this area and at volumes equivalent to 8-9 percent of the soil pore volume in this portion of the pilot test area where groundwater concentrations are greater than 100,000 µg/L.

4.3 Injection Points

Injection of carbon substrates can be performed through semi-permanent PVC wells or directly through direct-push (i.e., GeoProbe®) rods. Advantages of semi-permanent wells are that future, follow-up injections can be completed without additional drilling activity and wells and allow additional data collection points. Advantages of direct-push injections are that there is no well construction required so there is no added cost for well installation and abandonment. Additional advantages of direct-push injection points include the greater flexibility for treatment of vertical intervals and in moving injection locations if follow-up injections are required for improved distribution of injected amendments. For the EISB pilot test, all carbon substrates will be injected into the subsurface using direct-push tooling, for the following reasons:

- Avoiding installing injection wells (more than 60 locations, including some with two screened intervals) will offer cost savings, elimination of soils for disposal, and reduction of engineering oversight effort;
- Avoiding installing injection wells limits the on-site period of remediation activities that would potentially be disruptive to on-site operations by Star Gas;
- Follow-up injection is not anticipated for the near-future based on the active lifetime of the selected carbon substrates (three to five years); and
- The ZVI particles in EHC cannot be injected through a well-screen and require direct-push injection.

Injections to the groundwater will be performed using a regular-spaced injection grid to stimulate biodegradation throughout the pilot test area (**Figure 4**). Spacing of injection points will be approximately 12 feet, but actual spacing may vary in the field due to adjustments for surface and subsurface features. This grid spacing is selected based on observed subsurface stratigraphy from soil boring logs (predominance of silty ands and clayey silts), local hydrogeologic parameters (hydraulic conductivity and hydraulic gradient), and AECOM in-situ remediation in New York and New England in low permeability and/or heterogeneous silty, fine sand and tills. As a result, a total of 75 injection points will be used. When setting the grid, injection points will be offset at least five feet (or to the extent practicable) from existing injection wells and known underground utilities to minimize damage to utilities during drilling and to reduce the potential that the injected amendment does not short circuit through the utility conduits or well sand packs. Overhead utilities will also factor into the final location due to the safety concerns posed by the lines during injection point installation.

4.4 Field Injection Activities

Prior to commencing injections for the EISB pilot test, DigSafely New York notifications and private underground utility clearance will be conducted.

The EVO amendment will be shipped to the site as a liquid and will be stored in drums, totes, or other vendor supplied containers. The EHC amendment will be shipped to the site as a powder in 50 pound bags. The EVO containers and bags of EHC will be stored inside a storage container or other protective structure.

An injection system for preparation, mixing, and injection of biodegradation substrate solutions will consist of mixing tanks, mixers, pumps, piping, meters, valves, and fittings. All components will be selected from materials that are compatible for use with the selected amendments. Injection batches would be prepared by adding appropriate quantities of water to achieve the selected dilution concentration. A ChemGrout, or equivalent mixing unit, will be used for preparing the EHC slurry due to the granular ZVI. It is anticipated that no hard pipe or trenching will be used between the solution mixing station and the injection point, and that mobile above-ground, hoses will be used to convey remedial solutions directly to the injection points. A manifold would likely be employed to inject into multiple injection wells simultaneously. Flow totalizers, pressure gauges, and shut-off valves will be included on each active injection leg connected to an injection point to monitor injection pressure, flow rates, and total volume added to each point. All systems will be leak-checked daily prior to chemical injection by pressurizing the system with water to prevent spills from the injection system. An example process flow diagram for an EISB injection system is provided as **Figure 5**.

At each injection point, a direct-push drill rig will advance injection tooling to a targeted depth. Injection tooling can consist of a specialized injection tip, a screened interval, or similar device. A pre-determined volume will be injected, and then the injection tip will be advanced to the subsequent

injection target depth (generally two to four feet deeper), and the process is repeated. This method of direct-push injection is referred to as top-down injection; however, tooling to inject from deepest depth upward (bottom-up) will also be mobilized. To the extent practical, injections of EVO will be performed at low pressures (less than 10 pounds per square inch [PSI]); however, much higher injection pressures (100 to 200 PSI) are required to inject the ZVI particle slurry required for the EHC amendment. Based on AECOM in-situ remediation experience with the selected amendments and working in similar soil types, it is estimated that the injection flow rates will range from 1 to 3 gallons per minute at each point. Generally low pressures will be used to inject EOS, <5 to 10 pounds PSI with maximum allowable pressure of 20 PSI. Higher pressures are required to inject the micron-scale ZVI particles associated with EHC, with an anticipated pressure ranges of 100 to 200 PSI. To minimize mounding and improve delivery, injection will generally not be performed at adjacent wells at the same time. A field log will be maintained to record the solution composition, the volume of solution delivered into each injection well, the length of time required for injection, and the injection pressure. For performance of in-situ remediation, decontamination of subsurface injection materials will not be completed in between different injection locations, with the exception of observation (visual or olfactory) of gross contamination. No injection will be performed into any existing monitoring well in order to better evaluate performance of the pilot test activities.

Electricity to power remediation equipment will be provided by a gasoline-powered generator. Potable water for batching and injection will be delivered by tanker truck; prior to commencing injections the potable water source will be identified and laboratory analysis performed for VOCs and metals.

Remediation derived waste will consist of empty totes, empty bags, pallets, PPE, and miscellaneous trash. The empty totes will be shipped back to the EVO manufacturer for re-use. The other remediation derived waste will be placed in a dumpster and disposed of as municipal trash, as none of this waste is anticipated to come in contact with contaminated materials in the subsurface.

Following completion of all injection activities, all injection points will be surveyed, in addition to any additional site features (historic monitoring well MHC-23 was located after the most recent survey).

4.5 Community Air Monitoring Requirements

Air monitoring will be conducted during implementation of the EISB pilot test for protection of on-site workers and potential off-site receptors. The NYSDOH Generic Community Air Monitoring Plan (CAMP) will be used as guidance. Direct-push injection methods are generally non-intrusive activities and do not include any significant exposure to site workers to subsurface contamination. Consistent with monitoring well installation activities in 2012 at the Star Gas and MHBP sites, monitoring for VOCs will consist of periodic measurements in breathing zone of site workers using a photoionization detector (PID). Additional details will be included in a site-specific health and safety plan to be signed by a Certified Hazardous Materials Manager (CHMM).

4.6 Shallow Soil Sampling

As noted, the major source of VOC contamination at the property was the surficial release of VOCs that occurred as a result of a warehouse fire in 1963. During the in-situ injection event, while a direct-push rig is mobilized to the site, several shallow soil borings (to a depth of four feet) will be advanced to perform soil screeing with a PID and submit a limited number of soils samples for laboratory analysis of CVOCs. The objective of these soils borings will be to determine if any high concentrations of residual CVOCs are present that could provide a long-term source of contamination and re-contaminate areas that will be treated by EISB. To the extent possible, boring locations will be advanced in proximity to locations included in the 1998 SRI and 2007 RI reports; approximate locations of soil samples are shown on **Figure 4**.

4.7 Groundwater Performance Monitoring

Remediation performance monitoring will be performed to assess contaminant concentrations and transformation, the distribution of the ZVI and carbon substrate in the subsurface (using TOC analysis as well as field geochemistry parameters), and groundwater geochemistry. Groundwater samples for pilot test performance monitoring will be collected by low-flow techniques. Groundwater quality parameters will be measured in the field, with particular attention to pH, specific conductance (uS/cm), oxidation reduction potential (mV), and dissolved oxygen (mg/L) which will be used to evaluate the generation and distribution of reducing conditions. As a result of the generation of reducing conditions in groundwater, temporary mobilization of some metals may result. Laboratory analysis of select metals will be conducted as part of performance monitoring in select wells. **Table 4-2** presents the wells and monitoring parameters for the pilot test performance monitoring, and the monitoring wells include wells already installed at the Former Duso Chemical site (**Figures 2 and 4**). An overview of the pilot test performance monitoring sampling is shown below.

Monitoring Well	Sampling Frequency and Laboratory Analyses
BIW-1S	1 month after pilot injection • All wells: TOC Quarterly for one year after pilot injection • All wells: VOCs and TOC • Select wells: microbes, sulfate, select metals, methane/ethane/ethene
BIW-1D	
BIW-2S	
BIW-2D	
BIW-5S	
BIW-5D	
BIW-6S	
MHC-22	
MHC-23	
MHC-26	
BIW-6D	One year after pilot injection • All wells: VOCs
BIW-3S	
BIW-3D	
BIW-4	
MHC-24	
MHC-25S	

Groundwater sampling results from 2012 will be used as baseline conditions to evaluate the performance of the pilot test.

Purged water from groundwater sampling will be containerized in labeled, DOT approved 55-gallon drums for future off-site disposal/recycling.

4.8 Bioaugmentation and Polishing Treatment

Bioaugmentation has been performed following addition of carbon substrate and ZVI to enhance biodegradation at other sites, as the addition of carbon substrates and ZVI generate reducing conditions favorable for microbial reductive dechlorination. Advantages of bioaugmentation following addition of carbon substrate and is accelerated degradation of CVOCs by increasing the number of cells capable of dechlorinating site CVOCs. Microbial analysis of groundwater samples during 2012 indicated that dehalogenating bacteria (Dhc and Dhb) were observed within the pilot test area, but at relatively low cell counts. Cell counts of both microbial groups did significantly increase after EVO addition during the bench scale testing, and PCE and TCE were observed to fully dechlorinate to ethene and 1,1,1-TCA was dechlorinated to chloroethane. Based on these observations from the treatability test, no bioaugmentation is proposed as part of the field pilot study. However, bioaugmentation could be proposed in the future to further optimize in-situ treatment.

The bench-scale study observed reductive dechlorination of 1,1,1-TCA and 1,1-DCA to chloroethane. If significant concentrations of chloroethane are observed to accumulate following pilot test injections, additional treatment may be applied to reduce concentrations of this CVOC. As noted in Section 2.3, aerobic methane-oxidizing bacteria have been demonstrated to biodegrade chloroethane, including methods to increase dissolved oxygen to further stimulate aerobic bacteria that could perform these reactions.

Several groundwater monitoring rounds (Section 4.5) would be collected and evaluated prior to making any decision regarding bioaugmentation or additional treatments for residual CVOCs.

5.0 Schedule and Coordination

5.1 Schedule of Activities

The major activities for performance of the EISB pilot test include:

- Procurement of materials, equipment, and subcontractors
- Mobilization and delivery of materials and equipment
- Pilot Test Injections
- Pilot test performance monitoring

An anticipated schedule is provided on **Table 5-1**.

5.2 Subcontractors

Implementation of the EISB pilot test will require the services of the following subcontracted services:

- Direct-Push Injection
    - Direct-push drilling
    - Injection equipment and labor
- Remediation Amendment Suppliers
    - EOS Remediation (EOS PRO with vitamin supplements)
    - FMC Environmental (EHC)
- Analytical Laboratories
- Waste Disposal
- Utility Clearance
- Survey

5.3 Cost Estimate

A cost estimate for implementing the EISB pilot test as detailed in this work plan is provided in **Appendix F**.

5.4 Access Agreements

As identified by the treatment area described in **Figure 4**, implementation of the EISB pilot test will require access to several private properties. These include the Star Gas property (property 042826), the Conrail right of way spur property (011773), and the MHBP property (property 005836). Remediation activities to be conducted on each of these properties is summarized on the table below. Additional information on these properties is included in **Appendix G**. NYSDEC will be responsible for obtaining formal access to these properties, however the Contractor will be required to abide by the terms in the access agreement(s) during all phases of work.

Property	EISB Pilot Test Activities
Star Gas property (property 042826) 33 Fulton St, Poughkeepsie NY 12601	Remedial amendment batching/dilution activities Direct-push injection of remedial solutions into 63 locations
Conrail right of way spur property (011773) Spur N & E Of City, Poughkeepsie NY 12601	Direct-push injection of remedial solutions into 12 locations
MHBP property (property 005836) 3440-3444 North Rd, Poughkeepsie NY 12601	Bulk remedial amendment storage Storage of select remediation equipment for nights and weekends

6.0 References

The Chazen Companies. 1998. *Supplemental Remedial Investigation, MidHudson Business Park, Poughkeepsie, New York.* February 1998.

New York State Department of Environmental Conservation (NYSDEC), 2008. *Record of Decision*. March 2008.

O'Brien and Gere. 2007. *Remedial Investigation, Former Duso Chemical Site, Poughkeepsie, New York.* August 2007.

SiREM Laboratories, 2011. *Laboratory Biotreatability Study Report - Draft*. August 2011.

Tables

Table 5-1
EISB Pilot Test Schedule of Activities
Former Duso Chemical Site
Poughkeepsie, NY

Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Activity																																									
Finalize Pilot Study Work Plan																																									
UIC Permit Approval																																									
Procure Subcontractors																																									
Procure and Deliver Chemicals																																									
Injection					20-30 d																																				
Performance Monitoring						1 mo.		3 mo.			6 mo.			9 mo.			12 mo.						18 mo.						24 mo.											36 mo.	
Evaluate Need for Bioaugmentation																																									

Table 2-1
December 2012 Groundwater Sampling Summary
Former Duso Chemical Site
Poughkeepsie, NY

Well	ORP, pH, DO	TOC	VOCs	DHC	DHB	vcrA	M/E/E	Nitrate/ Nitrite	Phosphates	Sulfate	Chloride	VFA	Bromide
MHC-23	1	1	1	1	1	1	1	1	1	1	1	1	1
MHC-25S	1	1	1	1	1	1	1	1	1	1	1	1	1
MHC-26	1	1	1										
BIW-1D	1	1	1	1	1		1	1	1	1	1	1	1
BIW-1S	1	1	1	1	1		1	1	1	1	1	1	1
BIW-2D	1	1	1	1	1		1		1	1	1	1	1
BIW-2S	1	1	1	1	1	1	1		1	1	1	1	1
BIW-3D	1	1	1	1	1		1	1	1	1	1	1	1
BIW-3S	1	1	1	1	1	1	1	1	1	1	1	1	1
BIW-4	1	1	1	1	1		1	1	1	1	1	1	1
BIW-5D	1	1	1	1	1	1	1	1	1	1	1	1	1
BIW-5S	1	1	1	1	1	1	1	1	1	1	1	1	1
BIW-6D	1	1	1	1	1		1	1	1	1	1	1	1
BIW-6S	1	1	1	1	1	1	1	1	1	1	1	1	1
BIW-7	1	1	1	1	1	1	1	1	1	1	1	1	1
Total	15	15	15	14	14	8	14	12	14	14	14	14	14

Notes:
TOC = Total Organic Carbon
VOCs = Volatile Organic Compounds
DHC = *Dehalococcoides*
DHB = *Dehalobacter*
vcrA = Vinyl Chloride Reductase
M/E/E = Methane, Ethane, Ethene
VFA = Volatile Fatty Acids

Table 4-1
Summary of Design Parameters for Enhanced In-Situ Bioremediation Pilot Study
Former Duso Chemical Site - Poughkeepsie, NY

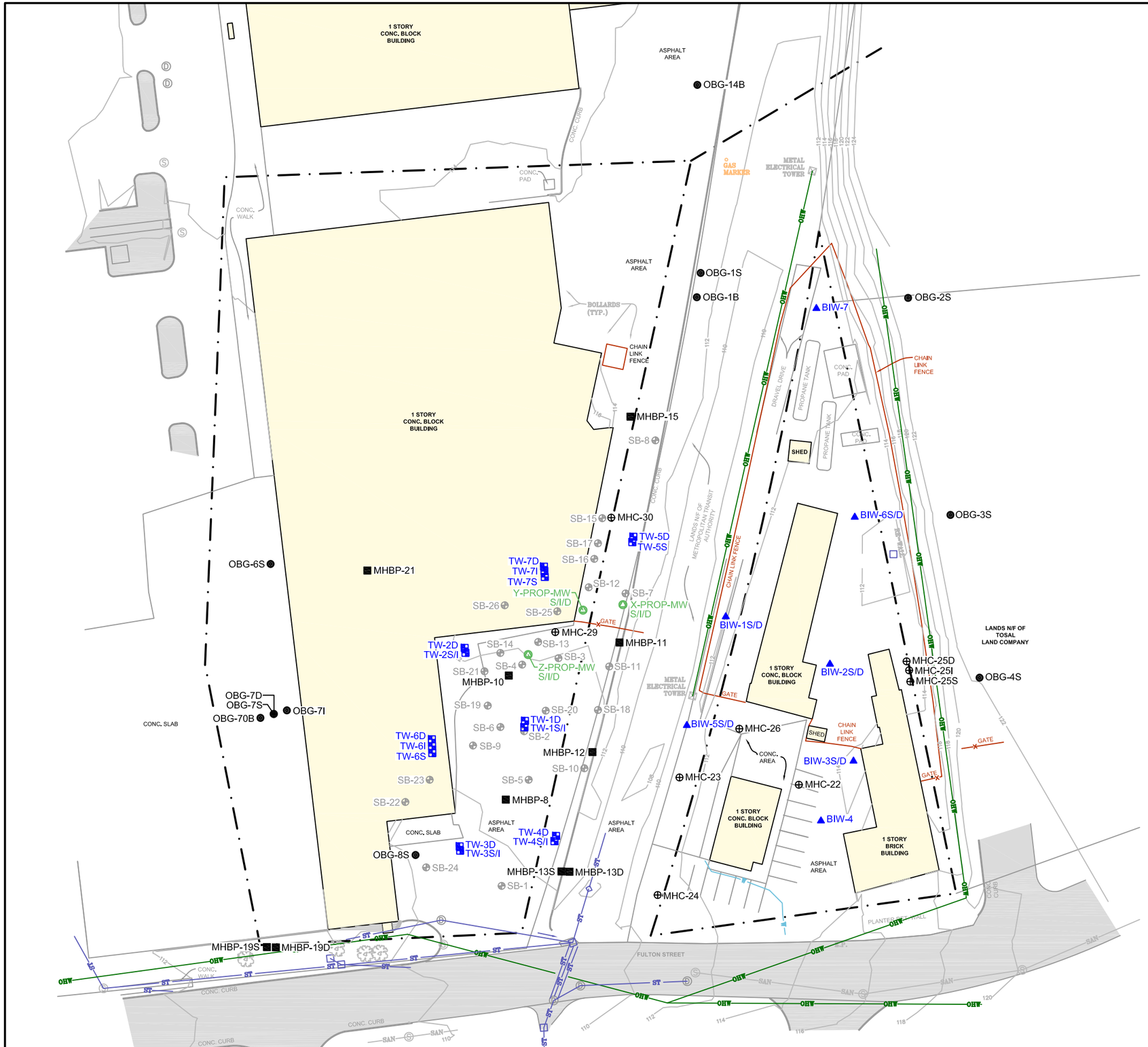
Parameter	East Area	Northeast Area	Center Area	Northwest	West Center	Southwest	Total
Area Description	Eastern Portion of Site in vicinity and between wells BIW-2S/D and MHC-22	North of BIW-2S to BIW-6S	Between two buildings, upgradient of well MHC-26	In vicinity of well BIW-1S/D	In vicinity of well BIW-5S/D	In vicinity of well MHC-23	
Depth to Ground Water	3 - 4 feet below ground surface						
Depth to Clayey Silt	19.5 to 22 feet below ground surface						
Target Treatment Thickness	4 - 16 (12 feet)	4 - 12 (8 feet)	4 - 18 (14 feet)	6 - 26 (20 feet)	4 - 24 (20 feet)	4 - 24 (20 feet)	
Target Treatment Area (sq ft)	2,035	1,855	1,170	2,485	1,525	1,120	10,190
Injection Well Spacing	12' grid						
Direct-Push Injection Points	17	14	8	18	9	9	75
Injectoin Volume Per Linear Foot	50	42	50	42	65	40	
Emulsified Vegetable Oil (EOS Pro) (gallons of 60%)	1,018	468	558	1,508	348	720	4,620 16 totes + 4 drums
Emulsified Vegetable Oil Dilution for Injection	10%						
Emulsified Vegetable Oil Solution Injection Volume (gallons)	10,200	4,704	5,600	15,120	3,510 (Inject EVO 4-10' bgs)	7,200	46,334
ZVI + Carbon (EHC)	--		--	--	7,850 lbs 3,830 total gallons (Inject EHC 10-24' bgs) 30 gallons per vertical linear foot, 0.35% soil dosage	--	
Max. cVOC concentrations (µg/L) (2011-2012)	1,1,1-TCA = 5,200 1,1-DCA = 8,500		1,1,1-TCA = 1,500 1,1-DCA = 1,100	1,1,1-TCA = 3,600 1,1-DCA = 2,400	Shallow 1,1,1-TCA = 560 1,1-DCA = 810 Deep 1,1,1-TCA = 30,000 1,1-DCA = 80,000 1,2-DCA = 6,800	1,1,1-TCA = 3,900 1,1-DCA = 590 TCE = 340 cis-1,2-DCE = 490	

Table 4-2
Enhanced In-Situ Bioremediation Pilot Study Performance Monitoring
Former Duso Chemical Site
Poughkeepsie, NY

Well	Time After Pilot Test Injection							
	1 month	3 months	6 months	9 months	12 months	18 months	24 months	36 months
Pilot Study Area Monitoring Wells								
BIW-1S	TOC	VOCs, TOC, Sulfate	VOCs, TOC, Sulfate	VOCs, TOC	VOCs, TOC	VOCs	VOCs	VOCs
BIW-1D	TOC	VOCs, TOC, Sulfate, As/Mn/Fe	VOCs, TOC, Sulfate, M/E/E	VOCs, TOC, M/E/E, Dhc/Dhb	VOCs, TOC, M/E/E, As/Mn/Fe, Dhc/Dhb	VOCs, TOC, M/E/E, As/Mn/Fe, Dhc/Dhb	VOCs, TOC, M/E/E, As/Mn/Fe, Dhc/Dhb	VOCs, TOC, M/E/E, As/Mn/Fe, Dhc/Dhb
BIW-2S	TOC	VOCs, TOC, Sulfate	VOCs, TOC, Sulfate	VOCs, TOC	VOCs, TOC, M/E/E	VOCs, TOC, M/E/E	VOCs, TOC, M/E/E	VOCs, TOC, M/E/E
BIW-2D	TOC	VOCs, TOC, Sulfate	VOCs, TOC, Sulfate	VOCs, TOC	VOCs, TOC	VOCs	VOCs	VOCs
BIW-5S	TOC	VOCs, TOC, Sulfate, As/Mn/Fe	VOCs, TOC, Sulfate, M/E/E	VOCs, TOC, M/E/E, Dhc/Dhb	VOCs, TOC, M/E/E, As/Mn/Fe, Dhc/Dhb	VOCs, TOC, M/E/E, As/Mn/Fe, Dhc/Dhb	VOCs, TOC, M/E/E, As/Mn/Fe, Dhc/Dhb	VOCs, TOC, M/E/E, As/Mn/Fe, Dhc/Dhb
BIW-5D	TOC	VOCs, TOC, Sulfate, As/Mn/Fe	VOCs, TOC, Sulfate, M/E/E	VOCs, TOC, M/E/E, Dhc/Dhb	VOCs, TOC, M/E/E, As/Mn/Fe, Dhc/Dhb	VOCs, TOC, M/E/E, As/Mn/Fe, Dhc/Dhb	VOCs, TOC, M/E/E, As/Mn/Fe, Dhc/Dhb	VOCs, TOC, M/E/E, As/Mn/Fe, Dhc/Dhb
BIW-6S	TOC	VOCs, TOC, Sulfate	VOCs, TOC, Sulfate	VOCs, TOC	VOCs, TOC, M/E/E, Dhc/Dhb	VOCs, TOC, M/E/E, Dhc/Dhb	VOCs, TOC	VOCs, TOC
MHC-22	TOC	VOCs, TOC, Sulfate	VOCs, TOC, Sulfate	VOCs, TOC	VOCs, TOC, M/E/E, Dhc/Dhb	VOCs, TOC, M/E/E, Dhc/Dhb	VOCs, TOC	VOCs, TOC
MHC-23	TOC	VOCs, TOC, Sulfate, As/Mn/Fe	VOCs, TOC, Sulfate, M/E/E	VOCs, TOC, M/E/E, Dhc/Dhb	VOCs, TOC, M/E/E, As/Mn/Fe, Dhc/Dhb	VOCs, TOC, M/E/E, As/Mn/Fe, Dhc/Dhb	VOCs, TOC, M/E/E, As/Mn/Fe, Dhc/Dhb	VOCs, TOC, M/E/E, As/Mn/Fe, Dhc/Dhb
MHC-26	TOC	VOCs, TOC, Sulfate, As/Mn/Fe	VOCs, TOC, Sulfate, M/E/E	VOCs, TOC, M/E/E, Dhc/Dhb	VOCs, TOC, M/E/E, As/Mn/Fe, Dhc/Dhb	VOCs, TOC, M/E/E, As/Mn/Fe, Dhc/Dhb	VOCs, TOC, M/E/E, As/Mn/Fe, Dhc/Dhb	VOCs, TOC, M/E/E, As/Mn/Fe, Dhc/Dhb
Monitoring Wells Outside of Pilot Study Area								
BIW-6D					VOCs		VOCs	VOCs
BIW-3S					VOCs		VOCs	VOCs
BIW-3D					VOCs		VOCs	VOCs
BIW-4					VOCs		VOCs	VOCs
MHC-24					VOCs		VOCs	VOCs
MHC-25S					VOCs		VOCs	VOCs
# of wells	10	10	10	10	16	10	16	16

Notes:
Additional analyses and/or wells may be added to the sampling program as necessary to further evaluate performance
TOC = Total Organic Carbon
VOCs = Volatile Organic Compounds
Dhc = *Dehalococcoides*
Dhb = *Dehalobacter*
As/Mn/Fe = Arsenic, Manganese, Iron
M/E/E = Methane, Ethane, Ethene

Figures



LEGEND

- BIW-1S/D ▲ NESTED BIOREMEDIATION INJECTION WELL LOCATION (2012)
- TW-1S/I ■ NESTED THERMAL WELL LOCATION (2012)
- X-PROP-MW S/I/D ▲ TRI-LEVEL STAINLESS STEEL WELL LOCATION (2011)
- SB-15 ⊕ AECOM MEMBRANE INTERFACE PROBE BORING LOCATION (2011)
- OBG-2S ● O'BRIEN & GERE WELL LOCATION (2005 & 2007)
- MHBP-11 ■ MID HUDSON BUSINESS PARK WELL LOCATION (1993-1994)
- MHC-30 ⊕ WELL LOCATION (1990s)
- CATCH BASIN
- Ⓓ MANHOLES
- TREES
- BUILDING
- ROAD / PAVEMENT
- TOPOGRAPHIC CONTOURS
- PROPERTY BOUNDARY (APPROXIMATE)
- FENCE (APPROXIMATE)
- PARCEL BOUNDARY
- OVERHEAD WIRES
- UNDERGROUND WATER
- SANITARY SEWER LINE
- STORMWATER LINE
- UNDERGROUND GAS

0 25 50 100

SCALE IN FEET

SOURCE: BASEMAP WAS PROVIDED BY S.Y. KIM LAND SURVEYOR, JOB NO: 5D-316-11, AUGUST 16, 2011.

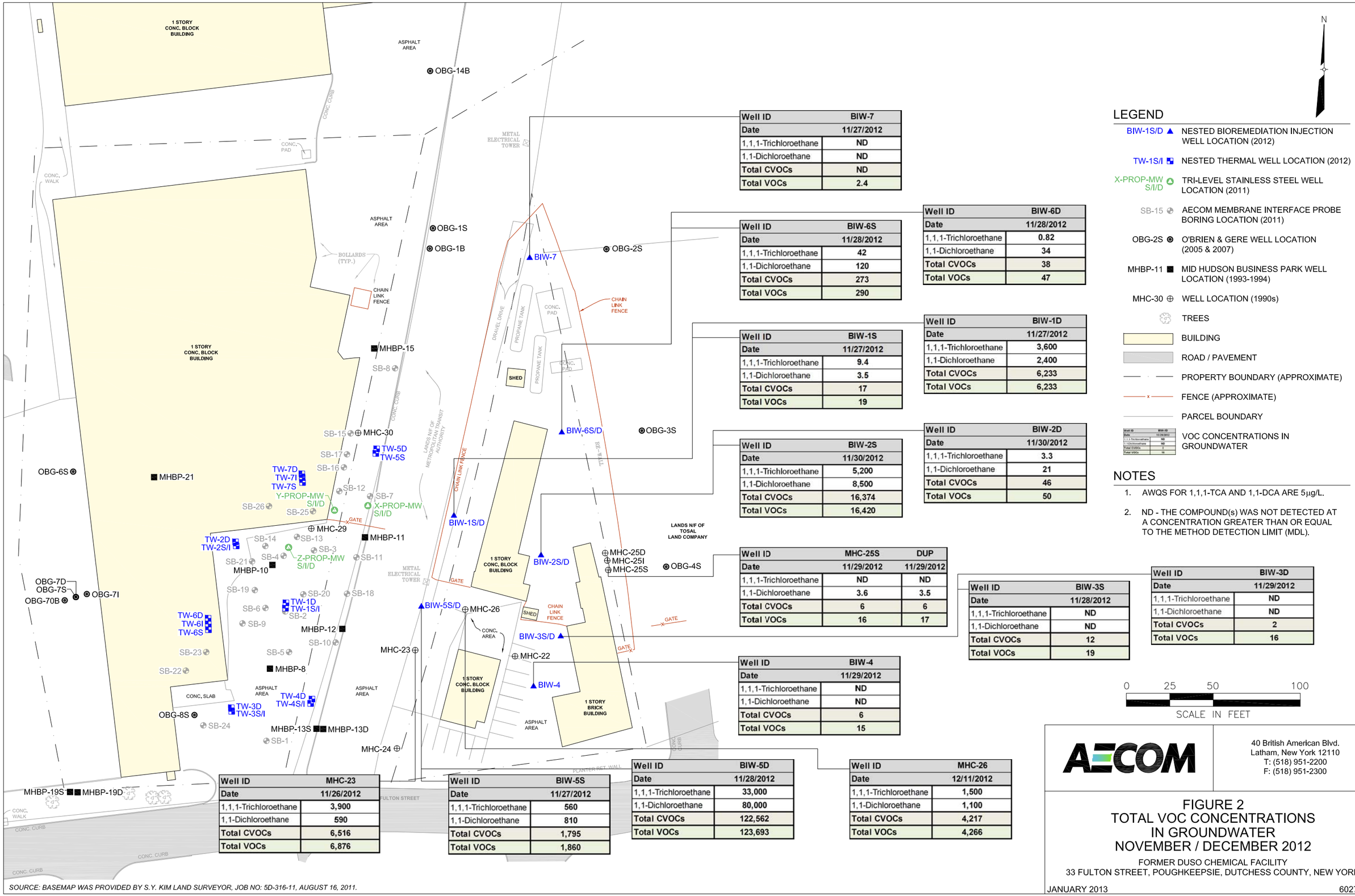
AECOM
40 British American Blvd.
Latham, New York 12110
T: (518) 951-2200
F: (518) 951-2300

FIGURE 1
SITE PLAN

FORMER DUSO CHEMICAL FACILITY
33 FULTON STREET, POUGHKEEPSIE, DUTCHESS COUNTY, NEW YORK

JANUARY 2013 60279080

L:\Group\earth\Latham NY Work\NYSDEC Former Duso Chem Site\60279080_000 Site Plan.dwg, 1/31/2013 1:20:23 PM, Splawnm



Well ID	BIW-7
Date	11/27/2012
1,1,1-Trichloroethane	ND
1,1-Dichloroethane	ND
Total CVOCs	ND
Total VOCs	2.4

Well ID	BIW-6S
Date	11/28/2012
1,1,1-Trichloroethane	42
1,1-Dichloroethane	120
Total CVOCs	273
Total VOCs	290

Well ID	BIW-6D
Date	11/28/2012
1,1,1-Trichloroethane	0.82
1,1-Dichloroethane	34
Total CVOCs	38
Total VOCs	47

Well ID	BIW-1S
Date	11/27/2012
1,1,1-Trichloroethane	9.4
1,1-Dichloroethane	3.5
Total CVOCs	17
Total VOCs	19

Well ID	BIW-1D
Date	11/27/2012
1,1,1-Trichloroethane	3,600
1,1-Dichloroethane	2,400
Total CVOCs	6,233
Total VOCs	6,233

Well ID	BIW-2S
Date	11/30/2012
1,1,1-Trichloroethane	5,200
1,1-Dichloroethane	8,500
Total CVOCs	16,374
Total VOCs	16,420

Well ID	BIW-2D
Date	11/30/2012
1,1,1-Trichloroethane	3.3
1,1-Dichloroethane	21
Total CVOCs	46
Total VOCs	50

Well ID	MHC-25S	DUP
Date	11/29/2012	11/29/2012
1,1,1-Trichloroethane	ND	ND
1,1-Dichloroethane	3.6	3.5
Total CVOCs	6	6
Total VOCs	16	17

Well ID	BIW-3S
Date	11/28/2012
1,1,1-Trichloroethane	ND
1,1-Dichloroethane	ND
Total CVOCs	12
Total VOCs	19

Well ID	BIW-3D
Date	11/29/2012
1,1,1-Trichloroethane	ND
1,1-Dichloroethane	ND
Total CVOCs	2
Total VOCs	16

Well ID	BIW-4
Date	11/29/2012
1,1,1-Trichloroethane	ND
1,1-Dichloroethane	ND
Total CVOCs	6
Total VOCs	15

Well ID	MHC-23
Date	11/26/2012
1,1,1-Trichloroethane	3,900
1,1-Dichloroethane	590
Total CVOCs	6,516
Total VOCs	6,876

Well ID	BIW-5S
Date	11/27/2012
1,1,1-Trichloroethane	560
1,1-Dichloroethane	810
Total CVOCs	1,795
Total VOCs	1,860

Well ID	BIW-5D
Date	11/28/2012
1,1,1-Trichloroethane	33,000
1,1-Dichloroethane	80,000
Total CVOCs	122,562
Total VOCs	123,693

Well ID	MHC-26
Date	12/11/2012
1,1,1-Trichloroethane	1,500
1,1-Dichloroethane	1,100
Total CVOCs	4,217
Total VOCs	4,266

AECOM
40 British American Blvd.
Latham, New York 12110
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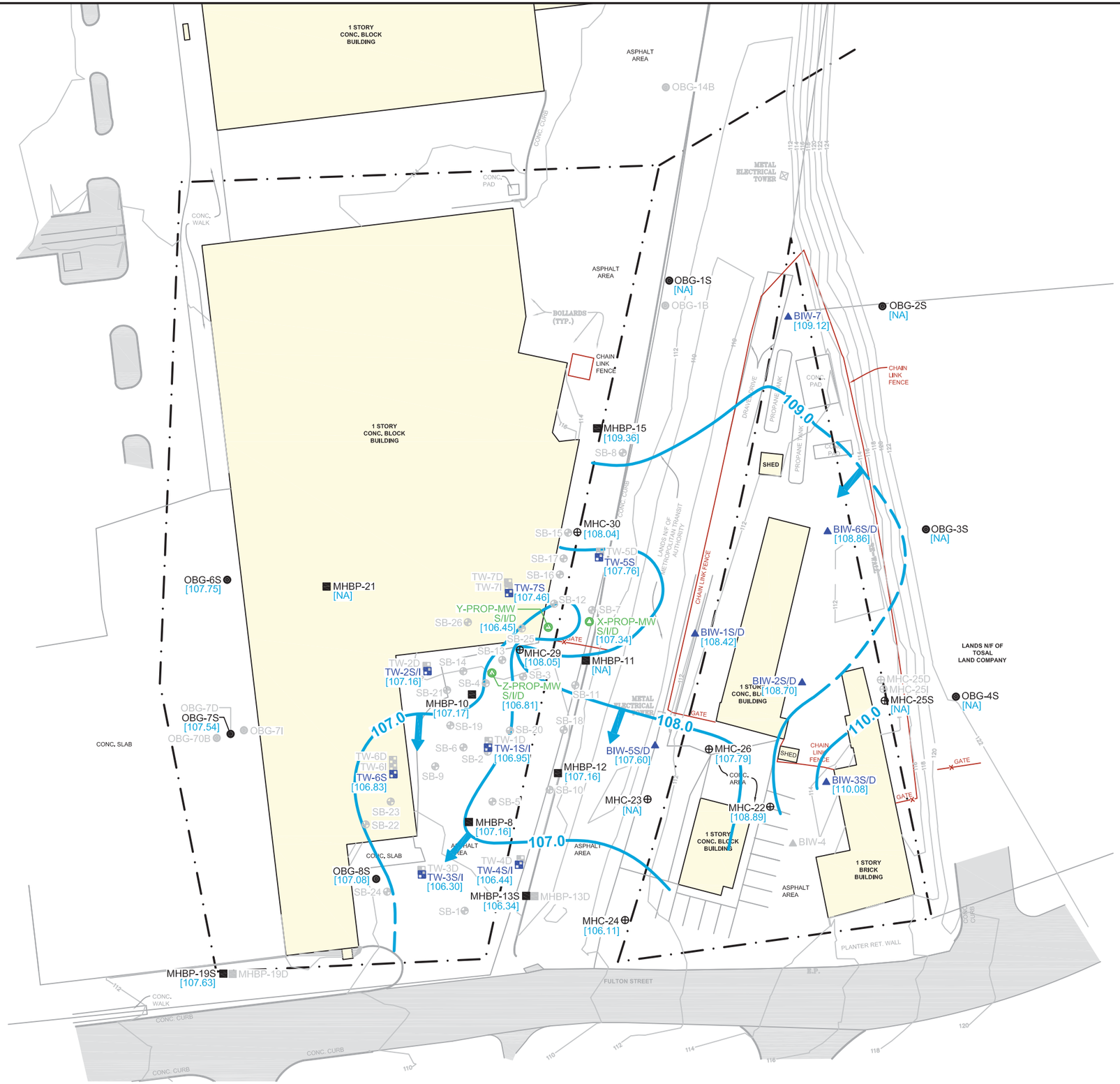
FIGURE 2
TOTAL VOC CONCENTRATIONS IN GROUNDWATER NOVEMBER / DECEMBER 2012

FORMER DUSO CHEMICAL FACILITY
33 FULTON STREET, POUGHKEEPSIE, DUTCHESS COUNTY, NEW YORK

JANUARY 2013 60279080



SOURCE: BASEMAP WAS PROVIDED BY S.Y. KIM LAND SURVEYOR, JOB NO: 5D-316-11, AUGUST 16, 2011.

AECOM
10 British American Blvd.
Latham, New York 12110
T: (518) 951-2200
F: (518) 951-2300

FIGURE 3A
GROUNDWATER CONTOUR MAP SHALLOW WELLS
DECEMBER 11, 2012

FORMER DUSO CHEMICAL FACILITY
33 FULTON STREET, POUGHKEEPSIE, DUTCHESS COUNTY, NEW YORK

JANUARY 2013 60279080

L:\Group\earth\Latham NY Work\NYSDEC Former Duso Chem Site\60279080_005 GW Contour Map Shallow Wells.dwg, 2/13/2013 3:30:15 PM, Splawnm

N

LEGEND

- BIW-1S/D — NESTED BIOREMEDIATION INJECTION WELL LOCATION (2012)
- TW-1S/I — NESTED THERMAL WELL LOCATION (2012)
- X-PROP-MW S/I/D — TRI-LEVEL STAINLESS STEEL WELL LOCATION (2011)
- SB-15 — AECOM MEMBRANE INTERFACE PROBE BORING LOCATION (2011)
- OBG-2S — O'BRIEN & GERE WELL LOCATION (2005 & 2007)
- MHBP-11 — MID HUDSON BUSINESS PARK WELL LOCATION (1993-1994)
- MHC-30 — WELL LOCATION (1990s)
- [109.12] — GROUNDWATER ELEVATION (ft amsl)
- [NA] — NOT ANALYZED
- GROUNDWATER FLOW DIRECTION (APPROXIMATE)
- BUILDING
- ROAD / PAVEMENT
- TOPOGRAPHIC CONTOURS
- GROUNDWATER ISOELEVATION CONTOUR (ft amsl) (DASHED WHERE INFERRED)
- PROPERTY BOUNDARY (APPROXIMATE)
- FENCE (APPROXIMATE)
- PARCEL BOUNDARY

NOTES

1. amsl - ABOVE MEAN SEA LEVEL
2. GROUNDWATER CONTOURS WERE CONSTRUCTED USING SHALLOW WELLS (CLAYEY SILT AND SAND) AND DEEP WELLS (SILTY CLAY).

0 25 50 100

SCALE IN FEET

SOURCE: BASEMAP WAS PROVIDED BY S.Y. KIM LAND SURVEYOR, JOB NO: 5D-316-11, AUGUST 16, 2011.

AECOM

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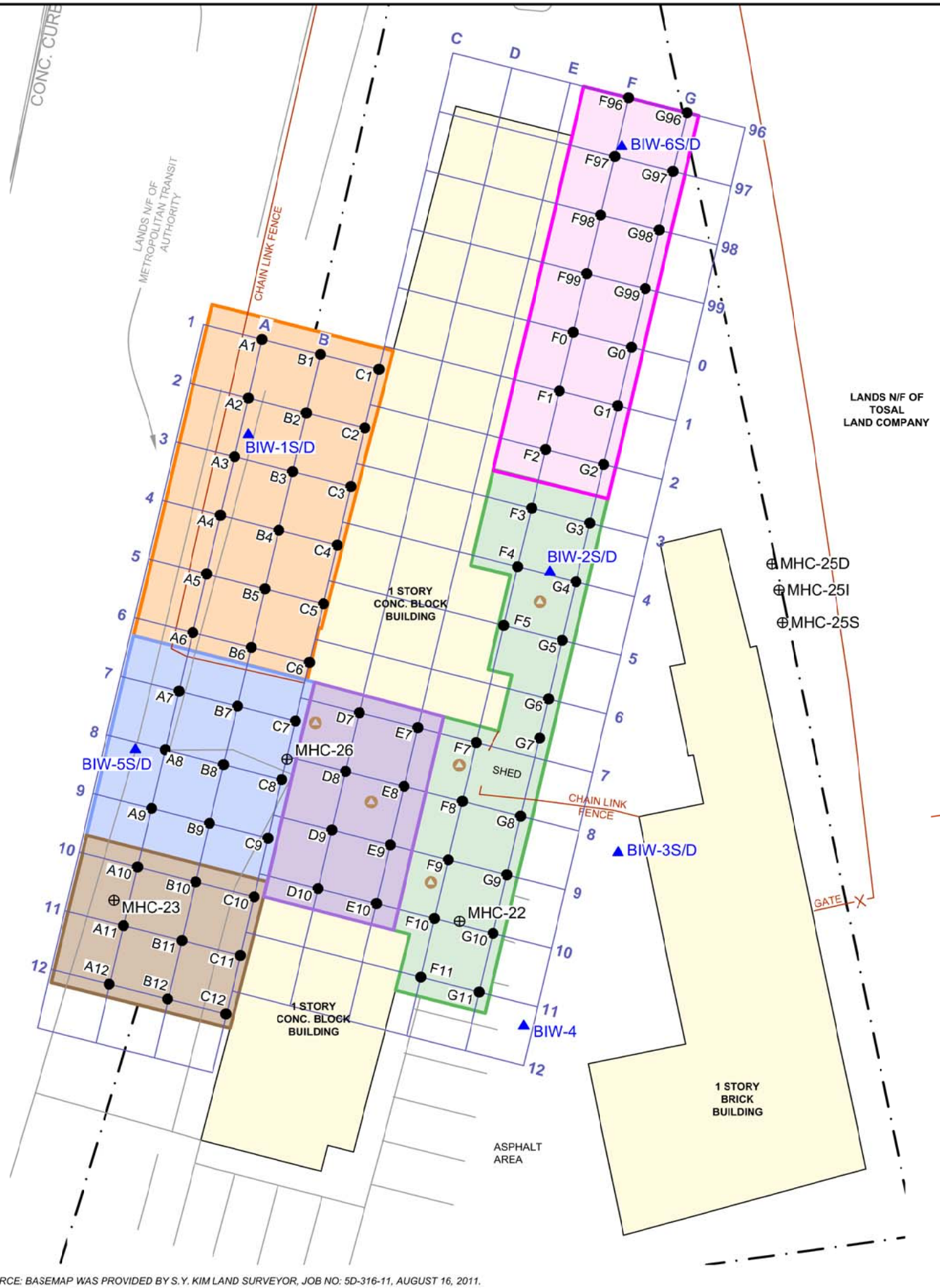
FIGURE 3B
GROUNDWATER CONTOUR MAP
DEEP WELLS
DECEMBER 11, 2012

FORMER DUSO CHEMICAL FACILITY
33 FULTON STREET, POUGHKEEPSIE, DUTCHESS COUNTY, NEW YORK

JANUARY 2013 60279080

L:\Group\earth\Latham NY Work\NYSDEC Former Duso Chem Site\60279080_006 GW Contour Map Deep Wells.dwg, 1/31/2013 1:39:58 PM, Splawnm



SOURCE: BASEMAP WAS PROVIDED BY S.Y. KIM LAND SURVEYOR, JOB NO: 5D-316-11, AUGUST 16, 2011.

LEGEND

- PROPOSED INJECTION POINT LOCATION
- PROPOSED SHALLOW SOIL BORING (LOCATIONS TO BE FINALIZED AT TIME OF COLLECTION)
- BIW-1S/D ▲ NESTED BIOREMEDIATION INJECTION WELL LOCATION (2012)
- OBG-2S ◉ O'BRIEN & GERE WELL LOCATION (2005 & 2007)
- MHC-30 ⊕ WELL LOCATION (1990s)
- BUILDING
- ROAD / PAVEMENT
- PROPERTY BOUNDARY (APPROXIMATE)
- FENCE (APPROXIMATE)

NOTES

AREA	POINTS	INJECTION INTERVAL (ft bgs)	VOLUME PER POINT (gallons)	VOLUME PER FOOT (gallons)
NORTHEAST	14	4-12 (8')	333	42
EAST AREA	17	4-16 (12')	596	50
CENTER AREA	8	4-18 (14')	700	50
NORTHWEST	18	6-26 (20')	800	40
WEST CENTER	9	4-10 (6') EOS 10-24 (14') EHC	390 (EOS) 420 (EHC)	65 (EOS) 30 (EHC)
SOUTHWEST	9	4-24 (20')	800	40

INJECTION POINT COORDINATES

Well ID	Northing	Easting	Well ID	Northing	Easting
A1	1053537.99	648104.38	E7	1053460.62	648135.43
A2	1053526.31	648101.62	E8	1053448.94	648132.67
A3	1053514.63	648098.86	E9	1053437.26	648129.91
A4	1053502.95	648096.10	E10	1053425.58	648127.15
A5	1053491.27	648093.34	F96	1053586.14	648177.40
A6	1053479.59	648090.59	F97	1053574.46	648174.64
A7	1053467.90	648087.83	F98	1053562.78	648171.88
A8	1053456.22	648085.07	F99	1053551.10	648169.13
A9	1053444.54	648082.31	F0	1053539.41	648166.37
A10	1053432.86	648079.55	F1	1053527.73	648163.61
A11	1053421.18	648076.79	F2	1053516.05	648160.85
A12	1053409.53	648073.90	F3	1053504.37	648158.09
B1	1053535.01	648116.01	F4	1053492.69	648155.33
B2	1053523.33	648113.25	F5	1053481.01	648152.57
B3	1053511.65	648110.49	F7	1053457.65	648147.06
B4	1053499.97	648107.73	F8	1053445.97	648144.30
B5	1053488.29	648104.97	F9	1053434.29	648141.54
B6	1053476.61	648102.21	F10	1053422.61	648138.78
B7	1053464.93	648099.45	F11	1053410.93	648136.02
B8	1053453.25	648096.70	G96	1053583.16	648189.03
B9	1053441.57	648093.94	G97	1053571.48	648186.27
B10	1053429.89	648091.18	G98	1053559.80	648183.51
B11	1053418.21	648088.42	G99	1053548.12	648180.75
B12	1053406.56	648085.53	G0	1053536.44	648177.99
C1	1053532.04	648127.63	G1	1053524.76	648175.24
C2	1053520.36	648124.88	G2	1053513.08	648172.48
C3	1053508.68	648122.12	G3	1053501.40	648169.72
C4	1053497.00	648119.36	G4	1053489.72	648166.96
C5	1053485.32	648116.60	G5	1053478.04	648164.20
C6	1053473.64	648113.84	G6	1053466.36	648161.44
C7	1053461.96	648111.08	G7	1053458.55	648159.67
C8	1053450.27	648108.32	G8	1053442.99	648155.92
C9	1053438.59	648105.57	G9	1053431.31	648153.17
C10	1053426.91	648102.81	G10	1053419.63	648150.41
C11	1053415.23	648100.05	G11	1053407.95	648147.65
C12	1053403.58	648097.16			
D7	1053463.60	648123.80			
D8	1053451.92	648121.04			
D9	1053440.24	648118.28			
D10	1053428.56	648115.52			

N

0 12.5 25 50
SCALE IN FEET

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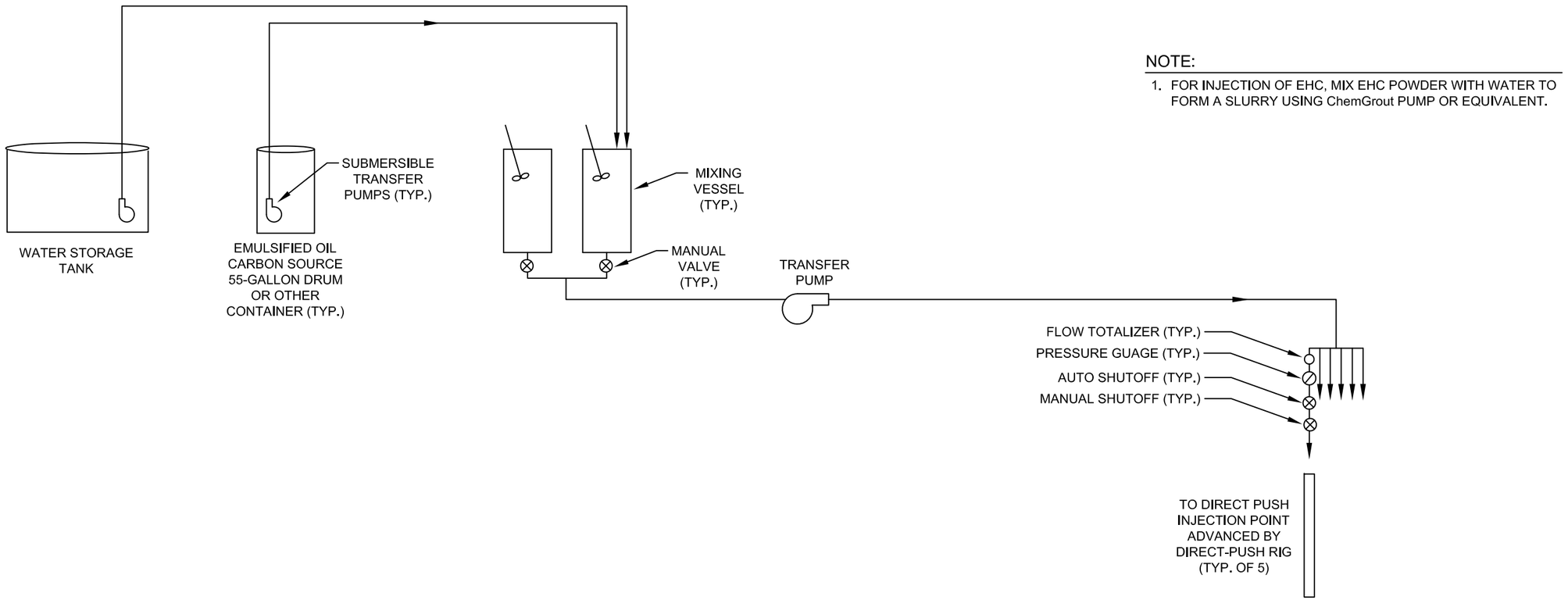
FIGURE 4
BIOREMEDIATION INJECTION PLAN

FORMER DUSO CHEMICAL FACILITY
33 FULTON STREET, POUGHKEEPSIE, DUTCHESS COUNTY, NEW YORK

MARCH 2013 60279080

EISB PILOT STUDY



NOTE:

1. FOR INJECTION OF EHC, MIX EHC POWDER WITH WATER TO FORM A SLURRY USING ChemGrout PUMP OR EQUIVALENT.

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FIGURE 5
BIOREMEDIATION PROCESS FLOW DIAGRAM

FORMER DUSO CHEMICAL FACILITY
33 FULTON STREET, POUGHKEEPSIE, DUTCHESS COUNTY, NEW YORK

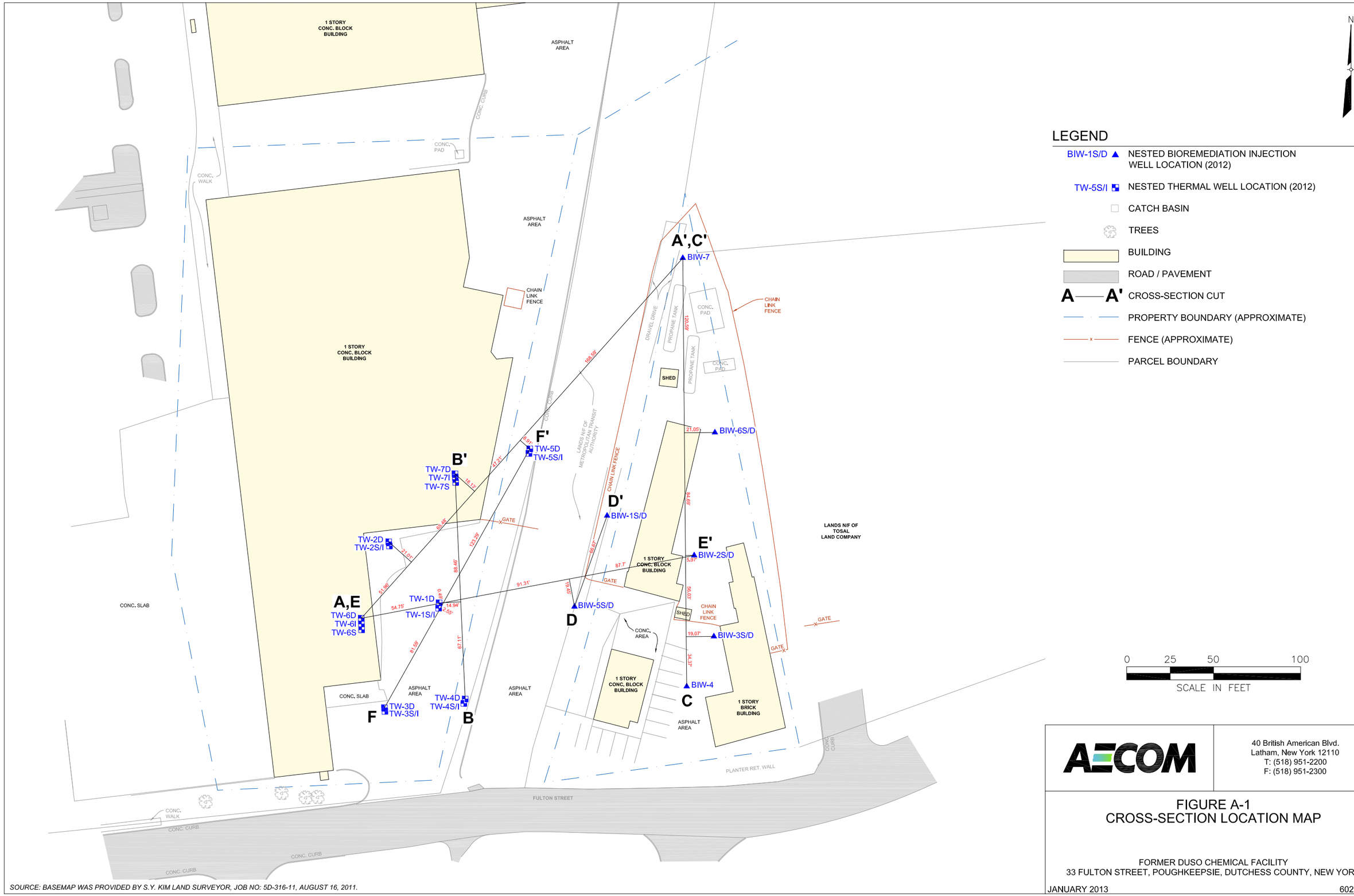
JANUARY 2013 60279080

Appendix A

2012 Field Investigation and Groundwater Sampling Results

Appendix A-1

Cross-Section Location Map



SOURCE: BASEMAP WAS PROVIDED BY S.Y. KIM LAND SURVEYOR, JOB NO: 5D-316-11, AUGUST 16, 2011.

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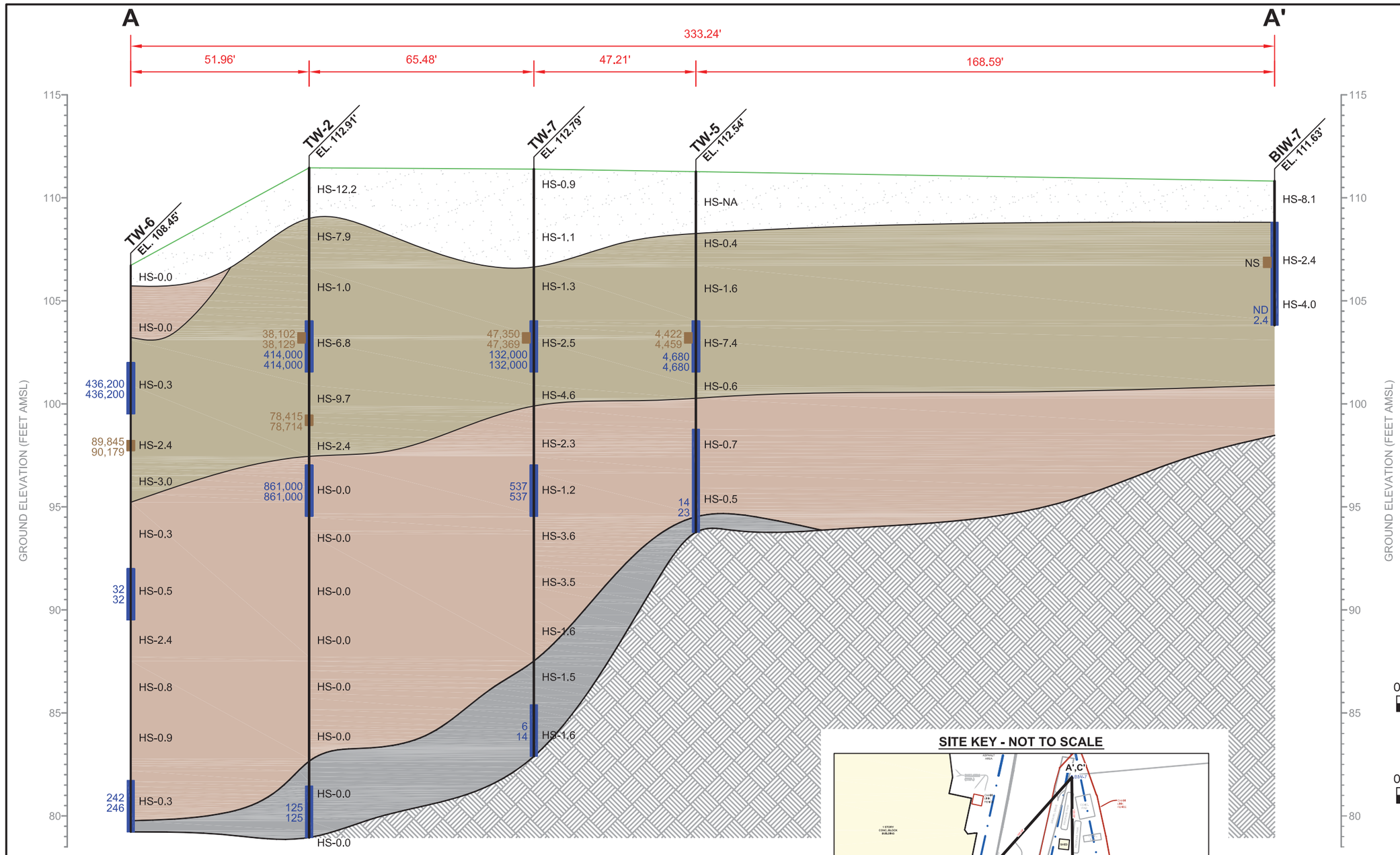
FIGURE A-1
CROSS-SECTION LOCATION MAP

FORMER DUSO CHEMICAL FACILITY
33 FULTON STREET, POUGHKEEPSIE, DUTCHESS COUNTY, NEW YORK

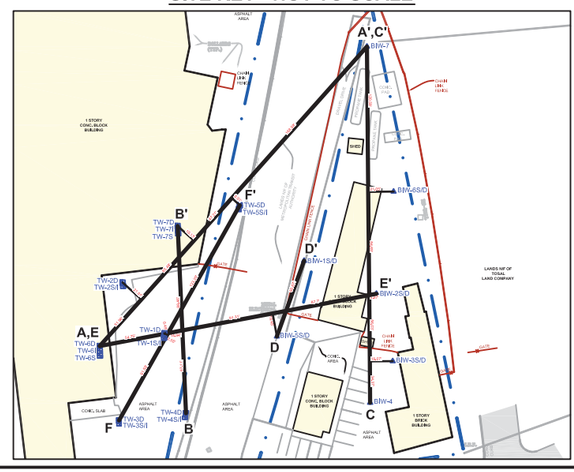
JANUARY 2013 60279080

Appendix A-2

Cross-Section A-A’



SITE KEY - NOT TO SCALE



LEGEND

- WELL
- SCREEN INTERVAL (FT.)
- SOIL SAMPLE
- 89,845 / 90,179 — TOTAL CHLORINATED VOLATILE ORGANIC COMPOUND (VOCS) IN SOIL / TOTAL VOCS IN SOIL
- 242 / 246 — TOTAL CHLORINATED VOLATILE ORGANIC COMPOUND (VOCS) IN GROUNDWATER / TOTAL VOCS IN GROUNDWATER
- SAND AND GRAVEL
- CLAYEY SILT AND SAND
- SILTY CLAY
- GLACIAL TILL
- BEDROCK

NOTES

1. NO SOIL SAMPLES WERE COLLECTED ON STAR GAS PROPERTY
2. SOIL RESULTS DISPLAYED IN MICROGRAMS PER KILOGRAM (µg/kg)
3. GROUNDWATER RESULTS DISPLAYED IN MICROGRAMS PER LITER (µg/L)
4. NA - NOT AVAILABLE
5. NS - NOT SAMPLED
6. HS - HEAD SPACE (PARTS PER MILLION [ppm])
7. ND - NON DETECT

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FIGURE A-2
CROSS-SECTION A-A'

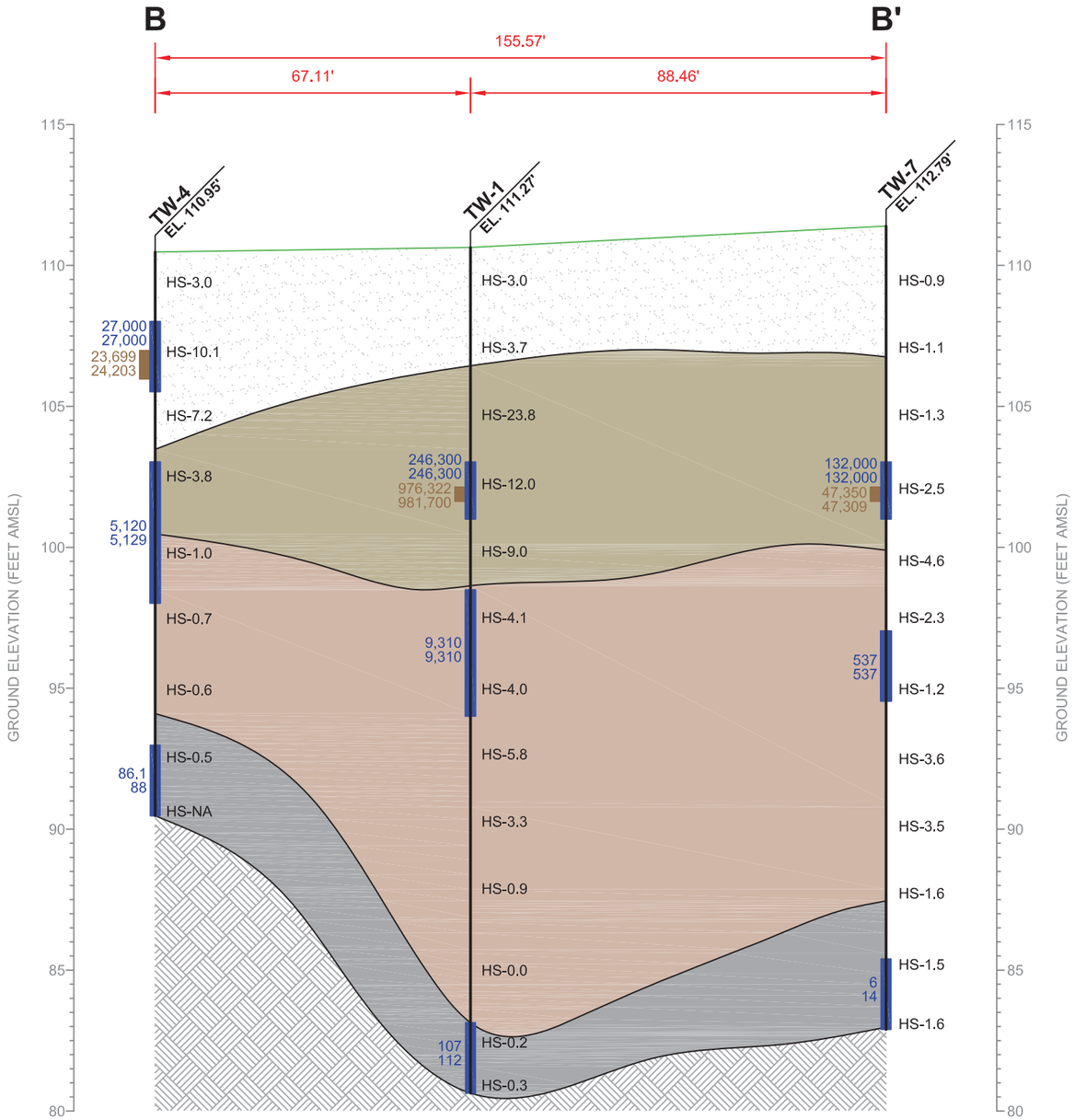
FORMER DUSO CHEMICAL FACILITY
33 FULTON STREET, POUGHKEEPSIE, DUTCHESS COUNTY, NEW YORK

JANUARY 2013 60279080

L:\Group\earth\Latham NY Work\NYSDEC Former Duso Chem Site\60279080_003 Cross-section A-A'.dwg, 2/1/2013 11:24:11 AM, Splawnm

Appendix A-3

Cross-Section B-B’



LEGEND

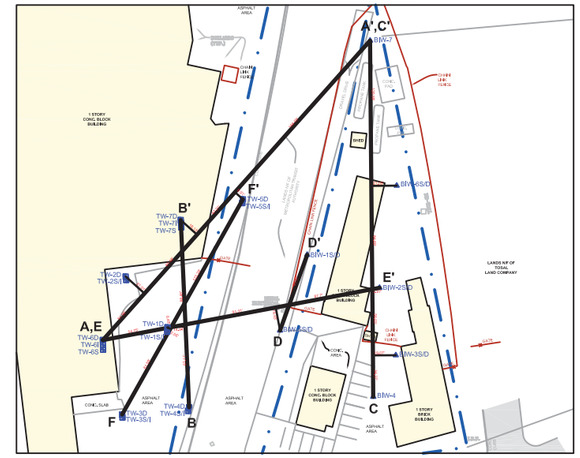
- WELL
- SCREEN INTERVAL (FT.)
- SOIL SAMPLE
- 23,699 / 24,203 — TOTAL CHLORINATED VOLATILE ORGANIC COMPOUND (VOCS) IN SOIL / TOTAL VOCS IN SOIL
- 86.1 / 88 — TOTAL CHLORINATED VOLATILE ORGANIC COMPOUND (VOCS) IN GROUNDWATER / TOTAL VOCS IN GROUNDWATER

- SAND AND GRAVEL
- CLAYEY SILT AND SAND
- SILTY CLAY
- GLACIAL TILL
- BEDROCK

NOTES

1. NO SOIL SAMPLES WERE COLLECTED ON STAR GAS PROPERTY
2. SOIL RESULTS DISPLAYED IN MICROGRAMS PER KILOGRAM (µg/kg)
3. GROUNDWATER RESULTS DISPLAYED IN MICROGRAMS PER LITER (µg/L)
4. NA - NOT AVAILABLE
5. NS - NOT SAMPLED
6. HS - HEAD SPACE (PARTS PER MILLION [ppm])
7. ND - NON DETECT

SITE KEY - NOT TO SCALE



0 15 30 60
SCALE IN FEET
HORIZONTAL SCALE

0 5 10 20
SCALE IN FEET
VERTICAL SCALE
3x EXAGGERATION

AECOM
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FIGURE A-3
CROSS-SECTION B-B'

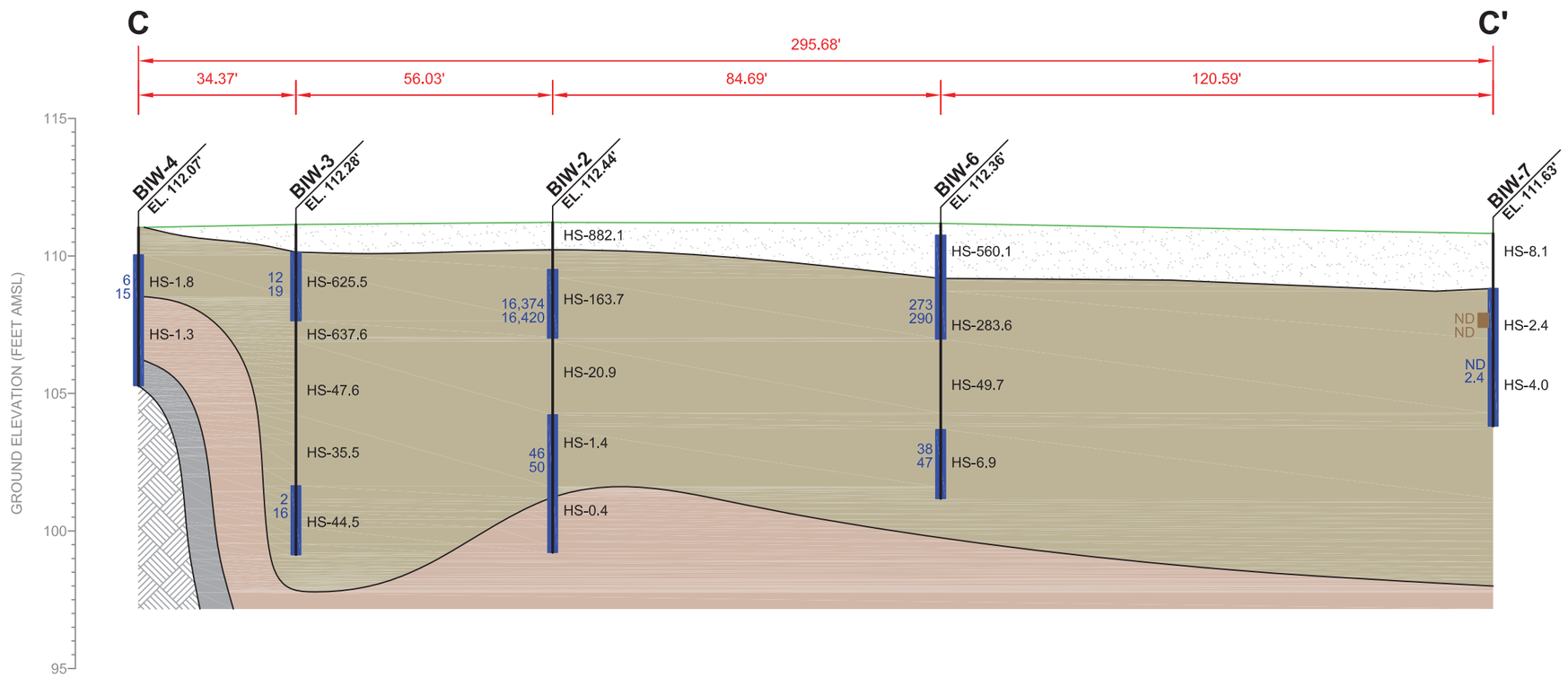
FORMER DUSO CHEMICAL FACILITY
33 FULTON STREET, POUGHKEEPSIE, DUTCHESS COUNTY, NEW YORK

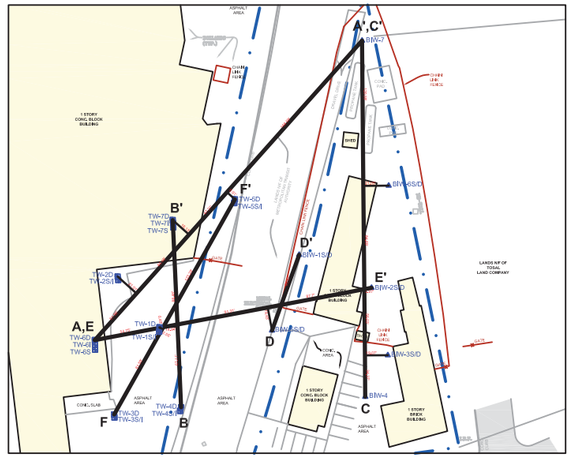
JANUARY 2013 60279080

L:\Group\earth\Latham NY Work\NYSDEC Former Duso Chem Site\60279080_008 Cross-section B-B'.dwg, 2/1/2013 11:23:59 AM, Splawnm

Appendix A-4

Cross-Section C-C’





0 15 30 60
SCALE IN FEET
HORIZONTAL SCALE

0 5 10 20
SCALE IN FEET
VERTICAL SCALE
3x EXAGGERATION

LEGEND

- WELL
- SCREEN INTERVAL (FT.)
- SOIL SAMPLE
- ND / ND — TOTAL CHLORINATED VOLATILE ORGANIC COMPOUND (VOCS) IN SOIL / TOTAL VOCS IN SOIL
- 2 / 16 — TOTAL CHLORINATED VOLATILE ORGANIC COMPOUND (VOCS) IN GROUNDWATER / TOTAL VOCS IN GROUNDWATER
- SAND AND GRAVEL
- CLAYEY SILT AND SAND
- SILTY CLAY
- GLACIAL TILL
- BEDROCK

NOTES

1. NO SOIL SAMPLES WERE COLLECTED ON STAR GAS PROPERTY
2. SOIL RESULTS DISPLAYED IN MICROGRAMS PER KILOGRAM (µg/kg)
3. GROUNDWATER RESULTS DISPLAYED IN MICROGRAMS PER LITER (µg/L)
4. NA - NOT AVAILABLE
5. NS - NOT SAMPLED
6. HS - HEAD SPACE (PARTS PER MILLION [ppm])
7. ND - NON DETECT

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FIGURE A-4
CROSS-SECTION C-C'

FORMER DUSO CHEMICAL FACILITY
33 FULTON STREET, POUGHKEEPSIE, DUTCHESS COUNTY, NEW YORK

JANUARY 2013 60279080

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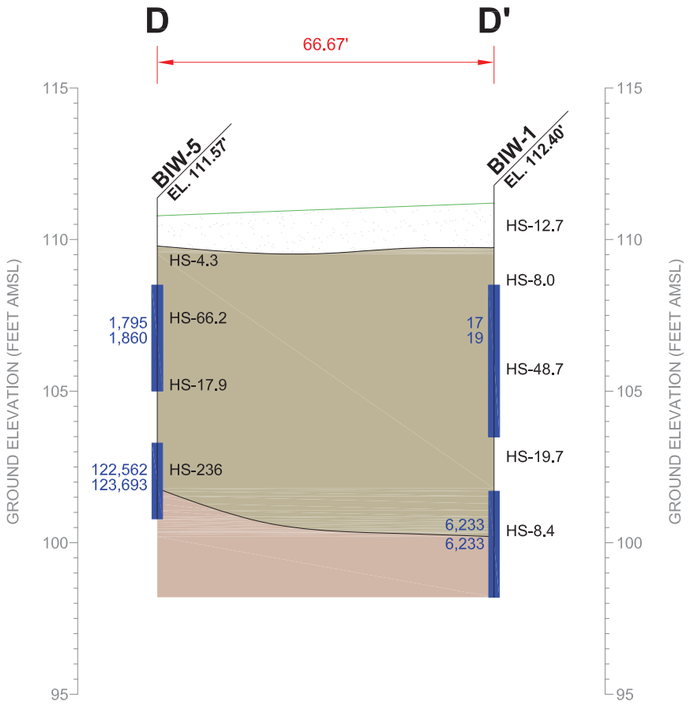
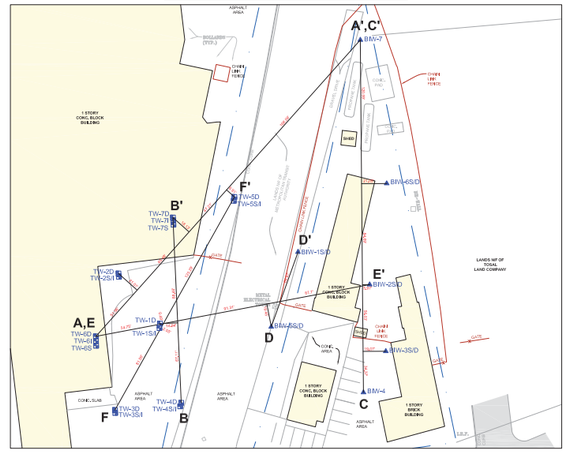
Appendix A-5

Cross-Section D-D’



SITE KEY - NOT TO SCALE



0 15 30 60
SCALE IN FEET
HORIZONTAL SCALE

0 5 10 20
SCALE IN FEET
VERTICAL SCALE
3x EXAGGERATION

LEGEND

- WELL
- SCREEN INTERVAL (FT.)
- SOIL SAMPLE
- # / # TOTAL CHLORINATED VOLATILE ORGANIC COMPOUND (VOCS) IN SOIL
  TOTAL VOCS IN SOIL
- 6,233 / 6,233 TOTAL CHLORINATED VOLATILE ORGANIC COMPOUND (VOCS) IN GROUNDWATER
  TOTAL VOCS IN GROUNDWATER

- SAND AND GRAVEL
- CLAYEY SILT AND SAND
- SILTY CLAY
- GLACIAL TILL
- BEDROCK

NOTES

1. NO SOIL SAMPLES WERE COLLECTED ON STAR GAS PROPERTY
2. SOIL RESULTS DISPLAYED IN MICROGRAMS PER KILOGRAM (µg/kg)
3. GROUNDWATER RESULTS DISPLAYED IN MICROGRAMS PER LITER (µg/L)
4. NA - NOT AVAILABLE
5. NS - NOT SAMPLED
6. HS - HEAD SPACE (PARTS PER MILLION [ppm])
7. ND - NON DETECT

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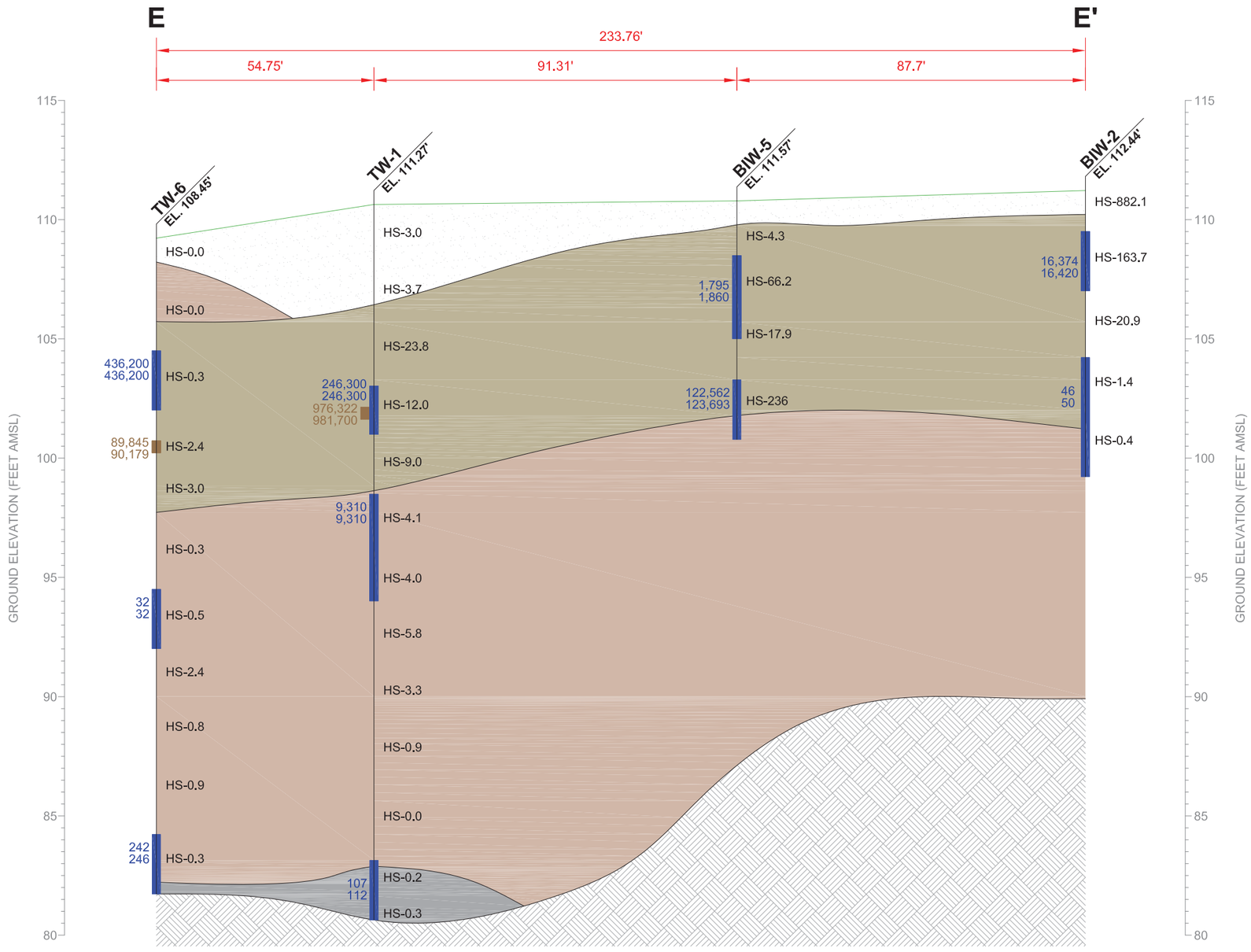
FIGURE A-5
CROSS-SECTION D-D'

FORMER DUSO CHEMICAL FACILITY
33 FULTON STREET, POUGHKEEPSIE, DUTCHESS COUNTY, NEW YORK

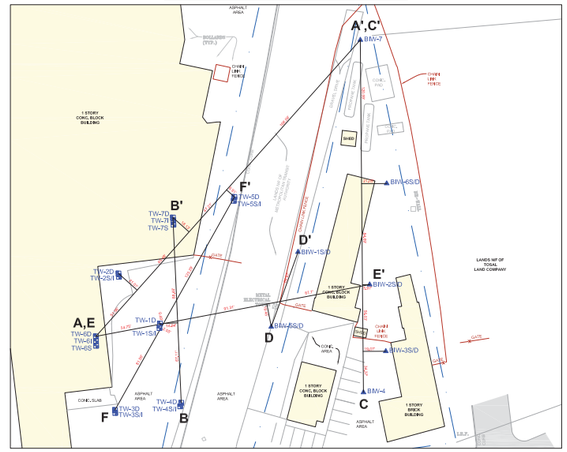
JANUARY 2013 60279080

Appendix A-6

Cross-Section E-E’



SITE KEY - NOT TO SCALE



0 15 30 60
SCALE IN FEET
HORIZONTAL SCALE

0 5 10 20
SCALE IN FEET
VERTICAL SCALE
3x EXAGGERATION

LEGEND

- WELL
- SCREEN INTERVAL (FT.)
- SOIL SAMPLE
- 89,845 / 90,179 — TOTAL CHLORINATED VOLATILE ORGANIC COMPOUND (VOCS) IN SOIL / TOTAL VOCS IN SOIL
- 242 / 246 — TOTAL CHLORINATED VOLATILE ORGANIC COMPOUND (VOCS) IN GROUNDWATER / TOTAL VOCS IN GROUNDWATER
- SAND AND GRAVEL
- CLAYEY SILT AND SAND
- SILTY CLAY
- GLACIAL TILL
- BEDROCK

NOTES

1. NO SOIL SAMPLES WERE COLLECTED ON STAR GAS PROPERTY
2. SOIL RESULTS DISPLAYED IN MICROGRAMS PER KILOGRAM (µg/kg)
3. GROUNDWATER RESULTS DISPLAYED IN MICROGRAMS PER LITER (µg/L)
4. NA - NOT AVAILABLE
5. NS - NOT SAMPLED
6. HS - HEAD SPACE (PARTS PER MILLION [ppm])
7. ND - NON DETECT

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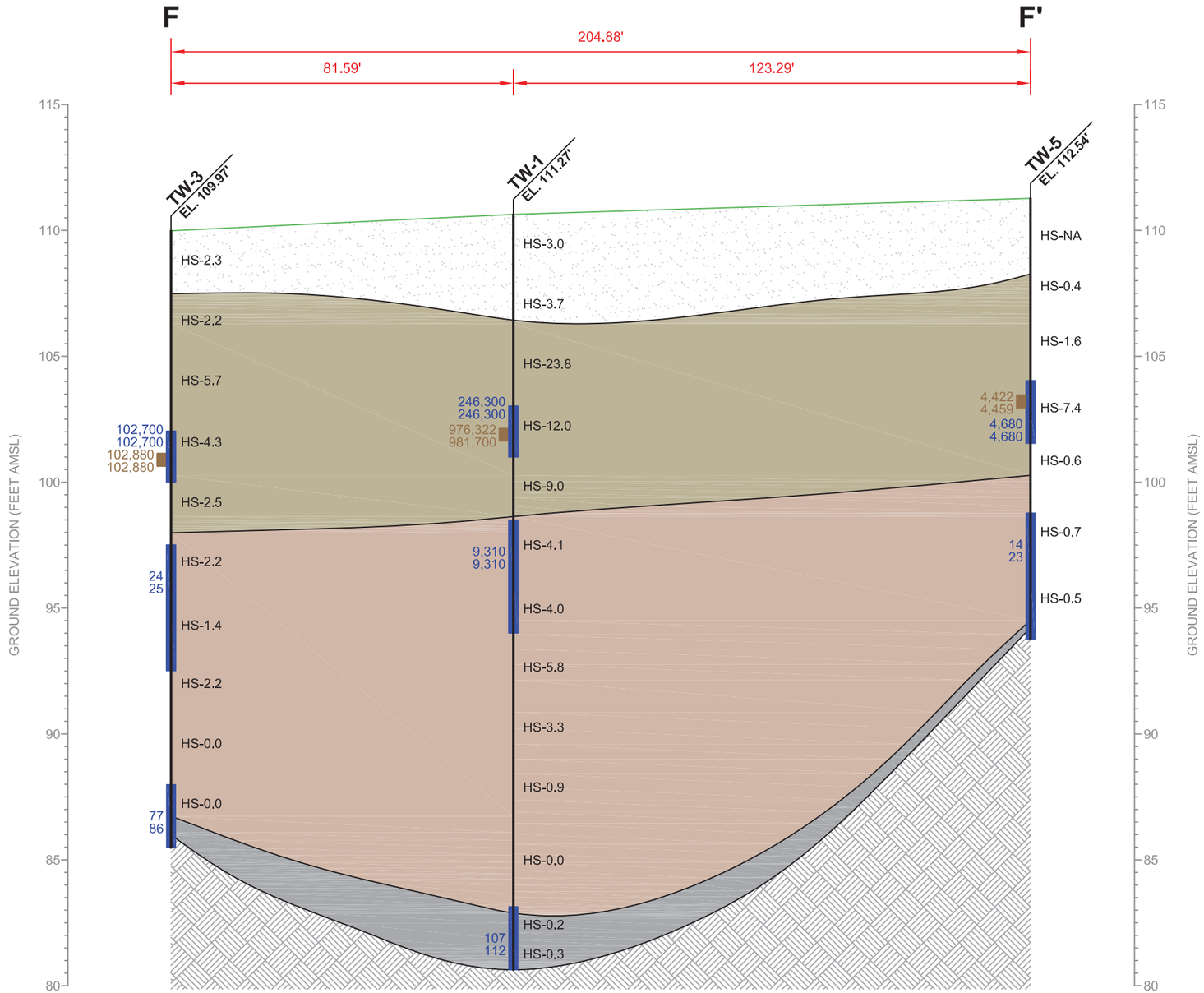
FIGURE A-6
CROSS-SECTION E-E'

FORMER DUSO CHEMICAL FACILITY
33 FULTON STREET, POUGHKEEPSIE, DUTCHESS COUNTY, NEW YORK

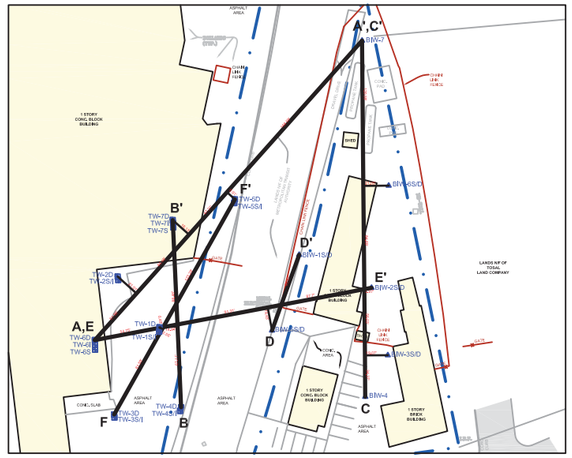
JANUARY 2013 60279080

Appendix A-7

Cross-Section F-F’



SITE KEY - NOT TO SCALE



0 15 30 60
SCALE IN FEET
HORIZONTAL SCALE

0 5 10 20
SCALE IN FEET
VERTICAL SCALE
3x EXAGGERATION

LEGEND

- WELL
- SCREEN INTERVAL (FT.)
- SOIL SAMPLE
- 102,880 / 102,880 — TOTAL CHLORINATED VOLATILE ORGANIC COMPOUND (VOCS) IN SOIL / TOTAL VOCS IN SOIL
- 77 / 86 — TOTAL CHLORINATED VOLATILE ORGANIC COMPOUND (VOCS) IN GROUNDWATER / TOTAL VOCS IN GROUNDWATER
- SAND AND GRAVEL
- CLAYEY SILTAND SAND
- SILTY CLAY
- GLACIAL TILL
- BEDROCK

NOTES

1. NO SOIL SAMPLES WERE COLLECTED ON STAR GAS PROPERTY
2. SOIL RESULTS DISPLAYED IN MICROGRAMS PER KILOGRAM (µg/kg)
3. GROUNDWATER RESULTS DISPLAYED IN MICROGRAMS PER LITER (µg/L)
4. NA - NOT AVAILABLE
5. NS - NOT SAMPLED
6. HS - HEAD SPACE (PARTS PER MILLION [ppm])
7. ND - NON DETECT

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FIGURE A-7
CROSS-SECTION F-F'

FORMER DUSO CHEMICAL FACILITY
33 FULTON STREET, POUGHKEEPSIE, DUTCHESS COUNTY, NEW YORK

JANUARY 2013 60279080

L:\Group\earth\Latham NY Work\NYSDEC Former Duso Chem Site\60279080_012 Cross-section F-F'.dwg, 2/1/2013 11:24:24 AM, Splawnm

Appendix A-8

Boring Logs

AECOM, Inc.
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Latham, New York 12110
Phone: (518) 951-2200
Fax: (518) 951-2300

BOREHOLE LOG

BORING ID #: **BIW-1S/D**

START DATE:8/14/12 END DATE: 8/14/12

PROJECT NAME: **Former Duso Chemical Company** PROJECT NO.: **60279080.1** PROJECT MANAGER: **Lindsay Mitchell**
SITE LOCATION: **Poughkeepsie, New York** BORING LOCATION:
DRILLING CO.: **GeoLogic** DRILLER: **Scott and John** DRILLING METHOD: **HSA with 2' Split Spoon**
BOREHOLE DIAMETER: **6.25"** DEPTH TO BEDROCK: TOTAL DEPTH DRILLED: **26'**
TOTAL DEPTH REACHED:**25.5'** INSPECTOR: **Greta White** WEATHER CONDITIONS:
EASTING: **648101.8** NORTHING: **1053518.9** ELEVATION AND DATUM: **112.40/ UTM 18**

FIELD SAMPLE INFORMATION								HAMMER	SAMPLER	ST. WATER LEVELS	DATE 1: DATE 2:	DEPTH 1: DEPTH 2:	TIME 1: TIME 2:
							WEIGHT(S)						
							FALL			CASING	TUBE	CORE	RIG TYPE:
							TYPE						
							ID/OD						
DEPTH (feet bgs)	Blow Counts	RECOVERY	PID (ppm)	ODOR OBSERVED	LAB ANALYSIS	VISIBLE PRODUCT	GEOLOGIC DESCRIPTION					LITHOLOGY/ SOIL TYPE	WATER LEVEL ---------- - REMARKS
0.0	35 37 31 22	1.2	1.0	N	N	N	Gray fine SAND, some Gravel Turns brown and silty last 2" with dark gray 1 cm lense just above					Dry; compact	
2.0	16 14 10 7	0.9	12.7	N	N	N	2-2.5' SAA, then black crispy, dry coal ash Last 1" is Gray brown SILT, trace fine Sand, Clay and Gravel					Dry	
4.0	3 3 5 6	1.0	1.1 / 0.8	N	N	N	4-4.25' Gray brown SILTY SAND, trace Gravel 4.25-4.5' Coarse SAND, little Silt, trace Gravel					Moist Wet @ 4.25'	
6.0	6 3 4 6	1.8	1.1	N	N	N	6-6.75' SAA 6.75-7.6' Orange brown fine SAND, trace Silt with a 1 cm clay lense at 7.4' 7.6' Gray fine SAND, trace Silt					Wet	
8.0	5 8 7 8	1.3	8.0	Y	N	N	8-8.5' Gray fine SAND, little Silt 8.5' Fine SAND, increasing Silt content with depth; last 1" SILT, little fine SAND, slight acetone-like odor.					Wet	
10.0	5 6 8 6	1.4	48.7	Y	N	Y	10-10.5' SAA 10.5 Gray fine SAND, trace Silt; Slight sheen last 2"					Wet	
12.0	5 4 3 6	2.0	34.7	Y	N	N	12-12.8' Gray SILT, little fine Sand, trace Clay 12.8-13.2' Fine SAND, trace Silt; Sheen 13.2-13.6' SILT, little fine Sand 13.6' Fine SAND, little Silt; 1 cm clay lense 2" from bottom					Wet	
14.0	4 3 4 6	1.7	19.7	Y	N	Y	Gray SILTY fine SAND, trace Clay; areas of higher sand/clay content - sheen in sandy layers					Wet	
16.0	4 3 2 1	2.0	11.8	Y	N	Y	16-17.3' Gray fine SAND, little Silt 17.3' 1" Lense of SILTY CLAY followed by SILTY SAND to bottom; Sheen/odor					Wet	
18.0	3 2 3 2	1.9	6.3	Y	N	Y	18-19 Gray fine SAND, some Silt, trace Clay; Slight odor and sheen 19-19.9' Gray SILT, little Clay, trace fine Sand; very slight odor, no sheen observed					Wet	

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BOREHOLE LOG

BORING ID #: **BIW-1S/D**

START DATE:8/14/12 END DATE: 8/14/12

PROJECT NAME: **Former Duso Chemical Company** PROJECT NO.: **60279080.1** PROJECT MANAGER: **Lindsay Mitchell**
SITE LOCATION: **Poughkeepsie, New York** BORING LOCATION:
DRILLING CO.: **GeoLogic** DRILLER: **Scott and John** DRILLING METHOD: **HSA with 2' Split Spoon**
BOREHOLE DIAMETER: **6.25"** DEPTH TO BEDROCK: TOTAL DEPTH DRILLED: **26'**
TOTAL DEPTH REACHED:**25.5'** INSPECTOR: **Greta White** WEATHER CONDITIONS:
EASTING: **648101.8** NORTHING: **1053518.9** ELEVATION AND DATUM: **112.40/ UTM 18**

FIELD SAMPLE INFORMATION								HAMMER	SAMPLER	ST. WATER LEVELS	DATE 1:	DEPTH 1:	TIME 1:
							WEIGHT(S)				DATE 2:	DEPTH 2:	TIME 2:
							FALL			CASING	TUBE	CORE	RIG TYPE:
							TYPE						
							ID/OD						
DEPTH (feet bgs)	Blow Counts	RECOVERY	PID (ppm)	ODOR OBSERVED	LAB ANALYSIS	VISIBLE PRODUCT	GEOLOGIC DESCRIPTION					LITHOLOGY/ SOIL TYPE	WATER LEVEL ---------- - REMARKS
20.0	2 2 3 3	1.8	8.4	Y	N	N	SAA; odor at top only					Wet	
22.0	3 4 4 3	1.9	5.2	N	N	N	Gray CLAYEY SILT, trace fine Sand					Wet	
24.0	2 2 4 3	1.5	3.6	Y	N	N	24-24.6' Gray SILT, little Clay, trace fine Sand; sheen, slight odor 24.6-25.5' Gray SILT, some Clay, trace fine Sand					Wet	
26.0													
28.0													
30.0													
32.0													
34.0													
36.0													
38.0													

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BOREHOLE LOG

BORING ID #: **BIW-2S/D**

START DATE: 8/9/12 END DATE: 8/9/12

PROJECT NAME: **Former Duso Chemical Company** PROJECT NO.: **60279080.1** PROJECT MANAGER: **Lindsay Mitchell**
SITE LOCATION: **Poughkeepsie, New York** BORING LOCATION:
DRILLING CO.: **GeoLogic** DRILLER: **Scott and John** DRILLING METHOD: **HSA with 2' Split Spoon**
BOREHOLE DIAMETER: **6.25"** DEPTH TO BEDROCK: TOTAL DEPTH DRILLED: **24'**
TOTAL DEPTH REACHED: **23.6'** INSPECTOR: **Greta White** WEATHER CONDITIONS:
EASTING: **648161.7** NORTHING: **1053491.6** ELEVATION AND DATUM: **112.44/ UTM 18**

FIELD SAMPLE INFORMATION

	HAMMER	SAMPLER	ST. WATER LEVELS	DATE 1: DATE 2:	DEPTH 1: DEPTH 2:	TIME 1: TIME 2:
WEIGHT(S)						
FALL			CASING	TUBE	CORE	RIG TYPE:
TYPE						
ID/OD						

DEPTH (feet bgs)	Blow Counts	RECOVERY	PID (ppm)	ODOR OBSERVED	LAB ANALYSIS	VISIBLE PRODUCT	GEOLOGIC DESCRIPTION	LITHOLOGY/ SOIL TYPE	WATER LEVEL / REMARKS
0.0	25 28 27 31	1.0	122.0	N	N	N	Brown SAND and GRAVEL; backfill; turns black at 0.5'; loose	Dry	
2.0	2 2 3 3	1.4	882.1	N	N	N	2-3' Black SILT, little fine Sand; plastic; strong odor 3' Olivey brown SILT, little fine Sand, trace Clay; moist at bottom	Dry Moist @ 3.3'	
4.0	1 1 2 3	0.8	163.7	N	N	N	Dark gray fine SAND, little Silt; strong odor	Moist Wet @4.7'	
6.0	3 4 4 4	1.3	11.5 / 15.4	N	N	N	6-6.4' SAA; increasing sand content and grain size with depth 6.4-6.7' Gravelly coarse SAND 6.7' 1" layer of SILTY CLAY then brown fine, medium SAND, trace Silt and Clay; increasing silt with depth; sheen on water	Wet	
8.0	6 9 9 7						No recovery after two attempts		
10.0	7 4 4 4	1.4	20.9	N	N	N	Gray fine SAND, little Silt, trace Clay; plastic; slight odor	Wet	
12.0	3 3 4 4	1.4	4.6	N	N	N	12-12.4' Gray SILTY SAND, trace Clay; very soft 12.4' Gray fine SAND, little Silt, trace Clay; plastic; slight odor	Wet	
14.0	2 3 2 3	1.5	1.4	N	N	N	Gray fine SAND, some Silt, trace Clay	Wet	
16.0	3 2 3 3	1.8	0.8	Y	N	N	Gray SILTY SAND, little Clay/some Clay (last 1"); plastic	Wet	
18.0	3 2 3 2	1.7	0.6	Y	N	N	Gray SILTY SAND, little Clay; plastic	Wet	

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BOREHOLE LOG

BORING ID #: **BIW-2S/D**

START DATE: 8/9/12 END DATE: 8/9/12

PROJECT NAME: **Former Duso Chemical Company** PROJECT NO.: **60279080.1** PROJECT MANAGER: **Lindsay Mitchell**
SITE LOCATION: **Poughkeepsie, New York** BORING LOCATION:
DRILLING CO.: **GeoLogic** DRILLER: **Scott and John** DRILLING METHOD: **HSA with 2' Split Spoon**
BOREHOLE DIAMETER: **6.25"** DEPTH TO BEDROCK: TOTAL DEPTH DRILLED: **24'**
TOTAL DEPTH REACHED:**23.6'** INSPECTOR: **Greta White** WEATHER CONDITIONS:
EASTING: **648161.7** NORTHING: **1053491.6** ELEVATION AND DATUM: **112.44/ UTM 18**

FIELD SAMPLE INFORMATION								HAMMER	SAMPLER	ST. WATER LEVELS	DATE 1:	DEPTH 1:	TIME 1:
							WEIGHT(S)				DATE 2:	DEPTH 2:	TIME 2:
							FALL			CASING	TUBE	CORE	RIG TYPE:
DEPTH (feet bgs)	Blow Counts	RECOVERY	PID (ppm)	ODOR OBSERVED	LAB ANALYSIS	VISIBLE PRODUCT	TYPE						
							ID/OD						
							GEOLOGIC DESCRIPTION					LITHOLOGY/ SOIL TYPE	WATER LEVEL ---------- REMARKS
20.0		1.7	0.4	Y	N	N	Gray SILT, some Clay, trace fine Sand; plastic					Wet	
22.0		1.7	0.3	Y	N	N	SAA					Wet	
24.0													
26.0													
28.0													
30.0													
32.0													
34.0													
36.0													
38.0													

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BOREHOLE LOG

BORING ID #: **BIW-3S/D**

START DATE: 8/7/12 END DATE: 8/7/12

PROJECT NAME: **Former Duso Chemical Company** PROJECT NO.: **60279080.1** PROJECT MANAGER: **Lindsay Mitchell**
SITE LOCATION: **Poughkeepsie, New York** BORING LOCATION:
DRILLING CO.: **GeoLogic** DRILLER: **Scott and John** DRILLING METHOD: **HSA with 2' Split Spoon**
BOREHOLE DIAMETER: **6.25"** DEPTH TO BEDROCK: TOTAL DEPTH DRILLED: **24'**
TOTAL DEPTH REACHED:**23'8"** INSPECTOR: **Greta White** WEATHER CONDITIONS:
EASTING: **648175.3** NORTHING: **1053435.7** ELEVATION AND DATUM: **112.28/ UTM 18**

FIELD SAMPLE INFORMATION								HAMMER	SAMPLER	ST. WATER LEVELS	DATE 1:	DEPTH 1:	TIME 1:
							WEIGHT(S)				DATE 2:	DEPTH 2:	TIME 2:
							FALL			CASING	TUBE	CORE	RIG TYPE:
							TYPE						
							ID/OD						
DEPTH (feet bgs)	Blow Counts	RECOVERY	PID (ppm)	ODOR OBSERVED	LAB ANALYSIS	VISIBLE PRODUCT	GEOLOGIC DESCRIPTION					LITHOLOGY/ SOIL TYPE	WATER LEVEL ---------- REMARKS
0.0	8 36 17 74	0.9	226.7	N	N	N	0-0.5' Asphalt 0.5' Gray brown SAND and GRAVEL; loose					Dry	
2.0	7 3 2 2	0.8	625.5	Y	N	N	Dark gray, slightly olive fine SAND, some Silt; plastic; petroleum-like odor					Wet	
4.0	4 3 3 4	1.4	637.6	Y	N	N	4-4.75' SAA 4.75-5' Medium, fine SAND, trace Silt; non-plastic; loose 5-5.4' SILT, some fine Sand, trace Clay; firm; plastic					Wet	
6.0	4 3 3 3	1.0	7.1	N	N	N	Olivey brown SILT, little Clay, trace fine Sand; firm; plastic					Moist	
8.0	4 5 6 7	1.4	22.2	N	N	N	8-8.4' SAA 8.4-9.4' Olivey brown SILT, little fine Sand, trace Clay (in lenses); firm; plastic					Moist	
10.0	5 5 6 6	1.2	47.6 / 17.0	Y	N	N	10-10.7' SAA; slightly firm; slight odor 10.7-11.2' Gray fine SAND, some Silt; firm; plastic					Wet	
12.0	4 6 5 6	1.0	3.2	N	N	N	SAA					Wet	
14.0	4 4 3 8	1.0	30.3	Y	N	N	SAA; slight odor					Wet	
16.0	3 4 4 6	1.2	14.1	N	N	N	16-16.8' SAA 16.8-17' Gray fine SAND, some Silt and subangular Gravel; plastic 17-17.2' Brown SAND and GRAVEL; loose					Wet Moist Wet	
18.0	3 4 4 4	1.0	35.5	N	N	N	18-18.4' Gray fine SAND, some Silt and subangular Gravel; plastic 18.4-18.7' Brown SAND and GRAVEL; loose 18.7-19' Gray shaley GRAVEL, little Silt and fine Sand; loose					Moist Wet	

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BOREHOLE LOG

BORING ID #: **BIW-3S/D**

START DATE: 8/7/12 END DATE: 8/7/12

PROJECT NAME: **Former Duso Chemical Company** PROJECT NO.: **60279080.1** PROJECT MANAGER: **Lindsay Mitchell**
SITE LOCATION: **Poughkeepsie, New York** BORING LOCATION:
DRILLING CO.: **GeoLogic** DRILLER: **Scott and John** DRILLING METHOD: **HSA with 2' Split Spoon**
BOREHOLE DIAMETER: **6.25"** DEPTH TO BEDROCK: TOTAL DEPTH DRILLED: **24'**
TOTAL DEPTH REACHED:**23'8"** INSPECTOR: **Greta White** WEATHER CONDITIONS:
EASTING: **648175.3** NORTHING: **1053435.7** ELEVATION AND DATUM: **112.28/ UTM 18**

FIELD SAMPLE INFORMATION								HAMMER	SAMPLER	ST. WATER LEVELS	DATE 1:	DEPTH 1:	TIME 1:
							WEIGHT(S)				DATE 2:	DEPTH 2:	TIME 2:
							FALL			CASING	TUBE	CORE	RIG TYPE:
DEPTH (feet bgs)	Blow Counts	RECOVERY	PID (ppm)	ODOR OBSERVED	LAB ANALYSIS	VISIBLE PRODUCT	TYPE						
							ID/OD						
							GEOLOGIC DESCRIPTION					LITHOLOGY/ SOIL TYPE	WATER LEVEL ---------- REMARKS
20.0	14 10 11 14	0.5	44.5	N	N	N	SAA					Wet	
22.0	20 20 27 74	1.8	35.2	N	N	N	22-22.3' Gray brown coarse(+) medium, fine(-) SAND; loose 22.3' Gray shaley GRAVEL, little Silt and fine Sand; loose					Wet	
24.0													
26.0													
28.0													
30.0													
32.0													
34.0													
36.0													
38.0													

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BOREHOLE LOG

BORING ID #: **BIW-4**

START DATE: 8/8/12 END DATE: 8/8/12

PROJECT NAME: **Former Duso Chemical Company** PROJECT NO.: **60279080.1** PROJECT MANAGER: **Lindsay Mitchell**
SITE LOCATION: **Poughkeepsie, New York** BORING LOCATION:
DRILLING CO.: **GeoLogic** DRILLER: **Scott and John** DRILLING METHOD: **HSA with 2' Split Spoon**
BOREHOLE DIAMETER: **6.25"** DEPTH TO BEDROCK: TOTAL DEPTH DRILLED: **12.1'**
TOTAL DEPTH REACHED:**11.6'** INSPECTOR: **Greta White** WEATHER CONDITIONS:
EASTING: **648156.5** NORTHING: **1053401.1** ELEVATION AND DATUM: **112.07/ UTM 18**

FIELD SAMPLE INFORMATION

	HAMMER	SAMPLER	ST. WATER LEVELS	DATE 1:	DEPTH 1:	TIME 1:
WEIGHT(S)				DATE 2:	DEPTH 2:	TIME 2:
FALL			CASING	TUBE	CORE	RIG TYPE:
TYPE						
ID/OD						

DEPTH (feet bgs)	Blow Counts	RECOVERY	PID (ppm)	ODOR OBSERVED	LAB ANALYSIS	VISIBLE PRODUCT	GEOLOGIC DESCRIPTION	LITHOLOGY/ SOIL TYPE	WATER LEVEL / REMARKS
0.0	10 11 50+	--	--	N	N	N	0-0.3' Asphalt 0.3-3' Concrete		
3.0	10 7 4 5	0.1	1.8	N	N	N	Brown angular GRAVEL, some fine Sand and Silt, trace Clay lenses; loose	Wet	
5.0	5 3 3 4	0.9	1.3	N	N	N	Orange brown SILT, little Clay and fine Sand; plastic; areas of higher/lower sand/clay content	Moist	
7.0	3 4 7 14	0.7	1.2	N	N	N	Orange brown SILT, some Clay; plastic	Moist	
9.0	11 29 31 30	0.9	1.3	N	N	N	9-9.4' Coarse(+), medium(-), fine(-) SAND 9.4-9.5' Orange brown SILT, some Clay; plastic 9.5' Gray till	Moist	
11.0	17 55 50+	0.6	1.3	N	N	N	11-11.5' SAA 11.5' Broken shale Refusal @ 12.1'	Moist	
13.0									
15.0									
17.0									
19.0									

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BOREHOLE LOG

BORING ID #: **BIW-5 S/D**

START DATE: 8/16/12 END DATE: 8/16/12

PROJECT NAME: **Former Duso Chemical Company** PROJECT NO.: **60279080.1** PROJECT MANAGER: **Lindsay Mitchell**
SITE LOCATION: **Poughkeepsie, New York** BORING LOCATION:
DRILLING CO.: **GeoLogic** DRILLER: **Scott and John** DRILLING METHOD: **HSA with 2' Split Spoon**
BOREHOLE DIAMETER: **6.25"** DEPTH TO BEDROCK: TOTAL DEPTH DRILLED: **20'**
TOTAL DEPTH REACHED:**19.1'** INSPECTOR: **Greta White** WEATHER CONDITIONS:
EASTING: **648079.1** NORTHING: **1053456.2** ELEVATION AND DATUM: **111.57/ UTM 18**

FIELD SAMPLE INFORMATION

	HAMMER	SAMPLER	ST. WATER LEVELS	DATE 1: DATE 2:	DEPTH 1: DEPTH 2:	TIME 1: TIME 2:
WEIGHT(S)						
FALL			CASING	TUBE	CORE	RIG TYPE:
TYPE						
ID/OD						

DEPTH (feet bgs)	Blow Counts	RECOVERY	PID (ppm)	ODOR OBSERVED	LAB ANALYSIS	VISIBLE PRODUCT	GEOLOGIC DESCRIPTION	LITHOLOGY/ SOIL TYPE	WATER LEVEL / REMARKS
0.0	4 5 12 15	1.2	2.8	N	N	N	0-0.8' Gray brown SAND and GRAVEL; backfill 0.8' Black crunchy coal ash; rock in shoe	Dry; loose	
2.0	4 4 3 4	0.9	2.8	N	N	N	Brown SILT, some fine Sand; non-plastic Last 1.5" is light brown	Dry	
4.0	5 5 5 3	0.7	4.3	N	N	N	SAA for 2" then fine(+), medium(-), coarse SAND, some Gravel, trace Silt; non plastic	Moist	
6.0	4 4 4 4	1.2	66.2	Y	N	N	6-6.25' SAA 6.25' Dark gray fine(-), medium, coarse(+) SAND, some Gravel, trace Silt	Wet; loose	
8.0	4 6 6 5	0.2	3.7	Y	N	N	Dark gray SILTY SAND, trace Clay; plastic; slight acetone-like odor.	Wet	
10.0	4 5 5 4	0.8	17.9	Y	N	N	Dark gray fine SAND, little Silt; slightly plastic; slight odor	Wet	
12.0	2 3 5 7	1.7	15.0	Y	N	N	12-12.7' SAA 12.7-13.4' Dark gray fine SAND, some Silt; intermittent clay beds >1" thick 13.4' Fine SAND, little Silt	Wet	
14.0	2 2 2 2	1.4	12.9	Y	N	N	Dark gray fine SAND, little Silt; slightly plastic; chemical-like odor	Wet	
16.0	2 2 3 3	1.7	23.6	Y	N	N	SAA; 1" clay lense at 17'	Wet	
18.0	3 3 3 2	1.1	4.0	Y	N	N	18-18.9' Dark gray SILTY SAND, little Clay; plastic; slight odor 18.9' SILT, some Clay; plastic	Wet Dry; firm	

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BOREHOLE LOG

BORING ID #: **BIW-6S/D**

START DATE: 8/15/12 END DATE: 8/15/12

PROJECT NAME: **Former Duso Chemical Company** PROJECT NO.: **60279080.1** PROJECT MANAGER: **Lindsay Mitchell**
SITE LOCATION: **Poughkeepsie, New York** BORING LOCATION:
DRILLING CO.: **GeoLogic** DRILLER: **Scott and John** DRILLING METHOD: **HSA with 2' Split Spoon**
BOREHOLE DIAMETER: **6.25"** DEPTH TO BEDROCK: TOTAL DEPTH DRILLED: **20'**
TOTAL DEPTH REACHED:**19.7'** INSPECTOR: **Greta White** WEATHER CONDITIONS:
EASTING: **648176.0** NORTHING: **1053576.4** ELEVATION AND DATUM: **112.36/ UTM 18**

FIELD SAMPLE INFORMATION								HAMMER	SAMPLER	ST. WATER LEVELS	DATE 1:	DEPTH 1:	TIME 1:
							WEIGHT(S)				DATE 2:	DEPTH 2:	TIME 2:
							FALL			CASING	TUBE	CORE	RIG TYPE:
							TYPE						
							ID/OD						
DEPTH (feet bgs)	Blow Counts	RECOVERY	PID (ppm)	ODOR OBSERVED	LAB ANALYSIS	VISIBLE PRODUCT	GEOLOGIC DESCRIPTION					LITHOLOGY/ SOIL TYPE	WATER LEVEL ---------- REMARKS
0.0	40 51 19 12	1.3	5.5	N	N	N	0-0.8' Fine, medium, course SAND and GRAVEL; backfill 0.8' Gray brown SILT, trace fine Sand and Gravel; 2" layer of black crunchy coal ash at bottom					Dry	
2.0	11 5 3 3	1.4	560.1	Y	N	N	2-2.4' SAA 2.4-2.8' White and black crushed shaley material; moist 2.8' Dark gray SILT, trace fine Sand and Clay with organics; plastic Petroleum-like odor at bottom					Dry Moist	
4.0	2 2 4 5	1.6	283.6	N	N	N	4-4.75' Greenish gray brown SILTY SAND 4.75' Fine SAND, trace Silt					Moist Wet @ 4.75'	
6.0	5 6 4 4	1.9	4.2	Y	N	N	6-6.5' SAA, increasing sand/grain size with depth; slight petroleum-like odor 6.5-7' Fine SAND and shaley GRAVEL, trace Silt; loose 7' Orange brown SILTY SAND; plastic					Wet	
8.0	3 5 8 7	1.9	105.9	Y	N	N	Olivey brown SILT, trace Clay and fine Sand; varying degrees of clay and sand content; plastic. 1" lense of SAND, some Gravel at 8.75'; loose Graying with depth; slight petroleum-like odor at bottom					Wet	
10.0	6 6 7 7	1.0	28.9	Y	N	N	Dark gray fine SAND, little Silt, trace Clay; plastic; slight petroleum-like odor					Wet	
12.0	4 6 7 7	1.4	49.7	N	N	N	SAA					Wet	
14.0		1.8	6.9	N	N	N	14-14.75' SAA 14.75' 1" layer of dark gray SILT; firm 14.8' SILTY SAND					Wet Dry Wet	
16.0		1.8	4.2	N	N	N	16-16.4' SAA 16.4' 1" layer of dark gray SILT; firm 16.5' SILTY SAND, trace Clay; plastic					Wet Dry Wet	
18.0	2 2 2 3	1.7	2.5	N	N	N	18-18.4' Dark gray SAA 18.4' SILT, little Clay and fine Sand; clay is in intermittent lenses of various sizes, all >1" thick					Wet	

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BOREHOLE LOG

BORING ID #: **BIW-7**

START DATE: 8/16/12 END DATE: 8/16/12

PROJECT NAME: **Former Duso Chemical Company** PROJECT NO.: **60279080.1** PROJECT MANAGER: **Lindsay Mitchell**
SITE LOCATION: **Poughkeepsie, New York** BORING LOCATION:
DRILLING CO.: **GeoLogic** DRILLER: **Scott and John** DRILLING METHOD: **HSA with 2' Split Spoon**
BOREHOLE DIAMETER: **6.25"** DEPTH TO BEDROCK: TOTAL DEPTH DRILLED: **14'**
TOTAL DEPTH REACHED:**13.3'** INSPECTOR: **Greta White** WEATHER CONDITIONS:
EASTING: **648153.8** NORTHING: **1053696.8** ELEVATION AND DATUM: **111.63/ UTM 18**

FIELD SAMPLE INFORMATION

	HAMMER	SAMPLER	ST. WATER LEVELS	DATE 1:	DEPTH 1:	TIME 1:
WEIGHT(S)				DATE 2:	DEPTH 2:	TIME 2:
FALL			CASING	TUBE	CORE	RIG TYPE:
TYPE						
ID/OD						

DEPTH (feet bgs)	Blow Counts	RECOVERY	PID (ppm)	ODOR OBSERVED	LAB ANALYSIS	VISIBLE PRODUCT	GEOLOGIC DESCRIPTION	LITHOLOGY/ SOIL TYPE	WATER LEVEL / REMARKS
0.0	13 16 8 5	1.6	1.9	Y	N	N	Olivey gray SAND and GRAVEL, trace Silt; backfill; compact Three 1" layers of white/brown crunchy material at 4, 2 and 1 inches from bottom Slight odor at bottom	Dry	
2.0	3 2 2 2	0.6	8.1	Y	N	N	Olivey gray SILT, trace fine Sand; organics; plastic; slight odor	Dry	
4.0	3 3 5 6	1.4	2.4	Y	N	N	4-4.8' SAA 4.8' Gray fine SAND, trace Silt; slight odor	Dry Wet	
6.0	5 4 5 7	1.2	2.3	Y	N	N	SAA	Wet	
8.0	3 5 5 7	1.7	2.4	N	N	N	8-8.8' Olivey gray SILT, trace Sand; plastic 8.8' Fine SAND, trace Silt	Moist Wet	
10.0	1 2 3 4	1.0	4.0	N	N	N	Gray fine(+) medium, coarse(-) SAND, trace Silt and Gravel	Wet	
12.0	3 3 3 4	1.3	2.4	N	N	N	SAA 1 cm layer of brown SILTY SAND at 12.7'	Wet	
14.0									
16.0									
18.0									

Appendix A-9

Well Construction Diagrams

AECOM

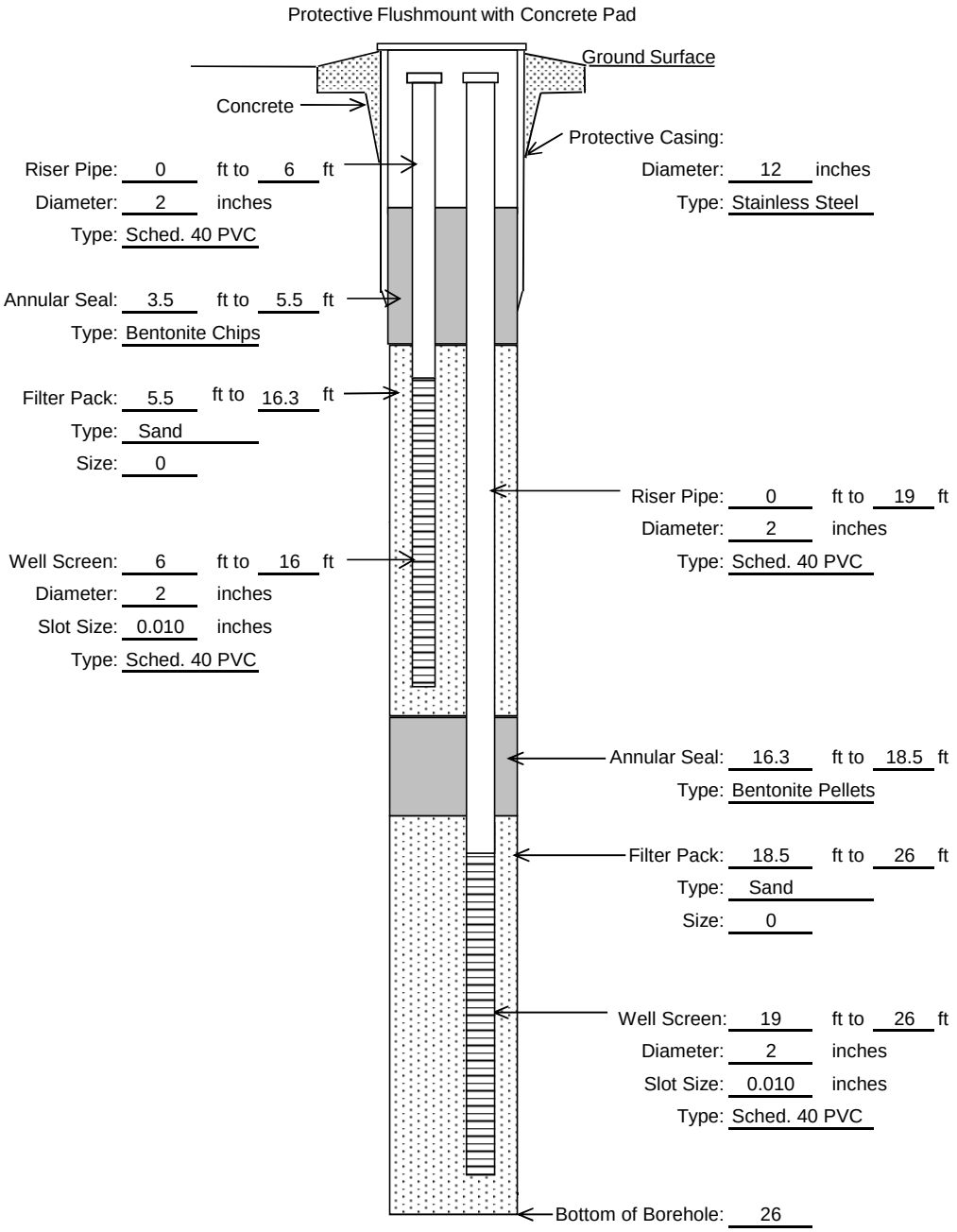
NESTED MONITORING WELL DIAGRAM
SINGLE-CASED
FLUSH-MOUNT COMPLETION

Well No. BIW-1

Project: Former DUSO Chemical Company	Location: Star Gas	Date of Completion: 8/14/12
AECOM Project Number: 60165024	Subcontractor: GeoLogic NY, Inc.	
Surface Elevation:	Drillers: Dave and John	Water Level 3.8 ft. On 8/14/12
Top of PVC Casing Elevation:	Geologist: Greta White	
Drilling Method: 6.25" Hollow Stem Augers	Development Method and Date: Whale Pump on 8/16/12	

Shallow Well: BIW-1S

Deep Well: BIW-1D



Note: All measurements are based on ground surface at 0.0 feet. Measurements are given in feet below grade. Diagram not to scale.

AECOM

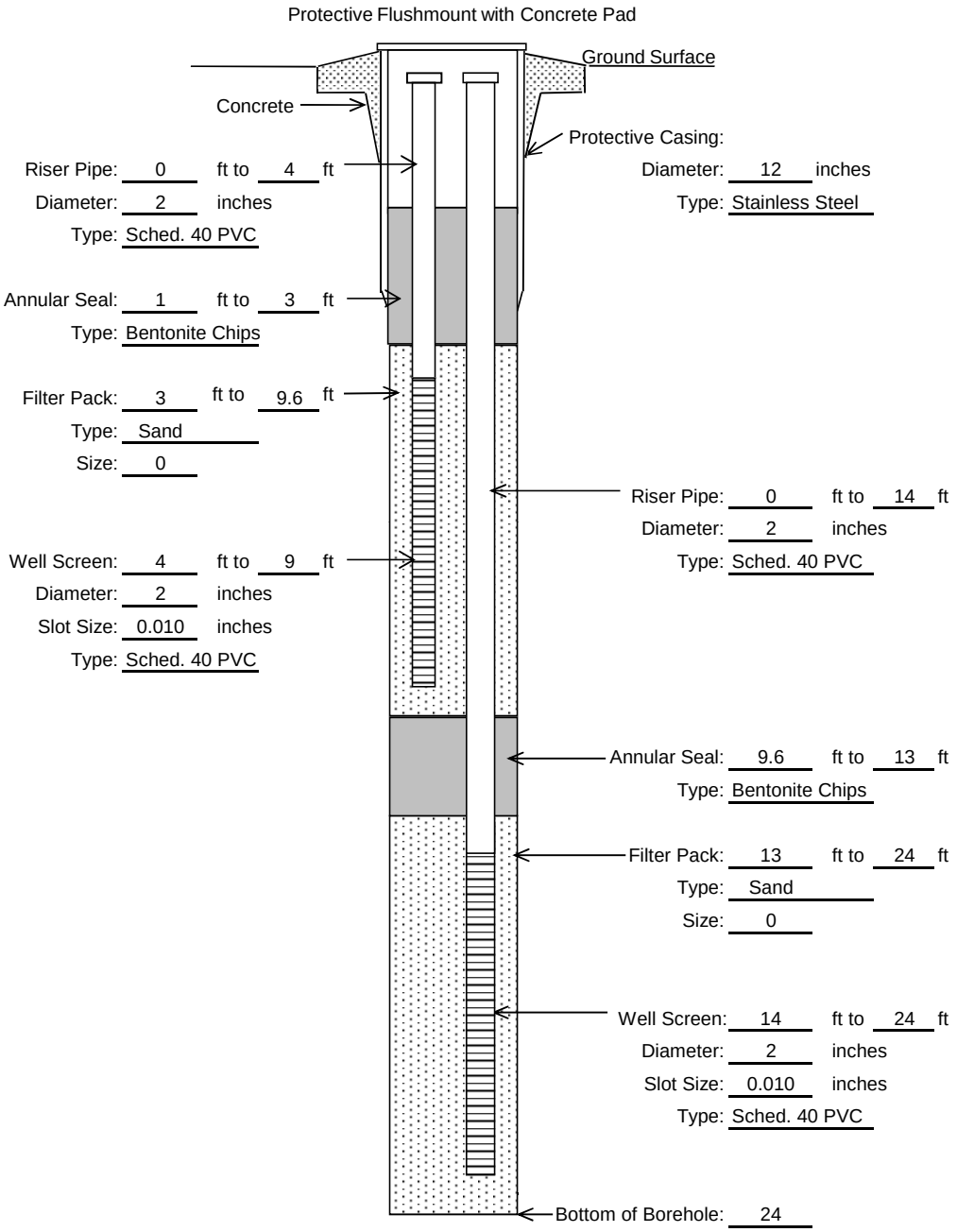
NESTED MONITORING WELL DIAGRAM
SINGLE-CASED
FLUSH-MOUNT COMPLETION

Well No. BIW-2

Project: Former DUSO Chemical Company	Location: Star Gas	Date of Completion: 8/10/12
AECOM Project Number: 60165024	Subcontractor: GeoLogic NY, Inc.	
Surface Elevation:	Drillers: Dave and John	Water Level 5.6 ft. On 8/9/12
Top of PVC Casing Elevation:	Geologist: Greta White	
Drilling Method: 6.25" Hollow Stem Augers	Development Method and Date: Whale Pump on 8/15/12	

Shallow Well: BIW-2S

Deep Well: BIW-2D



Note: All measurements are based on ground surface at 0.0 feet. Measurements are given in feet below grade. Diagram not to scale.

NESTED MONITORING WELL DIAGRAM
SINGLE-CASED
FLUSH-MOUNT COMPLETION

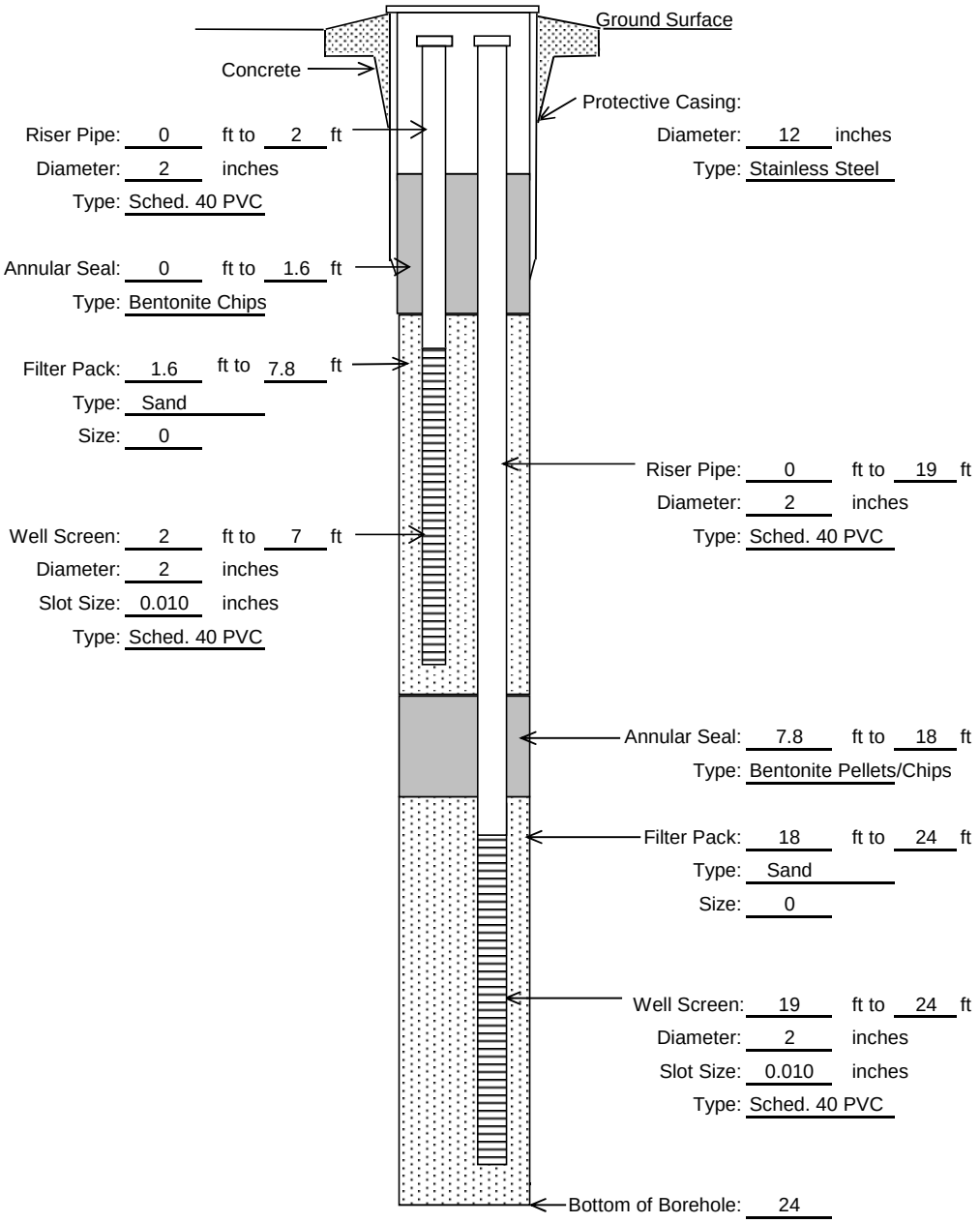
Well No. BIW-3

Project: Former DUSO Chemical Company	Location: Star Gas	Date of Completion: 8/8/12
AECOM Project Number: 60165024	Subcontractor: GeoLogic NY, Inc.	
Surface Elevation:	Drillers: Dave and John	Water Level 2.6 ft. On 8/7/12
Top of PVC Casing Elevation:	Geologist: Greta White	
Drilling Method: 6.25" Hollow Stem Augers	Development Method and Date: Whale Pump on 8/15/12	

Shallow Well: BIW-3S

Deep Well: BIW-3D

Protective Flushmount with Concrete Pad



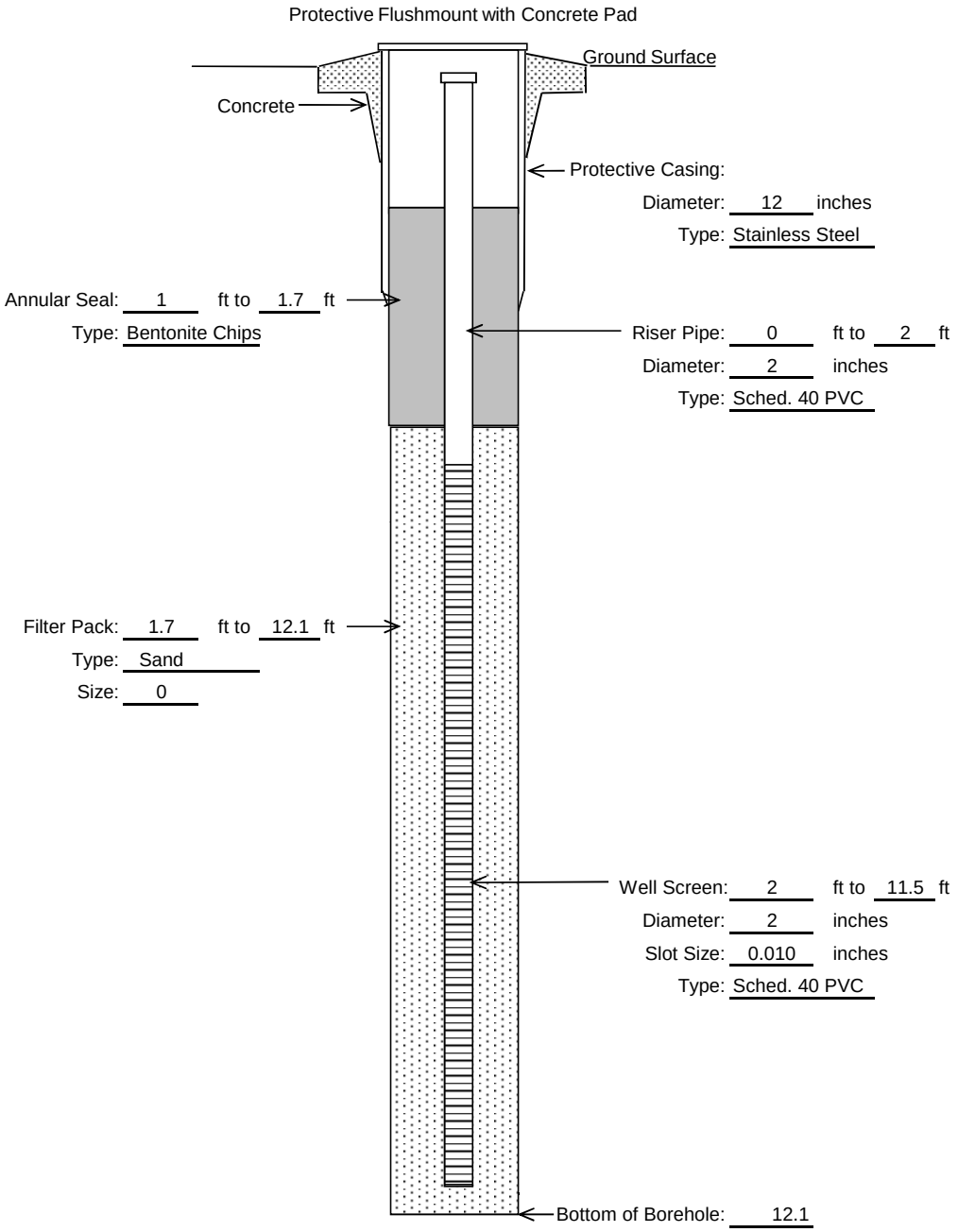
Note: All measurements are based on ground surface at 0.0 feet. Measurements are given in feet below grade. Diagram not to scale.

AECOM

MONITORING WELL DIAGRAM
SINGLE-CASED
FLUSH-MOUNT COMPLETION

Well No. BIW-4

Project: Former DUSO Chemical Company	Location: Star Gas	Date of Completion: 8/8/12
AECOM Project Number: 60165024	Subcontractor: GeoLogic NY, Inc.	
Surface Elevation:	Drillers: Dave and John	Water Level 2 ft. On 8/8/12
Top of PVC Casing Elevation:	Geologist: Greta White	
Drilling Method: 6.25" Hollow Stem Augers	Development Method and Date: Whale Pump on 8/16/12	



Note: All measurements are based on ground surface at 0.0 feet. Measurements are given in feet below grade. Diagram not to scale.

AECOM

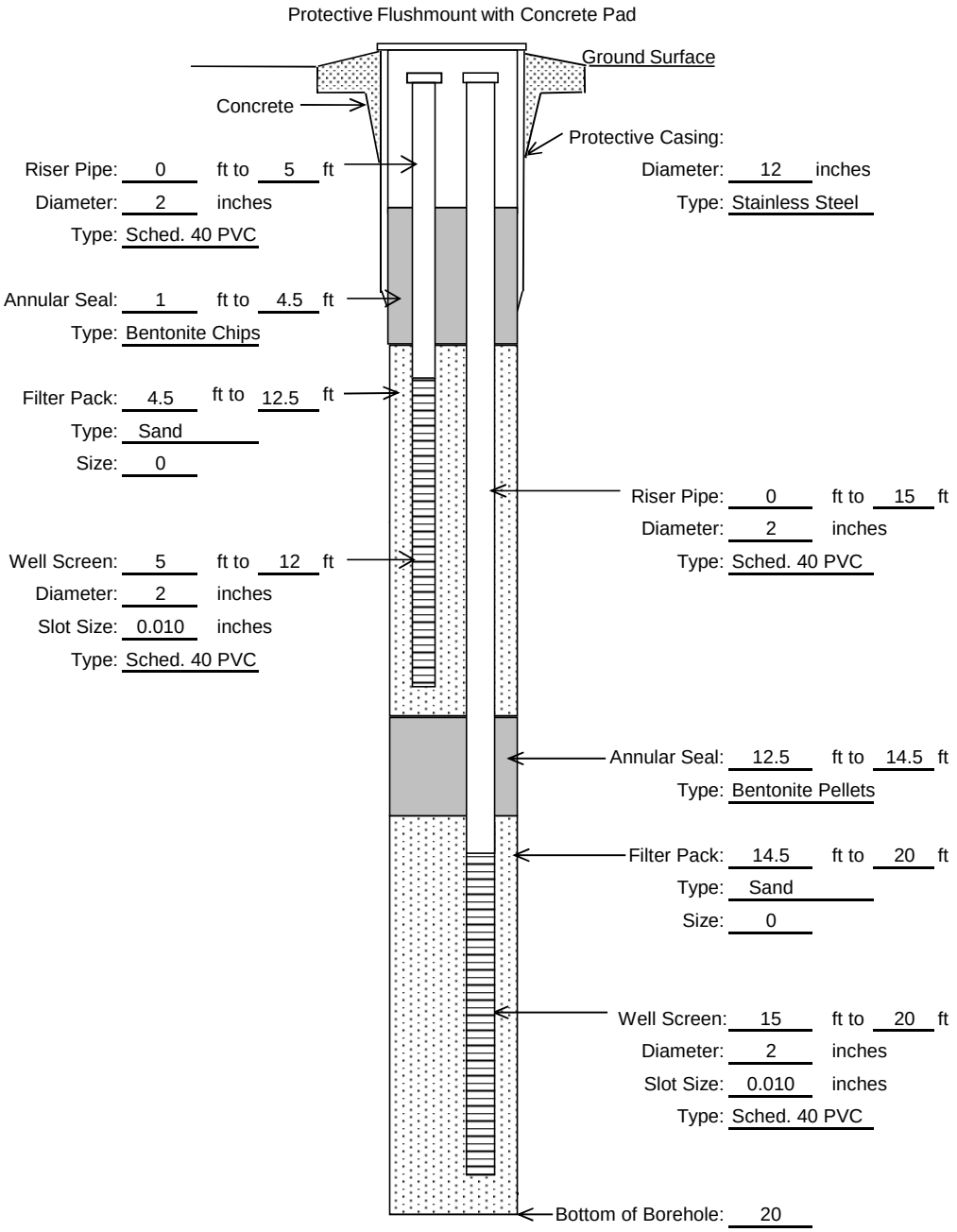
NESTED MONITORING WELL DIAGRAM
SINGLE-CASED
FLUSH-MOUNT COMPLETION

Well No. BIW-5

Project: Former DUSO Chemical Company	Location: Star Gas	Date of Completion: 8/16/12
AECOM Project Number: 60165024	Subcontractor: GeoLogic NY, Inc.	
Surface Elevation:	Drillers: Dave and John	Water Level 3.8 ft. On 8/16/12
Top of PVC Casing Elevation:	Geologist: Greta White	
Drilling Method: 6.25" Hollow Stem Augers	Development Method and Date: Whale Pump on 8/20/12	

Shallow Well: BIW-5S

Deep Well: BIW-5D



Note: All measurements are based on ground surface at 0.0 feet. Measurements are given in feet below grade. Diagram not to scale.

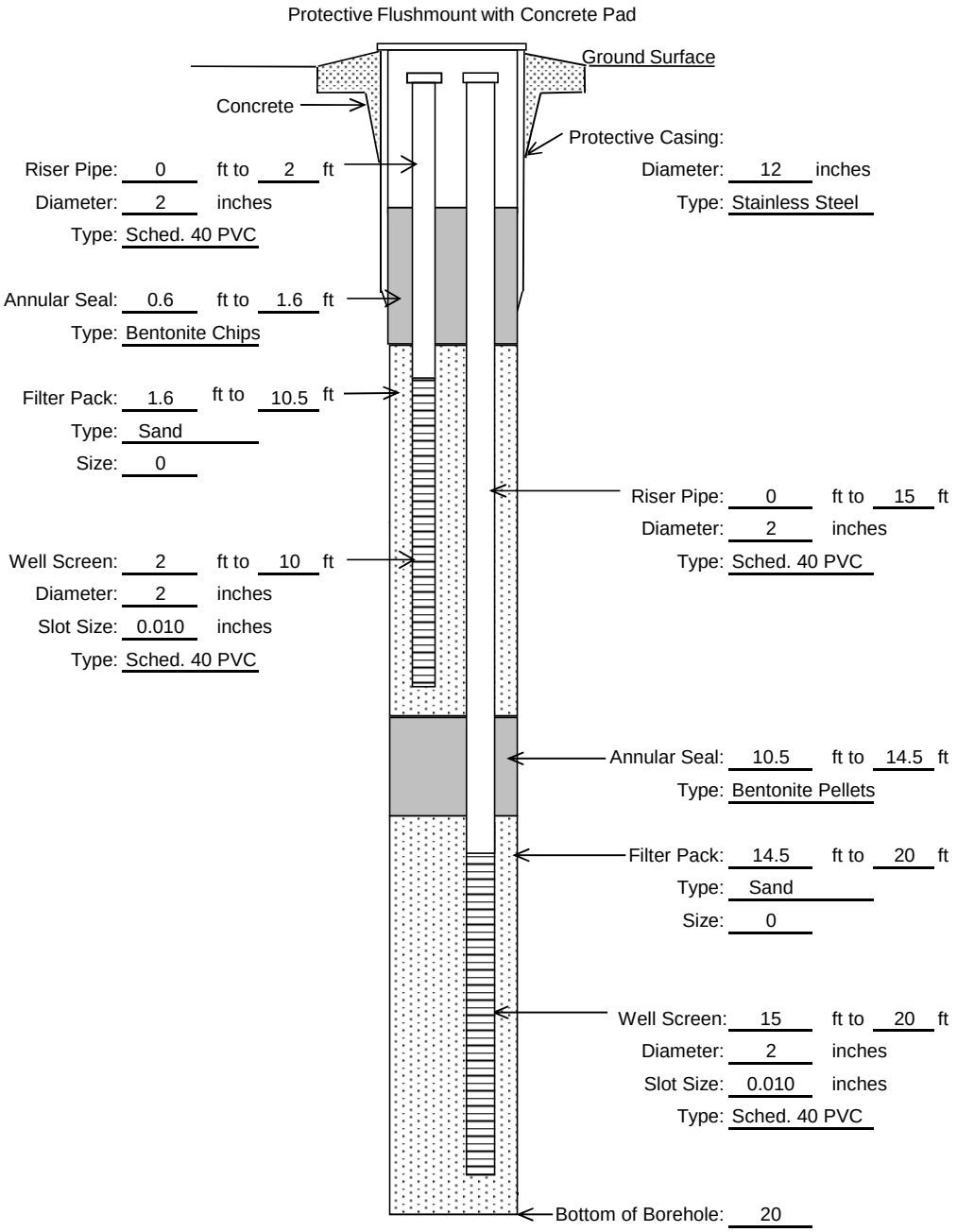
NESTED MONITORING WELL DIAGRAM
SINGLE-CASED
FLUSH-MOUNT COMPLETION

Well No. BIW-6

Project: Former DUSO Chemical Company	Location: Star Gas	Date of Completion: 8/15/12
AECOM Project Number: 60165024	Subcontractor: GeoLogic NY, Inc.	
Surface Elevation:	Drillers: Dave and John	Water Level 3.8 ft. On 8/15/12
Top of PVC Casing Elevation:	Geologist: Greta White	
Drilling Method: 6.25" Hollow Stem Augers	Development Method and Date: Whale Pump on 8/16/12	

Shallow Well: BIW-6S

Deep Well: BIW-6D



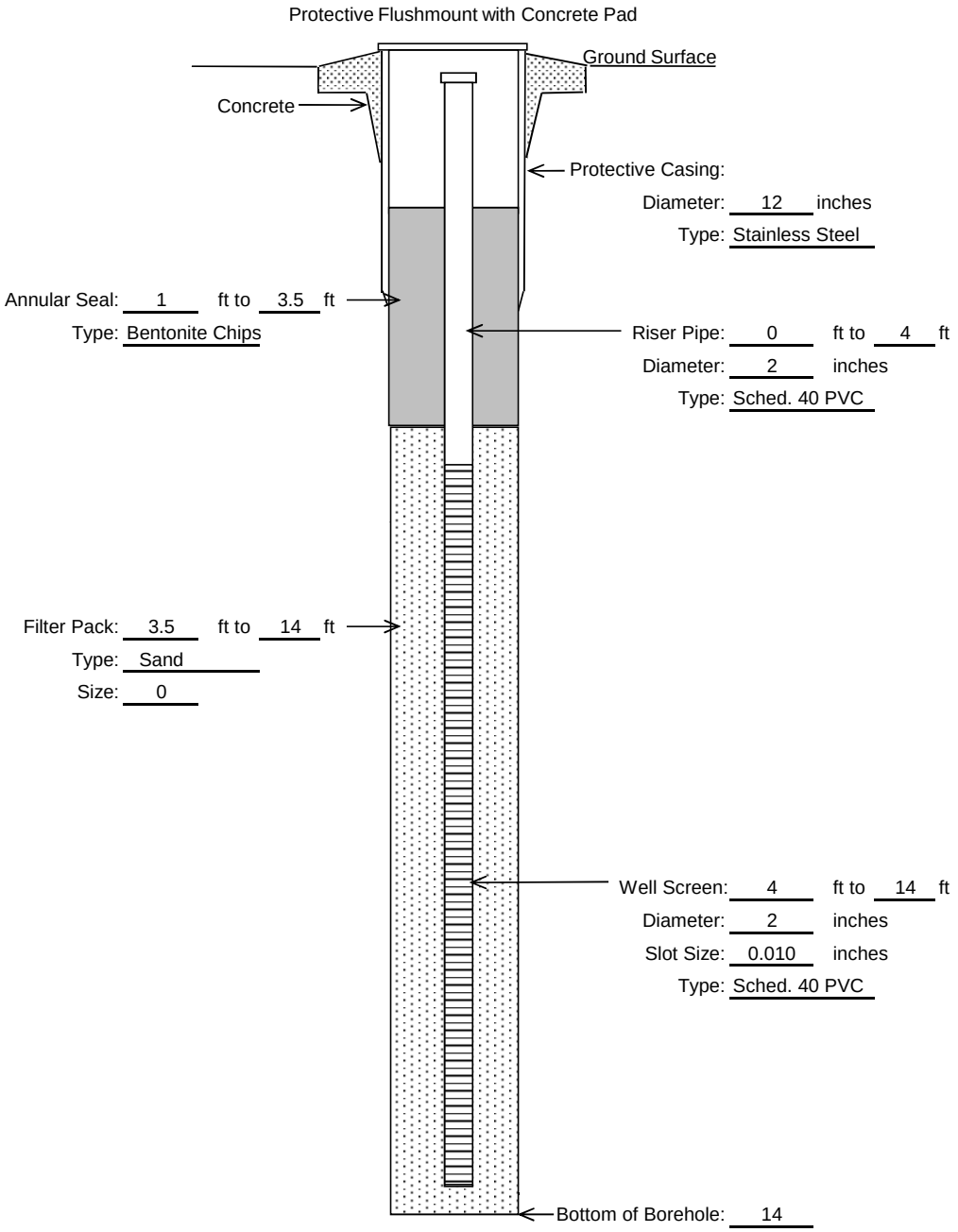
Note: All measurements are based on ground surface at 0.0 feet. Measurements are given in feet below grade. Diagram not to scale.

AECOM

MONITORING WELL DIAGRAM
SINGLE-CASED
FLUSH-MOUNT COMPLETION

Well No. BIW-7

Project: Former DUSO Chemical Company	Location: Star Gas	Date of Completion: 8/16/12
AECOM Project Number: 60165024	Subcontractor: GeoLogic NY, Inc.	
Surface Elevation:	Drillers: Dave and John	Water Level 0.3 ft. On 8/16/12
Top of PVC Casing Elevation:	Geologist: Greta White	
Drilling Method: 6.25" Hollow Stem Augers	Development Method and Date: Whale Pump on 8/17/12	



Note: All measurements are based on ground surface at 0.0 feet. Measurements are given in feet below grade. Diagram not to scale.

Appendix A-10

Monitoring Well Purging/Sampling Forms

Monitoring Well Purging/Sampling Form

Project Name and Number: Former Duso Chemical Company 60279080.3

Monitoring Well Number: MHC-23 Date: 11/26/12

Samplers: Mark Howard and Sam Rowe

Sample Number: MHC-23-112612 QA/QC Collected? No

Purging / Sampling Method: Peristaltic Pump with Dedicated Tubing/Low-Flow

1. L = Total Well Depth:	11.60	feet
2. D = Riser Diameter (I.D.):	0.17	feet
3. W = Static Depth to Water (TOC):	4.11	feet
4. C = Column of Water in Casing:	7.49	feet
5. V = Volume of Water in Well = $C(3.14159)(0.5D)^2(7.48)$		gal
6. D2 = Pump Setting Depth (ft):	10.60	feet
7. C2 = Column of water in Pump/Tubing (ft):		feet
8. Tubing Volume = C2(0.005737088)		gal

D (inches)	D (feet)
1-inch	0.08
2-inch	0.17
3-inch	0.25
4-inch	0.33
6-inch	0.50

Conversion factors to determine V given C

D (inches)	1-inch	2-inch	3-inch	4-inch	6-inch
V (gal / ft)	0.041	0.163	0.37	0.65	1.5

Water Quality Readings Collected Using YSI-556 and LaMotte 2020

Parameter	Units	Readings						
Time	24 hr	13:48	13:53	13:58	14:03	14:08	14:13	14:18
Water Level (0.33)	feet	4.13	4.12	4.12	4.12	4.13	4.13	4.13
Volume Purged	gal	—	0.25	0.50	0.65	0.75	1.0	1.25
Flow Rate	mL / min	150	150	150	150	150	150	150
Turbidity (+/- 10%)	NTU	365	142	79	45.7	33.4	21.9	15.5
Dissolved Oxygen (+/- 10%)	%	13.0	10.6	7.3	6.5	6.9	6.2	5.9
Dissolved Oxygen (+/- 10%)	mg/L	1.35	1.12	0.75	0.68	0.73	0.65	0.57
Eh / ORP (+/- 10)	MeV	-33.2	-8.7	-8.2	-6.5	-5.4	-6.9	-8.0
Specific Conductivity	mS/cm[c]	0.473	0.467	0.465	0.464	0.465	0.465	0.465
Conductivity (+/- 3%)	mS/cm	0.368	0.364	0.362	0.360	0.359	0.360	0.358
pH (+/- 0.1)	pH unit	7.34	7.12	7.13	7.11	7.10	7.13	7.11
Temp (+/- 0.5)	C	13.46	13.43	13.41	13.27	13.16	13.15	13.01
Color	Visual	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy
Odor	Olfactory	Chlo	Chlo	Chlo	Chlo	Chlo	Chlo	Chlo

Comments: Start Purge @13:48

End Purge @

* Three consecutive readings within range indicates stabilization of that parameter.

1 of 2

Monitoring Well Purging/Sampling Form

Project Name and Number: Former Duso Chemical Company 60279080.3

Monitoring Well Number: MHC-23 Date: 11/26/12

Samplers: Mark Howard and Sam Rowe

Sample Number: MHC-23-112612 QA/QC Collected? NO

Purging / Sampling Method: Peristaltic Pump with Dedicated Tubing/Low-Flow

1. L = Total Well Depth:	11.60	feet
2. D = Riser Diameter (I.D.):	0.17	feet
3. W = Static Depth to Water (TOC):	4.11	feet
4. C = Column of Water in Casing:		feet
5. V = Volume of Water in Well = $C(3.14159)(0.5D)^2(7.48)$		gal
6. D2 = Pump Setting Depth (ft):	10.60	feet
7. C2 = Column of water in Pump/Tubing (ft):		feet
8. Tubing Volume = C2(0.005737088)		gal

D (inches)	D (feet)
1-inch	0.08
2-inch	0.17
3-inch	0.25
4-inch	0.33
6-inch	0.50

Conversion factors to determine V given C

D (inches)	1-inch	2-inch	3-inch	4-inch	6-inch
V (gal / ft)	0.041	0.163	0.37	0.65	1.5

Water Quality Readings Collected Using YSI-556 and LaMotte 2020

Parameter	Units	Readings						
Time	24 hr	14:23	14:28	14:33				
Water Level (0.33)	feet	4.13	4.13	4.13				
Volume Purged	gal	1.5	1.60	1.75				
Flow Rate	mL / min	150	150	150				
Turbidity (+/- 10%)	NTU	17.3	16.22	16.53				
Dissolved Oxygen (+/- 10%)	%	5.4	4.6	5.3				
Dissolved Oxygen (+/- 10%)	mg/L	0.57	0.49	0.55				
Eh / ORP (+/- 10)	MeV	-4.3	-4.9	-8.7				
Specific Conductivity	mS/cm[c]	0.465	0.465	0.465				
Conductivity (+/- 3%)	mS/cm	0.357	0.357	0.357				
pH (+/- 0.1)	pH unit	7.01	7.02	7.06				
Temp (+/- 0.5)	C	12.82	12.88	12.86				
Color	Visual	Cloudy	Cloudy	Clear				
Odor	Olfactory	Chlo	Chlo	Chlo				

Comments: Sampled @ 14:33

* Three consecutive readings within range indicates stabilization of that parameter.

Monitoring Well Purging/Sampling Form

Project Name and Number: Former Duso Chemical Company 60279080.3

Monitoring Well Number: MHC-255 Date: 11/29/12

Samplers: Matt Dean ~~Mark Howard~~ and Sam Rowe

Sample Number: MHC-255112912 QA/QC Collected? NO

Purging / Sampling Method: Peristaltic Pump with Dedicated Tubing/Low-Flow

1. L = Total Well Depth:	13.19	feet
2. D = Riser Diameter (I.D.):	0.17	feet
3. W = Static Depth to Water (TOC):	2.43	feet
4. C = Column of Water in Casing:		feet
5. V = Volume of Water in Well = C(3.14159)(0.5D)^2(7.48)		gal
6. D2 = Pump Setting Depth (ft):	12.19	feet
7. C2 = Column of water in Pump/Tubing (ft):		feet
8. Tubing Volume = C2(0.005737088)		gal

D (inches)	D (feet)
~~1-inch~~	~~0.08~~
2-inch	0.17
~~3-inch~~	~~0.25~~
4-inch	0.33
6-inch	0.50

Conversion factors to determine V given C

D (inches)	1-inch	2-inch	3-inch	4-inch	6-inch
V (gal / ft)	0.041	0.163	0.37	0.65	1.5

Water Quality Readings Collected Using YSI-556 and LaMotte 2020

Parameter	Units	Readings						
Time	24 hr	9:04	9:09	9:14	9:19	9:24	9:29	9:34
Water Level (0.33)	feet	3.03	3.40	3.40	3.40	3.40	3.40	3.40
Volume Purged	gal	—	0.25	0.50	0.60	0.80	1.0	1.25
Flow Rate	mL / min	120	80	80	80	80	80	80
Turbidity (+/- 10%)	NTU	>1000	423	316	270	232	207	172
Dissolved Oxygen (+/- 10%)	%	34.9	15.9	11.8	10.9	9.7	8.7	7.9
Dissolved Oxygen (+/- 10%)	mg/L	3.78	1.62	1.27	1.18	1.05	0.93	0.86
Eh / ORP (+/- 10)	MeV	87.5	29.1	13.7	7.8	3.1	1.8	-1.8
Specific Conductivity	mS/cm[c]	1.166	1.184	1.196	1.197	1.197	1.198	1.199
Conductivity (+/- 3%)	mS/cm	0.831	0.884	0.896	0.892	0.896	0.898	0.898
pH (+/- 0.1)	pH unit	6.09	7.21	7.40	7.45	7.48	7.46	7.46
Temp (+/- 0.5)	C	9.62	11.02	11.88	11.68	11.85	11.88	11.86
Color	Visual	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy
Odor	Olfactory	Chlo	Chlo	Chlo	Chlo	Chlo	Chlo	Chlo

Comments: Start purge @ 9:04

* Three consecutive readings within range indicates stabilization of that parameter.

Monitoring Well Purging/Sampling Form

Project Name and Number: Former Duso Chemical Company 60279080.3

Monitoring Well Number: MHC-25S Date: 11/29/12

Samplers: Mark Howard and Sam Rowe

Sample Number: MHC-25S12912 QA/QC Collected? NO

Purging / Sampling Method: Peristaltic Pump with Dedicated Tubing/Low-Flow

1. L = Total Well Depth:	_____	feet
2. D = Riser Diameter (I.D.):	_____	feet
3. W = Static Depth to Water (TOC):	_____	feet
4. C = Column of Water in Casing:	_____	feet
5. V = Volume of Water in Well = $C(3.14159)(0.5D)^2(7.48)$	_____	gal
6. D2 = Pump Setting Depth (ft):	_____	feet
7. C2 = Column of water in Pump/Tubing (ft):	_____	feet
8. Tubing Volume = C2(0.005737088)	_____	gal

D (inches)	D (feet)
1-inch	0.08
2-inch	0.17
3-inch	0.25
4-inch	0.33
6-inch	0.50

Conversion factors to determine V given C

D (inches)	1-inch	2-inch	3-inch	4-inch	6-inch
V (gal / ft)	0.041	0.163	0.37	0.65	1.5

Water Quality Readings Collected Using YSI-556 and LaMotte 2020

Parameter	Units	Readings						
Time	24 hr	9:39	9:44	9:49	9:54			
Water Level (0.33)	feet	3.40	3.40	3.40	3.40			
Volume Purged	gal	1.40	1.60	1.75	1.90			
Flow Rate	mL / min	80	80	80	80			
Turbidity (+/- 10%)	NTU	143	115	89.4	73.7			
Dissolved Oxygen (+/- 10%)	%	7.6	6.9	6.5	5.7			
Dissolved Oxygen (+/- 10%)	mg/L	0.82	0.74	0.71	0.62			
Eh / ORP (+/- 10)	MeV	-6.3	-5.9	-7.9	-10.2			
Specific Conductivity	mS/cm[c]	1.200	1.201	1.201	1.201			
Conductivity (+/- 3%)	mS/cm	0.897	0.896	0.893	0.891			
pH (+/- 0.1)	pH unit	7.46	7.44	7.43	7.42			
Temp (+/- 0.5)	C	11.76	11.69	11.59	11.50			
Color	Visual	Cloudy	Cloudy	Cloudy	Clear			
Odor	Olfactory	Chlo	Chlo	Chlo	Chlo			

Comments: Sampled @ 9:54

Dup taken (DUP112912)

* Three consecutive readings within range indicates stabilization of that parameter.

Monitoring Well Purging/Sampling Form

Project Name and Number: Former Duso Chemical Company 60279080.3

Monitoring Well Number: MHBP-26 Date: 12/11/12

Samplers: Mark Howard and Sam Rowe

Sample Number: MHBP-26 121112 QA/QC Collected? no

Purging / Sampling Method: Peristaltic Pump with Dedicated Tubing/Low-Flow

1. L = Total Well Depth:	12.01	feet
2. D = Riser Diameter (I.D.):		feet
3. W = Static Depth to Water (TOC):	4.52	feet
4. C = Column of Water in Casing:		feet
5. V = Volume of Water in Well = C(3.14159)(0.5D)^2(7.48)		gal
6. D2 = Pump Setting Depth (ft):		feet
7. C2 = Column of water in Pump/Tubing (ft):		feet
8. Tubing Volume = C2(0.005737088)		gal

D (inches)	D (feet)
1-inch	0.08
2-inch	0.17
3-inch	0.25
4-inch	0.33
6-inch	0.50

Conversion factors to determine V given C

D (inches)	1-inch	2-inch	3-inch	4-inch	6-inch
V (gal / ft)	0.041	0.163	0.37	0.65	1.5

Water Quality Readings Collected Using YSI-556 and LaMotte 2020

Parameter	Units	Readings						
Time	24 hr	13:33	13:38	13:43	13:48	13:53	13:58	14:03
Water Level (0.33)	feet	4.87	4.94	4.94	4.94	4.94	4.94	4.94
Volume Purged	gal	—	0.25	0.40	0.60	0.80	1.0	1.20
Flow Rate	mL / min	100	100	100	100	100	100	100
Turbidity (+/- 10%)	NTU	180	110	90	65	45	35	26
Dissolved Oxygen (+/- 10%)	%	36.2	4.1	3.3	2.6	2.3	2.1	2.0
Dissolved Oxygen (+/- 10%)	mg/L	2.58	0.43	0.35	0.29	0.24	0.22	0.22
Eh / ORP (+/- 10)	MeV	-59.6	-96.6	-102.7	-107.4	-109.8	-110.0	-109.0
Specific Conductivity	mS/cm[c]	0.899	0.910	0.917	0.916	0.914	0.913	0.910
Conductivity (+/- 3%)	mS/cm	0.686	0.695	0.699	0.696	0.694	0.692	0.689
pH (+/- 0.1)	pH unit	7.57	7.75	7.79	7.76	7.69	7.61	7.60
Temp (+/- 0.5)	C	12.58	12.63	12.42	12.41	12.37	12.33	12.33
Color	Visual	Cloudy	Cloudy	Cloudy	Cloudy	Clear	Clear	Clear
Odor	Olfactory	Chlo	Chlo	Chlo	Chlo	Chlo	Chlo	Chlo

Comments:

Start purge @ 13:33

* Three consecutive readings within range indicates stabilization of that parameter.

Monitoring Well Purging/Sampling Form

Project Name and Number: Former Duso Chemical Company 60279080.3

Monitoring Well Number: MHBP-26 Date: 12/11/12

Samplers: Mark Howard and Sam Rowe

Sample Number: MHBP-26 12/11/12 QA/QC Collected? no

Purging / Sampling Method: Peristaltic Pump with Dedicated Tubing/Low-Flow

1. L = Total Well Depth: _____ feet
2. D = Riser Diameter (I.D.): _____ feet
3. W = Static Depth to Water (TOC): _____ feet
4. C = Column of Water in Casing: _____ feet
5. V = Volume of Water in Well = $C(3.14159)(0.5D)^2(7.48)$ _____ gal
6. D2 = Pump Setting Depth (ft): _____ feet
7. C2 = Column of water in Pump/Tubing (ft): _____ feet
8. Tubing Volume = C2(0.005737088) _____ gal

D (inches)	D (feet)
1-inch	0.08
2-inch	0.17
3-inch	0.25
4-inch	0.33
6-inch	0.50

Conversion factors to determine V given C

D (inches)	1-inch	2-inch	3-inch	4-inch	6-inch
V (gal / ft)	0.041	0.163	0.37	0.65	1.5

Water Quality Readings Collected Using YSI-556 and LaMotte 2020

Parameter	Units	Readings						
Time	24 hr	14:02	14:13					
Water Level (0.33)	feet	4.94	4.94					
Volume Purged	gal	1.40	1.60					
Flow Rate	mL / min	100	100					
Turbidity (+/- 10%)	NTU	21	16					
Dissolved Oxygen (+/- 10%)	%	2.0	1.9					
Dissolved Oxygen (+/- 10%)	mg/L	0.21	0.20					
Eh / ORP (+/- 10)	MeV	-107.5	-101.4					
Specific Conductivity	mS/cm[c]	0.904	0.898					
Conductivity (+/- 3%)	mS/cm	0.686	0.680					
pH (+/- 0.1)	pH unit	7.56	7.56					
Temp (+/- 0.5)	C	12.36	12.32					
Color	Visual	Clear	Clear					
Odor	Olfactory	Chlo	Chlo					

Comments:

Sampled @ 14:13

* Three consecutive readings within range indicates stabilization of that parameter.

Monitoring Well Purging/Sampling Form

Project Name and Number: Former Duso Chemical Company 60279080.3

Monitoring Well Number: BIW-15 Date: 11/27/12

Samplers: Mark Howard and Sam Rowe

Sample Number: BIW-IS11272 QA/QC Collected? NO

Purging / Sampling Method: Peristaltic Pump with Dedicated Tubing/Low-Flow

1. L = Total Well Depth:	15.70	feet
2. D = Riser Diameter (I.D.):	0.17	feet
3. W = Static Depth to Water (TOC):	3.76	feet
4. C = Column of Water in Casing:		feet
5. V = Volume of Water in Well = C(3.14159)(0.5D)^2(7.48)		gal
6. D2 = Pump Setting Depth (ft):	14.70	feet
7. C2 = Column of water in Pump/Tubing (ft):		feet
8. Tubing Volume = C2(0.005737088)		gal

D (inches)	D (feet)
1-inch	0.08
2-inch	0.17
3-inch	0.25
4-inch	0.33
6-inch	0.50

Conversion factors to determine V given C

D (inches)	1-inch	2-inch	3-inch	4-inch	6-inch
V (gal / ft)	0.041	0.163	0.37	0.65	1.5

Water Quality Readings Collected Using YSI-556 and LaMotte 2020

Parameter	Units	Readings						
Time	24 hr	10:23	10:28	10:33	10:38	10:43	10:48	10:53
Water Level (0.33)	feet	3.89	3.84	3.84	3.84	3.81	3.84	3.84
Volume Purged	gal	—	0.25	0.4	0.5	0.75	1.0	1.25
Flow Rate	mL / min	200	200	200	200	200	200	200
Turbidity (+/- 10%)	NTU	600	600	600	600	600	600	568
Dissolved Oxygen (+/- 10%)	%	999.9	36.0	26	25.2	24.5	23	19.3
Dissolved Oxygen (+/- 10%)	mg/L	232.37	3.84	2.81	2.72	2.64	2.48	1.87
Eh / ORP (+/- 10)	MeV	18.0	21.0	19.9	25.3	29.5	24.6	21.0
Specific Conductivity	mS/cm[c]	0.728	0.726	0.727	0.728	0.728	0.728	0.729
Conductivity (+/- 3%)	mS/cm	0.543	0.539	0.544	0.545	0.544	0.544	0.542
pH (+/- 0.1)	pH unit	7.77	7.57	7.54	7.50	7.47	7.46	7.44
Temp (+/- 0.5)	C	11.71	11.49	11.82	11.89	11.81	11.78	11.61
Color	Visual	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy
Odor	Olfactory	Chlo	Chlo	Chlo	Chlo	Chlo	Chlo	Chlo

Comments: Start Purge @ 10:23

* Three consecutive readings within range indicates stabilization of that parameter.

Monitoring Well Purging/Sampling Form

Project Name and Number: Former Duso Chemical Company 60279080.3

Monitoring Well Number: BIW-15 Date: 11/27 12

Samplers: Mark Howard and Sam Rowe

Sample Number: BIW-151127I2 QA/QC Collected? No

Purging / Sampling Method: Peristaltic Pump with Dedicated Tubing/Low-Flow

1. L = Total Well Depth:	_____	feet
2. D = Riser Diameter (I.D.):	_____	feet
3. W = Static Depth to Water (TOC):	_____	feet
4. C = Column of Water in Casing:	_____	feet
5. V = Volume of Water in Well = $C(3.14159)(0.5D)^2(7.48)$	_____	gal
6. D2 = Pump Setting Depth (ft):	_____	feet
7. C2 = Column of water in Pump/Tubing (ft):	_____	feet
8. Tubing Volume = C2(0.005737088)	_____	gal

D (inches)	D (feet)
1-inch	0.08
2-inch	0.17
3-inch	0.25
4-inch	0.33
6-inch	0.50

Conversion factors to determine V given C

D (inches)	1-inch	2-inch	3-inch	4-inch	6-inch
V (gal / ft)	0.041	0.163	0.37	0.65	1.5

Water Quality Readings Collected Using YSI-556 and LaMotte 2020

Parameter	Units	Readings						
Time	24 hr	10:58	11:03	11:08	11:13			
Water Level (0.33)	feet	3.24	3.24	3.24	3.24			
Volume Purged	gal	1.5	1.75	2.0	2.25			
Flow Rate	mL / min	200	200	200	200			
Turbidity (+/- 10%)	NTU	208	73.6	45.6				
Dissolved Oxygen (+/- 10%)	%	14.0	12.1	11.2	11.1			
Dissolved Oxygen (+/- 10%)	mg/L	1.51	1.32	1.30	1.28			
Eh / ORP (+/- 10)	MeV	18.8	17.6	17.5	17.9			
Specific Conductivity	mS/cm[c]	0.730	0.729	0.728	0.728			
Conductivity (+/- 3%)	mS/cm	0.542	0.540	0.538	0.539			
pH (+/- 0.1)	pH unit	7.43	7.40	7.39	7.39			
Temp (+/- 0.5)	C	11.52	11.38	11.36	11.37			
Color	Visual	Cloudy	Cloudy	Clear	Clear			
Odor	Olfactory	Chlo	Chlo	Chlo	Chlo			

Comments: Sample ID 1013

None Since Bubbles at 1452 1455

* Three consecutive readings within range indicates stabilization of that parameter.

Monitoring Well Purging/Sampling Form

Project Name and Number: Former Duso Chemical Company 60279080.3

Monitoring Well Number: BFW-1D Date: 11/27/12

Samplers: Mark Howard and Sam Rowe

Sample Number: BFW-1D112712 QA/QC Collected? NO

Purging / Sampling Method: Peristaltic Pump with Dedicated Tubing/Low-Flow

1. L = Total Well Depth:	25.51	feet
2. D = Riser Diameter (I.D.):	0.17	feet
3. W = Static Depth to Water (TOC):	3.56	feet
4. C = Column of Water in Casing:		feet
5. V = Volume of Water in Well = $C(3.14159)(0.5D)^2(7.48)$		gal
6. D2 = Pump Setting Depth (ft):	24.51	feet
7. C2 = Column of water in Pump/Tubing (ft):		feet
8. Tubing Volume = C2(0.005737088)		gal

D (inches)	D (feet)
1-inch	0.08
2-inch	0.17
3-inch	0.25
4-inch	0.33
6-inch	0.50

Conversion factors to determine V given C

D (inches)	1-inch	2-inch	3-inch	4-inch	6-inch
V (gal / ft)	0.041	0.163	0.37	0.65	1.5

Water Quality Readings Collected Using YSI-556 and LaMotte 2020

Parameter	Units	Readings						
Time	24 hr	13:04	13:09	13:14	13:19	13:24	13:29	13:34
Water Level (0.33)	feet	4.71	5.43	6.90	6.46	6.94	8.24	9.76
Volume Purged	gal	—	0.25	0.5	0.5	0.6	0.75	1.25
Flow Rate	mL / min	200	150	100	100	100	400	100
Turbidity (+/- 10%)	NTU	911	1000	1000	852	621	359	284
Dissolved Oxygen (+/- 10%)	%	65.7	20.7	18.7	18.0	17.0	14.6	39.5
Dissolved Oxygen (+/- 10%)	mg/L	7.35	2.26	2.06	2.01	1.90	1.55	4.27
Eh / ORP (+/- 10)	MeV	54.7	40.8	36.2	36.2	[illegible]	[illegible]	33.4
Specific Conductivity	mS/cm[c]	0.489	0.490	0.491	0.491	0.492	0.493	0.499
Conductivity (+/- 3%)	mS/cm	0.359	0.362	0.357	0.354	0.354	0.377	0.377
pH (+/- 0.1)	pH unit	7.96	7.90	7.89	7.87	7.85	7.81	7.84
Temp (+/- 0.5)	C	10.77	11.27	10.72	10.37	10.30	12.58	12.35
Color	Visual	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy
Odor	Olfactory	Chlo	Chlo	Chlo	Chlo	Chlo	Chlo	Chlo

Comments: Start purge @ 13:04

@ 13:29 - turn up speed on pump - well drawing down prior to increased speed

* Three consecutive readings within range indicates stabilization of that parameter.

Monitoring Well Purging/Sampling Form

Project Name and Number: Former Duso Chemical Company 60279080.3

Monitoring Well Number: BIW-1D Date: 11/27/12

Samplers: Mark Howard and Sam Rowe

Sample Number: BIW-1D112712 QA/QC Collected? NO

Purging / Sampling Method: Peristaltic Pump with Dedicated Tubing/Low-Flow

1. L = Total Well Depth:	_____	feet
2. D = Riser Diameter (I.D.):	_____	feet
3. W = Static Depth to Water (TOC):	_____	feet
4. C = Column of Water in Casing:	_____	feet
5. V = Volume of Water in Well = $C(3.14159)(0.5D)^2(7.48)$	_____	gal
6. D2 = Pump Setting Depth (ft):	_____	feet
7. C2 = Column of water in Pump/Tubing (ft):	_____	feet
8. Tubing Volume = C2(0.005737088)	_____	gal

D (inches)	D (feet)
1-inch	0.08
2-inch	0.17
3-inch	0.25
4-inch	0.33
6-inch	0.50

Conversion factors to determine V given C

D (inches)	1-inch	2-inch	3-inch	4-inch	6-inch
V (gal / ft)	0.041	0.163	0.37	0.65	1.5

Water Quality Readings Collected Using YSI-556 and LaMotte 2020

Parameter	Units	Readings						
Time	24 hr	13:39	13:44	13:49	13:54	13:59	14:04	14:09
Water Level (0.33)	feet	9.84	9.90	11.44	11.80	11.81	11.81	11.81
Volume Purged	gal	1.4	1.5	1.90	2.0	2.15	2.25	2.35
Flow Rate	mL / min	100	100	400	100	100	100	100
Turbidity (+/- 10%)	NTU	138	129	390	372	238	201	240
Dissolved Oxygen (+/- 10%)	%	40.8	36.3	17.6	22.8	24.2	25.5	24.5
Dissolved Oxygen (+/- 10%)	mg/L	4.54	4.08	1.84	2.51	2.73	2.86	2.78
Eh / ORP (+/- 10)	MeV	33.6	37.3	35.7	34.5	37.4	39.4	40.4
Specific Conductivity	mS/cm[c]	0.501	0.493	0.490	0.493	0.492	0.489	0.488
Conductivity (+/- 3%)	mS/cm	0.363	0.357	0.376	0.364	0.354	0.348	0.345
pH (+/- 0.1)	pH unit	7.83	7.79	7.78	7.80	7.78	7.76	7.75
Temp (+/- 0.5)	C	10.71	9.96	9.76	11.59	10.33	9.93	9.69
Color	Visual	Clear	Clear	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy
Odor	Olfactory	Chlo	Chlo	Chlo	Chlo	Chlo	Chlo	Chlo

Comments: Turn Pump up at 13:44 to full throttle - well drawing down prior to increased speed (400mL/min)

Turn pump to 100mL/min @ 13:49

2 of 3

* Three consecutive readings within range indicates stabilization of that parameter.

Monitoring Well Purging/Sampling Form

Project Name and Number: Former Duso Chemical Company 60279080.3

Monitoring Well Number: BIW-1D Date: 11/27/12

Samplers: Mark Howard and Sam Rowe

Sample Number: BIW-1D112712 QA/QC Collected? IVC

Purging / Sampling Method: Peristaltic Pump with Dedicated Tubing/Low-Flow

1. L = Total Well Depth: _____ feet
2. D = Riser Diameter (I.D.): _____ feet
3. W = Static Depth to Water (TOC): _____ feet
4. C = Column of Water in Casing: _____ feet
5. V = Volume of Water in Well = $C(3.14159)(0.5D)^2(7.48)$ _____ gal
6. D2 = Pump Setting Depth (ft): _____ feet
7. C2 = Column of water in Pump/Tubing (ft): _____ feet
8. Tubing Volume = C2(0.005737088) _____ gal

D (inches)	D (feet)
1-inch	0.08
2-inch	0.17
3-inch	0.25
4-inch	0.33
6-inch	0.50

Conversion factors to determine V given C

D (inches)	1-inch	2-inch	3-inch	4-inch	6-inch
V (gal / ft)	0.041	0.163	0.37	0.65	1.5

Water Quality Readings Collected Using YSI-556 and LaMotte 2020

Parameter	Units	Readings						
Time	24 hr	14:14	14:19	14:24				
Water Level (0.33)	feet	11.81	11.81	11.81				
Volume Purged	gal	2.40	2.50	2.60				
Flow Rate	mL / min	100	100	100				
Turbidity (+/- 10%)	NTU	200	222	165				
Dissolved Oxygen (+/- 10%)	%	24.9	24.6	24.1				
Dissolved Oxygen (+/- 10%)	mg/L	2.84	2.80	2.76				
Eh / ORP (+/- 10)	MeV	40.6	40.4	40.9				
Specific Conductivity	mS/cm[c]	0.486	0.486	0.486				
Conductivity (+/- 3%)	mS/cm	0.343	0.342	0.342				
pH (+/- 0.1)	pH unit	7.75	7.74	7.73				
Temp (+/- 0.5)	C	9.59	9.55	9.47				
Color	Visual	Cloudy	Cloudy	Cloudy				
Odor	Olfactory	Chlo	Chlo	Chlo				

Comments: Sampled @ 14:24

* Three consecutive readings within range indicates stabilization of that parameter.

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Monitoring Well Purging/Sampling Form

Project Name and Number: Former Duso Chemical Company 60279080.3

Monitoring Well Number: BIW-23 Date: 11/30/12

Samplers: Mark Howard and Sam Rowe

Sample Number: BIW-25113012 QA/QC Collected? N/C

Purging / Sampling Method: Peristaltic Pump with Dedicated Tubing/Low-Flow

1. L = Total Well Depth:	8.62	feet
2. D = Riser Diameter (I.D.):	0.17	feet
3. W = Static Depth to Water (TOC):	3.44 ~~3.49~~	feet
4. C = Column of Water in Casing:		feet
5. V = Volume of Water in Well = C(3.14159)(0.5D)^2(7.48)		gal
6. D2 = Pump Setting Depth (ft):	7.62	feet
7. C2 = Column of water in Pump/Tubing (ft):		feet
8. Tubing Volume = C2(0.005737088)		gal

D (inches)	D (feet)
1-inch	~~0.08~~
~~2-inch~~	0.17
~~3-inch~~	0.25
4-inch	0.33
6-inch	0.50

Conversion factors to determine V given C

D (inches)	1-inch	2-inch	3-inch	4-inch	6-inch
V (gal / ft)	0.041	0.163	0.37	0.65	1.5

Water Quality Readings Collected Using YSI-556 and LaMotte 2020

Parameter	Units	Readings						
Time	24 hr	10:32	10:37	10:42	10:47	10:52	10:57	11:02
Water Level (0.33)	feet	3.55	3.55	3.55	3.55	3.55	3.55	3.55
Volume Purged	gal	—	0.25	0.50	0.75	1.0	1.20	1.40
Flow Rate	mL / min	100	100	100	100	100	100	100
Turbidity (+/- 10%)	NTU	131	62.3	35.9	32.9	12.5	10.2	7.23
Dissolved Oxygen (+/- 10%)	%	38.9	13.7	12.2	10.8	9.1	7.8	7.1
Dissolved Oxygen (+/- 10%)	mg/L	4.33	1.49	1.32	1.18	0.99	0.85	0.77
Eh / ORP (+/- 10)	MeV	-12.5	-19.7	-20.4	-23.0	-25.8	-27.3	-33.0
Specific Conductivity	mS/cm[c]	1.376	1.373	1.370	1.375	1.321	1.291	1.274
Conductivity (+/- 3%)	mS/cm	1.007	1.006	1.017	1.005	0.977	0.975	0.941
pH (+/- 0.1)	pH unit	7.75	7.65	7.60	7.55	7.50	7.45	7.43
Temp (+/- 0.5)	C	10.94	11.50	11.53	11.42	11.37	11.48	11.55
Color	Visual	Cloudy	Cloudy	Clear	Clear	Clear	Clear	Clear
Odor	Olfactory	Chlo	Chlo	Chlo	Chlo	Chlo	Chlo	Chlo

Comments: Start purge @ 10:32

* Three consecutive readings within range indicates stabilization of that parameter.

Monitoring Well Purging/Sampling Form

Project Name and Number: Former Duso Chemical Company 60279080.3

Monitoring Well Number: BIW-25 Date: 11/30/12

Samplers: Mark Howard and Sam Rowe

Sample Number: BIW-25113012 QA/QC Collected? Y/O

Purging / Sampling Method: Peristaltic Pump with Dedicated Tubing/Low-Flow

1. L = Total Well Depth:	_____	feet
2. D = Riser Diameter (I.D.):	_____	feet
3. W = Static Depth to Water (TOC):	_____	feet
4. C = Column of Water in Casing:	_____	feet
5. V = Volume of Water in Well = $C(3.14159)(0.5D)^2(7.48)$	_____	gal
6. D2 = Pump Setting Depth (ft):	_____	feet
7. C2 = Column of water in Pump/Tubing (ft):	_____	feet
8. Tubing Volume = C2(0.005737088)	_____	gal

D (inches)	D (feet)
1-inch	0.08
2-inch	0.17
3-inch	0.25
4-inch	0.33
6-inch	0.50

Conversion factors to determine V given C

D (inches)	1-inch	2-inch	3-inch	4-inch	6-inch
V (gal / ft)	0.041	0.163	0.37	0.65	1.5

Water Quality Readings Collected Using YSI-556 and LaMotte 2020

Parameter	Units	Readings						
Time	24 hr	11:07	11:12	11:17	11:22			
Water Level (0.33)	feet	3.55	3.55	3.55	3.55			
Volume Purged	gal	1.50	1.75	2.0	2.25			
Flow Rate	mL / min	100	100	100	100			
Turbidity (+/- 10%)	NTU	4.2	4.1	24.0	24.0			
Dissolved Oxygen (+/- 10%)	%	6.3	5.6	5.2	5.0			
Dissolved Oxygen (+/- 10%)	mg/L	0.68	0.63	0.60	0.59			
Eh / ORP (+/- 10)	MeV	-34.2	-39.2	-38.8	-41.8			
Specific Conductivity	mS/cm[c]	1.237	1.215	1.210	1.207			
Conductivity (+/- 3%)	mS/cm	0.915	0.898	0.888	0.895			
pH (+/- 0.1)	pH unit	7.39	7.37	7.35	7.31			
Temp (+/- 0.5)	C	11.32	11.33	11.36	11.40			
Color	Visual	Clear	Clear	Clear	Clear			
Odor	Olfactory	Chlo	Chlo	Chlo	Chlo			

Comments: Sampled @ 11:22

* Three consecutive readings within range indicates stabilization of that parameter.

Monitoring Well Purging/Sampling Form

Project Name and Number: Former Duso Chemical Company 60279080.3

Monitoring Well Number: BIW-2D Date: 11/30/12

Samplers: Mark Howard and Sam Rowe

Sample Number: BIW-2D113012 QA/QC Collected? No

Purging / Sampling Method: Peristaltic Pump with Dedicated Tubing/Low-Flow

1. L = Total Well Depth:	23.47	feet
2. D = Riser Diameter (I.D.):	0.17	feet
3. W = Static Depth to Water (TOC):	2.40	feet
4. C = Column of Water in Casing:	21	feet
5. V = Volume of Water in Well = $C(3.14159)(0.5D)^2(7.48)$		gal
6. D2 = Pump Setting Depth (ft):	22.47	feet
7. C2 = Column of water in Pump/Tubing (ft):		feet
8. Tubing Volume = C2(0.005737088)		gal

D (inches)	D (feet)
1-inch	0.08
2-inch	0.17
3-inch	0.25
4-inch	0.33
6-inch	0.50

Conversion factors to determine V given C

D (inches)	1-inch	2-inch	3-inch	4-inch	6-inch
V (gal / ft)	0.041	0.163	0.37	0.65	1.5

Water Quality Readings Collected Using YSI-556 and LaMotte 2020

Parameter	Units	Readings						
Time	24 hr	8:35	8:40	8:45	8:50	8:55	9:00	9:05
Water Level (0.33)	feet	3.38	3.46	3.80	5.61	5.61	5.61	5.60
Volume Purged	gal	—	0.2	0.25	0.75	0.90	1.20	1.50
Flow Rate	mL / min	80	40	40	80	80	80	80
Turbidity (+/- 10%)	NTU	105.7	331	265	158	108.5	71.3	43.7
Dissolved Oxygen (+/- 10%)	%	38.0	18.4	16.3	9.5	9.8	9.1	8.1
Dissolved Oxygen (+/- 10%)	mg/L	4.16	2.01	1.79	1.00	1.06	0.99	0.87
Eh / ORP (+/- 10)	MeV	63.7	14.8	11.7	-1.5	-5.2	-6.0	-5.5
Specific Conductivity	mS/cm[c]	1.200	1.342	1.342	1.283	1.273	1.276	1.273
Conductivity (+/- 3%)	mS/cm	0.877	0.985	0.980	0.999	0.963	0.956	0.957
pH (+/- 0.1)	pH unit	7.27	7.87	7.93	7.77	7.95	7.93	7.88
Temp (+/- 0.5)	C	11.34	11.06	10.92	13.42	12.22	11.86	12.00
Color	Visual	Clear	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy
Odor	Olfactory	Chlo	Chlo	Chlo	Chlo	Chlo	Chlo	Chlo

Comments: Start purge @ 8:35
Increase pump speed @ 8:45 to full speed
Decrease pump speed @ 8:50

* Three consecutive readings within range indicates stabilization of that parameter.

Monitoring Well Purging/Sampling Form

Project Name and Number: Former Duso Chemical Company 60279080.3

Monitoring Well Number: BIW-2D1 Date: 11/30/12

Samplers: Mark Howard and Sam Rowe

Sample Number: BIW-2D113012 QA/QC Collected? No

Purging / Sampling Method: Peristaltic Pump with Dedicated Tubing/Low-Flow

1. L = Total Well Depth:	_____	feet
2. D = Riser Diameter (I.D.):	_____	feet
3. W = Static Depth to Water (TOC):	_____	feet
4. C = Column of Water in Casing:	_____	feet
5. V = Volume of Water in Well = $C(3.14159)(0.5D)^2(7.48)$	_____	gal
6. D2 = Pump Setting Depth (ft):	_____	feet
7. C2 = Column of water in Pump/Tubing (ft):	_____	feet
8. Tubing Volume = C2(0.005737088)	_____	gal

D (inches)	D (feet)
1-inch	0.08
2-inch	0.17
3-inch	0.25
4-inch	0.33
6-inch	0.50

Conversion factors to determine V given C

D (inches)	1-inch	2-inch	3-inch	4-inch	6-inch
V (gal / ft)	0.041	0.163	0.37	0.65	1.5

Water Quality Readings Collected Using YSI-556 and LaMotte 2020

Parameter	Units	Readings						
Time	24 hr	9:10	9:15	9:20				
Water Level (0.33)	feet	5.53	5.60	5.60				
Volume Purged	gal	1.5	1.75	2.0				
Flow Rate	mL / min	80	80	80				
Turbidity (+/- 10%)	NTU	34.9	23.0	15.3				
Dissolved Oxygen (+/- 10%)	%	7.6	8.2	8.2				
Dissolved Oxygen (+/- 10%)	mg/L	0.81	0.88	0.90				
Eh / ORP (+/- 10)	MeV	-6.8	-7.6	-5.4				
Specific Conductivity	mS/cm[c]	1.275	1.275	1.267				
Conductivity (+/- 3%)	mS/cm	0.959	0.959	0.958				
pH (+/- 0.1)	pH unit	7.85	7.83	7.80				
Temp (+/- 0.5)	C	12.01	12.03	12.21				
Color	Visual	clear	clear	clear				
Odor	Olfactory	Chlo	Chlo	Chlo				

Comments: Sample @ 9:20
MS/MSD taken (BIW-2D-MS113012)
(BIW-2D-MSD113012)

* Three consecutive readings within range indicates stabilization of that parameter.

Monitoring Well Purging/Sampling Form

Project Name and Number: Former Duso Chemical Company 60279080.3

Monitoring Well Number: BIW-35 Date: 11/28/12

Samplers: Mark Howard and Sam Rowe

Sample Number: BIW-351128-12 QA/QC Collected? NO

Purging / Sampling Method: Peristaltic Pump with Dedicated Tubing/Low-Flow

1. L = Total Well Depth:	6.68	feet
2. D = Riser Diameter (I.D.):		feet
3. W = Static Depth to Water (TOC):	2.07	feet
4. C = Column of Water in Casing:		feet
5. V = Volume of Water in Well = C(3.14159)(0.5D)^2(7.48)		gal
6. D2 = Pump Setting Depth (ft):		feet
7. C2 = Column of water in Pump/Tubing (ft):		feet
8. Tubing Volume = C2(0.005737088)		gal

D (inches)	D (feet)
1-inch	0.08
2-inch	0.17
3-inch	0.25
4-inch	0.33
6-inch	0.50

Conversion factors to determine V given C

D (inches)	1-inch	2-inch	3-inch	4-inch	6-inch
V (gal / ft)	0.041	0.163	0.37	0.65	1.5

Water Quality Readings Collected Using YSI-556 and LaMotte 2020

Parameter	Units	Readings						
Time	24 hr	15:04	15:11	15:16	15:21	15:26	15:31	15:36
Water Level (0.33)	feet	2.48	2.58	2.58	2.58	2.58	2.58	2.58
Volume Purged	gal	—	0.5	0.75	1 Gal	1.25	1.5	1.75
Flow Rate	mL / min	200	200	200	200	200	200	200
Turbidity (+/- 10%)	NTU	>1000	>1000	505	443	391	392	401
Dissolved Oxygen (+/- 10%)	%	32.1	24.6	25.4	26.5	26.5	26.4	26.4
Dissolved Oxygen (+/- 10%)	mg/L	3.48	2.70	2.81	2.94	2.94	2.93	2.93
Eh / ORP (+/- 10)	MeV	67.5	43.3	35.8	31.4	30.4	26.8	25.9
Specific Conductivity	mS/cm[c]	0.905	0.923	0.927	0.927	0.928	0.929	0.929
Conductivity (+/- 3%)	mS/cm	0.655	0.676	0.675	0.674	0.673	0.675	0.673
pH (+/- 0.1)	pH unit	6.98	7.56	7.67	7.72	7.69	7.72	7.71
Temp (+/- 0.5)	C	10.39	10.99	10.95	10.69	10.64	10.68	10.51
Color	Visual	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy
Odor	Olfactory	chlo	chlo	chlo	chlo	chlo	chlo	chlo

Comments: Start purge @ 15:06

* Three consecutive readings within range indicates stabilization of that parameter.

Monitoring Well Purging/Sampling Form

Project Name and Number: Former Duso Chemical Company 60279080.3

Monitoring Well Number: RIW-3S Date: 11/28/12

Samplers: Mark Howard and Sam Rowe

Sample Number: RIW-3S112812 QA/QC Collected? NO

Purging / Sampling Method: Peristaltic Pump with Dedicated Tubing/Low-Flow

1. L = Total Well Depth:	_____	feet
2. D = Riser Diameter (I.D.):	_____	feet
3. W = Static Depth to Water (TOC):	_____	feet
4. C = Column of Water in Casing:	_____	feet
5. V = Volume of Water in Well = $C(3.14159)(0.5D)^2(7.48)$	_____	gal
6. D2 = Pump Setting Depth (ft):	_____	feet
7. C2 = Column of water in Pump/Tubing (ft):	_____	feet
8. Tubing Volume = C2(0.005737088)	_____	gal

D (inches)	D (feet)
1-inch	0.08
2-inch	0.17
3-inch	0.25
4-inch	0.33
6-inch	0.50

Conversion factors to determine V given C

D (inches)	1-inch	2-inch	3-inch	4-inch	6-inch
V (gal / ft)	0.041	0.163	0.37	0.65	1.5

Water Quality Readings Collected Using YSI-556 and LaMotte 2020

Parameter	Units	Readings						
Time	24 hr	15:41	15:46	15:51	15:56			
Water Level (0.33)	feet	2.58	2.58	2.58	2.58			
Volume Purged	gal	1.90	2.25	2.50	2.75			
Flow Rate	mL / min	200	200	200	200			
Turbidity (+/- 10%)	NTU	374	281	251	216			
Dissolved Oxygen (+/- 10%)	%	26.2	27.7	27.6	28.1			
Dissolved Oxygen (+/- 10%)	mg/L	2.90	3.08	3.07	3.11			
Eh / ORP (+/- 10)	MeV	24.6	23.1	20.9	21.4			
Specific Conductivity	mS/cm[c]	0.929	0.929	0.930	0.930			
Conductivity (+/- 3%)	mS/cm	0.675	0.673	0.671	0.672			
pH (+/- 0.1)	pH unit	7.72	7.72	7.72	7.71			
Temp (+/- 0.5)	C	10.65	10.56	10.43	10.47			
Color	Visual	Cloudy	Cloudy	Cloudy	Cloudy			
Odor	Olfactory	Chlo	Chlo	Chlo	Chlo			

Comments: Sampled @ 15:56

* Three consecutive readings within range indicates stabilization of that parameter.

Monitoring Well Purging/Sampling Form

Project Name and Number: Former Duso Chemical Company 60279080.3

Monitoring Well Number: BTW-3D Date: 11/29/12

Samplers: Mark Howard and Sam Rowe

Sample Number: BTW-3D112912 QA/QC Collected? No

Purging / Sampling Method: Peristaltic Pump with Dedicated Tubing/Low-Flow

1. L = Total Well Depth:	23.49	feet
2. D = Riser Diameter (I.D.):	0.17	feet
3. W = Static Depth to Water (TOC):	4.20	feet
4. C = Column of Water in Casing:		feet
5. V = Volume of Water in Well = C(3.14159)(0.5D)^2(7.48)		gal
6. D2 = Pump Setting Depth (ft):	22.49	feet
7. C2 = Column of water in Pump/Tubing (ft):		feet
8. Tubing Volume = C2(0.005737088)		gal

D (inches)	D (feet)
1-inch	0.08
2-inch	0.17
3-inch	0.25
4-inch	0.33
6-inch	0.50

Conversion factors to determine V given C

D (inches)	1-inch	2-inch	3-inch	4-inch	6-inch
V (gal / ft)	0.041	0.163	0.37	0.65	1.5

Water Quality Readings Collected Using YSI-556 and LaMotte 2020

Parameter	Units	Readings						
Time	24 hr	13:17	13:22	13:27	13:32	13:37	13:42	13:47
Water Level (0.33)	feet	4.35	4.36	4.36	4.36	4.36	4.36	4.36
Volume Purged	gal	—	0.5	0.75	1.0	1.20	1.40	1.50
Flow Rate	mL / min	120	120	120	120	120	120	120
Turbidity (+/- 10%)	NTU	258	77.5	50.5	31.6	23.8	19.9	15.3
Dissolved Oxygen (+/- 10%)	%	29.7	11.0	8.0	6.3	6.7	6.7	5.5
Dissolved Oxygen (+/- 10%)	mg/L	3.15	1.14	0.81	0.64	0.68	0.68	0.56
Eh / ORP (+/- 10)	MeV	44.5	19.3	14.4	12.9	12.0	9.8	7.4
Specific Conductivity	mS/cm[c]	0.996	1.027	1.041	1.062	1.088	1.186	1.113
Conductivity (+/- 3%)	mS/cm	0.773	0.807	0.824	0.823	0.862	0.875	0.879
pH (+/- 0.1)	pH unit	8.45	8.95	8.92	8.78	8.65	8.56	8.50
Temp (+/- 0.5)	C	13.20	13.77	14.12	14.25	14.14	14.07	14.00
Color	Visual	Cloudy	Clear	Clear	Clear	Clear	Clear	Clear
Odor	Olfactory	Chlo	Chlo	Chlo	Chlo	Chlo	Chlo	Chlo

Comments: Start Purge @ 13:17

* Three consecutive readings within range indicates stabilization of that parameter.

Monitoring Well Purging/Sampling Form

Project Name and Number: Former Duso Chemical Company 60279080.3

Monitoring Well Number: BIW-31 Date: 11/29/12

Samplers: Mark Howard and Sam Rowe

Sample Number: BIW-3D112912 QA/QC Collected? No

Purging / Sampling Method: Peristaltic Pump with Dedicated Tubing/Low-Flow

1. L = Total Well Depth:	_____	feet
2. D = Riser Diameter (I.D.):	_____	feet
3. W = Static Depth to Water (TOC):	_____	feet
4. C = Column of Water in Casing:	_____	feet
5. V = Volume of Water in Well = $C(3.14159)(0.5D)^2(7.48)$	_____	gal
6. D2 = Pump Setting Depth (ft):	_____	feet
7. C2 = Column of water in Pump/Tubing (ft):	_____	feet
8. Tubing Volume = C2(0.005737088)	_____	gal

D (inches)	D (feet)
1-inch	0.08
2-inch	0.17
3-inch	0.25
4-inch	0.33
6-inch	0.50

Conversion factors to determine V given C

D (inches)	1-inch	2-inch	3-inch	4-inch	6-inch
V (gal / ft)	0.041	0.163	0.37	0.65	1.5

Water Quality Readings Collected Using YSI-556 and LaMotte 2020

Parameter	Units	Readings						
Time	24 hr	13:52	13:57	14:02	14:07			
Water Level (0.33)	feet	4.36	4.36	4.36	4.36			
Volume Purged	gal	1.70	2.0	2.25	2.50			
Flow Rate	mL / min	120	120	120	120			
Turbidity (+/- 10%)	NTU	14.7	13.5	13.0	8.67			
Dissolved Oxygen (+/- 10%)	%	4.5	4.1	3.7	3.6			
Dissolved Oxygen (+/- 10%)	mg/L	0.46	0.42	0.38	0.36			
Eh / ORP (+/- 10)	MeV	8.9	8.2	7.8	7.7			
Specific Conductivity	mS/cm[c]	1.119	1.124	1.130	1.132			
Conductivity (+/- 3%)	mS/cm	0.683	0.889	0.895	0.895			
pH (+/- 0.1)	pH unit	8.41	8.36	8.31	8.31			
Temp (+/- 0.5)	C	13.98	14.02	14.07	14.11			
Color	Visual	Clear	Clear	Clear	Clear			
Odor	Olfactory	Chlo	Chlo	Chlo	Chlo			

Comments: Sampled @ 14:07

* Three consecutive readings within range indicates stabilization of that parameter.

Monitoring Well Purging/Sampling Form

Project Name and Number: Former Duso Chemical Company 60279080.3

Monitoring Well Number: BIW-4 Date: 11/29/12

Samplers: Mark Howard and Sam Rowe

Sample Number: BIW-4112912 QA/QC Collected? NO

Purging / Sampling Method: Peristaltic Pump with Dedicated Tubing/Low-Flow

1. L = Total Well Depth:	10.96	feet
2. D = Riser Diameter (I.D.):	2.17	feet
3. W = Static Depth to Water (TOC):	3.91	feet
4. C = Column of Water in Casing:		feet
5. V = Volume of Water in Well = C(3.14159)(0.5D)^2(7.48)		gal
6. D2 = Pump Setting Depth (ft):	9.96	feet
7. C2 = Column of water in Pump/Tubing (ft):		feet
8. Tubing Volume = C2(0.005737088)		gal

D (inches)	D (feet)
1-inch	0.08
2-inch	0.17
3-inch	0.25
4-inch	0.33
6-inch	0.50

Conversion factors to determine V given C

D (inches)	1-inch	2-inch	3-inch	4-inch	6-inch
V (gal / ft)	0.041	0.163	0.37	0.65	1.5

Water Quality Readings Collected Using YSI-556 and LaMotte 2020

Parameter	Units	Readings						
Time	24 hr	10:47	10:52	10:57	11:02	11:07	11:12	11:17
Water Level (0.33)	feet	4.50	4.50	4.50	4.50	4.50	4.5	4.5
Volume Purged	gal	—	0.25	0.50	0.70	0.80	1.0	1.20
Flow Rate	mL / min	100	100	100	100	100	100	100
Turbidity (+/- 10%)	NTU	>1000	490	474	335	564	611	650
Dissolved Oxygen (+/- 10%)	%	60.6	41.7	37.6	34.5	34.5	34.2	32.3
Dissolved Oxygen (+/- 10%)	mg/L	7.06	4.78	4.25	3.87	3.88	3.80	3.59
Eh / ORP (+/- 10)	MeV	24.0	17.4	15.6	14.9	13.8	15.9	15.1
Specific Conductivity	mS/cm[c]	0.987	0.994	0.992	0.994	0.996	0.995	0.996
Conductivity (+/- 3%)	mS/cm	0.684	0.689	0.703	0.709	0.713	0.720	0.724
pH (+/- 0.1)	pH unit	7.66	7.69	7.69	7.71	7.69	7.64	7.65
Temp (+/- 0.5)	C	8.9C	9.39	9.74	9.91	10.11	10.56	10.72
Color	Visual	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy
Odor	Olfactory	Chlo	Chlo	Chlo	Chlo	Chlo	Chlo	Chlo

Comments: Start purge @ 10:47

* Three consecutive readings within range indicates stabilization of that parameter.

Monitoring Well Purging/Sampling Form

Project Name and Number: Former Duso Chemical Company 60279080.3

Monitoring Well Number: BIW-4 Date: 11/29/12

Samplers: Mark Howard and Sam Rowe

Sample Number: BIW-4112912 QA/QC Collected? YO

Purging / Sampling Method: Peristaltic Pump with Dedicated Tubing/Low-Flow

1. L = Total Well Depth:	_____	feet
2. D = Riser Diameter (I.D.):	_____	feet
3. W = Static Depth to Water (TOC):	_____	feet
4. C = Column of Water in Casing:	_____	feet
5. V = Volume of Water in Well = $C(3.14159)(0.5D)^2(7.48)$	_____	gal
6. D2 = Pump Setting Depth (ft):	_____	feet
7. C2 = Column of water in Pump/Tubing (ft):	_____	feet
8. Tubing Volume = C2(0.005737088)	_____	gal

D (inches)	D (feet)
1-inch	0.08
2-inch	0.17
3-inch	0.25
4-inch	0.33
6-inch	0.50

Conversion factors to determine V given C

D (inches)	1-inch	2-inch	3-inch	4-inch	6-inch
V (gal / ft)	0.041	0.163	0.37	0.65	1.5

Water Quality Readings Collected Using YSI-556 and LaMotte 2020

Parameter	Units	Readings						
Time	24 hr	11:22	11:37	11:32	11:37			
Water Level (0.33)	feet	4.5	4.5	4.5	4.5			
Volume Purged	gal	1.50	1.60	1.80	2.10			
Flow Rate	mL / min	100	100	100	100			
Turbidity (+/- 10%)	NTU	670	667	641	573			
Dissolved Oxygen (+/- 10%)	%	31.4	31.9	31.3	30.9			
Dissolved Oxygen (+/- 10%)	mg/L	3.44	3.50	3.45	3.39			
Eh / ORP (+/- 10)	MeV	15.2	15.6	17.3	12.4			
Specific Conductivity	mS/cm[c]	0.997	0.997	0.997	0.996			
Conductivity (+/- 3%)	mS/cm	0.732	0.733	0.734	0.737			
pH (+/- 0.1)	pH unit	7.65	7.64	7.63	7.63			
Temp (+/- 0.5)	C	11.06	11.15	11.19	11.39			
Color	Visual	Cloudy	Cloudy	Cloudy	Cloudy			
Odor	Olfactory	Chlo	Chlo	Chl	Chlo			

Comments: Sampled @ 11:37

* Three consecutive readings within range indicates stabilization of that parameter.

Monitoring Well Purging/Sampling Form

Project Name and Number: Former Duso Chemical Company 60279080.3

Monitoring Well Number: BIW-55 Date: 11/27/12

Samplers: Mark Howard and Sam Rowe

Sample Number: BIW-55112712 QA/QC Collected? NO

Purging / Sampling Method: Peristaltic Pump with Dedicated Tubing/Low-Flow

1. L = Total Well Depth:	11.06	feet
2. D = Riser Diameter (I.D.):	0.17	feet
3. W = Static Depth to Water (TOC):	3.64	feet
4. C = Column of Water in Casing:		feet
5. V = Volume of Water in Well = $C(3.14159)(0.5D)^2(7.48)$		gal
6. D2 = Pump Setting Depth (ft):	10.61	feet
7. C2 = Column of water in Pump/Tubing (ft):		feet
8. Tubing Volume = C2(0.005737088)		gal

D (inches)	D (feet)
1-inch	0.08
2-inch	0.17
3-inch	0.25
4-inch	0.33
6-inch	0.50

Conversion factors to determine V given C

D (inches)	1-inch	2-inch	3-inch	4-inch	6-inch
V (gal / ft)	0.041	0.163	0.37	0.65	1.5

Water Quality Readings Collected Using YSI-556 and LaMotte 2020

Parameter	Units	Readings						
Time	24 hr	15:12	15:17	15:22	15:27	15:32	15:37	15:42
Water Level (0.33)	feet	3.74	3.74	3.74	3.74	3.74	3.74	3.74
Volume Purged	gal	—	0.25	0.5	0.75	1.0	1.5	2.0
Flow Rate	mL / min	250	250	250	250	250	300	300
Turbidity (+/- 10%)	NTU	528	265	89	47.5	57.0	44.5	23.1
Dissolved Oxygen (+/- 10%)	%	17.0	5.4	3.4	2.7	4.2	5.3	5.0
Dissolved Oxygen (+/- 10%)	mg/L	1.73	0.60	0.37	0.29	0.45	0.57	0.54
Eh / ORP (+/- 10)	MeV	14.6	-21.8	-32.3	-28.6	-29.6	-27.9	-26.8
Specific Conductivity	mS/cm[c]	1.729	1.342	0.733	0.593	0.573	0.545	0.518
Conductivity (+/- 3%)	mS/cm	1.252	0.909	0.555	0.448	0.432	0.410	0.390
pH (+/- 0.1)	pH unit	6.70	7.42	7.63	7.58	7.53	7.52	7.51
Temp (+/- 0.5)	C	10.38	11.45	11.89	12.10	12.10	12.03	12.09
Color	Visual	Cloudy	Cloudy	Cloudy	Clear	clear	Clear	Clear
Odor	Olfactory	Chlo	Chlo	Chlo	Chlo	chlo	Chlo	Chlo

Comments: Start Purge @ 15:12

* Three consecutive readings within range indicates stabilization of that parameter.

Monitoring Well Purging/Sampling Form

Project Name and Number: Former Duso Chemical Company 60279080.3

Monitoring Well Number: BIW-5S Date: 11/27/12

Samplers: Mark Howard and Sam Rowe

Sample Number: BIW-5S112712 QA/QC Collected? No

Purging / Sampling Method: Peristaltic Pump with Dedicated Tubing/Low-Flow

1. L = Total Well Depth:	_____	feet
2. D = Riser Diameter (I.D.):	_____	feet
3. W = Static Depth to Water (TOC):	_____	feet
4. C = Column of Water in Casing:	_____	feet
5. V = Volume of Water in Well = $C(3.14159)(0.5D)^2(7.48)$	_____	gal
6. D2 = Pump Setting Depth (ft):	_____	feet
7. C2 = Column of water in Pump/Tubing (ft):	_____	feet
8. Tubing Volume = C2(0.005737088)	_____	gal

D (inches)	D (feet)
1-inch	0.08
2-inch	0.17
3-inch	0.25
4-inch	0.33
6-inch	0.50

Conversion factors to determine V given C

D (inches)	1-inch	2-inch	3-inch	4-inch	6-inch
V (gal / ft)	0.041	0.163	0.37	0.65	1.5

Water Quality Readings Collected Using YSI-556 and LaMotte 2020

Parameter	Units	Readings						
Time	24 hr	15:47	15:52	15:57				
Water Level (0.33)	feet	3.74	3.74	3.74				
Volume Purged	gal	2.25	2.50	2.75				
Flow Rate	mL / min	300	275	275				
Turbidity (+/- 10%)	NTU	20.8	17.7	14.0				
Dissolved Oxygen (+/- 10%)	%	4.4	3.6	3.5				
Dissolved Oxygen (+/- 10%)	mg/L	0.48	0.38	0.36				
Eh / ORP (+/- 10)	MeV	-26.8	-26.9	-26.9				
Specific Conductivity	mS/cm[c]	0.502	0.494	0.492				
Conductivity (+/- 3%)	mS/cm	0.378	0.372	0.370				
pH (+/- 0.1)	pH unit	7.49	7.48	7.48				
Temp (+/- 0.5)	C	12.03	12.03	12.03				
Color	Visual	clear	clear	clear				
Odor	Olfactory	chlo	chlo	chlo				

Comments: Sampled @ 15:57

* Three consecutive readings within range indicates stabilization of that parameter.

Monitoring Well Purging/Sampling Form

Project Name and Number: Former Duso Chemical Company 60279080.3

Monitoring Well Number: BIW-5D Date: 11/28/12

Samplers: Mark Howard and Sam Rowe

Sample Number: BIW-5D112812 QA/QC Collected? NO

Purging / Sampling Method: Peristaltic Pump with Dedicated Tubing/Low-Flow

1. L = Total Well Depth:	_____	feet
2. D = Riser Diameter (I.D.):	_____	feet
3. W = Static Depth to Water (TOC):	_____	feet
4. C = Column of Water in Casing:	_____	feet
5. V = Volume of Water in Well = $C(3.14159)(0.5D)^2(7.48)$	_____	gal
6. D2 = Pump Setting Depth (ft):	_____	feet
7. C2 = Column of water in Pump/Tubing (ft):	_____	feet
8. Tubing Volume = C2(0.005737088)	_____	gal

D (inches)	D (feet)
1-inch	0.08
2-inch	0.17
3-inch	0.25
4-inch	0.33
6-inch	0.50

Conversion factors to determine V given C

D (inches)	1-inch	2-inch	3-inch	4-inch	6-inch
V (gal / ft)	0.041	0.163	0.37	0.65	1.5

Water Quality Readings Collected Using YSI-556 and LaMotte 2020

Parameter	Units	Readings						
Time	24 hr	9:16	9:21	9:26	9:31			
Water Level (0.33)	feet	6.74	6.74	6.74	6.74			
Volume Purged	gal	1.25	1.40	1.65	1.75			
Flow Rate	mL / min	100	100	100	100			
Turbidity (+/- 10%)	NTU	18.9	15.3	13.2	11.9			
Dissolved Oxygen (+/- 10%)	%	6.8	6.2	5.6	5.1			
Dissolved Oxygen (+/- 10%)	mg/L	0.73	0.66	0.60	0.55			
Eh / ORP (+/- 10)	MeV	-57.7	-57.9	-57.1	-57.6			
Specific Conductivity	mS/cm[c]	2.179	2.179	2.180	2.183			
Conductivity (+/- 3%)	mS/cm	1.622	1.626	1.629	1.630			
pH (+/- 0.1)	pH unit	7.36	7.33	7.30	7.28			
Temp (+/- 0.5)	C	11.62	11.71	11.76	11.76			
Color	Visual	Clear	Clear	Clear	Clear			
Odor	Olfactory	Chlo	Chlo	Chlo	Chlo			

Comments: Sampled @ 9:31

* Three consecutive readings within range indicates stabilization of that parameter.

Monitoring Well Purging/Sampling Form

Project Name and Number: Former Duso Chemical Company 60279080.3

Monitoring Well Number: BTW-5D Date: 11/28/12

Samplers: Mark Howard and Sam Rowe

Sample Number: BTW-5D112812 QA/QC Collected? No

Purging / Sampling Method: Peristaltic Pump with Dedicated Tubing/Low-Flow

1. L = Total Well Depth:	19.68	feet
2. D = Riser Diameter (I.D.):	0.17	feet
3. W = Static Depth to Water (TOC):	3.60	feet
4. C = Column of Water in Casing:		feet
5. V = Volume of Water in Well = C(3.14159)(0.5D)^2(7.48)		gal
6. D2 = Pump Setting Depth (ft):	19.68	feet
7. C2 = Column of water in Pump/Tubing (ft):	16	feet
8. Tubing Volume = C2(0.005737088)		gal

D (inches)	D (feet)
1-inch	0.08
2-inch	0.17
3-inch	0.25
4-inch	0.33
6-inch	0.50

Conversion factors to determine V given C

D (inches)	1-inch	2-inch	3-inch	4-inch	6-inch
V (gal / ft)	0.041	0.163	0.37	0.65	1.5

Water Quality Readings Collected Using YSI-556 and LaMotte 2020

Parameter	Units	Readings						
Time	24 hr	8:41	8:46	8:51	8:56	9:01	9:06	9:11
Water Level (0.33)	feet	4.70	5.10	5.28	5.31	6.73	6.73	6.73
Volume Purged	gal	—	0.20	0.30	0.40	0.75	0.90	1.0
Flow Rate	mL / min	150	150	100	100	100	100	100
Turbidity (+/- 10%)	NTU	68.2	51.1	50.4	33.1	41.9	30.4	19.6
Dissolved Oxygen (+/- 10%)	%	33.6	18.4	16.5	16.3	7.0	6.7	6.0
Dissolved Oxygen (+/- 10%)	mg/L	3.89	2.04	1.82	1.82	0.74	0.72	0.65
Eh / ORP (+/- 10)	MeV	-56.8	-65.4	-60.5	-55.2	-61.4	-59.8	-57.9
Specific Conductivity	mS/cm[c]	2.131	2.160	2.164	2.175	2.181	2.192	2.182
Conductivity (+/- 3%)	mS/cm	1.489	1.563	1.568	1.564	1.688	1.641	1.623
pH (+/- 0.1)	pH unit	7.43	7.73	7.69	7.61	7.49	7.45	7.40
Temp (+/- 0.5)	C	9.21	10.52	10.59	10.30	13.04	11.90	11.57
Color	Visual	Clear	Clear	clear	Clear	Clear	clear	clear
Odor	Olfactory	Chlo	Chlo	Chlo	Chlo	Chlo	Chlo	Chlo

Comments: Start purge @ 8:41
8:46 Decrease flow rate - well drawing down
Increase speed to full throttle @ 8:56
Decrease speed to 100 ml/min @ 9:00

* Three consecutive readings within range indicates stabilization of that parameter.

Monitoring Well Purging/Sampling Form

Project Name and Number: Former Duso Chemical Company 60279080.3

Monitoring Well Number: BIW-6S Date: 11/28/13

Samplers: Mark Howard and Sam Rowe

Sample Number: BIW-6S112812 QA/QC Collected? No

Purging / Sampling Method: Peristaltic Pump with Dedicated Tubing/Low-Flow

1. L = Total Well Depth:	9.40	feet
2. D = Riser Diameter (I.D.):		feet
3. W = Static Depth to Water (TOC):	3.20	feet
4. C = Column of Water in Casing:		feet
5. V = Volume of Water in Well = $C(3.14159)(0.5D)^2(7.48)$		gal
6. D2 = Pump Setting Depth (ft):		feet
7. C2 = Column of water in Pump/Tubing (ft):		feet
8. Tubing Volume = C2(0.005737088)		gal

D (inches)	D (feet)
1-inch	0.08
2-inch	0.17
3-inch	0.25
4-inch	0.33
6-inch	0.50

Conversion factors to determine V given C

D (inches)	1-inch	2-inch	3-inch	4-inch	6-inch
V (gal / ft)	0.041	0.163	0.37	0.65	1.5

Water Quality Readings Collected Using YSI-556 and LaMotte 2020

Parameter	Units	Readings						
Time	24 hr	13:18	13:23	13:28	13:33	13:38	13:43	13:48
Water Level (0.33)	feet	3.28	3.28	3.28	3.28	3.28	3.28	3.28
Volume Purged	gal	—	0.20	0.40	0.60	0.75	0.90	1.1
Flow Rate	mL / min	120	120	120	120	120	120	120
Turbidity (+/- 10%)	NTU	411	328	188	124	84.2	80.0	50.7
Dissolved Oxygen (+/- 10%)	%	26.7	19.1	12.5	16.0	12.5	11.5	9.4
Dissolved Oxygen (+/- 10%)	mg/L	3.00	2.09	2.02	1.75	1.37	1.27	1.09
Eh / ORP (+/- 10)	MeV	50.7	20.0	12.4	8.4	5.1	7.2	9.5
Specific Conductivity	mS/cm[e]	0.697	0.692	0.684	0.684	0.681	0.680	0.676
Conductivity (+/- 3%)	mS/cm	0.514	0.514	0.507	0.506	0.499	0.497	0.494
pH (+/- 0.1)	pH unit	6.89	7.44	7.52	7.55	7.52	7.51	7.46
Temp (+/- 0.5)	C	11.05	11.52	11.43	11.33	11.01	10.95	10.95
Color	Visual	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy	Clear
Odor	Olfactory	Chl	Chl	Chl	Chl	Chl	Chl	Chl

Comments: Start purge @ 13:18

* Three consecutive readings within range indicates stabilization of that parameter.

Monitoring Well Purging/Sampling Form

Project Name and Number: Former Duso Chemical Company 60279080.3

Monitoring Well Number: BIW-6S Date: 11/28/12

Samplers: Mark Howard and Sam Rowe

Sample Number: BIW-6S11282 QA/QC Collected? No

Purging / Sampling Method: Peristaltic Pump with Dedicated Tubing/Low-Flow

1. L = Total Well Depth:	_____	feet
2. D = Riser Diameter (I.D.):	_____	feet
3. W = Static Depth to Water (TOC):	_____	feet
4. C = Column of Water in Casing:	_____	feet
5. V = Volume of Water in Well = $C(3.14159)(0.5D)^2(7.48)$	_____	gal
6. D2 = Pump Setting Depth (ft):	_____	feet
7. C2 = Column of water in Pump/Tubing (ft):	_____	feet
8. Tubing Volume = C2(0.005737088)	_____	gal

D (inches)	D (feet)
1-inch	0.08
2-inch	0.17
3-inch	0.25
4-inch	0.33
6-inch	0.50

Conversion factors to determine V given C

D (inches)	1-inch	2-inch	3-inch	4-inch	6-inch
V (gal / ft)	0.041	0.163	0.37	0.65	1.5

Water Quality Readings Collected Using YSI-556 and LaMotte 2020

Parameter	Units	Readings						
Time	24 hr	13:53	13:58	14:03	14:08	14:13		
Water Level (0.33)	feet	3.28	3.28	3.28	3.28	3.28		
Volume Purged	gal	1.25	1.40	1.60	1.75	2.0		
Flow Rate	mL / min	120	120	120	120	120		
Turbidity (+/- 10%)	NTU	37.4	27.7	20.2	21.1			
Dissolved Oxygen (+/- 10%)	%	9.6	8.5	7.8	7.4	6.5		
Dissolved Oxygen (+/- 10%)	mg/L	1.05	0.93	0.86	0.81	0.76		
Eh / ORP (+/- 10)	MeV	8.8	10.1	10.8	10.8	10.0		
Specific Conductivity	mS/cm^c	0.674	0.673	0.672	0.668	0.666		
Conductivity (+/- 3%)	mS/cm	0.494	0.494	0.493	0.492	0.492		
pH (+/- 0.1)	pH unit	7.45	7.43	7.41	7.40	7.40		
Temp (+/- 0.5)	C	11.00	11.05	11.16	11.24	11.37		
Color	Visual	Clear	Clear	Clear	Clear	Clear		
Odor	Olfactory	Chlo	Chlo	Chlo	Chlo	Chlo		

Comments: Sampled @ 14:13

* Three consecutive readings within range indicates stabilization of that parameter.

Monitoring Well Purging/Sampling Form

Project Name and Number: Former Duso Chemical Company 60279080.3

Monitoring Well Number: BIW-6D Date: 11/28/12

Samplers: Mark Howard and Sam Rowe

Sample Number: BIW-6D112812 QA/QC Collected? NO

Purging / Sampling Method: Peristaltic Pump with Dedicated Tubing/Low-Flow

1. L = Total Well Depth:	19.61	feet
2. D = Riser Diameter (I.D.):	0.17	feet
3. W = Static Depth to Water (TOC):	2.64	feet
4. C = Column of Water in Casing:		feet
5. V = Volume of Water in Well = C(3.14159)(0.5D)^2(7.48)		gal
6. D2 = Pump Setting Depth (ft):		feet
7. C2 = Column of water in Pump/Tubing (ft):		feet
8. Tubing Volume = C2(0.005737088)		gal

D (inches)	D (feet)
1-inch	0.08
2-inch	0.17
3-inch	0.25
4-inch	0.33
6-inch	0.50

Conversion factors to determine V given C

D (inches)	1-inch	2-inch	3-inch	4-inch	6-inch
V (gal / ft)	0.041	0.163	0.37	0.65	1.5

Water Quality Readings Collected Using YSI-556 and LaMotte 2020

Parameter	Units	Readings						
Time	24 hr	10:30	10:35	10:40	10:45	10:50	10:55	11:00
Water Level (0.33)	feet	3.23	3.60	3.66	4.90	5.0	5.15	1.45
Volume Purged	gal	—	0.20	0.25	0.5	0.75	0.80	1.25
Flow Rate	mL / min	150	100	100	100	100	100	—
Turbidity (+/- 10%)	NTU	110	153	112	39.8	22.7	19.5	26.7
Dissolved Oxygen (+/- 10%)	%	999.9	71.8	21.4	15.1	18.3	21.1	18.9
Dissolved Oxygen (+/- 10%)	mg/L	203.50	7.13	2.23	1.56	1.93	2.24	1.93
Eh / ORP (+/- 10)	MeV	-33.6	-28.1	-26.5	-27.8	-22.1	-17.4	-19.6
Specific Conductivity	mS/cm[c]	0.973	0.972	0.964	0.966	0.962	0.957	0.958
Conductivity (+/- 3%)	mS/cm	0.728	0.733	0.734	0.760	0.737	0.726	0.763
pH (+/- 0.1)	pH unit	8.03	7.86	7.82	7.83	7.87	7.84	7.85
Temp (+/- 0.5)	C	11.73	12.18	12.53	13.87	12.80	12.35	14.42
Color	Visual	Clear	Clear	clear	Clear	Clear	Clear	Clear
Odor	Olfactory	Chlo	Chlo	Chlo	Chlo	Chlo	Chlo	Chlo

Comments: Start purge @ 10:30
Turn Pump up to full speed @ 10:40
turned down to 100ml/min @ 10:44
Turn Pump up to full Speed @ 10:55
turn Pump down to 100 ml/min @ 11:00

* Three consecutive readings within range indicates stabilization of that parameter.

Monitoring Well Purging/Sampling Form

Project Name and Number: Former Duso Chemical Company 60279080.3

Monitoring Well Number: BDW-WP Date: 11/28/12

Samplers: Mark Howard and Sam Rowe

Sample Number: _____ QA/QC Collected? _____

Purging / Sampling Method: Peristaltic Pump with Dedicated Tubing/Low-Flow

1. L = Total Well Depth:	_____	feet
2. D = Riser Diameter (I.D.):	_____	feet
3. W = Static Depth to Water (TOC):	_____	feet
4. C = Column of Water in Casing:	_____	feet
5. V = Volume of Water in Well = $C(3.14159)(0.5D)^2(7.48)$	_____	gal
6. D2 = Pump Setting Depth (ft):	_____	feet
7. C2 = Column of water in Pump/Tubing (ft):	_____	feet
8. Tubing Volume = C2(0.005737088)	_____	gal

D (inches)	D (feet)
1-inch	0.08
2-inch	0.17
3-inch	0.25
4-inch	0.33
6-inch	0.50

Conversion factors to determine V given C

D (inches)	1-inch	2-inch	3-inch	4-inch	6-inch
V (gal / ft)	0.041	0.163	0.37	0.65	1.5

Water Quality Readings Collected Using YSI-556 and LaMotte 2020

Parameter	Units	Readings						
Time	24 hr	11:05	11:10	11:15	11:20	11:25	11:30	11:35
Water Level (0.33)	feet	7.53	7.65	7.59	7.54	7.53	7.51	
Volume Purged	gal	1.50	1.65	1.75	2.0	2.16	2.25	2.45
Flow Rate	mL / min	100	100	100	100	100	100	100
Turbidity (+/- 10%)	NTU	20.7	26.9	~~18.5~~	31.8	24.7	17.1	18.7
Dissolved Oxygen (+/- 10%)	%	19.7	23.1	24.6	22.5	21.0	20.8	18.7
Dissolved Oxygen (+/- 10%)	mg/L	2.05	2.41	2.58	2.34	2.22	2.19	1.75
Eh / ORP (+/- 10)	MeV	-16.2	-12.7	-13.0	-13.1	-15.9	-14.1	-16.5
Specific Conductivity	mS/cm[c]	.953	.954	.954	.955	.956	.956	.956
Conductivity (+/- 3%)	mS/cm	.745	.741	.737	.736	.736	.735	.736
pH (+/- 0.1)	pH unit	7.83	7.82	7.81	7.79	7.79	7.78	7.76
Temp (+/- 0.5)	C	13.56	13.32	13.04	13.02	12.95	12.93	12.99
Color	Visual	cloudy	cloudy	cloudy	cloudy	cloudy	cloudy	cloudy
Odor	Olfactory	petro	petro	petro	petro	petro	petro	petro

Comments: Sampled @ 11:35

* Three consecutive readings within range indicates stabilization of that parameter.

Monitoring Well Purging/Sampling Form

Project Name and Number: Former Duso Chemical Company 60279080.3

Monitoring Well Number: BTW-7 Date: 11/27/12

Samplers: Mark Howard and Sam Rowe

Sample Number: BTW-7112712 QA/QC Collected? NO

Purging / Sampling Method: Peristaltic Pump with Dedicated Tubing/Low-Flow

1. L = Total Well Depth:	13.65	feet
2. D = Riser Diameter (I.D.):	0.17	feet
3. W = Static Depth to Water (TOC):	2.34	feet
4. C = Column of Water in Casing:		feet
5. V = Volume of Water in Well = C(3.14159)(0.5D)^2(7.48)		gal
6. D2 = Pump Setting Depth (ft):	12.65	feet
7. C2 = Column of water in Pump/Tubing (ft):		feet
8. Tubing Volume = C2(0.005737088)		gal

D (inches)	D (feet)
1-inch	0.08
2-inch	0.17
3-inch	0.25
4-inch	0.33
6-inch	0.50

Conversion factors to determine V given C

D (inches)	1-inch	2-inch	3-inch	4-inch	6-inch
V (gal / ft)	0.041	0.163	0.37	0.65	1.5

Water Quality Readings Collected Using YSI-556 and LaMotte 2020

Parameter	Units	Readings						
Time	24 hr	8:31	8:36	8:41	8:46	8:51	8:56	9:01
Water Level (0.33)	feet	2.49	2.49	2.49	2.49	2.49	2.49	2.49
Volume Purged	gal	—	0.5	0.75	1	1.25	1.5	1.75
Flow Rate	mL / min	200	200	200	200	200	200	200
Turbidity (+/- 10%)	NTU	238	134	67.0	55.3	44.0	34.2	32.1
Dissolved Oxygen (+/- 10%)	%	18.0	11.3	10.1	9.2	8.4	8.8	9.2
Dissolved Oxygen (+/- 10%)	mg/L	1.91	1.22	1.09	0.99	0.91	0.95	0.98
Eh / ORP (+/- 10)	MeV	-147.2	-131.7	-117.9	-112.4	-109.9	-110.6	-110.7
Specific Conductivity	mS/cm[c]	0.829	0.773	0.772	0.770	0.768	0.767	0.765
Conductivity (+/- 3%)	mS/cm	0.604	0.575	0.572	0.576	0.578	0.576	0.576
pH (+/- 0.1)	pH unit	7.52	8.10	8.15	8.09	8.02	7.98	7.95
Temp (+/- 0.5)	C	10.60	11.61	11.87	11.90	12.03	12.10	12.16
Color	Visual	Iron Floc	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy
Odor	Olfactory	Chlo	Chlo	Chlo	Chlo	Chlo	Chlo	Chlo

Comments: Start Purge @ 8:31

* Three consecutive readings within range indicates stabilization of that parameter.

Monitoring Well Purging/Sampling Form

Project Name and Number: Former Duso Chemical Company 60279080.3

Monitoring Well Number: BIW-17 Date: 11/26/12

Samplers: Mark Howard and Sam Rowe

Sample Number: BIW-112712 QA/QC Collected? No

Purging / Sampling Method: Peristaltic Pump with Dedicated Tubing/Low-Flow

1. L = Total Well Depth:	13.65	feet
2. D = Riser Diameter (I.D.):	0.17	feet
3. W = Static Depth to Water (TOC):	2.34	feet
4. C = Column of Water in Casing:		feet
5. V = Volume of Water in Well = C(3.14159)(0.5D)^2(7.48)		gal
6. D2 = Pump Setting Depth (ft):	12.65	feet
7. C2 = Column of water in Pump/Tubing (ft):		feet
8. Tubing Volume = C2(0.005737088)		gal

D (inches)	D (feet)
1-inch	0.08
2-inch	0.17
3-inch	0.25
4-inch	0.33
6-inch	0.50

Conversion factors to determine V given C

D (inches)	1-inch	2-inch	3-inch	4-inch	6-inch
V (gal / ft)	0.041	0.163	0.37	0.65	1.5

Water Quality Readings Collected Using YSI-556 and LaMotte 2020

Parameter	Units	Readings						
Time	24 hr	9:06	9:11	9:16				
Water Level (0.33)	feet	2.49	2.49	2.49				
Volume Purged	gal	2.0	2.25	2.5				
Flow Rate	mL / min	200	200	200				
Turbidity (+/- 10%)	NTU	32.9	31.8	38.4				
Dissolved Oxygen (+/- 10%)	%	7.7	9.0	9.8				
Dissolved Oxygen (+/- 10%)	mg/L	0.83	0.96	1.07				
Eh / ORP (+/- 10)	MeV	-108.8	-111.6	-112.3				
Specific Conductivity	mS/cm^c	0.763	0.764	0.763				
Conductivity (+/- 3%)	mS/cm	0.574	0.574	0.573				
pH (+/- 0.1)	pH unit	7.87	7.85	7.80				
Temp (+/- 0.5)	C	12.15	12.01	11.99				
Color	Visual	Clear	Clear	Clear				
Odor	Olfactory	Chlo	Chlo	Chlo				

Comments: Sampled @ 9.16

* Three consecutive readings within range indicates stabilization of that parameter.

Appendix A-11

Monitoring Well Details and Depth-to-Groundwater Measurements - Star Gas Property

Appendix A-11
Monitoring Well Details and
Depth-to-Groundwater Measurements -
Star Gas Property
Former Duso Chemical Company
Poughkeepsie, New York
NYSDEC Site No. 3-14-103

Well Identification	Screened Material	Top of Casing Elevation (feet amsl)	Top of Screen (feet bgs)	Bottom of Screen (feet bgs)	Depth-to-Groundwater (feet bgs)	Total Well Depth (feet bgs)	Groundwater Elevation (feet amsl)
BIW-1D	Silty Sand and Silty Clay Interface	111.68	19	26	3.66	25.41	108.02
BIW-1S	Silty Sand	111.99	6	16	3.57	15.69	108.42
BIW-2D	Silty Sand and Silty Clay Interface	111.03	14	24	2.65	23.47	108.38
BIW-2S	Silty Sand	111.01	4	9	2.31	8.61	108.70
BIW-3D	Gravel and Sand	111.93	19	24	4.07	23.50	107.86
BIW-3S	Silty Sand	111.95	2	7	1.87	6.68	110.08
BIW-4	Silty Clay and Glacial Till Interface	112.54	2	11.5	4.01	11.05	108.53
BIW-5D	Silty Sand and Silty Clay Interface	110.93	15	20	3.78	19.68	107.15
BIW-5S	Silty Sand	111.19	5	12	3.59	11.60	107.60
BIW-6D	Silty Sand	111.92	15	20	2.59	19.60	109.33
BIW-6S	Silty Sand	111.93	2	10	3.07	9.39	108.86
BIW-7	Silty Sand	111.21	4	14	2.09	13.65	109.12
MHC-22	Silty Sand	113.03	3.5	13.5	4.14	12.46	108.89
MHC-23	Silty Sand	NA	3	13	3.94	11.59	NA
MHC-24	Silty Sand	111.58	3	13	5.47	12.38	106.11
MHC-25D	Bedrock	NA	36	41	6.18	40.64	NA
MHC-25I	Silty Clay	NA	22	27	1.30	26.40	NA
MHC-25S	Silty Sand	NA	4	14	1.95	13.21	NA
MHC-26	Silty Sand	113.23	3	13	4.58	12.01	108.65
OBG-2S	Silty Sand and Silty Clay Interface	123.19	9.1	19.1	NM	NM	NA
OBG-3S	Silty Clay	123.83	5.9	17.9	NM	NM	NA
OBG-4S	Silty Sand and Silty Clay Interface	122.17	4.3	14.3	NM	NM	NA

Notes:
Measurements collected on December 11, 2012
Top of casing and groundwater elevations based on USGS NAVD 1927
bgs - below ground surface
amsl - above mean sea level
NM - Not measured
NA - Not available
* - Screened material inferred, soil samples not recovered

Appendix A-12

Monitoring Well Details and Depth-to-Groundwater Measurements - Mid Hudson Business Park

Appendix A-12
Monitoring Well Details and
Depth-to-Groundwater Measurements -
Mid Hudson Business Park
Former Duso Chemical Company
Poughkeepsie, New York
NYSDEC Site No. 3-14-103

Well Identification	Screened Material	Top of Casing Elevation (feet amsl)	Top of Screen (feet bgs)	Bottom of Screen (feet bgs)	Depth-to-Groundwater (feet bgs)	Total Well Depth (feet bgs)	Groundwater Elevation (feet amsl)
MHBP-8	Silty Sand	110.57	5	15	3.41	12.70	107.16
MHBP-10	Silty Sand	111.50	5	15	4.33	11.79	107.17
MHBP-11	Silty Sand	112.06	10	20	NM	NM	NA
MHBP-12	Silty Sand	111.63	10	20	4.47	18.49	107.16
MHBP-13D	Bedrock	110.58	38.5	43.5	4.09	43.44	106.49
MHBP-13S	Silty Sand	110.29	10	20	3.95	16.00	106.34
MHBP-15	Silty Sand	112.74	4.5	14.5	NM**	24.88	NA
MHBP-19D	Bedrock	111.57	43	48	4.00	47.59	107.57
MHBP-19S	Silty Sand	111.71	2	12	4.08	11.02	107.63
MHBP-21	Silty Sand	NA	3	13	5.10	13.82	NA
MHC-29	Silty Sand	112.51	10	20	4.46	18.93	108.05
MHC-30	Silty Sand	112.57	9	19	4.53	16.45	108.04
OBG-1B	Bedrock	114.56	30.5	35.5	NM	NM	NA
OBG-1S	Silty Sand	115.39	8.9	18.9	NM	NM	NA
OBG-6S	Silty Sand	112.89	5	10	5.14	9.12	107.75
OBG-7D	Silty Clay	112.82	52	61.5	5.49	61.50	107.33
OBG-7I	Silty Sand and Silty Clay Interface	112.88	19.4	29.4	5.69	29.31	107.19
OBG-7S	Silty Sand	112.82	4.8	9.8	5.28	9.33	107.54
OBG-8S	Silty Sand	109.93	6.1	10.1	2.85	9.18	107.08
OGB-14B	Bedrock	112.61	15.1	24.6	NM	NM	NA
OBG-70B	Glacial Till	112.81	69.2	78.8	5.82	78.43	106.99
TW-1D	Glacial Till	110.63	55	60	3.50	60.10	107.13
TW-1I	Silty Clay	110.35	25	35	3.39	35.00	106.96
TW-1S	Silty Sand	110.70	15	20	3.75	19.97	106.95
TW-2D	Silty Clay and Glacial Till Interface	112.71	60	65	5.52	64.94	107.19
TW-2I	Silty Clay	112.31	30	35	5.24	34.32	107.07
TW-2S	Silty Sand	112.30	15	20	5.14	19.79	107.16
TW-3D	Silty Clay and Glacial Till Interface	109.69	44	49	2.84	47.42	106.85
TW-3I	Silty Clay	109.35	25	35	2.81	33.55	106.54
TW-3S	Silty Sand	109.43	15	20	3.13	19.99	106.30
TW-4D	Glacial Till	110.27	35	40	2.89	38.13	107.38
TW-4I	Silty Clay	110.39	15	25	3.96	23.89	106.43
TW-4S	Silty Sand	110.57	5	10	4.13	10.00	106.44
TW-5D	Silty Clay and Glacial Till Interface	112.14	25	35	4.11	35.08	108.03
TW-5S	Silty Sand	111.99	15	20	4.23	19.69	107.76
TW-6D	Silty Clay	108.27	50	55	1.32	53.24	106.95
TW-6I	Silty Clay	108.17	30	35	1.37	32.89	106.80
TW-6S	Silty Sand	108.03	15	20	1.20	19.69	106.83
TW-7D	Glacial Till	112.58	52	57	5.23	56.35	107.35
TW-7I	Silty Clay	112.57	30	35	5.04	33.45	107.53
TW-7S	Silty Sand	112.44	15	20	4.98	17.89	107.46
X-PROP-MW-D	Silty Clay*	112.35	37.5	42.5	5.12	38.27	107.23
X-PROP-MW-I	Silty Clay*	112.35	25	30	5.26	29.21	107.09
X-PROP-MW-S	Silty Sand*	112.35	15	20	5.01	19.89	107.34
Y-PROP-MW-D	Silty Clay*	112.56	52.5	57.5	5.39	56.24	107.17
Y-PROP-MW-I	Silty Clay*	112.56	35	40	7.88	38.10	104.68
Y-PROP-MW-S	Silty Sand*	112.56	15	20	6.11	17.53	106.45
Z-PROP-MW-D	Silty Clay*	112.01	55	60	4.62	58.51	107.39
Z-PROP-MW-I	Silty Clay*	112.01	35	40	4.68	37.38	107.33
Z-PROP-MW-S	Silty Sand*	112.01	15	20	5.20	19.55	106.81

Notes:
Measurements collected on December 11, 2012
Top of casing and groundwater elevations based on USGS NAVD 1927
bgs - below ground surface
amsl - above mean sea level
NM - Not measured
NA - Not available
* - Screened material inferred, soil samples not recovered
** - Water level probe malfunctioned at time of measurement

Appendix A-13

Groundwater Analytical Results - Star Gas Property

Appendix A-13
Groundwater Analytical Results - Star Gas Property
Former Duso Chemical Company
Poughkeepsie, New York
NYSDEC Site No. 3-14-103

Sample ID		AWQS/GV	BIW-1S 112712	BIW-1D 112712	BIW-2S 113012	BIW-2D 113012	BIW-3S 112812	BIW-3D 112912	BIW-4 112912	BIW-5S 112712	BIW-5D 112812	BIW-6S 112812	BIW-6D 112812	BIW-7 112712	MHC-23-112612	MHC-25S 112912	DUP112912[1]	MHC-26 121112
Date			11/27/2012	11/27/2012	11/30/2012	11/30/2012	11/28/2012	11/29/2012	11/29/2012	11/27/2012	11/28/2012	11/28/2012	11/28/2012	11/27/2012	11/26/2012	11/29/2012	11/29/2012	12/11/2012
Matrix			Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water
CAS No.	*VOC (µg/L)*																	
71-55-6	**1,1,1-Trichloroethane**	5	**9.4**	**3,600 D**	**5,200 D**	**3.3**	1 U	1 U	1 U	**560 D**	**33,000 D**	**42**	**0.82 J**	1 U	**3,900 D**	1 U	1 U	**1,500 D**
79-34-5	**1,1,2,2-Tetrachloroethane**	5	1 U	50 U	1 U	1 U	1 U	1 U	1 U	10 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	25 U
79-00-5	**1,1,2-Trichloroethane**	1	1 U	50 U	1 U	1 U	1 U	1 U	1 U	10 U	**1.0**	1 U	1 U	1 U	1 U	1 U	1 U	25 U
76-13-1	**1,1,2-Trichloro-1,2,2-trifluroethane**	1	1 U	50 U	1 U	1 U	1 U	1 U	1 U	**42 D**	1 U	1 U	1 U	1 U	**77**	1 U	1 U	25 U
75-34-3	**1,1-Dichloroethane**	5	**3.5**	**2,400 D**	**8,500 D**	**21**	1 U	1 U	1 U	**810 D**	**80,000 D**	**120 D**	**34**	1 U	**590 D**	**3.6**	**3.5**	**1,100 D**
75-35-4	**1,1-Dichloroethene**	5	1 U	**73 D**	**420 D**	1 U	1 U	1 U	1 U	10 U	**1,900 D**	**10**	1 U	1 U	**530 D**	1 U	1 U	**280 D**
120-82-1	**1,2,4-Trichlorobenzene**	5	1 U	50 U	1 U	1 U	1 U	1 U	1 U	10 U	1 U	1 U	1 U	1 U	**0.80 J**	1 U	1 U	25 U
96-12-8	**1,2-Dibromo-3-chloropropane**	0.04	1 U	50 U	1 U	1 U	1 U	1 U	1 U	10 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	25 U
106-93-4	**1,2-Dibromoethane**	0.0006	1 U	50 U	1 U	1 U	1 U	1 U	1 U	10 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	25 U
95-50-1	**1,2-Dichlorobenzene**	3	1 U	50 U	1 U	1 U	1 U	1 U	1 U	10 U	1 U	1 U	1 U	1 U	**260 D**	1 U	1 U	**30 D**
107-06-2	**1,2-Dichloroethane**	0.6	**0.3 J**	**160 D**	**170 D**	1 U	1 U	1 U	1 U	**77 D**	**6,800 D**	**53**	**2.8**	1 U	**35**	**2.8**	**2.7**	**27 D**
78-87-5	**1,2-Dichloropropane**	1	1 U	50 U	1 U	1 U	1 U	1 U	1 U	10 U	**5.0**	1 U	1 U	1 U	1 U	1 U	1 U	25 U
541-73-1	**1,3-Dichlorobenzene**	3	1 U	50 U	1 U	1 U	1 U	1 U	1 U	10 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	25 U
106-46-7	**1,4-Dichlorobenzene**	3	1 U	50 U	1 U	1 U	1 U	1 U	1 U	10 U	1 U	1 U	1 U	1 U	**26**	1 U	1 U	25 U
594-20-7	**2-Hexanone**	5	5 U	250 U	5 U	5 U	5 U	5 U	5 U	50 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	130 U
78-93-3	**2-Butanone (Methyl ethyl ketone)**	50(GV)	10 U	500 U	**2.8 J**	10 U	10 U	10 U	10 U	100 U	**280**	10 U	10 U	10 U	10 U	10 U	10 U	250 U
108-10-1	**4-Methyl-2-pentanone**	NA	5 U	250 U	5 U	5 U	5 U	5 U	5 U	50 U	**34**	5.0 U	5 U	5 U	5 U	5 U	5 U	130 U
67-64-1	**Acetone**	50 (GV)	10 U	500 U	**3.6 J**	**4.7 J**	**6.3 J**	**7.7 J**	**8.1 J**	100 U	**740 E**	**8.2 J**	**9.2 J**	10 U	**7.2 J**	**8.4 J**	**9.3 J**	250 U
71-43-2	**Benzene**	1	1 U	50 U	**1.1**	1 U	1 U	1 U	1 U	10 U	**3.0**	**0.76 J**	1 U	1 U	**1.4**	1 U	1 U	25 U
75-27-4	**Bromodichloromethane**	50(GV)	1 U	50 U	1 U	1 U	1 U	1 U	1 U	10 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	25 U
75-25-2	**Bromoform**	50(GV)	1 U	50 U	1 U	1 U	1 U	1 U	1 U	10 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	25 U
74-83-9	**Bromomethane**	5	1 U	50 U	1 U	1 U	1 U	1 U	1 U	10 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	25 U
75-15-0	**Carbon disulfide**	60(GV)	1 U	50 U	1 U	1 U	1 U	1 U	1 U	10 U	1 U	1 U	1 U	1 U	**0.46** J	1 U	1 U	25 U
56-23-5	**Carbon tetrachloride**	5	1 U	50 U	1 U	1 U	1 U	1 U	1 U	10 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	25 U
108-90-7	**Chlorobenzene**	5	1 U	50 U	1 U	1 U	1 U	1 U	1 U	10 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	25 U
75-00-3	**Chloroethane**	5	1 U	50 U	**1,000 D**	1 U	1 U*	1 U	1 U	**150 D**	**490 DJ**	1 U	1 U*	1 U	**220 D**	1 U	1 U	**860 D**
67-66-3	**Chloroform**	7	1 U	50 U	**0.52 J**	**0.99 J**	1 U	1 U	1 U	10 U	**22**	**0.76 J**	1 U	1 U	**2.1**	1 U	1 U	25 U
74-87-3	**Chloromethane**	5	1 U	50 U	1 U	1 U	1 U	1 U	1 U	10 U	1 U	1 U	1 U	1 U*	1 U	1 U	1 U	25 U
156-59-2	**cis-1,2-Dichloroethene**	5	**0.91 J**	50 U	**910 D**	**2.0**	1 U	1 U	1 U	**81 D**	**3.9**	**4.4**	1 U	1 U	**490 D**	1 U	1 U	**190 D**
10061-01-5	**cis-1,3-Dichloropropene**	0.4	1 U	50 U	1 U	1 U	1 U	1 U	1 U	10 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	25 U
110-82-7	**Cyclohexane**	50	1 U	50 U	1 U	1 U	1 U	1 U	1 U	10 U	1 U	1 U	1 U	1 U	**81**	1 U	1 U	25 U
124-48-1	**Dibromochloromethane**	50(GV)	1 U	50 U	1 U	1 U	1 U	1 U	1 U	10 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	25 U
75-71-8	**Dichlorodifluoromethane**	5	1 U	50 U	1 U	1 U	1 U	1 U	1 U	10 U	1 U	1 U	1 U	1 U*	1 U	1 U	1 U	25 U
100-41-4	**Ethylbenzene**	5	1 U	50 U	**1.2**	1 U	1 U	1 U	1 U	10 U	1 U	1 U	1 U	1 U	**4.7**	1 U	1 U	25 U
98-82-8	**Isopropylbenzene**	5	1 U	50 U	1 U	1 U	1 U	1 U	1 U	10 U	1 U	1 U	1 U	1 U	**3.7**	1 U	1 U	25 U
79-20-9	**Methyl acetate**	5	1 U	50 U	1 U	1 U	1 U	1 U	1 U	10 U	**0.90 J**	1 U	1 U	1 U	1 U	1 U	1 U	25 U
1634-04-4	**Methyl tert-butyl ether**	10(GV)	**1.8**	50 U	**6.2**	1 U	1 U	**4.3**	1 U	10 U	**73**	**8.2**	1 U	**2.4**	1 U	**1.6**	**1.8**	**23 DJ**
108-87-2	**Methylcyclohexane**	50	1 U	50 U	**0.76 J**	1 U	1 U	**2.6**	1 U	**65 D**	**0.47 J**	1 U	1 U	1 U	**250 D**	1 U	1 U	**26**
75-09-2	**Methylene chloride**	5	1 U	50 U	**1.2**	1 U	1 U	1 U	1 U	10 U	**25**	1 U	1 U	1 U	1 U	1 U	1 U	**12 DJ**
100-42-5	**Styrene**	5	1 U	50 U	1 U	1 U	1 U	1 U	1 U	10 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	25 U
127-18-4	**Tetrachloroethene**	5	**0.54 J**	50 U	**1.5**	**2.4**	**6.2**	**0.86 J**	**3.7**	**13 D**	**56**	**5.9**	1 U	1 U	**23**	1 U	1 U	25 U
108-88-3	**Toluene**	5	1 U	50 U	**25**	1 U	1 U	1 U	1 U	10 U	1 U	1 U	1 U	1 U	**4.1**	1 U	1 U	25 U
156-60-5	**trans-1,2-Dichloroethene**	5	1 U	50 U	**10**	1 U	1 U	1 U	1 U	10 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	25 U
10061-02-6	**trans-1,3-Dichloropropene**	0.4	1 U	50 U	1 U	1 U	1 U	1 U	1 U	10 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	25 U
79-01-6	**Trichloroethene**	5	**2.5**	50 U	**11**	**16**	**6.1**	**0.90 J**	**2.7**	**46 D**	**49**	**35**	1 U	1 U	**340 D**	1 U	1 U	**28 D**
75-69-4	**Trichlorofluoromethane**	5	1 U	50 U	1 U	1 U	1 U	1 U	1 U	10 U	1 U	1 U	1 U	1 U	**2.1**	1 U	1 U	25 U
75-01-4	**Vinyl chloride**	2	1 U	50 U	**150 D**	1 U	1 U	1 U	1 U	**16 D**	**210 E**	**2.2**	1 U	1 U	**20**	1 U	1 U	**190 D**
1330-20-7	**Xylenes, Total**	100	2 U	100 U	**4.7**	2 U	2 U	2 U	2 U	20 U	2 U	2 U	2 U	2 U	**7.8**	2 U	2 U	20 U
	Total CVOCs	NA	**17**	**6,233**	**16,374**	**46**	**12**	**2**	**6**	**1,795**	**122,562**	**273**	**38**	**ND**	**6,516**	**6**	**6**	**4,217**
	Total VOCs	NA	**19**	**6,233**	**16,420**	**50**	**19**	**16**	**15**	**1,860**	**123,693**	**290**	**47**	**2.4**	**6,876**	**16**	**17**	**4,266**
	Dissolved Gases (µg/L)																	
74-84-0	**Ethane**	NA	7.5 U	7.5 U	**22**	7.5 U	7.5 U	7.5 U	7.5 U	380 U	7.5 U	7.5 U	7.5 U	7.5 U	380 U	7.5 U	7.5 U	NS
74-85-1	**Ethene**	NA	7.0 U	7.0 U	**13**	7.0 U	7.0 U	7.0 U	7.0 U	350 U	**24**	7.0 U	7.0 U	7.0 U	350 U	7.0 U	7.0 U	NS
74-82-8	**Methane**	NA	**100**	**2.4 J**	**340**	**35**	**98**	**22**	**5.6**	**390 D**	**41**	**90**	**29**	**680**	**400**	**13**	**10**	NS
	General Chemistry (µg/L)																	
NA	**Bromide**	2,000	200 U	200 U	200 U	99 J	200 U	200 U	**370**	200 U	1,000 UD	200 U	**130 J**	200 U	200 U	200 U	**330**	NS
16887-00-6	**Chloride**	250,000	**84,200**	**52,700**	**200,000 D**	**302,000 D**	**129,000 D**	**194,000 D**	**141,000 D**	**34,000**	**531,000 D**	**43,200**	**151,000 D**	**71,100**	**31,600**	**217,000 D**	**213,000 D**	NS
14808-79-8	**Sulfate**	250,000	**18,100**	**35,200**	**4,600**	**42,800**	**27,300**	**46,600**	**32,000**	**4,000**	**64,200 D**	**23,100**	**36,000**	**5,500**	**3,400**	**17,200**	**17,200**	NS
14797-55-8	**Nitrate**	10,000	50 U	50 U	NS	NS	**130**	50 U	**130**	**49 J**	**49 J**	50 U	50 U	50 U	50 U	50 U	50 U	NS
14797-65-0	**Nitrite**		50 U	50 U	NS	NS	**24 J**	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	NS
NA	**Total Organic Carbon**	NA	**1,500**	1,000 U	**4,100**	1,000 U	**710 J**	**1,200**	**430 J**	**2,800**	**21,000**	**960 J**	1,000 U	**2,800**	**3,800**	**470 J**	1,000 U	**6,400**
14265-44-2	**Phosphate**	NA	**13**	**69**	10 U	10 U	**64**	10 U	**260**	**40**	**23**	**35**	**11**	**660**	**160**	10 U	10 U	NS
	Biological Analyses (cells)	NA																
NA	**Dehalococcoides (Dhc)**	NA	3,000 U	2,000 U	**2,000,000**	1,000 U	**2,000 J**	1,000 U	30,000 U	**3,000,000**	**2,000**	**9,000**	1,000 U	**2,000**	**700,000**	**50,000**	NS	NS
NA	**Dehalobacter (Dhb)**	NA	4,000 U	**60,000**	**6,000,000**	2,000 U	**200,000**	**10,000**	**10,000 J**	**2,000,000**	**700,000**	2,000 U	1,000 J	**200,000**	**4,000,000**	10,000 U	NS	NS
	Volatile Fatty Acids (mg/L)																	
NA	**Lactate**	NA	0.39 U	0.39 U	0.39 U	0.39 U	0.39 U	0.39 U	0.39 U	0.39 U	0.39 U	**0.64**	0.39 U	0.39 U	0.39 U	0.39 U	NS	NS
NA	**Acetate**	NA	**0.87**	**0.95**	**3.0**	**1.40**	**1.30**	**1.30**	**1.30**	**1.50**	**51**	**1.50**	**1.10**	**0.81**	**0.88**	**1.40**	NS	NS
NA	**Propionate**	NA	0.31 U	0.31 U	0.31 U	0.31 U	0.31 U	0.31 U	0.31 U	0.31 U	0.31 U	0.31 U	0.31 U	0.31 U	0.31 U	0.31 U	NS	NS
NA	**Formate**	NA	0.22 U	0.22 U	**1.30**	0.22 U	0.22 U	0.22 U	0.22 U	0.22 U	0.22 U	**13**	0.22 U	0.22 U	0.22 U	0.22 U	NS	NS
NA	**Butyrate**	NA	0.41 U	0.41 U	0.41 U	0.41 U	0.41 U	0.41 U	0.41 U	0.41 U	0.41 U	0.41 U	0.41 U	0.41 U	0.41 U	0.41 U	NS	NS
NA	**Pyruvate**	NA	0.69 U	0.69 U	0.69 U	0.69 U	0.69 U	0.69 U	0.69 U	0.69 U	0.69 U	0.69 U	0.69 U	0.69 U	0.69 U	0.69 U	NS	NS

Notes:
BOLD - The compound was detected at a concentration greater than or equal to the method detection limit (MDL).
BOLD/SHADED IN BLUE - The compound was detected at a concentration greater than New York State Ambient Water Quality Standards (AWQS) or Guidance Values (GV).
µg/L - micrograms per liter
mg/L - milligrams per liter
NA - Not Applicable
NS - Not Sampled
U/ND - The compoud was not detected at a concentration greater than or equal to the MDL.
J - The concentration given is an approximate value. The concentration is less than the reporting limit (RL) and greater than or equal to the MDL.
D - The reported value is from a secondary dilution analysis factor.
E - The compound concentration exceeded the calibration range.
[1] - Duplicate sample of MHC-25S 112912
* Laboratory control sample (LCS) or LCS Duplicate (LCSD) exceeds the control limits.

Appendix B

Enhanced Reductive Dechlorination Amendment Product Information and Material Safety Data Sheets

Material Safety Data Sheet

EHC®

MSDS #: EHC-C
Revision Date: 2012-04-30
Version 1

This MSDS has been prepared to meet U.S. OSHA Hazard Communication Standard 29 CFR 1910.1200 and Canada's Workplace Hazardous Materials Information System (WHMIS) requirements.

1. PRODUCT AND COMPANY IDENTIFICATION

Product name **EHC®**

Recommended use Bioremediation product for the remediation of contaminated soil and groundwater only. Not for use in potable drinking water.

Manufacturer

FMC CORPORATION
FMC Peroxygens
1735 Market Street
Philadelphia, PA 19103
Phone: +1 215/ 299-6000 (General Information)
E-Mail: msdsinfo@fmc.com

Emergency telephone number

For leak, fire, spill or accident emergencies, call:
+1 703-527-3887 (CHEMTREC)
+1 303 / 595 9048 (Medical - Call Collect)

2. Hazards identification

Emergency Overview

CONTAINMENT HAZARD:
Any vessel that contains wet EHC must be vented due to potential pressure build up from fermentation gases

Potential health effects

Acute Toxicity No significant health effects anticipated
Eyes Product dust may cause mechanical eye irritation.
Skin None known .
Inhalation Inhalation of dust in high concentration may cause irritation of respiratory system.
Ingestion Ingestion may cause gastrointestinal irritation, nausea, vomiting and diarrhea.

Chronic Toxicity No known chronic effects of components present at greater than 1%.

3. Composition/information on ingredients

Ingredients

Chemical Name	CAS-No	Weight %
Iron	7439-89-6	18-48
Organic Amendment	Proprietary	52-82

4. First aid measures

Eye contact — In case of contact, immediately flush skin with plenty of water. Get medical attention if irritation develops and persists.

Skin contact — Wash off with soap and water.

Inhalation — Remove person to fresh air. If signs/symptoms continue, get medical attention.

Ingestion — Rinse mouth with water and afterwards drink plenty of water or milk. Call a poison control center or doctor immediately for treatment advice.

5. Fire-fighting measures

Flammable properties — Combustible material.

Suitable extinguishing media — Dry chemical, CO_2, sand, earth, water spray or regular foam.

Explosion Data

Sensitivity to Mechanical Impact — not applicable
Sensitivity to Static Discharge — not applicable

Specific hazards arising from the chemical — Dry or powdered ingredients are combustible. Dispersal of finely divided dust from products into air may form mixtures that are ignitable and explosive. Minimize airborne dust generation and eliminate sources of ignition.

NFPA	Health Hazard 1	Flammability 1	Stability 0	Special Hazards -

NFPA/HMIS Ratings Legend — Severe = 4; Serious = 3; Moderate = 2; Slight = 1; Minimal = 0

6. Accidental release measures

Personal precautions — Avoid dust formation. For personal protection see section 8.

Methods for containment — Cover powder spill with plastic sheet or tarp to minimize spreading and keep powder dry.

Methods for cleaning up — Sweep or vacuum up spillage and return to container.

7. Handling and storage

Handling — Minimize dust generation and accumulation. Keep away from open flames, hot surfaces and sources of ignition. Refer to Section 8.

Storage — Keep tightly closed in a dry and cool place. Keep away from open flames, hot surfaces and sources of ignition. Any vessel that contains .? must be vented due to potential pressure build up from fermentation gases.

8. Exposure controls/personal protection

Exposure guidelines — Local nuisance dust standards apply.

Occupational exposure controls

Engineering measures	None under normal use conditions. Provide appropriate exhaust ventilation at places where dust is formed.

Personal Protective Equipment

General Information	If the product is used in mixtures, it is recommended that you contact the appropriate protective equipment suppliers, These recommendations apply to the product as supplied
Respiratory protection	Whenever dust in the worker's breathing zone cannot be controlled with ventilation or other engineering means, workers should wear respirators or dust masks approved by NIOSH/MSHA, EU CEN or comparable organization to protect against airborne dust.
Eye/face protection	Safety glasses with side-shields
Skin and body protection	No special precautions required.
Hand protection	No special precautions required

Hygiene measures	Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and immediately after handling the product.

9. Physical and chemical properties

Appearance	Light-tan powder
Physical state	solid
Odor	odorless
pH	5.6 (as aqueous solution)
Melting Point/Range	No information available.
Freezing point	No information available
Boiling Point/Range	not applicable
Flash Point	not applicable
Evaporation rate	not applicable
Autoignition Temperature	No information available.
Flammable properties	Combustible material
Vapor pressure	No information available
Vapor density	No information available
Density	0.80 g/mL
Water solubility	practically insoluble
Percent volatile	No information available
Partition coefficient:	not applicable
Viscosity	No information available
Oxidizing properties	not applicable

10. Stability and reactivity

Stability Stable.

Conditions to avoid Heat, flames and sparks

Materials to avoid Oxidizing agents Strong acids

Hazardous decomposition products None known

Hazardous polymerization Hazardous polymerization does not occur

11. Toxicological information

Acute effects

Remarks The product has not been tested. Data is based on component.

Eye irritation No data available for the formulation. Non-irritating (rabbit) (based on components)
Skin irritation No data available for the formulation. Non-irritating (rabbit) (based on components)

LD50 Oral Iron: 98.6 g/kg (rat)
LD50 Dermal No information available
LC50 Inhalation: Iron: > 100 mg/m^3 6 hr (rat)

Chronic Toxicity

Chronic Toxicity No known chronic effects of components present at greater than 1%.

Carcinogenicity Contains no ingredient listed as a carcinogen.

12. Ecological information

Ecotoxicity
The environmental impact of this product has not been fully investigated

Chemical Name	Toxicity to algae	Toxicity to fish	Toxicity to microorganisms	Toxicity to daphnia and other aquatic invertebrates
Iron		LC50= 13.6 mg/L Morone saxatilis 96 h LC50= 0.56 mg/L Cyprinus carpio 96 h		

13. Disposal considerations

Waste disposal methods

This material, as supplied, is not a hazardous waste according to Federal regulations (40 CFR 261). This material could become a hazardous waste if it is mixed with or otherwise comes in contact with a hazardous waste, if chemical additions are made to this material, or if the material is processed or otherwise altered. Consult 40 CFR 261 to determine whether the altered material is a hazardous waste. Consult the appropriate state, regional, or local regulations for additional requirements

Contaminated packaging

Dispose of in accordance with local regulations

14. Transport information

DOT not regulated

TDG not regulated

ICAO/IATA not regulated

IMDG/IMO not regulated

15. Regulatory information

International Inventories

TSCA Inventory (United States of America)	-
DSL (Canada)	Complies
NDSL (Canada)	Complies
EINECS/ELINCS (Europe)	Complies
ENCS (Japan)	-
IECSC (China)	Complies
KECL (Korea)	-
PICCS (Philippines)	Complies
AICS (Australia)	Complies
NZIoC (New Zealand)	Complies

U.S. Federal Regulations

SARA 313

Section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA). This product does not contain any chemicals which are subject to the reporting requirements of the Act and Title 40 of the Code of Federal Regulations, Part 372.

SARA 311/312 Hazard Categories

Acute Health Hazard	no
Chronic Health Hazard	no
Fire Hazard	no
Sudden Release of Pressure Hazard	no
Reactive Hazard	no

CERCLA

This material, as supplied, does not contain any substances regulated as hazardous substances under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) (40 CFR 302) or the Superfund Amendments and Reauthorization Act (SARA) (40 CFR 355). There may be specific reporting requirements at the local, regional, or state level pertaining to releases of this material.

International Regulations

Mexico - Grade No information available

Canada

This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations (CPR) and the MSDS contains all the information required by the CPR.

WHMIS Hazard Class

not determined

16. Other information

HMIS	Health Hazard 1	Flammability 1	Stability 0	Special precautions -

NFPA/HMIS Ratings Legend Severe = 4; Serious = 3; Moderate = 2; Slight = 1; Minimal = 0

Revision Date: 2012-04-30
Reason for revision: No information available.

Disclaimer

FMC Corporation believes that the information and recommendations contained herein (including data and statements) are accurate as of the date hereof. NO WARRANTY OF FITNESS FOR ANY PARTICULAR PURPOSE, WARRANTY OF MERCHANTABILITY OR ANY OTHER WARRANTY, EXPRESSED OR IMPLIED, IS MADE CONCERNING THE INFORMATION PROVIDED HEREIN. The information provided herein relates only to the specified product designated and may not be applicable where such product is used in combination with any other materials or in any process. , Further, since the conditions and methods of use are beyond the control of FMC Corporation, FMC corporation expressly disclaims any and all liability as to any results obtained or arising from any use of the products or reliance on such information.

Prepared By

FMC Corporation
FMC Logo and EHC - Trademarks of FMC Corporation

End of Material Safety Data Sheet

EOS Remediation, LLC

Experience you can rely on, Products you can trust™

EOS PRO

PRODUCT INFORMATION SHEET
Emulsified Oils Family

Description

EOS PRO (formerly 598B42) is a nutrient-enriched, DoD-validated, food-grade oil/water emulsion designed to quickly stimulate microbial activity while providing long-term nourishment to enhance anaerobic bioremediation of chlorinated solvents, nitrates, perchlorate, energetics, acid mine drainage, and other recalcitrant chemicals in contaminated groundwater. EOS PRO can also be used to reduce redox sensitive metals and radionuclides. The negative surface charges on the droplets combined with small droplet size promote effective transport in the subsurface.

EOS PRO benefits:

- Includes biostimulating vitamins and nutrients
- Rapidly-biodegradable substrates to "jump start" bacterial growth
- Slow release biodegradable substrates to promote long-term biological activity
- Small oil droplet size
- Negative surface charge
- Neutral pH
- Extensive third party validation

EOS PRO incorporates the proven patented EOS® technologies that clients have trusted for more than a decade. Made in the USA with US farmed soybean oil.

Chemical & Physical Properties

Oil Emulsion Concentrate: EOS PRO	Typical
Refined and Bleached US Soybean Oil (% by wt.)	59.8
Rapidly Biodegradable Soluble Substrate (% by wt.)	4
Other Organics (emulsifiers, food additives, etc.) (% by wt.)	10
Specific Gravity	0.96 - 0.98
pH (Standard Units)	6.0 - 7.0
Median Oil Droplet Size (microns)	1.0
Organic Carbon (% by wt.)	74
Mass of Hydrogen Produced (lbs. H_2 per lb. EOS PRO)	0.25

Packaging

Shipped in 55-gallon drums, 275-gallon IBC totes or bulk tankers (40,000 lbs.)

Handling & Storage

EOS PRO is shipped as a ready-to-use concentrated emulsion that can be diluted with water in the field to prepare a high quality suspension for easy injection. EOS PRO has a low viscosity and can be distributed with commonly available pumps or continuous metering with a diluter (e.g., Dosatron™). Dilution ratios for EOS PRO commonly range from 4:1 to 20:1 (water: EOS PRO) depending on site conditions. EOS PRO injections should be followed with additional chase water to maximize distribution of EOS PRO into the formation.

For best performance, use EOS PRO within 60 days of delivery and store at a temperature between 40°F (4°C) to 100°F (38°C).

Phone: 919.873.2204
Web: www.eosremediation.com

EHC® Original ISCR Reagent Demand Calculations

FMC ENVIRONMENTAL SOLUTIONS

Customer:	**AECOM**
Contact:	**Paul M. Dombrowski, P.E.**
Site Location:	**Poughkeepsie, NY**
Proposal Number:	**FMC-OPP-000435**

17-Jan-2013

PRODUCT OVERVIEW

EHC is composed of controlled-release carbon, zero valent iron (ZVI) particles and nutrients used for stimulating in situ chemical reduction (ISCR) of otherwise persistent organic compounds in groundwater. Following placement of EHC into the subsurface environment, a number of physical, chemical and microbiological processes combine to create very strong reducing conditions that stimulate rapid and complete dechlorination of organic solvents and other recalcitrant compounds (e.g., explosives and organochlorine pesticides).

EHC is delivered as a dry powder in 50-lb / 25-kg bags or super-sacs. EHC can be placed into the saturated zones in a variety of ways including direct push injections, hydraulic and pneumatic fracturing, and direct soil mixing. EHC is completely non-hazardous and safe to handle. EHC is manufactured in the USA, EU and Brazil.

SITE INFORMATION / ASSUMPTIONS

	Value	Unit	Comment
Treatment Area Dimensions:			
Width of targeted zone (perpendicular to gw flow)	25	ft	customer supplied
Length of targeted zone (parallel to gw flow)	50	ft	customer supplied
Depth to top of treatment zone	4	ft bgs	customer supplied
Treatment zone thickness	20	ft	customer supplied
Treatment volume	25,000	ft3	calculated value
Total Porosity	30	%	default value
Groundwater volume	7,500	ft3	calculated value
Soil bulk density	105	lbs/ft3	default value
Soil mass	1,313	ton	calculated value
Transport characteristics:			
Treatment time / design life for one application	3	years	default value
Linear groundwater flow velocity	193	ft/year	calculated value
Distance of inflowing gw over design life	578	ft	calculated value
Effective porosity for groundwater flow	25	%	default value
Volume of water passing region over design life	72270	ft3	calculated value
Soil type	medium		customer supplied
Fraction organic carbon in soil, foc	0.005		estimated value

CONTAMINANTS OF CONCERN (COCs)

Constituent	GW (mg/L)	Soil* (mg/kg)	Total COI Mass** (lb)
TCA	33	30.195	243.6
1,1-DCA	80	7.6	418.4
DCE	2	0.6	11.5
1,2-DCA	7	6.44	51.8
CA	0.5	0.2	3.0
PCE	0.1	0.1315	0.8
TCE	0.1	0.0535	0.6

*Unless provided, sorbed concentrations were roughly estimated based on expected groundwater concentrations, foc and Koc values. For a more refined estimate, it is recommended that actual values be verified via direct sampling of the targeted treatment interval.

**The total COI mass was estimated based on concentrations in soil and groundwater within the targeted area plus expected contributions from inflowing groundwater over the projected design life.

GEOCHEMICAL DATA

Competing Electron Acceptors	GW (mg/L)	Soil* (mg/kg)
Dissolved oxygen	1	2.87
Nitrate (as N)	0.05	0
Manganese (dissolved)	0	0
Iron (III)	0	0
Sulfate	50	0
Carbonate Alkalinity (as CaCO3)	0	0

*Unless provided, soil concentrations were roughly estimated based on expected groundwater concentrations, foc and Koc/Kd values. For a more refined estimate, it is recommended that actual values be verified via direct sampling of the targeted treatment interval.

ORP (mV)	-20	
pH	7.2	

STOICHIOMETRIC DEMAND CALCULATIONS

	GW (mg/L)	Soil (mg/kg)
H2 Demand from COIs	5.1	2.0
H2 Demand from Competing Electron Acceptors	4.1	0.4
Total H2 Demand	9.2	2.3
H2 Demand from Soil within Targeted Area	6.1	lb
H2 Demand from GW within Targeted Area	4.3	lb
H2 Demand from Influx over Design Life	41.6	lb
Total Estimated H2 Demand	52.1	lb

EHC DEMAND CALCULATIONS

The Stoichiometric demand for the targeted area was calculated using available data presented above, noting that the Stoichiometric demand represents minimum requirements and require a complete geochemical data set to be calculated accurately. Therefore, the resulting EHC dosing required to meet the estimated Stoichiometric demand was compared to our minimum guidelines for the selected type of application, selecting the higher

Application type: Source Area / Hot-Spot Treatment

	Value	Unit
Minimum EHC application rate to meet H2 demand	0.04	% by soil mass
Minimum recommended appl. rate for source area*	0.35	% by soil mass
Recommended EHC application rate	0.35	% by soil mass
Mass of EHC required	9,188	lbs
Mass of EHC per bag	50	lbs
Number of bags required	184	bags
Mass EHC (rounded up based on bag size)	9,200	lbs

*Our general recommended minimum guideline for the proposed application exceeds the dose rate required based on hydrogen demand calculations and was therefore used for the purpose of this dosing calculation.

OPTIONAL DHC INOCULANT

Although not typically required for ISCR, DHC inoculants have shown to improve removal kinetics, in particular for potential daughter products such as cis-DCE and VC. The DHC will be added after EHC application, once favorable redox conditions (ORP < -75 mV, DO <0.2 mg/L, pH between 6 and 8.5) have been attained. The DHC inoculant will contain at least 5 x10E10 cfu/ml of live bacteria including high numbers of dehalococcoides species with known abilities to biodegrade DCE. The target density of DHC cells in the treated aquifer is 1x10E6 cfu/ml.

	Value	Unit
Dechlorinating consortium concentration in inoculant	5.00E+10	DHC/L
Design final concentration after dilution in aquifer	2.50E+06	DHC/L
Volume of Inoculant Required	11	L

*Note: The minimum shipping volume of 13 L (one small keg) exceeds the caluclated requirement, and was therefore used in the quotation below.

COST ESTIMATE

Item	Quantity	Unit	Price	Cost
EHC [1, 2]	9,200	lbs	$2.65	$24,380
Shipping Estimate [3]	1	lump sum	$1,900	$1,900
Sub Total Cost				**$26,280**
Optional items:				
DHC Inoculum	13	L	$85	$1,105
DHC Shipping Estimate [4]	1	per canister	$190	$190
TOTAL COST [5]				**$27,575**

1) Price valid for 90 days from date at top of document. Terms: net 30 days.

2) Any applicable taxes not included. Please provide a copy of your tax exempt certificate or resale tax number when placing your order.

3) Shipping rate provided is an estimate. Standard delivery time can vary from 1-3 weeks from time of order, depending upon volume. Expedited transport can be arranged at extra cost. Unless requested otherwise, costs assume standard ground transport via truck, with no need for a lift gate or pallet jack.

4) Shipping rate via FedEx. For larger volumes, upon request the culture may be concentrated into a smaller volume to reduce shipping charges.

5) All sales are per FMC's Terms and Conditions.

Disclaimer:

The estimated dosage and recommended application methodology described in this document are based on the site information provided to us, but are not meant to constitute a guaranty of performance or a predictor of the speed at which a given site is remediated. The calculations in the Cost Estimate regarding the amount of product to be used in your project are based on stoichiometry or default minimum guideline values, and do not take into account the kinetics, or speed of the reaction. Note that the Stoichiometric mass represents the minimum anticipated amount needed to address the constituents of concern (COCs). As a result, these calculations should be used as a general approximation for purposes of an initial economic assessment. FMC recommends that you or your consultants complete a comprehensive remedial design that takes into consideration the precise nature of the COC impact and actual site conditions.

INSTALLATION

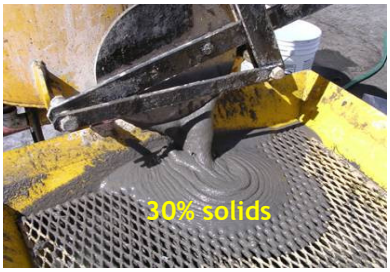
EHC is supplied as a dry powder which can be mixed with soil or slurried in water. Installation techniques vary widely depending on the application. For example, the powder can be directly mixed into the soil using deep soil mixing equipment or placed into an open excavation where prior soil removal has been conducted. A slurry can be made and the mixture can be injected into the subsurface using techniques such as direct injection through Geoprobe rods or hydraulic fracturing. Injection through fixed wells is not recommended given that the product does not dissolve in water. If application via wells or injection networks were to be the preferred installation method at your site, we instead recommend our soluble ISCR substrate EHC-L.

EHC Slurry Preparation:

The EHC slurry can been prepared in a variety of ways, including using paddle mixers, recirculation and manual mixing using a hand-held drill with a mixing attachment. However, particularly for larger projects, FMC recommends having a mechanical mixing system available on site. In general we recommend continuous mixing in smaller batches (<100 USG / 400 L) to avoid settling of solids at the bottom. For example Chem Grout's high pressure mixing and injection units are ideal for continuous preparation and injection of EHC. However, particularly for larger projects, FMC recommends having a mechanical mixing system available on site. In general we recommend continuous mixing in smaller batches (<100 USG / 400 L) to avoid settling of solids at the bottom.

The amount of water to prepare the EHC slurry could be varied depending on the desired injection volume and slurry properties. When applied via direct injection, normally a concentration of between 25 and 35% is targeted. The below table shows the amount of water needed per 50-lb / 25-kg bag depending on the targeted concentration and the resulting total injection volumes and percent pore fill (injection volume to total pore volume). Note that a thinner slurry will promote permeation into more permeable formations, whereas a more concentrated/more viscous slurry will promote fracturing and horizontal propagation into more fine-grained formations.

Target concentration (% solids):	**25%**	**30%**	**35%**
Mass EHC per bag (lbs)	50	50	50
Volume water per bag (USG)	18.0	14.0	11.1
Volume slurry per bag (lbs)	22.2	18.2	15.4
Total mass EHC (lbs)	9,200	9,200	9,200
Total volume water (USG)	3308	2573	2048
Total injection volume (USG)	4088	3358	2837
Injection volume to total pore volume	7.3%	6.0%	5.1%



INSTALLATION (continued)

Injection recommendations (can be altered):

The EHC slurry can be injected into the ground in a variety of ways including direct injection and hydraulic/pneumatic fracturing. The injection spacing will be determined based on the radius of influence and soil acceptance for the given application method, lithology and depth. Assuming installation via direct push injections and a radius of influence (ROI) of 5 to 8 ft (1.7 to 2.5 m), an injection spacing of 10 to 15 ft (3 to 5 m) is normally applied. For injection PRB applications, a closer spacing is normally recommended to create some overlap or the PRB may be made up of multiple off-set injection lines to improve contact.

Unless specified by the consultant, the below recommendations was based on our experience from other similar lithologies and considers both the estimated ROI and the estimated soil acceptance (maximum injection volume per vertical foot for lithology and depth) using direct injection. However, please note that actual ROI and soil acceptance can vary widely and are also highly influenced by the injection method employed (slurry viscosity, injection pressures and flow rates). **Therefore, PLEASE NOTE that the construction estimates presented below can be readily modified in the field as required (for example, the density of the slurry can be changed to modify the total injection volume or the injections spacing could be altered based in installation technology).**

	Value	Unit	Comment
Total EHC mass	9,200	lbs	calculated value
Concentration of EHC slurry to inject	25%	by weight	can be altered
Total volume of water required	3,307	U.S. gallons	calculated value
Approximate volume of slurry to inject	4,039	U.S. gallons	calculated value
Injection spacing (grid)	10	ft	customer provided
Number of injection points	13	locations	calculated value
Mass EHC per injection point	708	lbs	calculated value
Mass EHC per vertical foot	35	lbs	calculated value
Injection volume to total pore space volume	7.2%	by volume	calculated value

FMC
ENVIRONMENTAL SOLUTIONS

EHC®

In Situ Chemical Reduction Reagent

Reductive Remediation of Groundwater and Saturated Soil Contamination using Integrated Carbon and Zero Valent Iron Technology

EHC® in situ chemical reduction (ISCR) technology describes a family of remediation products used for the treatment of groundwater and saturated soil impacted by persistent organic compounds, including chlorinated solvents, pesticides and organic explosives. The EHC product is a modification of our Daramend® reductive bioremediation reagent which has been used since 1991 to treat > 10,000,000 tons of soil, sediment, and other solid materials. The synergistic mixture of zero valent iron (ZVI) and a carbon source, used in EHC® products, is FMC-patented technology.

EHC® applications generate very strong reducing conditions, with attainment of redox potentials (Eh) as low as -500 mV. This is significantly lower than the Eh achieved when using either organic materials (lactate, molasses, and sugars) or reduced metal alone. Eh potentials in this range facilitate the timely and effective removal of recalcitrant chlorinated organic compounds (e.g., carbon tetrachloride, 1,2-DCA) and other persistent compounds (e.g., perchlorate) with less formation of potentially problematic intermediates, such as cis-DCE and VC from the anaerobic degradation of PCE and TCE. Similarly, generation of chloroform and dichloromethane from anaerobic degradation of carbon tetrachloride can be reduced or eliminated.

Benefits include:

Patented, synergistic mix of ZVI and a carbon source

- Direct chemical reduction of contaminants through β–elimination pathway for abiotic reductive dehalogenation, minimizing DCE & VC production
- Indirect chemical reduction by dissolved iron and secondary iron corrosion products
- Stimulation of biological reduction of halogenated compounds through the fermentation of a complex carbon/nutrient source under strong reducing conditions
- Enhanced thermodynamic conditions for the decomposition of chlorinated solvents under very strong reducing conditions

Longevity

- Demonstrated effectiveness of over 5 years under field conditions

pH Neutral

- Does not result in aquifer acidification (supports activity of dehalogenators)

Potential Applications for use in the saturated zone:

- Direct push injections
- Hydraulic and pneumatic fracturing
- Permeable reactive barriers
- Direct application in an excavation

Examples of Contaminants of Concern

CHLORINATED VOCs
PCE, TCE, DCE, VC, TCA, DCA, Methylene Chloride, Carbon Tetrachloride

ORGANIC EXPLOSIVES
Perchlorate, TNT, DNT, RDX, HMX, tetryl, and others

CHLORINATED PESTICIDES
Toxaphene, DDT, Lindane, and others

For more information and detailed case studies, please visit our website.

ADVENTUS

Document 17-01-EIT-DL • www.environmental.fmc.com • Toll Free: 1-866-860-4760

SOIL & GROUNDWATER REMEDIATION

EOS Remediation, LLC

MATERIAL SAFETY DATA SHEET

EOS PRO, EOS LS, EOS 450, EOS XR

1. MANUFACTUER AND EMERGENCY CONTACT

Manufacturer:

EOS Remediation, LLC
1101 Nowell Road
Raleigh, NC 27607
www.EOSRemediation.com
Phone: 919-873-2204
Fax: 919-873-1074

24-Hour Emergency Contact:

ChemTel Inc.
Phone: 1-800-255-3924
International
Phone: 813-248-0585

Date of Preparation:
January 9, 2013

2. HAZARDOUS INGREDIENTS / IDENTITY INFORMATION

COMPONENT(S)	% by WEIGHT	CAS NO.	EXPOSURE LIMITS		
			OSHA PEL-TWA	ACGIH TLV-TWA	NIOSH REL-TWA
Soybean Oil	45 - 60*	8001-22-7	Mist: 15 mg/m^3 (total) 5 mg/m^3 (respirable)	NE	Mist: 10 mg/m^3 (total) 5 mg/m^3 (respirable)
Emulsifiers Trade Secret [1,2]	1 - 10	Proprietary	NE	NE	NE
Soluble Substrates Trade Secret [1,2]	4 - 8	Proprietary	Mist: 15 mg/m^3 (total) 5 mg/m^3 (respirable)	Mist: 10 mg/m^3	NE
Organic Substrate Trade Secret [1]	0 - 10	Proprietary	NE	Mist: 10 mg/m^3	NE
Food Additives / Preservatives Trade Secret [1]	0.1 - 1	Proprietary	NE	NE	NE
Nutrients / Extracts Trade Secret [1,2]	0 - 1	Proprietary	NE	NE	NE
Water	Balance	7732-18-5	NE	NE	NE

NE - Not established

1 - The precise composition of this product is proprietary information. A more complete disclosure will be provided to a physician in the event of a medical emergency.

2 - The soluble substrates and emulsifiers are generally recognized as safe for food contact.

* - Percentage of soybean oil varies by product.

3. PHYSICAL / CHEMICAL CHARACTERISTICS

pH:	Neutral
Boiling Point:	212°F
Specific Gravity:	0.96-0.98; 0.92 (pure oil phase)
Vapor Pressure:	Not established
Melting Point:	Liquid at room temperature
Percent Volatile by Volume (%):	25 - 48 (as water)
Vapor Density:	Heavier than air
Evaporation Rate:	Not established
Solubility in Water:	Dispersible
Appearance and Odor:	White liquid with vegetable oil odor

4. FIRE AND EXPLOSION HAZARD DATA

Flash Point:	>300°F
Flammable Limits:	Not established
Extinguishing Media:	CO_2, foam, dry chemical Note: Water, fog and foam may cause frothing and spattering.
Special Fire Fighting Procedures:	Wear self-contained breathing apparatus and chemical resistant clothing. Use water spray to cool fire exposed containers.
Unusual Fire Hazards:	Burning will cause oxides of carbon.
Unusual Explosion Hazards:	None

5. REACTIVITY DATA

Stability:	Stable
Incompatibility:	Strong acids and oxidizers
Hazardous Decomposition Products:	Thermal decomposition may produce oxides of carbon.
Hazardous Polymerization:	Will not occur
Conditions to Avoid:	None known

6. HEALTH HAZARD DATA

Routes of Entry:	Ingestion, dermal
Health Hazards:	
Acute:	Potential eye and skin irritant
Chronic:	None known
Carcinogenicity:	
N.T.P:	No
IARC:	No
OSHA:	No
Signs and Symptoms of Exposure:	None known
Medical Conditions Aggravated by Exposure:	None known

Emergency First Aid Procedures:

Inhalation:	Remove to fresh air.
Eyes:	Flush with water for 15 minutes; if irritation persists see a physician.
Skin:	Wash with mild soap and water.
Ingestion:	Product is non-toxic. If nausea occurs, induce vomiting and seek medical attention.

7. PRECAUTIONS FOR SAFE HANDLING AND USE

Handling and Storage:	Do not store near excessive heat or oxidizers.
Other Precautions:	None
Spill Response:	Soak up with dry absorbent and flush area with large amounts of water.
Waste Disposal Methods:	Dispose of according to Federal and local regulations for non-hazardous waste.

8. CONTROL MEASURES

Respiratory Protection:	Not normally required.
Ventilation:	Local exhaust
Protective Gloves:	Recommended
Eye Protection:	Recommended
Other Protective Clothing or Equipment:	None

The information contained herein is based on available data and is believed to be correct. However, EOS Remediation, LLC makes no warranty, expressed or implied, regarding the accuracy of this data or the results to be obtained thereof. This information and product are furnished on the condition that the person receiving them shall make his/her own determination as to the suitability of the product for his/her particular purpose.

Appendix C

Enhanced Reductive Dechlorination Amendment Calculations

AECOM

Enhanced In-Situ Bioremediation Pilot Study Volume and Dosage Calculation Table
Former Duso Chemical Site - Poughkeepsie, NY

This calculation focuses on determining the appropriate injection volume.
Emulsified vegetable oil quantities based on ESTCP calculations provided in Appendix C.

Area Name	Area ft^2	Thickness ft	Soil Volume ft^3	Pore Volume ft^3	Injection Points -	Pore Volume Target %	Injection Volume gallons	Volume per vertical foot gallons	Volume Per Point gallons	EISB Emulsified Vegetable Oil gallons	Volumetric Dilution (v/v) -
Emulsified Vegetable Oil											
East Area (MHC-22 to BIW-2)	2,035	12	24,420	7,326	17	18.5%	10138	50	596	1060	10.5%
Northeast (BIW-6S)	1,855	8	14,840	4,452	14	14.0%	4662	42	333	460	9.9%
Center Area (MHC-26)	1,170	14	16,380	4,914	8	16.0%	5881	53	735	605	10.3%
Northwest Area (BIW-1)	2,485	20	49,700	14,910	18	14.0%	15615	43	867	1570	10.1%
West Center Area (BIW-5S)	1,525	6	9,150	2,745	9	14.0%	2875	64	381	275	9.6%
Southwest Area (MHC-23)	1,120	20	22,400	6,720	9	14.0%	7038	39	782	685	9.7%
EVO Total	**10,190**		**136,890**	**41,067**	**75**		**46,210**			**4655**	
EVO Average		12				15.0%		**48**	616		**10.0%**

Area Name	Area ft^2	Thickness ft	Soil Volume ft^3	Pore Volume ft^3	Injection Points -	Volume Target %	Injection Volume gallons	Volume per vertical foot gallons	Volume Per Point gallons	EHC Mass pounds	EHC Dosage % Soil Mass
EHC (Carbon + ZVI)											
West Center Area (BIW-5D)	1,525	14	21,350	6,405	9	8.0%	3,833	**30**	426	**7850**	0.35%
SITE TOTAL	**10,190**		**158,240**	**47,472**	**75**		**50,043**				
Average		**14.1**									

Notes:

Assumed Porosity	30%	
Assumed Soil Bulk Density	105	lb/ft^3

SUBSTRATE ESTIMATING TOOL FOR ENHANCED ANAEROBIC BIOREMEDIATION OF CHLORINATED SOLVENTS

Version 1.2
November 2010

Site Data Input Table

TABLE S.1 - INPUT TABLE

Calculation Tables

Table S.2 - Substrate Calculations in Hydrogen

Table S.3 - Hydrogen Produced by Common Substrates

Table S.4 - Estimated Substrate Requirements for

Output Summary Table

TABLE S.5 - OUTPUT TABLE

PRINT SUMMARY TABLE

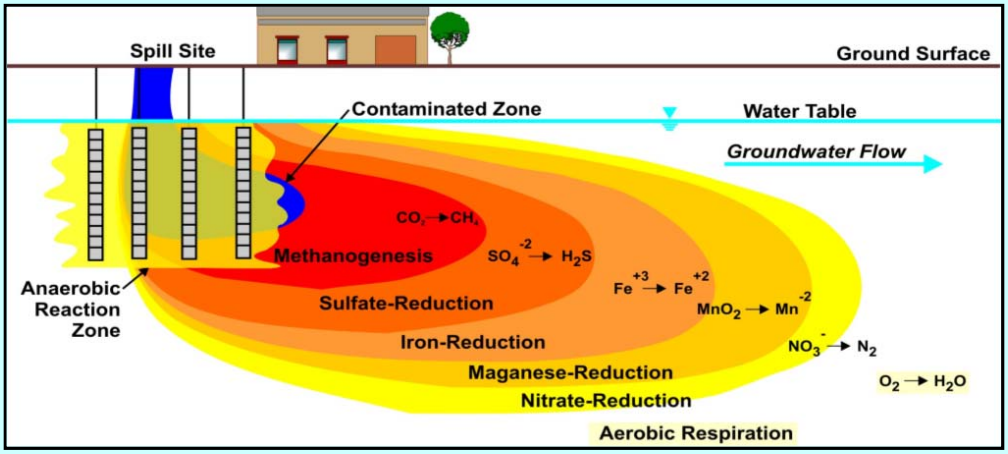


Table S.1 Input for Substrate Requirements in Hydrogen Equivalents

Site Name: Former Duso Chemical (Center - MHC-26)

RETURN TO COVER PAGE

NOTE: Unshaded boxes are user input.

1. Treatment Zone Physical Dimensions	Values	Range	Units	User Notes
Width (Perpendicular to predominant groundwater flow direction)	45	1-10,000	feet	Former Duso Chemical (Center - MHC-26)
Length (Parallel to predominant groundwater flow)	26	1-1,000	feet	
Saturated Thickness	14	1-100	feet	treatment thickness (4-18)
Treatment Zone Cross Sectional Area	630	--	ft^2	
Treatment Zone Volume	16,380	--	ft^3	
Treatment Zone Total Pore Volume (total volume x total porosity)	39,218	--	gallons	
Treatment Zone Effective Pore Volume (total volume x effective porosity)	34,315	--	gallons	
Design Period of Performance	4.0	.5 to 5	year	
Design Factor (times the electron acceptor hydrogen demand)	5.0	2 to 20	unitless	AECOM recommendation to use a design factor of 2 to 5
2. Treatment Zone Hydrogeologic Properties				
Total Porosity	32%	.05-50	percent	Assumed for silty sand
Effective Porosity	28%	.05-50	percent	Assumed for silty sand (conservative high for higher PV)
Average Aquifer Hydraulic Conductivity	4	.01-1000	ft/day	average from MHBP RI
Average Hydraulic Gradient	0.033	0.0001-0.1	ft/ft	average from 2 values in RI
Average Groundwater Seepage Velocity through the Treatment Zone	0.47	--	ft/day	
Average Groundwater Seepage Velocity through the Treatment Zone	172.1	--	ft/yr	
Average Groundwater Discharge through the Treatment Zone	227,104	--	gallons/year	
Soil Bulk Density	1.65	1.4-2.0	gm/cm^3	Assumed
Soil Fraction Organic Carbon (foc)	3.00%	0.01-10	percent	Assumed
3. Native Electron Acceptors				
A. Aqueous-Phase Native Electron Acceptors				
Oxygen	0.6	0.01 to 10	mg/L	
Nitrate	0.10	0.1 to- 20	mg/L	not detected in RI
Sulfate	35	10 to 5,000	mg/L	RI readings 2, 11, 43, 79 in MHC-23 and MHC-26
Carbon Dioxide (estimated as the amount of Methane produced)	10.0	0.1 to 20	mg/L	
B. Solid-Phase Native Electron Acceptors				
Manganese (IV) (estimated as the amount of Mn (II) produced)	10	0.1 to 20	mg/L	RI Mn 4-8 mg/L in slightly reducing GW, assume some productior
Iron (III) (estimated as the amount of Fe (II) produced)	12	0.1 to 20	mg/L	RI ~10 mg/L in slightly reducing GW, assume some production
4. Contaminant Electron Acceptors				
Tetrachloroethene (PCE)	0.000	--	mg/L	max conc from MHC-26 (2012)
Trichloroethene (TCE)	0.028	--	mg/L	
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	0.280	--	mg/L	
Vinyl Chloride (VC)	0.190	--	mg/L	
Carbon Tetrachloride (CT)	0.000	--	mg/L	
Trichloromethane (or chloroform) (CF)	0.000	--	mg/L	
Dichloromethane (or methylene chloride) (MC)	0.012	--	mg/L	
Chloromethane	0.000	--	mg/L	
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	--	mg/L	
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	1.500	--	mg/L	
Dichloroethane (1,1-DCA and 1,2-DCA)	1.100	--	mg/L	
Chloroethane	0.860	--	mg/L	
Perchlorate	0.000	--	mg/L	
5. Aquifer Geochemistry (Optional Screening Parameters)				
A. Aqueous Geochemistry				
Oxidation-Reduction Potential (ORP)	-25	-400 to +500	mV	2012 Field Sheets (avg BIW-2S, MHC-23, BIW-5S)
Temperature	13	5.0 to 30	ºC	2012 Field Sheets
pH	7.1	4.0 to 10.0	su	2012 Field Sheets (7.06-7.4)
Alkalinity	300	10 to 1,000	mg/L	
Total Dissolved Solids (TDS, or salinity)		10 to 1,000	mg/L	
Specific Conductivity	2000	100 to 10,000	µs/cm	2012 Field Sheets Approximate Average
Chloride		10 to 10,000	mg/L	
Sulfide - Pre injection	0.0	0.1 to 100	mg/L	
Sulfide - Post injection	0.0	0.1 to 100	mg/L	
B. Aquifer Matrix				
Total Iron	10000	200 to 20,000	mg/kg	Assumed
Cation Exchange Capacity	NA	1.0 to 10	meq/100 g	
Neutralization Potential	10.0%	1.0 to 100	Percent as $CaCO_3$	Assumed

NOTES:

Table S.2 Substrate Calculations in Hydrogen Equivalents

Site Name: Former Duso Chemical (Center - MHC-26)

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NOTE: Open cells are user input.

1. Treatment Zone Physical Dimensions

	Values	Range	Units
Width (Perpendicular to predominant groundwater flow direction)	45	1-10,000	feet
Length (Parallel to predominant groundwater flow)	26	1-1,000	feet
Saturated Thickness	14	1-100	feet
Treatment Zone Cross Sectional Area	630	--	ft^2
Treatment Zone Volume	16,380	--	ft^3
Treatment Zone Effective Pore Volume (total volume x effective porosity)	34,315	--	gallons
Design Period of Performance	4.0	.5 to 5	year

2. Treatment Zone Hydrogeologic Properties

Total Porosity	0.32	.05-50	
Effective Porosity	0.28	.05-50	
Average Aquifer Hydraulic Conductivity	4	.01-1000	ft/day
Average Hydraulic Gradient	0.033	0.1-0.0001	ft/ft
Average Groundwater Seepage Velocity through the Treatment Zone	0.47	--	ft/day
Average Groundwater Seepage Velocity through the Treatment Zone	172.1	--	ft/yr
Average Groundwater Flux through the Treatment Zon 0	227,104	--	gallons/year
Soil Bulk Density	1.65	1.4-2.0	gm/cm^3
Soil Fraction Organic Carbon (foc)	0.03	0.0001-0.1	

3. Initial Treatment Cell Electron-Acceptor Demand (one total pore volume)

A. Aqueous-Phase Native Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Oxygen	0.6	0.17	7.94	0.02	4
Nitrate (denitrification)	0.1	0.03	12.30	0.00	5
Sulfate	35	10.02	11.91	0.84	8
Carbon Dioxide (estimated as the amount of methane produced)	10.0	2.86	1.99	1.44	8
Soluble Competing Electron Acceptor Demand (lb.)				**2.30**	

B. Solid-Phase Native Electron Acceptors (Based on manganese and iron produced)	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Manganese (IV) (estimated as the amount of Mn (II) produced)	10.0	78.67	27.25	2.89	2
Iron (III) (estimated as the amount of Fe (II) produced)	12.0	94.40	55.41	1.70	1
Solid-Phase Competing Electron Acceptor Demand (lb.)				**4.59**	

C. Soluble Contaminant Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	0.000	0.00	20.57	0.00	8
Trichloroethene (TCE)	0.028	0.01	21.73	0.00	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	0.280	0.08	24.05	0.00	4
Vinyl Chloride (VC)	0.190	0.05	31.00	0.00	2
Carbon Tetrachloride (CT)	0.000	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	0.000	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	0.012	0.00	21.06	0.00	4
Chloromethane	0.000	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	1.500	0.43	22.06	0.02	6
Dichloroethane (1,1-DCA and 1,2-DCA)	1.100	0.31	24.55	0.01	4
Chloroethane	0.860	0.25	32.00	0.01	2
Perchlorate	0.000	0.00	12.33	0.00	6
Total Soluble Contaminant Electron Acceptor Demand (lb.)				**0.05**	

D. Sorbed Contaminant Electron Acceptors (Soil Concentration = Koc x foc x Cgw)	Koc (mL/g)	Soil Conc. (mg/kg)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	263	0.00	0.00	20.57	0.00	8
Trichloroethene (TCE)	107	0.09	0.15	21.73	0.01	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	45	0.38	0.64	24.05	0.03	4
Vinyl Chloride (VC)	3.0	0.02	0.03	31.00	0.00	2
Carbon Tetrachloride (CT)	224	0.00	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	63	0.00	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	28	0.01	0.02	21.06	0.00	4
Chloromethane	25	0.00	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	117	0.00	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	105	4.73	7.97	22.06	0.36	6
Dichloroethane (1,1-DCA and 1,2-DCA)	30	0.99	1.67	24.55	0.07	4
Chloroethane	3	0.08	0.14	32.00	0.00	2
Perchlorate	0.0	0.00	0.00	12.33	0.00	6
Total Sorbed Contaminant Electron Acceptor Demand (lb.)					**0.47**	

(continued)

Table S.2 Substrate Calculations in Hydrogen Equivalents

4. Treatment Cell Electron-Acceptor Flux (per year)

A. Soluble Native Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Oxygen	0.6	1.14	7.94	0.14	4
Nitrate (denitrification)	0.1	0.19	10.25	0.02	5
Sulfate	35	66.33	11.91	5.57	8
Carbon Dioxide (estimated as the amount of Methane produced)	10	18.95	1.99	9.52	8
Total Competing Electron Acceptor Demand Flux (lb/yr)				**15.3**	

B. Soluble Contaminant Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	0.000	0.00	20.57	0.00	8
Trichloroethene (TCE)	0.028	0.05	21.73	0.00	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	0.280	0.53	24.05	0.02	4
Vinyl Chloride (VC)	0.190	0.36	31.00	0.01	2
Carbon Tetrachloride (CT)	0.000	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	0.000	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	0.012	0.02	21.06	0.00	4
Chloromethane	0.000	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	1.500	2.84	22.06	0.13	6
Dichloroethane (1,1-DCA and 1,2-DCA)	1.100	2.08	24.55	0.08	4
Chloroethane	0.860	1.63	32.00	0.05	2
Perchlorate	0.000	0.00	12.33	0.00	6
Total Soluble Contaminant Electron Acceptor Demand Flux (lb/yr)				**0.30**	

Initial Hydrogen Requirement First Year (lb)	**23.0**
Total Life-Cycle Hydrogen Requirement (lb)	**69.6**

5. Design Factors

Microbial Efficiency Uncertainty Factor	2X - 4X
Methane and Solid-Phase Electron Acceptor Uncertainty	2X - 4X
Remedial Design Factor (e.g., Substrate Leaving Reaction Zone)	1X - 3X
Design Factor	**5.0**
Total Life-Cycle Hydrogen Requirement with Design Factor (lb)	**348.2**

6. Acronyns and Abbreviations

^{o}C =degrees celsius
µs/cm = microsiemens per centimeter
cm/day = centimeters per day
cm/sec = centimeters per second
ft^2 = square feet
ft/day = feet per day
ft/ft = foot per foot
ft/yr = feet per year
gm/cm^3 = grams per cubic centimeter
kg of CaCO3 per mg = kilograms of calcium carbonate per milligram
lb = pounds
meq/100 g = milliequivalents per 100 grams
mg/kg = milligrams per kilogram
mg/L = milligrams per liter
m/m = meters per meters
mV = millivolts
m/yr = meters per year
su = standard pH units
wt/wt H2 = concetration molecular hydrogen, weight per weight

Table S.3

Hydrogen Produced by Fermentation Reactions of Common Substrates

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Substrate	Molecular Formula	Substrate Molecular Weight (gm/mole)	Moles of Hydrogen Produced per Mole of Substrate	Ratio of Hydrogen Produced to Substrate (gm/gm)	Range of Moles H_2/Mole Substrate
Lactic Acid	$C_3H_6O_3$	90.1	2	0.0448	**2 to 3**
Molasses (assuming 100% sucrose)	$C_{12}H_{22}O_{11}$	342	8	0.0471	**8 to 11**
High Fructose Corn Syrup (assuming 50% fructose and 50% glucose)	$C_6H_{12}O_6$	180	4	0.0448	**4 to 6**
Ethanol	C_2H_6O	46.1	2	0.0875	**2 to 6**
Whey (assuming 100% lactose)	$C_{12}H_{22}O_{11}$	342	11	0.0648	**11**
HRC® (assumes 40% lactic acid and 40% glycerol by weight)	$C_{39}H_{56}O_{39}$	956	28	0.0590	**28**
Linoleic Acid (Soybean Oil, Corn Oil, Cotton Oil)	$C_{18}H_{32}O_2$	281	16	0.1150	**16**

Table S.4

Estimated Substrate Requirements for Hydrogen Demand in Table S.3

Design Life (years): 4

Substrate	Design Factor	Pure Substrate Mass Required to Fulfill Hydrogen Demand (pounds)	Substrate Product Required to Fulfill Hydrogen Demand (pounds)	Substrate Mass Required to Fulfill Hydrogen Demand (milligrams)	Effective Substrate Concentration (mg/L)
Lactic Acid	5.0	7,778	7,778	3.53E+09	989
Sodium Lactate Product (60 percent solution)	5.0	7,778	16,138	3.53E+09	989
Molasses (assuming 6 0	5.0	7,389	12,316	3.35E+09	939
HFCS (assuming 40% fructose and 40% glucose by weight)	5.0	7,780	9,725	3.53E+09	989
Ethanol Product (assuming 80% ethanol by weight)	5.0	3,978	4,973	1.80E+09	506
Whey (assuming 100% lactose)	5.0	5,369	7,671	2.44E+09	683
HRC® (assumes 40% lactic acid and 40% glycerol by weight)	5.0	5,896	5,896	2.67E+09	600
Linoleic Acid (Soybean Oil, Corn Oil, Cotton Oil)	5.0	3,028	3,028	1.37E+09	385
Commercial Vegetable Oil Emulsion Product (60% oil by weight)	5.0	3,028	5,046	1.37E+09	385

NOTES: Sodium Lactate Product

1. Assumes sodium lactate product is 60 percent sodium lactate by weight.
2. Molecular weight of sodium lactate (CH_3-CHOH-COONa) = 112.06.
3. Molecular weight of lactic Acid ($C_6H_6O_3$) = 90.08 .
4. Therefore, sodium lactate product yields 48.4 (0.60 x (90.08/112.06)) percent by weight lactic acid.
5. Weight of sodium lactate product = 11.0 pounds per gallon.
6. Pounds per gallon of lactic acid in product = 1.323 x 8.33 lb/gal H2O x 0.60 x (90.08/112.06) = 5.31 lb/gal.

NOTES: Standard HRC Product

1. Assumes HRC product is 40 percent lactic acid and 40 percent glycerol by weight.
2. HRC® weighs approximately 9.18 pounds per gallon.

NOTES: Vegetable Oil Emulsion Product

1. Assumes emulsion product is 60 percent soybean oil by weight.
2. Soybean oil is 7.8 pounds per gallon.
3. Assumes specific gravity of emulsion product is 0.96.

Table S.5 Output for Substrate Requirements in Hydrogen Equivalents

Site Name: Former Duso Chemical (Center - MHC-26)

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1. Treatment Zone Physical Dimensions

	Values	Units	Values	Units
Width (perpendicular to groundwater flow)	45	feet	14	meters
Length (parallel to groundwater flow)	26	feet	7.9	meters
Saturated Thickness	14	feet	4.3	meters
Design Period of Performance	4	years	4	years

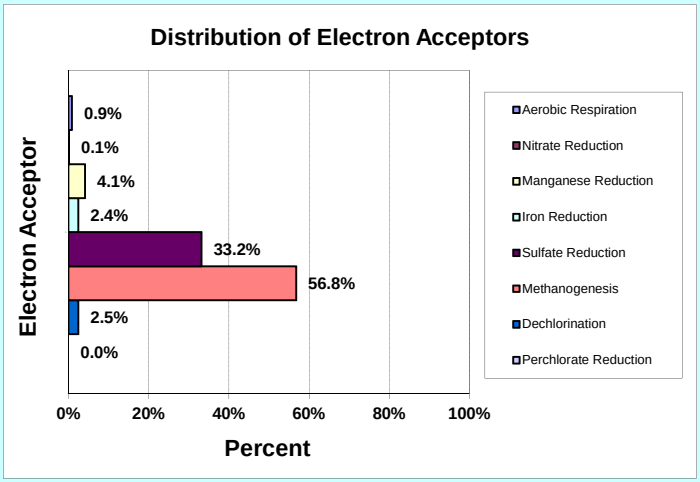
2. Treatment Zone Hydrogeologic Properties

	Values	Units	Values	Units
Total Porosity	0.32	percent	0.32	percent
Effective Porosity	0.28	percent	0.28	percent
Average Aquifer Hydraulic Conductivity	4	ft/day	1.4E-03	cm/sec
Average Hydraulic Gradient	0.033	ft/ft	0.033	m/m
Average Groundwater Seepage Velocity	0.47	ft/day	1.4E+01	cm/day
Average Groundwater Seepage Velocity	172	ft/yr	52.4	m/yr
Effective Treatment Zone Pore Volume	34,315	gallons	129,894	liters
Groundwater Flux (per year)	227,104	gallons/year	859,659	liters/year
Total Groundwater Volume Treated (over entire design period)	942,732	gallons total	3,568,529	liters total

3. Distribution of Electron Acceptor Demand

	Percent of Total	Hydrogen Demand (lb)
Aerobic Respiration	0.9%	0.594
Nitrate Reduction	0.1%	0.076
Sulfate Reduction	33.2%	23.118
Manganese Reduction	4.1%	2.887
Iron Reduction	2.4%	1.704
Methanogenesis	56.8%	39.531
Dechlorination	2.5%	1.722
Perchlorate Reduction	0.0%	0.000
Totals:	**100.00%**	**69.63**

Hydrogen demand in pounds/gallon:	7.39E-05
Hydrogen demand in grams per liter:	8.85E-03



4. Substrate Equivalents: Design Factor = 5.0

Product	Quantity (lb)	Quantity (gallons)	Effective Concentration (mg/L)	Effective concentration is for total volume of groundwater treated.
1. Sodium Lactate Product	16,138	1,467	989	as lactic acid
2. Molasses Product	12,316	1,026	939	as sucrose
3. Fructose Product	9,725	868	989	as fructose
4. Ethanol Product	4,973	721	506	as ethanol
5. Sweet Dry Whey (lactose)	7,671	sold by pound	683	as lactose
6. HRC®	5,896	sold by pound	600	as 40% lactic acid/40% glycerol
7. Linoleic Acid (Soybean Oil)	3,028	388	385	as soybean oil
8. Emulsified Vegetable Oil	5,046	647	385	as soybean oil

Notes:

1. Quantity assumes product is 60% sodium lactate by weight.
2. Quantity assumes product is 60% sucrose by weight and weighs 12 pounds per gallon.
3. Quantity assumes product is 80% fructose by weight and weighs 11.2 pounds per gallon.
4. Quantity assumes product is 80% ethanol by weight and weighs 6.9 pounds per gallon.
5. Quantity assumes product is 70% lactose by weight.
6. Quantity assumes HRC® is 40% lactic acid and 40% glycerol by weight.
7. Quantity of neat soybean oil, corn oil, or canola oil.
8. Quantity assumes commercial product is 60% soybean oil by weight.

SUBSTRATE ESTIMATING TOOL FOR ENHANCED ANAEROBIC BIOREMEDIATION OF CHLORINATED SOLVENTS

Version 1.2
November 2010

Site Data Input Table

TABLE S.1 - INPUT TABLE

Calculation Tables

Table S.2 - Substrate Calculations in Hydrogen

Table S.3 - Hydrogen Produced by Common Substrates

Table S.4 - Estimated Substrate Requirements for

Output Summary Table

TABLE S.5 - OUTPUT TABLE

PRINT SUMMARY TABLE

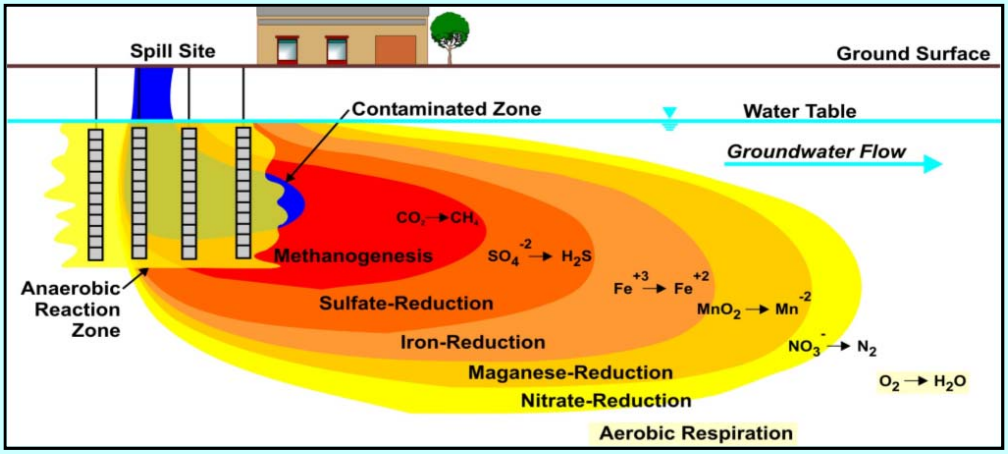


Table S.1 Input for Substrate Requirements in Hydrogen Equivalents

Site Name: Former Duso Chemical (east - BIW-2 to MHC-22)

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NOTE: Unshaded boxes are user input.

1. Treatment Zone Physical Dimensions	Values	Range	Units	User Notes
Width (Perpendicular to predominant groundwater flow direction)	101.5	1-10,000	feet	Former Duso Chemical (east - BIW-2 to MHC-22)
Length (Parallel to predominant groundwater flow)	20	1-1,000	feet	
Saturated Thickness	12	1-100	feet	treatment thickness (4-16)
Treatment Zone Cross Sectional Area	1218	--	ft^2	
Treatment Zone Volume	24,360	--	ft^3	
Treatment Zone Total Pore Volume (total volume x total porosity)	58,324	--	gallons	
Treatment Zone Effective Pore Volume (total volume x effective porosity)	51,033	--	gallons	
Design Period of Performance	4.0	.5 to 5	year	
Design Factor (times the electron acceptor hydrogen demand)	4.0	2 to 20	unitless	AECOM recommendation to use a design factor of 2 to 5
2. Treatment Zone Hydrogeologic Properties				
Total Porosity	32%	.05-50	percent	Assumed for silty sand
Effective Porosity	28%	.05-50	percent	Assumed for silty sand (conservative high for higher PV)
Average Aquifer Hydraulic Conductivity	4	.01-1000	ft/day	average from MHBP RI
Average Hydraulic Gradient	0.033	0.0001-0.1	ft/ft	average from 2 values in RI
Average Groundwater Seepage Velocity through the Treatment Zone	0.47	--	ft/day	
Average Groundwater Seepage Velocity through the Treatment Zone	172.1	--	ft/yr	
Average Groundwater Discharge through the Treatment Zone	439,068	--	gallons/year	
Soil Bulk Density	1.65	1.4-2.0	gm/cm^3	Assumed
Soil Fraction Organic Carbon (foc)	3.00%	0.01-10	percent	Assumed
3. Native Electron Acceptors				
A. Aqueous-Phase Native Electron Acceptors				
Oxygen	0.6	0.01 to 10	mg/L	
Nitrate	0.10	0.1 to- 20	mg/L	not detected in RI
Sulfate	35	10 to 5,000	mg/L	RI readings 2, 11, 43, 79 in MHC-23 and MHC-26
Carbon Dioxide (estimated as the amount of Methane produced)	10.0	0.1 to 20	mg/L	
B. Solid-Phase Native Electron Acceptors				
Manganese (IV) (estimated as the amount of Mn (II) produced)	10	0.1 to 20	mg/L	RI Mn 4-8 mg/L in slightly reducing GW, assume some productior
Iron (III) (estimated as the amount of Fe (II) produced)	12	0.1 to 20	mg/L	RI ~10 mg/L in slightly reducing GW, assume some production
4. Contaminant Electron Acceptors				
Tetrachloroethene (PCE)	0.100	--	mg/L	max conc from BIW-2S (2012) or MHC-22 (2011)
Trichloroethene (TCE)	0.050	--	mg/L	
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	0.990	--	mg/L	
Vinyl Chloride (VC)	0.190	--	mg/L	
Carbon Tetrachloride (CT)	0.000	--	mg/L	
Trichloromethane (or chloroform) (CF)	0.001	--	mg/L	
Dichloromethane (or methylene chloride) (MC)	0.001	--	mg/L	
Chloromethane	0.000	--	mg/L	
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	--	mg/L	
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	5.200	--	mg/L	
Dichloroethane (1,1-DCA and 1,2-DCA)	8.500	--	mg/L	
Chloroethane	1.100	--	mg/L	
Perchlorate	0.000	--	mg/L	
5. Aquifer Geochemistry (Optional Screening Parameters)				
A. Aqueous Geochemistry				
Oxidation-Reduction Potential (ORP)	-25	-400 to +500	mV	2012 Field Sheets (avg BIW-2S, MHC-23, BIW-5S)
Temperature	13	5.0 to 30	ºC	2012 Field Sheets
pH	7.1	4.0 to 10.0	su	2012 Field Sheets (7.06-7.4)
Alkalinity	300	10 to 1,000	mg/L	
Total Dissolved Solids (TDS, or salinity)		10 to 1,000	mg/L	
Specific Conductivity	2000	100 to 10,000	µs/cm	2012 Field Sheets Approximate Average
Chloride		10 to 10,000	mg/L	
Sulfide - Pre injection	0.0	0.1 to 100	mg/L	
Sulfide - Post injection	0.0	0.1 to 100	mg/L	
B. Aquifer Matrix				
Total Iron	10000	200 to 20,000	mg/kg	Assumed
Cation Exchange Capacity	NA	1.0 to 10	meq/100 g	
Neutralization Potential	10.0%	1.0 to 100	Percent as $CaCO_3$	Assumed

NOTES:

Table S.2 Substrate Calculations in Hydrogen Equivalents

Site Name: Former Duso Chemical (east - BIW-2 to MHC-22)

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NOTE: Open cells are user input.

1. Treatment Zone Physical Dimensions

	Values	Range	Units
Width (Perpendicular to predominant groundwater flow direction)	101.5	1-10,000	feet
Length (Parallel to predominant groundwater flow)	20	1-1,000	feet
Saturated Thickness	12	1-100	feet
Treatment Zone Cross Sectional Area	1218	--	ft^2
Treatment Zone Volume	24,360	--	ft^3
Treatment Zone Effective Pore Volume (total volume x effective porosity)	51,033	--	gallons
Design Period of Performance	4.0	.5 to 5	year

2. Treatment Zone Hydrogeologic Properties

Total Porosity	0.32	.05-50	
Effective Porosity	0.28	.05-50	
Average Aquifer Hydraulic Conductivity	4	.01-1000	ft/day
Average Hydraulic Gradient	0.033	0.1-0.0001	ft/ft
Average Groundwater Seepage Velocity through the Treatment Zone	0.47	--	ft/day
Average Groundwater Seepage Velocity through the Treatment Zone	172.1	--	ft/yr
Average Groundwater Flux through the Treatment Zon 0	439,068	--	gallons/year
Soil Bulk Density	1.65	1.4-2.0	gm/cm^3
Soil Fraction Organic Carbon (foc)	0.03	0.0001-0.1	

3. Initial Treatment Cell Electron-Acceptor Demand (one total pore volume)

A. Aqueous-Phase Native Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Oxygen	0.6	0.26	7.94	0.03	4
Nitrate (denitrification)	0.1	0.04	12.30	0.00	5
Sulfate	35	14.90	11.91	1.25	8
Carbon Dioxide (estimated as the amount of methane produced)	10.0	4.26	1.99	2.14	8
Soluble Competing Electron Acceptor Demand (lb.)				**3.43**	

B. Solid-Phase Native Electron Acceptors (Based on manganese and iron produced)	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Manganese (IV) (estimated as the amount of Mn (II) produced)	10.0	150.81	27.25	5.53	2
Iron (III) (estimated as the amount of Fe (II) produced)	12.0	180.97	55.41	3.27	1
Solid-Phase Competing Electron Acceptor Demand (lb.)				**8.80**	

C. Soluble Contaminant Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	0.100	0.04	20.57	0.00	8
Trichloroethene (TCE)	0.050	0.02	21.73	0.00	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	0.990	0.42	24.05	0.02	4
Vinyl Chloride (VC)	0.190	0.08	31.00	0.00	2
Carbon Tetrachloride (CT)	0.000	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	0.001	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	0.001	0.00	21.06	0.00	4
Chloromethane	0.000	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	5.200	2.21	22.06	0.10	6
Dichloroethane (1,1-DCA and 1,2-DCA)	8.500	3.62	24.55	0.15	4
Chloroethane	1.100	0.47	32.00	0.01	2
Perchlorate	0.000	0.00	12.33	0.00	6
Total Soluble Contaminant Electron Acceptor Demand (lb.)				**0.29**	

D. Sorbed Contaminant Electron Acceptors (Soil Concentration = Koc x foc x Cgw)	Koc (mL/g)	Soil Conc. (mg/kg)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	263	0.79	1.98	20.57	0.10	8
Trichloroethene (TCE)	107	0.16	0.40	21.73	0.02	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	45	1.34	3.35	24.05	0.14	4
Vinyl Chloride (VC)	3.0	0.02	0.04	31.00	0.00	2
Carbon Tetrachloride (CT)	224	0.00	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	63	0.00	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	28	0.00	0.00	21.06	0.00	4
Chloromethane	25	0.00	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	117	0.00	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	105	16.38	41.11	22.06	1.86	6
Dichloroethane (1,1-DCA and 1,2-DCA)	30	7.65	19.20	24.55	0.78	4
Chloroethane	3	0.11	0.27	32.00	0.01	2
Perchlorate	0.0	0.00	0.00	12.33	0.00	6
Total Sorbed Contaminant Electron Acceptor Demand (lb.)					**2.91**	

(continued)

Table S.2 Substrate Calculations in Hydrogen Equivalents

4. Treatment Cell Electron-Acceptor Flux (per year)

A. Soluble Native Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Oxygen	0.6	2.20	7.94	0.28	4
Nitrate (denitrification)	0.1	0.37	10.25	0.04	5
Sulfate	35	128.23	11.91	10.77	8
Carbon Dioxide (estimated as the amount of Methane produced)	10	36.64	1.99	18.41	8
Total Competing Electron Acceptor Demand Flux (lb/yr)				**29.5**	

B. Soluble Contaminant Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	0.100	0.37	20.57	0.02	8
Trichloroethene (TCE)	0.050	0.18	21.73	0.01	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	0.990	3.63	24.05	0.15	4
Vinyl Chloride (VC)	0.190	0.70	31.00	0.02	2
Carbon Tetrachloride (CT)	0.000	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	0.001	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	0.001	0.00	21.06	0.00	4
Chloromethane	0.000	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	5.200	19.05	22.06	0.86	6
Dichloroethane (1,1-DCA and 1,2-DCA)	8.500	31.14	24.55	1.27	4
Chloroethane	1.100	4.03	32.00	0.13	2
Perchlorate	0.000	0.00	12.33	0.00	6
Total Soluble Contaminant Electron Acceptor Demand Flux (lb/yr)				**2.46**	

Initial Hydrogen Requirement First Year (lb)	**47.4**
Total Life-Cycle Hydrogen Requirement (lb)	**143.2**

5. Design Factors

Microbial Efficiency Uncertainty Factor	2X - 4X
Methane and Solid-Phase Electron Acceptor Uncertainty	2X - 4X
Remedial Design Factor (e.g., Substrate Leaving Reaction Zone)	1X - 3X
Design Factor	**4.0**
Total Life-Cycle Hydrogen Requirement with Design Factor (lb)	**572.9**

6. Acronyns and Abbreviations

°C =degrees celsius
µs/cm = microsiemens per centimeter
cm/day = centimeters per day
cm/sec = centimeters per second
ft^2 = square feet
ft/day = feet per day
ft/ft = foot per foot
ft/yr = feet per year
gm/cm^3 = grams per cubic centimeter
kg of CaCO3 per mg = kilograms of calcium carbonate per milligram
lb = pounds
meq/100 g = milliequivalents per 100 grams
mg/kg = milligrams per kilogram
mg/L = milligrams per liter
m/m = meters per meters
mV = millivolts
m/yr = meters per year
su = standard pH units
wt/wt H2 = concetration molecular hydrogen, weight per weight

Table S.3

Hydrogen Produced by Fermentation Reactions of Common Substrates

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Substrate	Molecular Formula	Substrate Molecular Weight (gm/mole)	Moles of Hydrogen Produced per Mole of Substrate	Ratio of Hydrogen Produced to Substrate (gm/gm)	Range of Moles H_2/Mole Substrate
Lactic Acid	$C_3H_6O_3$	90.1	2	0.0448	**2 to 3**
Molasses (assuming 100% sucrose)	$C_{12}H_{22}O_{11}$	342	8	0.0471	**8 to 11**
High Fructose Corn Syrup (assuming 50% fructose and 50% glucose)	$C_6H_{12}O_6$	180	4	0.0448	**4 to 6**
Ethanol	C_2H_6O	46.1	2	0.0875	**2 to 6**
Whey (assuming 100% lactose)	$C_{12}H_{22}O_{11}$	342	11	0.0648	**11**
HRC® (assumes 40% lactic acid and 40% glycerol by weight)	$C_{39}H_{56}O_{39}$	956	28	0.0590	**28**
Linoleic Acid (Soybean Oil, Corn Oil, Cotton Oil)	$C_{18}H_{32}O_2$	281	16	0.1150	**16**

Table S.4

Estimated Substrate Requirements for Hydrogen Demand in Table S.3

Design Life (years): 4

Substrate	Design Factor	Pure Substrate Mass Required to Fulfill Hydrogen Demand (pounds)	Substrate Product Required to Fulfill Hydrogen Demand (pounds)	Substrate Mass Required to Fulfill Hydrogen Demand (milligrams)	Effective Substrate Concentration (mg/L)
Lactic Acid	4.0	12,799	12,799	5.81E+09	849
Sodium Lactate Product (60 percent solution)	4.0	12,799	26,553	5.81E+09	849
Molasses (assuming 6 0	4.0	12,159	20,264	5.52E+09	806
HFCS (assuming 40% fructose and 40% glucose by weight)	4.0	12,802	16,002	5.81E+09	849
Ethanol Product (assuming 80% ethanol by weight)	4.0	6,546	8,182	2.97E+09	434
Whey (assuming 100% lactose)	4.0	8,835	12,621	4.01E+09	586
HRC® (assumes 40% lactic acid and 40% glycerol by weight)	4.0	9,702	9,702	4.40E+09	515
Linoleic Acid (Soybean Oil, Corn Oil, Cotton Oil)	4.0	4,982	4,982	2.26E+09	330
Commercial Vegetable Oil Emulsion Product (60% oil by weight)	4.0	4,982	8,303	2.26E+09	330

NOTES: Sodium Lactate Product

1. Assumes sodium lactate product is 60 percent sodium lactate by weight.
2. Molecular weight of sodium lactate (CH_3-CHOH-COONa) = 112.06.
3. Molecular weight of lactic Acid ($C_6H_6O_3$) = 90.08 .
4. Therefore, sodium lactate product yields 48.4 (0.60 x (90.08/112.06)) percent by weight lactic acid.
5. Weight of sodium lactate product = 11.0 pounds per gallon.
6. Pounds per gallon of lactic acid in product = 1.323 x 8.33 lb/gal H2O x 0.60 x (90.08/112.06) = 5.31 lb/gal.

NOTES: Standard HRC Product

1. Assumes HRC product is 40 percent lactic acid and 40 percent glycerol by weight.
2. HRC® weighs approximately 9.18 pounds per gallon.

NOTES: Vegetable Oil Emulsion Product

1. Assumes emulsion product is 60 percent soybean oil by weight.
2. Soybean oil is 7.8 pounds per gallon.
3. Assumes specific gravity of emulsion product is 0.96.

Table S.5 Output for Substrate Requirements in Hydrogen Equivalents

Site Name: Former Duso Chemical (east - BIW-2 to MHC-22)

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1. Treatment Zone Physical Dimensions

	Values	Units	Values	Units
Width (perpendicular to groundwater flow)	101.5	feet	31	meters
Length (parallel to groundwater flow)	20	feet	6.1	meters
Saturated Thickness	12	feet	3.7	meters
Design Period of Performance	4	years	4	years

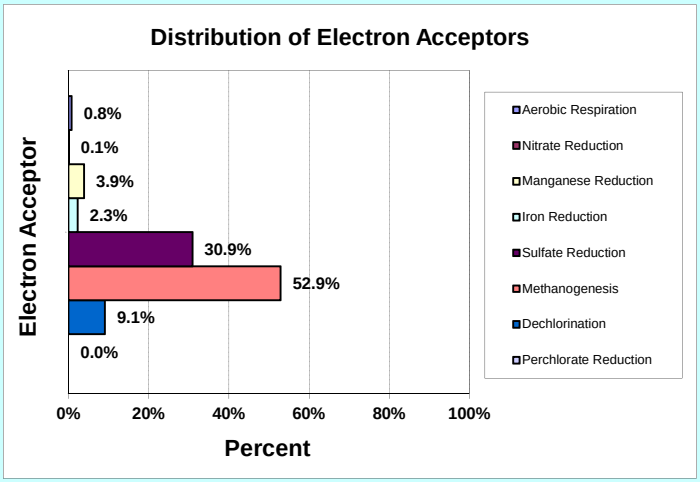
2. Treatment Zone Hydrogeologic Properties

	Values	Units	Values	Units
Total Porosity	0.32	percent	0.32	percent
Effective Porosity	0.28	percent	0.28	percent
Average Aquifer Hydraulic Conductivity	4	ft/day	1.4E-03	cm/sec
Average Hydraulic Gradient	0.033	ft/ft	0.033	m/m
Average Groundwater Seepage Velocity	0.47	ft/day	1.4E+01	cm/day
Average Groundwater Seepage Velocity	172	ft/yr	52.4	m/yr
Effective Treatment Zone Pore Volume	51,033	gallons	193,176	liters
Groundwater Flux (per year)	439,068	gallons/year	1,662,007	liters/year
Total Groundwater Volume Treated (over entire design period)	1,807,305	gallons total	6,841,203	liters total

3. Distribution of Electron Acceptor Demand

	Percent of Total	Hydrogen Demand (lb)
Aerobic Respiration	0.8%	1.140
Nitrate Reduction	0.1%	0.146
Sulfate Reduction	30.9%	44.319
Manganese Reduction	3.9%	5.534
Iron Reduction	2.3%	3.266
Methanogenesis	52.9%	75.785
Dechlorination	9.1%	13.028
Perchlorate Reduction	0.0%	0.000
Totals:	**100.00%**	**143.22**

Hydrogen demand in pounds/gallon:	7.92E-05
Hydrogen demand in grams per liter:	9.50E-03



4. Substrate Equivalents: Design Factor = 4.0

Product	Quantity (lb)	Quantity (gallons)	Effective Concentration (mg/L)	Effective concentration is for total volume of groundwater treated.
1. Sodium Lactate Product	26,553	2,414	849	as lactic acid
2. Molasses Product	20,264	1,689	806	as sucrose
3. Fructose Product	16,002	1,429	849	as fructose
4. Ethanol Product	8,182	1,186	434	as ethanol
5. Sweet Dry Whey (lactose)	12,621	sold by pound	586	as lactose
6. HRC®	9,702	sold by pound	515	as 40% lactic acid/40% glycerol
7. Linoleic Acid (Soybean Oil)	4,982	639	330	as soybean oil
8. Emulsified Vegetable Oil	8,303	1,064	330	as soybean oil

Notes:

1. Quantity assumes product is 60% sodium lactate by weight.
2. Quantity assumes product is 60% sucrose by weight and weighs 12 pounds per gallon.
3. Quantity assumes product is 80% fructose by weight and weighs 11.2 pounds per gallon.
4. Quantity assumes product is 80% ethanol by weight and weighs 6.9 pounds per gallon.
5. Quantity assumes product is 70% lactose by weight.
6. Quantity assumes HRC® is 40% lactic acid and 40% glycerol by weight.
7. Quantity of neat soybean oil, corn oil, or canola oil.
8. Quantity assumes commercial product is 60% soybean oil by weight.

SUBSTRATE ESTIMATING TOOL FOR ENHANCED ANAEROBIC BIOREMEDIATION OF CHLORINATED SOLVENTS

Version 1.2
November 2010

Site Data Input Table

TABLE S.1 - INPUT TABLE

Calculation Tables

Table S.2 - Substrate Calculations in Hydrogen

Table S.3 - Hydrogen Produced by Common Substrates

Table S.4 - Estimated Substrate Requirements for

Output Summary Table

TABLE S.5 - OUTPUT TABLE

PRINT SUMMARY TABLE

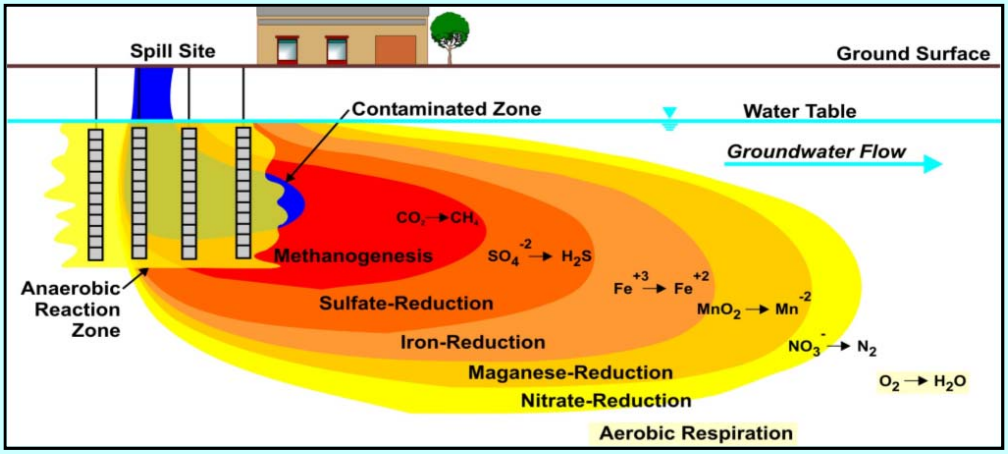


Table S.1 Input for Substrate Requirements in Hydrogen Equivalents

Site Name: Former Duso Chemical (northeast - BIW-6S)

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NOTE: Unshaded boxes are user input.

1. Treatment Zone Physical Dimensions	Values	Range	Units	User Notes
Width (Perpendicular to predominant groundwater flow direction)	92	1-10,000	feet	Former Duso Chemical (east - BIW-6S)
Length (Parallel to predominant groundwater flow)	20	1-1,000	feet	
Saturated Thickness	8	1-100	feet	treatment thickness (4-12)
Treatment Zone Cross Sectional Area	736	--	ft^2	
Treatment Zone Volume	14,720	--	ft^3	
Treatment Zone Total Pore Volume (total volume x total porosity)	35,243	--	gallons	
Treatment Zone Effective Pore Volume (total volume x effective porosity)	30,838	--	gallons	
Design Period of Performance	4.0	.5 to 5	year	
Design Factor (times the electron acceptor hydrogen demand)	3.0	2 to 20	unitless	AECOM recommendation to use a design factor of 2 to 5
2. Treatment Zone Hydrogeologic Properties				
Total Porosity	32%	.05-50	percent	Assumed for silty sand
Effective Porosity	28%	.05-50	percent	Assumed for silty sand (conservative high for higher PV)
Average Aquifer Hydraulic Conductivity	4	.01-1000	ft/day	average from MHBP RI
Average Hydraulic Gradient	0.033	0.0001-0.1	ft/ft	average from 2 values in RI
Average Groundwater Seepage Velocity through the Treatment Zone	0.47	--	ft/day	
Average Groundwater Seepage Velocity through the Treatment Zone	172.1	--	ft/yr	
Average Groundwater Discharge through the Treatment Zone	265,315	--	gallons/year	
Soil Bulk Density	1.65	1.4-2.0	gm/cm^3	Assumed
Soil Fraction Organic Carbon (foc)	3.00%	0.01-10	percent	Assumed
3. Native Electron Acceptors				
A. Aqueous-Phase Native Electron Acceptors				
Oxygen	0.6	0.01 to 10	mg/L	
Nitrate	0.10	0.1 to- 20	mg/L	not detected in RI
Sulfate	35	10 to 5,000	mg/L	RI readings 2, 11, 43, 79 in MHC-23 and MHC-26
Carbon Dioxide (estimated as the amount of Methane produced)	10.0	0.1 to 20	mg/L	
B. Solid-Phase Native Electron Acceptors				
Manganese (IV) (estimated as the amount of Mn (II) produced)	10	0.1 to 20	mg/L	RI Mn 4-8 mg/L in slightly reducing GW, assume some productior
Iron (III) (estimated as the amount of Fe (II) produced)	12	0.1 to 20	mg/L	RI ~10 mg/L in slightly reducing GW, assume some production
4. Contaminant Electron Acceptors				
Tetrachloroethene (PCE)	0.010	--	mg/L	avg conc from BIW-6S + BIW-2S (2012)
Trichloroethene (TCE)	0.035	--	mg/L	
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	0.465	--	mg/L	
Vinyl Chloride (VC)	0.010	--	mg/L	
Carbon Tetrachloride (CT)	0.000	--	mg/L	
Trichloromethane (or chloroform) (CF)	0.001	--	mg/L	
Dichloromethane (or methylene chloride) (MC)	0.001	--	mg/L	
Chloromethane	0.000	--	mg/L	
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	--	mg/L	
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	2.600	--	mg/L	
Dichloroethane (1,1-DCA and 1,2-DCA)	4.300	--	mg/L	
Chloroethane	0.500	--	mg/L	
Perchlorate	0.000	--	mg/L	
5. Aquifer Geochemistry (Optional Screening Parameters)				
A. Aqueous Geochemistry				
Oxidation-Reduction Potential (ORP)	-25	-400 to +500	mV	2012 Field Sheets (avg BIW-2S, MHC-23, BIW-5S)
Temperature	13	5.0 to 30	ºC	2012 Field Sheets
pH	7.1	4.0 to 10.0	su	2012 Field Sheets (7.06-7.4)
Alkalinity	300	10 to 1,000	mg/L	SB55147 - SE-MW07, Collected on 8-23-12
Total Dissolved Solids (TDS, or salinity)		10 to 1,000	mg/L	
Specific Conductivity	2000	100 to 10,000	µs/cm	2012 Field Sheets Approximate Average
Chloride		10 to 10,000	mg/L	
Sulfide - Pre injection	0.0	0.1 to 100	mg/L	
Sulfide - Post injection	0.0	0.1 to 100	mg/L	
B. Aquifer Matrix				
Total Iron	10000	200 to 20,000	mg/kg	Assumed
Cation Exchange Capacity	NA	1.0 to 10	meq/100 g	
Neutralization Potential	10.0%	1.0 to 100	Percent as $CaCO_3$	Assumed

NOTES:

Table S.2 Substrate Calculations in Hydrogen Equivalents

Site Name: Former Duso Chemical (northeast - BIW-6S)

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NOTE: Open cells are user input.

1. Treatment Zone Physical Dimensions

	Values	Range	Units
Width (Perpendicular to predominant groundwater flow direction)	92	1-10,000	feet
Length (Parallel to predominant groundwater flow)	20	1-1,000	feet
Saturated Thickness	8	1-100	feet
Treatment Zone Cross Sectional Area	736	--	ft^2
Treatment Zone Volume	14,720	--	ft^3
Treatment Zone Effective Pore Volume (total volume x effective porosity)	30,838	--	gallons
Design Period of Performance	4.0	.5 to 5	year

2. Treatment Zone Hydrogeologic Properties

Total Porosity	0.32	.05-50	
Effective Porosity	0.28	.05-50	
Average Aquifer Hydraulic Conductivity	4	.01-1000	ft/day
Average Hydraulic Gradient	0.033	0.1-0.0001	ft/ft
Average Groundwater Seepage Velocity through the Treatment Zone	0.47	--	ft/day
Average Groundwater Seepage Velocity through the Treatment Zone	172.1	--	ft/yr
Average Groundwater Flux through the Treatment Zon 0	265,315	--	gallons/year
Soil Bulk Density	1.65	1.4-2.0	gm/cm^3
Soil Fraction Organic Carbon (foc)	0.03	0.0001-0.1	

3. Initial Treatment Cell Electron-Acceptor Demand (one total pore volume)

A. Aqueous-Phase Native Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Oxygen	0.6	0.15	7.94	0.02	4
Nitrate (denitrification)	0.1	0.03	12.30	0.00	5
Sulfate	35	9.01	11.91	0.76	8
Carbon Dioxide (estimated as the amount of methane produced)	10.0	2.57	1.99	1.29	8
Soluble Competing Electron Acceptor Demand (lb.)				**2.07**	

B. Solid-Phase Native Electron Acceptors (Based on manganese and iron produced)	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Manganese (IV) (estimated as the amount of Mn (II) produced)	10.0	91.13	27.25	3.34	2
Iron (III) (estimated as the amount of Fe (II) produced)	12.0	109.36	55.41	1.97	1
Solid-Phase Competing Electron Acceptor Demand (lb.)				**5.32**	

C. Soluble Contaminant Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	0.010	0.00	20.57	0.00	8
Trichloroethene (TCE)	0.035	0.01	21.73	0.00	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	0.465	0.12	24.05	0.00	4
Vinyl Chloride (VC)	0.010	0.00	31.00	0.00	2
Carbon Tetrachloride (CT)	0.000	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	0.001	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	0.001	0.00	21.06	0.00	4
Chloromethane	0.000	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	2.600	0.67	22.06	0.03	6
Dichloroethane (1,1-DCA and 1,2-DCA)	4.300	1.11	24.55	0.05	4
Chloroethane	0.500	0.13	32.00	0.00	2
Perchlorate	0.000	0.00	12.33	0.00	6
Total Soluble Contaminant Electron Acceptor Demand (lb.)				**0.09**	

D. Sorbed Contaminant Electron Acceptors (Soil Concentration = Koc x foc x Cgw)	Koc (mL/g)	Soil Conc. (mg/kg)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	263	0.08	0.12	20.57	0.01	8
Trichloroethene (TCE)	107	0.11	0.17	21.73	0.01	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	45	0.63	0.95	24.05	0.04	4
Vinyl Chloride (VC)	3.0	0.00	0.00	31.00	0.00	2
Carbon Tetrachloride (CT)	224	0.00	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	63	0.00	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	28	0.00	0.00	21.06	0.00	4
Chloromethane	25	0.00	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	117	0.00	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	105	8.19	12.42	22.06	0.56	6
Dichloroethane (1,1-DCA and 1,2-DCA)	30	3.87	5.87	24.55	0.24	4
Chloroethane	3	0.05	0.07	32.00	0.00	2
Perchlorate	0.0	0.00	0.00	12.33	0.00	6
Total Sorbed Contaminant Electron Acceptor Demand (lb.)					**0.86**	

(continued)

Table S.2 Substrate Calculations in Hydrogen Equivalents

4. Treatment Cell Electron-Acceptor Flux (per year)

A. Soluble Native Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Oxygen	0.6	1.33	7.94	0.17	4
Nitrate (denitrification)	0.1	0.22	10.25	0.02	5
Sulfate	35	77.49	11.91	6.51	8
Carbon Dioxide (estimated as the amount of Methane produced)	10	22.14	1.99	11.13	8
Total Competing Electron Acceptor Demand Flux (lb/yr)				**17.8**	

B. Soluble Contaminant Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	0.010	0.02	20.57	0.00	8
Trichloroethene (TCE)	0.035	0.08	21.73	0.00	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	0.465	1.03	24.05	0.04	4
Vinyl Chloride (VC)	0.010	0.02	31.00	0.00	2
Carbon Tetrachloride (CT)	0.000	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	0.001	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	0.001	0.00	21.06	0.00	4
Chloromethane	0.000	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	2.600	5.76	22.06	0.26	6
Dichloroethane (1,1-DCA and 1,2-DCA)	4.300	9.52	24.55	0.39	4
Chloroethane	0.500	1.11	32.00	0.03	2
Perchlorate	0.000	0.00	12.33	0.00	6
Total Soluble Contaminant Electron Acceptor Demand Flux (lb/yr)				**0.73**	

Initial Hydrogen Requirement First Year (lb)	**26.9**
Total Life-Cycle Hydrogen Requirement (lb)	**82.5**

5. Design Factors

Microbial Efficiency Uncertainty Factor	2X - 4X
Methane and Solid-Phase Electron Acceptor Uncertainty	2X - 4X
Remedial Design Factor (e.g., Substrate Leaving Reaction Zone)	1X - 3X
Design Factor	**3.0**
Total Life-Cycle Hydrogen Requirement with Design Factor (lb)	**247.6**

6. Acronyns and Abbreviations

^{o}C =degrees celsius
µs/cm = microsiemens per centimeter
cm/day = centimeters per day
cm/sec = centimeters per second
ft^2 = square feet
ft/day = feet per day
ft/ft = foot per foot
ft/yr = feet per year
gm/cm^3 = grams per cubic centimeter
kg of CaCO3 per mg = kilograms of calcium carbonate per milligram
lb = pounds
meq/100 g = milliequivalents per 100 grams
mg/kg = milligrams per kilogram
mg/L = milligrams per liter
m/m = meters per meters
mV = millivolts
m/yr = meters per year
su = standard pH units
wt/wt H2 = concetration molecular hydrogen, weight per weight

Table S.3

Hydrogen Produced by Fermentation Reactions of Common Substrates

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Substrate	Molecular Formula	Substrate Molecular Weight (gm/mole)	Moles of Hydrogen Produced per Mole of Substrate	Ratio of Hydrogen Produced to Substrate (gm/gm)	Range of Moles H_2/Mole Substrate
Lactic Acid	$C_3H_6O_3$	90.1	2	0.0448	**2 to 3**
Molasses (assuming 100% sucrose)	$C_{12}H_{22}O_{11}$	342	8	0.0471	**8 to 11**
High Fructose Corn Syrup (assuming 50% fructose and 50% glucose)	$C_6H_{12}O_6$	180	4	0.0448	**4 to 6**
Ethanol	C_2H_6O	46.1	2	0.0875	**2 to 6**
Whey (assuming 100% lactose)	$C_{12}H_{22}O_{11}$	342	11	0.0648	**11**
HRC® (assumes 40% lactic acid and 40% glycerol by weight)	$C_{39}H_{56}O_{39}$	956	28	0.0590	**28**
Linoleic Acid (Soybean Oil, Corn Oil, Cotton Oil)	$C_{18}H_{32}O_2$	281	16	0.1150	**16**

Table S.4
Estimated Substrate Requirements for Hydrogen Demand in Table S.3

Design Life (years): 4

Substrate	Design Factor	Pure Substrate Mass Required to Fulfill Hydrogen Demand (pounds)	Substrate Product Required to Fulfill Hydrogen Demand (pounds)	Substrate Mass Required to Fulfill Hydrogen Demand (milligrams)	Effective Substrate Concentration (mg/L)
Lactic Acid	3.0	5,532	5,532	2.51E+09	607
Sodium Lactate Product (60 percent solution)	3.0	5,532	11,477	2.51E+09	607
Molasses (assuming 6 0	3.0	5,255	8,759	2.38E+09	577
HFCS (assuming 40% fructose and 40% glucose by weight)	3.0	5,533	6,917	2.51E+09	607
Ethanol Product (assuming 80% ethanol by weight)	3.0	2,829	3,537	1.28E+09	310
Whey (assuming 100% lactose)	3.0	3,819	5,455	1.73E+09	419
HRC® (assumes 40% lactic acid and 40% glycerol by weight)	3.0	4,194	4,194	1.90E+09	368
Linoleic Acid (Soybean Oil, Corn Oil, Cotton Oil)	3.0	2,153	2,153	9.77E+08	236
Commercial Vegetable Oil Emulsion Product (60% oil by weight)	3.0	2,153	3,589	9.77E+08	236

NOTES: Sodium Lactate Product

1. Assumes sodium lactate product is 60 percent sodium lactate by weight.
2. Molecular weight of sodium lactate (CH_3-CHOH-COONa) = 112.06.
3. Molecular weight of lactic Acid ($C_6H_6O_3$) = 90.08 .
4. Therefore, sodium lactate product yields 48.4 (0.60 x (90.08/112.06)) percent by weight lactic acid.
5. Weight of sodium lactate product = 11.0 pounds per gallon.
6. Pounds per gallon of lactic acid in product = 1.323 x 8.33 lb/gal H2O x 0.60 x (90.08/112.06) = 5.31 lb/gal.

NOTES: Standard HRC Product

1. Assumes HRC product is 40 percent lactic acid and 40 percent glycerol by weight.
2. HRC® weighs approximately 9.18 pounds per gallon.

NOTES: Vegetable Oil Emulsion Product

1. Assumes emulsion product is 60 percent soybean oil by weight.
2. Soybean oil is 7.8 pounds per gallon.
3. Assumes specific gravity of emulsion product is 0.96.

Table S.5 Output for Substrate Requirements in Hydrogen Equivalents

Site Name: Former Duso Chemical (northeast - BIW-6S)

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1. Treatment Zone Physical Dimensions

	Values	Units	Values	Units
Width (perpendicular to groundwater flow)	92	feet	28	meters
Length (parallel to groundwater flow)	20	feet	6.1	meters
Saturated Thickness	8	feet	2.4	meters
Design Period of Performance	4	years	4	years

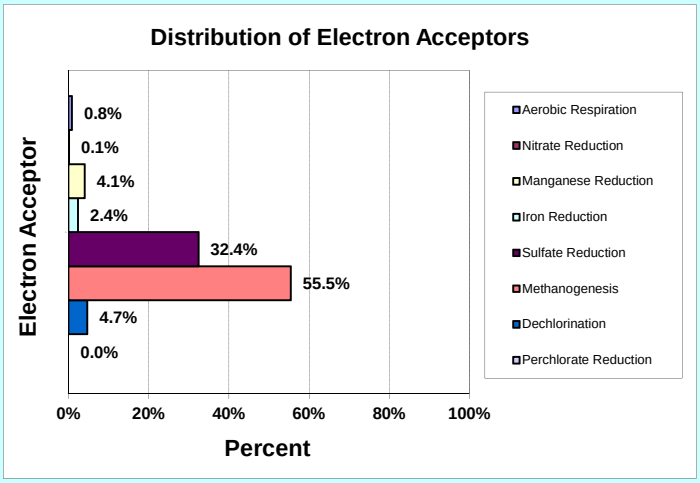
2. Treatment Zone Hydrogeologic Properties

	Values	Units	Values	Units
Total Porosity	0.32	percent	0.32	percent
Effective Porosity	0.28	percent	0.28	percent
Average Aquifer Hydraulic Conductivity	4	ft/day	1.4E-03	cm/sec
Average Hydraulic Gradient	0.033	ft/ft	0.033	m/m
Average Groundwater Seepage Velocity	0.47	ft/day	1.4E+01	cm/day
Average Groundwater Seepage Velocity	172	ft/yr	52.4	m/yr
Effective Treatment Zone Pore Volume	30,838	gallons	116,731	liters
Groundwater Flux (per year)	265,315	gallons/year	1,004,300	liters/year
Total Groundwater Volume Treated (over entire design period)	1,092,099	gallons total	4,133,929	liters total

3. Distribution of Electron Acceptor Demand

	Percent of Total	Hydrogen Demand (lb)
Aerobic Respiration	0.8%	0.689
Nitrate Reduction	0.1%	0.088
Sulfate Reduction	32.4%	26.781
Manganese Reduction	4.1%	3.344
Iron Reduction	2.4%	1.974
Methanogenesis	55.5%	45.794
Dechlorination	4.7%	3.870
Perchlorate Reduction	0.0%	0.000
Totals:	**100.00%**	**82.54**

Hydrogen demand in pounds/gallon:	7.56E-05
Hydrogen demand in grams per liter:	9.06E-03



4. Substrate Equivalents: Design Factor = 3.0

Product	Quantity (lb)	Quantity (gallons)	Effective Concentration (mg/L)	Effective concentration is for total volume of groundwater treated.
1. Sodium Lactate Product	11,477	1,043	607	as lactic acid
2. Molasses Product	8,759	730	577	as sucrose
3. Fructose Product	6,917	618	607	as fructose
4. Ethanol Product	3,537	513	310	as ethanol
5. Sweet Dry Whey (lactose)	5,455	sold by pound	419	as lactose
6. HRC®	4,194	sold by pound	368	as 40% lactic acid/40% glycerol
7. Linoleic Acid (Soybean Oil)	2,153	276	236	as soybean oil
8. Emulsified Vegetable Oil	3,589	460	236	as soybean oil

Notes:

1. Quantity assumes product is 60% sodium lactate by weight.
2. Quantity assumes product is 60% sucrose by weight and weighs 12 pounds per gallon.
3. Quantity assumes product is 80% fructose by weight and weighs 11.2 pounds per gallon.
4. Quantity assumes product is 80% ethanol by weight and weighs 6.9 pounds per gallon.
5. Quantity assumes product is 70% lactose by weight.
6. Quantity assumes HRC® is 40% lactic acid and 40% glycerol by weight.
7. Quantity of neat soybean oil, corn oil, or canola oil.
8. Quantity assumes commercial product is 60% soybean oil by weight.

SUBSTRATE ESTIMATING TOOL FOR ENHANCED ANAEROBIC BIOREMEDIATION OF CHLORINATED SOLVENTS

Version 1.2
November 2010

Site Data Input Table

TABLE S.1 - INPUT TABLE

Calculation Tables

Table S.2 - Substrate Calculations in Hydrogen

Table S.3 - Hydrogen Produced by Common Substrates

Table S.4 - Estimated Substrate Requirements for

Output Summary Table

TABLE S.5 - OUTPUT TABLE

PRINT SUMMARY TABLE

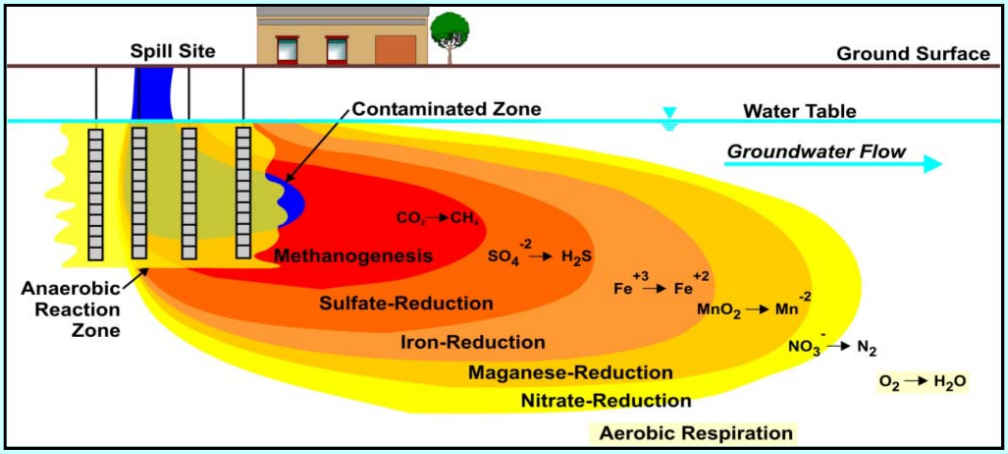


Table S.1 Input for Substrate Requirements in Hydrogen Equivalents

Site Name: Former Duso Chemical (Northwest - BIW-1D)

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NOTE: Unshaded boxes are user input.

1. Treatment Zone Physical Dimensions	Values	Range	Units	User Notes
Width (Perpendicular to predominant groundwater flow direction)	71	1-10,000	feet	Former Duso Chemical (Northwest - BIW-1D)
Length (Parallel to predominant groundwater flow)	35	1-1,000	feet	
Saturated Thickness	20	1-100	feet	treatment thickness (6-26)
Treatment Zone Cross Sectional Area	1420	--	ft^2	
Treatment Zone Volume	49,700	--	ft^3	
Treatment Zone Total Pore Volume (total volume x total porosity)	118,994	--	gallons	
Treatment Zone Effective Pore Volume (total volume x effective porosity)	104,120	--	gallons	
Design Period of Performance	4.0	.5 to 5	year	
Design Factor (times the electron acceptor hydrogen demand)	5.0	2 to 20	unitless	AECOM recommendation to use a design factor of 2 to 5
2. Treatment Zone Hydrogeologic Properties				
Total Porosity	32%	.05-50	percent	Assumed for silty sand
Effective Porosity	28%	.05-50	percent	Assumed for silty sand (conservative high for higher PV)
Average Aquifer Hydraulic Conductivity	4	.01-1000	ft/day	average from MHBP RI
Average Hydraulic Gradient	0.033	0.0001-0.1	ft/ft	average from 2 values in RI
Average Groundwater Seepage Velocity through the Treatment Zone	0.47	--	ft/day	
Average Groundwater Seepage Velocity through the Treatment Zone	172.1	--	ft/yr	
Average Groundwater Discharge through the Treatment Zone	511,886	--	gallons/year	
Soil Bulk Density	1.65	1.4-2.0	gm/cm^3	Assumed
Soil Fraction Organic Carbon (foc)	3.00%	0.01-10	percent	Assumed
3. Native Electron Acceptors				
A. Aqueous-Phase Native Electron Acceptors				
Oxygen	0.6	0.01 to 10	mg/L	
Nitrate	0.10	0.1 to- 20	mg/L	not detected in RI
Sulfate	35	10 to 5,000	mg/L	RI readings 2, 11, 43, 79 in MHC-23 and MHC-26
Carbon Dioxide (estimated as the amount of Methane produced)	10.0	0.1 to 20	mg/L	
B. Solid-Phase Native Electron Acceptors				
Manganese (IV) (estimated as the amount of Mn (II) produced)	10	0.1 to 20	mg/L	RI Mn 4-8 mg/L in slightly reducing GW, assume some productior
Iron (III) (estimated as the amount of Fe (II) produced)	12	0.1 to 20	mg/L	RI ~10 mg/L in slightly reducing GW, assume some production
4. Contaminant Electron Acceptors				
Tetrachloroethene (PCE)	0.001	--	mg/L	max conc from BIW-1D
Trichloroethene (TCE)	0.003	--	mg/L	
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	2.400	--	mg/L	
Vinyl Chloride (VC)	0.000	--	mg/L	
Carbon Tetrachloride (CT)	0.000	--	mg/L	
Trichloromethane (or chloroform) (CF)	0.000	--	mg/L	
Dichloromethane (or methylene chloride) (MC)	0.000	--	mg/L	
Chloromethane	0.000	--	mg/L	
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	--	mg/L	
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	3.600	--	mg/L	
Dichloroethane (1,1-DCA and 1,2-DCA)	2.400	--	mg/L	
Chloroethane	0.000	--	mg/L	
Perchlorate	0.000	--	mg/L	
5. Aquifer Geochemistry (Optional Screening Parameters)				
A. Aqueous Geochemistry				
Oxidation-Reduction Potential (ORP)	-25	-400 to +500	mV	2012 Field Sheets (avg BIW-2S, MHC-23, BIW-5S)
Temperature	13	5.0 to 30	ºC	2012 Field Sheets
pH	7.1	4.0 to 10.0	su	2012 Field Sheets (7.06-7.4)
Alkalinity	300	10 to 1,000	mg/L	
Total Dissolved Solids (TDS, or salinity)		10 to 1,000	mg/L	
Specific Conductivity	2000	100 to 10,000	µs/cm	2012 Field Sheets Approximate Average
Chloride		10 to 10,000	mg/L	
Sulfide - Pre injection	0.0	0.1 to 100	mg/L	
Sulfide - Post injection	0.0	0.1 to 100	mg/L	
B. Aquifer Matrix				
Total Iron	10000	200 to 20,000	mg/kg	Assumed
Cation Exchange Capacity	NA	1.0 to 10	meq/100 g	
Neutralization Potential	10.0%	1.0 to 100	Percent as $CaCO_3$	Assumed

NOTES:

Table S.2 Substrate Calculations in Hydrogen Equivalents

Site Name: Former Duso Chemical (Northwest - BIW-1D)

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NOTE: Open cells are user input.

1. Treatment Zone Physical Dimensions

	Values	Range	Units
Width (Perpendicular to predominant groundwater flow direction)	71	1-10,000	feet
Length (Parallel to predominant groundwater flow)	35	1-1,000	feet
Saturated Thickness	20	1-100	feet
Treatment Zone Cross Sectional Area	1420	--	ft^2
Treatment Zone Volume	49,700	--	ft^3
Treatment Zone Effective Pore Volume (total volume x effective porosity)	104,120	--	gallons
Design Period of Performance	4.0	.5 to 5	year

2. Treatment Zone Hydrogeologic Properties

Total Porosity	0.32	.05-50	
Effective Porosity	0.28	.05-50	
Average Aquifer Hydraulic Conductivity	4	.01-1000	ft/day
Average Hydraulic Gradient	0.033	0.1-0.0001	ft/ft
Average Groundwater Seepage Velocity through the Treatment Zone	0.47	--	ft/day
Average Groundwater Seepage Velocity through the Treatment Zone	172.1	--	ft/yr
Average Groundwater Flux through the Treatment Zon 0	511,886	--	gallons/year
Soil Bulk Density	1.65	1.4-2.0	gm/cm^3
Soil Fraction Organic Carbon (foc)	0.03	0.0001-0.1	

3. Initial Treatment Cell Electron-Acceptor Demand (one total pore volume)

A. Aqueous-Phase Native Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Oxygen	0.6	0.52	7.94	0.07	4
Nitrate (denitrification)	0.1	0.09	12.30	0.01	5
Sulfate	35	30.41	11.91	2.55	8
Carbon Dioxide (estimated as the amount of methane produced)	10.0	8.69	1.99	4.37	8
Soluble Competing Electron Acceptor Demand (lb.)				**6.99**	

B. Solid-Phase Native Electron Acceptors (Based on manganese and iron produced)	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Manganese (IV) (estimated as the amount of Mn (II) produced)	10.0	179.55	27.25	6.59	2
Iron (III) (estimated as the amount of Fe (II) produced)	12.0	215.46	55.41	3.89	1
Solid-Phase Competing Electron Acceptor Demand (lb.)				**10.48**	

C. Soluble Contaminant Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	0.001	0.00	20.57	0.00	8
Trichloroethene (TCE)	0.003	0.00	21.73	0.00	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	2.400	2.09	24.05	0.09	4
Vinyl Chloride (VC)	0.000	0.00	31.00	0.00	2
Carbon Tetrachloride (CT)	0.000	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	0.000	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	0.000	0.00	21.06	0.00	4
Chloromethane	0.000	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	3.600	3.13	22.06	0.14	6
Dichloroethane (1,1-DCA and 1,2-DCA)	2.400	2.09	24.55	0.08	4
Chloroethane	0.000	0.00	32.00	0.00	2
Perchlorate	0.000	0.00	12.33	0.00	6
Total Soluble Contaminant Electron Acceptor Demand (lb.)				**0.31**	

D. Sorbed Contaminant Electron Acceptors (Soil Concentration = Koc x foc x Cgw)	Koc (mL/g)	Soil Conc. (mg/kg)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	263	0.00	0.02	20.57	0.00	8
Trichloroethene (TCE)	107	0.01	0.04	21.73	0.00	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	45	3.24	16.59	24.05	0.69	4
Vinyl Chloride (VC)	3.0	0.00	0.00	31.00	0.00	2
Carbon Tetrachloride (CT)	224	0.00	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	63	0.00	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	28	0.00	0.00	21.06	0.00	4
Chloromethane	25	0.00	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	117	0.00	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	105	11.34	58.07	22.06	2.63	6
Dichloroethane (1,1-DCA and 1,2-DCA)	30	2.16	11.06	24.55	0.45	4
Chloroethane	3	0.00	0.00	32.00	0.00	2
Perchlorate	0.0	0.00	0.00	12.33	0.00	6
Total Sorbed Contaminant Electron Acceptor Demand (lb.)					**3.78**	

(continued)

Table S.2 Substrate Calculations in Hydrogen Equivalents

4. Treatment Cell Electron-Acceptor Flux (per year)

A. Soluble Native Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Oxygen	0.6	2.56	7.94	0.32	4
Nitrate (denitrification)	0.1	0.43	10.25	0.04	5
Sulfate	35	149.50	11.91	12.55	8
Carbon Dioxide (estimated as the amount of Methane produced)	10	42.71	1.99	21.46	8
Total Competing Electron Acceptor Demand Flux (lb/yr)				**34.4**	

B. Soluble Contaminant Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	0.001	0.00	20.57	0.00	8
Trichloroethene (TCE)	0.003	0.01	21.73	0.00	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	2.400	10.25	24.05	0.43	4
Vinyl Chloride (VC)	0.000	0.00	31.00	0.00	2
Carbon Tetrachloride (CT)	0.000	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	0.000	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	0.000	0.00	21.06	0.00	4
Chloromethane	0.000	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	3.600	15.38	22.06	0.70	6
Dichloroethane (1,1-DCA and 1,2-DCA)	2.400	10.25	24.55	0.42	4
Chloroethane	0.000	0.00	32.00	0.00	2
Perchlorate	0.000	0.00	12.33	0.00	6
Total Soluble Contaminant Electron Acceptor Demand Flux (lb/yr)				**1.54**	

Initial Hydrogen Requirement First Year (lb)	**57.5**
Total Life-Cycle Hydrogen Requirement (lb)	**165.3**

5. Design Factors

Microbial Efficiency Uncertainty Factor	2X - 4X
Methane and Solid-Phase Electron Acceptor Uncertainty	2X - 4X
Remedial Design Factor (e.g., Substrate Leaving Reaction Zone)	1X - 3X
Design Factor	**5.0**
Total Life-Cycle Hydrogen Requirement with Design Factor (lb)	**826.3**

6. Acronyns and Abbreviations

°C =degrees celsius
µs/cm = microsiemens per centimeter
cm/day = centimeters per day
cm/sec = centimeters per second
ft^2 = square feet
ft/day = feet per day
ft/ft = foot per foot
ft/yr = feet per year
gm/cm^3 = grams per cubic centimeter
kg of CaCO3 per mg = kilograms of calcium carbonate per milligram
lb = pounds
meq/100 g = milliequivalents per 100 grams
mg/kg = milligrams per kilogram
mg/L = milligrams per liter
m/m = meters per meters
mV = millivolts
m/yr = meters per year
su = standard pH units
wt/wt H2 = concetration molecular hydrogen, weight per weight

Table S.3

Hydrogen Produced by Fermentation Reactions of Common Substrates

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Substrate	Molecular Formula	Substrate Molecular Weight (gm/mole)	Moles of Hydrogen Produced per Mole of Substrate	Ratio of Hydrogen Produced to Substrate (gm/gm)	Range of Moles H_2/Mole Substrate
Lactic Acid	$C_3H_6O_3$	90.1	2	0.0448	**2 to 3**
Molasses (assuming 100% sucrose)	$C_{12}H_{22}O_{11}$	342	8	0.0471	**8 to 11**
High Fructose Corn Syrup (assuming 50% fructose and 50% glucose)	$C_6H_{12}O_6$	180	4	0.0448	**4 to 6**
Ethanol	C_2H_6O	46.1	2	0.0875	**2 to 6**
Whey (assuming 100% lactose)	$C_{12}H_{22}O_{11}$	342	11	0.0648	**11**
HRC® (assumes 40% lactic acid and 40% glycerol by weight)	$C_{39}H_{56}O_{39}$	956	28	0.0590	**28**
Linoleic Acid (Soybean Oil, Corn Oil, Cotton Oil)	$C_{18}H_{32}O_2$	281	16	0.1150	**16**

Table S.4

Estimated Substrate Requirements for Hydrogen Demand in Table S.3

Design Life (years): 4

Substrate	Design Factor	Pure Substrate Mass Required to Fulfill Hydrogen Demand (pounds)	Substrate Product Required to Fulfill Hydrogen Demand (pounds)	Substrate Mass Required to Fulfill Hydrogen Demand (milligrams)	Effective Substrate Concentration (mg/L)
Lactic Acid	5.0	18,460	18,460	8.37E+09	1,028
Sodium Lactate Product (60 percent solution)	5.0	18,460	38,298	8.37E+09	1,028
Molasses (assuming 6 0	5.0	17,536	29,227	7.95E+09	977
HFCS (assuming 40% fructose and 40% glucose by weight)	5.0	18,464	23,080	8.38E+09	1,028
Ethanol Product (assuming 80% ethanol by weight)	5.0	9,441	11,801	4.28E+09	526
Whey (assuming 100% lactose)	5.0	12,743	18,204	5.78E+09	710
HRC® (assumes 40% lactic acid and 40% glycerol by weight)	5.0	13,993	13,993	6.35E+09	623
Linoleic Acid (Soybean Oil, Corn Oil, Cotton Oil)	5.0	7,185	7,185	3.26E+09	400
Commercial Vegetable Oil Emulsion Product (60% oil by weight)	5.0	7,185	11,975	3.26E+09	400

NOTES: Sodium Lactate Product

1. Assumes sodium lactate product is 60 percent sodium lactate by weight.
2. Molecular weight of sodium lactate (CH_3-CHOH-COONa) = 112.06.
3. Molecular weight of lactic Acid ($C_6H_6O_3$) = 90.08 .
4. Therefore, sodium lactate product yields 48.4 (0.60 x (90.08/112.06)) percent by weight lactic acid.
5. Weight of sodium lactate product = 11.0 pounds per gallon.
6. Pounds per gallon of lactic acid in product = 1.323 x 8.33 lb/gal H2O x 0.60 x (90.08/112.06) = 5.31 lb/gal.

NOTES: Standard HRC Product

1. Assumes HRC product is 40 percent lactic acid and 40 percent glycerol by weight.
2. HRC® weighs approximately 9.18 pounds per gallon.

NOTES: Vegetable Oil Emulsion Product

1. Assumes emulsion product is 60 percent soybean oil by weight.
2. Soybean oil is 7.8 pounds per gallon.
3. Assumes specific gravity of emulsion product is 0.96.

Table S.5 Output for Substrate Requirements in Hydrogen Equivalents

Site Name: Former Duso Chemical (Northwest - BIW-1D)

RETURN TO COVER PAGE

1. Treatment Zone Physical Dimensions

	Values	Units	Values	Units
Width (perpendicular to groundwater flow)	71	feet	22	meters
Length (parallel to groundwater flow)	35	feet	10.7	meters
Saturated Thickness	20	feet	6.1	meters
Design Period of Performance	4	years	4	years

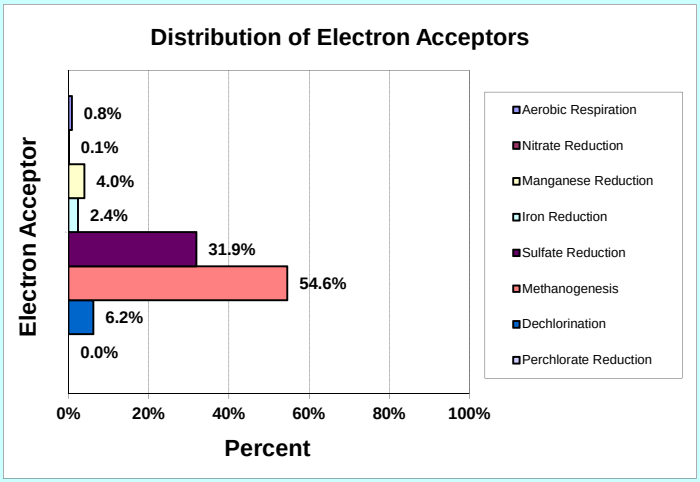
2. Treatment Zone Hydrogeologic Properties

	Values	Units	Values	Units
Total Porosity	0.32	percent	0.32	percent
Effective Porosity	0.28	percent	0.28	percent
Average Aquifer Hydraulic Conductivity	4	ft/day	1.4E-03	cm/sec
Average Hydraulic Gradient	0.033	ft/ft	0.033	m/m
Average Groundwater Seepage Velocity	0.47	ft/day	1.4E+01	cm/day
Average Groundwater Seepage Velocity	172	ft/yr	52.4	m/yr
Effective Treatment Zone Pore Volume	104,120	gallons	394,124	liters
Groundwater Flux (per year)	511,886	gallons/year	1,937,643	liters/year
Total Groundwater Volume Treated (over entire design period)	2,151,662	gallons total	8,144,698	liters total

3. Distribution of Electron Acceptor Demand

	Percent of Total	Hydrogen Demand (lb)
Aerobic Respiration	0.8%	1.357
Nitrate Reduction	0.1%	0.174
Sulfate Reduction	31.9%	52.763
Manganese Reduction	4.0%	6.589
Iron Reduction	2.4%	3.888
Methanogenesis	54.6%	90.224
Dechlorination	6.2%	10.255
Perchlorate Reduction	0.0%	0.000
Totals:	**100.00%**	**165.25**

Hydrogen demand in pounds/gallon:	7.68E-05
Hydrogen demand in grams per liter:	9.20E-03



4. Substrate Equivalents: Design Factor = 5.0

Product	Quantity (lb)	Quantity (gallons)	Effective Concentration (mg/L)	Effective concentration is for total volume of groundwater treated.
1. Sodium Lactate Product	38,298	3,482	1,028	as lactic acid
2. Molasses Product	29,227	2,436	977	as sucrose
3. Fructose Product	23,080	2,061	1,028	as fructose
4. Ethanol Product	11,801	1,710	526	as ethanol
5. Sweet Dry Whey (lactose)	18,204	sold by pound	710	as lactose
6. HRC®	13,993	sold by pound	623	as 40% lactic acid/40% glycerol
7. Linoleic Acid (Soybean Oil)	7,185	921	400	as soybean oil
8. Emulsified Vegetable Oil	11,975	1,535	400	as soybean oil

Notes:

1. Quantity assumes product is 60% sodium lactate by weight.
2. Quantity assumes product is 60% sucrose by weight and weighs 12 pounds per gallon.
3. Quantity assumes product is 80% fructose by weight and weighs 11.2 pounds per gallon.
4. Quantity assumes product is 80% ethanol by weight and weighs 6.9 pounds per gallon.
5. Quantity assumes product is 70% lactose by weight.
6. Quantity assumes HRC® is 40% lactic acid and 40% glycerol by weight.
7. Quantity of neat soybean oil, corn oil, or canola oil.
8. Quantity assumes commercial product is 60% soybean oil by weight.

SUBSTRATE ESTIMATING TOOL FOR ENHANCED ANAEROBIC BIOREMEDIATION OF CHLORINATED SOLVENTS

Version 1.2
November 2010

Site Data Input Table

TABLE S.1 - INPUT TABLE

Calculation Tables

Table S.2 - Substrate Calculations in Hydrogen

Table S.3 - Hydrogen Produced by Common Substrates

Table S.4 - Estimated Substrate Requirements for

Output Summary Table

TABLE S.5 - OUTPUT TABLE

PRINT SUMMARY TABLE

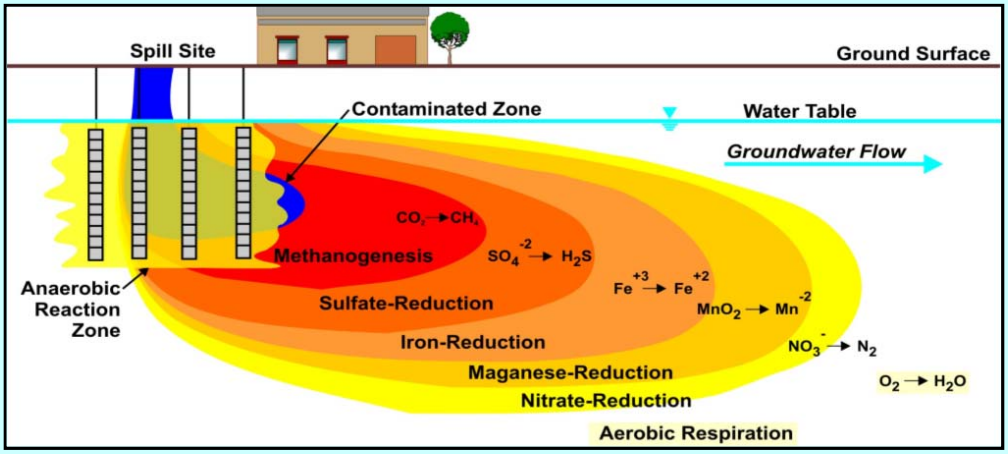


Table S.1 Input for Substrate Requirements in Hydrogen Equivalents

Site Name: Former Duso Chemical (Southwest - MHC-23)

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NOTE: Unshaded boxes are user input.

1. Treatment Zone Physical Dimensions	Values	Range	Units	User Notes
Width (Perpendicular to predominant groundwater flow direction)	32	1-10,000	feet	Former Duso Chemical (Southwest - MHC-23)
Length (Parallel to predominant groundwater flow)	35	1-1,000	feet	
Saturated Thickness	20	1-100	feet	treatment thickness (6-26)
Treatment Zone Cross Sectional Area	640	--	ft^2	
Treatment Zone Volume	22,400	--	ft^3	
Treatment Zone Total Pore Volume (total volume x total porosity)	53,631	--	gallons	
Treatment Zone Effective Pore Volume (total volume x effective porosity)	46,927	--	gallons	
Design Period of Performance	4.0	.5 to 5	year	
Design Factor (times the electron acceptor hydrogen demand)	5.0	2 to 20	unitless	AECOM recommendation to use a design factor of 2 to 5
2. Treatment Zone Hydrogeologic Properties				
Total Porosity	32%	.05-50	percent	Assumed for silty sand
Effective Porosity	28%	.05-50	percent	Assumed for silty sand (conservative high for higher PV)
Average Aquifer Hydraulic Conductivity	4	.01-1000	ft/day	average from MHBP RI
Average Hydraulic Gradient	0.033	0.0001-0.1	ft/ft	average from 2 values in RI
Average Groundwater Seepage Velocity through the Treatment Zone	0.47	--	ft/day	
Average Groundwater Seepage Velocity through the Treatment Zone	172.1	--	ft/yr	
Average Groundwater Discharge through the Treatment Zone	230,709	--	gallons/year	
Soil Bulk Density	1.65	1.4-2.0	gm/cm^3	Assumed
Soil Fraction Organic Carbon (foc)	3.00%	0.01-10	percent	Assumed
3. Native Electron Acceptors				
A. Aqueous-Phase Native Electron Acceptors				
Oxygen	0.6	0.01 to 10	mg/L	
Nitrate	0.10	0.1 to- 20	mg/L	not detected in RI
Sulfate	35	10 to 5,000	mg/L	RI readings 2, 11, 43, 79 in MHC-23 and MHC-26
Carbon Dioxide (estimated as the amount of Methane produced)	10.0	0.1 to 20	mg/L	
B. Solid-Phase Native Electron Acceptors				
Manganese (IV) (estimated as the amount of Mn (II) produced)	10	0.1 to 20	mg/L	RI Mn 4-8 mg/L in slightly reducing GW, assume some productior
Iron (III) (estimated as the amount of Fe (II) produced)	12	0.1 to 20	mg/L	RI ~10 mg/L in slightly reducing GW, assume some production
4. Contaminant Electron Acceptors				
Tetrachloroethene (PCE)	0.023	--	mg/L	max conc from MHC-23
Trichloroethene (TCE)	0.340	--	mg/L	
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	0.530	--	mg/L	
Vinyl Chloride (VC)	0.020	--	mg/L	
Carbon Tetrachloride (CT)	0.000	--	mg/L	
Trichloromethane (or chloroform) (CF)	0.002	--	mg/L	
Dichloromethane (or methylene chloride) (MC)	0.000	--	mg/L	
Chloromethane	0.000	--	mg/L	
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	--	mg/L	
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	3.900	--	mg/L	
Dichloroethane (1,1-DCA and 1,2-DCA)	0.590	--	mg/L	
Chloroethane	0.220	--	mg/L	need to add Chloroethane
Perchlorate	0.000	--	mg/L	
5. Aquifer Geochemistry (Optional Screening Parameters)				
A. Aqueous Geochemistry				
Oxidation-Reduction Potential (ORP)	-25	-400 to +500	mV	2012 Field Sheets (avg BIW-2S, MHC-23, BIW-5S)
Temperature	13	5.0 to 30	ºC	2012 Field Sheets
pH	7.1	4.0 to 10.0	su	2012 Field Sheets (7.06-7.4)
Alkalinity	300	10 to 1,000	mg/L	
Total Dissolved Solids (TDS, or salinity)		10 to 1,000	mg/L	
Specific Conductivity	2000	100 to 10,000	µs/cm	2012 Field Sheets Approximate Average
Chloride		10 to 10,000	mg/L	
Sulfide - Pre injection	0.0	0.1 to 100	mg/L	
Sulfide - Post injection	0.0	0.1 to 100	mg/L	
B. Aquifer Matrix				
Total Iron	10000	200 to 20,000	mg/kg	Assumed
Cation Exchange Capacity	NA	1.0 to 10	meq/100 g	
Neutralization Potential	10.0%	1.0 to 100	Percent as $CaCO_3$	Assumed

NOTES:

Table S.2 Substrate Calculations in Hydrogen Equivalents

Site Name: Former Duso Chemical (Southwest - MHC-23)

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NOTE: Open cells are user input.

1. Treatment Zone Physical Dimensions

	Values	Range	Units
Width (Perpendicular to predominant groundwater flow direction)	32	1-10,000	feet
Length (Parallel to predominant groundwater flow)	35	1-1,000	feet
Saturated Thickness	20	1-100	feet
Treatment Zone Cross Sectional Area	640	--	ft^2
Treatment Zone Volume	22,400	--	ft^3
Treatment Zone Effective Pore Volume (total volume x effective porosity)	46,927	--	gallons
Design Period of Performance	4.0	.5 to 5	year

2. Treatment Zone Hydrogeologic Properties

Total Porosity	0.32	.05-50	
Effective Porosity	0.28	.05-50	
Average Aquifer Hydraulic Conductivity	4	.01-1000	ft/day
Average Hydraulic Gradient	0.033	0.1-0.0001	ft/ft
Average Groundwater Seepage Velocity through the Treatment Zone	0.47	--	ft/day
Average Groundwater Seepage Velocity through the Treatment Zone	172.1	--	ft/yr
Average Groundwater Flux through the Treatment Zon 0	230,709	--	gallons/year
Soil Bulk Density	1.65	1.4-2.0	gm/cm^3
Soil Fraction Organic Carbon (foc)	0.03	0.0001-0.1	

3. Initial Treatment Cell Electron-Acceptor Demand (one total pore volume)

A. Aqueous-Phase Native Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Oxygen	0.6	0.23	7.94	0.03	4
Nitrate (denitrification)	0.1	0.04	12.30	0.00	5
Sulfate	35	13.71	11.91	1.15	8
Carbon Dioxide (estimated as the amount of methane produced)	10.0	3.92	1.99	1.97	8
Soluble Competing Electron Acceptor Demand (lb.)				**3.15**	

B. Solid-Phase Native Electron Acceptors (Based on manganese and iron produced)	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Manganese (IV) (estimated as the amount of Mn (II) produced)	10.0	80.92	27.25	2.97	2
Iron (III) (estimated as the amount of Fe (II) produced)	12.0	97.11	55.41	1.75	1
Solid-Phase Competing Electron Acceptor Demand (lb.)				**4.72**	

C. Soluble Contaminant Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	0.023	0.01	20.57	0.00	8
Trichloroethene (TCE)	0.340	0.13	21.73	0.01	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	0.530	0.21	24.05	0.01	4
Vinyl Chloride (VC)	0.020	0.01	31.00	0.00	2
Carbon Tetrachloride (CT)	0.000	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	0.002	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	0.000	0.00	21.06	0.00	4
Chloromethane	0.000	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	3.900	1.53	22.06	0.07	6
Dichloroethane (1,1-DCA and 1,2-DCA)	0.590	0.23	24.55	0.01	4
Chloroethane	0.220	0.09	32.00	0.00	2
Perchlorate	0.000	0.00	12.33	0.00	6
Total Soluble Contaminant Electron Acceptor Demand (lb.)				**0.10**	

D. Sorbed Contaminant Electron Acceptors (Soil Concentration = Koc x foc x Cgw)	Koc (mL/g)	Soil Conc. (mg/kg)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	263	0.18	0.42	20.57	0.02	8
Trichloroethene (TCE)	107	1.09	2.52	21.73	0.12	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	45	0.72	1.65	24.05	0.07	4
Vinyl Chloride (VC)	3.0	0.00	0.00	31.00	0.00	2
Carbon Tetrachloride (CT)	224	0.00	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	63	0.00	0.01	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	28	0.00	0.00	21.06	0.00	4
Chloromethane	25	0.00	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	117	0.00	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	105	12.29	28.35	22.06	1.29	6
Dichloroethane (1,1-DCA and 1,2-DCA)	30	0.53	1.23	24.55	0.05	4
Chloroethane	3	0.02	0.05	32.00	0.00	2
Perchlorate	0.0	0.00	0.00	12.33	0.00	6
Total Sorbed Contaminant Electron Acceptor Demand (lb.)					**1.54**	

(continued)

Table S.2 Substrate Calculations in Hydrogen Equivalents

4. Treatment Cell Electron-Acceptor Flux (per year)

A. Soluble Native Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Oxygen	0.6	1.16	7.94	0.15	4
Nitrate (denitrification)	0.1	0.19	10.25	0.02	5
Sulfate	35	67.38	11.91	5.66	8
Carbon Dioxide (estimated as the amount of Methane produced)	10	19.25	1.99	9.67	8
Total Competing Electron Acceptor Demand Flux (lb/yr)				**15.5**	

B. Soluble Contaminant Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	0.023	0.04	20.57	0.00	8
Trichloroethene (TCE)	0.340	0.65	21.73	0.03	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	0.530	1.02	24.05	0.04	4
Vinyl Chloride (VC)	0.020	0.04	31.00	0.00	2
Carbon Tetrachloride (CT)	0.000	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	0.002	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	0.000	0.00	21.06	0.00	4
Chloromethane	0.000	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	3.900	7.51	22.06	0.34	6
Dichloroethane (1,1-DCA and 1,2-DCA)	0.590	1.14	24.55	0.05	4
Chloroethane	0.220	0.42	32.00	0.01	2
Perchlorate	0.000	0.00	12.33	0.00	6
Total Soluble Contaminant Electron Acceptor Demand Flux (lb/yr)				**0.48**	

Initial Hydrogen Requirement First Year (lb)	**25.5**
Total Life-Cycle Hydrogen Requirement (lb)	**73.4**

5. Design Factors

Microbial Efficiency Uncertainty Factor	2X - 4X
Methane and Solid-Phase Electron Acceptor Uncertainty	2X - 4X
Remedial Design Factor (e.g., Substrate Leaving Reaction Zone)	1X - 3X
Design Factor	**5.0**
Total Life-Cycle Hydrogen Requirement with Design Factor (lb)	**367.0**

6. Acronyns and Abbreviations

°C =degrees celsius
µs/cm = microsiemens per centimeter
cm/day = centimeters per day
cm/sec = centimeters per second
ft^2 = square feet
ft/day = feet per day
ft/ft = foot per foot
ft/yr = feet per year
gm/cm^3 = grams per cubic centimeter
kg of CaCO3 per mg = kilograms of calcium carbonate per milligram
lb = pounds
meq/100 g = milliequivalents per 100 grams
mg/kg = milligrams per kilogram
mg/L = milligrams per liter
m/m = meters per meters
mV = millivolts
m/yr = meters per year
su = standard pH units
wt/wt H2 = concetration molecular hydrogen, weight per weight

Table S.3

Hydrogen Produced by Fermentation Reactions of Common Substrates

RETURN TO COVER PAGE

Substrate	Molecular Formula	Substrate Molecular Weight (gm/mole)	Moles of Hydrogen Produced per Mole of Substrate	Ratio of Hydrogen Produced to Substrate (gm/gm)	Range of Moles H_2/Mole Substrate
Lactic Acid	$C_3H_6O_3$	90.1	2	0.0448	**2 to 3**
Molasses (assuming 100% sucrose)	$C_{12}H_{22}O_{11}$	342	8	0.0471	**8 to 11**
High Fructose Corn Syrup (assuming 50% fructose and 50% glucose)	$C_6H_{12}O_6$	180	4	0.0448	**4 to 6**
Ethanol	C_2H_6O	46.1	2	0.0875	**2 to 6**
Whey (assuming 100% lactose)	$C_{12}H_{22}O_{11}$	342	11	0.0648	**11**
HRC® (assumes 40% lactic acid and 40% glycerol by weight)	$C_{39}H_{56}O_{39}$	956	28	0.0590	**28**
Linoleic Acid (Soybean Oil, Corn Oil, Cotton Oil)	$C_{18}H_{32}O_2$	281	16	0.1150	**16**

Table S.4

Estimated Substrate Requirements for Hydrogen Demand in Table S.3

Design Life (years): 4

Substrate	Design Factor	Pure Substrate Mass Required to Fulfill Hydrogen Demand (pounds)	Substrate Product Required to Fulfill Hydrogen Demand (pounds)	Substrate Mass Required to Fulfill Hydrogen Demand (milligrams)	Effective Substrate Concentration (mg/L)
Lactic Acid	5.0	8,199	8,199	3.72E+09	1,013
Sodium Lactate Product (60 percent solution)	5.0	8,199	17,011	3.72E+09	1,013
Molasses (assuming 6 0	5.0	7,789	12,982	3.53E+09	962
HFCS (assuming 40% fructose and 40% glucose by weight)	5.0	8,201	10,251	3.72E+09	1,013
Ethanol Product (assuming 80% ethanol by weight)	5.0	4,193	5,242	1.90E+09	518
Whey (assuming 100% lactose)	5.0	5,660	8,086	2.57E+09	699
HRC® (assumes 40% lactic acid and 40% glycerol by weight)	5.0	6,215	6,215	2.82E+09	614
Linoleic Acid (Soybean Oil, Corn Oil, Cotton Oil)	5.0	3,191	3,191	1.45E+09	394
Commercial Vegetable Oil Emulsion Product (60% oil by weight)	5.0	3,191	5,319	1.45E+09	394

NOTES: Sodium Lactate Product

1. Assumes sodium lactate product is 60 percent sodium lactate by weight.
2. Molecular weight of sodium lactate (CH_3-CHOH-COONa) = 112.06.
3. Molecular weight of lactic Acid ($C_6H_6O_3$) = 90.08 .
4. Therefore, sodium lactate product yields 48.4 (0.60 x (90.08/112.06)) percent by weight lactic acid.
5. Weight of sodium lactate product = 11.0 pounds per gallon.
6. Pounds per gallon of lactic acid in product = 1.323 x 8.33 lb/gal H2O x 0.60 x (90.08/112.06) = 5.31 lb/gal.

NOTES: Standard HRC Product

1. Assumes HRC product is 40 percent lactic acid and 40 percent glycerol by weight.
2. HRC® weighs approximately 9.18 pounds per gallon.

NOTES: Vegetable Oil Emulsion Product

1. Assumes emulsion product is 60 percent soybean oil by weight.
2. Soybean oil is 7.8 pounds per gallon.
3. Assumes specific gravity of emulsion product is 0.96.

Table S.5 Output for Substrate Requirements in Hydrogen Equivalents

Site Name: Former Duso Chemical (Southwest - MHC-23)

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1. Treatment Zone Physical Dimensions

	Values	Units	Values	Units
Width (perpendicular to groundwater flow)	32	feet	10	meters
Length (parallel to groundwater flow)	35	feet	10.7	meters
Saturated Thickness	20	feet	6.1	meters
Design Period of Performance	4	years	4	years

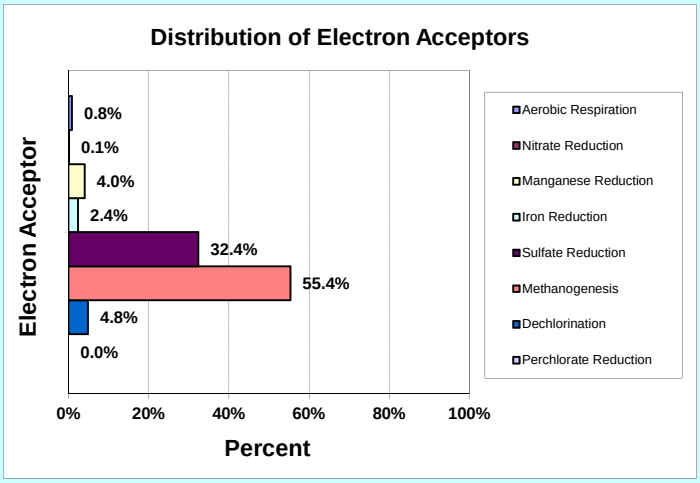
2. Treatment Zone Hydrogeologic Properties

	Values	Units	Values	Units
Total Porosity	0.32	percent	0.32	percent
Effective Porosity	0.28	percent	0.28	percent
Average Aquifer Hydraulic Conductivity	4	ft/day	1.4E-03	cm/sec
Average Hydraulic Gradient	0.033	ft/ft	0.033	m/m
Average Groundwater Seepage Velocity	0.47	ft/day	1.4E+01	cm/day
Average Groundwater Seepage Velocity	172	ft/yr	52.4	m/yr
Effective Treatment Zone Pore Volume	46,927	gallons	177,633	liters
Groundwater Flux (per year)	230,709	gallons/year	873,304	liters/year
Total Groundwater Volume Treated (over entire design period)	969,763	gallons total	3,670,850	liters total

3. Distribution of Electron Acceptor Demand

	Percent of Total	Hydrogen Demand (lb)
Aerobic Respiration	0.8%	0.612
Nitrate Reduction	0.1%	0.078
Sulfate Reduction	32.4%	23.781
Manganese Reduction	4.0%	2.970
Iron Reduction	2.4%	1.753
Methanogenesis	55.4%	40.664
Dechlorination	4.8%	3.543
Perchlorate Reduction	0.0%	0.000
Totals:	**100.00%**	**73.40**

Hydrogen demand in pounds/gallon:	7.57E-05
Hydrogen demand in grams per liter:	9.07E-03



4. Substrate Equivalents: Design Factor = 5.0

Product	Quantity (lb)	Quantity (gallons)	Effective Concentration (mg/L)	Effective concentration is for total volume of groundwater treated.
1. Sodium Lactate Product	17,011	1,546	1,013	as lactic acid
2. Molasses Product	12,982	1,082	962	as sucrose
3. Fructose Product	10,251	915	1,013	as fructose
4. Ethanol Product	5,242	760	518	as ethanol
5. Sweet Dry Whey (lactose)	8,086	sold by pound	699	as lactose
6. HRC®	6,215	sold by pound	614	as 40% lactic acid/40% glycerol
7. Linoleic Acid (Soybean Oil)	3,191	409	394	as soybean oil
8. Emulsified Vegetable Oil	5,319	682	394	as soybean oil

Notes:

1. Quantity assumes product is 60% sodium lactate by weight.
2. Quantity assumes product is 60% sucrose by weight and weighs 12 pounds per gallon.
3. Quantity assumes product is 80% fructose by weight and weighs 11.2 pounds per gallon.
4. Quantity assumes product is 80% ethanol by weight and weighs 6.9 pounds per gallon.
5. Quantity assumes product is 70% lactose by weight.
6. Quantity assumes HRC® is 40% lactic acid and 40% glycerol by weight.
7. Quantity of neat soybean oil, corn oil, or canola oil.
8. Quantity assumes commercial product is 60% soybean oil by weight.

SUBSTRATE ESTIMATING TOOL FOR ENHANCED ANAEROBIC BIOREMEDIATION OF CHLORINATED SOLVENTS

Version 1.2
November 2010

Site Data Input Table

TABLE S.1 - INPUT TABLE

Calculation Tables

Table S.2 - Substrate Calculations in Hydrogen

Table S.3 - Hydrogen Produced by Common Substrates

Table S.4 - Estimated Substrate Requirements for

Output Summary Table

TABLE S.5 - OUTPUT TABLE

PRINT SUMMARY TABLE

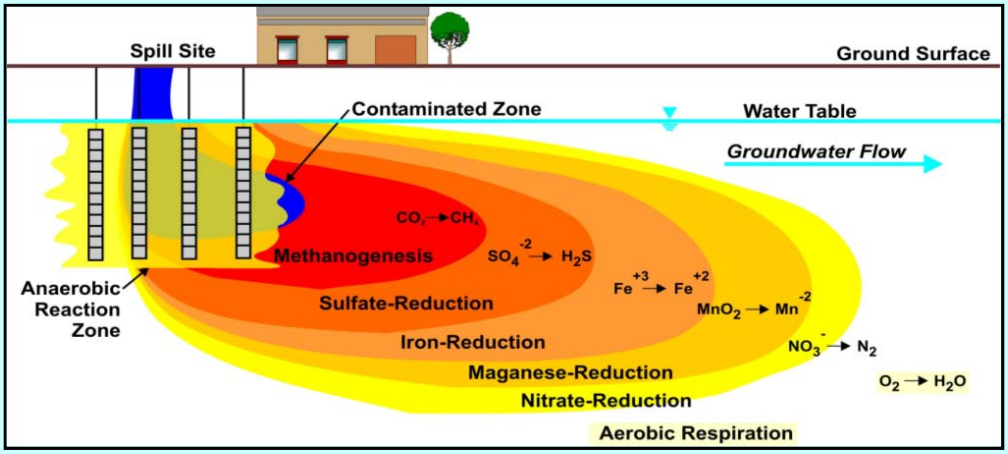


Table S.1 Input for Substrate Requirements in Hydrogen Equivalents

Site Name: Former Duso Chemical (West Center - BIW-5D)

RETURN TO COVER PAGE

NOTE: Unshaded boxes are user input.

1. Treatment Zone Physical Dimensions	Values	Range	Units	User Notes
Width (Perpendicular to predominant groundwater flow direction)	40	1-10,000	feet	Former Duso Chemical (West Center - BIW-5D)
Length (Parallel to predominant groundwater flow)	38	1-1,000	feet	
Saturated Thickness	14	1-100	feet	treatment thickness (10-24)
Treatment Zone Cross Sectional Area	560	--	ft^2	assume EHC treatment for this interval
Treatment Zone Volume	21,280	--	ft^3	
Treatment Zone Total Pore Volume (total volume x total porosity)	50,949	--	gallons	
Treatment Zone Effective Pore Volume (total volume x effective porosity)	44,581	--	gallons	
Design Period of Performance	4.0	.5 to 5	year	
Design Factor (times the electron acceptor hydrogen demand)	5.0	2 to 20	unitless	AECOM recommendation to use a design factor of 2 to 5
2. Treatment Zone Hydrogeologic Properties				
Total Porosity	32%	.05-50	percent	Assumed for silty sand
Effective Porosity	28%	.05-50	percent	Assumed for silty sand (conservative high for higher PV)
Average Aquifer Hydraulic Conductivity	4	.01-1000	ft/day	average from MHBP RI
Average Hydraulic Gradient	0.033	0.0001-0.1	ft/ft	average from 2 values in RI
Average Groundwater Seepage Velocity through the Treatment Zone	0.47	--	ft/day	
Average Groundwater Seepage Velocity through the Treatment Zone	172.1	--	ft/yr	
Average Groundwater Discharge through the Treatment Zone	201,870	--	gallons/year	
Soil Bulk Density	1.65	1.4-2.0	gm/cm^3	Assumed
Soil Fraction Organic Carbon (foc)	3.00%	0.01-10	percent	Assumed
3. Native Electron Acceptors				
A. Aqueous-Phase Native Electron Acceptors				
Oxygen	0.6	0.01 to 10	mg/L	
Nitrate	0.10	0.1 to- 20	mg/L	not detected in RI
Sulfate	35	10 to 5,000	mg/L	RI readings 2, 11, 43, 79 in MHC-23 and MHC-26
Carbon Dioxide (estimated as the amount of Methane produced)	10.0	0.1 to 20	mg/L	
B. Solid-Phase Native Electron Acceptors				
Manganese (IV) (estimated as the amount of Mn (II) produced)	10	0.1 to 20	mg/L	RI Mn 4-8 mg/L in slightly reducing GW, assume some productior
Iron (III) (estimated as the amount of Fe (II) produced)	12	0.1 to 20	mg/L	RI ~10 mg/L in slightly reducing GW, assume some production
4. Contaminant Electron Acceptors				
Tetrachloroethene (PCE)	0.056	--	mg/L	max conc from BIW-5D
Trichloroethene (TCE)	0.049	--	mg/L	
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	2.000	--	mg/L	
Vinyl Chloride (VC)	0.210	--	mg/L	
Carbon Tetrachloride (CT)	0.000	--	mg/L	
Trichloromethane (or chloroform) (CF)	0.000	--	mg/L	
Dichloromethane (or methylene chloride) (MC)	0.025	--	mg/L	
Chloromethane	0.000	--	mg/L	
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	--	mg/L	
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	33.000	--	mg/L	
Dichloroethane (1,1-DCA and 1,2-DCA)	87.000	--	mg/L	
Chloroethane	0.400	--	mg/L	need to add Chloroethane
Perchlorate	0.000	--	mg/L	
5. Aquifer Geochemistry (Optional Screening Parameters)				
A. Aqueous Geochemistry				
Oxidation-Reduction Potential (ORP)	-25	-400 to +500	mV	2012 Field Sheets (avg BIW-2S, MHC-23, BIW-5S)
Temperature	13	5.0 to 30	ºC	2012 Field Sheets
pH	7.1	4.0 to 10.0	su	2012 Field Sheets (7.06-7.4)
Alkalinity	300	10 to 1,000	mg/L	
Total Dissolved Solids (TDS, or salinity)		10 to 1,000	mg/L	
Specific Conductivity	2000	100 to 10,000	µs/cm	2012 Field Sheets Approximate Average
Chloride		10 to 10,000	mg/L	
Sulfide - Pre injection	0.0	0.1 to 100	mg/L	
Sulfide - Post injection	0.0	0.1 to 100	mg/L	
B. Aquifer Matrix				
Total Iron	10000	200 to 20,000	mg/kg	Assumed
Cation Exchange Capacity	NA	1.0 to 10	meq/100 g	
Neutralization Potential	10.0%	1.0 to 100	Percent as $CaCO_3$	Assumed

NOTES:

Table S.2 Substrate Calculations in Hydrogen Equivalents

Site Name: Former Duso Chemical (West Center - BIW-5D)

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NOTE: Open cells are user input.

1. Treatment Zone Physical Dimensions

	Values	Range	Units
Width (Perpendicular to predominant groundwater flow direction)	40	1-10,000	feet
Length (Parallel to predominant groundwater flow)	38	1-1,000	feet
Saturated Thickness	14	1-100	feet
Treatment Zone Cross Sectional Area	560	--	ft^2
Treatment Zone Volume	21,280	--	ft^3
Treatment Zone Effective Pore Volume (total volume x effective porosity)	44,581	--	gallons
Design Period of Performance	4.0	.5 to 5	year

2. Treatment Zone Hydrogeologic Properties

Total Porosity	0.32	.05-50	
Effective Porosity	0.28	.05-50	
Average Aquifer Hydraulic Conductivity	4	.01-1000	ft/day
Average Hydraulic Gradient	0.033	0.1-0.0001	ft/ft
Average Groundwater Seepage Velocity through the Treatment Zone	0.47	--	ft/day
Average Groundwater Seepage Velocity through the Treatment Zone	172.1	--	ft/yr
Average Groundwater Flux through the Treatment Zon 0	201,870	--	gallons/year
Soil Bulk Density	1.65	1.4-2.0	gm/cm^3
Soil Fraction Organic Carbon (foc)	0.03	0.0001-0.1	

3. Initial Treatment Cell Electron-Acceptor Demand (one total pore volume)

A. Aqueous-Phase Native Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Oxygen	0.6	0.22	7.94	0.03	4
Nitrate (denitrification)	0.1	0.04	12.30	0.00	5
Sulfate	35	13.02	11.91	1.09	8
Carbon Dioxide (estimated as the amount of methane produced)	10.0	3.72	1.99	1.87	8
Soluble Competing Electron Acceptor Demand (lb.)				**2.99**	

B. Solid-Phase Native Electron Acceptors (Based on manganese and iron produced)	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Manganese (IV) (estimated as the amount of Mn (II) produced)	10.0	71.10	27.25	2.61	2
Iron (III) (estimated as the amount of Fe (II) produced)	12.0	85.32	55.41	1.54	1
Solid-Phase Competing Electron Acceptor Demand (lb.)				**4.15**	

C. Soluble Contaminant Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	0.056	0.02	20.57	0.00	8
Trichloroethene (TCE)	0.049	0.02	21.73	0.00	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	2.000	0.74	24.05	0.03	4
Vinyl Chloride (VC)	0.210	0.08	31.00	0.00	2
Carbon Tetrachloride (CT)	0.000	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	0.000	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	0.025	0.01	21.06	0.00	4
Chloromethane	0.000	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	33.000	12.28	22.06	0.56	6
Dichloroethane (1,1-DCA and 1,2-DCA)	87.000	32.36	24.55	1.32	4
Chloroethane	0.400	0.15	32.00	0.00	2
Perchlorate	0.000	0.00	12.33	0.00	6
Total Soluble Contaminant Electron Acceptor Demand (lb.)				**1.92**	

D. Sorbed Contaminant Electron Acceptors (Soil Concentration = Koc x foc x Cgw)	Koc (mL/g)	Soil Conc. (mg/kg)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	263	0.44	0.97	20.57	0.05	8
Trichloroethene (TCE)	107	0.16	0.34	21.73	0.02	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	45	2.70	5.92	24.05	0.25	4
Vinyl Chloride (VC)	3.0	0.02	0.04	31.00	0.00	2
Carbon Tetrachloride (CT)	224	0.00	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	63	0.00	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	28	0.02	0.05	21.06	0.00	4
Chloromethane	25	0.00	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	117	0.00	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	105	103.95	227.90	22.06	10.33	6
Dichloroethane (1,1-DCA and 1,2-DCA)	30	78.30	171.66	24.55	6.99	4
Chloroethane	3	0.04	0.08	32.00	0.00	2
Perchlorate	0.0	0.00	0.00	12.33	0.00	6
Total Sorbed Contaminant Electron Acceptor Demand (lb.)					**17.64**	

(continued)

Table S.2 Substrate Calculations in Hydrogen Equivalents

4. Treatment Cell Electron-Acceptor Flux (per year)

A. Soluble Native Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Oxygen	0.6	1.01	7.94	0.13	4
Nitrate (denitrification)	0.1	0.17	10.25	0.02	5
Sulfate	35	58.96	11.91	4.95	8
Carbon Dioxide (estimated as the amount of Methane produced)	10	16.85	1.99	8.46	8
Total Competing Electron Acceptor Demand Flux (lb/yr)				**13.6**	

B. Soluble Contaminant Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	0.056	0.09	20.57	0.00	8
Trichloroethene (TCE)	0.049	0.08	21.73	0.00	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	2.000	3.37	24.05	0.14	4
Vinyl Chloride (VC)	0.210	0.35	31.00	0.01	2
Carbon Tetrachloride (CT)	0.000	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	0.000	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	0.025	0.04	21.06	0.00	4
Chloromethane	0.000	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	33.000	55.59	22.06	2.52	6
Dichloroethane (1,1-DCA and 1,2-DCA)	87.000	146.55	24.55	5.97	4
Chloroethane	0.400	0.67	32.00	0.02	2
Perchlorate	0.000	0.00	12.33	0.00	6
Total Soluble Contaminant Electron Acceptor Demand Flux (lb/yr)				**8.67**	

Initial Hydrogen Requirement First Year (lb)	**48.9**
Total Life-Cycle Hydrogen Requirement (lb)	**115.6**

5. Design Factors

Microbial Efficiency Uncertainty Factor	2X - 4X
Methane and Solid-Phase Electron Acceptor Uncertainty	2X - 4X
Remedial Design Factor (e.g., Substrate Leaving Reaction Zone)	1X - 3X
Design Factor	**5.0**
Total Life-Cycle Hydrogen Requirement with Design Factor (lb)	**578.1**

6. Acronyns and Abbreviations

^{o}C =degrees celsius
µs/cm = microsiemens per centimeter
cm/day = centimeters per day
cm/sec = centimeters per second
ft^2 = square feet
ft/day = feet per day
ft/ft = foot per foot
ft/yr = feet per year
gm/cm^3 = grams per cubic centimeter
kg of CaCO3 per mg = kilograms of calcium carbonate per milligram
lb = pounds
meq/100 g = milliequivalents per 100 grams
mg/kg = milligrams per kilogram
mg/L = milligrams per liter
m/m = meters per meters
mV = millivolts
m/yr = meters per year
su = standard pH units
wt/wt H2 = concetration molecular hydrogen, weight per weight

Table S.3

Hydrogen Produced by Fermentation Reactions of Common Substrates

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Substrate	Molecular Formula	Substrate Molecular Weight (gm/mole)	Moles of Hydrogen Produced per Mole of Substrate	Ratio of Hydrogen Produced to Substrate (gm/gm)	Range of Moles H_2/Mole Substrate
Lactic Acid	$C_3H_6O_3$	90.1	2	0.0448	**2 to 3**
Molasses (assuming 100% sucrose)	$C_{12}H_{22}O_{11}$	342	8	0.0471	**8 to 11**
High Fructose Corn Syrup (assuming 50% fructose and 50% glucose)	$C_6H_{12}O_6$	180	4	0.0448	**4 to 6**
Ethanol	C_2H_6O	46.1	2	0.0875	**2 to 6**
Whey (assuming 100% lactose)	$C_{12}H_{22}O_{11}$	342	11	0.0648	**11**
HRC® (assumes 40% lactic acid and 40% glycerol by weight)	$C_{39}H_{56}O_{39}$	956	28	0.0590	**28**
Linoleic Acid (Soybean Oil, Corn Oil, Cotton Oil)	$C_{18}H_{32}O_2$	281	16	0.1150	**16**

Table S.4

Estimated Substrate Requirements for Hydrogen Demand in Table S.3

Design Life (years): 4

Substrate	Design Factor	Pure Substrate Mass Required to Fulfill Hydrogen Demand (pounds)	Substrate Product Required to Fulfill Hydrogen Demand (pounds)	Substrate Mass Required to Fulfill Hydrogen Demand (milligrams)	Effective Substrate Concentration (mg/L)
Lactic Acid	5.0	12,916	12,916	5.86E+09	1,816
Sodium Lactate Product (60 percent solution)	5.0	12,916	26,796	5.86E+09	1,816
Molasses (assuming 6 0	5.0	12,270	20,450	5.57E+09	1,726
HFCS (assuming 40% fructose and 40% glucose by weight)	5.0	12,919	16,148	5.86E+09	1,817
Ethanol Product (assuming 80% ethanol by weight)	5.0	6,606	8,257	3.00E+09	929
Whey (assuming 100% lactose)	5.0	8,916	12,737	4.04E+09	1,254
HRC® (assumes 40% lactic acid and 40% glycerol by weight)	5.0	9,791	9,791	4.44E+09	1,102
Linoleic Acid (Soybean Oil, Corn Oil, Cotton Oil)	5.0	5,027	5,027	2.28E+09	707
Commercial Vegetable Oil Emulsion Product (60% oil by weight)	5.0	5,027	8,379	2.28E+09	707

NOTES: Sodium Lactate Product

1. Assumes sodium lactate product is 60 percent sodium lactate by weight.
2. Molecular weight of sodium lactate (CH_3-CHOH-COONa) = 112.06.
3. Molecular weight of lactic Acid ($C_6H_6O_3$) = 90.08 .
4. Therefore, sodium lactate product yields 48.4 (0.60 x (90.08/112.06)) percent by weight lactic acid.
5. Weight of sodium lactate product = 11.0 pounds per gallon.
6. Pounds per gallon of lactic acid in product = 1.323 x 8.33 lb/gal H2O x 0.60 x (90.08/112.06) = 5.31 lb/gal.

NOTES: Standard HRC Product

1. Assumes HRC product is 40 percent lactic acid and 40 percent glycerol by weight.
2. HRC® weighs approximately 9.18 pounds per gallon.

NOTES: Vegetable Oil Emulsion Product

1. Assumes emulsion product is 60 percent soybean oil by weight.
2. Soybean oil is 7.8 pounds per gallon.
3. Assumes specific gravity of emulsion product is 0.96.

Table S.5 Output for Substrate Requirements in Hydrogen Equivalents

Site Name: Former Duso Chemical (West Center - BIW-5D)

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1. Treatment Zone Physical Dimensions

	Values	Units	Values	Units
Width (perpendicular to groundwater flow)	40	feet	12	meters
Length (parallel to groundwater flow)	38	feet	11.6	meters
Saturated Thickness	14	feet	4.3	meters
Design Period of Performance	4	years	4	years

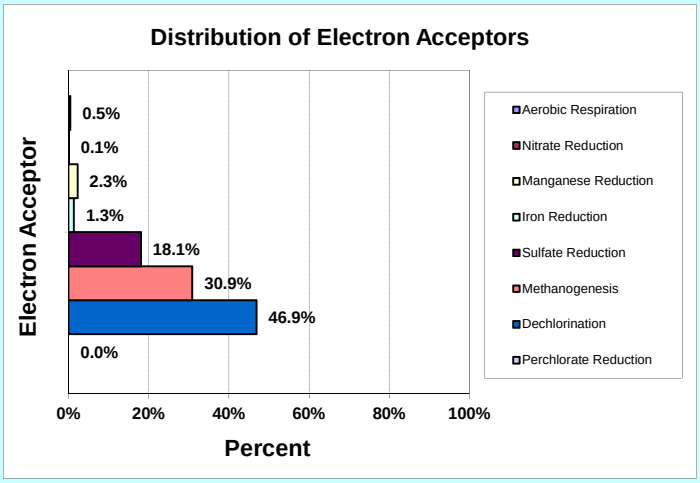
2. Treatment Zone Hydrogeologic Properties

	Values	Units	Values	Units
Total Porosity	0.32	percent	0.32	percent
Effective Porosity	0.28	percent	0.28	percent
Average Aquifer Hydraulic Conductivity	4	ft/day	1.4E-03	cm/sec
Average Hydraulic Gradient	0.033	ft/ft	0.033	m/m
Average Groundwater Seepage Velocity	0.47	ft/day	1.4E+01	cm/day
Average Groundwater Seepage Velocity	172	ft/yr	52.4	m/yr
Effective Treatment Zone Pore Volume	44,581	gallons	168,752	liters
Groundwater Flux (per year)	201,870	gallons/year	764,141	liters/year
Total Groundwater Volume Treated (over entire design period)	852,062	gallons total	3,225,316	liters total

3. Distribution of Electron Acceptor Demand

	Percent of Total	Hydrogen Demand (lb)
Aerobic Respiration	0.5%	0.537
Nitrate Reduction	0.1%	0.069
Sulfate Reduction	18.1%	20.894
Manganese Reduction	2.3%	2.609
Iron Reduction	1.3%	1.540
Methanogenesis	30.9%	35.729
Dechlorination	46.9%	54.243
Perchlorate Reduction	0.0%	0.000
Totals:	**100.00%**	**115.62**

Hydrogen demand in pounds/gallon:	1.36E-04
Hydrogen demand in grams per liter:	1.63E-02



4. Substrate Equivalents: Design Factor = 5.0

Product	Quantity (lb)	Quantity (gallons)	Effective Concentration (mg/L)	Effective concentration is for total volume of groundwater treated.
1. Sodium Lactate Product	26,796	2,436	1,816	as lactic acid
2. Molasses Product	20,450	1,704	1,726	as sucrose
3. Fructose Product	16,148	1,442	1,817	as fructose
4. Ethanol Product	8,257	1,197	929	as ethanol
5. Sweet Dry Whey (lactose)	12,737	sold by pound	1,254	as lactose
6. HRC®	9,791	sold by pound	1,102	as 40% lactic acid/40% glycerol
7. Linoleic Acid (Soybean Oil)	5,027	645	707	as soybean oil
8. Emulsified Vegetable Oil	8,379	1,074	707	as soybean oil

Notes:

1. Quantity assumes product is 60% sodium lactate by weight.
2. Quantity assumes product is 60% sucrose by weight and weighs 12 pounds per gallon.
3. Quantity assumes product is 80% fructose by weight and weighs 11.2 pounds per gallon.
4. Quantity assumes product is 80% ethanol by weight and weighs 6.9 pounds per gallon.
5. Quantity assumes product is 70% lactose by weight.
6. Quantity assumes HRC® is 40% lactic acid and 40% glycerol by weight.
7. Quantity of neat soybean oil, corn oil, or canola oil.
8. Quantity assumes commercial product is 60% soybean oil by weight.

SUBSTRATE ESTIMATING TOOL FOR ENHANCED ANAEROBIC BIOREMEDIATION OF CHLORINATED SOLVENTS

Version 1.2
November 2010

Site Data Input Table

TABLE S.1 - INPUT TABLE

Calculation Tables

Table S.2 - Substrate Calculations in Hydrogen

Table S.3 - Hydrogen Produced by Common Substrates

Table S.4 - Estimated Substrate Requirements for

Output Summary Table

TABLE S.5 - OUTPUT TABLE

PRINT SUMMARY TABLE

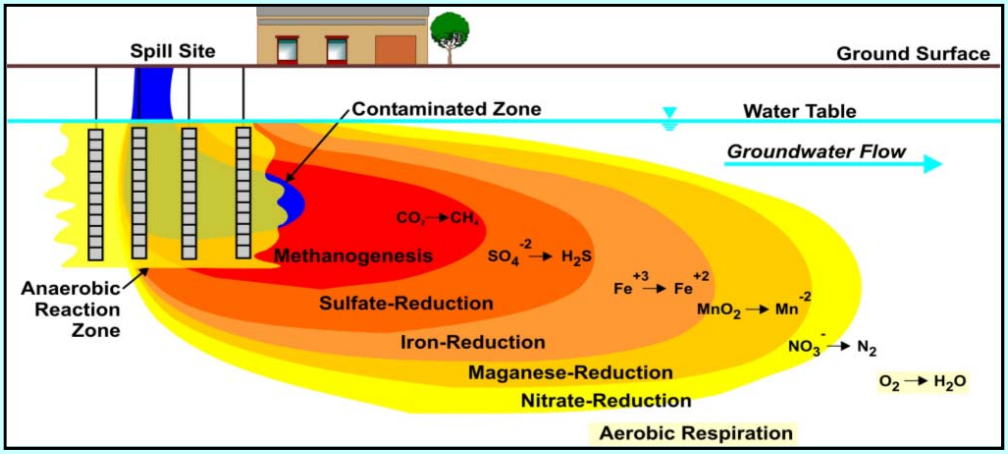


Table S.1 Input for Substrate Requirements in Hydrogen Equivalents

Site Name: ormer Duso Chemical (West Center Shallow - BIW-5S)

RETURN TO COVER PAGE

NOTE: Unshaded boxes are user input.

1. Treatment Zone Physical Dimensions	Values	Range	Units	User Notes
Width (Perpendicular to predominant groundwater flow direction)	40	1-10,000	feet	Former Duso Chemical (West Center Shallow - BIW-5S)
Length (Parallel to predominant groundwater flow)	38	1-1,000	feet	
Saturated Thickness	6	1-100	feet	treatment thickness (4-10) for EOS
Treatment Zone Cross Sectional Area	240	--	ft^2	assume EHC for 10-24'
Treatment Zone Volume	9,120	--	ft^3	
Treatment Zone Total Pore Volume (total volume x total porosity)	21,835	--	gallons	
Treatment Zone Effective Pore Volume (total volume x effective porosity)	19,106	--	gallons	
Design Period of Performance	4.0	.5 to 5	year	
Design Factor (times the electron acceptor hydrogen demand)	5.0	2 to 20	unitless	AECOM recommendation to use a design factor of 2 to 5
2. Treatment Zone Hydrogeologic Properties				
Total Porosity	32%	.05-50	percent	Assumed for silty sand
Effective Porosity	28%	.05-50	percent	Assumed for silty sand (conservative high for higher PV)
Average Aquifer Hydraulic Conductivity	4	.01-1000	ft/day	average from MHBP RI
Average Hydraulic Gradient	0.033	0.0001-0.1	ft/ft	average from 2 values in RI
Average Groundwater Seepage Velocity through the Treatment Zone	0.47	--	ft/day	
Average Groundwater Seepage Velocity through the Treatment Zone	172.1	--	ft/yr	
Average Groundwater Discharge through the Treatment Zone	86,516	--	gallons/year	
Soil Bulk Density	1.65	1.4-2.0	gm/cm^3	Assumed
Soil Fraction Organic Carbon (foc)	3.00%	0.01-10	percent	Assumed
3. Native Electron Acceptors				
A. Aqueous-Phase Native Electron Acceptors				
Oxygen	0.6	0.01 to 10	mg/L	
Nitrate	0.10	0.1 to- 20	mg/L	not detected in RI
Sulfate	35	10 to 5,000	mg/L	RI readings 2, 11, 43, 79 in MHC-23 and MHC-26
Carbon Dioxide (estimated as the amount of Methane produced)	10.0	0.1 to 20	mg/L	
B. Solid-Phase Native Electron Acceptors				
Manganese (IV) (estimated as the amount of Mn (II) produced)	10	0.1 to 20	mg/L	RI Mn 4-8 mg/L in slightly reducing GW, assume some productior
Iron (III) (estimated as the amount of Fe (II) produced)	12	0.1 to 20	mg/L	RI ~10 mg/L in slightly reducing GW, assume some production
4. Contaminant Electron Acceptors				
Tetrachloroethene (PCE)	0.050	--	mg/L	max conc from BIW-5S
Trichloroethene (TCE)	0.050	--	mg/L	
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	0.200	--	mg/L	
Vinyl Chloride (VC)	0.050	--	mg/L	
Carbon Tetrachloride (CT)	0.000	--	mg/L	
Trichloromethane (or chloroform) (CF)	0.000	--	mg/L	
Dichloromethane (or methylene chloride) (MC)	0.025	--	mg/L	
Chloromethane	0.000	--	mg/L	
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	--	mg/L	
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	0.600	--	mg/L	
Dichloroethane (1,1-DCA and 1,2-DCA)	1.000	--	mg/L	
Chloroethane	0.200	--	mg/L	need to add Chloroethane
Perchlorate	0.000	--	mg/L	
5. Aquifer Geochemistry (Optional Screening Parameters)				
A. Aqueous Geochemistry				
Oxidation-Reduction Potential (ORP)	-25	-400 to +500	mV	2012 Field Sheets (avg BIW-2S, MHC-23, BIW-5S)
Temperature	13	5.0 to 30	ºC	2012 Field Sheets
pH	7.1	4.0 to 10.0	su	2012 Field Sheets (7.06-7.4)
Alkalinity	300	10 to 1,000	mg/L	
Total Dissolved Solids (TDS, or salinity)		10 to 1,000	mg/L	
Specific Conductivity	2000	100 to 10,000	µs/cm	2012 Field Sheets Approximate Average
Chloride		10 to 10,000	mg/L	
Sulfide - Pre injection	0.0	0.1 to 100	mg/L	
Sulfide - Post injection	0.0	0.1 to 100	mg/L	
B. Aquifer Matrix				
Total Iron	10000	200 to 20,000	mg/kg	Assumed
Cation Exchange Capacity	NA	1.0 to 10	meq/100 g	
Neutralization Potential	10.0%	1.0 to 100	Percent as $CaCO_3$	Assumed

NOTES:

Table S.2 Substrate Calculations in Hydrogen Equivalents

Site Name: Former Duso Chemical (West Center Shallow - BIW-5S)

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NOTE: Open cells are user input.

1. Treatment Zone Physical Dimensions

	Values	Range	Units
Width (Perpendicular to predominant groundwater flow direction)	40	1-10,000	feet
Length (Parallel to predominant groundwater flow)	38	1-1,000	feet
Saturated Thickness	6	1-100	feet
Treatment Zone Cross Sectional Area	240	--	ft^2
Treatment Zone Volume	9,120	--	ft^3
Treatment Zone Effective Pore Volume (total volume x effective porosity)	19,106	--	gallons
Design Period of Performance	4.0	.5 to 5	year

2. Treatment Zone Hydrogeologic Properties

Total Porosity	0.32	.05-50	
Effective Porosity	0.28	.05-50	
Average Aquifer Hydraulic Conductivity	4	.01-1000	ft/day
Average Hydraulic Gradient	0.033	0.1-0.0001	ft/ft
Average Groundwater Seepage Velocity through the Treatment Zone	0.47	--	ft/day
Average Groundwater Seepage Velocity through the Treatment Zone	172.1	--	ft/yr
Average Groundwater Flux through the Treatment Zon 0	86,516	--	gallons/year
Soil Bulk Density	1.65	1.4-2.0	gm/cm^3
Soil Fraction Organic Carbon (foc)	0.03	0.0001-0.1	

3. Initial Treatment Cell Electron-Acceptor Demand (one total pore volume)

A. Aqueous-Phase Native Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Oxygen	0.6	0.10	7.94	0.01	4
Nitrate (denitrification)	0.1	0.02	12.30	0.00	5
Sulfate	35	5.58	11.91	0.47	8
Carbon Dioxide (estimated as the amount of methane produced)	10.0	1.59	1.99	0.80	8
Soluble Competing Electron Acceptor Demand (lb.)				**1.28**	

B. Solid-Phase Native Electron Acceptors (Based on manganese and iron produced)	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Manganese (IV) (estimated as the amount of Mn (II) produced)	10.0	30.47	27.25	1.12	2
Iron (III) (estimated as the amount of Fe (II) produced)	12.0	36.57	55.41	0.66	1
Solid-Phase Competing Electron Acceptor Demand (lb.)				**1.78**	

C. Soluble Contaminant Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	0.050	0.01	20.57	0.00	8
Trichloroethene (TCE)	0.050	0.01	21.73	0.00	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	0.200	0.03	24.05	0.00	4
Vinyl Chloride (VC)	0.050	0.01	31.00	0.00	2
Carbon Tetrachloride (CT)	0.000	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	0.000	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	0.025	0.00	21.06	0.00	4
Chloromethane	0.000	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	0.600	0.10	22.06	0.00	6
Dichloroethane (1,1-DCA and 1,2-DCA)	1.000	0.16	24.55	0.01	4
Chloroethane	0.200	0.03	32.00	0.00	2
Perchlorate	0.000	0.00	12.33	0.00	6
Total Soluble Contaminant Electron Acceptor Demand (lb.)				**0.01**	

D. Sorbed Contaminant Electron Acceptors (Soil Concentration = Koc x foc x Cgw)	Koc (mL/g)	Soil Conc. (mg/kg)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	263	0.39	0.37	20.57	0.02	8
Trichloroethene (TCE)	107	0.16	0.15	21.73	0.01	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	45	0.27	0.25	24.05	0.01	4
Vinyl Chloride (VC)	3.0	0.00	0.00	31.00	0.00	2
Carbon Tetrachloride (CT)	224	0.00	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	63	0.00	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	28	0.02	0.02	21.06	0.00	4
Chloromethane	25	0.00	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	117	0.00	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	105	1.89	1.78	22.06	0.08	6
Dichloroethane (1,1-DCA and 1,2-DCA)	30	0.90	0.85	24.55	0.03	4
Chloroethane	3	0.02	0.02	32.00	0.00	2
Perchlorate	0.0	0.00	0.00	12.33	0.00	6
Total Sorbed Contaminant Electron Acceptor Demand (lb.)					**0.15**	

(continued)

Table S.2 Substrate Calculations in Hydrogen Equivalents

4. Treatment Cell Electron-Acceptor Flux (per year)

A. Soluble Native Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Oxygen	0.6	0.43	7.94	0.05	4
Nitrate (denitrification)	0.1	0.07	10.25	0.01	5
Sulfate	35	25.27	11.91	2.12	8
Carbon Dioxide (estimated as the amount of Methane produced)	10	7.22	1.99	3.63	8
Total Competing Electron Acceptor Demand Flux (lb/yr)				**5.8**	

B. Soluble Contaminant Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	0.050	0.04	20.57	0.00	8
Trichloroethene (TCE)	0.050	0.04	21.73	0.00	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	0.200	0.14	24.05	0.01	4
Vinyl Chloride (VC)	0.050	0.04	31.00	0.00	2
Carbon Tetrachloride (CT)	0.000	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	0.000	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	0.025	0.02	21.06	0.00	4
Chloromethane	0.000	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	0.600	0.43	22.06	0.02	6
Dichloroethane (1,1-DCA and 1,2-DCA)	1.000	0.72	24.55	0.03	4
Chloroethane	0.200	0.14	32.00	0.00	2
Perchlorate	0.000	0.00	12.33	0.00	6
Total Soluble Contaminant Electron Acceptor Demand Flux (lb/yr)				**0.06**	

Initial Hydrogen Requirement First Year (lb)	**9.1**
Total Life-Cycle Hydrogen Requirement (lb)	**26.7**

5. Design Factors

Microbial Efficiency Uncertainty Factor	2X - 4X
Methane and Solid-Phase Electron Acceptor Uncertainty	2X - 4X
Remedial Design Factor (e.g., Substrate Leaving Reaction Zone)	1X - 3X
Design Factor	**5.0**
Total Life-Cycle Hydrogen Requirement with Design Factor (lb)	**133.7**

6. Acronyns and Abbreviations

°C =degrees celsius
µs/cm = microsiemens per centimeter
cm/day = centimeters per day
cm/sec = centimeters per second
ft^2 = square feet
ft/day = feet per day
ft/ft = foot per foot
ft/yr = feet per year
gm/cm^3 = grams per cubic centimeter
kg of CaCO3 per mg = kilograms of calcium carbonate per milligram
lb = pounds
meq/100 g = milliequivalents per 100 grams
mg/kg = milligrams per kilogram
mg/L = milligrams per liter
m/m = meters per meters
mV = millivolts
m/yr = meters per year
su = standard pH units
wt/wt H2 = concetration molecular hydrogen, weight per weight

Table S.3

Hydrogen Produced by Fermentation Reactions of Common Substrates

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Substrate	Molecular Formula	Substrate Molecular Weight (gm/mole)	Moles of Hydrogen Produced per Mole of Substrate	Ratio of Hydrogen Produced to Substrate (gm/gm)	Range of Moles H_2/Mole Substrate
Lactic Acid	$C_3H_6O_3$	90.1	2	0.0448	**2 to 3**
Molasses (assuming 100% sucrose)	$C_{12}H_{22}O_{11}$	342	8	0.0471	**8 to 11**
High Fructose Corn Syrup (assuming 50% fructose and 50% glucose)	$C_6H_{12}O_6$	180	4	0.0448	**4 to 6**
Ethanol	C_2H_6O	46.1	2	0.0875	**2 to 6**
Whey (assuming 100% lactose)	$C_{12}H_{22}O_{11}$	342	11	0.0648	**11**
HRC® (assumes 40% lactic acid and 40% glycerol by weight)	$C_{39}H_{56}O_{39}$	956	28	0.0590	**28**
Linoleic Acid (Soybean Oil, Corn Oil, Cotton Oil)	$C_{18}H_{32}O_2$	281	16	0.1150	**16**

Table S.4
Estimated Substrate Requirements for Hydrogen Demand in Table S.3

Design Life (years): 4

Substrate	Design Factor	Pure Substrate Mass Required to Fulfill Hydrogen Demand (pounds)	Substrate Product Required to Fulfill Hydrogen Demand (pounds)	Substrate Mass Required to Fulfill Hydrogen Demand (milligrams)	Effective Substrate Concentration (mg/L)
Lactic Acid	5.0	2,986	2,986	1.35E+09	980
Sodium Lactate Product (60 percent solution)	5.0	2,986	6,195	1.35E+09	980
Molasses (assuming 6 0	5.0	2,837	4,728	1.29E+09	931
HFCS (assuming 40% fructose and 40% glucose by weight)	5.0	2,987	3,733	1.35E+09	980
Ethanol Product (assuming 80% ethanol by weight)	5.0	1,527	1,909	6.93E+08	501
Whey (assuming 100% lactose)	5.0	2,061	2,945	9.35E+08	676
HRC® (assumes 40% lactic acid and 40% glycerol by weight)	5.0	2,264	2,264	1.03E+09	594
Linoleic Acid (Soybean Oil, Corn Oil, Cotton Oil)	5.0	1,162	1,162	5.27E+08	381
Commercial Vegetable Oil Emulsion Product (60% oil by weight)	5.0	1,162	1,937	5.27E+08	381

NOTES: Sodium Lactate Product

1. Assumes sodium lactate product is 60 percent sodium lactate by weight.
2. Molecular weight of sodium lactate (CH_3-CHOH-COONa) = 112.06.
3. Molecular weight of lactic Acid ($C_6H_6O_3$) = 90.08 .
4. Therefore, sodium lactate product yields 48.4 (0.60 x (90.08/112.06)) percent by weight lactic acid.
5. Weight of sodium lactate product = 11.0 pounds per gallon.
6. Pounds per gallon of lactic acid in product = 1.323 x 8.33 lb/gal H2O x 0.60 x (90.08/112.06) = 5.31 lb/gal.

NOTES: Standard HRC Product

1. Assumes HRC product is 40 percent lactic acid and 40 percent glycerol by weight.
2. HRC® weighs approximately 9.18 pounds per gallon.

NOTES: Vegetable Oil Emulsion Product

1. Assumes emulsion product is 60 percent soybean oil by weight.
2. Soybean oil is 7.8 pounds per gallon.
3. Assumes specific gravity of emulsion product is 0.96.

Table S.5 Output for Substrate Requirements in Hydrogen Equivalents

Site Name: Former Duso Chemical (West Center Shallow - BIW-5S)

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1. Treatment Zone Physical Dimensions

	Values	Units	Values	Units
Width (perpendicular to groundwater flow)	40	feet	12	meters
Length (parallel to groundwater flow)	38	feet	11.6	meters
Saturated Thickness	6	feet	1.8	meters
Design Period of Performance	4	years	4	years

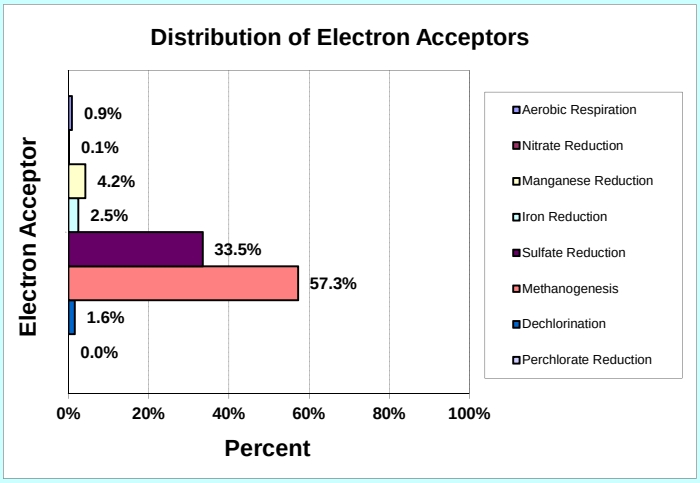
2. Treatment Zone Hydrogeologic Properties

	Values	Units	Values	Units
Total Porosity	0.32	percent	0.32	percent
Effective Porosity	0.28	percent	0.28	percent
Average Aquifer Hydraulic Conductivity	4	ft/day	1.4E-03	cm/sec
Average Hydraulic Gradient	0.033	ft/ft	0.033	m/m
Average Groundwater Seepage Velocity	0.47	ft/day	1.4E+01	cm/day
Average Groundwater Seepage Velocity	172	ft/yr	52.4	m/yr
Effective Treatment Zone Pore Volume	19,106	gallons	72,322	liters
Groundwater Flux (per year)	86,516	gallons/year	327,489	liters/year
Total Groundwater Volume Treated (over entire design period)	365,169	gallons total	1,382,278	liters total

3. Distribution of Electron Acceptor Demand

	Percent of Total	Hydrogen Demand (lb)
Aerobic Respiration	0.9%	0.230
Nitrate Reduction	0.1%	0.029
Sulfate Reduction	33.5%	8.955
Manganese Reduction	4.2%	1.118
Iron Reduction	2.5%	0.660
Methanogenesis	57.3%	15.312
Dechlorination	1.6%	0.426
Perchlorate Reduction	0.0%	0.000
Totals:	**100.00%**	**26.73**

Hydrogen demand in pounds/gallon:	7.32E-05
Hydrogen demand in grams per liter:	8.77E-03



4. Substrate Equivalents: Design Factor = 5.0

Product	Quantity (lb)	Quantity (gallons)	Effective Concentration (mg/L)	Effective concentration is for total volume of groundwater treated.
1. Sodium Lactate Product	6,195	563	980	as lactic acid
2. Molasses Product	4,728	394	931	as sucrose
3. Fructose Product	3,733	333	980	as fructose
4. Ethanol Product	1,909	277	501	as ethanol
5. Sweet Dry Whey (lactose)	2,945	sold by pound	676	as lactose
6. HRC®	2,264	sold by pound	594	as 40% lactic acid/40% glycerol
7. Linoleic Acid (Soybean Oil)	1,162	149	381	as soybean oil
8. Emulsified Vegetable Oil	1,937	248	381	as soybean oil

Notes:

1. Quantity assumes product is 60% sodium lactate by weight.
2. Quantity assumes product is 60% sucrose by weight and weighs 12 pounds per gallon.
3. Quantity assumes product is 80% fructose by weight and weighs 11.2 pounds per gallon.
4. Quantity assumes product is 80% ethanol by weight and weighs 6.9 pounds per gallon.
5. Quantity assumes product is 70% lactose by weight.
6. Quantity assumes HRC® is 40% lactic acid and 40% glycerol by weight.
7. Quantity of neat soybean oil, corn oil, or canola oil.
8. Quantity assumes commercial product is 60% soybean oil by weight.

Appendix D

SiREM Laboratories
Biotreatability Study Report

Prepared for:

AECOM
40 British American Blvd.,
Latham, NY 12110

LABORATORY BIOTREATABILITY STUDY TO EVALUATE BIODEGRADATION OF CHLORINATED SOLVENTS IN GROUNDWATER

Former Duso Chemical Site
Poughkeepsie New York

Prepared by:

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Guelph, Ontario N1G 5G3

SiREM Ref: TL0139.19

30 August 2011

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1,1-DCA	1,1-dichloroethane
1,2-DCA	1,2-dichloroethane
1,1-DCE	1,1-dichloroethene
TCA	1,1,1-trichloroethane
cells/liter	cells per liter
cis-1,2-DCE	*cis*-1,2-dichloroethene
cVOC	chlorinated volatile organic compound
CA	chloroethane
°C	degrees Celsius
°C/min	degrees Celsius per minute
Dhb	*Dehalobacter*
Dhc	*Dehalococcoides*
DHG	dissolved hydrocarbon gases
EOS 598B42	emulsified oil substrate 59.8% enriched with vitamin B12
ERD	enhanced reductive dechlorination
GC	gas chromatograph
Geosyntec	Geosyntec Consultants
IC	ion chromatograph
µg/L	micrograms per liter
µL	microliters
min	minutes
mg/L	milligrams per liter
mL	milliliters
mL/min	milliliters per minute
mM	millimolar
mmol/bottle	millimole per bottle
ORP	oxygen reducing potential
%	per cent
QL	quantitation limit
qPCR	quantitative polymerase chain reaction
RPM	revolutions per minute
rRNA	16S ribonucleic acid
SiREM	SiREM Laboratories
PCE	tetrachloroethene
TCE	trichloroethene
VC	vinyl chloride
vcrA	vinyl chloride reductase
VFA	volatile fatty acid

1. INTRODUCTION

AECOM retained SiREM Laboratory (SiREM) to perform a laboratory biotreatability study to assess the potential for in situ bioremediation of chlorinated volatile organic compounds (cVOCs) in groundwater at the Former Duso Chemical Site in Poughkeepsie, NY (the Site). The purpose of the study was to assess anaerobic biodegradation of the Site contaminants, namely chlorinated ethenes (tetrachloroethene [PCE], trichloroethene [TCE], cis-1,2-dichloroethene [cDCE], 1,1-dichloroethene [1,1-DCE] and vinyl chloride [VC]) and chlorinated ethanes (1,1,1-trichloroethane [1,1,1-TCA], 1,1-dichloroethane [1,1-DCA], 1,2-dichloroethane [1,2-DCA] and chloroethane [CA]).

Groundwater and soil used in this study were collected from locations SGSB3, MHC-22, MHC-24, MHC-26 (groundwater), and SB-1, SB-2, SB-3 and SB-4 (soil) on 21 March 2011. The material was received by SiREM on 24 March 2011.

The remainder of this report contains a summary of key biodegradation processes (Section 1.1), the experimental materials and methods (Section 2), the results and discussion of the microcosm study (Section 3), conclusions (Section 4) and report references (Section 5).

1.1 Summary of Biodegradation Processes

Biological degradation products of PCE include TCE, *c*DCE, VC and the fully dechlorinated end product ethene. Breakdown products of 1,1,1-TCA include 1,1-DCA, and CA, while 1,1-DCE and acetate can be produced from an abiotic elimination reaction. 1,2-DCA primarily degrades via dihaloelimination to ethene. Figure 1 contains degradation pathways for the chlorinated ethanes and 1,1-DCE and Figure 2 contains degradation pathways for the chlorinated ethenes and 1,2-DCA.

Natural attenuation processes can occur in situ and are often mediated by indigenous microbial populations present at contaminated sites. Enhanced reductive dechlorination (ERD) can, in certain cases, be achieved by stimulating the indigenous microbial populations through the addition of electron donors. Bioaugmentation is the process in which a microbial population known to promote ERD or other biodegradation processes is introduced to groundwater to enhance the rate or extent of biodegradation. *Dehalococcoides* (Dhc) microorganisms are known to be responsible for mediating the complete dechlorination of PCE, TCE, cDCE, 1,1-DCE, VC and 1,2-DCA to ethene (Major et al., 2002; Duhamel et al., 2002). 1,1,1-TCA has been observed to inhibit anaerobic biological processes including methanogenesis and ERD

of chlorinated ethenes that are mediated by the Dhc group of organisms (Grostern and Edwards, 2006). Overcoming this inhibition is important when dealing with chlorinated ethanes and chlorinated ethenes as co-contaminants and this has been demonstrated to be possible when other dehalogenating organisms such as *Dehalobacter* (Dhb) that are known to degrade 1,1,1-TCA are present.

2. MATERIALS AND METHODS

The following sections describe the materials and methods used for microcosm construction and incubation (Section 2.1), and microcosm sampling and analysis (Section 2.2).

2.1 Microcosm Construction and Incubation

A total of 9 microcosms were constructed on 13 April 2011. Site soil and groundwater were placed in a disposable anaerobic glove bag with the materials required to construct the various treatment and control microcosms. Of the four samples of groundwater received three were used in microcosm construction (SGSB-3, MHC-26 and MHC-22). The three types of groundwater were mixed together prior to the microcosm construction. The glove bag was purged with a carbon dioxide/nitrogen (20:80) gas mixture in order to create an anaerobic environment. The soil from the different cores was combined and mixed by hand to improve reproducibility between replicates. Microcosms were constructed by filling sterile 250 milliliter (mL) (nominal volume) screw cap Boston round clear glass bottles (Systems Plus, New Hamburg, ON) with 60 mL of homogenized soil and 200 mL of Site groundwater. The bottles were capped with Mininert™ closures to allow repetitive sampling of the bottle with minimal VOC loss and to allow amendments, as needed, throughout the incubation period. All controls and treatments were constructed in triplicate. Table 1 summarizes the details of microcosm construction and amendments for the treatment and control microcosms.

Anaerobic sterile control microcosms were constructed to quantify potential abiotic and experimental VOC losses from the microcosms. The sterile controls were constructed by autoclaving the Site soil at 121 degrees Celsius (°C) and 15 pounds per square inch pressure for 45 to 60 minutes (min). After autoclaving, the control microcosms were returned to the anaerobic chamber, filled with 200 mL of Site groundwater and amended with 2.8 mL of 2.7 per cent (%) mercuric chloride (equal to a final liquid concentration of 0.05%) and 0.5 mL of 5% sodium azide (equal to a final liquid concentration of 0.017%) to inhibit microbial activity.

All microcosms were sampled and incubated in an anaerobic chamber (Coy Laboratory Products, Grass Lake, MI) filled with an atmosphere of approximately 80% nitrogen, 10% carbon dioxide, and 10% hydrogen (Linde gases, Guelph, ON). Hydrogen was added to scavenge low levels of oxygen via a palladium catalyst, and anaerobic conditions were verified using resazurin-containing mineral medium, which turns pink if oxygen is present. During quiescent incubation, all microcosms were covered to minimize photodegradation, and stored horizontally to minimize VOC losses via the (submerged) Mininert^{TM} closure. Microcosms were incubated for a period of up to 203 days at 22^{o}C (room temperature).

AECOM specified that the initial, *c*DCE, 1,1-DCA, and 1,1,1-TCA concentrations, in the microcosms should be 3 milligrams per liter (mg/L), 10 mg/L, and 2 mg/L, respectively to represent concentrations measured at the Site. The initial concentrations measured in the prepared microcosms were not at these target concentrations; therefore on 19 April 2011 (Day -1), the microcosms were amended with 175 microliters (µL) of a saturated *c*DCE water stock (3,500 mg/L), 268µL of saturated 1,1-DCA water stock (5,060 mg/L), and 244 µL of a saturated 1,1,1-TCA water stock (1,495mg/L) to reach the target concentrations in the microcosms.

Treatment microcosms were amended with Emulsified Oil Substrate 59.8% enriched with vitamin B12 (EOS® 598 B42) (EOS Remediation, Inc., Raleigh, NC) as the electron donor. These microcosms were amended with 334 µL of EOS® 598 B42 corresponding to a target concentration of 0.1% as oil (EOS® 598 B42 is 59.8% soybean oil). The amount of EOS® 598 B42 electron donor added was based on experience with prior laboratory studies and corresponds to a percentage of what is typically added in the field.

2.2 Microcosm and Reactor Sampling and Analysis

2.2.1 Microcosm Sampling

Aqueous samples were collected from the control and treatment microcosms on a weekly to biweekly (i.e., every two weeks) basis for analysis of cVOCs, dissolved hydrocarbon gases (DHGs) (ethene, ethane, and methane), and anions (sulfate, nitrate, nitrite, chloride, phosphate, bromide). Aqueous samples were also collected periodically for analysis of volatile fatty acids (VFAs) (lactate, acetate, propionate, formate, butyrate, and pyruvate), pH, Dhc and Dhb. Microcosms were sampled using gas-tight 1 mL Hamilton glass syringes. Separate sets of syringes were used for the bioaugmented and non-bioaugmented treatments to minimize the potential for transfer of KB-1® microorganisms from bioaugmented to non-bioaugmented treatments.

Syringes were cleaned with acidified water (pH ~2) and rinsed 10 times with deionized water between samples, to ensure that VOCs and microorganisms were not transferred between replicates or treatments. The analytical methods employed by SiREM are described below.

2.2.2 Analysis of cVOCs and Dissolved Hydrocarbon Gases

This section describes the methods used to quantify the cVOCs and DHGs. The quantitation limits (QL) for the cVOCs and DHGs were typically 5 to 10 micrograms per liter (µg/L) in the microcosms based on the lowest concentration standards that were included in the linear calibration trend.

Aqueous cVOC and DHG concentrations in the microcosms were measured using a Hewlett-Packard (Hewlett Packard 7890) gas chromatograph (GC) equipped with an auto sampler (Hewlett Packard G1888) programmed to heat each sample vial to 75°C for 45 min prior to headspace injection into a GSQ Plot column (0.53 mL x 30 meters, J&W) and a flame ionization detector. Sample vials were heated to ensure that all VOCs in the aqueous sample would partition into the headspace. The injector temperature was 200°C, and the detector temperature was 250°C. The oven temperature was programmed as follows: 35°C for 2 min, increased to 100°C at 50 degrees Celsius per minute (°C/min), then increased to 185°C at 25°C/min and held at 185°C for 6.80 min. The carrier gas was helium at a flow rate of 11 milliliters per minute (mL/min).

After withdrawing a 1 mL sample (as described in section 2.2.1), the sample was injected into a 10 mL auto sampler vial containing 5.0 mL of acidified deionized water (pH ~2). The water was acidified to inhibit microbial activity between microcosm sampling and GC analysis. The vial was sealed with an inert Teflon®-coated septum and aluminium crimp cap for automated injection of 3 mL of headspace onto the GC. One VOC standard was analyzed with each set of samples to verify the instrument five-point calibration curve using methanolic stock solutions containing known concentrations of the target analytes. Calibration was performed using external standards purchased as standard solutions (Sigma, St Louis, MO), where known volumes of standard solutions were added to acidified water in auto sampler vials and analyzed as described above for microcosm samples. Data were integrated using Chemstation Software (Agilent Technologies, Santa Clara, CA).

2.2.3 Analysis of Anions and Total Volatile Fatty Acids

This section describes the methods used to quantify anions and total VFAs. This analysis was performed on a Dionex DX-600 ion chromatograph (IC) equipped with a Dionex AS-40 auto sampler and an AS18 column, the sample loop volume was 25 μL. An isocratic separation was performed using 33 millimolar (mM) reagent grade sodium hydroxide (Fisher Scientific, Ottawa, ON) eluent for 13 min. One standard was analysed with each set of samples tested in order to verify the seven-point calibration using external standards of known concentrations. External standards were prepared gravimetrically using chemicals of the highest purity available (Sigma St Louis, MO or Bioshop, Burlington, ON). Data were integrated using Peaknet Chromatography software (Dionex, Oakville, ON). The QLs were as follows: 0.25 mg/L total VFA, 0.03 mg/L chloride, 0.12 mg/L nitrite, 0.10 mg/L nitrate, 0.72 mg/L sulfate, 0.57 mg/L phosphate and 0.39 mg/L bromide. The total VFA value includes lactate, formate, acetate, propionate, pyruvate and butyrate (valerate has not been confirmed), as this particular analytical method does not resolve VFAs. The VFA method described below (Section 2.2.4) is used to quantify individual VFAs.

A 0.5 mL sample was withdrawn (as described in section 2.2.1), after which the sample was placed in a 1.5 mL micro-centrifuge tube. Samples were centrifuged for five minutes at 13,000 revolutions per minute (RPM) to remove solids. The supernatant was removed, diluted 10-fold in deionized water and placed in a Dionex auto sampler vial with a cap that filters the sample during automated injection onto the IC.

2.2.4 Analysis of Volatile Fatty Acids

This section describes the methods used to quantify individual VFAs (lactate, acetate, propionate, formate, butyrate and pyruvate). This analysis was performed on a Dionex DX-600 IC equipped with a Dionex AS-40 auto sampler and an AS11-HC column, the sample loop volume was 25 μL. A gradient separation was performed using the following eluent profile; 1.0 mM sodium hydroxide for 8.0 min to 15 mM at 18.0 min and proceeding to 30 mM at 28.0 min. with a flow rate of 1.5 mL/min. Calibration was performed using external standards of known concentrations. One standard was analysed with each set of samples to verify the instrument's seven-point calibration curve produced using external standards of known concentrations. External standards were prepared gravimetrically using chemicals of the highest purity available (Sigma St. Louis, MO or Bioshop, Burlington, ON). Data were integrated using Peaknet chromatography software (Dionex, Oakville, ON). The QLs were as follows: lactate 0.40 mg/L, acetate 0.54 mg/L, propionate 0.31 mg/L, formate 0.23 mg/L, butyrate 0.41 mg/L, and pyruvate 0.69 mg/L.

A 0.5 mL sample was withdrawn (as described in section 2.2.1), after which the sample was placed in a 1.5 mL micro-centrifuge tube. Samples were centrifuged for five minutes at 13,000 RPM in a micro-centrifuge to remove solids. The supernatant was removed, diluted 50-fold in deionized water and placed in a Dionex auto sampler vial with a cap that filters the sample during automated injection onto the IC.

2.2.5 Analysis of pH

The pH measurements were performed using an Oakton pH spear with combination pH electrode (Oakton, Vernon Hills, IL). A 500 µL sample was taken (as described in section 2.2.1), the vial was removed from the glove box and the pH was measured on the lab bench. The pH spear was calibrated at each sampling event according to the manufacturer's instructions using pH 4.0, 7.0 and 10 standards.

2.2.6 Analysis of Oxidation-reduction Potential (ORP)

On 14 July 2011 (Day 85) a 2 mL aqueous sample was removed from each of the EOS® 598 B42 amended microcosms to measure the oxidation-reduction potential (ORP). The 2 mL sample was placed into a 10 mL glass vial for the ORP measurements which were performed using a Corning 313 meter with double junction ORP electrode (Ag/AgCl reference). A single point calibration of the meter was performed at each sampling event with Zobell ORP calibration solution.

2.2.7 Gene Trac® *Dehalococcoides* and *Dehalobacter*Testing

Gene-Trac® quantitative polymerase chain reaction (qPCR) testing was performed in this study to quantify and characterize Dhc microorganisms known to facilitate the dechlorination of PCE to ethene and Dhb microorganisms known to facility the dechlorination of 1,1,1-TCA to CA.The method for the analysis is provided in Appendix A.

The Gene-Trac® Dhc and Dhb tests quantify the total Dhc and Dhb population by targeting the16S ribosomal ribonucleic acid (rRNA) gene whereas the Gene-Trac® VC test targets the Dhc vinyl chloride reductase (*vcrA*) gene. The *vcrA* gene is present in only a subset of Dhc populations, and is a functional gene responsible for complete dechlorination of cDCE and VC to ethene (Mueller et al., 2004). There is a strong correlation between the presence of vcrA and complete dechlorination of chloroethenes to non-toxic ethene.

As per AECOM request a 100 mL sample from groundwater SGSB3 and MHC-26 were collected for baseline analysis. These samples represented background microbiological conditions, and were tested to identify if indigenous dechlorinating organisms were present in the site materials used to construct the microcosms.

On 29 June 2011 (Day 70) and 17 August 2011 (Day 119), a 10 mL composite sample was collected (3.3 mL from each triplicate) for the mid-point and end point sampling respectively, and submitted for Gene-Trac® Dhc, Dhb and *vcrA* testing. (Test Certificates are provided in Appendix A)

3. RESULTS AND DISCUSSION

The following section presents and discusses the results of the biotreatability study. Section 3.1 discusses the results for the anaerobic sterile and active control microcosms, and Section 3.2 discusses the results for the EOS® 598 B42 amended microcosms.

Tables 2A, 2B, 2C, and 2D provide cVOC, ethene, ethane, methane, anion, VFA, and pH data from the control and treatment microcosms over the incubation period for the study. All cVOC, ethene, ethane, and methane concentrations are presented in units of mg/L and millimoles per microcosm bottle (mmol/bottle) to demonstrate mass balances on a molar basis. Concentrations were converted from mg/L to mmol/bottle using Henry's Law as demonstrated in Appendix B. Table 3 summarizes the Gene-Trac® results, Table 4 presents the cVOC half-lives, and Figures 3 through 5 present trends in the concentrations of cVOCs, ethene, and ethane in the control and treatment microcosms over the incubation period for the study.

3.1 Anaerobic Sterile and Active Control Microcosms

The cVOC concentrations in the sterile control microcosms remained stable over the incubation period and there were no increases in degradation products (Figure 3). Sulfate concentrations also remained stable in all three microcosms. These results confirm that there was no mass loss of cVOCs in the treatment microcosms resulting from abiotic degradation or experimental losses (e.g., sorption or loss through microcosm closures).

The cVOC concentrations also remained stable in the anaerobic active control microcosms over the incubation period, with the exception of slight decreases in the cDCE and 1, 1, 1-TCA concentrations (Figure 4). cDCE and 1,1,1-TCA degradation

products did not increase indicating that the decreases cDCE and 1,1,1-TCA were not due to reductive dechlorination and may have been the result of abiotic degradation. Sulfate reduction was observed throughout the duration of the study. These data suggest that the intrinsic biodegradation activity at the Site may be limited due to a lack of available nutrients (e.g., electron donors or co metabolites) to promote degradation of the cVOCs.

3.2 EOS® 598 B42 Amended Microcosms

The addition of EOS® 598 B42 alone promoted the complete dechlorination of chlorinated ethenes to ethene, 1,1,1-TCA and 1,1-DCA to CA and partial dechlorination of 1,2-DCA (Figure 5). cDCE decreased rapidly with corresponding increases in VC. cDCE and VC reached non-detect levels by day 70 with corresponding increases in ethene. 1,1 DCE reached non-detect levels by day 119. 1,1,1-TCA and 1,1-DCA also decreased rapidly and reached non-detect levels by days 42 and 85 respectively with a corresponding increase in CA. 1,2-DCA concentrations remained stable to Day 42 (average concentration of 0.66 mg/L) followed by a slow decrease to an average concentration of 0.092 mg/L by Day 119. Sulfate reduction was observed and was essentially complete by Day 28 (Table 2B). Methane concentrations increased throughout the incubation period (Table 2A) indicating that methanogenic microorganisms were present in the site material and consumed a portion of the available electron donor.

Lactate was detected at time zero and decreased to non-detect by day 56 indicating that the lactate component of the EOS® 598 B42 was utilized. Acetate, propionate, and butyrate were all detected at day 56 indicating that fermentation of the EOS® 598 B42 was occurring (Table 2C). The pH of the sterile and active controls remained stable throughout the duration of the study (Table 2D), while the pH of the treatment microcosms decreased only slightly over the incubation period reaching an average value of 6.60 on Day 119 (Table 2D). This indicates that the acid buffering properties of the Site materials were sufficient to maintain a relatively neutral pH during reductive dechlorination and electron donor fermentation (both acid producing processes). The optimum pH for reductive dechlorination is 6.8 to 7.5 (Middledorp et al., 1999) and complete dechlorination can occur between a pH range of 6.0 and 8.0 (SiREM, unpublished data). These results suggest that application of buffering agents is not likely to be required to support ERD at the Site. On day 85 the ORP of the EOS® 598 B42 amended microcosms was measured as requested by AECOM. The results indicated that highly reducing conditions (i.e., <-100 millivolts) required for dechlorination were established in the microcosms.

Table 3 summarizes the Gene-Trac® test results for baseline groundwater and aqueous samples collected from the baseline groundwater and microcosms throughout the study.

The baseline analysis performed on the two groundwater types used for this study (SGSB-3 and MHC-26) indicated a low to moderate population of Dhc (determined by vinyl chloride reductase gene *[vcrA]* found in Dhc) and Dhb. At Day 62 composite samples from both the active control and EOS® 598 B42 microcosms were analyzed for *vcrA* and Dhb. The active control continued to have a low to moderate Dhc and Dhb populations (5E+06 cells per liter (cells/L) and 4E+06 cells/L respectively). However, when treated with EOS® 598 B42 the indigenous population of Dhc and Dhb was able to flourish to high levels (6E+09 cells/L and 3E+09 cells/L respectively), which supports the dechlorination data observed. Typically Dhc concentrations above 1 x 10^7cells/L are required for high rates of *in situ* reductive dechlorination (Lu et al., 2006) and ethene production. There is currently no industry standard for Dhb, but 1 x 10^7cells/L is often used. At Day 119 both the active control and EOS® 598 B42 amended microcosms were sampled. A slight decrease in Dhc and Dhb populations was observed in the electron donor amended sample, most likely due to the fact that the both the chlorinated ethenes and ethanes in the electron donor amended microcosms were essentially depleted prior to sample collection. A similar decrease was observed for the active control sample, but the populations remained low throughout the duration of the study.

These data suggest that intrinsic microorganisms present at the site may be capable of dechlorinating chlorinated ethenes and ethanes with EOS® 598 B42 as the electron donor.

3.3 Degradation Half-Lives for Chlorinated Ethenes and Chlorinated Ethanes

Laboratory half-lives were calculated based on the average dechlorination observed in the individual treatment microcosm replicates as indicated in Table 4. First order reaction kinetics was assumed for all calculations as described in Newell et al, 2002. The half- lives were calculated using the following relationship:

$$\text{Half life} = \ln(2)/[\ln(C_2/C_1)/(t_2-t_1)]$$

where,

C_1 is the concentration at early time (t_1 days)

C_2 is the concentration at later time (t_2 days)

Based on the data collected, the calculated dechlorination half-lives for the chlorinated ethenes (TCE, cDCE, VC and 1,1-DCE) were 21 days, 5.8 days, 2.6 days and 8.3 days respectively (Table 4). The calculated dechlorination half-lives for the chlorinated ethanes were in a similar range with 1,1,1-TCA and 1,1-DCA half lives of 5.3 and 3.8 days respectively. The highest half life calculated was 45 days for 1,2-DCA. The dechlorination of 1,2-DCA wasn't observed until dechlorination of the other chlorinated compounds was essentially complete leading to the higher half life for 1,2-DCA.

4. CONCLUSIONS

The laboratory biotreatability study results indicate the following:

1. The rate and extent of intrinsic degradation of the chlorinated ethenes and ethanes in Site groundwater is limited by the lack of available nutrients (e.g., electron donors) at the Site.

2. EOS® 598 B42 amendment promoted the appropriate geochemical conditions (i.e., sulfate reducing conditions) and maintenance of suitable pH for bioremediation of chlorinated ethenes and ethanes.

3. EOS® 598 B42 supported increases of indigenous Dhc and Dhb populations to levels associated with complete dechlorination.

4. Indigenous bacteria present at the Site appear to be capable of completely dechlorinating the chlorinated ethenes to ethene, 1,1,1-TCA and 1,1-DCA to CA and partial dechlorination of 1,2-DCA with the addition of EOS® 598 B42 as the electron donor.

Based on the results of this study, EOS® 598 B42 as electron donor may be an effective remedial approach to reduce chlorinated ethenes and chlorinated ethanes concentrations in Site groundwater.

5. REFERENCES

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TABLES

TABLE 1: SUMMARY OF MICROCOSM CONTROLS AND TREATMENTS SiREM
Former Duso Chemical, Poughkeepsie, New York

Microcosm Name	Control/Treatment	Description
ANSC	Anaerobic Sterile Control	Autoclaved and amended with mercuric chloride and sodium azide.
ANAC	Anaerobic Active Control	No amendments added
EOS® 598 B42 Amended	EOS® 598 B42 Amended and Bioaugmentation	Initial electron donor target concentration of 0.1% as oil.

Notes:

ANSC – anaerobic sterile control
ANAC – anaerobic active control
EOS® – emulsified oil substrate
% - percent

TABLE 2A: Summary of Microcosm Chlorinated VOCs, Ethene, Ethane, and Methane Results
Former Duso Chemical, Poughkeepsie, New York

Treatment	Date	Day	Replicate	Chlorinated Ethenes							Chlorinated Ethanes					Methane	Comment
				PCE	TCE	cDCE	1,1-DCE	VC	Ethene	Total Ethenes	1,1,1-TCA	1,1-DCA	1,2-DCA	CA	Ethane	Methane	
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mmol/bottle	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	
Anaerobic Sterile Control	13-Apr-11	-7															Poisoned with mercuric chloride and sodium azide.
																	Amended the first replicate with resazurin.
	19-Apr-11	-1															Spiked with cDCE, 1,1-DCA and 1,1,1-TCA to target concentrations of 3, 10 and 2 ppm respectively.
	20-Apr-11	0	ANSC-1	<0.010	0.029	6.5	<0.010	<0.010	<0.010	--	1.1	7.2	0.22	0.24	<0.010	0.035	
			ANSC-2	<0.010	0.032	5.9	0.011	0.010	<0.010	--	1.2	7.4	0.22	0.27	<0.010	0.077	
			ANSC-3	<0.010	0.032	5.6	0.014	0.014	<0.010	--	1.1	7.2	0.23	0.28	<0.010	0.029	
			Average Concentration (mg/L)	ND	0.031	6.0	0.0083	0.0079	ND	--	1.1	7.3	0.22	0.26	ND	0.047	
			Standard Deviation (mmoles)	0.0E+00	2.9E-06	9.9E-04	1.7E-05	2.5E-05	0.0E+00	--	5.0E-05	2.8E-04	1.3E-05	6.4E-05	0.0E+00	1.2E-03	
			Average Total mmoles	**ND**	**0.000049**	**0.013**	**0.000019**	**0.000028**	**ND**	**1.3E-02**	**0.0019**	**0.015**	**0.00045**	**0.00084**	**ND**	**0.0022**	
	04-May-11	14	ANSC-1	<0.010	0.037	5.8	0.012	<0.010	<0.010	--	0.94	6.9	0.22	0.21	<0.010	0.028	
			ANSC-2	<0.010	0.030	6.1	0.014	0.011	<0.010	--	1.1	7.8	0.23	0.27	<0.010	0.027	
			ANSC-3	0.012	0.040	5.7	0.013	<0.010	<0.010	--	1.0	7.2	0.31	0.26	<0.010	0.027	
			Average Concentration (mg/L)	0.0041	0.036	5.9	0.013	0.0036	ND	--	1.0	7.3	0.25	0.25	ND	0.027	
			Standard Deviation (mmoles)	9.4E-06	7.6E-06	4.3E-04	3.1E-06	2.2E-05	0.0E+00	--	1.6E-04	9.0E-04	1.0E-04	1.0E-04	0.0E+00	1.0E-05	
			Average Total mmoles	**0.0000054**	**0.000057**	**0.012**	**0.000030**	**0.000013**	**ND**	**1.2E-02**	**0.0017**	**0.015**	**0.00051**	**0.00080**	**ND**	**0.0013**	
	17-May-11	27	ANSC-1	<0.010	0.024	5.7	0.014	<0.010	<0.010	--	0.91	6.6	0.22	0.20	<0.010	0.030	
			ANSC-2	<0.010	0.029	5.6	0.016	0.014	<0.010	--	1.1	7.3	0.22	0.25	<0.010	0.030	
			ANSC-3	0.017	0.017	5.4	0.019	<0.010	<0.010	--	0.98	6.7	0.24	0.24	<0.010	0.030	
			Average Concentration (mg/L)	0.0058	0.023	5.6	0.017	0.0047	ND	--	0.98	6.9	0.23	0.23	ND	0.030	
			Standard Deviation (mmoles)	1.3E-05	9.4E-06	3.3E-04	5.8E-06	2.8E-05	0.0E+00	--	1.1E-04	8.1E-04	3.0E-05	8.4E-05	0.0E+00	2.1E-05	
			Average Total mmoles	**0.0000077**	**0.000037**	**0.012**	**0.000038**	**0.000016**	**ND**	**1.2E-02**	**0.0016**	**0.014**	**0.00046**	**0.00074**	**ND**	**0.0014**	
	15-Jun-11	56	ANSC-1	0.015	0.042	5.6	0.020	<0.010	<0.010	--	0.87	6.8	0.23	0.19	<0.010	0.028	
			ANSC-2	<0.010	0.043	5.6	<0.010	0.011	<0.010	--	1.0	7.3	0.22	0.24	<0.010	0.027	
			ANSC-3	0.023	0.032	5.2	<0.010	<0.010	<0.010	--	0.92	6.8	0.23	0.23	<0.010	0.027	
			Average Concentration (mg/L)	0.012	0.039	5.5	0.0065	0.0035	ND	--	0.93	7.0	0.23	0.22	ND	0.027	
			Standard Deviation (mmoles)	1.5E-05	9.1E-06	4.4E-04	2.6E-05	2.1E-05	0.0E+00	--	1.1E-04	5.8E-04	6.5E-06	7.5E-05	0.0E+00	2.3E-05	
			Average Total mmoles	**0.000016**	**0.000062**	**0.012**	**0.000015**	**0.000012**	**ND**	**1.2E-02**	**0.0015**	**0.014**	**0.00046**	**0.00070**	**ND**	**0.0013**	
	17-Aug-11	119	ANSC-1	0.023	0.032	5.3	0.033	<0.010	<0.010	--	0.81	6.9	0.21	0.18	<0.010	0.032	
			ANSC-2	<0.010	0.031	5.5	0.037	0.011	<0.010	--	0.92	7.1	0.22	0.21	<0.010	0.049	
			ANSC-3	0.045	0.032	5.3	0.036	<0.010	<0.010	--	0.86	6.8	0.23	0.21	<0.010	0.029	
			Average Concentration (mg/L)	0.023	0.032	5.4	0.035	0.0036	ND	--	0.86	6.9	0.22	0.20	ND	0.037	
			Standard Deviation (mmoles)	3.0E-05	7.1E-07	2.4E-04	5.3E-06	2.2E-05	0.0E+00	--	9.3E-05	3.2E-04	1.7E-05	6.4E-05	0.0E+00	5.1E-04	
			Average Total mmoles	**0.000030**	**0.000050**	**0.011**	**0.000081**	**0.000013**	**ND**	**1.1E-02**	**0.0014**	**0.014**	**0.00045**	**0.00064**	**ND**	**0.0017**	
Anaerobic Active Control	13-Apr-11	-7															Amended the first replicate with resazurin.
	19-Apr-11	-1															Spiked with cDCE, 1,1-DCA and 1,1,1-TCA to target concentrations of 3, 10 and 2 ppm respectively.
	20-Apr-11	0	ANAC-1	0.013	0.081	6.9	0.043	0.030	<0.010	--	1.4	9.3	0.58	0.51	<0.010	0.030	
			ANAC-2	0.011	0.074	7.2	0.039	0.027	<0.010	--	1.4	8.3	0.54	0.47	<0.010	0.028	
			ANAC-3	0.042	0.081	6.9	0.042	0.028	0.012	--	1.6	8.7	0.63	0.45	<0.010	0.027	
			Average Concentration (mg/L)	0.022	0.079	7.0	0.042	0.028	0.0038	--	1.4	8.8	0.58	0.48	ND	0.028	
			Standard Deviation (mmoles)	2.3E-05	6.1E-06	3.7E-04	4.8E-06	4.9E-06	8.8E-05	--	1.7E-04	1.1E-03	9.7E-05	1.1E-04	0.0E+00	7.7E-05	
			Average Total mmoles	**0.000029**	**0.00013**	**0.015**	**0.000095**	**0.000099**	**0.000051**	**1.5E-02**	**0.0024**	**0.018**	**0.0012**	**0.0015**	**ND**	**0.0013**	
	04-May-11	14	ANAC-1	0.029	0.10	6.6	0.062	0.031	<0.010	--	1.3	9.1	0.63	0.52	<0.010	0.027	
			ANAC-2	<0.010	0.087	6.0	0.055	0.029	<0.010	--	1.3	8.7	0.56	0.48	<0.010	0.033	
			ANAC-3	0.029	0.081	6.5	0.048	0.027	<0.010	--	1.4	8.7	0.58	0.42	<0.010	0.027	
			Average Concentration (mg/L)	0.019	0.090	6.4	0.055	0.029	ND	--	1.3	8.9	0.59	0.47	ND	0.029	
			Standard Deviation (mmoles)	2.2E-05	1.7E-05	6.4E-04	1.6E-05	7.2E-06	0.0E+00	--	7.4E-05	5.2E-04	8.0E-05	1.5E-04	0.0E+00	1.7E-04	
			Average Total mmoles	**0.000025**	**0.00014**	**0.014**	**0.00013**	**0.0001**	**ND**	**1.4E-02**	**0.0022**	**0.018**	**0.0012**	**0.0015**	**ND**	**0.0013**	
	17-May-11	27	ANAC-1	<0.010	0.10	6.4	0.064	0.029	<0.010	--	1.2	8.8	0.59	0.49	<0.010	0.030	
			ANAC-2	0.079	0.095	5.8	0.057	0.028	<0.010	--	1.3	8.9	0.58	0.46	<0.010	0.031	
			ANAC-3	0.027	0.087	6.0	0.056	0.022	<0.010	--	1.3	8.5	0.59	0.40	<0.010	0.031	
			Average Concentration (mg/L)	0.035	0.095	6.1	0.059	0.026	ND	--	1.3	8.7	0.59	0.45	ND	0.030	
			Standard Deviation (mmoles)	5.3E-05	1.2E-05	6.4E-04	9.2E-06	1.3E-05	0.0E+00	--	9.1E-05	3.9E-04	9.7E-06	1.4E-04	0.0E+00	2.4E-05	
			Average Total mmoles	**0.000047**	**0.00015**	**0.013**	**0.00013**	**0.000091**	**ND**	**1.3E-02**	**0.0021**	**0.018**	**0.0012**	**0.0015**	**ND**	**0.0014**	
	15-Jun-11	56	ANAC-1	0.044	0.12	6.3	0.068	0.029	<0.010	--	1.1	8.6	0.66	0.45	<0.010	0.028	
			ANAC-2	0.028	0.077	6.2	0.071	0.027	<0.010	--	1.1	8.4	0.54	0.44	<0.010	0.026	
			ANAC-3	0.039	0.081	6.0	0.063	0.026	<0.010	--	1.1	8.1	0.57	0.37	<0.010	0.026	
			Average Concentration (mg/L)	0.037	0.094	6.2	0.067	0.027	ND	--	1.1	8.4	0.59	0.42	ND	0.027	
			Standard Deviation (mmoles)	1.1E-05	4.2E-05	2.7E-04	9.8E-06	4.9E-06	0.0E+00	--	3.7E-05	5.3E-04	1.3E-04	1.3E-04	0.0E+00	3.3E-05	
			Average Total mmoles	**0.000049**	**0.00015**	**0.013**	**0.00015**	**0.000095**	**ND**	**1.3E-02**	**0.0019**	**0.017**	**0.0012**	**0.0014**	**ND**	**0.0012**	
	17-Aug-11	119	ANAC-1	<0.010	0.098	5.8	0.066	0.025	<0.010	--	0.78	7.8	0.65	0.36	<0.010	0.034	
			ANAC-2	0.093	0.088	6.1	0.085	0.029	<0.010	--	1.1	8.4	0.63	0.41	<0.010	0.052	
			ANAC-3	0.016	0.055	5.5	0.058	0.020	<0.010	--	0.74	7.6	0.62	0.30	<0.010	0.019	
			Average Concentration (mg/L)	0.036	0.080	5.8	0.070	0.025	ND	--	0.87	7.9	0.63	0.35	ND	0.035	
			Standard Deviation (mmoles)	6.5E-05	3.6E-05	5.9E-04	3.1E-05	1.6E-05	0.0E+00	--	3.3E-04	9.4E-04	3.5E-05	1.8E-04	0.0E+00	7.7E-04	
			Average Total mmoles	**0.000048**	**0.00013**	**0.012**	**0.00016**	**0.000087**	**ND**	**1.2E-02**	**0.0015**	**0.016**	**0.0013**	**0.0011**	**ND**	**0.0016**	

TABLE 2A: Summary of Microcosm Chlorinated VOCs, Ethene, Ethane, and Methane Results
Former Duso Chemical, Poughkeepsie, New York

Treatment	Date	Day	Replicate	Chlorinated Ethenes							Chlorinated Ethanes					Methane	Comment
				PCE	TCE	cDCE	1,1-DCE	VC	Ethene	Total Ethenes	1,1,1-TCA	1,1-DCA	1,2-DCA	CA	Ethane	Methane	
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mmol/bottle	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	
Amended with EOS® 598B42	13-Apr-11	-7															Amended the first replicate with resazurin.
	19-Apr-11	-1															Spiked with cDCE, 1,1-DCA and 1,1,1-TCA to target concentrations of 3, 10 and 2 ppm respectively.
	20-Apr-11	0	EOS® 598B42-1	0.020	0.056	6.2	0.044	0.034	0.013	--	1.1	8.0	0.62	0.46	<0.010	0.029	Amended with 334 ul of EOS®598 B42 to a target concentration of 0.1% as oil.
			EOS® 598B42-2	<0.010	0.055	6.3	0.032	0.022	<0.010	--	1.1	8.0	0.59	0.28	<0.010	0.028	
			EOS® 598B42-3	0.017	0.047	6.4	0.044	0.034	<0.010	--	1.1	8.5	0.63	0.42	<0.010	0.027	
			Average Concentration (mg/L)	0.012	0.053	6.3	0.040	0.030	0.0043	--	1.1	8.2	0.61	0.39	ND	0.028	
			Standard Deviation (mmoles)	1.4E-05	8.2E-06	2.2E-04	1.5E-05	2.5E-05	9.9E-05	--	5.4E-05	5.9E-04	4.4E-05	3.1E-04	0.0E+00	3.4E-05	
			Average Total mmoles	**0.000016**	**0.000084**	**0.013**	**0.000091**	**0.0001**	**0.000057**	**1.3E-02**	**0.0019**	**0.017**	**0.0012**	**0.0013**	**ND**	**0.0013**	
	04-May-11	14	EOS® 598B42-1	0.023	0.065	6.0	0.053	0.040	<0.010	--	1.1	8.2	0.58	0.47	<0.010	0.027	
			EOS® 598B42-2	0.025	0.018	5.7	0.058	0.046	<0.010	--	1.1	8.4	0.68	0.43	<0.010	0.026	
			EOS® 598B42-3	<0.010	0.024	6.0	0.049	0.031	<0.010	--	1.1	7.9	0.65	0.28	<0.010	0.027	
			Average Concentration (mg/L)	0.016	0.036	5.9	0.054	0.039	ND	--	1.1	8.2	0.64	0.39	ND	0.027	
			Standard Deviation (mmoles)	1.8E-05	4.1E-05	4.5E-04	1.1E-05	2.7E-05	0.0E+00	--	5.8E-05	5.2E-04	1.1E-04	3.2E-04	0.0E+00	3.0E-05	
			Average Total mmoles	**0.000021**	**0.000058**	**0.013**	**0.00012**	**0.00014**	**ND**	**1.3E-02**	**0.0018**	**0.017**	**0.0013**	**0.0013**	**ND**	**0.0013**	
	17-May-11	27	EOS® 598B42-1	0.031	0.039	4.1	0.058	0.11	<0.010	--	0.17	0.20	0.61	7.7	<0.010	0.030	
			EOS® 598B42-2	0.021	<0.010	5.0	0.049	0.34	<0.010	--	0.023	5.2	0.70	3.3	<0.010	0.030	
			EOS® 598B42-3	0.027	0.022	4.0	0.062	0.15	<0.010	--	0.45	0.14	0.70	7.7	<0.010	0.030	
			Average Concentration (mg/L)	0.026	0.020	4.4	0.056	0.20	ND	--	0.21	1.8	0.67	6.2	ND	0.030	
			Standard Deviation (mmoles)	6.7E-06	3.1E-05	1.1E-03	1.5E-05	4.4E-04	0.0E+00	--	3.6E-04	6.0E-03	1.0E-04	8.2E-03	0.0E+00	2.1E-05	
			Average Total mmoles	**0.000034**	**0.000032**	**0.0093**	**0.00013**	**0.0007**	**ND**	**1.0E-02**	**0.00035**	**0.0038**	**0.0014**	**0.020**	**ND**	**0.0014**	
	01-Jun-11	42	EOS® 598B42-1	<0.010	0.048	3.7	0.058	0.39	<0.010	--	<0.010	<0.010	0.66	7.8	<0.010	0.37	
			EOS® 598B42-2	<0.010	0.017	0.47	0.013	2.6	0.067	--	<0.010	0.013	0.66	7.6	<0.010	0.25	
			EOS® 598B42-3	<0.010	0.027	3.4	0.059	0.71	<0.010	--	<0.010	<0.010	0.75	8.2	<0.010	0.26	
			Average Concentration (mg/L)	ND	0.030	2.5	0.044	1.2	0.022	--	ND	0.0043	0.69	7.9	ND	0.29	
			Standard Deviation (mmoles)	0.0E+00	2.5E-05	3.8E-03	6.0E-05	4.1E-03	5.1E-04	--	0.0E+00	1.5E-05	1.1E-04	9.8E-04	0.0E+00	3.2E-03	
			Average Total mmoles	**ND**	**0.000049**	**0.0054**	**0.000099**	**0.0043**	**0.00030**	**1.0E-02**	**ND**	**0.0000088**	**0.0014**	**0.025**	**ND**	**0.014**	
	08-Jun-11	49	EOS® 598B42-1	<0.010	0.055	2.8	<0.010	0.97	0.036	--	<0.010	<0.010	0.66	7.8	<0.010	0.87	
			EOS® 598B42-2	<0.010	<0.010	0.011	0.012	1.5	0.40	--	<0.010	0.02	0.55	7.5	<0.010	1.2	
			EOS® 598B42-3	<0.010	0.022	2.1	0.041	1.5	0.029	--	<0.010	0.055	0.73	7.9	<0.010	0.74	
			Average Concentration (mg/L)	ND	0.026	1.7	0.018	1.3	0.15	--	ND	0.025	0.64	7.7	ND	0.93	
			Standard Deviation (mmoles)	0.0E+00	4.4E-05	3.1E-03	4.8E-05	1.1E-03	2.8E-03	--	0.0E+00	5.8E-05	1.9E-04	5.8E-04	0.0E+00	1.1E-02	
			Average Total mmoles	**ND**	**0.000041**	**0.0035**	**0.000040**	**0.0047**	**0.002**	**1.0E-02**	**ND**	**0.000052**	**0.0013**	**0.025**	**ND**	**0.043**	
	15-Jun-11	56	EOS® 598B42-1	<0.010	0.039	0.43	<0.010	1.0	0.40	--	<0.010	0.049	0.59	7.5	<0.010	1.9	
			EOS® 598B42-2	<0.010	<0.010	<0.010	<0.010	0.050	0.56	--	<0.010	0.021	0.44	7.1	<0.010	2.3	
			EOS® 598B42-3	<0.010	<0.010	0.13	<0.010	1.8	0.25	--	<0.010	0.079	0.61	7.4	<0.010	1.4	
			Average Concentration (mg/L)	ND	0.013	0.19	ND	0.96	0.40	--	ND	0.050	0.55	7.3	ND	1.9	
			Standard Deviation (mmoles)	0.0E+00	3.6E-05	4.8E-04	0.0E+00	3.1E-03	2.0E-03	--	0.0E+00	6.0E-05	1.9E-04	8.3E-04	0.0E+00	2.2E-02	
			Average Total mmoles	**ND**	**0.000021**	**0.00040**	**ND**	**0.0034**	**0.0053**	**9.1E-03**	**ND**	**0.00010**	**0.0011**	**0.024**	**ND**	**0.086**	
	29-Jun-11	70	EOS® 598B42-1	<0.010	<0.010	<0.010	0.014	<0.010	0.53	--	<0.010	0.013	0.42	7.2	<0.010	14	
			EOS® 598B42-2	<0.010	<0.010	<0.010	0.012	<0.010	0.47	--	<0.010	0.018	0.37	7.1	<0.010	10	
			EOS® 598B42-3	<0.010	<0.010	<0.010	<0.010	<0.010	0.56	--	<0.010	0.081	0.40	7.6	<0.010	6.9	
			Average Concentration (mg/L)	ND	ND	ND	0.0088	ND	0.52	--	ND	0.037	0.40	7.3	ND	10	
			Standard Deviation (mmoles)	0.0E+00	0.0E+00	0.0E+00	1.8E-05	0.0E+00	5.7E-04	--	0.0E+00	7.8E-05	5.9E-05	8.1E-04	0.0E+00	1.7E-01	
			Average Total mmoles	**ND**	**ND**	**ND**	**0.000020**	**ND**	**0.0068**	**6.8E-03**	**ND**	**0.000077**	**0.00080**	**0.024**	**ND**	**0.48**	
	14-Jul-11	85	EOS® 598B42-1	<0.010	<0.010	<0.010	<0.010	<0.010	0.51	--	<0.010	<0.010	0.19	7.1	<0.010	36	
			EOS® 598B42-2	<0.010	<0.010	<0.010	0.014	<0.010	0.41	--	<0.010	<0.010	0.22	6.5	<0.010	42	
			EOS® 598B42-3	0.010	<0.010	<0.010	0.012	<0.010	0.41	--	<0.010	<0.010	0.17	6.8	<0.010	39	
			Average Concentration (mg/L)	0.0034	ND	ND	0.0086	ND	0.44	--	ND	ND	0.20	6.8	ND	39	
			Standard Deviation (mmoles)	7.8E-06	0.0E+00	0.0E+00	1.7E-05	0.0E+00	7.3E-04	--	0.0E+00	0.0E+00	5.6E-05	9.8E-04	0.0E+00	1.4E-01	
			Average Total mmoles	**0.0000045**	**ND**	**ND**	**0.000019**	**ND**	**0.0058**	**5.8E-03**	**ND**	**ND**	**0.00040**	**0.022**	**ND**	**1.8**	
	03-Aug-11	105	EOS® 598B42-1	<0.010	<0.010	<0.010	0.049	<0.010	0.19	--	<0.010	<0.010	0.08	5.6	<0.010	48	
			EOS® 598B42-2	0.011	<0.010	<0.010	0.018	<0.010	0.28	--	<0.010	<0.010	0.13	6.2	<0.010	48	
			EOS® 598B42-3	<0.010	<0.010	<0.010	<0.010	<0.010	0.39	--	<0.010	<0.010	0.11	6.7	<0.010	95	
			Average Concentration (mg/L)	0.0038	ND	ND	0.022	ND	0.29	--	ND	ND	0.11	6.2	ND	64	
			Standard Deviation (mmoles)	8.6E-06	0.0E+00	0.0E+00	5.6E-05	0.0E+00	1.3E-03	--	0.0E+00	0.0E+00	5.1E-05	1.8E-03	0.0E+00	1.3E+00	
			Average Total mmoles	**0.0000050**	**ND**	**ND**	**0.000051**	**ND**	**0.0038**	**3.9E-03**	**ND**	**ND**	**0.00022**	**0.020**	**ND**	**3.0**	
	17-Aug-11	119	EOS® 598B42-1	<0.010	<0.010	<0.010	<0.010	<0.010	0.15	--	<0.010	<0.010	0.079	5.4	<0.010	39	
			EOS® 598B42-2	0.013	<0.010	<0.010	<0.010	<0.010	0.25	--	<0.010	<0.010	0.11	5.9	<0.010	41	
			EOS® 598B42-3	<0.010	0.013	<0.010	<0.010	<0.010	0.29	--	<0.010	<0.010	0.089	6.0	<0.010	79	
			Average Concentration (mg/L)	0.0042	0.0045	ND	ND	ND	0.23	--	ND	ND	0.092	5.7	ND	53	
			Standard Deviation (mmoles)	9.7E-06	1.2E-05	0.0E+00	0.0E+00	0.0E+00	9.2E-04	--	0.0E+00	0.0E+00	3.0E-05	1.1E-03	0.0E+00	1.1E+00	
			Average Total mmoles	**0.0000056**	**0.0000072**	**ND**	**ND**	**ND**	**0.0030**	**3.0E-03**	**ND**	**ND**	**0.00019**	**0.019**	**ND**	**2.5**	

Notes:

ANAC - anaerobic active control
ANSC - anaerobic sterile control
CA - chloroethane
cDCE - cis-1,2-dichloroethene
EOS - emulsified oil substrate
mg/L - milligrams per liter
mmoles - millimoles
mmol/bottle - millimoles per bottle
ND - not detected
PCE - tetrachloroethene
TCE - trichloroethene
VC - vinyl chloride
-- - not analyzed/not applicable
< - compound not detected, the associated value is the detected limit
1,1-DCE - 1,1- dichloroethene
1,1,1-TCA - 1,1,1-trichloroethane
1,1-DCA - 1,1-dichloroethane
1,2-DCA - 1,2-dichlororethane

TABLE 2B: SUMMARY OF MICROCOSM ANION RESULTS
Former Duso Chemical, Poughkeepsie, New York

TREATMENT	DATE	DAY	Treatment Replicate	Chloride	Nitrite	Nitrate	Sulfate	Bromide	Phosphate
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Anaerobic Sterile Control	20-Apr-11	0	ANSC-1	293	<0.12	21	50	<0.39	<0.57
			ANSC-2	289	<0.12	19	51	<0.39	<0.57
			ANSC-3	279	<0.12	20	45	<0.39	<0.57
			Average Concentratior	**287**	**ND**	**20**	**49**	**ND**	**ND**
	18-May-11	28	ANSC-1	320	<0.12	24	46	<0.39	<0.57
			ANSC-2	324	<0.12	23	57	<0.39	<0.57
			ANSC-3	309	<0.12	22	43	<0.39	<0.57
			Average Concentratior	**318**	**ND**	**23**	**49**	**ND**	**ND**
	15-Jun-11	56	ANSC-1	334	<0.12	21	57	<0.39	<0.57
			ANSC-2	355	<0.12	23	66	<0.39	<0.57
			ANSC-3	337	<0.12	21	56	<0.39	<0.57
			Average Concentratior	**342**	**ND**	**22**	**60**	**ND**	**ND**
Anaerobic Active Control	20-Apr-11	0	ANAC-1	221	<0.12	1.2	93	<0.39	<0.57
			ANAC -2	207	<0.12	<0.10	40	<0.39	<0.57
			ANAC -3	215	<0.12	<0.10	41	<0.39	<0.57
			Average Concentratior	**214**	**ND**	**0.40**	**58**	**ND**	**ND**
	18-May-11	28	ANAC-1	220	<0.12	1.9	43	<0.39	<0.57
			ANAC -2	213	<0.12	0.59	48	<0.39	<0.57
			ANAC -3	214	<0.12	3.4	33	<0.39	<0.57
			Average Concentratior	**216**	**ND**	**2.0**	**41**	**ND**	**ND**
	15-Jun-11	56	ANAC-1	229	<0.12	<0.10	40	<0.39	<0.57
			ANAC -2	229	<0.12	<0.10	60	<0.39	<0.57
			ANAC -3	224	<0.12	<0.10	41	<0.39	<0.57
			Average Concentratior	**227**	**ND**	**ND**	**47**	**ND**	**ND**
Amended with EOS®598B42	20-Apr-11	0	EOS®598 B42-2	210	<0.12	<0.10	37	<0.39	<0.57
			EOS®598 B42-2	242	<0.12	<0.10	42	<0.39	<0.57
			EOS®598 B42-3	219	<0.12	<0.10	41	<0.39	<0.57
			Average Concentration	**224**	**ND**	**ND**	**40**	**ND**	**ND**
	18-May-11	28	EOS®598 B42-2	221	<0.12	1.2	0.20	<0.39	<0.57
			EOS®598 B42-2	230	<0.12	0.32	1.2	<0.39	<0.57
			EOS®598 B42-3	219	<0.12	0.63	1.3	<0.39	<0.57
			Average Concentration	**223**	**ND**	**0.71**	**0.89**	**ND**	**ND**
	15-Jun-11	56	EOS®598 B42-2	229	<0.12	<0.10	2.6	<0.39	<0.57
			EOS®598 B42-2	230	<0.12	0.92	2.4	<0.39	<0.57
			EOS®598 B42-3	225	<0.12	<0.10	2.9	<0.39	<0.57
			Average Concentration	**228**	**ND**	**0.31**	**2.7**	**ND**	**ND**

Notes:

ANAC - anaerobic active control
ANSC - anaerobic sterile control
EOS - emulsified oil substrate
mg/L - milligrams per liter
ND - not detected
< - compound not detected, the associated value is the detected limit

TABLE 2C: SUMMARY OF MICROCOSM VFA RESULTS

Former Duso Chemical, Poughkeepsie, New York

TREATMENT	DATE	DAY	Treatment Replicate	Lactate	Acetate	Propionate	Formate	Butyrate	Pyruvate
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Amended with EOS®598 B42	20-Apr-11	0	EOS®598 B42-1	48	<0.54	<0.31	0.47	<0.41	<0.69
			EOS®598 B42-2	34	<0.54	<0.31	0.66	<0.41	<0.69
			EOS®598 B42-3	63	<0.54	1.9	<0.22	<0.41	<0.69
			Average Concentration	**48**	**ND**	**1.9**	**0.57**	**ND**	**ND**
	15-Jun-11	56	EOS®598 B42-1	<0.39	290	15	0.67	16	<0.69
			EOS®598 B42-2	<0.39	227	1.8	0.88	17	<0.69
			EOS®598 B42-3	<0.39	252	20	0.58	17	<0.69
			Average Concentration	**ND**	**256**	**12**	**0.71**	**16**	**ND**

Notes:

EOS - emulsified oil substrate
mg/L - milligrams per liter
ND - not detected
< - compound not detected, the associated value is the detected limit

TABLE 2D: SUMMARY OF MICROCOSM pH RESULTS SiREM

Former Duso Chemical, Poughkeepsie, New York

TREATMENT	DATE	DAY	Treatment Replicate	pH	ORP (mV)
Anaerobic Sterile Control	20-Apr-11	0	ANSC-1	6.51	---
			ANSC-2	6.69	---
			ANSC-3	6.68	---
			Average	**6.63**	**n/a**
	17-May-11	27	ANSC-1	6.58	---
			ANSC-2	6.55	---
			ANSC-3	6.64	---
			Average	**6.59**	**n/a**
	15-Jun	56	ANSC-1	6.72	---
			ANSC-2	6.75	---
			ANSC-3	6.73	---
			Average	**6.73**	**n/a**
	17-Aug	119	ANAC -1	6.74	---
			ANAC -2	6.79	---
			ANAC -3	6.78	---
			Average	**6.77**	**n/a**
Anaerobic Active Control	20-Apr-11	0	ANAC -1	6.75	---
			ANAC -2	6.85	---
			ANAC -3	6.83	---
			Average	**6.81**	**n/a**
	17-May-11	27	ANAC -1	6.76	---
			ANAC -2	6.64	---
			ANAC -3	6.66	---
			Average	**6.69**	**n/a**
	15-Jun	56	ANAC -1	6.83	---
			ANAC -2	6.85	---
			ANAC -3	6.93	---
			Average	**6.87**	**n/a**
	17-Aug	119	ANAC -1	6.89	---
			ANAC -2	6.85	---
			ANAC -3	6.98	---
			Average	**6.91**	**n/a**
Amended with EOS®598B42	20-Apr-11	0	EOS®598 B42-1	6.70	---
			EOS®598 B42-2	6.75	---
			EOS®598 B42-3	6.80	---
			Average	**6.75**	**n/a**
	17-May-11	27	EOS®598 B42-1	6.44	---
			EOS®598 B42-2	6.52	---
			EOS®598 B42-3	6.46	---
			Average	**6.47**	**n/a**
	8-Jun	49	EOS®598 B42-1	6.68	---
			EOS®598 B42-2	6.75	---
			EOS®598 B42-3	6.64	---
			Average	**6.69**	**n/a**
	15-Jun	56	EOS®598 B42-1	6.55	---
			EOS®598 B42-2	6.58	---
			EOS®598 B42-3	6.60	---
			Average	**6.58**	**n/a**
	13-Jul	84	EOS®598 B42-1	6.60	-120
			EOS®598 B42-2	6.67	-124
			EOS®598 B42-3	6.74	-123
			Average	**6.67**	**-122**
	3-Aug	105	EOS®598 B42-1	6.59	---
			EOS®598 B42-2	6.75	---
			EOS®598 B42-3	6.65	---
			Average	**6.66**	**n/a**
	17-Aug	119	EOS®598 B42-1	6.57	---
			EOS®598 B42-2	6.61	---
			EOS®598 B42-3	6.62	---
			Average	**6.60**	**n/a**

Notes:

ANAC - anaerobic active control
ANSC - anaerobic sterile control
EOS - emulsified oil substrate
mV - millivolts
n/a - not applicable
ORP - Oxydation Reduction Potential

TABLE 3: SUMMARY OF GENE-TRAC® RESULTS

Former Duso Chemical, Poughkeepsie, New York

Sample ID	Replicate Sample ID	Sample Date	Day	*Dehalococcoides* Enumeration (Gene-Trac® Dhc)	Vinyl Chloride Reductase Enumeration (Gene-Trac® VC)	*Dehalobacter* Enumeration (Gene-Trac® Dhb)
Baseline Groundwater	SGSB-3	21-Mar-11	NA	6 x 10^6/liter	7 x 10^6/liter	3 x 10^6/liter
	MHC-26	21-Mar-11	NA	8 x 10^5/liter	5 x 10^5/liter	3 x 10^4/liter
Anaerobic Active Control	4,5,6	29-Jun-11	70	7 x 10^6/liter	5 x 10^6/liter	4 x 10^6/liter
	4,5,6	17-Aug-11	119	1 x 10^6/liter	9 x 10^5/liter	6 x 10^5/liter
EOS® 598 B42 Amended	7,8,9	29-Jun-11	70	8 x 10^9/liter	6 x 10^9/liter	3 x 10^9/liter
	7,8,9	17-Aug-11	119	2 x 10^9/liter	1 x 10^9/liter	2 x 10^7/liter

Notes:

ANAC - anaerobic active control

EOS® - emulsified oil substrate

NA - not applicable/not analyzed

ND - not detected

TABLE 4: HALF LIVES (DAYS) OF CHLORINATED ETHENES DETECTED IN MICROCOSMS
Former Duso Chemical, Poughkeepsiek New York

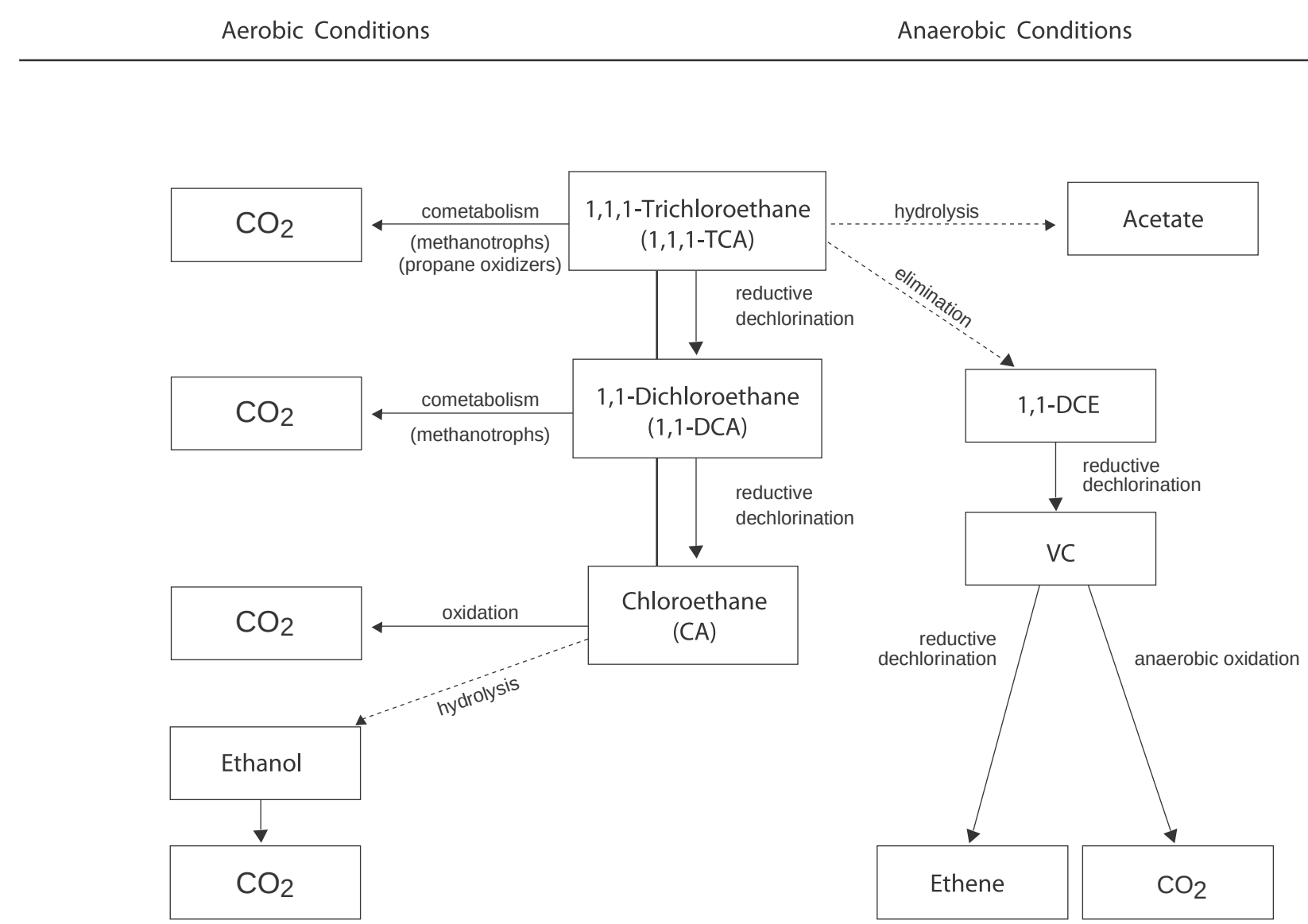
Treatment	TCE			cDCE			VC			1,1-DCE			1,1,1-TCA			1,1-DCA			1,2-DCA			CA		
	Half Life (Days)	T_1 (Day)	T_2 (Days)	**Half Life (Days)**	T_1 (Day)	T_2 (Days)	**Half Life (Days)**	T_1 (Day)	T_2 (Days)	**Half Life (Days)**	T_1 (Day)	T_2 (Days)	**Half Life (Days)**	T_1 (Day)	T_2 (Days)	**Half Life (Days)**	T_1 (Day)	T_2 (Days)	**Half Life (Days)**	T_1 (Day)	T_2 (Days)	**Half Life (Days)**	T_1 (Day)	T_2 (Days)
Anaerobic Sterile Control	~	NA	NA	494	NA	NA	~	NA	NA	~	NA	NA	270	NA	NA	1195	0	119	~	NA	NA	303	NA	NA
Anaerobic Active Control	~	NA	NA	370	0	119	523	NA	NA	~	NA	NA	175	0	119	700	0	119	~	NA	NA	266	0	119
EOS® 598 B42	21	0	70	5.8	0	56	2.6	49	70	8.3	27	56	5.3	0	42	3.8	0	42	45	0	119	177	42	119

Notes:

CA - chloroethane
cDCE - cis-1,2-dichloroethene
1,2-DCA - 1,2-dichloroethane
1,1-DCA - 1,1-dichloroehthane
1,1-DCE- 1,1-dichloroethene

1,1,1-TCA - 1,1,1-trichloroethane
NA - not applicable
TCE - trichloroethene
PCE - tetrachloroethene
VC - vinyl chloride
~ net degradation of compound was not detected over duration of study

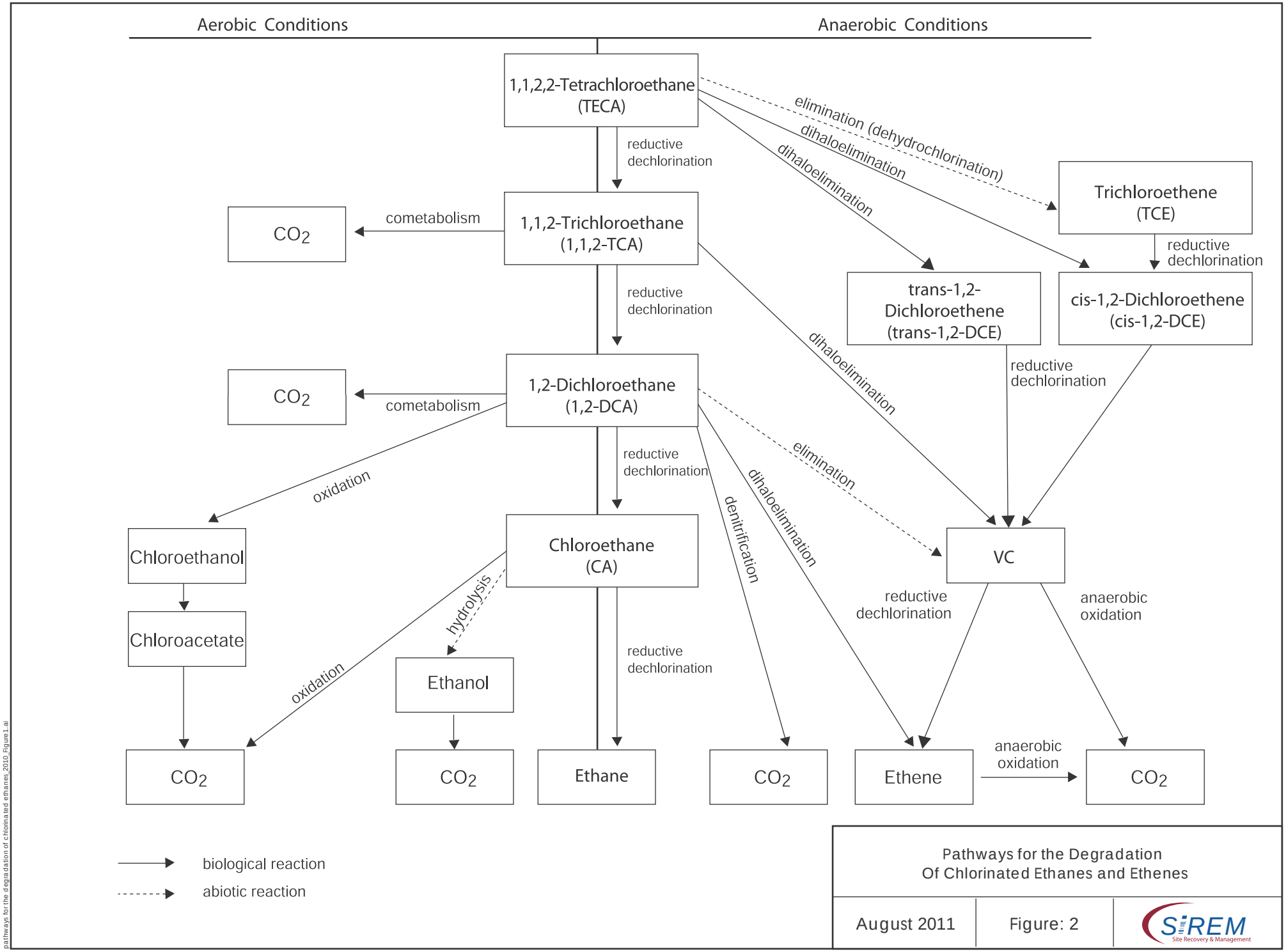
FIGURES

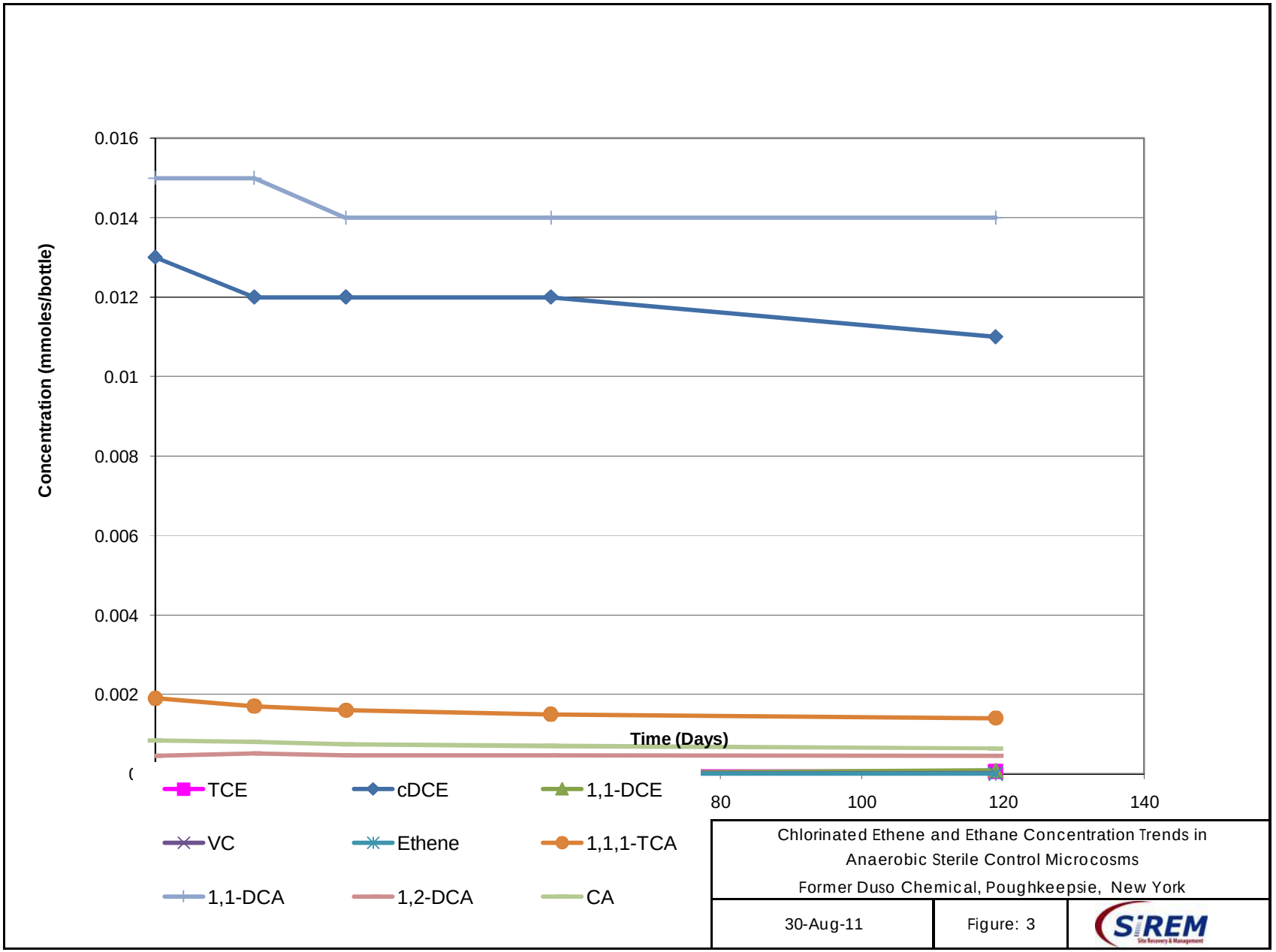


Pathways for the Degradation of
Chlorinated Ethanes and 1,1-DCE

August 2011	Figure: 1	SiREM Site Recovery & Management

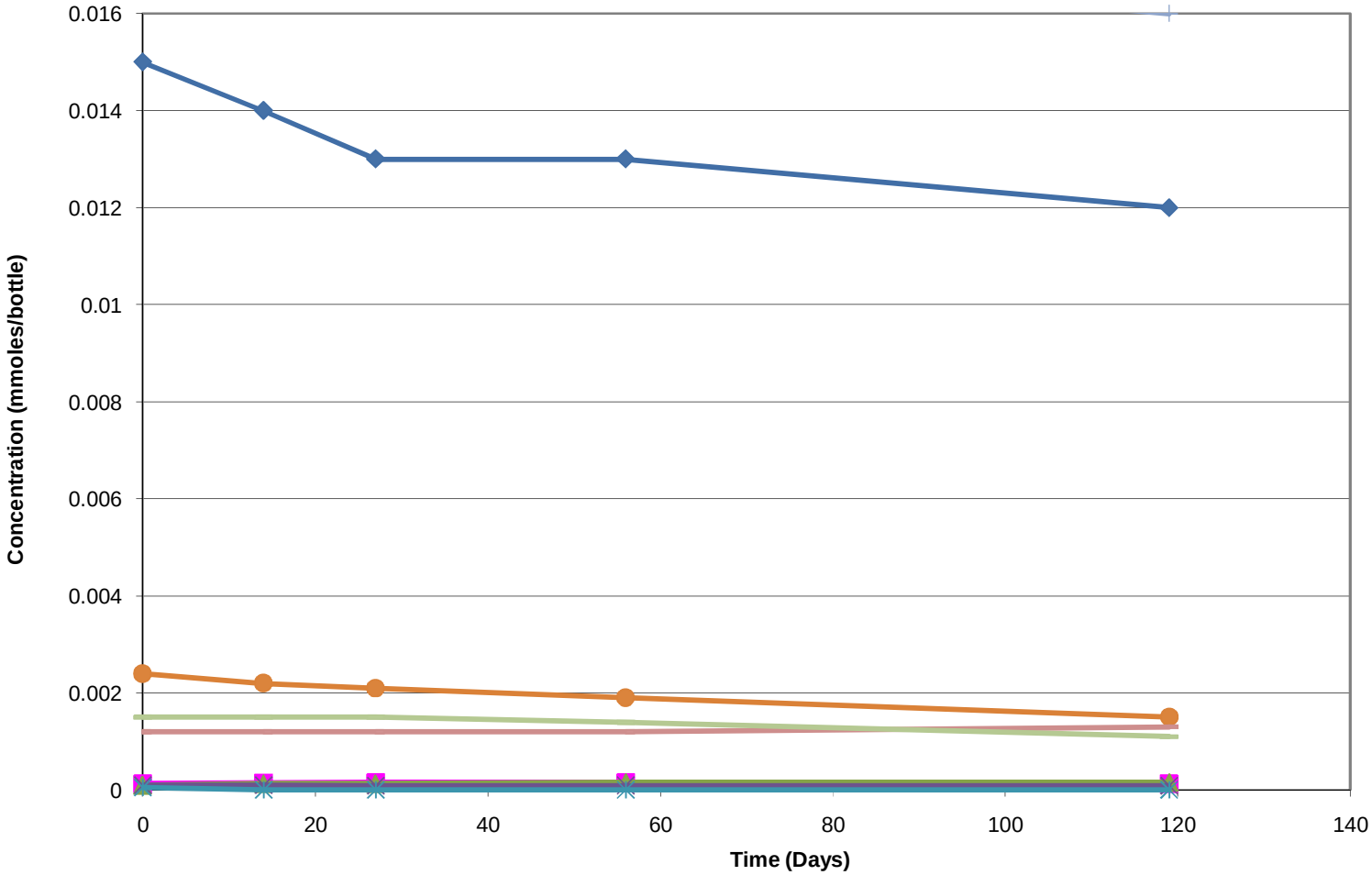
pathway_1,1,1-TCA.ai


Aerobic Conditions
Anaerobic Conditions
1,1,2,2-Tetrachloroethane (TECA)
1,1,2-Trichloroethane (1,1,2-TCA)
1,2-Dichloroethane (1,2-DCA)
Chloroethane (CA)
Trichloroethene (TCE)
trans-1,2-Dichloroethene (trans-1,2-DCE)
cis-1,2-Dichloroethene (cis-1,2-DCE)
VC
Ethene
Ethane
Ethanol
Chloroethanol
Chloroacetate
CO2
reductive dechlorination
elimination (dehydrochlorination)
dihaloelimination
cometabolism
oxidation
hydrolysis
denitrification
elimination
anaerobic oxidation
biological reaction
abiotic reaction
Pathways for the Degradation Of Chlorinated Ethanes and Ethenes
August 2011
Figure: 2
SiREM
Site Recovery & Management
pathways for the degradation of chlorinated ethanes_2010_Figure1.ai



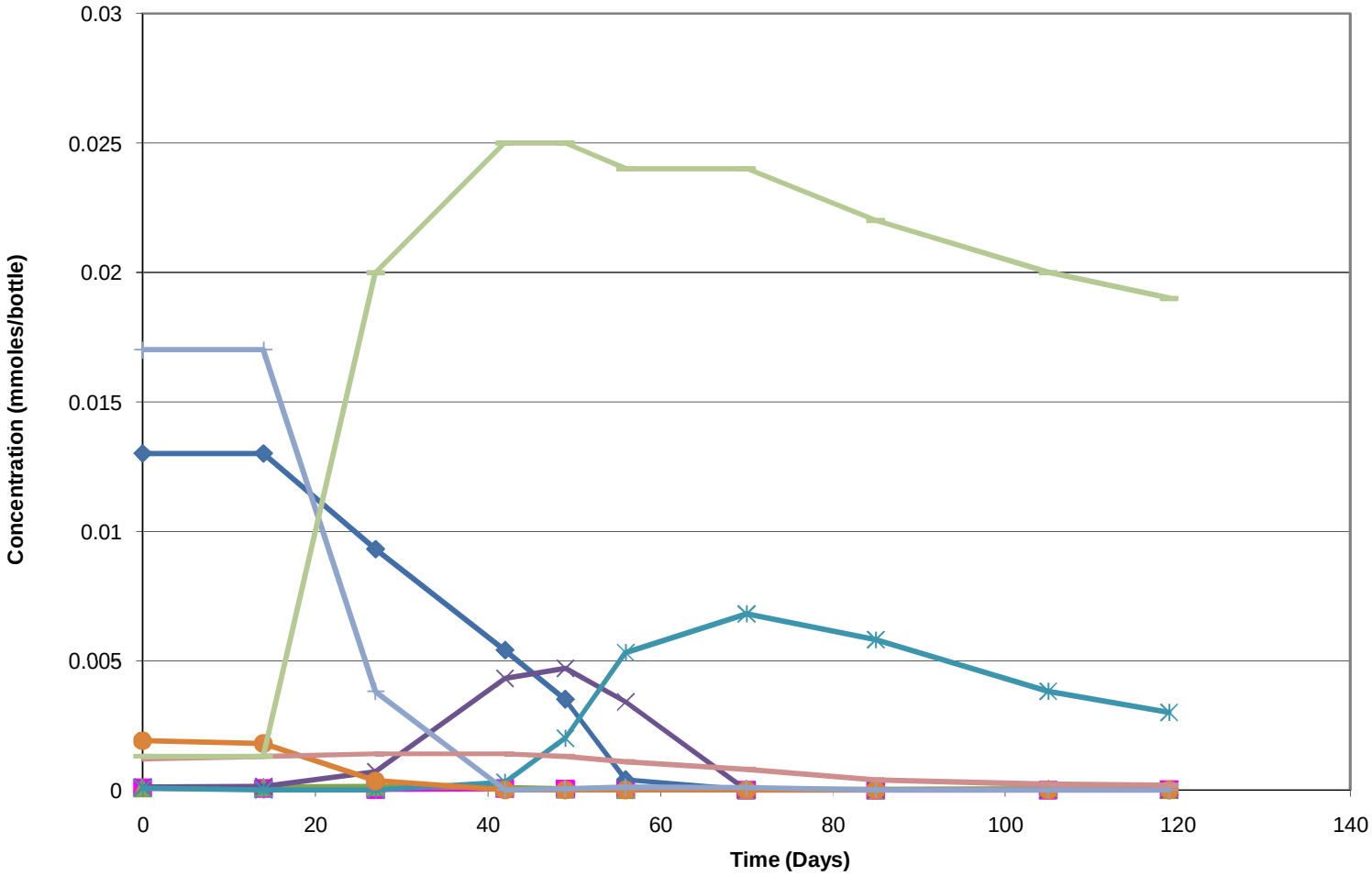
Chlorinated Ethene and Ethane Concentration Trends in Anaerobic Sterile Control Microcosms
Former Duso Chemical, Poughkeepsie, New York

30-Aug-11	Figure: 3	SiREM



Chlorinated Ethene and Ethane Concentration Trends in
Anaerobic Active Control Microcosms
Former Duso Chemical, Poughkeepsie, New York

30-Aug-11	Figure: 4	SiREM



Chlorinated Ethene and Ethane Concentration Trends in
EOS 598® B42 Amended Microcosms
Former Duso Chemical, Poughkeepsie, New York

30-Aug-11	Figure: 5	SiREM

APPENDIX A: Gene-Trac Reports

www.siremlab.com
130 Research Lane, Suite 2
Guelph, Ontario N1G 5G3
Phone (519) 822-2265
Fax (519) 822-3151

Certificate of Analysis: Gene-Trac® *Dehalococcoides* Assay

Customer: Dan Servatas, AECOM

Project: Former Duso Chemical

Customer Reference: Not Provided

SiREM Reference: S-2200

Report Issued: 18-Apr-11

Data Files: MyiQ-DHC-QPCR-0751
DHC-QPCR-Check-gel-0541
iQ5-DB-DHC-QPCR-0200

Table 1a: Test Results

Customer Sample ID	SiREM Sample ID	Sample Collection Date	Sample Matrix	Percent Dhc *	*Dehalococcoides* Enumeration/Liter **
SGSB-3	DHC-7175	21-Mar-11	Groundwater	0.3-0.9%	6×10^6
MHC-26	DHC-7176	21-Mar-11	Groundwater	0.04-0.1%	8×10^5

Notes:

* Percent *Dehalococcoides* (Dhc) in microbial population. This value is calculated by dividing the number of Dhc 16S ribosomal ribonucleic acid (rRNA) gene copies by the total number of bacteria as estimated by the mass of DNA extracted from the sample. Range represents normal variation in Dhc enumeration.

** Based on quantification of Dhc 16S rRNA gene copies. Dhc are generally reported to contain one 16S rRNA gene copy per cell; therefore, this number is often interpreted to represent the number of Dhc cells present in the sample.

J The associated value is an estimated quantity between the method detection limit and quantitation limit.
U Not detected, associated value is the quantification limit.
B Analyte was also detected in the method blank.
NA Not applicable as *Dehalococcoides* not detected and/or quantifiable DNA not extracted from the sample.

Analyst: J. Wilkinson
Jen Wilkinson
Biotechnology Technologist

Approved: Ximena Druar
Ximena Druar, B.Sc.
Molecular Biology Coordinator

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130 Research Lane, Suite 2
Guelph, Ontario N1G 5G3
Phone (519) 822-2265
Fax (519) 822-3151

Certificate of Analysis: Gene-Trac® VC, Vinyl Chloride Reductase (*vcrA*) Assay

Customer: Dan Servatas, AECOM

Project: Former Duso Chemical

Customer Reference: Not Provided

SiREM Reference: S-2200

Report Issued: 18-Apr-11

Data Files: iQ5-VC-QPCR-0376
VC-QPCR-Check-gel-0398

Table 1b: Test Results

Customer Sample ID	SiREM Sample ID	Sample Collection Date	Sample Matrix	Percent *vcrA* *	Vinyl Chloride Reductase (*vcrA*) Gene Copies/Liter
SGSB-3	VCR-2534	21-Mar-11	Groundwater	0.3-1%	7×10^6
MHC-26	VCR-2535	21-Mar-11	Groundwater	0.03-0.08%	5×10^5

Notes:

* Percentage of bacteria in the microbial population that harbor the *vcrA* gene. This value is calculated by dividing the measured number of cells haboring the vinyl chloride reductase A (*vcrA*) gene by the total number of bacteria in the sample estimated using the mass of DNA extracted from the sample. Range represents normal variation in enumeration of *vcrA* .

J The associated value is an estimated quantity between the method detection limit and quantitation limit.

U Not detected, associated value is the quantification limit.

B Analyte was also detected in the method blank.

NA Not applicable as *vcrA* not detected and/or quantifiable DNA not extracted from the sample.

Analyst: J. Wilkinson
Jen Wilkinson
Biotechnology Technologist

Approved: Ximena Druar
Ximena Druar, B.Sc.
Molecular Biology Coordinator

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130 Research Lane, Suite 2
Guelph, Ontario N1G 5G3
Phone (519) 822-2265
Fax (519) 822-3151

Certificate of Analysis: Gene-Trac® *Dehalobacter* Assay

Customer: Dan Servatas, AECOM

Project: Former Duso Chemical

Customer Reference: Not Provided

SiREM Reference: S-2200

Report Issued: 18-Apr-11

Data Files: MyiQ-DHB-QPCR-0151
DHB-QPCR-Check-gel-074

Table 1c: Test Results

Customer Sample ID	SiREM Sample ID	Sample Collection Date	Sample Matrix	Percent Dhb*	*Dehalobacter* 16S rRNA Gene Copies/ Liter
SGSB-3	DHB-0402	21-Mar-11	Groundwater	0.2-0.5%	3×10^6
MHC-26	DHB-0403	21-Mar-11	Groundwater	0.001-0.004%	3×10^4

Notes:

* Percent *Dehalobacter* (Dhb) in microbial population. This value is calculated by dividing the number of Dhb 16S ribosomal ribonucleic acid (rRNA) gene copies by the total number of bacteria as estimated by the mass of DNA extracted from the sample. Range represents normal variation in Dhb enumeration.

J The associated value is an estimated quantity between the method detection limit and quantitation limit.
U Not detected, associated value is the quantification limit.
B Analyte was also detected in the method blank.
NA Not applicable as *Dehalobacter* not detected and/or quantifiable DNA not extracted from the sample.

Analyst: J. Wilkinson
Jen Wilkinson
Biotechnology Technologist

Approved: Ximena Druar
Ximena Druar, B.Sc.
Molecular Biology Coordinator

Table 2: Detailed Test Parameters, Test Reference S-2200

Customer Sample ID	SGSB-3	MHC-26
SiREM Sample ID	DHC-7175/VCR-2534/DHB-0402	DHC-7176/VCR-2535/DHB-0403
Date Received	24-Mar-11	24-Mar-11
Sample Temperature	5 ˚C	5 ˚C
Volume Used for DNA Extraction	100 mL	100 mL
Filtration Date	1-Apr-11	1-Apr-11
DNA Extraction Date	11-Apr-11	11-Apr-11
DNA Concentration in Sample (extractable)	4013 ng/L	4223 ng/L
PCR Amplifiable DNA	Detected	Detected
Dhc qPCR Date Analyzed	12-Apr-11	12-Apr-11
***vcrA* qPCR Date Analyzed**	15-Apr-11	15-Apr-11
Dhb qPCR Date Analyzed	15-Apr-11	15-Apr-11
Laboratory Controls (see Tables 3, 4 & 5)	Passed	Passed
Comments	- -	- -

Notes:

Refer to Tables 3, 4 & 5 for detailed results of controls.
ng/L = nanograms per liter
mL = milliliters
°C = degrees Celsius
PCR = polymerase chain reaction
qPCR = quantitative PCR
Dhb = *Dehalobacter*
Dhc = *Dehalococcoides*
DNA = Deoxyribonucleic acid
vcrA = vinyl chloride reductase

Table 3: Gene-Trac Dhc Control Results, Test Reference S-2200

Laboratory Control	Analysis Date	Control Description	Spiked Dhc 16S rRNA Gene Copies per Liter	Recovered Dhc 16S rRNA Gene Copies per Liter	Comments
Positive Control Low Concentration	12-Apr-11	qPCR with KB-1 genomic DNA (CSLD-0389)	3.6×10^5	3.9×10^5	- -
Positive Control High Concentration	12-Apr-11	qPCR with KB-1 genomic DNA (CSHD-0389)	3.0×10^7	3.0×10^7	- -
DNA Extraction Blank	12-Apr-11	Tris Reagent Blank (TBD-0349)	0	3.9×10^3U	- -
Negative Control	12-Apr-11	DNA extraction sterile water (FB-1410)	0	3.9×10^3U	- -

Notes:

Dhc = *Dehalococcoides*

qPCR = quantitative PCR

DNA = Deoxyribonucleic acid

16S rRNA = 16S ribosomal ribonucleic acid

U Not detected, associated value is the quantification limit.

Table 4: Gene-Trac VC Control Results, Test Reference S-2200

Laboratory Control	Analysis Date	Control Description	Spiked *vcrA* reductase Gene Copies per Liter	Recovered *vcrA* reductase Gene Copies per Liter	Comments
Positive Control Low Concentration	15-Apr-11	qPCR with KB-1 genomic DNA (CSLV-0244)	4.8×10^5	3.7×10^5	- -
Positive Control High Concentration	15-Apr-11	qPCR with KB-1 genomic DNA (CSHV-0244)	3.6×10^7	4.1×10^7	- -
Negative Control	15-Apr-11	Tris Reagent Blank (TBV-0215)	0	3.9×10^3U	- -
DNA Extraction Blank	15-Apr-11	DNA extraction sterile water (FB-1410)	0	3.9×10^3U	

Notes:

qPCR = quantitative PCR

DNA = Deoxyribonucleic acid

16S rRNA = 16S ribosomal ribonucleic acid

vcrA = vinyl chloride reductase

U Not detected, associated value is the quantification limit.

Table 5: Gene-Trac Dhb Control Results, Test Reference S-2200

Laboratory Control	Analysis Date	Control Description	Spiked Dhb 16S rRNA Gene Copies per Liter	Recovered Dhb 16S rRNA Gene Copies per Liter	Comments
Positive Control Low Concentration	15-Apr-11	qPCR with WBC2 genomic DNA (CSLDB-0112)	8.7×10^5	5.4×10^5	- -
DNA Extraction Blank	15-Apr-11	DNA extraction sterile water (FB-1410)	0	3.9×10^3U	- -
Negative Control	15-Apr-11	Tris Reagent Blank	0	3.9×10^3U	- -

Notes:

qPCR = quantitative PCR

Dhb = *Dehalobacter*

DNA = Deoxyribonucleic acid

16S rRNA = 16S ribosomal ribonucleic acid

U Not detected, associated value is the quantification limit.

№ 3116

Chain-of-Custody Form

SIREM Site Recovery & Management

130 Research Lane, Suite 2 ◦ Guelph, Ontario, Canada N1G 5G3 ◦ Phone (519) 822-2265 or toll free 1-866-251-1747 Fax (519) 822-3151

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Page 1 of 1

Lab # S-2200

Project Name	Former Duso Chemical
Project #	
Project Manager	Dan Servatas
Email Address	arthur.tadder@aecom.com
Company	AECOM
Address	40 British American Blvd Latham NY 12110
Phone #	(518) 951 2200
Fax #	(518) 951 2300
Sampler's Signature	Mark Howard
Sampler's Printed Name	Mark Howard

Analysis

Preservative: 2

Customer Sample ID	Sampling Date	Sampling Time	Matrix	# of Containers	Gene-Trac Dhc	Gene-Trac VC	Gene-Trac Dhb	VOC 524.2 (MTBE)	Treatability Testing	Other Information
SG-SB-3	3/21/11	1452	GW	1				X		
MHC-24	3/21/11	1600	GW	1				X		
MHC-26	3/21/11	1430	GW	1				X		
MHC-22	3/21/11	1516	GW	1				X		
Star Gas SB-1	3/21/11		C	2				X		
Star Gas SB-2	3/21/11		C	2				X		
Star Gas SB-3	3/21/11		C	2				X		
Star Gas SB-4	3/21/11		C	2				X		

Preservative Key
0. None
1. HCl
2. Other None
3. Other

Sample Receipt
Cooler Condition: GOOD
Cooler Temperature: 5°C
Custody Seals: Yes ☒ No ☐

Billing Information
P.O. #
Bill To: Dan Servatas
40 British American Blvd
Latham NY 12110

Turnaround Time Requested
Normal ☒
Rush ☐

For Lab Use Only
Proposal #:

Relinquished By:	Received By:	Relinquished By:	Received By:	Relinquished By:	Received By:
Signature: Mark Howard	Signature: [signature]	Signature	Signature	Signature	Signature
Printed Name: Mark Howard	Printed Name: D. Vespoli	Printed Name	Printed Name	Printed Name	Printed Name
Firm: AECOM	Firm: SIREM	Firm	Firm	Firm	Firm
Date/Time: 3/22/11 1830	Date/Time: mar-24'11 2pm	Date/Time	Date/Time	Date/Time	Date/Time

Distribution: White - Return to Originator: Yellow - Lab Copy: Pink - Retained by Client

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130 Research Lane, Suite 2
Guelph, Ontario N1G 5G3
Phone (519) 822-2265
Fax (519) 822-3151

Certificate of Analysis: Gene-Trac® *Dehalococcoides* Assay

Customer: Arthur Taddeo, AECOM
Project: Former Duso Chemical
Customer Reference: not provided

SiREM Reference: S-2265
Report Issued: 29-Jun-11
Data Files: iQ5-DHC-QPCR-0780
DHC-QPCR-Check-gel-0563
MyiQ-DB-DHC-QPCR-0217

Table 1a: Test Results

Customer Sample ID	SiREM Sample ID	Sample Collection Date	Sample Matrix	Percent Dhc *	*Dehalococcoides* Enumeration/Liter **
ANAC composite	DHC-7386	21-Jun-11	Microcosm	0.03-0.08%	7×10^6
EOS composite	DHC-7387	21-Jun-11	Microcosm	27-62%	8×10^9

Notes:

* Percent *Dehalococcoides* (Dhc) in microbial population. This value is calculated by dividing the number of Dhc 16S ribosomal ribonucleic acid (rRNA) gene copies by the total number of bacteria as estimated by the mass of DNA extracted from the sample. Range represents normal variation in Dhc enumeration.

** Based on quantification of Dhc 16S rRNA gene copies. Dhc are generally reported to contain one 16S rRNA gene copy per cell; therefore, this number is often interpreted to represent the number of Dhc cells present in the sample.

J The associated value is an estimated quantity between the method detection limit and quantitation limit.
U Not detected, associated value is the quantification limit.
B Analyte was also detected in the method blank.
NA Not applicable as *Dehalococcoides* not detected and/or quantifiable DNA not extracted from the sample.

Analyst: J. Wilkinson
Jen Wilkinson
Biotechnology Technologist

Approved: Ximena Druar
Ximena Druar, B.Sc.
Molecular Biology Coordinator

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Phone (519) 822-2265
Fax (519) 822-3151

Certificate of Analysis: Gene-Trac® VC, Vinyl Chloride Reductase (*vcrA*) Assay

Customer: Arthur Taddeo, AECOM

Project: Former Duso Chemical

Customer Reference: not provided

SiREM Reference: S-2265

Report Issued: 29-Jun-11

Data Files: MyiQ-VC-QPCR-0394
VC-QPCR-Check-gel-0415
MyiQ-DB-VC-QPCR-0151

Table 1b: Test Results

Customer Sample ID	SiREM Sample ID	Sample Collection Date	Sample Matrix	Percent *vcrA* *	Vinyl Chloride Reductase (*vcrA*) Gene Copies/Liter
ANAC composite	VCR-2663	21-Jun-11	Microcosm	0.02-0.05%	5×10^6
EOS composite	VCR-2664	21-Jun-11	Microcosm	20-49%	6×10^9

Notes:

* Percentage of bacteria in the microbial population that harbor the *vcrA* gene. This value is calculated by dividing the measured number of cells haboring the vinyl chloride reductase A (*vcrA*) gene by the total number of bacteria in the sample estimated using the mass of DNA extracted from the sample. Range represents normal variation in enumeration of *vcrA* .

J The associated value is an estimated quantity between the method detection limit and quantitation limit.
U Not detected, associated value is the quantification limit.
B Analyte was also detected in the method blank.
NA Not applicable as *vcrA* not detected and/or quantifiable DNA not extracted from the sample.

Analyst: J. Wilkinson
Jen Wilkinson
Biotechnology Technologist

Approved: Ximena Druar
Ximena Druar, B.Sc.
Molecular Biology Coordinator

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Guelph, Ontario N1G 5G3
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Fax (519) 822-3151

Certificate of Analysis: Gene-Trac® *Dehalobacter* Assay

Customer: Arthur Taddeo, AECOM
Project: Former Duso Chemical
Customer Reference: not provided

SiREM Reference: S-2265
Report Issued: 29-Jun-11
Data Files: iQ5-DHB-QPCR-0161
DHB-QPCR-Check-gel-0082
iQ5-DB-DHB-QPCR-0001

Table 1c: Test Results

Customer Sample ID	SiREM Sample ID	Sample Collection Date	Sample Matrix	Percent Dhb*	*Dehalobacter* 16S rRNA Gene Copies/ Liter
ANAC composite	DHB-0442	21-Jun-11	Microcosm	0.01-0.04%	4×10^6
EOS composite	DHB-0443	21-Jun-11	Microcosm	12-31%	3×10^9

Notes:

* Percent *Dehalobacter* (Dhb) in microbial population. This value is calculated by dividing the number of Dhb 16S ribosomal ribonucleic acid (rRNA) gene copies by the total number of bacteria as estimated by the mass of DNA extracted from the sample. Range represents normal variation in Dhb enumeration.

J The associated value is an estimated quantity between the method detection limit and quantitation limit.
U Not detected, associated value is the quantification limit.
B Analyte was also detected in the method blank.
NA Not applicable as *Dehalobacter* not detected and/or quantifiable DNA not extracted from the sample.

Analyst: J. Wilkinson
Jen Wilkinson
Biotechnology Technologist

Approved: Ximena Druar
Ximena Druar, B.Sc.
Molecular Biology Coordinator

Table 2: Detailed Test Parameters, Test Reference S-2265

Customer Sample ID	ANAC composite	EOS composite
SiREM Sample ID	DHC-7386/VCR-2663/DHB-0442	DHC-7387/VCR-2664/DHB-0443
Date Received	21-Jun-11	21-Jun-11
Sample Temperature	NA	NA
Volume Used for DNA Extraction	10 mL	10 mL
Filtration Date	22-Jun-11	22-Jun-11
DNA Extraction Date	23-Jun-11	23-Jun-11
DNA Concentration in Sample (extractable)	53775 ng/L	48825 ng/L
PCR Amplifiable DNA	Detected	Detected
Dhc qPCR Date Analyzed	24-Jun-11	24-Jun-11
***vcrA* qPCR Date Analyzed**	27-Jun-11	27-Jun-11
Dhb qPCR Date Analyzed	27-Jun-11	27-Jun-11
Laboratory Controls (see Tables 3, 4 & 5)	Passed	Passed
Comments	- -	- -

Notes:

Refer to Tables 3 & 4 for detailed results of controls.
NA = not applicable
mL = milliliters
ng/L = nanograms per liter
Dhc = *Dehalococcoides*
vcrA = vinyl chloride reductase
Dhb = *Dehalobacter*
°C = degrees Celsius
PCR = polymerase chain reaction
qPCR = quantitative PCR
DNA = Deoxyribonucleic acid

Table 3: Gene-Trac Dhc Control Results, Test Reference S-2265

Laboratory Control	Analysis Date	Control Description	Spiked Dhc 16S rRNA Gene Copies per Liter	Recovered Dhc 16S rRNA Gene Copies per Liter	Comments
Positive Control Low Concentration	24-Jun-11	qPCR with KB-1 genomic DNA (CSLD-0418)	4.2×10^5	4.8×10^5	- -
Positive Control High Concentration	24-Jun-11	qPCR with KB-1 genomic DNA (CSHD-0418)	4.0×10^7	4.2×10^7	- -
Negative Control	24-Jun-11	Tris Reagent Blank (TBD-0378)	0	3.9×10^3U	- -
DNA Extraction Blank	24-Jun-11	DNA extraction sterile water (FB-1464)	0	3.9×10^3U	- -

Notes:

Dhc = *Dehalococcoides*

qPCR = quantitative PCR

DNA = Deoxyribonucleic acid

16S rRNA = 16S ribosomal ribonucleic acid

U Not detected, associated value is the quantification limit.

Table 4: Gene-Trac VC Control Results, Test Reference S-2265

Laboratory Control	Analysis Date	Control Description	Spiked *vcrA* reductase Gene Copies per Liter	Recovered *vcrA* reductase Gene Copies per Liter	Comments
Positive Control Low Concentration	27-Jun-11	qPCR with KB-1 genomic DNA (CSLV-0262)	5.8×10^5	4.8×10^5	- -
Positive Control High Concentration	27-Jun-11	qPCR with KB-1 genomic DNA (CSHV-0262)	4.6×10^7	5.8×10^7	- -
Negative Control	27-Jun-11	Tris Reagent Blank (TBV-0233)	0	3.9×10^3U	- -
DNA Extraction Blank	27-Jun-11	DNA extraction sterile water (FB-1464)	0	3.9×10^3U	

Notes:

qPCR = quantitative PCR

DNA = Deoxyribonucleic acid

16S rRNA = 16S ribosomal ribonucleic acid

vcrA = vinyl chloride reductase

U Not detected, associated value is the quantification limit.

Table 5: Gene-Trac Dhb Control Results, Test Reference S-2265

Laboratory Control	Analysis Date	Control Description	Spiked Dhb 16S rRNA Gene Copies per Liter	Recovered Dhb 16S rRNA Gene Copies per Liter	Comments
Positive Control	27-Jun-11	qPCR with WBC2 genomic DNA (CSLDB-0122)	9.0×10^5	1.1×10^6	- -
Negative Control	27-Jun-11	Tris Reagent Blank	0	3.9×10^3U	- -
DNA Extraction Blank	28-Jul-11	DNA extraction sterile water (FB-1464)	0	3.9×10^3U	- -

Notes:

qPCR = quantitative PCR

Dhb = *Dehalobacter*

DNA = Deoxyribonucleic acid

16S rRNA = 16S ribosomal ribonucleic acid

U Not detected, associated value is the quantification limit.

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Guelph, Ontario N1G 5G3
Phone (519) 822-2265
Fax (519) 822-3151

Certificate of Analysis: Gene-Trac® *Dehalococcoides* Assay

Customer: Dan Servatas, AECOM

Project: Former Duso Chemical

Customer Reference: Not Provided

SiREM Reference: S-2303

Report Issued: 29-Aug-11

Data Files: MyiQ-DHC-QPCR-0803
DHC-QPCR-Check-gel-0580
iQ5-DB-DHC-QPCR-0229

Table 1a: Test Results

Customer Sample ID	SiREM Sample ID	Sample Collection Date	Sample Matrix	Percent Dhc *	*Dehalococcoides* Enumeration/Liter **
DUSO-ANAC-170811	DHC-7502	17-Aug-11	Microcosm	0.006-0.02%	1×10^6
DUSO-EOS-170811	DHC-7503	17-Aug-11	Microcosm	4-12%	2×10^9

Notes:

* Percent *Dehalococcoides* (Dhc) in microbial population. This value is calculated by dividing the number of Dhc 16S ribosomal ribonucleic acid (rRNA) gene copies by the total number of bacteria as estimated by the mass of DNA extracted from the sample. Range represents normal variation in Dhc enumeration.

** Based on quantification of Dhc 16S rRNA gene copies. Dhc are generally reported to contain one 16S rRNA gene copy per cell; therefore, this number is often interpreted to represent the number of Dhc cells present in the sample.

J The associated value is an estimated quantity between the method detection limit and quantitation limit.
U Not detected, associated value is the quantification limit.
B Analyte was also detected in the method blank.
NA Not applicable as *Dehalococcoides* not detected and/or quantifiable DNA not extracted from the sample.

Analyst: Kela Bartle
Kela Bartle, B.Sc.
Biotechnology Technologist

Approved: Ximena Druar
Ximena Druar, B.Sc.
Molecular Biology Coordinator

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Fax (519) 822-3151

Certificate of Analysis: Gene-Trac® VC, Vinyl Chloride Reductase (*vcrA*) Assay

Customer: Dan Servatas, AECOM

Project: Former Duso Chemical

Customer Reference: Not Provided

SiREM Reference: S-2303

Report Issued: 29-Aug-11

Data Files: MyiQ-VC-QPCR-0404
VC-QPCR-Check-gel-0424
MyiQ-DB-VC-QPCR-0160

Table 1b: Test Results

Customer Sample ID	SiREM Sample ID	Sample Collection Date	Sample Matrix	Percent *vcrA* *	Vinyl Chloride Reductase (*vcrA*) Gene Copies/Liter
DUSO-ANAC-170811	VCR-2738	17-Aug-11	Microcosm	0.004-0.01%	9×10^{5}B
DUSO-EOS-170811	VCR-2739	17-Aug-11	Microcosm	3-9%	1×10^{9}B

Notes:

* Percentage of bacteria in the microbial population that harbor the *vcrA* gene. This value is calculated by dividing the measured number of cells haboring the vinyl chloride reductase A (*vcrA*) gene by the total number of bacteria in the sample estimated using the mass of DNA extracted from the sample. Range represents normal variation in enumeration of *vcrA* .

J The associated value is an estimated quantity between the method detection limit and quantitation limit.

U Not detected, associated value is the quantification limit.

B Analyte was also detected in the method blank.

NA Not applicable as *vcrA* not detected and/or quantifiable DNA not extracted from the sample.

Analyst: Kela Bartle
Kela Bartle
Biotechnology Technologist

Approved: Ximena Druar
Ximena Druar, B.Sc.
Molecular Biology Coordinator

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Phone (519) 822-2265
Fax (519) 822-3151

Certificate of Analysis: Gene-Trac® *Dehalobacter* Assay

Customer: Dan Servatas, AECOM

Project: Former Duso Chemical

Customer Reference: Not Provided

SiREM Reference: S-2303

Report Issued: 29-Aug-11

Data Files: MyiQ-DHB-QPCR-0171
DHB-QPCR-Check-gel-0089
iQ5-DB-DHB-QPCR-0008

Table 1c: Test Results

Customer Sample ID	SiREM Sample ID	Sample Collection Date	Sample Matrix	Percent Dhb*	*Dehalobacter* 16S rRNA Gene Copies/ Liter
DUSO-ANAC-170811	DHB-0472	17-Aug-11	Microcosm	0.003-0.008%	6×10^5B
DUSO-EOS-170811	DHB-0473	17-Aug-11	Microcosm	0.05-0.1%	2×10^7B

Notes:

* Percent *Dehalobacter* (Dhb) in microbial population. This value is calculated by dividing the number of Dhb 16S ribosomal ribonucleic acid (rRNA) gene copies by the total number of bacteria as estimated by the mass of DNA extracted from the sample. Range represents normal variation in Dhb enumeration.

J The associated value is an estimated quantity between the method detection limit and quantitation limit.
U Not detected, associated value is the quantification limit.
B Analyte was also detected in the method blank.
NA Not applicable as *Dehalobacter* not detected and/or quantifiable DNA not extracted from the sample.

Analyst: Kela Bartle
Kela Bartle, B.Sc.
Biotechnology Technologist

Approved: Ximena Druar
Ximena Druar, B.Sc.
Molecular Biology Coordinator

Table 2: Detailed Test Parameters, Test Reference S-2303

Customer Sample ID	DUSO-ANAC-170811	DUSO-EOS-170811
SiREM Sample ID	DHC-7502/VCR-2738/DHB-0472	DHC-7503/VCR-2739/DHB-0473
Date Received	17-Aug-11	17-Aug-11
Sample Temperature	NA	NA
Volume Used for DNA Extraction	10 mL	10 mL
Filtration Date	17-Aug-11	17-Aug-11
DNA Extraction Date	17-Aug-11	17-Aug-11
DNA Concentration in Sample (extractable)	44475 ng/L	76425 ng/L
PCR Amplifiable DNA	Detected	Detected
Dhc qPCR Date Analyzed	18-Aug-11	18-Aug-11
***vcrA* qPCR Date Analyzed**	22-Aug-11	22-Aug-11
Dhb qPCR Date Analyzed	25-Aug-11	25-Aug-11
Laboratory Controls (see Tables 3, 4 & 5)	Passed	Passed
Comments	- -	- -

Notes:

Refer to Tables 3, 4 & 5 for detailed results of controls.
NA = not applicable
mL = milliliters
ng/L = nanograms per liter
DNA = Deoxyribonucleic acid
PCR = polymerase chain reaction
qPCR = quantitative PCR
°C = degrees Celsius
Dhc = *Dehalococcoides*
Dhb = *Dehalobacter*
vcrA = vinyl chloride reductase

Table 3: Gene-Trac Dhc Control Results, Test Reference S-2303

Laboratory Control	Analysis Date	Control Description	Spiked Dhc 16S rRNA Gene Copies per Liter	Recovered Dhc 16S rRNA Gene Copies per Liter	Comments
Positive Control Low Concentration	18-Aug-11	qPCR with KB-1 genomic DNA (CSLD-0441)	2.5×10^5	3.1×10^5	- -
Positive Control High Concentration	18-Aug-11	qPCR with KB-1 genomic DNA (CSHD-0441)	2.8×10^7	3.5×10^7	- -
Negative Control	18-Aug-11	Tris Reagent Blank (TBD-0401)	0	3.9×10^3U	- -
DNA Extraction Blank	18-Aug-11	DNA extraction sterile water (FB-1498)	0	3.9×10^3U	- -

Notes:

Dhc = *Dehalococcoides*

qPCR = quantitative PCR

DNA = Deoxyribonucleic acid

16S rRNA = 16S ribosomal ribonucleic acid

U Not detected, associated value is the quantification limit.

Table 4: Gene-Trac VC Control Results, Test Reference S-2303

Laboratory Control	Analysis Date	Control Description	Spiked *vcrA* reductase Gene Copies per Liter	Recovered *vcrA* reductase Gene Copies per Liter	Comments
Positive Control Low Concentration	22-Aug-11	qPCR with KB-1 genomic DNA (CSLV-0272)	2.8×10^5	1.5×10^5	- -
Positive Control High Concentration	22-Aug-11	qPCR with KB-1 genomic DNA (CSHV-0272)	3.2×10^7	2.3×10^7	- -
Negative Control	22-Aug-11	Tris Reagent Blank (TBV-0243)	0	3.9×10^3U	- -
DNA Extraction Blank	19-Aug-11	DNA extraction sterile water (FB-1498)	0	6.4×10^3	See Note 1

Notes:

qPCR = quantitative PCR

DNA = Deoxyribonucleic acid

16S rRNA = 16S ribosomal ribonucleic acid

vcrA = vinyl chloride reductase

U Not detected, associated value is the quantification limit.

[1]Acceptable as test results for relevant samples exceeded DNA Extraction Blank test result by at least 10-fold.

Table 5: Gene-Trac Dhb Control Results, Test Reference S-2303

Laboratory Control	Analysis Date	Control Description	Spiked Dhb 16S rRNA Gene Copies per Liter	Recovered Dhb 16S rRNA Gene Copies per Liter	Comments
Positive Control Low Concentration	25-Aug-11	qPCR with WBC2 genomic DNA (CSLDB-0132)	3.0×10^5	2.6×10^5	- -
Positive Control High Concentration	25-Aug-11	qPCR with WBC2 genomic DNA (CSHDB-0132)	3.3×10^7	3.0×10^7	- -
Negative Control	25-Aug-11	Tris Reagent Blank	0	3.9×10^3U	- -
DNA Extraction Blank	19-Aug-11	DNA extraction sterile water (FB-1498)	0	1.9×10^3J	See Note 1

Notes:

qPCR = quantitative PCR

Dhb = *Dehalobacter*

DNA = Deoxyribonucleic acid

16S rRNA = 16S ribosomal ribonucleic acid

U Not detected, associated value is the quantification limit.

J The associated value is an estimated quantity between the method detection limit and quantitation limit.

[1]Acceptable as test results for relevant samples exceeded DNA Extraction Blank test result by at least 10-fold.

№ 3249

Chain-of-Custody Form

SiREM Site Recovery & Management

130 Research Lane, Suite 2 ◦ Guelph, Ontario, Canada N1G 5G3 ◦ Phone (519) 822-2265 or toll free 1-866-251-1747 Fax (519) 822-3151
www.siremlab.com

Lab # S-2303

Page ___ of ___

Project Name	Project #
DUSO Chemical.	
Project Manager	
Email Address	
Company AECom, Art Tadeo	
Address	
Phone #	Fax #
Sampler's Signature	Sampler's Printed Name

Analysis

Preservative

Gene-Trac Dhc | Gene-Trac VC | Gene-Trac Dhb

Preservative Key
0. None
1. HCl
2. Other _____
3. Other _____

Customer Sample ID	Sampling Date	Sampling Time	Matrix	# of Containers	Other Information
~~DUSO-ANSC-170811~~			~~W~~	~~1x10ml~~	
DUSO-ANAC-170811			W	1x10ml	
DUSO-EOS-170811			W	1x10ml	

Sample Receipt
Cooler Condition:
Cooler Temperature:
Custody Seals: Yes ☐ No ☐

Billing Information
P.O. #
Bill To:

Turnaround Time Requested
Normal ☐
Rush ☐

For Lab Use Only
Proposal #: _____

Relinquished By:	Received By:	Relinquished By:	Received By:	Relinquished By:	Received By:
Signature	Signature	Signature	Signature	Signature	Signature
Printed Name	Printed Name D. Nespoli	Printed Name	Printed Name	Printed Name	Printed Name
Firm	Firm SiREM	Firm	Firm	Firm	Firm
Date/Time	Date/Time AUG 17 '11	Date/Time	Date/Time	Date/Time	Date/Time

Distribution: White - Return to Originator: Yellow - Lab Copy: Pink - Retained by Client

№ 3116

Chain-of-Custody Form

SIREM Site Recovery & Management

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Page 1 of 1

Lab # S-2200

Project Name	Former Duso Chemical
Project #	
Project Manager	Dan Servatas
Email Address	arthur.tadder@aecom.com
Company	AECOM
Address	40 British American Blvd Latham NY 12110
Phone #	(518) 951 2200
Fax #	(518) 951 2300
Sampler's Signature	Mark Howard
Sampler's Printed Name	Mark Howard

Analysis

Preservative: 2

Customer Sample ID	Sampling Date	Sampling Time	Matrix	# of Containers	Gene-Trac Dhc	Gene-Trac VC	Gene-Trac Dhb	VOC 524.2 (MTBE)	Treatability Testing	Other Information
SG-SB-3	3/21/11	1452	GW	1				X		
MHC-24	3/21/11	1600	GW	1				X		
MHC-26	3/21/11	1430	GW	1				X		
MHC-22	3/21/11	1516	GW	1				X		
Star Gas SB-1	3/21/11		C	2				X		
Star Gas SB-2	3/21/11		C	2				X		
Star Gas SB-3	3/21/11		C	2				X		
Star Gas SB-4	3/21/11		C	2				X		

Preservative Key
0. None
1. HCl
2. Other None
3. Other

Sample Receipt
Cooler Condition: GOOD
Cooler Temperature: 5°C
Custody Seals: Yes ☒ No ☐

Billing Information
P.O. #
Bill To: Dan Servatas
40 British American Blvd
Latham NY 12110

Turnaround Time Requested
Normal ☒
Rush ☐

For Lab Use Only
Proposal #:

Relinquished By:	Received By:	Relinquished By:	Received By:	Relinquished By:	Received By:
Signature: Mark Howard	Signature: [signature]	Signature	Signature	Signature	Signature
Printed Name: Mark Howard	Printed Name: D. Vespoli	Printed Name	Printed Name	Printed Name	Printed Name
Firm: AECOM	Firm: SIREM	Firm	Firm	Firm	Firm
Date/Time: 3/22/11 1830	Date/Time: mar-24'11 2pm	Date/Time	Date/Time	Date/Time	Date/Time

Distribution: White - Return to Originator: Yellow - Lab Copy: Pink - Retained by Client

APPENDIX B: Henry's Law Calculation

The following Henry's Law calculation was used to convert aqueous concentrations (Table 2A) to total mmoles of each analyte per microcosm bottle (Figures 3 to 5):

$$\text{Total mmoles} = \frac{C_{liq} \times (V_{liq} + H \times V_{gas})}{\text{Molecular Weight (mg/mmol)}}.$$

Where

C_{liq} = liquid concentration (mg/L)
V_{liq} = liquid volume (0.20 L) per bottle
V_{gas} = headspace volume (0.02 L) per bottle
H = Henry's Law constant (dimensionless)

The Henry's Law constants used are summarized in the table below.

Analyte	Henry's Law Constant [a] (dimensionless)
Trichloroethene	0.48
cis-1,2-dichloroethene	0.31
1,1-dichloroethene	1.04
Vinyl chloride	0.95
Ethene	8.76
1,1,1-trichlorolethane	1.13
1,1-dichloroethane	0.23
chloroethane	0.48
Ethane	20.42
Methane	27.2

[a] Source: Montgomery, J.H. 2000. *Groundwater Chemicals Desk Reference, Third Edition.* CRC Press LLC, Boca Raton, FL.

Appendix E

Underground Injection Control Inventory Notification

U.S. ENVIRONMENTAL PROTECTION AGENCY, REGION 2

UNDERGROUND INJECTION CONTROL PROGRAM

SITE REMEDIATION INJECTION WELL INVENTORY SPREADSHEET

e-Mail Completed Forms to Region2_UIC@epa.gov or Fax to (212) 637-3953

Facility Name	Facility Street	Facility City	Facility State	Facility Zip Code	Facility Phone (if applicable)	Facility Latitude (decimal degrees)	Facility Longitude (negative decimal degrees)	Owner Name	Owner Mailing Address	Owner City	Owner State	Owner Zip	Injection Well Type	Number of Injection wells	Chemical(s) and concentration(s) being injected	Frequency of Injection	Anticipated Total Duration of Injection
Former Duso Chemical Site NYSDEC Site # 3-14-103	33 Fulton Street	Poughkeepsie	NY	12601	No phone at facility (use NYSDEC PM Phone 518. 402.9814)	41.7003	73.9214	David J. Chiusano (NYSDEC)	625 Broadway, 12th Floor	Albany	NY	12233	Remediation	75 (injection using direct-push methods; no injection wells to be constructed)	1. Emulsified Vegetable Oil (EOS Pro), 10% v/v (75 pts) 2. Plant Based Carbon Substrate with Zero Valent Iron (EHC), 0.35% soil volume (9 pts)	1 time	4-8 weeks

From: Underhill, Scott
Sent: Wednesday, March 13, 2013 1:35 PM
To: Region2_UIC@epa.gov
Cc: David Chiusano
Subject: UIC Notification for Former Duso Chemical Site NYSDEC Site #3-14-103
Attachments: DUSO IGP-22 Att1_DEC_Inventory_Spreadsheet 092809.xlsx

On behalf of the New York State Department of Environmental Conservation (NYSDEC) Division of Remediation (DER), AECOM is presenting this notification of remediation injections at the Former Duso Chemical Site (NYSDEC Site #3-14-103) in Poughkeepsie, NY, which is a NYSDEC led site. In accordance with the DER Internal Guidance Policy (IGP-22), notification is being made directly by NYSDEC's consultant using the inventory spreadsheet which was created by EPA Region 2 for exclusive use by DEC (attached). Per the ROD issued by NYSDEC in March 2008, the selected remedy for this site is Enhanced In-Situ Bioremediation via reductive dechlorination as the primary contaminants are chlorinated volatile organic compounds (CVOCs). The proposed injection plan includes injection of an emulsified vegetable oil (EOS Pro) into 75 injection points using direct-push methods; a limited number of injection points located in the area of highest concentrations will also receive zero valent iron and a plant based carbon substrate (EHC). AECOM has successfully and safely implemented these remedial amendments for treatment of CVOCs at nearly 100 sites. Please note a range of four to eight weeks is presented as injection duration, and the actual duration will be determined by subsurface conditions. The NYSDEC project manager is David Chiusano. Please contact Mr. Chiusano (copied to this email) or myself with any questions regarding the notification or the proposed remedial plan.

Thank you,
Scott

Scott Underhill, PE
Project Manager
Environment
D 518.951.2208 M 518.396.7638
scott.underhill@aecom.com

AECOM
40 British American Blvd, Latham, NY 12110
T 518.951.2200 F 518.951.2300
www.aecom.com

Appendix F

Enhanced In-Situ Bioremediation Pilot Study Subcontractor Cost Estimate

FORMER DUSO CHEMICAL SITE
33 Fulton Street, Poughkeepsie, NY

Enhanced In-Situ Bioremediation Pilot Study
Engineer's Cost Estimate for Remediation Subcontractor Costs

DESCRIPTION	UNIT	QUANTITY	RATE	TOTAL COST	ESTIMATE/SOURCE NOTES
INJECTION SUBCONTRACTOR (assume subcontractor procures all chemicals and provides all labor, equipment, and supplies to perform the injections)					
Mobilization	1	LS	$10,000	$10,000	Conservative Allowance based on AECOM experience 2011-2013
Mobilization Misc. & Additional	1	LS	$1,500	$1,500	Dumpster, connections, etc
Injection Subcontractor (labor, rig, equipment for ZVI points)	7	days	$4,200	$29,400	Average cost from AECOM experience 2011-2013 in the northeast with day rate quotes from $2,500 to $6200 (n=4)
Injection Subcontractor (labor, rig, equipment for VO points)	20	days	$3,200	$64,000	Average cost from AECOM experience 2011-2013 in the northeast with day rate quotes from $1,500 to $6200 (n=5)
Subcontractor Per Diem	27	days	$450	$12,150	AECOM experience 2011-2013 (assume 2-3 person crew)
Bentonite Chips for Hole Fill	95	bags	$25	$2,375	allowance based on field experience
Water Tanker Trailer Rental	5	weeks	$500	$2,500	based on quotes received for other projects in CT, NY, and MA
Water Delivery	12	deliveries	$350	$4,200	Each delivery 4,000-5,000 gallons to fill tanker (Estimated volume of 48,000 gallons)
Remediation Chemicals					
EHC (FMC)	7850	lbs	$2.65	$20,803	FMC quote January 2013
EHC (FMC) Delivery	1	shipment	$1,900	$1,900	FMC quote January 2013
Vegetable Oil (EOS Pro)	15	totes	$4,000	$60,000	average of EOS quote Jan. 2013 and AECOM EOS invoice Oct 2012
Vegetable Oil (EOS Pro)	4	drums	$840	$3,360	EOS invoice October 2012
Vegetable Oil (EOS Pro) Delivery	1	shipment	$3,500	$3,700	EOS quote January 2013 + 25%
Subcontractor Markup on Chemical			4%	$4,423	
INJECTION CONTRACTOR TOTAL				**$220,310**	

DESCRIPTION	UNIT	QUANTITY	RATE	TOTAL COST	ESTIMATE/SOURCE NOTES
GROUNDWATER PERFORMANCE MONITORING (includes labor, equipment, and supplies to perform groundwater performance sampling and analytical laboratory costs)					
Per the EISB Pilot Test Work Plan, assumes sampling following injection at 1 month (water quality parameters only), 3 months, 6 months, 9 months, 12 months, 18 months, 24 months, and 36 months					
Field Sampling Labor					assume 3 wells per person per day
7-9 well events	8	event	$3,135	$25,080	assume 8 hours on site plus roundtrip travel
Sampling Equipment	8	event	$1,500	$12,000	Allowance, including YSI, peristaltic pumps, water levels, Turb Meters, PID, PPE, vehicle rental, misc
Laboratory Analyses					
VOCs	63	samples	$55	$3,465	Test America, 2012
TOC	66	samples	$21	$1,386	Test America, 2012
Sulfate	18	samples	$10	$180	Test America, 2012
M/E/E	36	samples	$90	$3,240	Test America, 2012
DHC/DHB	27	samples	$380	$10,260	SiREM, 2012
Volatile Fatty Acids	18	samples	$55	$990	SiREM, 2012
As/Fe/Mn	25	samples	$40	$1,000	assumption based on recent AECOM in-situ projects
QC Samples (20% of analytical total)	20%			$4,200	
PERFORMANCE MONITORING COST				**$61,801**	

Appendix G

Property Access Information


990867
9.71 Ac.(s)
059876
2.91 Ac.
083848
1.607 Ac.
FM 5638 - 1
POUGHKEEPSIE
005836
5.81 Ac.(s)
062838
042826
FULTON ST
336.5
341.1'
175
767.8'
224
385(s)
005805
225
BECK PL

ParcelAccess

Parcel Grid Identification #:
134689-6162-05-005836-0000
Municipality: Poughkeepsie

Parcel Location
3440-3444 North Rd

Owner Name on March 1
Midhudson Center LLC , *(P)*

Primary *(P)* Owner Mail Address

PO Box 9273
Oak Brook IL 605229273

Parcel Details

Size (acres):	5.81 Ac (S)	Land Use Class:	(452) Commercial: Retail Services: Area or Neighborhood Shopping Centers
File Map:	10650	Agri. Dist.:	(0)
File Lot #:	3	School District:	(133201) Hyde Park Central School District
Split Town			

Assessment Information (Current)
*** 2013 assessments not yet established ***

Last Sale/Transfer

Sales Price:	Sale Date:	Deed Book:	Deed Page:	Sale Condition:	No. Parcels:
$0	0	1957	0612	( )	0

Site Information:
Site Number: 1

Water Supply:	Sewer Type:	Desirability:	Zoning Code:	Used As:
(3) Comm/public	(3) Comm/public	(3) Superior	FC	(D03) Local center

Commercial/Industrial/Utility Building Information:
Site Number: 1
Bldg Sec.: 1 Bldg. Number: 1

Year Built:	No. Stories:	Gross Floor Area:	Boeck Model	Const. Qual.:
2000	1	54700	(0325) Shopping ctr/strip load sup	(2) Average +

Air Cond. %:	Sprinkler %:	Alarm %:	No. Elevator:	Basement sf.:
0	0	0	0	0

Number Identical:	Condition Code:
1	3

Commercial Rental Information:
Site Number: 1

Use Number: 1
Used As: (D03) Local center

Unit Code:	Total Rent Area:	Area 1 Bdrms Apts	Area 2 Bdrms Apts	Area 3 Bdrms Apts
(01) Square feet	24700	0	0	0

Total Units:	No. 1 Bdrms Apts	No. 2 Bdrms Apts	No. 3 Bdrms Apts
1	0	0	0

Site Number: 1
Use Number: 2
Used As: (Z98) Non-contrib

Unit Code:	Total Rent Area:	Area 1 Bdrms Apts	Area 2 Bdrms Apts	Area 3 Bdrms Apts
( )	31600	0	0	0

Total Units:	No. 1 Bdrms Apts	No. 2 Bdrms Apts	No. 3 Bdrms Apts
0	0	0	0

Site Number: 1
Use Number: 3
Used As: (F03) Dstr wrhouse

Unit Code:	Total Rent Area:	Area 1 Bdrms Apts	Area 2 Bdrms Apts	Area 3 Bdrms Apts
( )	6900	0	0	0

Total Units:	No. 1 Bdrms Apts	No. 2 Bdrms Apts	No. 3 Bdrms Apts
0	0	0	0

Special District Information:

Special District: 999Y2

Primary Units:	Advalorem Value	Spec. Dist. Name:
20800	0	Townwide Drain Imp

Special District: CL057

Primary Units:	Advalorem Value	Spec. Dist. Name:
0	4450000	Consolidated Light

Special District: FF025

Primary Units:	Advalorem Value	Spec. Dist. Name:
0	4450000	Fairview Fire Pok

Special District: GL000

Primary Units:	Advalorem Value	Spec. Dist. Name:
0	4450000	Pok Lib District

Special District: TW0K3

Primary Units:	Advalorem Value	Spec. Dist. Name:
35900	0	Town Wide Wat Imp

Special District: WS0P4

Primary Units:	Advalorem Value	Spec. Dist. Name:
28900	0	4th Ward Swr Imp Cap

ParcelAccess

Parcel Grid Identification #:
134689-6162-05-011773-0000
Municipality: Poughkeepsie

Parcel Location
Spur N & E Of City

Owner Name on March 1
New York Central Lines LLC , *(P)*

Primary *(P)* Owner Mail Address
500 Water St
Jacksonville FL 322020000

Parcel Details

Size (acres):	11.5 Ac (C)	Land Use Class:	(340) Vacant Land Located in Industrial Areas
File Map:		Agri. Dist.:	(0)
File Lot #:		School District:	(133201) Hyde Park Central School District
Split Town			

Assessment Information (Current)
*** 2013 assessments not yet established ***

Last Sale/Transfer

Sales Price:	Sale Date:	Deed Book:	Deed Page:	Sale Condition:	No. Parcels:
$0	0	21999	05513	( )	0

Site Information:

Site Number: 1

Water Supply:	Sewer Type:	Desirability:	Zoning Code:	Used As:
(1) None	(1) None	(1) Inferior	FC	( )

Special District Information:

Special District: 999Y2

Primary Units:	Advalorem Value	Spec. Dist. Name:
9300	0	Townwide Drain Imp

Special District: CL057

Primary Units:	Advalorem Value	Spec. Dist. Name:
0	466000	Consolidated Light

Special District: FF025

Primary Units:	Advalorem Value	Spec. Dist. Name:
0	466000	Fairview Fire Pok

Special District: GL000

Primary Units:	Advalorem Value	Spec. Dist. Name:
0	466000	Pok Lib District

Special District: TW0K3

Primary Units:	Advalorem Value	Spec. Dist. Name:
4800	0	Town Wide Wat Imp

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ParcelAccess

Parcel Grid Identification #:
134689-6162-05-042826-0000
Municipality: Poughkeepsie

Parcel Location
33 Fulton St

Owner Name on March 1
Star Gas Properties Inc , *(P)*

Primary *(P)* Owner Mail Address
33 Fulton St
Poughkeepsie NY 126010000

Parcel Details

Size (acres):	.7 Ac	Land Use Class:	(441) Commercial: Storage, Warehouse and Distribution Facilities: Gasoline, Fuel, Oil, Liquid Petroleum Storage and or Distribution
File Map:		Agri. Dist.:	(0)
File Lot #:		School District:	(133201) Hyde Park Central School District
Split Town			

Assessment Information (Current)
*** 2013 assessments not yet established ***

Last Sale/Transfer

Sales Price:	Sale Date:	Deed Book:	Deed Page:	Sale Condition:	No. Parcels:
$0	0	1984	0657	( )	0

Site Information:

Site Number: 1

Water Supply:	Sewer Type:	Desirability:	Zoning Code:	Used As:
(3) Comm/public	(3) Comm/public	(3) Superior	FC	(F06) Nat gas dstr

Commercial/Industrial/Utility Building Information:

Site Number: 1

Bldg Sec.: 1 Bldg. Number: 1

Year Built:	No. Stories:	Gross Floor Area:	Boeck Model	Const. Qual.:
0	0	7400	(0832) 1 sty warehouse wood mill	(3) Above Average

Air Cond. %:	Sprinkler %:	Alarm %:	No. Elevator:	Basement sf.:
0	0	0	0	3200

Number Identical:	Condition Code:
1	3

Site Number: 1

Bldg Sec.: 1 Bldg. Number: 2

Year Built:	No. Stories:	Gross Floor Area:	Boeck Model	Const. Qual.:
1965	1	1470	(0312) 1 sty store load sup	(2) Average

Air Cond. %:	Sprinkler %:	Alarm %:	No. Elevator:	Basement sf.:
100	0	0	0	0

Number Identical:	Condition Code:
1	3

Site Number: 1

Bldg Sec.: 1 Bldg. Number: 3

Year Built:	No. Stories:	Gross Floor Area:	Boeck Model	Const. Qual.:
1965	1	3240	(0832) 1 sty warehouse wood mill	(2) Average

Air Cond. %:	Sprinkler %:	Alarm %:	No. Elevator:	Basement sf.:
0	0	0	0	0

Number Identical:	Condition Code:
1	3

Commercial Rental Information:

Site Number: 1
Use Number: 1
Used As: (F06) Nat gas dstr

Unit Code:	Total Rent Area:	Area 1 Bdrms Apts	Area 2 Bdrms Apts	Area 3 Bdrms Apts
(01) Square feet	7910	0	0	0

Total Units:	No. 1 Bdrms Apts	No. 2 Bdrms Apts	No. 3 Bdrms Apts
0	0	0	0

Site Number: 1
Use Number: 2
Used As: (Z98) Non-contrib

Unit Code:	Total Rent Area:	Area 1 Bdrms Apts	Area 2 Bdrms Apts	Area 3 Bdrms Apts
(01) Square feet	7400	0	0	0

Total Units:	No. 1 Bdrms Apts	No. 2 Bdrms Apts	No. 3 Bdrms Apts
0	0	0	0

Improvements:

Site Number: 1

Improvement Number: 1

Structure Code:	Dim 1:	Dim 2	Quantity	Year Built
(RG4) Gar-1.0 det	0	0	1	1950

Condition:	Grade	Sq. Ft.
(3) Normal	C	150

Site Number: 1

Improvement Number: 2

Structure Code:	Dim 1:	Dim 2	Quantity	Year Built
(FC3) Shed-galvnzd	0	0	1	1950

Condition:	Grade	Sq. Ft.
(3) Normal	C	285

Site Number: 1

Improvement Number: 3

Structure Code:	Dim 1:	Dim 2	Quantity	Year Built

(FC3) Shed-galvnzd	0	0	1	1950

Condition: (3) Normal — Grade: C — Sq. Ft.: 240

Site Number: 1

Improvement Number: 4

Structure Code:	Dim 1:	Dim 2	Quantity	Year Built
(FC3) Shed-galvnzd	0	0	1	1950

Condition: (3) Normal — Grade: C — Sq. Ft.: 144

Site Number: 1

Improvement Number: 5

Structure Code:	Dim 1:	Dim 2	Quantity	Year Built
(TK6) Tank-hz bulk	0	0	1	1962

Condition: (3) Normal — Grade: C — Sq. Ft.: 30000

Site Number: 1

Improvement Number: 6

Structure Code:	Dim 1:	Dim 2	Quantity	Year Built
(TK6) Tank-hz bulk	0	0	1	1950

Condition: (3) Normal — Grade: C — Sq. Ft.: 15000

Site Number: 1

Improvement Number: 7

Structure Code:	Dim 1:	Dim 2	Quantity	Year Built
(LP4) Pavng-asphlt	0	0	1	1985

Condition: (3) Normal — Grade: C — Sq. Ft.: 10000

Special District Information:

Special District: 999Y2

Primary Units:	Advalorem Value	Spec. Dist. Name:
2300	0	Townwide Drain Imp

Special District: CL057

Primary Units:	Advalorem Value	Spec. Dist. Name:
0	451500	Consolidated Light

Special District: FF025

Primary Units:	Advalorem Value	Spec. Dist. Name:
0	451500	Fairview Fire Pok

Special District: GL000

Primary Units:	Advalorem Value	Spec. Dist. Name:
0	451500	Pok Lib District

Special District: TW0K3

Primary Units:	Advalorem Value	Spec. Dist. Name:
3900	0	Town Wide Wat Imp

Special District: WS0P4

Primary Units:	Advalorem Value	Spec. Dist. Name:
3100	0	4th Ward Swr Imp Cap

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