S-16653

SiREM

Chain-of-Custody Form

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130 Stone Road West
Guelph ON, Canada N1G 3Z2
(519) 822-2265

Lab # ~~S-16645~~

* Part of a treatability study

*Project Name: Brunswick Deep Benzene	*Project #:
*Project Manager: Duane Graves	*Company:
*Email Address: dgraves@geosyntec.com	
Address (Street):	
City	State/Province	Country
*Phone #:	
*Sampler's Signature: J Webb	*Sampler's Printed Name: Jen Webb

Analysis

Client Sample ID	Sampling Date	Sampling Time	Matrix	# of Containers	Gene-Trac DHC	Gene-Trac VC	Gene-Trac DHB	Gene-Trac DHG	Treatability Study	ORH2	SRB	Peptococcaceae	abc A			Other Information
Intrinsic Control	12/4/2020	4:00	agu	1						✓	✓	✓	✓			
Nitrate Amended/NRBC	↓	↓	↓	1						✓	✓	✓	✓			
Nitrate and DAP Amended	↓	↓	↓	1						✓	✓	✓	✓			

Preservative Key
0. None
1. HCL
2. Other
3. Other
4. Other
5. Other
6. Other

Billing Information
P.O. #:
*Bill To:

Turnaround Time Requested
Normal ☐
Rush ☐

For Lab Use Only
Cooler Condition: N/A
Cooler Temperature: N/A
Custody Seals: Yes ☐ No ☐

For Lab Use Only
Proposal #:

Relinquished By:	Received By:	Relinquished By:	Received By:	Relinquished By:	Received By:
Signature: J Webb	Signature: J. Wilkinson	Signature	Signature	Signature	Signature
Printed Name: Jen Webb	Printed Name: J. Wilkinson	Printed Name	Printed Name	Printed Name	Printed Name
Firm: SiREM	Firm: SiREM	Firm	Firm	Firm	Firm
Date/Time: 12Nov20 4:00pm	Date/Time: 13Nov20.	Date/Time	Date/Time	Date/Time	Date/Time

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APPENDIX L

Deep Zone of Upper Surficial Aquifer – Groundwater Interim Corrective Measure Work Plan – *In situ* Anaerobic Biobarrier

GEORGIA
DEPARTMENT OF NATURAL RESOURCES
ENVIRONMENTAL PROTECTION DIVISION

Richard E. Dunn, Director

Land Protection Branch
2 Martin Luther King, Jr. Drive
Suite 1054, East Tower
Atlanta, Georgia 30334
404-657-8600

October 14, 2021

Sent via email and USPS

Mr. Tim Hassett
Project Manager
Hercules, LLC
500 Hercules Road
Wilmington, DE 19808-1599

Mr. Ron Kurtz
Director of Operations
DRT America, Inc.
2801 Cook Street
Brunswick, Georgia 31520

RE: Interim Corrective Measure Work Plan
Deep Zone of Upper Surficial Aquifer
Anaerobic Biobarrier
Hercules/Pinova - Brunswick Facility
HW Facility Permit No. HW-52(D&S)-2
EPA ID# GAD004065520

Dear Mr. Hassett and Mr. Kurtz:

The Georgia Environmental Protection Division (EPD) has reviewed the *Interim Corrective Measure Work Plan Deep Zone of Upper Surficial Aquifer- Anaerobic Biobarrier* dated September 2021. The work plan adequately addresses the comments noted in our August 27, 2021, letter. No additional comments were noted during the review; therefore, the plan is approved.

Please notify us when implementation of the approved plan is scheduled. Should you have any questions, please contact Penny Gaynor at (470) 938 3364 or Penny.Gaynor@dnr.ga.gov.

Sincerely,

Jim McNamara

Digitally signed by Jim McNamara
Date: 2021.10.14 08:14:55 -04'00'

Jim McNamara
Program Manager
Hazardous Waste Corrective Action Program

File: Hercules, Brunswick 216-0060 (G)

Geosyntec consultants

1255 Roberts Boulevard, Suite 200
Kennesaw, Georgia 30144
PH 678.202.9500
FAX 678.202.9501
www.geosyntec.com

September 24, 2021

Penny Gaynor
Georgia Environmental Protection Division
2 Martin Luther King, Jr. Dr. SE
Suite 1054, East Tower
Atlanta, GA 30334

Subject: **Interim Corrective Measure Work Plan - Deep Zone of Upper Surficial Aquifer – Anaerobic Biobarrier**
Hercules/Pinova Facility, Brunswick, Georgia

Dear Penny:

I am enclosing for review and approval by the Georgia Department of Natural Resources, Environmental Protection Division ("EPD") a document titled *Interim Corrective Measure Work Plan - Deep Zone of Upper Surficial Aquifer – Anaerobic Biobarrier, Hercules/Pinova Facility, Brunswick, GA* that Geosyntec Consultants, Inc. ("Geosyntec") has prepared on behalf of Hercules LLC in connection with activities at an industrial facility located at 2801 Cook Street in Brunswick, Georgia (the "Brunswick facility"). This plan incorporates comments received on August 27, 2021 from EPD related to the initial June 2021 submittal of the document. Please do not hesitate to contact us if you should have any questions regarding the enclosed revised document.

Sincerely,

Shanna Thompson

Shanna Thompson, PE (GA, AL)
Principal

Copies to: Mike Crews, Pinova
Timothy Hassett, Hercules LLC

GR6881M

Prepared for

Hercules, LLC
500 Hercules Road
Wilmington, DE 19808

INTERIM CORRECTIVE MEASURE WORK PLAN

DEEP ZONE OF UPPER SURFICIAL AQUIFER – ANAEROBIC BIOBARRIER HERCULES LLC/PINOVA INC. BRUNWICK FACILITY BRUNSWICK, GEORGIA

Prepared by

Geosyntec consultants
engineers | scientists | innovators

1255 Roberts Boulevard, Suite 200
Kennesaw, Georgia 30144

Project Number GR6881M

September 2021

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1.0 INTRODUCTION

This Interim Corrective Measures Work Plan (the "Work Plan") has been prepared by Geosyntec Consultants ("Geosyntec") on behalf of Hercules LLC ("Hercules") for submission to the Georgia Department of Natural Resources, Environmental Protection Division ("EPD") in connection with environmental conditions at an industrial facility at 2801 Cook Street in Brunswick, Glynn County, Georgia (referred to hereinafter as the "Brunswick facility" or the "Site") as shown in **Figure 1**. Hercules is addressing environmental conditions at the Brunswick facility pursuant to the corrective action program under the Resource Conservation and Recovery Act ("RCRA") as administered by EPD. The purpose of the interim corrective measures (the "ICM") described in the Work Plan is to reduce the mass flux and concentrations of selected constituents of potential concern ("COPCs") that are detected in elevated concentrations in groundwater in the deep zone of the upper surficial aquifer underlying the southeastern portion of main operational area of the Brunswick facility along west side of the U.S. Highway 17 corridor. This area is shown on **Figure 2** along with the boundaries of the Brunswick facility.

The ICM presented herein will utilize *in situ* bioremediation in the form of a biologically active permeable reactive barrier (referred to as a "biobarrier" in this Work Plan) to achieve mass flux reductions of COPCs in groundwater. This ICM will specifically target methylene chloride and chloroform in the treatment area because these two COPCs represent the majority of the volatile organic compounds ("VOCs") that have been detected in groundwater in the area of the proposed biobarrier. For instance, the concentrations of methylene chloride and chloroform comprised more than 90 percent ("%") of the VOCs detected in monitoring well MW-10D during the December 2020 semi-annual groundwater monitoring event. Although this ICM targets methylene chloride and chloroform specifically, other COPCs will be monitored in the treatment area to evaluate the fate of those COPCs as presented in the performance monitoring plan in Section 6, below.

The biobarrier described herein is one of multiple ICMs for groundwater being implemented at the Brunswick facility. As described in the Corrective Action Plan ("CAP") submitted to EPD on February 1, 2021 (Geosyntec, 2021), the interim corrective measures described in this Work Plan may be extended to other areas at the Brunswick facility along the U.S. Highway 17 corridor, as necessary, based on the performance of the ICM and ongoing site investigation activities.

As discussed in more detail in later sections of this Work Plan, *in situ* enhanced bioremediation involves injecting amendments into the groundwater treatment zone through injection wells to promote conditions favorable for bacteria to consume or degrade COPCs that are present. Bioremediation in groundwater requires growth of specific bacteria known to degrade organic contaminants to be effective. In many cases, the bacteria are naturally occurring in the environment. If the bacteria are not naturally occurring, or are present in low concentrations, the injected amendments can include bacterial consortiums to augment the indigenous bacterial population and enhance the existing degradation processes.

1.1 Site History

As described in detail in the CAP that Hercules submitted to EPD (Geosyntec, 2021), the operational history of the Brunswick facility spans more than a century. Yaryan Rosin and Turpentine Company began operations at the Brunswick facility in 1911 on a 70-acre parcel. Hercules purchased the Brunswick facility in 1920. Over time, Hercules acquired additional parcels of land and significantly expanded the scope of the manufacturing operations at the Brunswick facility. After several recent transactions reduced the overall size of the Brunswick facility from its greatest extent, the total area of the Brunswick facility now encompasses approximately 321 acres of land. In January 2010, Hercules sold the southern portion of the Brunswick facility to Pinova, Inc. ("Pinova"), which continues to operate the manufacturing processes in that portion of the Brunswick facility for the production of wood rosins, resins, and terpene oils for a wide variety of end uses. Hercules continues to own the remaining portions of the Brunswick facility. No manufacturing operations are conducted on property currently owned by Hercules. The ICM described in this Work Plan is expected to take place in the portion of the Brunswick facility that Pinova owns.

1.2 Overview of Site Geology and Hydrogeology

While the ICM described in this Work Plan is expected to be performed in the deep zone of the upper surficial aquifer, a broader description of the water-bearing zones and the characteristics of the hydrogeologic units beneath the Brunswick facility to a depth of approximately 200 feet below ground surface ("ft bgs") is provided below for reference. The geologic and hydrogeologic units that underlie the Brunswick facility to that depth include: the upper surficial aquifer (extending to approximately 100 ft bgs), a semi-confining unit separating the upper surficial aquifer from the lower surficial aquifer, and the lower surficial aquifer (extending to approximately 200 ft bgs). The upper surficial

aquifer is divided into three zones: shallow (~ 0–40 ft bgs), intermediate (~ 40–70 ft bgs), and deep (~70–100 ft bgs) as shown on **Figure 3**.

The aquifer zones are generally based on differences in geologic materials and hydraulic conductivities, and the vertical distribution of VOCs in groundwater. The shallow zone of the upper surficial aquifer is generally composed of interbedded clays, silts, silty sands, clayey sands, and light brown/tan or gray fine to coarse sands. The vadose zone overlying the shallow zone of the upper surficial aquifer is generally very thin, with the seasonal high-water table at a depth of only a few feet in many portions of the Brunswick facility. The intermediate zone of the upper surficial aquifer is primarily composed of gray fine to coarse sand, interbedded with varying amounts of clays, silts, silty sands, clayey sands, and gravel; cemented sands are also sometimes encountered in the intermediate zone. The deep zone of the upper surficial aquifer is composed of gray, fine to coarse sand, with relatively lesser amounts of clayey sands, silty sands, silts, and clays. Another characteristic of the deep zone of the upper surficial aquifer is the prevalence of coarse sand and sand with gravel intervals that may provide preferential groundwater flow pathways where they are linearly continuous. The lower surficial aquifer beneath the Brunswick facility is generally composed of olive green to gray fine sands, silty sands, clayey sands, and silts. The lower surficial aquifer is separated from the upper surficial aquifer by a semi-confining layer consisting primarily of silts and clays. Geologic cross-sections showing subsurface conditions are provided in **Appendix A**.

Within the upper surficial aquifer underlying the Brunswick facility and adjacent areas, the prevailing direction of groundwater flow is toward the east-southeast, with local variations due to heterogeneities in the subsurface units. This groundwater flow direction is interpreted based on potentiometric surface contour maps. A potentiometric surface contour map for the deep zone of the upper surficial aquifer based on groundwater elevation measurements collected as part of the December 2020 semi-annual groundwater monitoring event for the Brunswick facility is presented as **Figure 4**. The groundwater flow rate in the deep zone of the upper surficial aquifer is on the order of 55 feet per year.

1.3 Constituents of Potential Concern

Groundwater in the targeted portion of the deep zone of the upper surficial aquifer was selected for interim corrective measures based on the presence of elevated concentrations of COPCs, specifically chloroform and methylene chloride. As described in the conceptual site model ("CSM") presented in the CAP, COPCs in source areas in the main manufacturing portion of the Brunswick facility have migrated vertically downward from

the shallow zone to the deep zone of the upper surficial aquifer. Once COPCs reach the deep zone of the upper surficial aquifer, they can migrate eastward in the deep zone of the upper surficial aquifer in the downgradient direction. Naturally occurring processes affect the migration of COPCs along the flow path in the groundwater system including sorption, dispersion, dilution, and degradation. These natural attenuation processes reduce the mass of COPCs present in groundwater and slow down the migration of COPCs relative to groundwater flow velocities. The presence of chloroform and methylene chloride in groundwater in the deep zone of the upper surficial aquifer in the vicinity of U.S. Highway 17 is consistent with the reductive dechlorination of carbon tetrachloride that was historically released at upgradient locations in the former toxaphene production area. Carbon tetrachloride degrades sequentially to chloroform, then to methylene chloride (dichloromethane), and finally to organic acids and carbon dioxide under anaerobic conditions.

2.0 BASIS OF INTERIM CORRECTIVE MEASURES PLAN

This section of the Work Plan discusses the objectives of the planned corrective measures, provides a summary of previous studies that were used as a basis for selecting the planned corrective measures, and provides an overview of the selected corrective measures.

2.1 Objectives of Corrective Measures

The interim corrective measures for groundwater in the deep zone of the upper surficial aquifer in the southeastern portion of the main manufacturing area at the Brunswick facility along the U.S. Highway 17 corridor are intended to serve two purposes:

- To reduce the concentrations of chloroform and methylene chloride within the target treatment area in order to reduce the mass flux of these COPCs migrating to the east in the deep zone of the upper surficial aquifer.

- To provide information regarding best practices for removal of chloroform and methylene chloride in groundwater in the deep zone of the upper surficial aquifer which may then be expanded to address those target COPCs in groundwater in other locations within the Brunswick facility, as necessary. For example, based on conditions that are encountered and the performance of the biobarrier, the linear extent of the biobarrier may be extended to the north and/or the south.

Chloroform and methylene chloride are the primary COPCs in groundwater in the deep zone of the upper surficial aquifer in the southeastern portion of the main manufacturing area at the Brunswick facility along the U.S. Highway 17 corridor targeted for treatment using the planned anaerobic biobarrier. As described in the CAP, the initial objective is to reduce the mass flux and concentrations of chloroform and methylene chloride in the treatment area by 50 %. This objective may be modified, subject to review and approval by EPD, based on updates and refinements to the CSM and appropriate fate and transport evaluations. The planned anaerobic biobarrier is also expected to reduce the mass flux and concentrations of other VOCs in groundwater susceptible to anaerobic biodegradation.

2.2 Basis for Selection of Remedial Technology

As discussed in the CAP (Geosyntec, 2021), a combination of desktop and laboratory evaluations were performed that led to the selection of enhanced *in situ* bioremediation in the form a biobarrier as the remedial technology to be used for groundwater in the deep

zone of the upper surficial aquifer underlying the southeastern portion of the main manufacturing area at the Brunswick facility along the U.S. Highway 17 corridor. A broad range of potential remedial technologies including groundwater extraction and treatment (i.e., pump and treat), *in situ* chemical oxidation, *in situ* chemical reduction, enhanced *in situ* bioremediation and phytoremediation were considered. The potential technologies were compared based on their implementability, effectiveness, relative cost, and potential for disruption to on-site manufacturing operations. As a result of the screening process, bench scale treatability studies were performed to further evaluate potential *in situ* remedial technologies.

Bench scale treatability studies were performed to evaluate degradation of chloroform and methylene chloride via reductive dechlorination. These bench scale treatability studies are described in detail in the report prepared by SiREM Laboratory that is included in **Appendix C**. The biotreatability studies involved the preparation of microcosms using groundwater and soils from the target treatment zone to test the dechlorination potential of using an electron donor (i.e., lactate) and a bioaugmentation culture (KB-1® Plus). Groundwater for the bench scale treatability studies was collected from monitoring well MW-28D and soils (aquifer solids) for the treatability studies were collected from a soil boring drilled near monitoring well MW-28D. The soils were collected at a depth interval between 78 ft bgs and 90 ft bgs corresponding to the deep zone of the upper surficial aquifer.

The bench scale treatability studies demonstrated that reductive dechlorination is effective in reducing concentrations of chloroform and methylene chloride in groundwater in the presence of an electron donor. In addition, the degradation of chloroform and methylene chloride was accelerated with bioaugmentation using KB-1® Plus.

2.3 Planned Interim Corrective Measures

Based on the results of the bench scale treatability studies discussed above, Hercules plans to install an anaerobic biobarrier for reductive dechlorination of chloroform and methylene chloride in groundwater in the deep zone of the upper surficial aquifer beneath the Brunswick facility near U.S. Highway 17.

Because chlorinated compounds (i.e., chloroform and methylene chloride) are used as electron acceptors during the reductive dechlorination process, there must be an organic carbon substrate to serve as an electron donor to enhance microbial growth and degradation of these COPCs. A soluble carbon substrate (i.e., lactate) was used in the

treatability studies as an electron donor to stimulate microbial activity. The treatability studies demonstrated that lactate would be effective for full scale implementation, but it would be consumed quickly. Therefore, a longer-lasting electron donor (i.e., emulsified vegetable oil) will be used as the primary electron donor for implementation of the anaerobic biobarrier. Emulsified vegetable oil ("EVO") and a bioaugmentation culture (i.e., KB-1® Plus) will be injected through a series of injection wells to deliver the amendments into the treatment zone in the deep zone of the upper surficial aquifer. As discussed in greater detail in Section 4.3.1, below, a deoxygenating amendment will also be mixed with the bioaugmentation culture, and food grade sodium bicarbonate will be used to adjust the pH of the groundwater in the treatment zone should the need arise. The amendments are expected to create a zone of enhanced biological activity around the injection wells. The injection well network will be installed perpendicular to the natural groundwater flow path, and as impacted groundwater flows through this zone of enhanced biological activity, COPCs will be biologically degraded and destroyed.

3.0 PRE-IMPLEMENTATION ACTIVITIES AND SITE PREPARATION

Several planning and preparatory steps will be performed prior to field mobilization to install the anaerobic biobarrier including: health and safety planning, permitting, contractor and amendment procurement, and utility clearances. These steps are discussed in this section of the Work Plan.

3.1 Health and Safety Planning

The existing Health and Safety Plan ("HASP") for environmental work at the Brunswick facility will be amended to include the tasks, hazards, and hazard mitigation procedures related to implementation of the anaerobic biobarrier. Pertinent elements of the amendments to the HASP will address hazard identification and mitigation, establishment of work zones, personal protective equipment ("PPE") requirements for each task, ingress/egress procedures, decontamination procedures, worker breathing space monitoring, chemical storage requirements, spill prevention procedures, and spill control procedures and countermeasures. Preparation, handling and injection of bioremediation amendments will be performed by or under the direct supervision of field personnel who have received project-specific health and safety training and instruction in the handling of these amendments.

Field personnel will apply "good housekeeping" measures during injection events to prevent accidental slips, trips, or falls on injection system components. Secondary containment will be placed under the storage tanks and mixing tanks that are used for the remedial amendments, and injection pumps and manifolds used during the injection process. Spill kits will be available to address any accidental spills of the remedial amendments (e.g., vegetable oil and sodium bicarbonate)

3.2 Permitting

Injection of a fluid into the subsurface via an injection well in Georgia requires an underground injection control ("UIC") permit from EPD. Geosyntec will prepare a permit application for submission to EPD to use Class V injection wells for delivery of bioremediation amendments to the treatment zone in the deep zone of the upper surficial aquifer. Geosyntec will prepare the permit application form and checklist. The UIC permit application package will include this Work Plan and other pertinent details required by the UIC permit application.

3.3 Contractor and Remedial Amendment Procurement

Geosyntec will develop procurement packages for use in communicating the scope of work to contractors and suppliers. It is anticipated that the following contractors will be needed: a drilling contractor for well installation activities, a subsurface utility locator, an injection contractor and chemical suppliers (i.e., suppliers for the selected electron donor, bioaugmentation culture, and deoxygenating amendment that will be used). There are also multiple components of the planned ICM that will require communication and coordination with Pinova regarding health and safety procedures and field logistics. Some of the items that will be coordinated with Pinova are the delivery procedures and storage locations that will be used for remediation amendments, the locations where batching operations will occur, water sources that will be used, personal protective equipment requirements that will be followed, and the elements of the health and safety monitoring program that will be implemented.

3.4 Utility Clearance

A private utility locator will mark the locations of underground utilities prior to commencement of well installation activities. The locations of underground utilities will be used to help finalize the locations for performance monitoring wells and injection wells. The utility clearance process will include using both magnetometer assessments and ground-penetrating radar surveys to locate underground utilities. A preliminary utility survey was performed in February 2021 by Ground Penetrating Radar Systems, Inc. Based on this utility survey, the locations of underground and aboveground utilities that were identified are shown in **Figure 5**. The locations of the performance monitoring wells and injection wells described in Sections 4.1 and 4.4, below, are based on current knowledge of the underground and aboveground utilities that are present, and may be modified as additional information is obtained.

4.0 ANAEROBIC BIOBARRIER CONCEPTUAL DESIGN

This section of the Work Plan provides details regarding the design basis for the anaerobic biobarrier, including general details concerning the injection well network layout and design, and the selection of bioremediation amendments.

4.1 Biobarrier Well Layout

A network of 18 injection well clusters (designated as injection well clusters INJ-01 through INJ-18) with two injection wells per cluster will be installed as shown in **Figure 6.** The two injection wells comprising each injection well cluster will be screened at differing intervals (one shallower and one deeper) to vertically cover the deep zone of the upper surficial aquifer. The injection well layout assumes an approximate 30-foot spacing, on center, between each injection well cluster with an assumed 15-foot radius of influence ("ROI") for each injection well cluster to allow for ROIs to overlap and thereby create a laterally continuous treatment zone. In the southern portion of the treatment zone, the injection well clusters are arranged in two rows which will create a treatment zone up to 60 feet wide in the direction of groundwater flow. Installation of two rows of injection well clusters is not possible in the northern part of the treatment zone due to limitations posed by underground and aboveground utilities as shown in **Figure 6**. Considering that the groundwater velocity is approximately 55 feet per year in the deep zone of the surficial aquifer, the retention time of the contaminated groundwater within the biobarrier is anticipated be approximately 400 days, which is expected to be sufficient time for the degradation of target COPCs to occur based on the results of the bench scale treatability studies.

4.2 Injection Well Design

The injection wells will be screened to target depth intervals ranging between approximately 70 ft bgs and 95 ft bgs based on the approximate depth and thickness of the higher permeable zones (i.e., coarse sand) in the deep zone of the upper surficial aquifer. The target depth intervals for the well screens for the injection wells may be modified based on lithologic and analytical information collected during the installation of performance monitoring wells (as described in Section 5.1, below) and baseline sampling activities (as described in Section 6.2, below). The installation of performance monitoring wells and baseline sampling activities will be completed before the installation of the injection wells.

The planned construction details for the injection wells are provided in **Table 1**. Two injection wells will be installed in a single borehole but screened at different depth intervals as shown in **Table 1**. The borehole diameter will be a minimum of 8 inches. The injection wells will be constructed with 2-inch diameter Schedule 40 polyvinyl chloride ("PVC") riser pipes and 0.01-inch slotted well screens. The well screen for each injection well is expected to be 10 feet long. A 20/30 sand filter pack will be installed around the injection well screen to 1 foot above the top of the screen for the deeper injection well and to 2 feet above the top of the screen for the shallower injection well. A bentonite seal that is 2 feet thick will be installed above the top of the sand filter pack for the deeper injection well and below the sand filter pack for the shallower injection well within each borehole to separate the well screens for the two injection wells from each other. In addition, a bentonite seal that is 2 feet thick will be installed above the top of the sand filter pack for the shallower injection well within each borehole, and the remaining annular space between the top of the bentonite seal and the ground surface will be grouted.

Each injection well cluster will be completed approximately 3 feet above the ground surface with a protective cover within a concrete pad measuring 3 feet by 3 feet. The tops of the injection wells will be finished with Schedule 40 PVC 2-inch slip to 2-inch female threaded connections with threaded caps. The 2-inch female threaded connection on each injection well will be used to attach an adapter to a male cam-lock for connection to reinforced flexible injection hoses at the time of injection activities.

4.3 Injection Design

This section of the Work Plan describes the design of the injection process for the biobarrier including the selection of remedial amendments that are expected to be used, dosage calculations and injection volumes. **Appendix D** includes the design calculations and assumptions. **Table 2** summarizes the injection design volumes.

4.3.1. Amendment Selection

EVO has been selected as a long-lasting electron donor source to be used to stimulate the anaerobic reductive dechlorination of chloroform and methylene chloride in the deep zone of the upper surficial aquifer. There are multiple vendors which are providing EVO for environmental remediation applications. It is assumed for purposes of the calculations presented herein that SRS®-FRL (manufactured by Terra Systems) will be used as the electron donor source. During the bidding and procurement process, a similar EVO product may be selected based on the availability of the product and the unit price. In the

event that a similar EVO product is selected, Hercules will notify EPD and include a description of the selected product in the UIC permit application that will be submitted.

SRS®-FRL consists of the following components:

- food grade soybean oil (a slow release electron donor) - 60% by weight
- sodium lactate (a fast release electron donor) - 5.5% by weight
- emulsifiers (proprietary) and nutrients (yeast extract, nitrogen and phosphorous to support microbial growth) - 7.5-10% by weight
- vitamin B12 (an important micronutrient) and food grade nutrients (proprietary) – less than 1% by weight (minimum of 250 micrograms per liter ("µg/L"))
- water – approximately 23.5–26% by weight

In addition to injecting an EVO product to serve as a long-lasting electron donor source, Hercules anticipates injecting a bioaugmentation culture to increase the microbial population in the subsurface that is capable of degrading chloroform and methylene chloride. The bioaugmentation culture that Hercules plans to use is KB-1®Plus. KB-1® Plus is sensitive to oxidizing conditions (e.g., dissolved oxygen at concentrations greater than 0.5 milligrams per liter ("mg/L")). Therefore, a deoxygenating amendment (i.e., KB-1® Primer) will be mixed with water from the water supply system that is planned to be sourced from the Brunswick facility to generate anaerobic water. The anaerobic water in turn will be used in the preparation of the injectate to help ensure that elevated levels of dissolved oxygen are not introduced into the treatment zone through the injection process.

The fermentation process occurring during the microbial reactions associated with the reductive dechlorination of chloroform and methylene chloride may generate some acidity. Based on the results of the treatability studies, groundwater in the deep zone of the upper surficial aquifer within the treatment zone appears to have sufficient buffering capacity to neutralize the acidity that may be generated during the microbial reactions. If low pH (i.e., a pH of 6 standard units or lower) is detected during the baseline sampling activities as described in Section 6.2, below, food grade sodium bicarbonate will be used to buffer the acidity generated from the microbial reactions and to maintain an optimal pH of 6 to 8 standard units for the microbial activities.

Safety data sheets and manufacturer's information about SRS®-FRL, KB-1® Plus, sodium bicarbonate and KB-1® Primer are included in **Appendix C**.

4.3.2. Electron Donor Dosing and Total Injection Volumes

The volume of EVO to be injected as part of establishing the anaerobic biobarrier was estimated based on the following design assumptions and parameters:

- A uniform total porosity of 0.30 and an assumed effective porosity of 0.25 within the target treatment zone;
- A desired ROI for each injection well of 15 feet;
- A treatment zone that is 25 feet deep (i.e., 70 ft bgs to 95 ft bgs), which can be modified based on lithologic information collected during the installation of the performance monitoring wells; and
- An electron donor (the soybean oil portion of SRS®-FRL) dosage of 8 grams per liter ("g/L") in the pore volume taking into account that SRS®-FRL is 60% by weight comprised of soybean oil.

The EVO dosing calculations are provided in **Appendix D**. Based on these calculations, approximately 10,080 gallons of EVO will need to be injected into the treatment zone (i.e., approximately 280 gallons of EVO per injection well or approximately 22.4 gallons of EVO per foot of vertical treatment interval).

The total volume of the injectate (i.e., EVO and anaerobic water mixture) to be injected is estimated to be approximately 148,705 gallons based on a desired ROI for each injection well of 15 feet, an effective porosity of the target treatment zone of 0.25 and an effective pore volume displacement of 25%. The injection volume calculations are included in **Appendix D**.

4.3.2. Anaerobic Water Preparation

Anaerobic water will be used: (i) to dilute the bulk EVO, (ii) to flush the injection tooling of the diluted electron donor amendment, (iii) to push the bioaugmentation culture into the formation, and (iv) to provide an immediate anaerobic environment for the bioaugmentation culture. To conservatively estimate the volume of anaerobic water that will be needed, the total volume of EVO (10,080 gallons) was subtracted from the total injectate volume (148,705 gallons), resulting in approximately 138,625 gallons of

anaerobic water (i.e., approximately 3,851 gallons per injection well or 308 gallons per foot of vertical treatment interval) being required. Calculations for the amount of anaerobic water that will be required are provided in **Appendix D**.

Separate tanks (e.g., a 1,500-gallon batch tank and a 20,000-gallon frac tank) will be used for generating anaerobic water. Anaerobic water will be generated by mixing water from an on-site water source and KB-1® Primer (to rapidly generate anaerobic conditions). KB-1® Primer will be dosed in accordance with the manufacturer's recommendations (at a dosing rate of 7 pounds per 1,000 gallons); therefore, approximately 970 pounds of KB-1® Primer is expected to be used.

4.3.3 Bioaugmentation Culture Dosing

A minimum volume of 270 liters ("L") (7.5 L per injection well or 0.6 L per foot of vertical treatment interval) of bioaugmentation culture (KB-1® Plus) is required. The minimum volume of bioaugmentation culture was estimated based on a target of 1.0×10^7 cells per milliliter ("cells/mL") of dehalobacter ("*Dhb*") in the pore volume of the treatment area. KB-1® Plus contains 1.0×10^{11} cells/mL of *Dhb*. The calculations are included in **Attachment D**.

4.3.4 Injectate Buffering

If a buffering amendment is required to maintain a pH of 6 to 8 standard units during the microbial reactions, food grade sodium bicarbonate will be injected. Assuming a target concentration of 2 g/L of sodium bicarbonate in the pore volume of the treatment area, a total of 11,877 pounds (330 pounds per injection well or 26.4 pounds per foot of vertical treatment interval) of sodium bicarbonate will be required. The calculations are provided in **Attachment D**.

4.4 Performance Monitoring Well Design

Thirteen monitoring wells (designated as monitoring wells PMW-01A/B and PMW-03A/B through PMW-07A/B installed as six, two-well clusters and monitoring well PMW-02A installed as a single monitoring well) will be installed to monitor the effectiveness of the biobarrier in reducing the mass flux and concentrations of chloroform and methylene chloride in the target treatment zone. The locations of the thirteen new performance monitoring wells are shown in **Figure 7**. Existing monitoring well MW-10D will be used for performance monitoring and will be coupled with performance monitoring well PMW-02A. The new performance monitoring wells will be installed to

monitor groundwater in the deep zone of the upper surficial aquifer between approximately 70 ft bgs and 95 ft bgs. The boreholes for the new performance monitoring wells will be advanced using sonic drilling techniques.

The rationale for each of the performance monitoring wells that will be installed is provided below.

- Monitoring well clusters PMW-01A/B, PMW-03A/B and PMW-05A/B are located along a transect perpendicular to the groundwater flow direction upgradient from the biobarrier. These monitoring wells will be used to estimate the mass flux and concentrations of chloroform and methylene chloride entering the biobarrier and to measure hydraulic gradients along the biobarrier. The mass flux estimation methodology is discussed in Section 6.2, below.

- Monitoring well clusters PMW-04A/B and PMW-06A/B, and monitoring well PMW-02A coupled with existing monitoring well MW-10D are located immediately downgradient of the biobarrier along a transect perpendicular to the groundwater flow direction. These monitoring wells will be used to estimate the changes in mass flux and concentrations of chloroform and methylene chloride due to the biobarrier.

- The monitoring well cluster PMW-07A/B will be installed approximately 40 feet downgradient from the biobarrier. Therefore, groundwater conditions at this monitoring well cluster may not be influenced significantly from the presence of the biobarrier during the first year of groundwater monitoring. This monitoring well cluster will provide information concerning baseline concentrations of COPCs in groundwater downgradient of the biobarrier, and the baseline concentrations will be used to help evaluate the long-term effectiveness of the biobarrier.

The anticipated locations of these performance monitoring wells are subject to modifications in the field based on the field conditions that are encountered (e.g., drilling refusal, utilities and Pinova's operations).

Each performance monitoring well will be constructed using 2-inch schedule 40 PVC riser pipe and well screen. With the exception of performance monitoring well PMW-02A, the screened interval for each performance monitoring well is expected to be 10 feet

long. The construction details of the proposed performance monitoring wells are provided in **Table 3**.

At each location except monitoring well PMW-02A, the screened intervals of the performance monitoring well clusters will be from 84-94 ft bgs and 72-82 ft bgs. The screened interval of monitoring well PMW-02A will be from 72 ft bgs to 88 ft bgs because existing monitoring well MW-10D will be used to monitor the interval from 88 ft bgs to 95 ft bgs. The anticipated screened intervals of the performance monitoring wells may be revised in the field based on results obtained from the evaluation of the soil cores that are collected at each proposed performance monitoring well cluster location.

5.0 FIELD IMPLEMENTATION

Field activities in connection with creating the anaerobic biobarrier in the deep zone of the upper surficial aquifer underlying the southeastern portion of the main manufacturing area at the Brunswick facility along the U.S. Highway 17 corridor include installing injection and performance monitoring wells, completing a pneumatic slug test, and injecting remedial amendments via injection wells to distribute the amendments throughout the targeted treatment zone. This section of the Work Plan explains field implementation of the various components of the ICM.

5.1 Installation of Injection and Performance Monitoring Wells

Installation of performance monitoring wells will occur prior to installation of injection wells so that adjustments relating to the screened intervals of the injection wells can be made as necessary based on the information obtained during installation of the performance monitoring wells. Borings for injection wells and performance monitoring wells associated with the anaerobic biobarrier will be drilled by a Georgia licensed driller using sonic drilling techniques. As discussed in Section 3.4, above, a utility clearance will be performed prior to the commencement of well installation activities. For each well location, the driller will clear the well location for utilities to a depth of 5 ft bgs via soft digging techniques as a precaution.

Prior to installing each well, a soil core with a maximum depth of 95 ft bgs will be collected at the location of the well by the drilling subcontractor. The soil cores will be logged by field personnel to identify potential high mass flux zones in the subsurface (i.e., higher permeable zones such sandy layers), to identify the depths of confining units and low permeable zones (i.e., silty and clayey layers) that are present, and to gather information pertinent to making any necessary adjustments to the well depths or targeted screened intervals for the wells.

Each well will be developed using a submersible pump, or equivalent, at least 24 hours after grouting to optimize the performance of the well (either as an injection well or a performance monitoring well) by cleaning out any fine particles potentially introduced in the well during the drilling process. The submersible pump will be lowered to the total depth of the well, and once at that depth, groundwater extraction will commence until the water is visibly free of particulate matter. During the development of each well, field parameters including pH, temperature and specific conductivity will be measured with a multi-parameter meter for an initial assessment of these parameters in the treatment area.

5.2 Pneumatic Slug Tests

Following the installation and development of the performance monitoring wells, pneumatic slug tests (using nitrogen gas to depress the water table inside each of the performance monitoring wells) will be conducted at all newly installed performance monitoring wells (except at monitoring well cluster PMW-07A/B) to obtain estimated hydraulic conductivity ("K") values for the subsurface strata. Slug tests will not be performed at monitoring well cluster PMW-07A/B because the monitoring well cluster is not within the alignment of the downgradient mass flux transect and the monitoring well cluster will not be used for mass flux calculations. The slug tests will be performed no sooner than 24 hours after well development activities are completed. If practicable, the slug tests will not be performed until water levels have returned to at least 95% of their original static levels in the performance monitoring wells.

Prior to attaching slug testing equipment at each performance monitoring well, the initial depth to water and the depth of the well will be recorded. A transducer will be used to measure water pressures (i.e., water levels above the transducer). The transducer will be lowered a minimum of 10 feet below the top of the water column to maintain the transducer within the water column during water displacement. Nitrogen gas will then be introduced into the well at a pressure of approximately 4.5 pounds per square inch ("psi") to depress the water table within the well. The transducer will record real-time changes to the depth to groundwater during the entirety of the slug test. Upon reaching equilibrium, the applied pressure will be released, and water pressure data will be recorded using the transducer until the depth to water is within approximately 10 percent of the initial reading or for one hour, whichever comes first.

The data from the transducers will be uploaded to a computer and analyzed using an aquifer test analysis software (e.g., AQTESOLV® developed by Hydrosolve, Inc.) to estimate the hydraulic conductivity within the screened intervals of each of the performance monitoring wells. In addition to the slug tests, the transducers will be kept in the performance monitoring wells for up to three days following the slug tests to assess tidal effects and daily changes in the hydraulic gradients. The estimated hydraulic conductivities will be used to help estimate mass flux as discussed in Section 6.3, below.

5.3 Chemical Storage and Spill Prevention

EVO, KB-1® Plus, and other remedial amendments will be delivered to the Site and stored in an area where they will stay dry and protected from direct sunlight. The storage locations will be selected prior to mobilization in consultation with Pinova.

The batching tanks for preparing anaerobic water and injectate, and the injection manifold for the injection system will be placed inside spill containment structures, and spill response supplies will be kept in an easily accessible location in the work area. Spill response supplies will include chemically-compatible absorbent media, water for dilution, and mild alkali amendments for neutralization. The remedial amendments that will be used consist in significant part of food grade materials.

5.4 Equipment Staging and Water Tightness Testing

The staging and batching area for the anaerobic biobarrier will be established near the new injection wells. The staging and batching area will include provisions for chemical and equipment storage, batching tank setup, and space to store necessary equipment (including an air compressor and an injection trailer) during off hours. The batching equipment will consist of the necessary tanks, pumps, hoses, and pipes/fixtures to prepare the remedial amendments and deliver them to the injection wells. While anticipated to be located within the staging area, the batching equipment may be repositioned closer to the injection wells if deemed to be permissible in accordance with Pinova's site safety requirements. Prior to using field-assembled equipment for batching or transfer of remedial amendments, the equipment will be tested with unamended water to confirm that the equipment and fittings are water-tight.

5.5 Injection Sequencing, Batching, and Process Monitoring

Anaerobic water will be generated by separately mixing water from the water supply system obtained from an on-site source at the Brunswick facility and KB-1® Primer at the ratios discussed in Section 4.3.2, above. The on-site water source will be identified in coordination with Pinova personnel. Prior to using the anaerobic water for injectate preparation, Geosyntec will monitor the water chemistry. The target injectate water chemistry is as follows:

- pH between 6 and 8 standard units; and
- oxidation reduction potential ("ORP") below -75 millivolts ("mV").

Additional KB-1® Primer may be added to the water until the target chemistry is achieved. Once sufficient anaerobic water has been prepared, the electron donor amendment and buffering amendment (if needed) will be added directly to a mixing tank(s) in concentrate form and mixed with anaerobic water at the ratios shown in **Table 2**. Dedicated utility

pumps may be used to continuously recirculate and stir the electron donor amendment and anaerobic water in the mixing tank(s).

The prepared injectate in the mixing tank will be delivered to each injection well with a pump (e.g., centrifugal or double-diaphragm pump) connected to a manifold that includes individual flow meters, pressure gages, and ball valves. The manifold will allow for the metering and control of flow to each injection well so that changes can be made in the field in response to observed pressures and flow rates. The sustained injection rate to each injection well is anticipated to be between 4 gallons per minute ("gpm") and 8 gpm. The injection process will be initiated with a gravity-feed method. If a sufficient injection rate (i.e., 4 gpm per injection well) cannot be obtained using the gravity-feed method, the injection pressure will be increased to maintain a flow rate between 4 gpm and 8 gpm. The injection process will be performed at a minimum of four injection wells simultaneously.

Initially, approximately 80% of the EVO and the buffering amendment (if needed) mixed with anaerobic water will be injected in each injection well. The bioaugmentation culture (KB-1® Plus) will then be injected in each injection well. A small amount of anaerobic water will be added before and after the KB-1® Plus injection to flush the injection lines. KB-1® Plus will be injected directly at each injection well via a side-port integral to the well head assembly or manifold assembly using an inert gas cylinder (e.g., nitrogen or argon) to produce the pressure necessary for the injection. Inert gas will also be used to purge the KB-1® Plus feedline of any ambient air prior to injection.

Once the KB-1® Plus bioaugmentation culture has been injected, the remaining 20% of the EVO and the buffering amendment (if needed) mixed with anaerobic water will follow. After the injection is completed at each location, a small amount of anaerobic water will be used to flush the well screens to prevent potential biofouling of the well screens.

During injection activities, the injection rate, cumulative volume, and injection pressure will be monitored at each injection location on a routine basis. Monitoring will also include measurement of groundwater levels in monitoring wells around the injection locations and visual observations for short-circuiting/daylighting of the amendments to the ground surface. The operational data will be used to support refinements in the injection regime and to confirm that overall injection targets are met. Should the monitoring data indicate that short-circuiting and/or daylighting at the ground surface is

occurring, the injections will be temporarily suspended, and injection rates/pressures will be decreased and/or the injection process will be re-configured.

5.6 Waste Management

Solid and liquid investigation derived waste ("IDW") will be containerized separately to the extent practical and staged in the Central Accumulation Area in the portion of the Brunswick facility that Hercules owns. Solid IDW (e.g., used absorbent material) and liquid IDW (e.g., decontamination fluids and well purge water) will be containerized in drums, which will be clearly labeled, as appropriate, indicating the name of the generator, contact information, generation date, and general contents. If generated, IDW will be characterized as soon as practicable (generally within approximately 30 days) to allow adequate time for appropriate management and off-site disposal.

6.0 PERFORMANCE MONITORING

Groundwater will be monitored in the area of the anaerobic biobarrier before, during, and after the creation of the anaerobic biobarrier. The groundwater monitoring activities that will be undertaken during injection of remedial amendments will utilize field monitoring equipment for evaluating potential groundwater mounding and the radius of influence that is achieved at each injection well in terms of delivery of the remedial amendments, as further described in Section 6.1 of this Work Plan. The main purpose of the groundwater monitoring activities before and after the injection of remedial amendments will be to assess changes in concentrations of chloroform and methylene chloride in the area of the biobarrier based on laboratory analysis. Other analyses will also be included as part of the groundwater monitoring activities as described in Section 6.2 of this Work Plan.

6.1 Subsurface Monitoring During Injection Activities

Prior to the initiation of injection activities, water elevations and groundwater quality parameters will be measured at all performance monitoring wells. The following groundwater quality parameters will be measured and recorded:

- Temperature;
- pH;
- Specific conductivity;
- Dissolved oxygen; and
- ORP.

During injection of the remedial amendments, these same groundwater quality parameters will be monitored daily at the performance monitoring wells located within 50 feet of the active injection points to evaluate the radius of influence that is achieved at each injection well in terms of distribution of the remedial amendments within the target treatment zone. Visual observations of the presence of EVO, which has a milky white color, will also be completed using a bailer on a daily basis at the performance monitoring wells located within 50 feet of the active injection points. Although the entire suite of water quality parameters listed above will be assessed, changes in ORP and specific conductivity are

typically the first indicators that remedial amendments have reached monitoring points in proximity to the injection wells.

Water levels will be recorded from the selected performance monitoring wells a minimum of every four hours during injection of the remedial amendments. If groundwater surfaces at the ground surface, injection activities will be temporarily suspended to allow groundwater in the treatment area to recover to pre-injection groundwater levels.

6.2. Performance Monitoring Plan

A groundwater performance monitoring program will be implemented to evaluate the effectiveness of the anaerobic biobarrier in reducing the concentrations and mass flux of chloroform and methylene chloride. A baseline monitoring event and four post-injection performance monitoring events will be performed as summarized in **Table 4.** The post-injection performance monitoring activities will be performed at three-month intervals corresponding to periods of three months, six months, nine months and twelve months after completion of the injection of the remedial amendments. Additional performance monitoring events beyond twelve months after the completion of the injection of the remedial amendments may be needed depending on the monitoring results that are obtained to evaluate long-term effectiveness of the ICM. A proposed long-term monitoring plan will be included in the corrective action effectiveness report as discussed in Section 7. For each monitoring event, performance monitoring wells will be sampled using low-flow techniques.

For the first monitoring event three months after the completion of the injection activities, only measurements of field parameters (including pH, specific conductance, temperature, dissolved oxygen and ORP) and groundwater levels will be collected. Visual observations that are indicative of the injected remedial amendments, odor and color (e.g., milky white for EVO) will be noted on field forms. Subsequent performance monitoring events occurring at six months, nine months and twelve months after the completion of the injection activities will include measurements of field parameters and groundwater levels together with collection of groundwater samples for laboratory analysis. The groundwater samples will be shipped under chain of custody protocols to TestAmerica in Savannah, Georgia and SiREM Laboratory in Ontario, Canada for analysis.

The groundwater samples will be analyzed for the following parameters:

- VOCs using Method 8260C issued by the United States Environmental Protection Agency ("EPA") to track progress toward the corrective action objectives.

- Dissolved methane (Method RSK-175) and chloride (EPA Method 9251) as potential products from biological processes.

- Sulfate (EPA Method 9056A or equivalent), sulfide (EPA Method 9030 or equivalent), nitrate (EPA Method 353.2 or equivalent), nitrite (EPA Method 353.2 or equivalent), alkalinity (SM 2320B), dissolved iron (EPA Method 6020B or equivalent), and total iron and manganese (EPA Method 6020B or equivalent) as indicators of groundwater chemistry favorable for the microbial population that is responsible for the reductive dechlorination of chloroform and methylene chloride.

- Total organic carbon using SM 5310 to evaluate the presence of organic carbon to promote microbial growth.

- Key microorganisms and functional genes (i.e., dehalobacter, chloroform reductase and total bacteria) using Gene-Trac® testing to evaluate whether suitable microorganisms are present in proximity to the anaerobic biobarrier in the deep zone of the upper surficial aquifer.

6.3. Data Analysis

The total mass flux through the anaerobic biobarrier will be calculated using contaminant concentration data, the hydraulic conductivity in the area of the biobarrier, and the hydraulic gradient across the biobarrier using the following equation:

$$J = KiC/A$$

In this equation:

- J is the mass flux of a particular COPC in grams per unit time per unit cross-sectional area;

- A is the cross-sectional area of groundwater flow through the biobarrier. The flow area depends on the vertical extent of the monitored area (i.e., the vertical intervals of corresponding performance monitoring well screens) and the

width of the biobarrier represented by the locations of the performance monitoring wells;

- K is the hydraulic conductivity in the area of the biobarrier estimated from the results of the pneumatic slug tests as discussed in Section 5.2, above;

- i is the hydraulic gradient between upgradient and downgradient performance monitoring wells using the groundwater elevations collected during each performance monitoring event; and

- C is the concentration of a COPC measured during a performance monitoring event.

Generally, mass flux will be calculated using concentrations of COPCs from groundwater quality data collected from each transect of performance monitoring wells. Based on the variability of the calculation input parameters (hydraulic conductivity, hydraulic gradients, and groundwater quality), a sensitivity analysis will be performed using technical guidance relating to mass flux calculations issued by the Interstate Technology Regulatory Council titled *Use and Measurement of Mass Flux and Mass Discharge* (ITRC, 2010). The final input parameters to calculate mass flux will be evaluated based on the results of the sensitivity analysis. The mass flux methodology will be presented in the Construction Completion Report ("CCR") submitted to EPD following implementation of the biobarrier. Additional analyses will also be performed to optimize the effectiveness of the biobarrier by reviewing the mass flux of COPCs through specific flow tubes represented by the performance monitoring well network both spatially and vertically. The estimated mass flux from the post-injection performance monitoring events will be compared with the estimated mass flux from the baseline monitoring event to evaluate the performance of the biobarrier.

It should also be noted that as demonstrated in the treatability studies, biological reduction of chloroform first converts chloroform to methylene chloride. Methylene chloride then degrades to non-toxic products. Therefore, it is likely that the mass flux and concentrations of chloroform may decrease initially while the mass flux and concentrations of methylene chloride may increase temporarily. After sufficient growth of the microbial population, it is anticipated that both COPCs will be degraded.

7.0 REPORTING

The CCR will be submitted to EPD following the 3-month post injection performance monitoring event. The CCR will summarize the injection activities that were completed (including information regarding amendment dosing and volumes injected) and will include boring logs for the injection and performance monitoring wells, slug test results, updated geologic cross sections showing the injection well and performance monitoring well networks, measurements of field parameters, and initial baseline groundwater monitoring results. The CCR will also present the mass flux calculation methodologies based on the collected data.

Progress reports will be submitted to EPD following the 6-month and 9-month performance monitoring events. The progress reports will briefly summarize the data collection activities, the analytical results that are obtained, and any key field observations obtained during the performance monitoring events.

An initial corrective action effectiveness report for the anerobic biobarrier will be prepared following the 12-month performance monitoring event. The report will present the analytical data that were obtained, the analyses of reductions in concentrations and mass flux of COPCs, the relative progress towards meeting the objectives of the ICM, and the proposed long-term monitoring plan to be implemented. The corrective action effectiveness report may also include recommendations for future actions consistent with the data and observations that are presented.

The initial corrective action effectiveness report for the anerobic biobarrier will be a stand-alone report. Following the submission of the first corrective action effectiveness report, Hercules anticipates that further corrective action effectiveness reports for the anerobic biobarrier will be presented annually as part of the groundwater monitoring reports currently required under the hazardous waste permit for the Brunswick facility that EPD has issued to Hercules and Pinova. The effectiveness reporting schedule may be modified, as approved by EPD.

Hercules will also send copies of the CCR and corrective action monitoring reports to the EPD UIC permitting office to fulfill a substantive requirement of the UIC permitting program.

8.0 SCHEDULE

As previously described, installation and operation of an anaerobic biobarrier to address chloroform and methylene chloride in groundwater in the deep zone of the upper surficial aquifer underlying the southeastern portion of the main operational area of the Brunswick facility along the west side of the U.S. Highway 17 corridor will include, among other things, planning, well installation, injection, and monitoring activities. The work is anticipated to progress in the following sequence of steps. An estimated target duration for completion for each step in the process is also presented with the understanding that the duration of a particular step and the associated target schedule may be modified based on conditions that are encountered and the results that are obtained. Because the steps are sequential, a change in the duration of one step will likely affect the target completion schedule for subsequent steps. Hercules will keep EPD informed of the progress in implementing this Work Plan via regularly scheduled Triad meetings or other communications. The tentative schedule after EPD approval of the Work Plan is as follows:

- Pre-mobilization planning, procurement, and permitting: Two months after EPD approval of the Work Plan;
- Well installation and baseline sampling (three-month duration): Five months after EPD approval of the Work Plan;
- Field injections of remedial amendments (three-month duration): Eight months after EPD approval of the Work Plan;
- Initial (3-month) performance monitoring event and preparation of construction completion report (one-month duration): Twelve months after EPD approval of the Work Plan;
- Subsequent (6-month) performance monitoring event and preparation of progress report (one month after receipt of validated laboratory analytical results): Sixteen months after EPD approval of the Work Plan;
- Subsequent (9-month) performance monitoring event and preparation of progress report (one month after receipt of validated laboratory analytical results): Nineteen months after EPD approval of the Work Plan; and

- Subsequent (12-month) performance monitoring event and preparation of initial corrective action effectiveness report (approximately two months after receipt of validated laboratory analytical results): Twenty-four months after EPD approval of the Work Plan.

9.0 REFERENCES

Geosyntec. 2021. Corrective Action Plan. Hercules/Pinova Brunswick Facility, Brunswick, Georgia. February 2021.

Interstate Technology Regulatory Council (ITRC). 2010. Use and Measurement of Mass Flux and Mass Discharge. August 2010

TABLES

Table 1
Proposed Injection Well Construction Details
Deep Zone of Upper Surficial Aquifer - Anaerobic Biobarrier
Hercules LLC/Pinova Inc Brunswick Facility, Brunswick, GA

Well Cluster ID	Shallower Injection Well				Bentonite Seal Between Two Well Screen	Deeper Injection Well		
	Maximum Depth	Screened Interval	Sand Pack Interval	Bentonite Seal		Maximum Depth	Screened Interval	Sand Pack Interval
	(ft bgs)	(ft bgs)	(ft bgs)	(ft bgs)	(ft bgs)	(ft bgs)	(ft bgs)	(ft bgs)
INJ-01	82	82 to 72	82 to 70	70 to 68	84 to 82	95	95 to 85	95 to 84
INJ-02	82	82 to 72	82 to 70	70 to 68	84 to 82	95	95 to 85	95 to 84
INJ-03	82	82 to 72	82 to 70	70 to 68	84 to 82	95	95 to 85	95 to 84
INJ-04	82	82 to 72	82 to 70	70 to 68	84 to 82	95	95 to 85	95 to 84
INJ-05	82	82 to 72	82 to 70	70 to 68	84 to 82	95	95 to 85	95 to 84
INJ-06	82	82 to 72	82 to 70	70 to 68	84 to 82	95	95 to 85	95 to 84
INJ-07	82	82 to 72	82 to 70	70 to 68	84 to 82	95	95 to 85	95 to 84
INJ-08	82	82 to 72	82 to 70	70 to 68	84 to 82	95	95 to 85	95 to 84
INJ-09	82	82 to 72	82 to 70	70 to 68	84 to 82	95	95 to 85	95 to 84
INJ-10	82	82 to 72	82 to 70	70 to 68	84 to 82	95	95 to 85	95 to 84
INJ-11	82	82 to 72	82 to 70	70 to 68	84 to 82	95	95 to 85	95 to 84
INJ-12	82	82 to 72	82 to 70	70 to 68	84 to 82	95	95 to 85	95 to 84
INJ-13	82	82 to 72	82 to 70	70 to 68	84 to 82	95	95 to 85	95 to 84
INJ-14	82	82 to 72	82 to 70	70 to 68	84 to 82	95	95 to 85	95 to 84
INJ-15	82	82 to 72	82 to 70	70 to 68	84 to 82	95	95 to 85	95 to 84
INJ-16	82	82 to 72	82 to 70	70 to 68	84 to 82	95	95 to 85	95 to 84
INJ-17	82	82 to 72	82 to 70	70 to 68	84 to 82	95	95 to 85	95 to 84
INJ-18	82	82 to 72	82 to 70	70 to 68	84 to 82	95	95 to 85	95 to 84

Notes:

ft bgs - feet below ground surface.

1. All injection wells will be constructed with 2-inch diameter 0.01 inch slotted screens. Well components will consist of Schedule 40 polyvinyl chloride.
2. The sand pack will extend one foot above the top of screen for the deeper injection well and two feet above the screen for the shallower injection well.
3. Both injection wells in a well cluster (deeper and shallower well) will be installed in the same borehole with a minimum diameter of 8 inches. Two feet of bentonite seal will separate the well screens in the borehole.
4. The screened intervals/lengths for the injection wells have been selected to target a treatment zone of high permeability material (i.e., medium to coarse sand) in the deep zone of the upper surficial aquifer. The screened intervals/lengths for the injection wells are subject to change based on the depth of the confining layer and low permeability layers (i.e., silty, clayey layers) that may be encountered during well installation activities.
5. The locations for the injections wells may be modified due to the accessibility of the proposed locations and other field conditions that are encountered.

Table 2
Injection Design Summary
Deep Zone of Upper Surficial Aquifer - Anaerobic Biobarrier
Hercules LLC/Pinova Inc Brunswick Facility, Brunswick, GA

Well ID	Shallower Interval					Deeper Interval				
	Approximate Treatment Zone	60% EVO	Anaerobic Water	Sodium Bicarbonate Buffer (if needed)	Bioaugmentation Culture (KB-1® Plus)	Approximate Treatment Zone	60% EVO	Anaerobic Water	Sodium Bicarbonate Buffer (if needed)	Bioaugmentation Culture (KB-1® Plus)
	(ft bgs)	(gallons)	(gallons)	(pounds)	(liters)	(ft bgs)	(gallons)	(gallons)	(pounds)	(liters)
INJ-01	70 to 82.5	280	3,851	330	7.5	82.5 to 95	280	3,851	330	7.5
INJ-02	70 to 82.5	280	3,851	330	7.5	82.5 to 95	280	3,851	330	7.5
INJ-03	70 to 82.5	280	3,851	330	7.5	82.5 to 95	280	3,851	330	7.5
INJ-04	70 to 82.5	280	3,851	330	7.5	82.5 to 95	280	3,851	330	7.5
INJ-05	70 to 82.5	280	3,851	330	7.5	82.5 to 95	280	3,851	330	7.5
INJ-06	70 to 82.5	280	3,851	330	7.5	82.5 to 95	280	3,851	330	7.5
INJ-07	70 to 82.5	280	3,851	330	7.5	82.5 to 95	280	3,851	330	7.5
INJ-08	70 to 82.5	280	3,851	330	7.5	82.5 to 95	280	3,851	330	7.5
INJ-09	70 to 82.5	280	3,851	330	7.5	82.5 to 95	280	3,851	330	7.5
INJ-10	70 to 82.5	280	3,851	330	7.5	82.5 to 95	280	3,851	330	7.5
INJ-11	70 to 82.5	280	3,851	330	7.5	82.5 to 95	280	3,851	330	7.5
INJ-12	70 to 82.5	280	3,851	330	7.5	82.5 to 95	280	3,851	330	7.5
INJ-13	70 to 82.5	280	3,851	330	7.5	82.5 to 95	280	3,851	330	7.5
INJ-14	70 to 82.5	280	3,851	330	7.5	82.5 to 95	280	3,851	330	7.5
INJ-15	70 to 82.5	280	3,851	330	7.5	82.5 to 95	280	3,851	330	7.5
INJ-16	70 to 82.5	280	3,851	330	7.5	82.5 to 95	280	3,851	330	7.5
INJ-17	70 to 82.5	280	3,851	330	7.5	82.5 to 95	280	3,851	330	7.5
INJ-18	70 to 82.5	280	3,851	330	7.5	82.5 to 95	280	3,851	330	7.5
Total Volumes:	**--**	**5,040**	**69,313**	**5,939**	**135**	**--**	**5,040**	**69,313**	**5,939**	**135**

Notes:

ft bgs - feet below ground surface

1. Refer to Appendix D for detailed calculations and assumptions.

2. The injection quantities for each treatment zone interval are based on the assumption that each interval has a vertical dimension of 12.5 feet. The injection quantities may change based on the treatment zone intervals that are actually established as determined by the thickness of the preferential mass flux zone in the deep zone of the upper surficial aquifer.

Table 3
Proposed Performance Monitoring Well Construction Details
Deep Zone of Upper Surficial Aquifer - Anaerobic Biobarrier
Hercules LLC/Pinova Inc Brunswick Facility, Brunswick, GA

Well ID	Shallower Performance Monitoring Wells (A)				Deeper Performance Monitoring Wells (B)			
	Maximum Depth	Screened Interval	Sand Pack Interval	Bentonite Seal	Maximum Depth	Screened Interval	Sand Pack Interval	Bentonite Seal
	(ft bgs)	(ft bgs)	(ft bgs)	(ft bgs)	(ft bgs)	(ft bgs)	(ft bgs)	(ft bgs)
PMW-01A/B	83	82 to 72	83 to 71	71 to 68	95	94 to 84	95 to 83	83 to 80
PMW-02A	83	88 to 72	83 to 71	71 to 68	--	--	--	--
PMW-03A/B	83	82 to 72	83 to 71	71 to 68	95	94 to 84	95 to 83	83 to 80
PMW-04A/B	83	82 to 72	83 to 71	71 to 68	95	94 to 84	95 to 83	83 to 80
PMW-05A/B	83	82 to 72	83 to 71	71 to 68	95	94 to 84	95 to 83	83 to 80
PMW-06A/B	83	82 to 72	83 to 71	71 to 68	95	94 to 84	95 to 83	83 to 80
PMW-07A/B	83	82 to 72	83 to 71	71 to 68	95	94 to 84	95 to 83	83 to 80
MW-10D	--	--	--	--	95.4	87.8 to 95.4	95 to 83	71 to 68

Notes:

ft bgs - indicates feet below ground surface.

-- not applicable

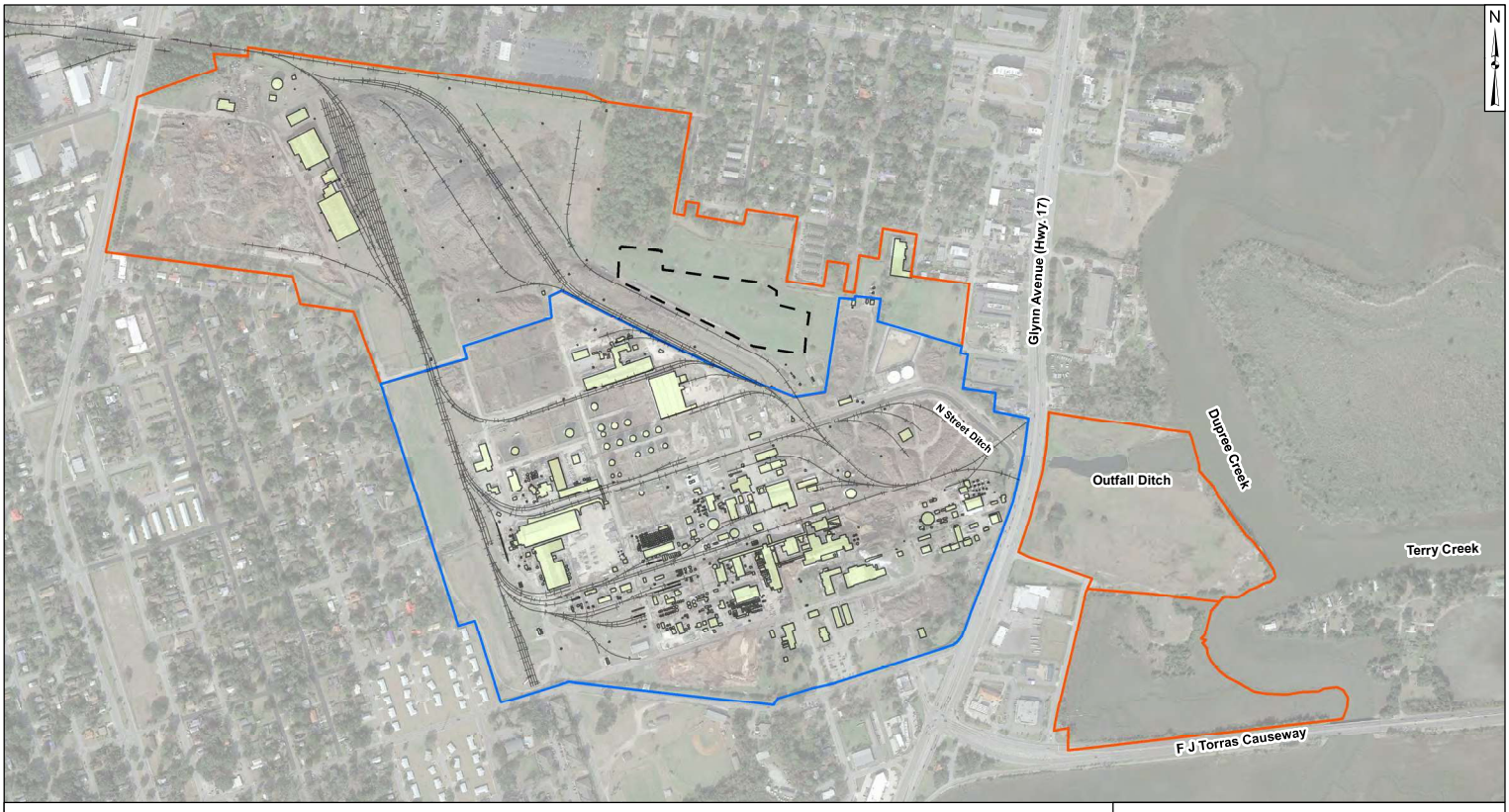
1. All performance monitoring wells will be constructed with 2-inch diameter 0.01 inch slotted screens. Well components will consist of Schedule 40 polyvinyl chloride.
2. Each performance monitoring well will have a one-foot sump at the bottom of the well screen and the sand pack will extend one foot above the top of the well screen.
3. Monitoring well MW-10D is an existing monitoring well in the deep zone of the upper surficial aquifer that will be used for performance monitoring. Performance monitoring well PMW-02A will be coupled with monitoring well MW-10D to monitor the treatment zone.
4. The screened depths/intervals for the performance monitoring wells may be modified based on the lithology that is encountered during well installation activities
5. The locations for the performance monitoring wells may be modified due to the accessibility of the proposed locations and other field conditions that are encountered.

Table 4
Proposed Performance Monitoring Plan
Deep Zone of Upper Surficial Aquifer - Anaerobic Biobarrier
Hercules LLC/Pinova Inc Brunswick Facility, Brunswick, GA

Monitoring Event	Monitoring Parameters	Analytical Method	Monitoring Wells
Baseline	Depth to Water	N/A	PMW-01A/B, PMW-02A, PMW-03A/B, PMW-04A/B, PMW-05A/B, PMW-06A/B, MW-10D, PMW-07A/B
	Field Parameters[1]	N/A	
	VOCs	EPA 8260C	
	Total Organic Carbon	SM 5310	
	Dissolved Methane	RSK-175	
	Sulfate	EPA 9056A	
	Sulfide	EPA 9030	
	Nitrate/Nitrite	EPA 353.2	
	Chloride	EPA 9251	
	Total Iron and Manganese	EPA 6020B	
	Dissolved Iron	EPA 6020B	
	Alkalinity	SM 2320B	
	Microbial Parameters[2]	Gene-Trac®	MW-10D, PMW-02A, PMW-04A/B, PMW-06A/B
3-Month Post-Injections	Depth to Water	N/A	All performance monitoring wells
	Field Parameters[1, 3]	N/A	MW-10D, PMW-02A, PMW-04A/B, PMW-06A/B
6-Month Post-Injection	Depth to Water	N/A	PMW-01A/B, PMW-02A, PMW-03A/B, PMW-04A/B, PMW-05A/B, PMW-06A/B, MW-10D
	Field Parameters[1]	N/A	
	VOCs	EPA 8260C	
	Total Organic Carbon	SM 5310	
	Dissolved Methane	RSK-175	
	Sulfate	EPA 9056A	
	Sulfide	EPA 9030	
	Nitrate/Nitrite	EPA 353.2	
	Chloride	EPA 9251	
	Total Iron and Manganese	EPA 6020B	
	Dissolved Iron	EPA 6020B	
	Alkalinity	SM 2320B	
	Microbial Parameters[2]	Gene-Trac®	MW-10D, PMW-02A, PMW-04A/B, PMW-06A/B
9-Month Post-Injection	Depth to Water	N/A	PMW-01A/B, PMW-02A, PMW-03A/B, PMW-04A/B, PMW-05A/B, PMW-06A/B, MW-10D
	Field Parameters[1]	N/A	
	VOCs	EPA 8260C	
	Total Organic Carbon	SM 5310	
	Dissolved Methane	RSK-175	
	Sulfate	EPA 9056A	
	Sulfide	EPA 9030	
	Nitrate/Nitrite	EPA 353.2	
	Chloride	EPA 9251	
	Total Iron and Manganese	EPA 6020B	
	Dissolved Iron	EPA 6020B	
	Alkalinity	SM 2320B	
	Microbial Parameters[2]	Gene-Trac®	--
12-Month Post-Injection	Depth to Water	N/A	PMW-01A/B, PMW-02A, PMW-03A/B, PMW-04A/B, PMW-05A/B, PMW-06A/B, MW-10D, PMW-07A/B
	Field Parameters[1]	N/A	
	VOCs	EPA 8260C	
	Total Organic Carbon	SM 5310	
	Dissolved Methane	RSK-175	
	Sulfate	EPA 9056A	
	Sulfide	EPA 9030	
	Nitrate/Nitrite	EPA 353.2	
	Chloride	EPA 9251	
	Total Iron and Manganese	EPA 6020B	
	Dissolved Iron	EPA 6020B	
	Alkalinity	SM 2320B	
	Microbial Parameters[2]	Gene-Trac®	MW-10D, PMW-02A, PMW-04A/B, PMW-06A/B

Notes:
VOCs- volatile organic compounds
EPA - Environmental Protection Agency
N/A - not applicable
-- - not analyzed
1- pH, dissolved oxygen (DO), oxidation-reduction potential (ORP), specific conductivity, and temperature
2- Dehalobacter, chloroform reductase and total bacteria
3- Only monitoring wells immediately downgradient of the biobarrier will be sampled for the field parameters because the influence of the biobarrier is not expected to extend to other performance monitoring wells during this monitoring event.

FIGURES



Legend

- Railroad
- Pinova, Inc. Property
- Hercules LLC Property
- Approximate location of closed surface impoundments
- Structure

0 250 500 1,000 Feet

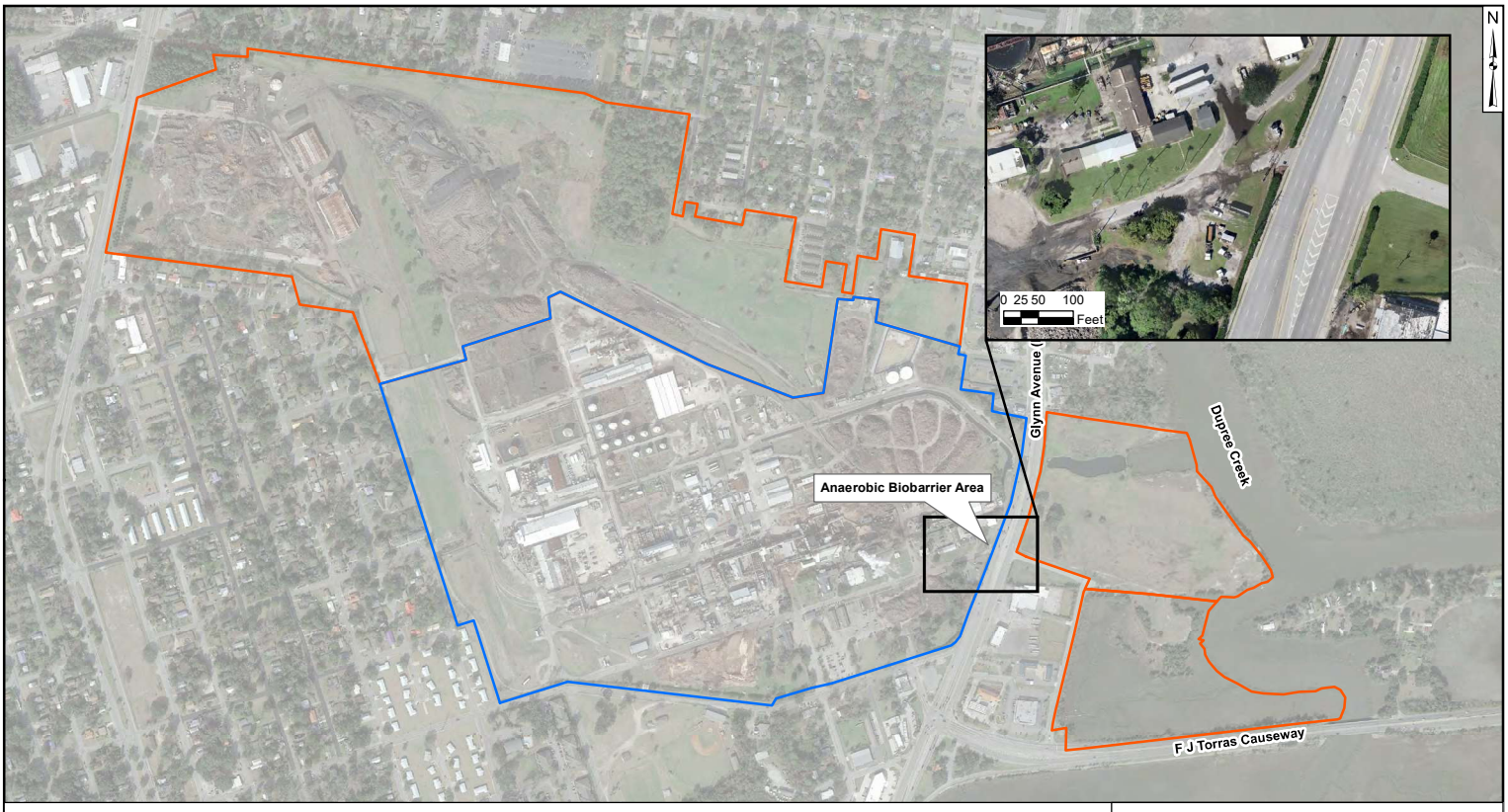
Notes:
1. Aerial photograph approximate date - January 2019. Source: Google Earth.

Site Location
Hercules/Pinova Facility
Brunswick, Georgia

Geosyntec consultants

Kennesaw, GA | June 2021

Figure 1



Legend

- Pinova, Inc. Property
- Hercules LLC

0 250 500 1,000
Feet

Notes:
1. Aerial Photograph approximate date - January 2019. Source: Google Earth.

Anaerobic Biobarrier Treatment Area Location
Hercules/Pinova Facility
Brunswick, Georgia

Geosyntec consultants

Kennesaw, GA | June 2021

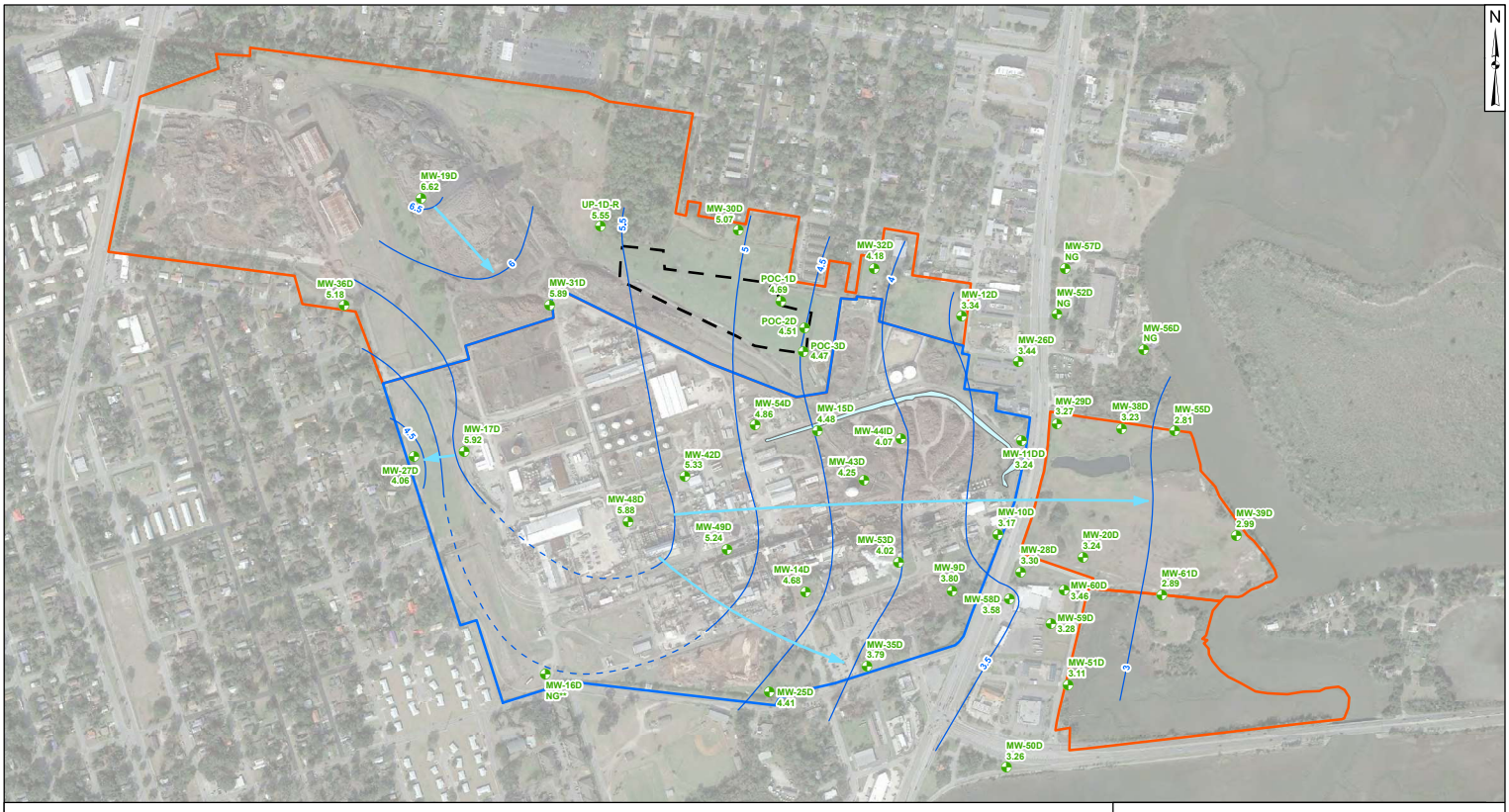
Figure 2

Geologic Epoch	Aquifer System	Aquifer and Confining Units	Approximate Aquifer or Confining Unit Depth (ft bgs)	Aquifer Zone	Approximate Zone Depth (ft bgs)
Post-Miocene	Surficial Aquifer System	Upper Surficial Aquifer	0 to 100	Shallow Zone	0 to 40
				Intermediate Zone	40 to 70
				Deep Zone	70 to 100
		Confining Unit (if present)	90 to 100 (if present)		
Miocene		Lower Surficial Aquifer	100 to 200		
	Brunswick Aquifer System	Confining Unit	200 to 280		
		Upper Brunswick Aquifer	280 to 355		
		Confining Unit	355 to 400		
		Lower Brunswick Aquifer	400 to 475		
	Floridan Aquifer System	Upper Floridan Confining Unit	475 to 500		
Oligocene to Eocene		Upper Floridan Aquifer	500 to 970		
		Lower Floridan Confining Unit	970 to 1000		
		Lower Floridan Aquifer	>1000+		

Notes:
1. Ft bgs = feet below ground surface.
2. Figure modified from Figure 1-3 in *Refined Conceptual Site Model, Hercules/Pinova Brunswick Facility, Brunswick, Georgia. March 15, 2019.* (Integral, 2019).
3. Geologic epochs are approximate and estimated from Brunswick Pulp and Paper Co., Glynn County Cross Section, found on Plate 2 in *Geology and Groundwater Resources of the Coastal Area of Georgia. Bulletin 113.* (Clarke, et al., 1990).
4. In general, aquifer/confining unit depths and zone depths are generalizations and should be considered as approximate depth intervals for the Site. Depths are generally derived from Integral (2019) and from Brunswick Pulp and Paper Co., Glynn County cross section, found on Plate 2 in Clarke, et al. (1990).
5. The confining unit depth separating the upper surficial aquifer from the lower surficial aquifer is based on the boring log for monitoring well MW-52D.

Aquifers and Confining Units	Geosyntec consultants	Figure
Kennesaw, GA	June 2021	**3**

Source file: \\Aro-01\prj1$\H\Hercules\Brunswick\GIS\Figure 3-1 Aquifer and Confining Units.pptx



Legend

- Monitoring Well for Deep Zone of Upper Surficial Aquifer
- Groundwater Elevation Iso-Contour (ft MSL)
- Groundwater Elevation Iso-Contour (ft MSL) Dashed Where Inferred
- Approximate Groundwater Flow Direction - Deep Zone of Upper Surficial Aquifer
- Approximate Location of Closed Surface Impoundments
- Pinova, Inc. Property
- Hercules LLC Property
- N Street Ditch

0 275 550 1,100 Feet

Notes:

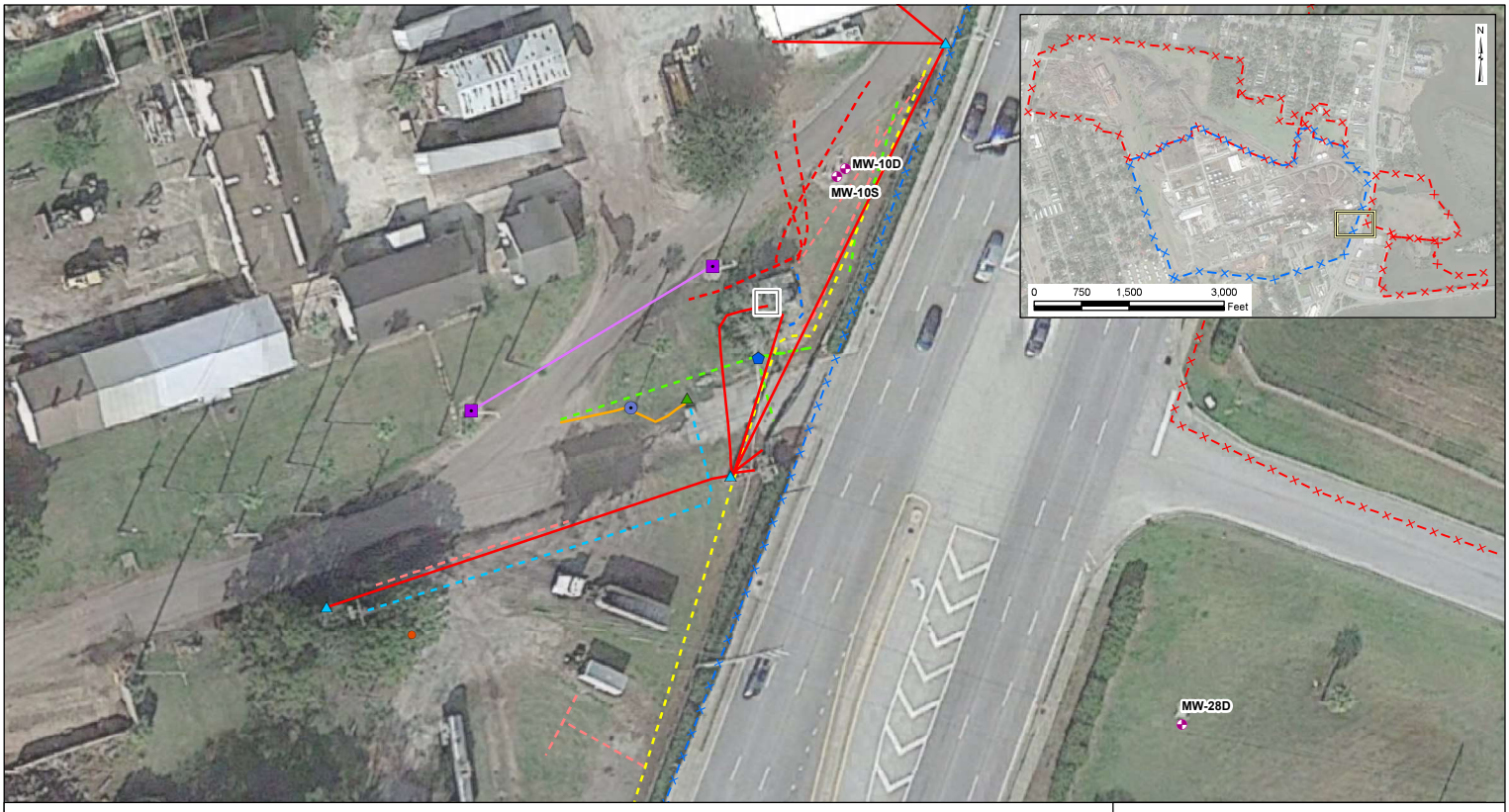
1. Water level measurements recorded on December 7, 2020. Elevations provided in feet above mean sea level (ft MSL).
2. NG = Not gauged.
3. ** indicates well was observed to be damaged and was not gauged during the December 2020 groundwater sampling event.
4. Aerial photograph approximate date - January 2019. Source: Google Earth.

Potentiometric Map
Surficial Aquifer, Deep Zone of Upper Unit
Hercules/Pinova, Inc. Facility
Brunswick, Georgia

Geosyntec consultants

Kennesaw, GA | June 2021

Figure 4



Legend

- Monitoring Well – Surficial Aquifer, Upper Unit
- Unknown Utilities
- Water Riser
- Storm Water Catch Basin Square
- Electric Cabinet
- Electric Street Light
- Electric Powerpole
- Communication Pedestal
- Pinova, Inc. Property
- Hercules LLC Property
- Communication Line
- Electrical Ground Wire
- Electrical Line
- Electrical Street Light Line
- Storm Water Line
- Water Line
- Irrigation Line
- Unknown Line

0 20 40 80 Feet

N

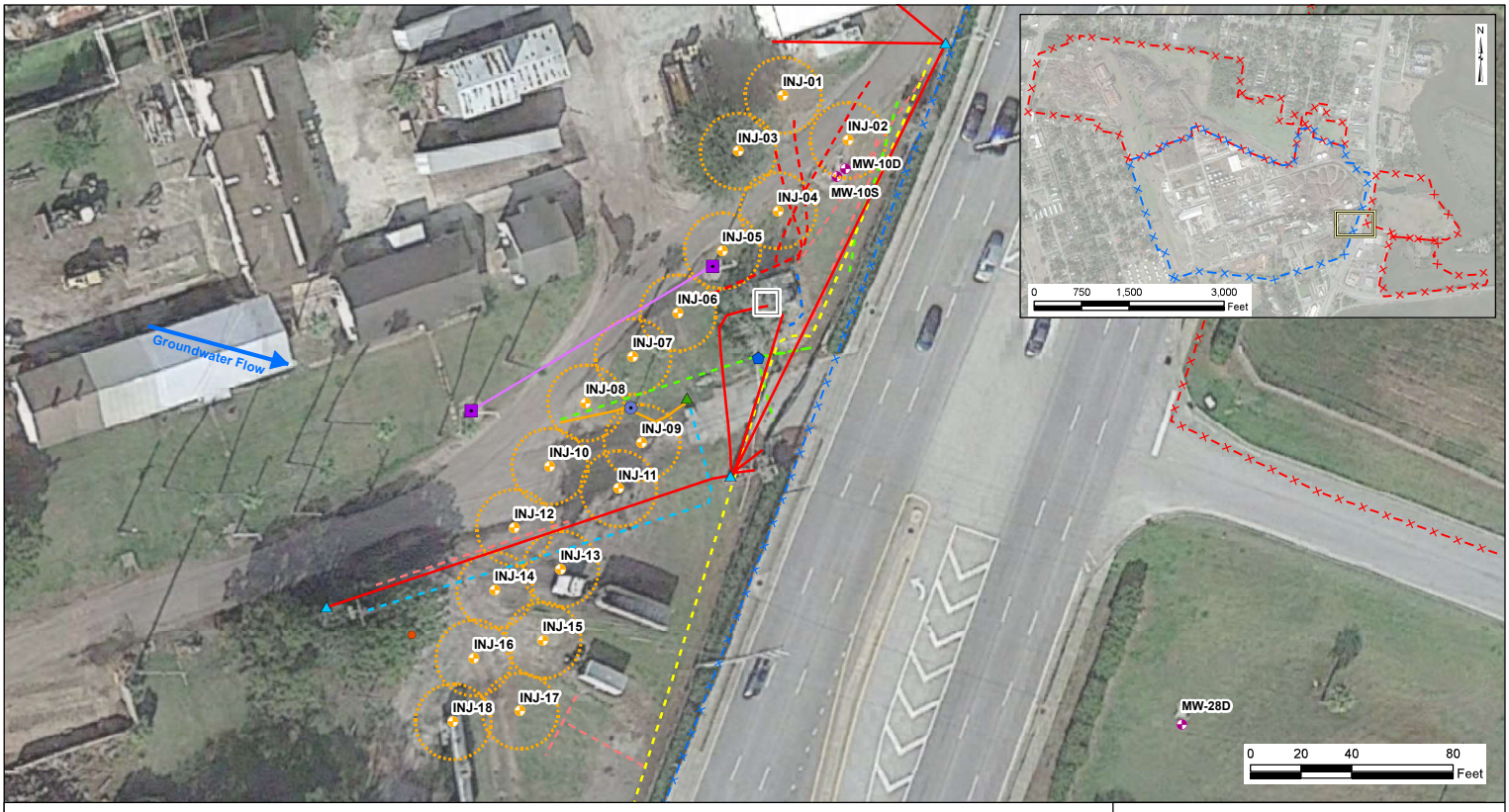
Notes:
1. Aboveground utilities are designated by solid lines and underground are designated by dashed lines.
2. Aerial photograph approximate date - January 2019. Source: Google Earth.

Anaerobic Biobarrier Treatment Area
Existing Site Features and Utilities
Hercules/Pinova Facility
Brunswick, Georgia

Geosyntec consultants

Kennesaw, GA | June 2021

Figure 5



Legend

- Monitoring Well – Surficial Aquifer, Upper Unit
- Approximate Location of Proposed Injection Well Clusters
- 15ft Radius of Influence (ROI)
- Unknown Utilities
- Water Riser
- Storm Water Catch Basin Square
- Electric Cabinet
- Electric Street Light
- Electric Powerpole
- Communication Pedestal
- Pinova, Inc. Property
- Hercules LLC Property
- Communication Line
- Electrical Ground Wire
- Electrical Line
- Electrical Street Light Line
- Storm Water Line
- Water Line
- Irrigation Line
- Unknown Line

Notes:
1. Aboveground utilities are designated by solid lines and underground are designated by dashed lines.
2. Each injection well cluster will include two injection wells to cover a treatment zone of 70 to 95 feet below ground surface.
3. Proposed injection well locations may change in the field based on driller access, utility locations and Pinova operations.
4. Aerial photograph approximate date - January 2019. Source: Google Earth.

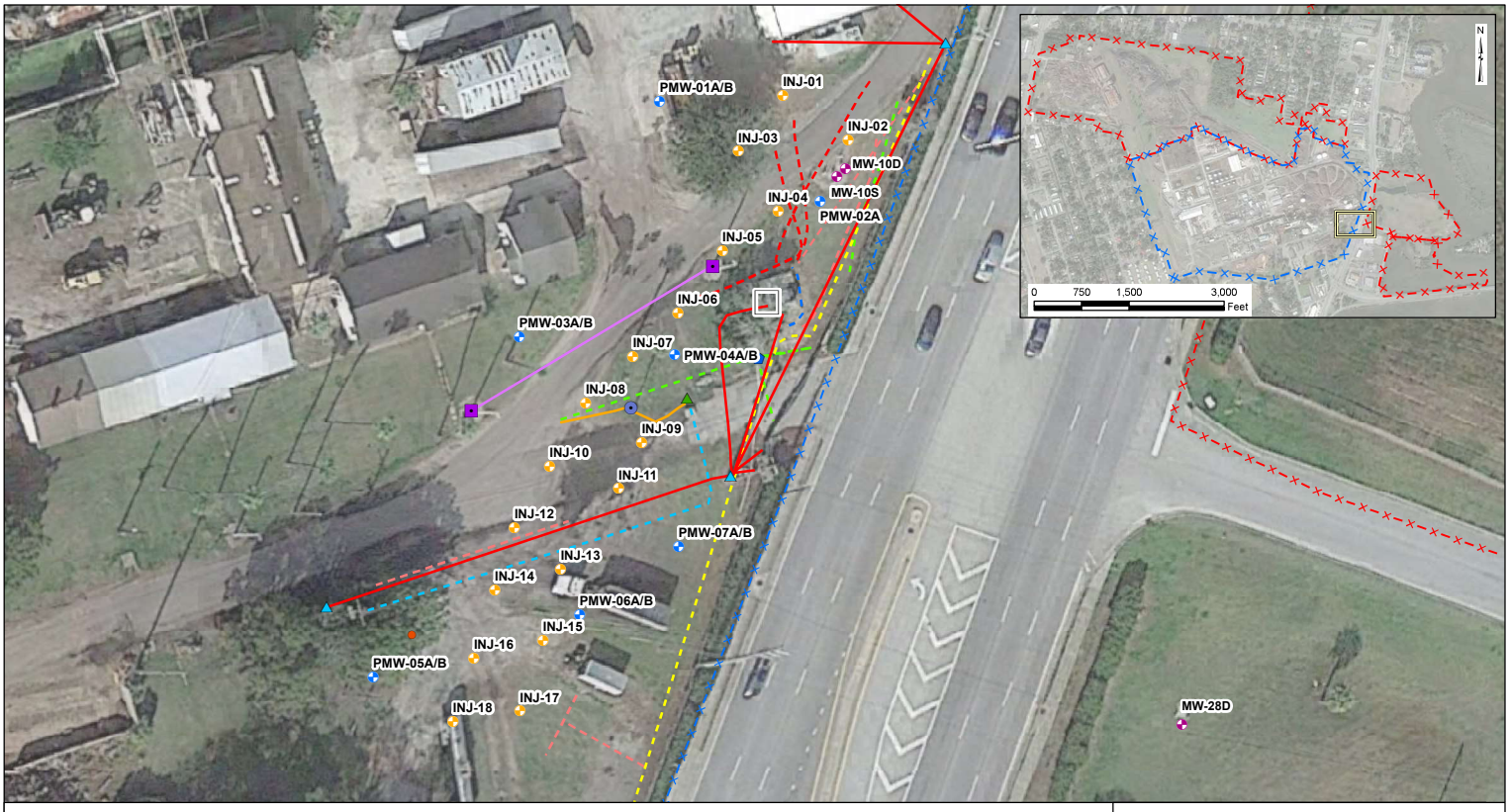
N

Proposed Anaerobic Biobarrier Layout
Hercules/Pinova Facility
Brunswick, Georgia

Geosyntec consultants

Kennesaw, GA | June 2021

Figure 6



Legend

- Monitoring Well – Surficial Aquifer, Upper Unit
- Proposed Performance Monitoring Well Cluster
- Proposed Injection Well Clusters
- Unknown Utilities
- Water Riser
- Storm Water Catch Basin Square
- Electric Cabinet
- Electric Street Light
- Electric Powerpole
- Communication Pedestal
- Pinova, Inc. Property
- Hercules LLC Property
- Communication Line
- Electrical Ground Wire
- Electrical Line
- Electrical Street Light Line
- Storm Water Line
- Water Line
- Irrigation Line
- Unknown Line

0 20 40 80 Feet

N

Notes:

1. Aboveground utilites are designated by solid lines and underground are designated by dashed lines.
2. "A" designates a proposed performance monitoring well screened approximately from 72 to 82 feet below ground surface. "B" designates a proposed performance monitoring well screened approximately from 84 to 94 feet below ground surface.
3. Proposed monitoring well locations may change in the field based on driller access, utility locations and Pinova operations.
4. Aerial photograph approximate date - January 2019. Source: Google Earth.

Proposed Performance Monitoring Well Locations
Hercules/Pinova Facility
Brunswick, Georgia

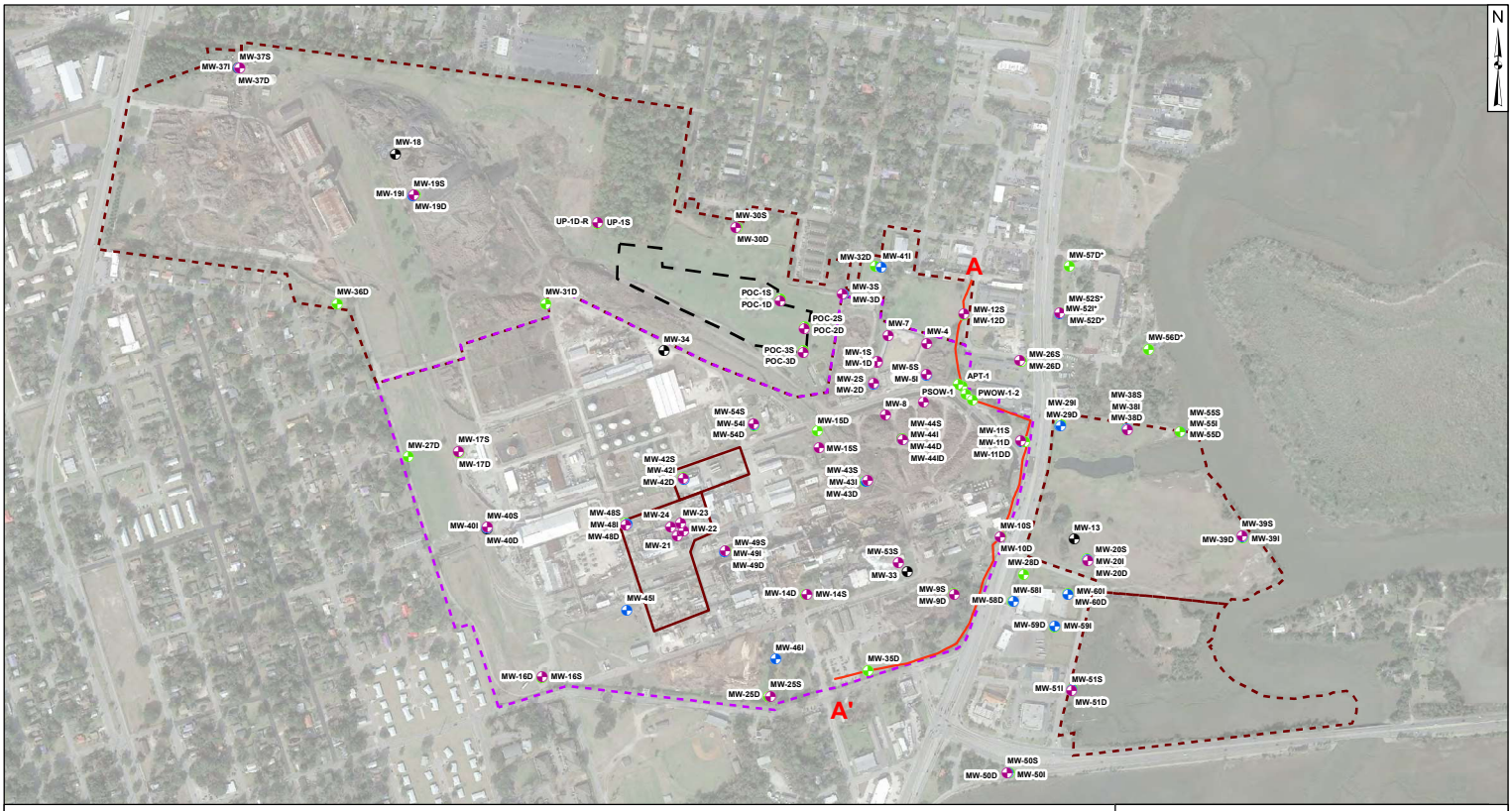
Geosyntec consultants

Kennesaw, GA | September 2021

Figure 7

APPENDIX A

Geologic Cross Sections



Legend

- Surficial Aquifer, Shallow Zone of Upper Unit Wells
- Surficial Aquifer, Intermediate Zone of Upper Unit Wells
- Surficial Aquifer, Deep Zone of Upper Unit Wells
- Surficial Aquifer, Lower Unit Wells
- Cross Section Line
- Approximate Location of Closed Surface Impoundments
- Approximate Extent of Potential Source Areas
- Pinova Property
- Hercules Property

0 275 550 1,100 Feet

Notes:
1. Aerial photograph approximate date - January 2019. Source: Google Earth.
2. * = Property owner has not allowed access since 2017.

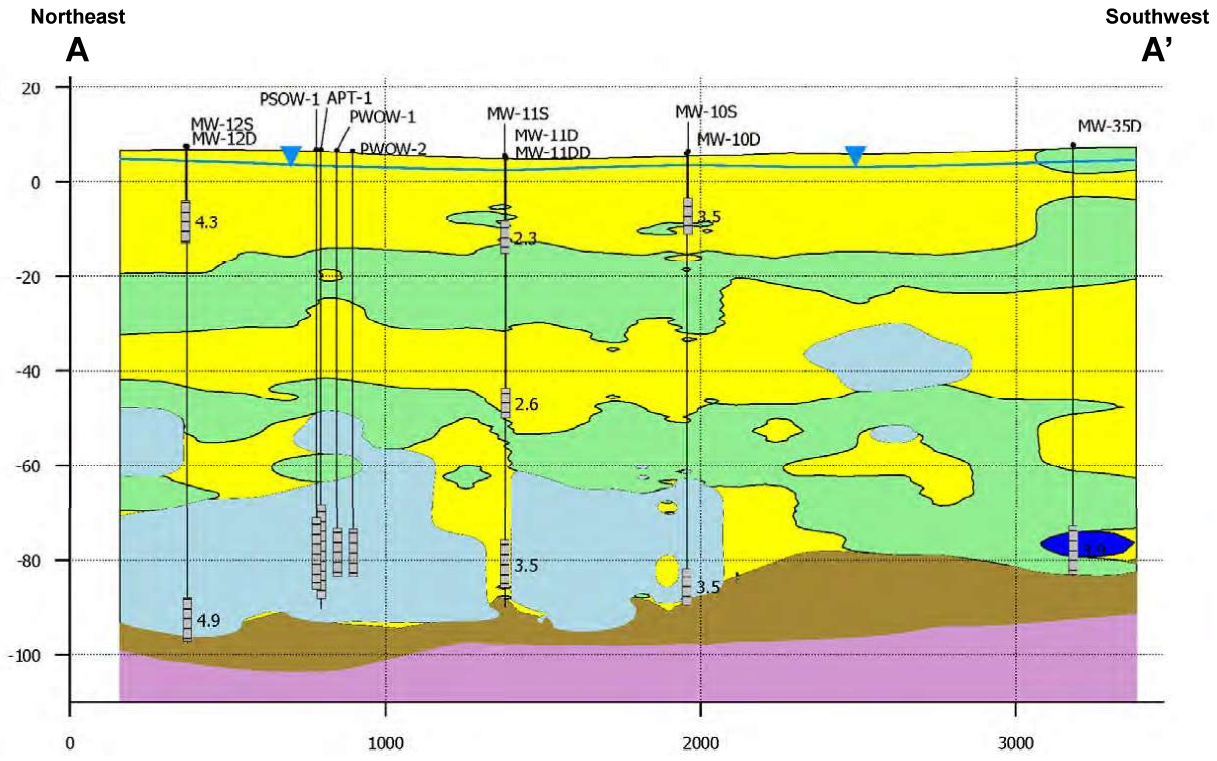
Path: N:\Ashland\Brunswick Plant\GIS\MXD\Deep GW ICM\Figure 1-4 Cross Section Key Map.mxd

Cross Section Location Map
Hercules/Pinova Facility
Brunswick, Georgia

Geosyntec consultants

Kennesaw, GA | September 2021

Figure 1



Notes:
1. Lower permeability soils in the Upper Surficial Aquifer includes silty sands, clayey sands, sands, silts, clays, and cemented sands.
2. Groundwater elevations measured December 9, 2019.
3. The presented thicknesses of confining unit and lower surficial aquifer unit were estimated using other boring logs outside of the scale of this figure.

Cross Section A-A'	Geosyntec consultants	Figure 2
Kennesaw, GA	September 2021	

APPENDIX B

Biotreatability Study Laboratory Report

Prepared for:

Geosyntec Consultants Inc.
1255 Roberts Blvd #200
Kennesaw, GA 30144

Laboratory Biotreatability Study to Evaluate Anaerobic In-Situ Bioremediation of Chlorinated Methanes in Groundwater

Deep Zone of Upper Surficial Aquifer - Hercules/Pinova Facility, Brunswick, GA

Prepared by:

130 Stone Road West
Guelph, Ontario N1G 3Z2

SiREM Ref: GR6881C

27 January 2021

siremlab.com

SiREM

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LIST OF ABBREVIATIONS

the Site	Brunswick Site
CO_2	carbon dioxide
cVOC	chlorinated volatile organic compound
CF	chloroform
CM	chloromethane
°C	degrees Celsius
°C/min	degrees Celsius per minute
Dhb	*Dehalobacter*
DCM	dichloromethane
DHG	dissolved hydrocarbon gases
ERD	enhanced reductive dechlorination
FID	flame ionization detector
GC	gas chromatograph
Geosyntec	Geosyntec Consultants Inc.
gene copies/L	gene copies per liter
IC	ion chromatograph
µg/L	micrograms per litre
µL	microliter
min	minutes
mg/L	milligrams per litre
mL	millilitres
mL/min	milliliters per minute
mM	millimolar
mmol/bottle	millimoles per bottle
ND	non-detect
%	percent
psi	pounds per square inch
QL	quantitation limit
RPM	revolutions per minute
SiREM	SiREM Laboratory
VFA	volatile fatty acid
VOC	volatile organic compound

1. INTRODUCTION

Geosyntec Consultants Inc. (Geosyntec) retained SiREM Laboratory (SiREM) to perform a laboratory biotreatability study to assess the potential for in situ bioremediation of chlorinated methane compounds in groundwater for the deep zone of upper surficial aquifer at the Brunswick Site in Georgia (the Site). The objective of the study was to assess anaerobic biodegradation of the target compounds, namely chloroform (CF), dichloromethane (DCM), chloromethane (CM), and methane.

The groundwater labelled MW-28D was collected on 28 Feb 2020 by Geosyntec personnel and received by SiREM on 4 Mar 2020 at a temperature of 9 degrees Celsius (°C). The soil labelled TSB-01_MW28D (83-84, 84-85, 85-86, 86-87) was collected on 4 Mar 2020 by Geosyntec personnel and received by SiREM on 12 Mar 2020 at a temperature of 4 °C. Refer to Appendix A for the chain of custody documentation received with the materials.

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 CF may potentially include DCM, CM, methane, and the end product carbon dioxide (CO_2) as shown Figure 1; with the most commonly found pathway highlighted in green.

The presence of CF may inhibit microbial activity, notably impairing the activity of aerobic bacteria, fermentative and methanogenic microbes. Natural attenuation processes can occur in situ and are often mediated by indigenous microbial populations present at chlorinated methane 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. KB-1® Plus is a custom formulated natural microbial consortium containing microorganisms (including *Dehalobacter* [*Dhb*]) capable of degrading CF to DCM. The KB-1® Plus culture also has the ability to further degrade DCM to acetate and CO_2, most likely by a fermentation pathway (SiREM, unpublished data). In addition, recent research has also identified a *Dhb* strain responsible for the fermentation of DCM (Justicia-Leon et al., 2012) (as highlighted by the green arrows in Figure 1).

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

2.1.1 Microcosm Construction

Biotreatability microcosms were constructed in a disposable anaerobic glove bag containing the Site groundwater and all the materials required to construct the treatment and control microcosms. The glove bag was purged with nitrogen gas to create an anaerobic environment and to protect any microorganisms present in the site materials from oxygen exposure.

Microcosms were constructed on 26 March 2020 (Day -11) by filling sterile 250 millilitre (mL) (nominal volume) screw cap Boston round clear glass bottles (Systems Plus, New Hamburg, ON) with 200 mL of Site groundwater. The bottles were capped with Mininert™ closures to allow repetitive sampling with minimal chlorinated volatile organic compound (cVOC) loss and to allow nutrient amendment, as needed, throughout the incubation period. All treatment and control microcosms were constructed in triplicate. Table 1 summarizes the details of microcosm construction and the amendments used for the treatment and control microcosms.

Anaerobic sterile control microcosms were constructed to quantify potential abiotic and experimental cVOC losses from the microcosms. The sterile controls were constructed by autoclaving the Site geologic materials at 121 °C and 15 pounds per square inch (psi) pressure for 45 minutes (min). After autoclaving the sterile control microcosms were returned to the anaerobic chamber, filled with 200 mL of Site groundwater, and amended with mercuric chloride and sodium azide as described in Tables 1 and 2.

2.1.2 Microcosm Amendments and Incubation

All microcosms were sampled and incubated in an anaerobic chamber (Coy Laboratory Products, Grass Lake, MI) filled with an atmosphere of approximately 80 percent (%) nitrogen, 10% CO_2 and 10% hydrogen (Linde Gases, Guelph, ON). Hydrogen in the anaerobic chamber functions to scavenge trace oxygen via a palladium catalyst. Anaerobic conditions in the anaerobic chamber were verified using an indicator containing resazurin (Sigma, St. Louis, MO) in a mineral medium, which turns pink in the presence of oxygen. During quiescent incubation, all microcosms were covered to minimize photodegradation, and stored horizontally to minimize cVOC losses via the (submerged) Mininert™ closure. Microcosms were incubated for a period of up to 164 days at approximately 22 °C (room temperature).

After consultation with Geosyntec, it was decided that the CF concentrations in the microcosms were representative of concentrations measured at the Site, so it was not necessary to spike the microcosms.

Treatment microcosms were amended with electron donor on 7 April 2020 (Day 0) and 14 July 2020 (Day 98). Lactate as sodium lactate (CHEMCO Inc, St-Augustin-de-Desmaures, Quebec) was the selected electron donor evaluated in this study. The first microcosm of each treatment and control was amended with resazurin (Sigma, St. Louis, MO) to monitor redox conditions. Resazurin turns from pink to clear in the absence of oxygen and can be used to indicate the on-set of reducing conditions. Details of amendments are provided in Tables 1 and 2.

Bioaugmentation may improve the extent and rate of dechlorination for chlorinated methanes. Microcosms are typically bioaugmented after reducing conditions required by the KB-1® Plus culture are achieved. Suitable reducing conditions are typically achieved after electron donor addition and are indicated by changes of the resazurin indicator color (from pink to clear), and the on-set of sulfate reduction. Sulfate reduction was observed on Day 20. Therefore, the Lactate Amended/KB-1 Plus treatment microcosms were bioaugmented with KB-1® Plus culture on 12 May 2020 (Day 35). The first replicate of this treatment was bioaugmented a second time on Day 99 after observing limited dechlorination activity relative to the second and third replicates. Details of bioaugmentation are presented in Tables 1 and 2.

2.2 Microcosm Sampling and Analysis

2.2.1 Microcosm Sampling Schedules

Aqueous samples were collected from the control and treatment microcosms approximately every 2-4 weeks for analysis of cVOCs, dissolved hydrocarbon gases (DHGs – ethene, ethane, and methane), and pH. Aqueous samples were also collected less frequently for analysis of volatile fatty acids (VFAs – lactate, acetate, propionate, formate, butyrate, pyruvate) and anions (sulfate, nitrate, nitrite, chloride, phosphate, bromide). The 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® Plus microorganisms from bioaugmented to non-bioaugmented treatments. Syringes were cleaned with acidified water (pH ~2) and rinsed 10 times with de-ionized water between samples to ensure that volatile organic compounds (VOCs) and microorganisms were not transferred between different samples or treatments.

2.2.2 Analysis of cVOCs and Dissolved Hydrocarbon Gases

This section describes the methods used to quantify the VOCs and DHGs. The quantitation limits (QL) for the VOCs and DHGs are 20 micrograms per liter (µg/L) in the microcosms based on the sample dilution factor used and the lowest concentration standards that are included in the linear calibration trend.

Aqueous VOC and DHG concentrations in the microcosms are measured using an Agilent 7890 gas chromatograph (GC) equipped with an Agilent G1888 headspace autosampler programmed to heat each sample vial to 75 °C for 45 min prior to headspace injection into a GSQ Plot column (0.53 millimeters x 30 meters, J&W) with a flame ionization detector (FID). Sample vials are heated to ensure that all VOCs in the aqueous sample partition into the headspace. The injector temperature is 200 °C, and the detector temperature is 250 °C. The oven temperature is 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 helium carrier gas is to flow at a rate of 11 milliliters per minute (mL/min).

After withdrawing a sample (as described in Section 2.2.1) from the microcosms, the sample is injected into a 10 mL auto sampler vial containing acidified DI water (pH ~2). The sample volume is added to the vial containing acidified DI water to bring the total volume up to 6 mL. The water

is acidified to inhibit microbial activity between microcosm sampling and GC analysis. The vial is sealed with an inert Teflon™-lined septum and aluminum crimp cap for automated injection of 3 mL of headspace onto the GC. One VOC standard is 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, Missouri), where known volumes of standard solutions were added to acidified water in auto sampler vials and analyzed as described above for microcosm samples. Data are integrated using Chemstation Software (Agilent Technologies, Santa Clara, California).

2.2.3 Analysis of Anions and Total Volatile Fatty Acids

Anions and total VFA analysis was performed on a Thermo-Fisher ICS-2100 ion chromatograph (IC) equipped with a Thermo-Fisher AS-DV autosampler and an AS18 column. An isocratic separation was performed using 33 millimolar (mM) reagent grade sodium hydroxide eluent generator cartridge (Thermo Scientific, Burlington, 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 Chromeleon 7® Chromatography software (Thermo-Fisher, Burlington, ON). The QLs were as follows: 0.07 milligrams per liter (mg/L) total VFA, 0.07 mg/L chloride, 0.09 mg/L nitrite, 0.09 mg/L nitrate, 0.07 mg/L sulfate, 0.07 mg/L phosphate and 0.08 mg/L bromide. The total VFA value was initially calibrated as lactate, but includes lactate, formate, acetate, propionate, pyruvate and butyrate (valerate has not been confirmed). 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 50-fold in DI water and placed in a Thermo-Fisher autosampler vial with a cap that filters the sample during automated injection onto the IC through a 25 microliter (µL) sample loop.

2.2.4 Analysis of Volatile Fatty Acids

Individual VFA (lactate, acetate, propionate, formate, butyrate and pyruvate) analysis was performed on a Thermo-Fisher ICS-2100 IC equipped with a Thermo-Fisher AS-DV autosampler and an AS11-HC column. 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 0.25 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 Chromeleon 7® Chromatography software (Thermo-Fisher, Burlington, 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 DI water and placed in a Thermo-Fisher autosampler vial with a cap that filters the sample during automated injection onto the IC through a 25 µL sample loop.

2.2.5 Analysis of pH

The pH measurements were performed using an Oakton pH spear with a combination pH electrode (Oakton, Vernon Hills, IL). A 0.5 mL sample was collected (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.

3. RESULTS AND DISCUSSION

The following sections present and discuss the results of the biotreatability study:

- Redox processes (Section 3.1),
- Volatile Fatty Acids (Section 3.2),
- pH (Section 3.3)
- Chlorinated ethenes biodegradation results (Section 3.4),

Tables 2, 3, 4, 5, and 6 provide chlorinated methanes, methane, anion, VFA, pH, and Gene-Trac data from the control and treatment microcosms over the incubation period for the study. All chlorinated methane 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. All anion and VFA concentrations are reported in mg/L. Gene-Trac data is reported in gene copies per liter (gene copies/L). Table 6 presents the cVOC half-lives. Figures 2 through 6 present trends in the concentrations of chlorinated methanes and methane in the control and treatment microcosms over the incubation period for the study.

3.1 Redox Processes

The addition of electron donor typically results in microbial activity that promotes changes in the redox conditions in groundwater. Aerobic or mildly reducing redox conditions will become more reduced, providing the conditions necessary to support anaerobic degradation of chlorinated methanes.

The sequence of redox reactions in groundwater is well known (Appelo and Postma, 1994). Oxygen is first consumed, followed by nitrate (denitrification), iron, manganese, and sulfate reduction. The final step is CO_2 reduction producing methane (methanogenesis). The consumption of each species in sequence indicates that conditions are becoming increasingly reducing. Dechlorination of chlorinated methanes typically occurs in the range of sulfate reducing to methanogenic conditions.

In the sterile and active control microcosms, nitrate remained at non-detect (ND) throughout the incubation period and sulfate concentrations remained relatively stable (Table 3). Methane concentrations also did not increase (Table 2). This suggests that reducing conditions were not established in these microcosms. These observations are consistent with the low level of microbial activity expected in the sterile control microcosms and suggest that there were either insufficient populations of indigenous CF degrading bacteria or inappropriate conditions for their activity.

In the Lactate Amended treatment, sulfate degraded from 38 mg/L on Day 0 to 4.6 mg/L on Day 20. On Day 20 sulfate was at ND in replicates 1 and 3. Sulfate persisted at a reduced concentration in replicate 2 until reaching non-detect on Day 91. The concentration of methane remained relatively stable throughout the incubation period.

In the Lactate Amended/KB-1 Plus® Bioaugmented treatment, sulfate degraded from 41 mg/L on Day 0 to 4.6 mg/L on Day 20. The data indicates there was a partial rebound in sulfate concentrations from Day 20 to Day 35, but an overall trend of sulfate reduction was observed with complete reduction of sulfate being observed on Day 91. The concentration of methane increased slightly over the incubation period.

These results suggest that using lactate as an electron donor can support the creation of reducing conditions necessary for ERD of chlorinated methanes to occur.

3.2 Volatile Fatty Acids

Lactate is a fermentable electron donor source to promote microbial activity. The fermentation results in the production of hydrogen, which is the ultimate electron donor used by dechlorinators.

Lactate was detected at Time 0 in the treatments (Table 4). Excluding a suspected outlier in replicate 3 of the Lactate Amended treatment, the average lactate concentration was 237 mg/L. By Day 35 the concentration of lactate reached ND with a corresponding increase in the concentration of acetate. On Day 66 acetate concentrations remained relatively stable and there were detections of propionate.

These results indicate that the fermentable portions of the electron donors were being actively consumed and fermented.

3.3 pH

The optimum pH for reductive dechlorination is 6.8 to 7.5 (Middledorp et al., 1999) with dechlorination occurring at reasonable rates in the 6.0 to 8.5 pH range (SiREM, unpublished data). The pH in all control microcosms was measured to be between 5.79 and 6.72 throughout the incubation period with a large majority of measurements between 6.1 and 6.6 (Table 5).

These results suggest that the Site materials can provide and maintain a pH in the acceptable range for reductive dechlorination.

3.4 Gene-Trac®

Samples from the bulk groundwater and treatment microcosms were submitted for analysis of *Dhb* and cfrA (Table 6 and Appendix B). cfrA is a functional gene of Dhb that is associated with reduction of chlorinated methanes.

The baseline groundwater results, which were used to represent the time zero conditions, were reported as being 1 x 10^6 gene copies/L of *Dhb* and 2 x 10^7 gene copies/L of cfrA. On Day 140 the count of *Dhb* increased to 10^8 for both treatments, but cfrA decreased to 10^6.

These results suggest that *Dhb* with the appropriate genes for reductive dechlorination were present in microbial populations native to the Site and persisted in both treatments throughout the incubation period. However, the Gene-Trac data does not correspond with the chlorinated methane concentration data where a comparatively strong dechlorination performance was observed for the Lactate Amended/KB-1® Plus Bioaugmented treatment, possibly due to sampling being done after active CF and DCM degradation occurred

3.5 cVOC Biodegradation Results

3.5.1 Degradation Half-Lives for Chlorinated Methanes

Laboratory half-lives were calculated based on the average dechlorination observed in the treatment microcosms as indicated in Table 6. 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:

$$Half - life = \frac{\ln(2)}{\left[\frac{\ln\left(\frac{C_2}{C_1}\right)}{t_2 - t_1}\right]}$$

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 CF and DCM were determined (Table 6). Half-lives were not determined in situations where the concentration remained stable or increased throughout the study period.

3.5.2 Anaerobic Sterile and Active Control Microcosms

All chlorinated methane concentrations in the sterile and active control microcosms remained relatively stable over the incubation period with no increases in degradation products, therefore half-lives were not calculated (Table 2 and Figures 2 and 3). These results are consistent with the limited microbial activity suggested by the lack of observed sulfate reduction (Table 3) and methanogenesis measured in these control microcosms.

3.5.3 Lactate Amended Microcosms

In the Lactate Amended treatment, the concentration of CF decreased from Day 20 to Day 49 (Table 2 and Figure 4). This activity ceased following Day 49, and after consultation with Geosyntec the microcosms were amended with additional lactate on Day 99. After Day 99, CF dechlorination accelerated and continued for the remainder of the incubation period. Throughout the incubation period CF dechlorination was accompanied by a corresponding increase in the concentration of DCM. The half-life of CF was calculated to be 18 days (Table 7). The concentration of DCM did not decrease; therefore, no half-life was calculated. These results suggest that intrinsic CF degrading populations were present at the site, but DCM degrading bacteria were either not present or their activity was inhibited.

These results suggest that complete degradation of chlorinated methanes in the Site material may not be possible when using lactate amendment alone.

3.5.4 Lactate Amended/KB-1® Plus Bioaugmented Microcosms

In the Lactate Amended/KB-1® Plus Bioaugmented treatment, the concentration of CF decreased steadily after bioaugmentation on Day 35 until it was ND on Day 133 (Table 2 and Figure 5). At the same time there, was a corresponding increase in the concentration of DCM. From Day 119 to the end of the incubation period net degradation of DCM was observed. Towards the end of the incubation period there was an increase in the concentration of methane supporting that complete dechlorination CF, and DCM was occurring. Half-lives of CF and DCM were calculated to be 9.2 and 19 days, respectively (Table 7).

Since the timing of dechlorination activity varied notably between replicates for this treatment the replicates were also plotted individually (Figure 6) and separate half-lives were calculated (Table 7). Replicate 1 had limited activity prior to the second lactate amendment on Day 99. As a result, this replicate was also bioaugmented with KB-1® Plus at that time. Afterwards dechlorination was rapid and complete. In contrast, dechlorination activity in replicates 2 and 3 was sustained from the initial bioaugmentation to the end of the incubation period. However, the activity was more

gradual and the incubation period did not extend long enough to observe complete dechlorination of DCM. The half-lives of CF and DCM were between 3.1 and 6.7 times shorter for replicate 1 than for replicates 2 and 3.

These results suggest that complete degradation of chlorinated methanes in the Site material may be possible when using lactate amendment in combination with KB-1® Plus bioaugmentation.

4. CONCLUSIONS

The laboratory biotreatability study results suggest the following conclusions:

1. Lactate amendment can promote the appropriate geochemical conditions for reductive dechlorination of chlorinated methanes.

2. The native bacterial populations at the Site appear to be suitable for facilitating dechlorination of CF to DCM, but not degradation of DCM.

3. Complete dechlorination of CF and DCM was achieved after KB-1® Plus bioaugmentation with lactate as the electron donor.

4. The Site materials can provide and maintain a pH in the acceptable range for reductive dechlorination.

The results of this study indicate that ERD using KB-1® Plus bioaugmentation combined with lactate as an electron donor has the potential to be an effective remedial approach for the Site.

5. REFERENCES

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TABLES

TABLE 1: SUMMARY OF MICROCOSM CONTROLS, TREATMENTS AND AMENDMENTS
Deep Zone of Upper Surficial Aquifer - Brunswick, GA

Treatment/Control	Assigned Microcosm Number	Number of Microcosms	Geological Material (g)	Groundwater (mL)	Headspace (mL)	Sodium Azide	Mercuric Chloride	Rezasurin	Electron Donor Amended	Bioaugmentation
Anaerobic Sterile Control	1 to 3	3	60	200	20	Amended with 0.5 mL of a 5% solution on Day -11.	Amended with 2.8 mL of a 2.7% solution on Day -11.	Amended first replicate with 100 µL of a 1,000 mg/L solution on Day -11.	--	--
Intrinsic Control	4 to 6	3	60	200	20	--	--		--	--
Lactate Amended	7 to 9	3	60	200	20	--	--		Amended with 39 µL of a 60% sodium lactate solution to a target a final concentration of 117 mg/L based on the calculated stoichiometric demand with a 5 times safety factor. This amendment was repeated on Day 98.	--
Lactate Amended/KB-1® Plus Bioaugmented	10 to 12	3	60	200	20	--	--			Bioaugmented with 0.5 mL of KB-1® Plus on Day 35 and repeated on Day 99 for replicate 1 only.

Notes:

-- - not applicable
% - percent
µL - microliter
g - grams
mg/L - milligrams per liter
mL - milliliters

TABLE 2: SUMMARY OF MICROCOSM cVOC AND DHG RESULTS SiREM
Deep Zone of Upper Surficial Aquifer - Brunswick, GA

Treatment	Date	Day	Replicate	DHGs			Chlorinated Methanes and Methane				Comment
				Ethene	Acetylene	Ethane	CF	DCM	CM	Methane	
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	
Anaerobic Sterile Control	27-Mar-20	-11									Poisoned with mercuric chloride and sodium azide.
											Amended the first replicate with 100 µL resazurin.
	07-Apr-20	0	ANSC-1	<0.040	<0.0040	<0.040	28	<0.040	<0.040	0.41	
			ANSC-2	<0.040	<0.0040	<0.040	28	<0.040	<0.040	0.43	
			ANSC-3	<0.040	<0.0040	<0.040	29	<0.040	<0.040	0.4	
			Average Concentration (mg/L)	ND	ND	ND	28	ND	ND	0.41	
			Standard Deviation (mmoles)	0.0E+00	0.0E+00	0.0E+00	1.2E-03	0.0E+00	0.0E+00	7.2E-04	
			Average Total mmoles	**ND**	**ND**	**ND**	**0.048**	**ND**	**ND**	**0.019**	
	27-Apr-20	20	ANSC-1	<0.040	<0.0040	<0.040	30	<0.040	<0.040	0.45	
			ANSC-2	<0.040	<0.0040	<0.040	30	<0.040	<0.040	0.45	
			ANSC-3	<0.040	<0.0040	<0.040	30	<0.040	<0.040	0.40	
			Average Concentration (mg/L)	ND	ND	ND	30	ND	ND	0.43	
			Standard Deviation (mmoles)	0.0E+00	0.0E+00	0.0E+00	6.0E-04	0.0E+00	0.0E+00	1.2E-03	
			Average Total mmoles	**ND**	**ND**	**ND**	**0.051**	**ND**	**ND**	**0.02**	
	12-May-20	35	ANSC-1	<0.040	<0.0040	<0.040	35	<0.040	<0.040	0.48	
			ANSC-2	<0.040	<0.0040	<0.040	31	<0.040	<0.040	0.45	
			ANSC-3	<0.040	<0.0040	<0.040	33	<0.040	<0.040	0.44	
			Average Concentration (mg/L)	ND	ND	ND	33	ND	ND	0.45	
			Standard Deviation (mmoles)	0.0E+00	0.0E+00	0.0E+00	3.1E-03	0.0E+00	0.0E+00	9.8E-04	
			Average Total mmoles	**ND**	**ND**	**ND**	**0.056**	**ND**	**ND**	**0.021**	
	26-May-20	49	ANSC-1	<0.040	<0.0040	<0.040	30	<0.040	<0.040	0.46	
			ANSC-2	<0.040	<0.0040	<0.040	29	<0.040	<0.040	0.46	
			ANSC-3	<0.040	<0.0040	<0.040	31	<0.040	<0.040	0.42	
			Average Concentration (mg/L)	ND	ND	ND	30	ND	ND	0.45	
			Standard Deviation (mmoles)	0.0E+00	0.0E+00	0.0E+00	1.6E-03	0.0E+00	0.0E+00	1.1E-03	
			Average Total mmoles	**ND**	**ND**	**ND**	**0.052**	**ND**	**ND**	**0.021**	
	12-Jun-20	66	ANSC-1	<0.040	<0.0040	<0.040	31	<0.040	<0.040	0.36	
			ANSC-2	<0.040	<0.0040	<0.040	27	<0.040	<0.040	0.32	
			ANSC-3	<0.040	<0.0040	<0.040	32	<0.040	<0.040	0.32	
			Average Concentration (mg/L)	ND	ND	ND	30	ND	ND	0.33	
			Standard Deviation (mmoles)	0.0E+00	0.0E+00	0.0E+00	4.5E-03	0.0E+00	0.0E+00	1.2E-03	
			Average Total mmoles	**ND**	**ND**	**ND**	**0.051**	**ND**	**ND**	**0.015**	
	04-Aug-20	119	ANSC-1	<0.040	<0.0040	<0.040	32	<0.040	<0.040	0.43	
			ANSC-2	<0.040	<0.0040	<0.040	27	<0.040	<0.040	0.21	
			ANSC-3	<0.040	<0.0040	<0.040	32	<0.040	<0.040	0.39	
			Average Concentration (mg/L)	ND	ND	ND	31	ND	ND	0.34	
			Standard Deviation (mmoles)	0.0E+00	0.0E+00	0.0E+00	4.7E-03	0.0E+00	0.0E+00	5.5E-03	
			Average Total mmoles	**ND**	**ND**	**ND**	**0.052**	**ND**	**ND**	**0.016**	
	18-Aug-20	133	ANSC-1	<0.040	<0.0040	<0.040	31	<0.040	<0.040	0.39	
			ANSC-2	<0.040	<0.0040	<0.040	31	<0.040	<0.040	0.41	
			ANSC-3	<0.040	<0.0040	<0.040	32	<0.040	<0.040	0.39	
			Average Concentration (mg/L)	ND	ND	ND	32	ND	ND	0.40	
			Standard Deviation (mmoles)	0.0E+00	0.0E+00	0.0E+00	8.0E-04	0.0E+00	0.0E+00	6.5E-04	
			Average Total mmoles	**ND**	**ND**	**ND**	**0.054**	**ND**	**ND**	**0.018**	
	01-Sep-20	147	ANSC-1	<0.040	<0.0040	<0.040	31	<0.040	<0.040	0.36	
			ANSC-2	<0.040	<0.0040	<0.040	30	<0.040	<0.040	0.38	
			ANSC-3	<0.040	<0.0040	<0.040	32	<0.040	<0.040	0.35	
			Average Concentration (mg/L)	ND	ND	ND	31	ND	ND	0.36	
			Standard Deviation (mmoles)	0.0E+00	0.0E+00	0.0E+00	1.6E-03	0.0E+00	0.0E+00	5.5E-04	
			Average Total mmoles	**ND**	**ND**	**ND**	**0.053**	**ND**	**ND**	**0.017**	

TABLE 2: SUMMARY OF MICROCOSM cVOC AND DHG RESULTS SiREM
Deep Zone of Upper Surficial Aquifer - Brunswick, GA

Treatment	Date	Day	Replicate	DHGs			Chlorinated Methanes and Methane				Comment
				Ethene	Acetylene	Ethane	CF	DCM	CM	Methane	
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	
Anaerobic Active Control	27-Mar-20	-11									Amended the first replicate with 100 µL resazurin.
	07-Apr-20	0	ANAC-1	<0.040	<0.0040	<0.040	29	<0.040	<0.040	0.37	
			ANAC-2	<0.040	<0.0040	<0.040	29	<0.040	<0.040	0.42	
			ANAC-3	<0.040	<0.0040	<0.040	29	<0.040	<0.040	0.35	
			Average Concentration (mg/L)	ND	ND	ND	29	ND	ND	0.38	
			Standard Deviation (mmoles)	0.0E+00	0.0E+00	0.0E+00	4.9E-04	0.0E+00	0.0E+00	1.5E-03	
			Average Total mmoles	**ND**	**ND**	**ND**	**0.049**	**ND**	**ND**	**0.018**	
	27-Apr-20	20	ANAC-1	<0.040	<0.0040	<0.040	30	<0.040	<0.040	0.37	
			ANAC-2	<0.040	<0.0040	<0.040	26	<0.040	<0.040	0.37	
			ANAC-3	<0.040	<0.0040	<0.040	31	<0.040	<0.040	0.41	
			Average Concentration (mg/L)	ND	ND	ND	29	ND	ND	0.39	
			Standard Deviation (mmoles)	0.0E+00	0.0E+00	0.0E+00	4.5E-03	0.0E+00	0.0E+00	1.0E-03	
			Average Total mmoles	**ND**	**ND**	**ND**	**0.05**	**ND**	**ND**	**0.018**	
	12-May-20	35	ANAC-1	<0.040	<0.0040	<0.040	33	0.044	<0.040	0.38	
			ANAC-2	<0.040	<0.0040	<0.040	32	<0.040	<0.040	0.44	
			ANAC-3	<0.040	<0.0040	<0.040	32	0.061	<0.040	0.41	
			Average Concentration (mg/L)	ND	ND	ND	32	0.035	ND	0.41	
			Standard Deviation (mmoles)	0.0E+00	0.0E+00	0.0E+00	1.3E-03	7.7E-05	0.0E+00	1.5E-03	
			Average Total mmoles	**ND**	**ND**	**ND**	**0.055**	**0.000085**	**ND**	**0.019**	
	26-May-20	49	ANAC-1	<0.040	<0.0040	<0.040	31	<0.040	<0.040	0.37	
			ANAC-2	<0.040	<0.0040	<0.040	27	<0.040	<0.040	0.41	
			ANAC-3	<0.040	<0.0040	<0.040	21	0.044	<0.040	0.29	
			Average Concentration (mg/L)	ND	ND	ND	26	0.015	ND	0.36	
			Standard Deviation (mmoles)	0.0E+00	0.0E+00	0.0E+00	7.7E-03	6.2E-05	0.0E+00	2.8E-03	
			Average Total mmoles	**ND**	**ND**	**ND**	**0.045**	**0.000036**	**ND**	**0.017**	
	12-Jun-20	66	ANAC-1	--	--	--	--	--	--	--	
			ANAC-2	<0.040	<0.0040	<0.040	31	0.054	<0.040	0.39	
			ANAC-3	<0.040	<0.0040	<0.040	32	<0.040	<0.040	0.37	
			Average Concentration (mg/L)	ND	ND	ND	32	0.027	ND	0.38	
			Standard Deviation (mmoles)	0.0E+00	0.0E+00	0.0E+00	2.0E-03	9.3E-05	0.0E+00	7.2E-04	
			Average Total mmoles	**ND**	**ND**	**ND**	**0.054**	**0.000066**	**ND**	**0.017**	
	04-Aug-20	119	ANAC-1	<0.040	<0.0040	<0.040	32	<0.040	<0.040	0.38	
			ANAC-2	<0.040	<0.0040	<0.040	31	<0.040	<0.040	0.43	
			ANAC-3	<0.040	<0.0040	<0.040	32	<0.040	<0.040	0.41	
			Average Concentration (mg/L)	ND	ND	ND	32	ND	ND	0.41	
			Standard Deviation (mmoles)	0.0E+00	0.0E+00	0.0E+00	1.5E-03	0.0E+00	0.0E+00	1.1E-03	
			Average Total mmoles	**ND**	**ND**	**ND**	**0.054**	**ND**	**ND**	**0.019**	
	18-Aug-20	133	ANAC-1	<0.040	<0.0040	<0.040	33	0.051	<0.040	0.36	
			ANAC-2	<0.040	<0.0040	<0.040	32	0.059	<0.040	0.43	
			ANAC-3	<0.040	<0.0040	<0.040	33	0.10	<0.040	0.39	
			Average Concentration (mg/L)	ND	ND	ND	33	0.071	ND	0.39	
			Standard Deviation (mmoles)	0.0E+00	0.0E+00	0.0E+00	1.0E-03	6.9E-05	0.0E+00	1.7E-03	
			Average Total mmoles	**ND**	**ND**	**ND**	**0.056**	**0.00017**	**ND**	**0.018**	

TABLE 2: SUMMARY OF MICROCOSM cVOC AND DHG RESULTS SiREM
Deep Zone of Upper Surficial Aquifer - Brunswick, GA

Treatment	Date	Day	Replicate	DHGs			Chlorinated Methanes and Methane				Comment
				Ethene	Acetylene	Ethane	CF	DCM	CM	Methane	
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	
Anaerobic Active Control	01-Sep-20	147	ANAC-1	<0.040	<0.0040	<0.040	32	0.075	<0.040	0.33	
Continued			ANAC-2	<0.040	<0.0040	<0.040	32	0.069	<0.040	0.41	
			ANAC-3	<0.040	<0.0040	<0.040	33	0.12	<0.040	0.38	
			Average Concentration (mg/L)	ND	ND	ND	32	0.087	ND	0.38	
			Standard Deviation (mmoles)	0.0E+00	0.0E+00	0.0E+00	6.9E-04	6.5E-05	0.0E+00	1.9E-03	
			Average Total mmoles	**ND**	**ND**	**ND**	**0.055**	**0.00021**	**ND**	**0.017**	
Lactate Amended	27-Mar-20	-11									Amended the first replicate with 100 µL resazurin.
	07-Apr-20	0									Amended with 39 µL to target 117 mg/L lactate.
			LAC-1	<0.040	<0.0040	<0.040	29	<0.040	<0.040	0.36	
			LAC-2	<0.040	<0.0040	<0.040	30	<0.040	<0.040	0.37	
			LAC-3	<0.040	<0.0040	<0.040	27	<0.040	<0.040	0.48	
			Average Concentration (mg/L)	ND	ND	ND	28	ND	ND	0.4	
			Standard Deviation (mmoles)	0.0E+00	0.0E+00	0.0E+00	2.3E-03	0.0E+00	0.0E+00	3.1E-03	
			Average Total mmoles	**ND**	**ND**	**ND**	**0.048**	**ND**	**ND**	**0.019**	
	27-Apr-20	20	LAC-1	<0.040	<0.0040	<0.040	29	0.23	<0.040	0.37	
			LAC-2	<0.040	<0.0040	<0.040	31	0.10	<0.040	0.40	
			LAC-3	<0.040	<0.0040	<0.040	29	0.44	<0.040	0.50	
			Average Concentration (mg/L)	ND	ND	ND	30	0.26	ND	0.42	
			Standard Deviation (mmoles)	0.0E+00	0.0E+00	0.0E+00	1.2E-03	4.2E-04	0.0E+00	3.0E-03	
			Average Total mmoles	**ND**	**ND**	**ND**	**0.051**	**0.00063**	**ND**	**0.02**	
	12-May-20	35	LAC-1	<0.040	<0.0040	<0.040	26	4.4	<0.040	0.38	
			LAC-2	<0.040	<0.0040	<0.040	34	0.19	<0.040	0.42	
			LAC-3	<0.040	<0.0040	<0.040	20	11	<0.040	0.5	
			Average Concentration (mg/L)	ND	ND	ND	27	5.3	ND	0.43	
			Standard Deviation (mmoles)	0.0E+00	0.0E+00	0.0E+00	1.1E-02	1.4E-02	0.0E+00	2.9E-03	
			Average Total mmoles	**ND**	**ND**	**ND**	**0.045**	**0.013**	**ND**	**0.02**	
	26-May-20	49	LAC-1	<0.040	<0.0040	<0.040	12	4.2	<0.040	0.23	
			LAC-2	<0.040	<0.0040	<0.040	30	0.26	<0.040	0.42	
			LAC-3	<0.040	<0.0040	<0.040	15	11	<0.040	0.43	
			Average Concentration (mg/L)	ND	ND	ND	19	5.1	ND	0.36	
			Standard Deviation (mmoles)	0.0E+00	0.0E+00	0.0E+00	1.6E-02	1.3E-02	0.0E+00	5.1E-03	
			Average Total mmoles	**ND**	**ND**	**ND**	**0.032**	**0.012**	**ND**	**0.017**	
	12-Jun-20	66	LAC-1	<0.040	<0.0040	<0.040	17	9.8	<0.040	0.32	
			LAC-2	<0.040	<0.0040	<0.040	31	0.71	<0.040	0.3	
			LAC-3	<0.040	<0.0040	<0.040	13	14	<0.040	0.36	
			Average Concentration (mg/L)	ND	ND	ND	20	8.2	ND	0.33	
			Standard Deviation (mmoles)	0.0E+00	0.0E+00	0.0E+00	1.6E-02	1.7E-02	0.0E+00	1.5E-03	
			Average Total mmoles	**ND**	**ND**	**ND**	**0.034**	**0.02**	**ND**	**0.015**	
	14-Jul-20	98									Amended with 39 µL to target 117 mg/L lactate.
	15-Jul-20	99	LAC-1	<0.040	<0.0040	<0.040	13	13	<0.040	0.30	
			LAC-2	<0.040	<0.0040	<0.040	28	3.1	<0.040	0.33	
			LAC-3	<0.040	<0.0040	<0.040	7.6	18	<0.040	0.39	
			Average Concentration (mg/L)	ND	ND	ND	16	12	ND	0.34	
			Standard Deviation (mmoles)	0.0E+00	0.0E+00	0.0E+00	1.8E-02	1.9E-02	0.0E+00	2.0E-03	
			Average Total mmoles	**ND**	**ND**	**ND**	**0.028**	**0.028**	**ND**	**0.016**	

TABLE 2: SUMMARY OF MICROCOSM cVOC AND DHG RESULTS SiREM
Deep Zone of Upper Surficial Aquifer - Brunswick, GA

Treatment	Date	Day	Replicate	DHGs			Chlorinated Methanes and Methane				Comment
				Ethene	Acetylene	Ethane	CF	DCM	CM	Methane	
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	
Lactate Amended Continued	04-Aug-20	119	LAC-1	<0.040	<0.0040	<0.040	0.36	23	<0.040	0.31	
			LAC-2	<0.040	<0.0040	<0.040	11	15	<0.040	0.32	
			LAC-3	<0.040	<0.0040	<0.040	0.59	24	<0.040	0.36	
			Average Concentration (mg/L)	ND	ND	ND	4.1	21	ND	0.33	
			Standard Deviation (mmoles)	0.0E+00	0.0E+00	0.0E+00	1.1E-02	1.2E-02	0.0E+00	1.4E-03	
			Average Total mmoles	**ND**	**ND**	**ND**	**0.0069**	**0.051**	**ND**	**0.015**	
	18-Aug-20	133	LAC-1	<0.040	<0.0040	<0.040	0.063	23	<0.040	0.30	
			LAC-2	<0.040	<0.0040	<0.040	7.2	18	<0.040	0.32	
			LAC-3	<0.040	<0.0040	<0.040	<0.040	25	<0.040	0.35	
			Average Concentration (mg/L)	ND	ND	ND	2.4	22	ND	0.32	
			Standard Deviation (mmoles)	0.0E+00	0.0E+00	0.0E+00	7.0E-03	8.7E-03	0.0E+00	1.2E-03	
			Average Total mmoles	**ND**	**ND**	**ND**	**0.0041**	**0.054**	**ND**	**0.015**	
	01-Sep-20	147	LAC-1	<0.040	<0.0040	<0.040	<0.040	23	<0.040	0.29	
			LAC-2	<0.040	<0.0040	<0.040	2.7	21	<0.040	0.27	
			LAC-3	<0.040	<0.0040	<0.040	<0.040	25	0.047	0.33	
			Average Concentration (mg/L)	ND	ND	ND	0.9	23	0.016	0.3	
			Standard Deviation (mmoles)	0.0E+00	0.0E+00	0.0E+00	2.7E-03	4.1E-03	1.1E-04	1.4E-03	
			Average Total mmoles	**ND**	**ND**	**ND**	**0.0015**	**0.056**	**0.000062**	**0.014**	
Lactate Amended/KB-1® Bioaugmented	27-Mar-20	-11									Amended the first replicate with 100 µL resazurin.
	07-Apr-20	0									Amended with 39 µL to target 117 mg/L lactate.
			LAC+BIO-1	<0.040	<0.0040	<0.040	30	<0.040	<0.040	0.38	
			LAC+BIO-2	<0.040	<0.0040	<0.040	29	<0.040	<0.040	0.35	
			LAC+BIO-3	<0.040	<0.0040	<0.040	29	<0.040	<0.040	0.41	
			Average Concentration (mg/L)	ND	ND	ND	29	ND	ND	0.38	
			Standard Deviation (mmoles)	0.0E+00	0.0E+00	0.0E+00	5.6E-04	0.0E+00	0.0E+00	1.2E-03	
			Average Total mmoles	**ND**	**ND**	**ND**	**0.05**	**ND**	**ND**	**0.018**	
	27-Apr-20	20	LAC+BIO-1	<0.040	<0.0040	<0.040	31	0.16	<0.040	0.37	
			LAC+BIO-2	<0.040	<0.0040	<0.040	30	0.21	<0.040	0.39	
			LAC+BIO-3	<0.040	<0.0040	<0.040	31	0.13	<0.040	0.42	
			Average Concentration (mg/L)	ND	ND	ND	31	0.17	ND	0.39	
			Standard Deviation (mmoles)	0.0E+00	0.0E+00	0.0E+00	7.3E-04	9.0E-05	0.0E+00	1.1E-03	
			Average Total mmoles	**ND**	**ND**	**ND**	**0.052**	**0.00041**	**ND**	**0.018**	
	12-May-20	35									Bioaugmented with KB-1® Plus.
			LAC+BIO-1	<0.040	<0.0040	<0.040	38	0.23	<0.040	0.40	
			LAC+BIO-2	<0.040	<0.0040	<0.040	30	4.4	<0.040	0.42	
			LAC+BIO-3	<0.040	<0.0040	<0.040	32	2.4	<0.040	0.47	
			Average Concentration (mg/L)	ND	ND	ND	33	2.4	ND	0.43	
			Standard Deviation (mmoles)	0.0E+00	0.0E+00	0.0E+00	6.9E-03	5.2E-03	0.0E+00	1.5E-03	
			Average Total mmoles	**ND**	**ND**	**ND**	**0.057**	**0.0057**	**ND**	**0.02**	
	26-May-20	49	LAC+BIO-1	<0.040	<0.0040	<0.040	29	0.24	<0.040	0.36	
			LAC+BIO-2	<0.040	<0.0040	<0.040	19	7.9	<0.040	0.35	
			LAC+BIO-3	<0.040	<0.0040	<0.040	24	4.2	<0.040	0.41	
			Average Concentration (mg/L)	ND	ND	ND	24	4.1	ND	0.37	
			Standard Deviation (mmoles)	0.0E+00	0.0E+00	0.0E+00	8.6E-03	9.4E-03	0.0E+00	1.6E-03	
			Average Total mmoles	**ND**	**ND**	**ND**	**0.041**	**0.01**	**ND**	**0.017**	

TABLE 2: SUMMARY OF MICROCOSM cVOC AND DHG RESULTS SiREM
Deep Zone of Upper Surficial Aquifer - Brunswick, GA

Treatment	Date	Day	Replicate	DHGs			Chlorinated Methanes and Methane				Comment
				Ethene	Acetylene	Ethane	CF	DCM	CM	Methane	
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	
Lactate Amended/KB-1® Bioaugmented Continued	12-Jun-20	66	LAC+BIO-1	<0.040	<0.0040	<0.040	31	0.32	<0.040	0.26	
			LAC+BIO-2	<0.040	<0.0040	<0.040	13	12	<0.040	0.30	
			LAC+BIO-3	<0.040	<0.0040	<0.040	21	6.8	<0.040	0.37	
			Average Concentration (mg/L)	ND	ND	ND	22	6.4	ND	0.31	
			Standard Deviation (mmoles)	0.0E+00	0.0E+00	0.0E+00	1.6E-02	1.4E-02	0.0E+00	2.6E-03	
			Average Total mmoles	**ND**	**ND**	**ND**	**0.037**	**0.016**	**ND**	**0.014**	
	14-Jul-20	98									Amended with 39 µL to target 117 mg/L lactate.
	15-Jul-20	99	LAC+BIO-1	<0.040	<0.0040	<0.040	30	1.0	<0.040	0.28	
			LAC+BIO-2	<0.040	<0.0040	<0.040	0.20	17	<0.040	0.31	
			LAC+BIO-3	<0.040	<0.0040	<0.040	17	9.6	<0.040	0.37	
			Average Concentration (mg/L)	ND	ND	ND	16	9.2	ND	0.32	
			Standard Deviation (mmoles)	0.0E+00	0.0E+00	0.0E+00	2.5E-02	1.9E-02	0.0E+00	2.1E-03	
			Average Total mmoles	**ND**	**ND**	**ND**	**0.026**	**0.022**	**ND**	**0.015**	
											Bioaugmented replicate 1 with KB-1® Plus.
	04-Aug-20	119	LAC+BIO-1	<0.040	<0.0040	<0.040	<0.040	12	<0.040	0.37	
			LAC+BIO-2	<0.040	<0.0040	<0.040	<0.040	15	<0.040	0.40	
			LAC+BIO-3	<0.040	<0.0040	<0.040	1.8	19	<0.040	0.36	
			Average Concentration (mg/L)	ND	ND	ND	0.61	15	ND	0.37	
			Standard Deviation (mmoles)	0.0E+00	0.0E+00	0.0E+00	1.8E-03	8.6E-03	0.0E+00	1.0E-03	
			Average Total mmoles	**ND**	**ND**	**ND**	**0.0010**	**0.037**	**ND**	**0.017**	
	18-Aug-20	133	LAC+BIO-1	<0.040	<0.0040	<0.040	<0.040	0.18	<0.040	0.46	
			LAC+BIO-2	<0.040	<0.0040	<0.040	<0.040	13	<0.040	0.40	
			LAC+BIO-3	<0.040	<0.0040	<0.040	<0.040	17	<0.040	0.34	
			Average Concentration (mg/L)	ND	ND	ND	ND	10	ND	0.40	
			Standard Deviation (mmoles)	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.2E-02	0.0E+00	2.7E-03	
			Average Total mmoles	**ND**	**ND**	**ND**	**ND**	**0.024**	**ND**	**0.018**	
	01-Sep-20	147	LAC+BIO-1	<0.040	<0.0040	<0.040	<0.040	0.041	<0.040	0.41	
			LAC+BIO-2	<0.040	<0.0040	<0.040	<0.040	9.2	0.046	0.52	
			LAC+BIO-3	<0.040	<0.0040	<0.040	<0.040	15	0.048	0.43	
			Average Concentration (mg/L)	ND	ND	ND	ND	8.2	0.031	0.46	
			Standard Deviation (mmoles)	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.9E-02	1.1E-04	2.8E-03	
			Average Total mmoles	**ND**	**ND**	**ND**	**ND**	**0.02**	**0.00013**	**0.021**	
	18-Sep-20	164	LAC+BIO-1	0.35	<0.0040	<0.040	<0.040	<0.040	<0.040	0.47	
			LAC+BIO-2	<0.040	<0.0040	<0.040	<0.040	1.5	0.043	0.47	
			LAC+BIO-3	<0.040	<0.0040	<0.040	<0.040	7.3	0.053	0.41	
			Average Concentration (mg/L)	0.12	ND	ND	ND	3	0.032	0.45	
			Standard Deviation (mmoles)	2.6E-03	0.0E+00	0.0E+00	0.0E+00	9.4E-03	1.1E-04	1.7E-03	
			Average Total mmoles	**0.0015**	**ND**	**ND**	**ND**	**0.0072**	**0.00013**	**0.021**	

Notes:

< - compound not detected, the associated value is the detection limit
-- - not applicable
µL - microliter
CF- chloroform
CM - chloromethane
DCM - dichloromethane
DHG - dissolved hydrocarbon gases
mg/L - milligrams per liter
mL - milliliters

TABLE 3: SUMMARY OF MICROCOSM ANION RESULTS

Deep Zone of Upper Surficial Aquifer - Brunswick, GA

SiREM

Treatment	Date	Day	Replicate	Total VFAs	Chloride	Nitrite-N	Nitrate-N	Sulfate	Phosphate
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Anaerobic Sterile Control	7-Apr-20	0	ANSC-1	<0.07	1,823	<0.09	<0.09	58	<0.07
			ANSC-2	<0.07	1,891	<0.09	<0.09	43	<0.07
			ANSC-3	<0.07	1,814	<0.09	<0.09	50	<0.07
			Average	ND	1,843	ND	ND	50	ND
	27-Apr-20	20	ANSC-1	<0.07	2,310	<0.09	<0.09	63	<0.07
			ANSC-2	<0.07	1,956	<0.09	<0.09	38	<0.07
			ANSC-3	<0.07	2,035	<0.09	<0.09	43	<0.07
			Average	ND	2,100	ND	ND	48	ND
	12-May-20	35	ANSC-1	<0.07	2,380	<0.09	<0.09	68	<0.07
			ANSC-2	<0.07	2,142	<0.09	<0.09	44	<0.07
			ANSC-3	<0.07	2,313	<0.09	<0.09	60	<0.07
			Average	ND	2,279	ND	ND	57	ND
	26-May-20	49	ANSC-1	<0.07	2,367	<0.09	<0.09	60	<0.07
			ANSC-2	<0.07	2,147	<0.09	<0.09	35	<0.07
			ANSC-3	<0.07	2,268	<0.09	<0.09	43	1
			Average	ND	2,261	ND	ND	46	ND
	7-Jul-20	91	ANSC-1	8.0	2,640	<0.09	<0.09	80	<0.07
			ANSC-2	<0.07	2,188	<0.09	<0.09	44	<0.07
			ANSC-3	<0.07	2,299	<0.09	<0.09	66	<0.07
			Average	2.7	2,376	ND	ND	63	ND
Anaerobic Active Control	7-Apr-20	0	ANAC-1	<0.07	1,867	<0.09	<0.09	30	<0.07
			ANAC-2	<0.07	1,977	<0.09	<0.09	45	<0.07
			ANAC-3	<0.07	1,899	<0.09	<0.09	34	<0.07
			Average	ND	1,914	ND	ND	37	ND
	27-Apr-20	20	ANAC-1	<0.07	2,435	<0.09	<0.09	33	<0.07
			ANAC-2	9.2	2,243	<0.09	<0.09	50	<0.07
			ANAC-3	<0.07	2,276	<0.09	<0.09	32	<0.07
			Average	3.1	2,318	ND	ND	38	ND
	12-May-20	35	ANAC-1	<0.07	2,224	<0.09	<0.09	31	<0.07
			ANAC-2	<0.07	2,300	<0.09	<0.09	44	<0.07
			ANAC-3	<0.07	2,207	<0.09	<0.09	32	<0.07
			Average	ND	2,244	ND	ND	36	ND
	26-May-20	49	ANAC-1	<0.07	2,146	<0.09	<0.09	28	<0.07
			ANAC-2	<0.07	2,193	<0.09	<0.09	36	<0.07
			ANAC-3	<0.07	2,212	<0.09	<0.09	31	<0.07
			Average	ND	2,184	ND	ND	32	ND
	7-Jul-20	91	ANAC-1	<0.07	2,671	<0.09	<0.09	53	<0.07
			ANAC-2	<0.07	2,517	<0.09	<0.09	78	<0.07
			ANAC-3	<0.07	2,312	<0.09	<0.09	51	<0.07
			Average	ND	2,500	ND	ND	61	ND
Lactate Amended	7-Apr-20	0	LAC-1	141	1,903	<0.09	<0.09	29	<0.07
			LAC-2	230	1,782	<0.09	<0.09	52	<0.07
			LAC-3	693	1,827	<0.09	<0.09	35	<0.07
			Average	355	1,837	ND	ND	38	ND
	27-Apr-20	20	LAC-1	95	2,337	<0.09	<0.09	<0.07	<0.07
			LAC-2	94	2,267	<0.09	<0.09	14	<0.07
			LAC-3	114	2,228	<0.09	<0.09	<0.07	<0.07
			Average	101	2,277	ND	ND	4.6	ND
	12-May-20	35	LAC-1	90	2,208	<0.09	<0.09	<0.07	<0.07
			LAC-2	92	2,268	<0.09	<0.09	14	<0.07
			LAC-3	90	2,249	<0.09	<0.09	<0.07	<0.07
			Average	91	2,242	ND	ND	4.7	ND
	26-May-20	49	LAC-1	92	2,218	<0.09	<0.09	<0.07	<0.07
			LAC-2	86	2,316	<0.09	<0.09	4.6	<0.07
			LAC-3	87	2,189	<0.09	<0.09	<0.07	<0.07
			Average	88	2,241	ND	ND	1.5	ND
	7-Jul-20	91	LAC-1	81	2,154	<0.09	<0.09	<0.07	<0.07
			LAC-2	73	2,215	<0.09	<0.09	<0.07	<0.07
			LAC-3	77	2,000	<0.09	<0.09	<0.07	<0.07
			Average	77	2,123	ND	ND	ND	ND

TABLE 3: SUMMARY OF MICROCOSM ANION RESULTS

Deep Zone of Upper Surficial Aquifer - Brunswick, GA

Lactate Amended/KB-1 Plus Bioaugmented	7-Apr-20	0	LAC+BIO-1	177	1,895	<0.09	<0.09	52	<0.07
			LAC+BIO-2	203	1,804	<0.09	<0.09	34	<0.07
			LAC+BIO-3	250	1,799	<0.09	<0.09	37	<0.07
			Average	**210**	**1,833**	ND	ND	**41**	ND
	27-Apr-20	20	LAC+BIO-1	97	2,739	<0.09	<0.09	12	<0.07
			LAC+BIO-2	88	2,060	<0.09	<0.09	<0.07	<0.07
			LAC+BIO-3	101	2,744	<0.09	<0.09	<0.07	<0.07
			Average	**96**	**2,514**	ND	ND	**3.9**	ND
	12-May-20	35	LAC+BIO-1	93	2,273	<0.09	<0.09	17	<0.07
			LAC+BIO-2	96	2,287	<0.09	<0.09	<0.07	<0.07
			LAC+BIO-3	95	2,358	<0.09	<0.09	6.3	<0.07
			Average	**95**	**2,306**	ND	ND	**7.6**	ND
	26-May-20	49	LAC+BIO-1	109	2,614	<0.09	<0.09	19	<0.07
			LAC+BIO-2	102	2,346	<0.09	<0.09	1.5	<0.07
			LAC+BIO-3	84	2,155	<0.09	<0.09	0.92	<0.07
			Average	**98**	**2,372**	ND	ND	**7.0**	ND
	7-Jul-20	91	LAC+BIO-1	70	2,208	<0.09	<0.09	<0.07	<0.07
			LAC+BIO-2	76	1,848	<0.09	<0.09	<0.07	<0.07
			LAC+BIO-3	94	2,532	<0.09	<0.09	<0.07	<0.07
			Average	**80**	**2,196**	ND	ND	ND	ND

Notes:

< - compound not detected, the associated value is the detection limit

mg/L - milligrams per liter

Nitrate-N - nitrate-nitrogen

Nitrite-N - nitrite-nitrogen

VFAs - total volatile fatty acids, calibrated as lactate but may include other VFAs such as formate, acetate, propionate, pyruvate and butyrate

TABLE 4: SUMMARY OF MICROCOSM VFA RESULTS SiREM

Deep Zone of Upper Surficial Aquifer - Brunswick, GA

Treatment	Date	Day	Microcosm	Replicate	Lactate	Acetate	Propionate	Formate	Butyrate	Pyruvate
					mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Lactate Amended	7-Apr-20	0	7	LAC-1	154	<0.54	<0.31	<0.22	<0.41	<0.69
			8	LAC-2	253	<0.54	<0.31	<0.22	<0.41	<0.69
			9	LAC-3	839	<0.54	<0.31	<0.22	<0.41	<0.69
				Average Concentration (mg/L)	**415**	**ND**	**ND**	**ND**	**ND**	**ND**
	12-May-20	35	7	LAC-1	<0.39	87	<0.31	<0.22	<0.41	<0.69
			8	LAC-2	<0.39	94	<0.31	<0.22	<0.41	<0.69
			9	LAC-3	<0.39	86	<0.31	<0.22	<0.41	<0.69
				Average Concentration (mg/L)	**ND**	**89**	**ND**	**ND**	**ND**	**ND**
	12-Jun-20	66	7	LAC-1	<0.39	95	14	<0.22	<0.41	<0.69
			8	LAC-2	<0.39	85	<0.31	<0.22	<0.41	<0.69
			9	LAC-3	<0.39	91	12	<0.22	<0.41	<0.69
				Average Concentration (mg/L)	**ND**	**90**	**8.7**	**ND**	**ND**	**ND**
Lactate Amended/KB-1® Bioaugmented	7-Apr-20	0	10	LAC+BIO-1	196	<0.54	<0.31	<0.22	<0.41	<0.69
			11	LAC+BIO-2	274	<0.54	<0.31	<0.22	<0.41	<0.69
			12	LAC+BIO-3	307	<0.54	<0.31	<0.22	<0.41	<0.69
				Average Concentration (mg/L)	**259**	**ND**	**ND**	**ND**	**ND**	**ND**
	12-May-20	35	10	LAC+BIO-1	<0.39	103	<0.31	<0.22	<0.41	<0.69
			11	LAC+BIO-2	<0.39	93	<0.31	<0.22	<0.41	<0.69
			12	LAC+BIO-3	<0.39	89	<0.31	<0.22	<0.41	<0.69
				Average Concentration (mg/L)	**ND**	**95**	**ND**	**ND**	**ND**	**ND**
	12-Jun-20	66	10	LAC+BIO-1	<0.39	102	<0.31	<0.22	<0.41	<0.69
			11	LAC+BIO-2	<0.39	97	13	<0.22	<0.41	<0.69
			12	LAC+BIO-3	<0.39	100	1.3	<0.22	<0.41	<0.69
				Average Concentration (mg/L)	**ND**	**100**	**4.8**	**ND**	**ND**	**ND**

Notes:

< - compound not detected, the associated value is the detection limi

ND - not detected

mg/L - milligrams per liter

TABLE 5: SUMMARY OF MICROCOSM pH RESULTS
Deep Zone of Upper Surficial Aquifer - Brunswick, GA

Treatment	Date	Day	Replicate	pH
Anaerobic Sterile Control	7-Apr-20	0	ANSC-1	6.00
			ANSC-2	6.08
			ANSC-3	6.07
			Average	**6.05**
	27-Apr-20	20	ANSC-1	5.79
			ANSC-2	5.89
			ANSC-3	5.91
			Average	**5.86**
	12-May-20	35	ANSC-1	6.42
			ANSC-2	6.39
			ANSC-3	6.39
			Average	**6.40**
	26-May-20	49	ANSC-1	6.37
			ANSC-2	6.36
			ANSC-3	6.32
			Average	**6.35**
	12-Jun-20	66	ANSC-1	6.13
			ANSC-2	6.13
			ANSC-3	6.16
			Average	**6.14**
	7-Jul-20	91	ANSC-1	6.39
			ANSC-2	6.43
			ANSC-3	6.39
			Average	**6.40**
	4-Aug-20	119	ANSC-1	6.34
			ANSC-2	6.35
			ANSC-3	6.31
			Average	**6.33**
	18-Aug-20	133	ANSC-1	6.34
			ANSC-2	6.33
			ANSC-3	6.32
			Average	**6.33**
	1-Sep-20	147	ANSC-1	6.30
			ANSC-2	6.29
			ANSC-3	6.25
			Average	**6.28**
Anaerobic Active Control	7-Apr-20	0	ANAC-1	6.15
			ANAC-2	6.13
			ANAC-3	6.16
			Average	**6.15**
	27-Apr-20	20	ANAC-1	6.11
			ANAC-2	6.10
			ANAC-3	6.10
			Average	**6.10**
	12-May-20	35	ANAC-1	6.58
			ANAC-2	6.55
			ANAC-3	6.56
			Average	**6.56**
	26-May-20	49	ANAC-1	6.49
			ANAC-2	6.49
			ANAC-3	6.48
			Average	**6.49**
	12-Jun-20	66	ANAC-1	6.41
			ANAC-2	6.37
			ANAC-3	6.36
			Average	**6.38**
	7-Jul-20	91	ANAC-1	6.61
			ANAC-2	6.72
			ANAC-3	6.64
			Average	**6.66**
	4-Aug-20	119	ANAC-1	6.56
			ANAC-2	6.43
			ANAC-3	6.57
			Average	**6.52**
	18-Aug-20	133	ANAC-1	6.55
			ANAC-2	6.48
			ANAC-3	6.54
			Average	**6.52**
	1-Sep-20	147	ANAC-1	6.43
			ANAC-2	6.47
			ANAC-3	6.50
			Average	**6.47**
Lactate Amended	7-Apr-20	0	LAC-1	6.18
			LAC-2	6.14
			LAC-3	6.13
			Average	**6.15**
	27-Apr-20	20	LAC-1	6.16
			LAC-2	6.16
			LAC-3	6.17
			Average	**6.16**
	12-May-20	35	LAC-1	6.61
			LAC-2	6.68
			LAC-3	6.69
			Average	**6.66**
	26-May-20	49	LAC-1	6.50
			LAC-2	6.55
			LAC-3	6.52
			Average	**6.52**
	12-Jun-20	66	LAC-1	6.31
			LAC-2	6.35
			LAC-3	6.33
			Average	**6.33**
	7-Jul-20	91	LAC-1	6.59
			LAC-2	6.65
			LAC-3	6.63
			Average	**6.62**

TABLE 5: SUMMARY OF MICROCOSM pH RESULTS
Deep Zone of Upper Surficial Aquifer - Brunswick, GA

Treatment	Date	Day	Replicate	pH
Lactate Amended Continued	4-Aug-20	119	LAC-1	6.50
			LAC-2	6.49
			LAC-3	6.49
			Average	**6.49**
	18-Aug-20	133	LAC-1	6.48
			LAC-2	6.52
			LAC-3	6.52
			Average	**6.51**
	1-Sep-20	147	LAC-1	6.44
			LAC-2	6.46
			LAC-3	6.43
			Average	**6.44**
Lactate Amended/KB-1® Bioaugmented	7-Apr-20	0	LAC+BIO-1	6.11
			LAC+BIO-2	6.15
			LAC+BIO-3	6.15
			Average	**6.14**
	27-Apr-20	20	LAC+BIO-1	6.15
			LAC+BIO-2	6.16
			LAC+BIO-3	6.14
			Average	**6.15**
	12-May-20	35	LAC+BIO-1	6.59
			LAC+BIO-2	6.60
			LAC+BIO-3	6.61
			Average	**6.60**
	26-May-20	49	LAC+BIO-1	6.52
			LAC+BIO-2	6.52
			LAC+BIO-3	6.52
			Average	**6.52**
	12-Jun-20	66	LAC+BIO-1	6.33
			LAC+BIO-2	6.33
			LAC+BIO-3	6.36
			Average	**6.34**
	7-Jul-20	91	LAC+BIO-1	6.60
			LAC+BIO-2	6.53
			LAC+BIO-3	6.61
			Average	**6.58**
	4-Aug-20	119	LAC+BIO-1	6.45
			LAC+BIO-2	6.44
			LAC+BIO-3	6.50
			Average	**6.46**
	18-Aug-20	133	LAC+BIO-1	6.45
			LAC+BIO-2	6.44
			LAC+BIO-3	6.49
			Average	**6.46**
	1-Sep-20	147	LAC+BIO-1	6.30
			LAC+BIO-2	6.39
			LAC+BIO-3	6.42
			Average	**6.37**

Notes:

TABLE 6: SUMMARY OF MICROCOSM GENE-TRAC® RESULTS SiREM

Deep Zone of Upper Surficial Aquifer - Brunswick, GA

Treatment	Date	Day	*Dhb*	cfrA
			gene copies/L	gene copies/L
Baseline - MW-28D Groundwater	30-Mar-20	Baseline	1×10^6	2×10^7
Lactate Amended	26-May-20	49	7×10^7	1×10^7
	25-Aug-20	140	2×10^8	3×10^6
Lactate Amended/KB-1® Plus Bioaugmented	12-May-20	35	Bioaugmented with KB-1® Plus	
	26-May-20	49	2×10^8	4×10^6
	15-Jul-20	99	Bioaugmented Replicate 1 with KB-1® Plus	
	25-Aug-20	140	9×10^8	8×10^6

Notes:

cfrA - chloroform reductase

Dhb - *Dehalobacter*

gene copies/L - gene copies per liter

TABLE 7: HALF-LIVES (DAYS) OF CHLORINATED METHANES DETECTED IN MICROCOSMS

SiREM

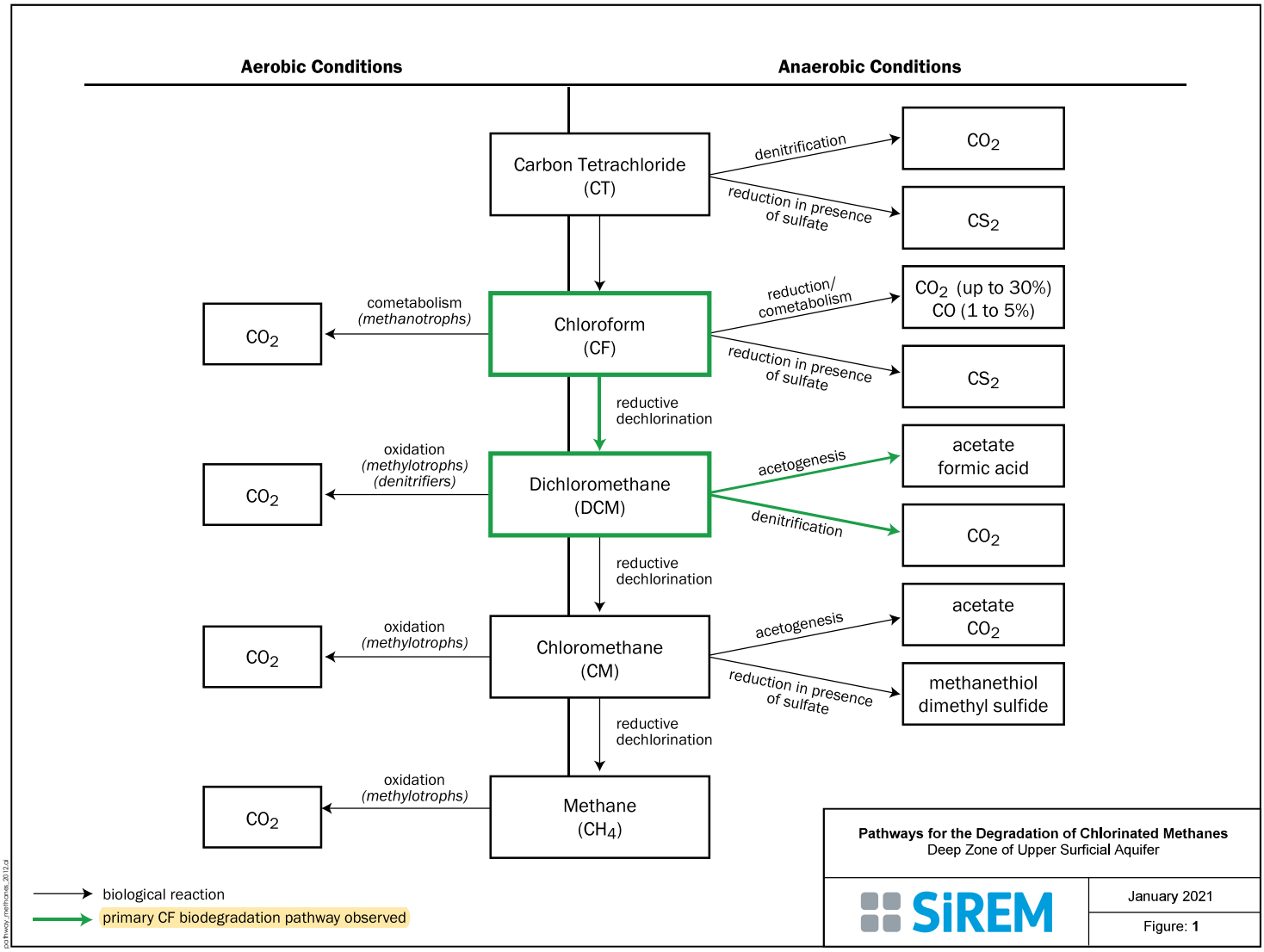
Deep Zone of Upper Surficial Aquifer - Brunswick, GA

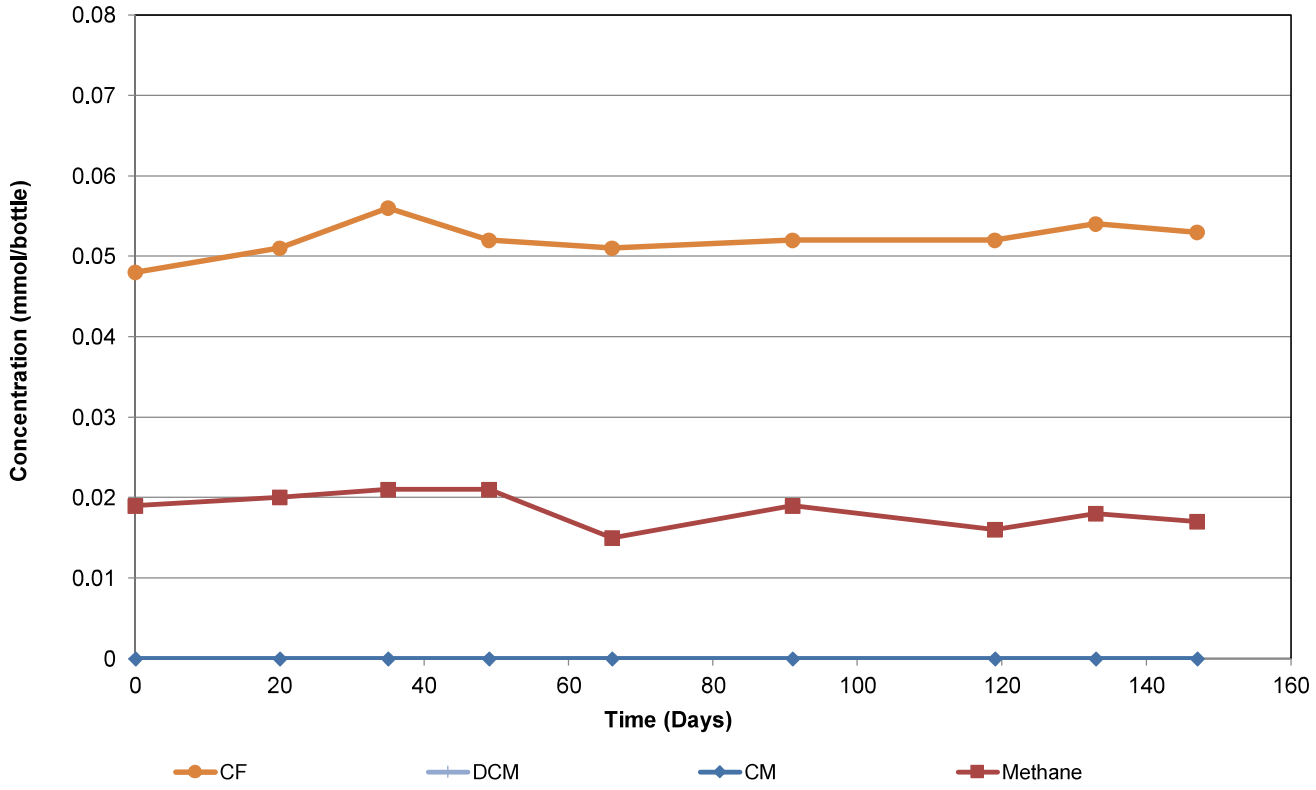
Treatment/Control	CF			DCM			CM		
	Half Life (Days)	T_1 (Day)	T_2 (Days)	**Half Life (Days)**	T_1 (Day)	T_2 (Days)	**Half Life (Days)**	T_1 (Day)	T_2 (Days)
Anaerobic Sterile Control	~	--	--	~	--	--	~	--	--
Anaerobic Active Control	~	--	--	~	--	--	~	--	--
Lactate Amended	**18**	20	164	~	--	--	~	--	--
Lactate Amended/KB-1® Bioaugmented	**9.2***	35	133	**19***	119	164	~	--	--
Lactate Amended/KB-1® Bioaugmented Replicate 1	**2.6***	91	119	**4.9***	119	164	~	--	--
Lactate Amended/KB-1® Bioaugmented Replicate 2	**8.0***	35	119	**21***	91	164	~	--	--
Lactate Amended/KB-1® Bioaugmented Replicate 3	**9.2***	35	133	**33***	119	164	~	--	--

Notes:

* half lives determined after the addition of KB-1® Plus
~ - net degradation of compound was not detected over duration of study
CF - chloroform
CM - chloromethane
DCM - dichloromethane

FIGURES


Aerobic Conditions
Anaerobic Conditions
Carbon Tetrachloride (CT)
denitrification
reduction in presence of sulfate
CO_2
CS_2
Chloroform (CF)
cometabolism (methanotrophs)
CO_2
reduction/ cometabolism
CO_2 (up to 30%) CO (1 to 5%)
reduction in presence of sulfate
CS_2
reductive dechlorination
Dichloromethane (DCM)
oxidation (methylotrophs) (denitrifiers)
CO_2
acetogenesis
acetate formic acid
denitrification
CO_2
reductive dechlorination
Chloromethane (CM)
oxidation (methylotrophs)
CO_2
acetogenesis
acetate CO_2
reduction in presence of sulfate
methanethiol dimethyl sulfide
reductive dechlorination
Methane (CH_4)
oxidation (methylotrophs)
CO_2
biological reaction
primary CF biodegradation pathway observed
Pathways for the Degradation of Chlorinated Methanes
Deep Zone of Upper Surficial Aquifer
SiREM
January 2021
Figure: 1



Notes:

CF - chloroform
CM - chloromethane
DCM - dichloromethane
mmoles/bottle - millimoles per bottle

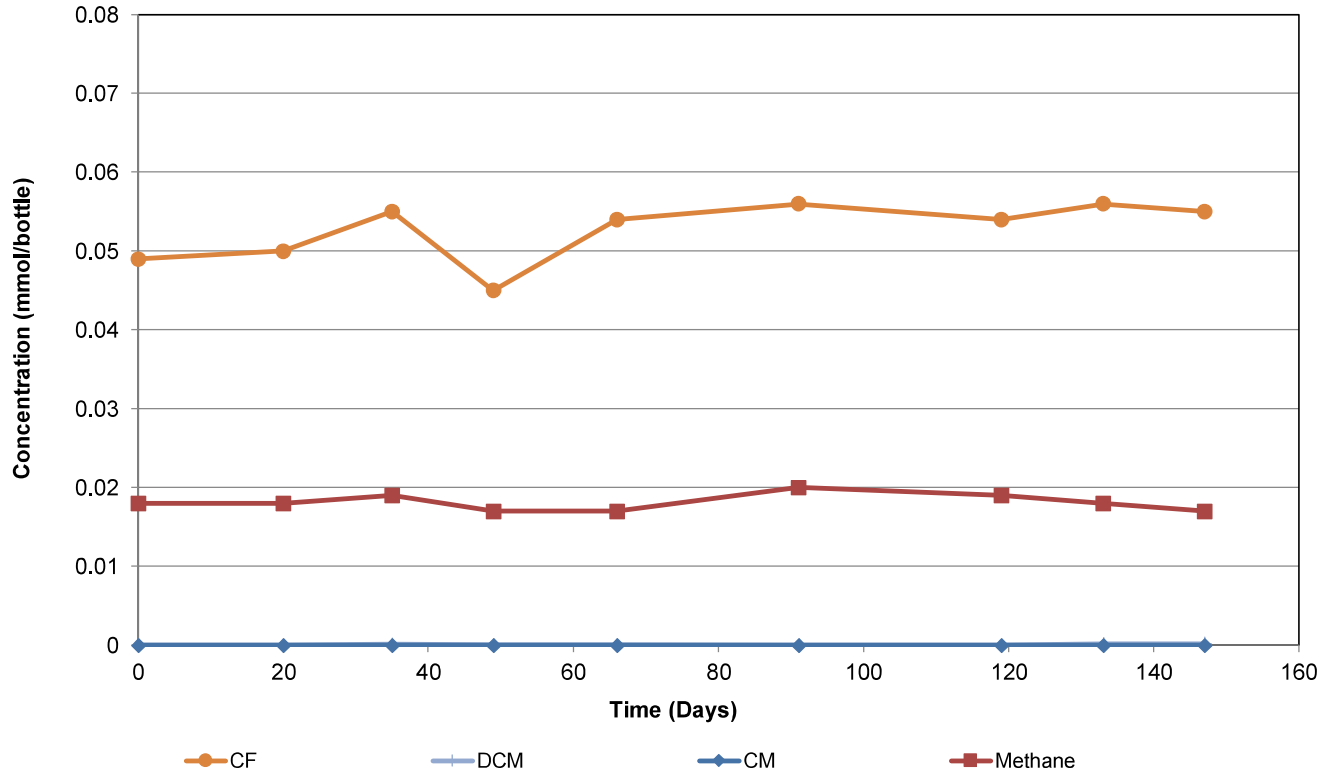
Chlorinated Methane and Methane Concentration Trends in Sterile Control Microcosms

Deep Zone of Upper Surficial Aquifer - Brunswick, GA

SiREM

January 2021

Figure: **2**



Notes:

CF - chloroform
CM - chloromethane
DCM - dichloromethane
mmoles/bottle - millimoles per bottle

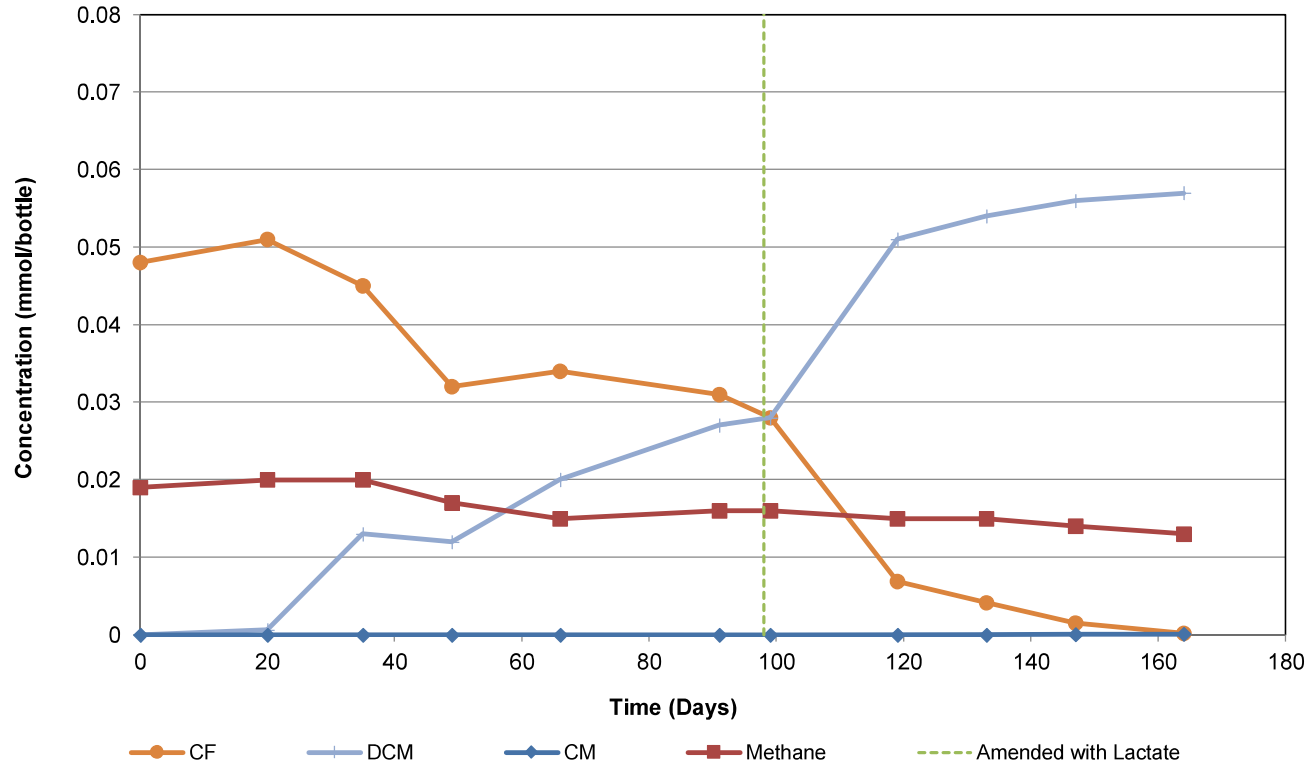
Chlorinated Methane and Methane Concentration Trends in Active Control Microcosms

Deep Zone of Upper Surficial Aquifer - Brunswick, GA

SiREM

January 2021

Figure: **3**



Notes:

CF - chloroform
CM - chloromethane
DCM - dichloromethane
mmoles/bottle - millimoles per bottle

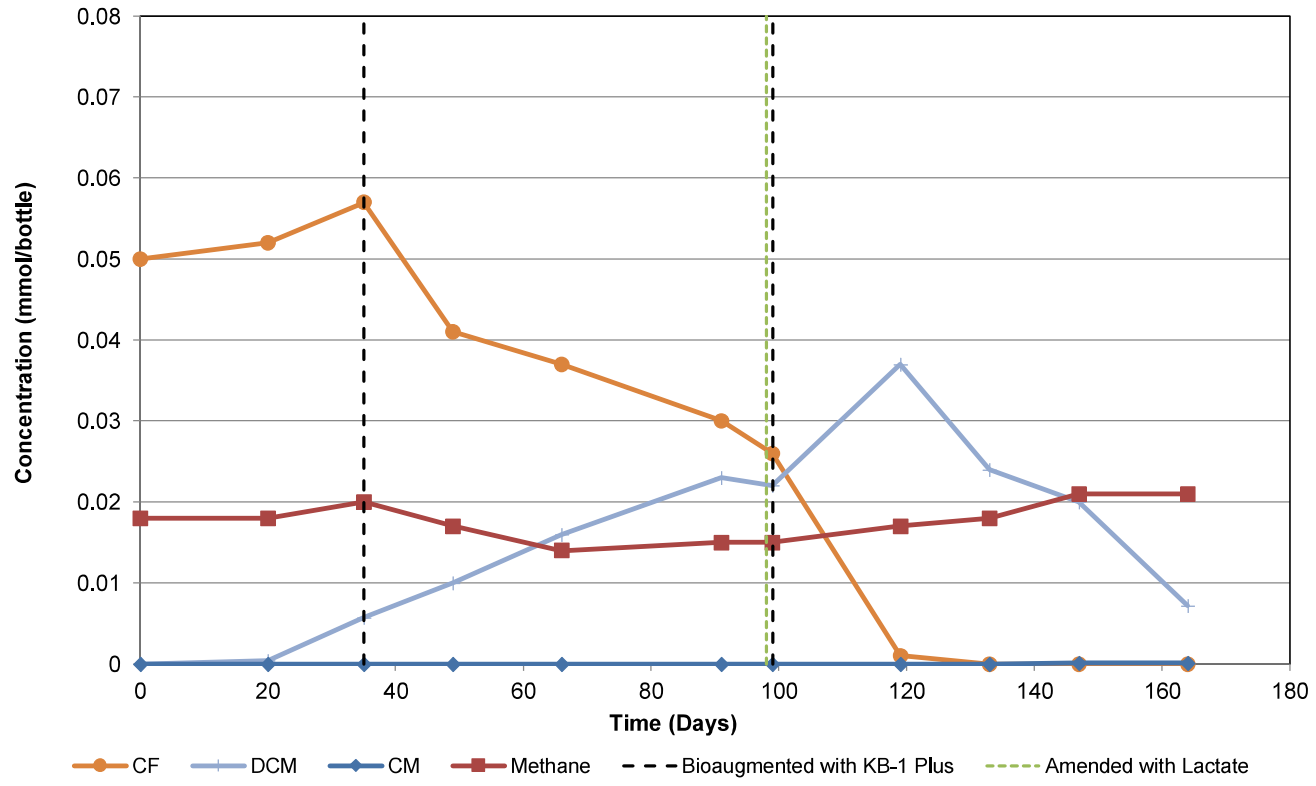
Chlorinated Methane and Methane Concentration Trends in Lactate Amended Microcosms

Deep Zone of Upper Surficial Aquifer - Brunswick, GA

SiREM

January 2021

Figure: **4**



Notes:

Day 99 bioaugmentation to Replicate 1 only
CF - chloroform
CM - chloromethane
DCM - dichloromethane
mmoles/bottle - millimoles per bottle

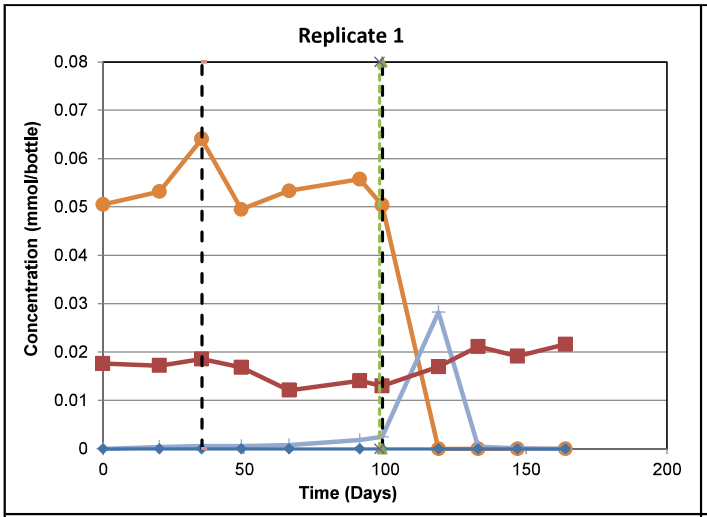
Chlorinated Methane and Methane Concentration Trends in Lactate Amended/KB-1 Plus Bioaugmented Microcosms

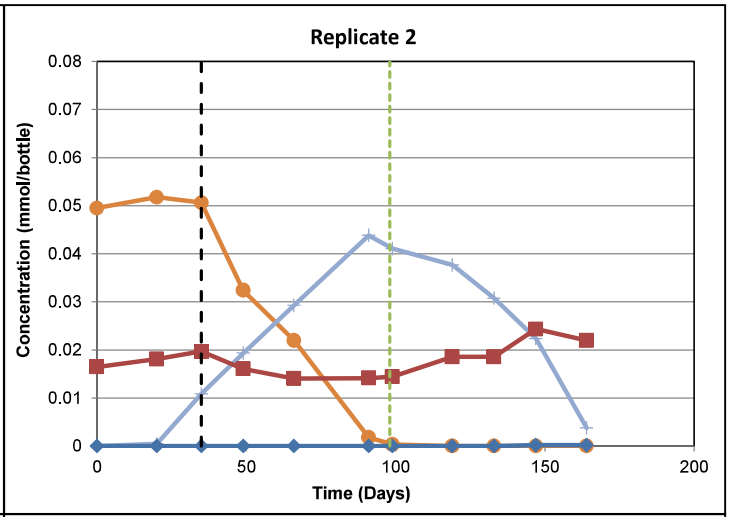
Deep Zone of Upper Surficial Aquifer - Brunswick, GA

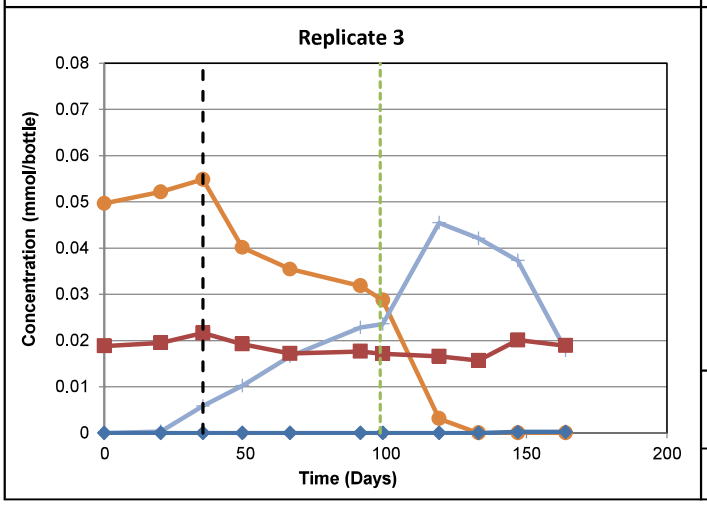
SiREM

January 2021

Figure: **5**







Legend:

CF — DCM — CM — Methane

- - - Bioaugmented with KB-1 Plus

---- Amended with Lactate

Notes:

CF - chloroform
CM - chloromethane
DCM - dichloromethane
CM - chloromethane
mmoles/bottle - millimoles per bottle

Chlorinated Methane and Methane Concentration Trends in Lactate Amended/KB-1 Plus Bioaugmented Microcosms by Individual Replicate

Deep Zone of Upper Surficial Aquifer - Brunswick, GA

January 2021 | Figure: 6 | SiREM

APPENDIX A: Chain of Custody Documentation

SiREM

Chain-of-Custody Form

siremlab.com

130 Stone Rd. W
Guelph, ON N1G 3Z2
(519) 822-2265

Lab # S-5735

*Project Name: Brunswick Hercules/Pinova	*Project #: GR6381
*Project Manager: Adrian Reimer	*Company: Geosyntec
*Email Address: areimer@geosyntec.com	
Address (Street): 1255 Roberts Boulevard	
City: Kennesaw	State/Province: GA
Country: USA	
*Phone #: +1 470-367-7557	
*Sampler's Signature	*Sampler's Printed Name

Analysis

Preservative Key: O

0. None
1. HCL
2. Other
3. Other
4. Other
5. Other
6. Other

Client Sample ID	Sampling Date	Sampling Time	Matrix	# of Containers	Gene-Trac DHC	Gene-Trac FGA (vcrA, bvcA, tceA)	Gene-Trac DHB	Gene-Trac DHG	Gene-Trac SRB	Volatile Fatty Acids	Dissolved hydrocarbon gases	Treatability Study	Other Information
MW-28D*	2/28/20	1240	water	2								X	2 x 4L plastic bottles
MW-29D**			water	5								X	5 x 4L plastic bottles
													* MW28D: chloroform, Area and benzene (chlorobenzene)
													** As MW28D plus inhibition of nitrate mediated benzene remed.

Billing Information

P.O. #:

*Bill To:

Turnaround Time Requested

Normal ☐
Rush ☐

For Lab Use Only

Cooler Condition: Good

Cooler Temperature: 9°C

Custody Seals: Yes ☐ No ☑

For Lab Use Only

Proposal #: Si-4402-013120 / Si-4384-013020

Relinquished By:	Received By:	Relinquished By:	Received By:	Relinquished By:	Received By:
Signature: [signature]	Signature: [signature]	Signature: [signature]	Signature: [signature]	Signature:	Signature:
Printed Name: Christine Hug	Printed Name: Ben Weinmann	Printed Name: Ben Weinmann	Printed Name: Rachel Hallman	Printed Name:	Printed Name:
Firm: Geosyntec Cons.	Firm: Geosyntec Consultants	Firm: Geosyntec Consultants	Firm: SiREM	Firm:	Firm:
Date/Time: 2/28/2020 1300	Date/Time: 2/29/2020 1305	Date/Time: 3/2/20	Date/Time: 3/4/20 1430	Date/Time:	Date/Time:

Distribution: White - return to Originator; Yellow - Lab Copy; Pink - Retained by Client

* Mandatory Fields

Chain-of-Custody Form

Lab # S-5746

*Project Name: Brunswick Hercules/Pinova	*Project #: GRG881B
*Project Manager: Adria Reimer	*Company: Geosyntec
*Email Address: areimer@geosyntec.com	
Address (Street): 1255 Roberts Blvd	
City: Kennesaw	State/Province: GA	Country: USA
*Phone #: 678-202-9564	
*Sampler's Signature: Ben W	*Sampler's Printed Name: Ben Weinmann

Analysis

Preservative Key
0. None
1. HCL
2. Other ____
3. Other ____
4. Other ____
5. Other ____
6. Other ____

	Client Sample ID	Sampling Date	Sampling Time	Matrix	# of Containers	Gene-Trac DHC	Gene-Trac VC	Gene-Trac DHB	Gene-Trac DHG	Treatability Study	Other Information
1	ISB-01_MW28D_83-84	3/4/20	0945	S	1					X	
2	ISB01_MW28D_84-85	3/4/20	0950	S	1					X	
3	ISB-01_MW28D_85-86	3/4/20	0955	S	1					X	
4	ISB-01_MW28D-86-87	3/4/20	1000	S	1					X	
5	ISB-02_MW29D_78-80	3/4/20	1200	S	1					X	
6	ISB-02_MW29D_80-82	3/4/20	1205	S	1					X	
7	ISB-02_MW29D_84-86	3/4/20	1210	S	1					X	
8	ISB-02_MW29D_86-88	3/4/20	1215	S	1					X	
9	ISB-01_MW29D_89-90	3/4/20	1220	S	1					X	

Billing Information
P.O. #:
*Bill To:

Turnaround Time Requested
Normal ☐
Rush ☐

For Lab Use Only
Cooler Condition: Good
Cooler Temperature: 4°C
Custody Seals: Yes ☑ No ☐

For Lab Use Only
Proposal #: ____

Relinquished By:	Received By:	Relinquished By:	Received By:	Relinquished By:	Received By:
Signature: Ben W	Signature: Rachel Hallman	Signature:	Signature:	Signature:	Signature:
Printed Name: Ben Weinmann	Printed Name: Rachel Hallman	Printed Name:	Printed Name:	Printed Name:	Printed Name:
Firm: Geosyntec	Firm: SiREM	Firm:	Firm:	Firm:	Firm:
Date/Time: 3/9/21 1530	Date/Time: 3-12-20 10:00	Date/Time:	Date/Time:	Date/Time:	Date/Time:

Distribution: White - return to Originator; Yellow - Lab Copy; Pink - Retained by Client
* Mandatory Fields

APPENDIX B: Gene-Trac® Reports

SiREM
Leading Science · Lasting Solutions

Certificate of Analysis: Gene-Trac® *Dehalobacter* Assay

Customer: Duane Graves, Geosyntec Consultants
Project: Brunswick Deep LF
Customer Reference: Si-4384

SiREM Reference: S-5817
Report Date: 15-Jun-20
Data Files: iQ5A-DHB-QPCR-0512
iQ5A-DB-DHB-QPCR-0320

Table 1a: Test Results

Sample ID	*Dehalobacter* (Dhb)	
	Percent Dhb[(1)]	Gene Copies/Liter
Si-4384-BULK	0.04 - 0.1 %	1×10^6

See final page for notes.

Analyst: J. Wilkinson
Jennifer Wilkinson
Senior Laboratory Technician II

Approved: Ximena Druar
Ximena Druar, B.Sc.
Genetic Testing Coordinator

SiREM
Leading Science · Lasting Solutions

Certificate of Analysis: Gene-Trac® *cfrA/dcrA*
Chloroform Reductase A/ Dichloroethane Dehalogenase Assay

Customer: Duane Graves, Geosyntec Consultants

Project: Brunswick Deep LF

Customer Reference: Si-4384

SiREM Reference: S-5817

Report Date: 15-Jun-20

Data Files: iQ5B-cfrA-QPCR-0023
iQ5B-cfrA-DB-QPCR-0023

Table 1b: Test Results

Sample ID	Chloroform Reductase A/ Dichloroethane Dehalogenase (*cfrA* /dcrA)	
	Percent *cfrA* (1)	*cfrA* Gene Copies/Liter
Si-4384-BULK	0.6 - 2 %	2×10^7

See final page for notes.

Analyst: J. Wilkinson
Jennifer Wilkinson
Senior Laboratory Technician II

Approved: J. Wilkinson
Ximena Druar, B.Sc.
Genetic Testing Coordinator

SiREM
Leading Science · Lasting Solutions

130 Stone Rd. W
Guelph, ON N1G 3Z2
(519) 822-2265

Certificate of Analysis: Gene-Trac® ORM-2, Assay

Customer: Duane Graves, Geosyntec Consultants

Project: Brunswick Deep LF

Customer Reference: Si-4384

SiREM Reference: S-5817

Report Date: 15-Jun-20

Data Files: iQ5C-ORM2-QPCR-0138
iQ5C-ORM2-DB-QPCR-0138

Table 1c: Test Results

Sample ID	Deltaproteobacterium ORM-2	
	Percent ORM-2[(1)]	ORM-2 16S rRNA Gene Copies/Liter
Si-4384-BULK	0.004 - 0.01 %	1×10^5

See final page for notes.

Analyst: J. Wilkinson
Jennifer Wilkinson
Senior Laboratory Technician II

Approved: Ximena Druar
Ximena Druar, B.Sc.
Genetic Testing Coordinator

SiREM
Leading Science · Lasting Solutions

130 Stone Rd. W
Guelph, ON N1G 3Z2
(519) 822-2265

Certificate of Analysis: Gene-Trac® SRB, Sulfate Reducing Bacteria (*dsrA*) Assay

Customer: Duane Graves, Geosyntec Consultants

Project: Brunswick Deep LF

Customer Reference: Si-4384

SiREM Reference: S-5817

Report Date: 15-Jun-20

Data Files: iQ5B-SRB-QPCR-0060
iQ5B-DB-SRB-QPCR-0060

Table 1d: Test Results

Sample ID	Sulfate Reducing Bacteria (*dsrA*)	
	Percent *dsrA* (1)	*dsrA* Gene Copies/Liter
Si-4384-BULK	0.07 - 0.2 %	2×10^6

See final page for notes.

Analyst: J. Wilkinson
Jennifer Wilkinson
Senior Laboratory Technician II

Approved: Ximena Druar
Ximena Druar, B.Sc.
Genetic Testing Coordinator

SiREM
Leading Science · Lasting Solutions

Certificate of Analysis: Gene-Trac® abcA Benzene Carboxylase Assay

Customer: Duane Graves, Geosyntec Consultants

Project: Brunswick Deep LF

Customer Reference: Si-4384

SiREM Reference: S-5817

Report Date: 15-Jun-20

Data Files: iQ5A-abcA-QPCR-0115
iQ5A-DB-abcA-QPCR-0115

Table 1e: Test Results

Sample ID	Benzene Carboxylase (*abcA*)	
	Percent *abcA* (1)	*abcA* Gene Copies/Liter
Si-4384-BULK	NA	9×10^3 U

See final page for notes.

Analyst: J. Wilkinson
Jennifer Wilkinson
Senior Laboratory Technician II

Approved: Ximena Druar
Ximena Druar, B.Sc.
Genetic Testing Coordinator

SiREM
Leading Science · Lasting Solutions

Certificate of Analysis: Gene-Trac® Pepto-ben *Peptococcaceae* Assay

Customer: Duane Graves, Geosyntec Consultants

Project: Brunswick Deep LF

Customer Reference: Si-4384

SiREM Reference: S-5817

Report Date: 15-Jun-20

Data Files: iQ5C-Pepto-QPCR-0113
iQ5C-DB-Pepto-QPCR-0113

Table 1f: Test Results

Sample ID	*Peptococcaceae*	
	Percent *Peptococcaceae* (1)	*Peptococcaceae* 16S rRNA Gene Copies/Liter
Si-4384-BULK	NA	9×10^3 U

See final page for notes.

Analyst: J. Wilkinson
Jennifer Wilkinson
Senior Laboratory Technician II

Approved: Ximena Druar
Ximena Druar, B.Sc.
Genetic Testing Coordinator

Table 2: Detailed Test Parameters, Test Refe

Customer Sample ID
SiREM Dhb Test ID
SiREM *cfrA* Test ID
SiREM ORM-2 Test ID
SiREM SRB Test ID
SiREM *abcA* Test ID
SiREM PeptoBen Test ID
Date Sampled [(2)]
Matrix
Date Received [(2)]
Sample Temperature
Filtration Date [(2)]
Volume Used for DNA Extraction
DNA Extraction Date
DNA Concentration in Sample (extractable)
PCR Amplifiable DNA
Dhb qPCR Date Analyzed
***cfrA* qPCR Date Analyzed**
ORM-2 qPCR Date Analyzed
SRB qPCR Date Analyzed
***abcA* qPCR Date Analyzed**
PeptoBen qPCR Date Analyzed
Laboratory Controls (see Tables 3, 4, 5, 6, 7, & 8)
Comments

See final page for notes.

Table 2: Detailed Test Parameters, Test Reference S-5817

Customer Sample ID	Si-4384-BULK
SiREM Dhb Test ID	DHB-2242
SiREM *cfrA* Test ID	CFR-0058
SiREM ORM-2 Test ID	ORM-0196
SiREM SRB Test ID	SRB-0336
SiREM *abcA* Test ID	ABC-0162
SiREM PeptoBen Test ID	PEP-0140
Date Sampled [(2)]	29-Apr-20
Matrix	Groundwater
Date Received [(2)]	29-Apr-20
Sample Temperature	NA
Filtration Date [(2)]	4-May-20
Volume Used for DNA Extraction	300 mL
DNA Extraction Date	6-May-20
DNA Concentration in Sample (extractable)	5635 ng/L
PCR Amplifiable DNA	Detected
Dhb qPCR Date Analyzed	24-May-20
***cfrA* qPCR Date Analyzed**	10-Jun-20
ORM-2 qPCR Date Analyzed	7-May-20
SRB qPCR Date Analyzed	7-May-20
***abcA* qPCR Date Analyzed**	13-May-20
PeptoBen qPCR Date Analyzed	10-Jun-20
Laboratory Controls (see Tables 3, 4, 5, 6, 7, & 8)	Passed
Comments	- -

See final page for notes.

Table 3: Gene-Trac Dhb Control Results, Test Reference S-5817

Laboratory Control	Analysis Date	Control Description	Dhb 16S rRNA		Comments
			Spiked Gene Copies per Liter	Recovered Gene Copies per Liter	
Positive Control Low Concentration	24-May-20	Genomic DNA (CSLDB-0471)	2.6×10^{8}	2.8×10^{8}	Passed
Positive Control High Concentration	24-May-20	Genomic DNA (CSHDB-0471)	3.7×10^{10}	3.0×10^{10}	Passed
DNA Extraction Blank	24-May-20	Sterile Water (FB-3540)	0	2.6×10^{3} U	Passed
Negative Control	24-May-20	Test Reagent Blank (TBDB-0471)	0	2.6×10^{3} U	Passed

See final page for notes.

Table 4: Gene-Trac *cfrA/dcrA* Control Results, Test Reference S-5817

Laboratory Control	Analysis Date	Control Description	*cfrA*		Comments
			Spiked Gene Copies per Liter	Recovered Gene Copies per Liter	
Positive Control Low Concentration	10-Jun-20	Genomic DNA (CSLC-0023)	8.2×10^6	4.6×10^6	Passed
Positive Control High Concentration	10-Jun-20	Genomic DNA (CSHC-0023)	1.8×10^9	2.2×10^9	Passed
DNA Extraction Blank	10-Jun-20	Sterile Water (FB-3540)	0	2.6×10^3 U	Passed
Negative Control	10-Jun-20	Test Reagent Blank (TBC-0023)	0	2.6×10^3 U	Passed

See final page for notes.

Table 5: Gene-Trac ORM-2 Control Results, Test Reference S-5817

Laboratory Control	Analysis Date	Control Description	ORM-2		Comments
			Spiked Gene Copies per Liter	Recovered Gene Copies per Liter	
Positive Control Low Concentration	7-May-20	Genomic DNA (CSLO-0138)	5.2×10^{8}	1.9×10^{8} (3)	See Note 3
Positive Control High Concentration	7-May-20	Genomic DNA (CSHO-0138)	9.1×10^{9}	5.4×10^{9}	Passed
DNA Extraction Blank	7-May-20	Sterile Water (FB-3540)	0	2.6×10^{3} U	Passed
Negative Control	7-May-20	Test Reagent Blank (TBO-0138)	0	2.6×10^{3} U	Passed

See final page for notes.

Table 6: Gene-Trac SRB Control Results, Test Reference S-5817

Laboratory Control	Analysis Date	Control Description	*dsrA*		Comments
			Spiked Gene Copies per Liter	Recovered Gene Copies per Liter	
Positive Control Low Concentration	7-May-20	Genomic DNA (CSLSR-0060)	1.0×10^6	1.1×10^6	Passed
Positive Control High Concentration	7-May-20	Genomic DNA (CSHSR-0060)	8.2×10^7	7.8×10^7	Passed
DNA Extraction Blank	7-May-20	Sterile Water (FB-3540)	0	2.6×10^3 U	Passed
Negative Control	7-May-20	Test Reagent Blank (TBSR-0060)	0	2.6×10^3 U	Passed

See final page for notes.

Table 7: Gene-Trac *abcA* Control Results, Test Reference S-5817

Laboratory Control	Analysis Date	Control Description	*abcA*		Comments
			Spiked Gene Copies per Reaction	Recovered Gene Copies per Reaction	
Positive Control Low Concentration	13-May-20	Plasmid DNA (CSLAB-0115)	3.5×10^4	$1.6 \times 10^{4\ (3)}$	See Note 3
Positive Control High Concentration	13-May-20	PlasmidGenomic DNA (CSHAB-0115)	3.5×10^6	1.8×10^6	Passed
DNA Extraction Blank	13-May-20	Sterile Water (FB-3540)	0	2.0×10^1 U	Passed
Negative Control	13-May-20	Test Reagent Blank (TBAB-0115)	0	2.0×10^1 U	Passed

See final page for notes.

Table 8: Gene-Trac Pepto-ben Control Results, Test Reference S-5817

Laboratory Control	Analysis Date	Control Description	Pepto-ben		Comments
			Spiked Gene Copies per Reaction	Recovered Gene Copies per Reaction	
Positive Control Low Concentration	10-Jun-20	Genomic DNA (CSLPE-0113)	3.8×10^5	$1.6 \times 10^{5\ (3)}$	See Note 3
Positive Control High Concentration	10-Jun-20	Genomic DNA (CSHPE-0113)	4.1×10^7	4.4×10^7	Passed
DNA Extraction Blank	10-Jun-20	Sterile Water (FB-3540)	0	2.0×10^1 U	Passed
Negative Control	10-Jun-20	Test Reagent Blank (TBPE-0113)	0	2.0×10^1 U	Passed

See final page for notes.

Notes:
Dhb = *Dehalobacter*
cfrA = chloroform reductase A
ORM-2 = Deltaproteobacterium ORM-2
dsrA = *dissimilatory sulfate reductase A*
abcA = Benzene Carboxylase
J The associated value is an estimated quantity between the method detection limit and quantitation limit.
U Not detected, associated value is the quantitation limit.
B Analyte was detected in the method blank within an order of magnitude of the test sample.
E Extracted genomic DNA was not detected in the sample.
I Sample inhibited the test reaction based on inability to PCR amplify extracted DNA with universal primers.
ng/L = nanograms per liter
mL = milliliter
NA = not applicable
ND = not detected
DNA = deoxyribonucleic acid
16S rRNA = 16S ribosomal ribonucleic acid
PCR = polymerase chain reaction
qPCR = quantitative PCR
°C = degrees Celsius

[1]Percent *Dehalobacter*, *cfrA*, ORM-2, *Peptococcaceae, dsrA,* or *abcA* in microbial population. This value is calculated by dividing the number of specific gene copies by the total number of bacteria as estimated by the mass of DNA extracted from the sample. Range represents normal variation in enumeration.

[2]Samples are stabilized by freezing at -80 °C upon sample reception (field filters) or in-lab filtration (groundwater). Hold time not exceeded if sampling date is within 14 days of date received or filtration date.

[3]Control was outside recovery limit guidelines (+/- 50%), however, test results are deemed acceptable if one of two positive controls falls within the recovery limit.

SiREM

Chain-of-Custody Form

siremlab.com

180A Market Place Boulevard
Knoxville, TN 37922
1-866-251-1747

Lab # S-5817

Part of Brunswick Deep CF treatbility study.

*Project Name: Brunswick Deep CF	*Project #: Si-43824
*Project Manager: Sandra on behalf of Duane Graves	*Company: SiREM
*Email Address: ssande@siremlab.com	
Address (Street)	
City	State/Province / Country
*Phone #	
*Sampler's Signature	*Sampler's Printed Name: Steve Sande

Analysis

Client Sample ID	Sampling Date	Sampling Time	Matrix	# of Containers	Gene-Trac DHC	Gene-Trac FGA	Gene-Trac DHB	Gene-Trac DHG	Dhb, cfrA	ORM-2	SRB	pqlo-ben	abcA			Other Information
Si-43824-BULK	29Apr20		GW	1					x	x	x	x	x			

Preservative Key
0. None
1. HCL
2. Other _____
3. Other _____
4. Other _____
5. Other _____
6. Other _____

Billing Information
P.O. #
*Bill To:

Turnaround Time Requested
Normal ☐
Rush ☐

For Lab Use Only
Cooler Condition:
Cooler Temperature:
Custody Seals: Yes ☐ No ☐

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: Steve Sande	Printed Name: Steve Sande	Printed Name	Printed Name	Printed Name	Printed Name
Firm: SiREM	Firm: SiREM	Firm	Firm	Firm	Firm
Date/Time: 29Apr20	Date/Time: 29Apr20	Date/Time	Date/Time	Date/Time	Date/Time

Distribution: White - return to Originator; Yellow - Lab Copy; Pink - Retained by Client

** Mandatory Fields*

SiREM
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Certificate of Analysis: Gene-Trac® Dhb, *Dehalobacter* Assay

Customer: Ali Ciblak, Geosyntec Consultants
Project: Brunswick Deep CF
Customer Reference: Si-4384

SiREM Reference: S-5869
Report Date: 16-Jun-20
Data Files: iQ5A-DHB-QPCR-0513
iQ5A-DB-DHB-QPCR-0321

Table 1a: Test Results

Sample ID	*Dehalobacter* (Dhb)	
	Percent Dhb[(1)]	Gene Copies/Liter
Si-4384-DC-7/8/9-MID	7 -19 %	7×10^7
Si-4384-DC-10/11/12-MID	7 - 19 %	2×10^8

See final page for notes.

Analyst: J. Wilkinson
Jennifer Wilkinson
Senior Laboratory Technician II

Approved: Ximena Druar
Ximena Druar, B.Sc.
Genetic Testing Coordinator

SiREM
Leading Science · Lasting Solutions

Certificate of Analysis: Gene-Trac® cfrA, Chloroform Reductase A (*cfrA*) Assay

Customer: Ali Ciblak, Geosyntec Consultants
Project: Brunswick Deep CF
Customer Reference: Si-4384

SiREM Reference: S-5869
Report Date: 16-Jun-20
Data Files: iQ5B-cfrA-QPCR-0023
iQ5B-cfrA-DB-QPCR-0023

Table 1b: Test Results

Sample ID	Chloroform Reductase A (*cfrA*)	
	Percent *cfrA* (1)	*cfrA* Gene Copies/Liter
Si-4384-DC-7/8/9-MID	1 - 4 %	1×10^7
Si-4384-DC-10/11/12-MID	0.1 - 0.4 %	4×10^6

See final page for notes.

Analyst: J. Wilkinson
Jennifer Wilkinson
Senior Laboratory Technician II

Approved: Ximena Druar
Ximena Druar, B.Sc.
Genetic Testing Coordinator

Table 2: Detailed Test Parameters, Test Reference S-5869

Customer Sample ID	Si-4384-DC-7/8/9-MID	Si-4384-DC-10/11/12-MID
SiREM Dhb Test ID	DHB-2267	DHB-2268
SiREM *cfrA* Test ID	CFR-0068	CFR-0069
Date Sampled[(2)]	26-May-20	26-May-20
Matrix	Microcosm	Microcosm
Date Received[(2)]	28-May-20	28-May-20
Sample Temperature	NA	NA
Filtration Date[(2)]	28-May-20	28-May-20
Volume Used for DNA Extraction	15 mL	15 mL
DNA Extraction Date	29-May-20	29-May-20
DNA Concentration in Sample (extractable)	2100 ng/L (J)	6750 ng/L (J)
PCR Amplifiable DNA	Detected	Detected
Dhb qPCR Date Analyzed	2-Jun-20	2-Jun-20
***cfrA* qPCR Date Analyzed**	10-Jun-20	10-Jun-20
Laboratory Controls (see Tables 3 & 4)	Passed	Passed
Comments	- -	- -

See final page for notes.

Table 3: Gene-Trac Dhb Control Results, Test Reference S-5869

Laboratory Control	Analysis Date	Control Description	Dhb 16S rRNA		Comments
			Spiked Gene Copies per Liter	Recovered Gene Copies per Liter	
Positive Control Low Concentration	2-Jun-20	Genomic DNA (CSLDB-0472)	2.6×10^{8}	2.7×10^{8}	Passed
Positive Control High Concentration	2-Jun-20	Genomic DNA (CSHDB-0472)	3.7×10^{10}	3.6×10^{10}	Passed
DNA Extraction Blank	2-Jun-20	Sterile Water (FB-3555)	0	2.6×10^{3} U	Passed
Negative Control	2-Jun-20	Test Reagent Blank (TBDB-0472)	0	2.6×10^{3} U	Passed

See final page for notes.

Table 4: Gene-Trac *cfrA* Control Results, Test Reference S-5869

Laboratory Control	Analysis Date	Control Description	*cfrA*		Comments
			Spiked Gene Copies per Liter	Recovered Gene Copies per Liter	
Positive Control Low Concentration	10-Jun-20	Genomic DNA (CSLC-0023)	8.2×10^6	4.6×10^6	Passed
Positive Control High Concentration	10-Jun-20	Genomic DNA (CSHC-0023)	1.8×10^9	2.2×10^9	Passed
DNA Extraction Blank	10-Jun-20	Sterile Water (FB-3555)	0	2.6×10^3 U	Passed
Negative Control	10-Jun-20	Test Reagent Blank (TBC-0023)	0	2.6×10^3 U	Passed

See final page for notes.

Notes:

Dhb = *Dehalobacter*

cfrA = chloroform reductase A

J The associated value is an estimated quantity between the method detection limit and quantitation limit.

U Not detected, associated value is the quantitation limit.

B Analyte was detected in the method blank within an order of magnitude of the test sample.

E Extracted genomic DNA was not detected in the sample.

I Sample inhibited the test reaction based on inability to PCR amplify extracted DNA with universal primers.

ng/L = nanograms per liter

mL = milliliter

NA = not applicable

ND = not detected

DNA = deoxyribonucleic acid

16S rRNA = 16S ribosomal ribonucleic acid

PCR = polymerase chain reaction

qPCR = quantitative PCR

°C = degrees Celsius

[1]Percent *Dehalobacter* (Dhb) or *cfrA* in microbial population. This value is calculated by dividing the number of Dhb 16S ribosomal ribonucleic acid (rRNA) or *cfrA* gene copies by the total number of bacteria as estimated by the mass of DNA extracted from the sample. Range represents normal variation in enumeration.

[2]Samples are stabilized by freezing at -80 °C upon sample reception (field filters) or in-lab filtration (groundwater). Hold time not exceeded if sampling date is within 14 days of date received or filtration date.

[3]Control results are deemed acceptable if one of two positive controls falls within the recovery limit guidelines (+/- 50%).

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siremlab.com

130 Stone Rd. W
Guelph, ON N1G 3Z2
(519) 822-2265

Lab # S-5869

* Sample part of Brunswick Deep CF Treatability Study Si-4384 *

*Project Name: Brunswick Deep CF	*Project #: Si-4384
*Project Manager: Sandra Dworatzek on behalf of Ali Ciblak	*Company: SiREM
*Email Address	
Address (Street)	
City / State/Province / Country	
*Phone #	
*Sampler's Signature	*Sampler's Printed Name: Steve Sande

Preservative Key

0. None
1. HCL
2. Other
3. Other
4. Other
5. Other
6. Other

Client Sample ID	Sampling Date	Sampling Time	Matrix	# of Containers	Gene-Trac DHC	Gene-Trac VC	cfrA Gene-Trac DHB	Gene-Trac DHG	Gene-Trac tceA	Volatile Fatty Acids	Dissolved hydrocarbon gases	Treatability Study				Other Information
Si-4384-DC-7/8/9-MID	26May20		gw	1			x									
Si-4384-DC-10/11/12-MID	26May20		gw	1			x									

Analysis

Billing Information

P.O. #

*Bill To:

Turnaround Time Requested

Normal ☐
Rush ☐

For Lab Use Only

Cooler Condition:

Cooler Temperature:

Custody Seals: Yes ☐ No ☐

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: Steve Sande	Printed Name: Steve Sande	Printed Name	Printed Name	Printed Name	Printed Name
Firm	Firm	Firm	Firm	Firm	Firm
Date/Time: 28May20	Date/Time: 28May20	Date/Time	Date/Time	Date/Time	Date/Time

Distribution: White - return to Originator: Yellow - Lab Copy: Pink - Retained by Client

** Mandatory Fields*

SiREM
Leading Science · Lasting Solutions

Certificate of Analysis: Gene-Trac® *Dehalobacter* Assay

Customer: Ali Ciblak, Geosyntec Consultants
Project: Brunswick Deep CF
Customer Reference: GR6881

SiREM Reference: S-6100
Report Date: 9-Sep-20
Data Files: iQ5A-DHB-QPCR-0520
iQ5A-DB-DHB-QPCR-0328

Table 1a: Test Results

Sample ID	*Dehalobacter* (Dhb)	
	Percent Dhb[(1)]	Gene Copies/Liter
Si-4384-DC-7/8/9-END	1 - 4 %	2×10^8
Si-4384-DC-10/11/12-END	4 - 13 %	9×10^8

See final page for notes.

Analyst: Taylor Aris
Taylor Aris, B.Sc.
Laboratory Technician

Approved: Ximena Druar
Ximena Druar, B.Sc.
Genetic Testing Supervisor

SiREM
Leading Science · Lasting Solutions

Certificate of Analysis: Gene-Trac® cfrA/dcrA Chloroform Reductase A/ Dichloroethane Dehalogenase Assay

Customer: Ali Ciblak, Geosyntec Consultants
Project: Brunswick Deep CF
Customer Reference: GR6881

SiREM Reference: S-6100
Report Date: 9-Sep-20
Data Files: iQ5B-cfrA-QPCR-0027
iQ5B-cfrA-DB-QPCR-0026

Table 1b: Test Results

Sample ID	Chloroform Reductase A/ Dichloroethane Dehalogenase (*cfrA* /dcrA)	
	Percent *cfrA* (1)	*cfrA* Gene Copies/Liter
Si-4384-DC-7/8/9-END	0.02 - 0.06 %	3×10^6
Si-4384-DC-10/11/12-END	0.04 - 0.1 %	8×10^6

See final page for notes.

Analyst: Taylor Aris, B.Sc.
Laboratory Technician

Approved: Ximena Druar, B.Sc.
Genetic Testing Supervisor

Table 2: Detailed Test Parameters, Test Reference S-6100

Customer Sample ID	Si-4384-DC-7/8/9-END	Si-4384-DC-10/11/12-END
SiREM Dhb Test ID	DHB-2306	DHB-2307
SiREM *cfrA/dcrA* Test ID	CFR-0103	CFR-0104
Date Sampled[(2)]	25-Aug-20	25-Aug-20
Matrix	Groundwater	Groundwater
Date Received[(2)]	26-Aug-20	25-Aug-20
Sample Temperature	NA	NA
Filtration Date[(2)]	28-Aug-20	28-Aug-20
Volume Used for DNA Extraction	15 mL	15 mL
DNA Extraction Date	28-Aug-20	28-Aug-20
DNA Concentration in Sample (extractable)	32000 ng/L	39000 ng/L
PCR Amplifiable DNA	Detected	Detected
Dhb qPCR Date Analyzed	3-Sep-20	3-Sep-20
***cfrA* qPCR Date Analyzed**	8-Sep-20	8-Sep-20
Laboratory Controls (see Tables 3 & 4)	Passed	Passed
Comments	- -	- -

See final page for notes.

Table 3: Gene-Trac Dhb Control Results, Test Reference S-6100

Laboratory Control	Analysis Date	Control Description	Dhb 16S rRNA		Comments
			Spiked Gene Copies per Liter	Recovered Gene Copies per Liter	
Positive Control Low Concentration	3-Sep-20	Genomic DNA (CSLDB-0479)	2.6×10^{8}	2.2×10^{8}	Passed
Positive Control High Concentration	3-Sep-20	Genomic DNA (CSHDB-0479)	3.7×10^{10}	3.6×10^{10}	Passed
DNA Extraction Blank	3-Sep-20	Sterile Water (FB-3620)	0	2.6×10^{3} U	Passed
Negative Control	3-Sep-20	Test Reagent Blank (TBDB-0479)	0	2.6×10^{3} U	Passed

See final page for notes.

Table 4: Gene-Trac cfrA/dcrA Control Results, Test Reference S-6100

Laboratory Control	Analysis Date	Control Description	*cfrA*		Comments
			Spiked Gene Copies per Liter	Recovered Gene Copies per Liter	
Positive Control Low Concentration	8-Sep-20	Genomic DNA (CSLC-0027)	8.2×10^6	5.9×10^6	Passed
Positive Control High Concentration	8-Sep-20	Genomic DNA (CSHC-0027)	1.8×10^9	1.9×10^9	Passed
DNA Extraction Blank	8-Sep-20	Sterile Water (FB-3620)	0	2.6×10^3 U	Passed
Negative Control	8-Sep-20	Test Reagent Blank (TBC-0027)	0	2.6×10^3 U	Passed

See final page for notes.

Notes:
Dhb= = *Dehalobacter*
cfrA = chloroform reductase A
J The associated value is an estimated quantity between the method detection limit and quantitation limit.
U Not detected, associated value is the quantitation limit.
B Analyte was detected in the method blank within an order of magnitude of the test sample.
E Extracted genomic DNA was not detected in the sample.
I Sample inhibited the test reaction based on inability to PCR amplify extracted DNA with universal primers.
ng/L = nanograms per liter
mL = milliliter
NA = not applicable
ND = not detected
DNA = deoxyribonucleic acid
16S rRNA = 16S ribosomal ribonucleic acid
PCR = polymerase chain reaction
qPCR = quantitative PCR
°C = degrees Celsius

[1] Percent Dhb or *cfrA* in microbial population. This value is calculated by dividing the number of chloroform reductase A (*cfrA*) gene copies by the total number of bacteria as estimated by the mass of DNA extracted from the sample. Range represents normal variation in enumeration.

[2]Samples are stabilized by freezing at -80 °C upon sample reception (field filters) or in-lab filtration (groundwater). Hold time not exceeded if sampling date is within 14 days of date received or filtration date.

[2]Control was outside recovery limit guidelines (+/- 50%), however, test results are deemed acceptable if one of two positive controls falls within the recovery limit.

SiREM

Chain-of-Custody Form

siremlab.com

* Sample part of Brunswick Deep CF Treatability Study Si-4384 *

130 Stone Rd. W
Guelph, ON N1G 3Z2
(519) 822-2265

Lab # S-6100

*Project Name: Brunswick Deep CF	*Project #: Si-4384
*Project Manager: Sandra Dworatzek on behalf of Ali Ciblak	*Company: SiREM
*Email Address	
Address (Street)	
City / State/Province / Country	
*Phone #	
*Sampler's Signature	*Sampler's Printed Name: Steve Sande

Analysis

Client Sample ID	Sampling Date	Sampling Time	Matrix	# of Containers	Gene-Trac DHC	Gene-Trac VC	Gene-Trac DHB (cfrA)	Gene-Trac DHG	Gene-Trac tceA	Volatile Fatty Acids	Dissolved hydrocarbon gases	Treatability Study				Other Information
Si-4384-DC-7/8/9-END	25Aug20		gw	1			x									
Si-4384-DC-10/11/12-END	25Aug20		gw	1			x									

Preservative Key

0. None
1. HCL
2. Other _____
3. Other _____
4. Other _____
5. Other _____
6. Other _____

Billing Information

P.O. #

*Bill To:

Turnaround Time Requested

Normal ☐
Rush ☐

For Lab Use Only

Cooler Condition:

Cooler Temperature:

Custody Seals: Yes ☐ No ☐

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: Steve Sande	Printed Name: Steve Sande	Printed Name	Printed Name	Printed Name	Printed Name
Firm	Firm	Firm	Firm	Firm	Firm
Date/Time: 25Aug20	Date/Time: 25Aug20	Date/Time	Date/Time	Date/Time	Date/Time

Distribution: White - return to Originator: Yellow - Lab Copy: Pink - Retained by Client

** Mandatory Fields*

APPENDIX C: Henry's Law Calculation

The following Henry's Law calculation was used to convert aqueous concentrations (Table 2) to total mmoles of each analyte per microcosm bottle (Figures 2 to 5):

$$Total\ mmoles = \frac{C_{liq} \cdot \left(V_{liq} + H \cdot V_{gas}\right)}{Molecular\ Weight\ (\frac{mg}{mmol})}$$

Where

C_{liq} = liquid concentration (mg/L)
V_{liq} = liquid volume (0.225 L) per bottle
V_{gas} = headspace volume (0.025 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)
Tetrachloroethene	0.602
Trichloroethene	0.417
cis-1,2-dichloroethene	0.184
1,1-Dichloroethene	1.06
Vinyl chloride	1.08
Ethene	8.78
1,1,1-Trichloroethane	0.609
1,1-Dichloroethane	0.256
Chloroethane	0.495
Ethane	20.5
Chloroform	0.178
Dichloromethane	0.121
Methane	27.3
CFC-113	21.7
CFC-123a	1.05

[a] Source: Montgomery, J.H. 2000. *Groundwater Chemicals Desk Reference, Third Edition.* CRC Press LLC, Boca Raton, FL.

APPENDIX C

Bioremediation Amendment Product Information

Patented *Injection Ready* 60% SRS®-FRL Large Droplet Emulsified Vegetable Oil (EVO) Substrate for Maximum Retention

SAFETY DATA SHEET

1. Product Identification

Synonyms:	60% Large Droplet Slow Release Substrate (SRS®-FRL) Emulsified Vegetable Oil Substrate (EVO)
Recommended Use:	Treatment of groundwater contaminated with chlorinated solvents and other anaerobically degradable compounds.
Supplier:	Terra Systems, Inc. 130 Hickman Road, Suite 1 Claymont, Delaware 19703 Telephone (302) 798-9553 Fax (302) 798-9554 www.terrasystems.net

2. Hazards Identification

Emergency Overview	
Caution:	May cause eye irritation.
Health Rating:	1 - Slight
Flammability Rating:	1 - Slight
Reactivity Rating:	1 - Slight
Contact Rating:	1 - Slight
Protective Equipment:	Goggles; Proper Gloves
Storage Color Code:	Green (General Storage)
Potential Health Effects	
Inhalation:	Not expected to be a health hazard. If heated, may produce vapors or mists that irritate the mucous membranes and cause irritation, dizziness, and nausea. Remove to fresh air.
Ingestion:	Not expected to be a health hazard via ingestion. Large doses may produce abdominal spasms or diarrhea.
Skin Contact:	No adverse effects expected. May cause irritation or sensitization in sensitive individuals.
Eye Contact:	May cause mild irritation, possible reddening.
Chronic Exposure:	No information found.
Aggravation of Pre-existing Conditions:	No information found.

3. Composition/Information on Ingredients

Ingredient	Synonyms	CAS #	Percent	Hazardous
Soy bean oil	Soya oil	8001-22-7	60%	No
Emulsifiers and proprietary nutrient package containing nitrogen, phosphorus and vitamin B_{12}		Mixture	7.5 - 10%	No
Sodium lactate	2-hydroxpropionic acid sodium salt	72-17-3	5.5%	Yes
Water		7732-18-5	Difference	No

The emulsifiers and nutrient package mixture is a trade secret and consists of ingredients of unknown acute toxicity.

4. First Aid Measures

Inhalation: Not expected to require first aid measures. Remove to fresh air. Get medical attention for any breathing difficulty.

Ingestion: If large amounts were swallowed, give water to drink and get medical advice.

Skin Contact: Not expected to require first aid measures. Wash exposed area with soap and water. Get medical advice if irritation develops.

Eye Contact: Immediately flush eyes with plenty of water for at least 15 minutes, lifting upper and lower eyelids occasionally. Get medical attention if irritation persists.

5. Fire Fighting Measures

Fire: Flash point: >200 C (>392 F). Not considered to be a fire hazard. Isolate from heat and open flame.

Explosion: Not considered to be an explosion hazard. Closed containers may explode if exposed to extreme heat.

Fire Extinguishing Media: Dry chemical, foam, or carbon dioxide. Water spray may be ineffective on fire but can protect fire-fighters and cool closed containers. Use fog nozzles if water is used.

Special Information: In the event of a fire, wear full protective clothing and NIOSH-approved self-contained breathing apparatus with full face piece operated in the pressure demand or other positive pressure mode.

6. Accidental Release Measures

Clean-up personnel may require protective clothing. Absorb in sand, paper towels, “Oil Dry”, or other inert material. Scoop up and containerize for disposal. Flush trace residues to sewer with soap and water. Containerized waste may be sent to an approved waste disposal facility.

7. Handling and Storage

Store in a cool, dry, ventilated area. Do not store in sunlight or above 32 C (90 F). Keep container tightly closed and upright when not in use to prevent leakage. Observe all warnings and precautions listed for the product. Protect against physical damage.

If container begins to bulge, open cap slowly to release carbon dioxide from biological activity on the SRS-SD and call TSI.

Containers of this material are not hazardous when empty since they do not contain vapors or harmful substances; if drum or tote is observed to bulge, keep cap off as pressurization can occur on empty container with caps in place unless container is thoroughly rinsed.

8. Exposure Controls/Personal Protection

Airborne Exposure Limits:	None established.
Ventilation System:	Not expected to require any special ventilation.
Personal Respirators (NIOSH Approved):	Not expected to require personal respirator usage.
Skin Protection:	Wear protective gloves and clean body-covering clothing.
Eye Protection:	Use chemical safety goggles and/or a full-face shield where splashing is possible. Provide readily accessible eye wash stations and safety showers.
Slips, Trips, and Falls:	Material is slippery when spilled. Clean up with sand, paper towels, “Oil Dry”, or other inert material.

9. Physical and Chemical Properties

Appearance:	White liquid.
Odor:	Vegetable oil.
Solubility:	Miscible in water.
Specific Gravity (water=1):	0.95-0.98. 8.09 pounds per gallon.
pH:	6-7 (40% aqueous solution)
% Volatiles by volume @ 21C (70F):	Negligible.
Boiling Point:	≥ 100C (≥ 212F)
Melting Point:	No information found.
Flash Point (F):	No information found.
Autoignition Temperature:	No information found.
Decomposition Temperature:	No information found.
Vapor Density (Air=1):	No information found.
Vapor Pressure (mm Hg):	< 1.0 @ 20C (68F).
Evaporation Rate (BuAc=1):	No information found.
Viscosity @23 C (73 F):	213 centipoises (1.2 centipoises diluted 1:10)
Partition Coefficient (octanol/water):	No information found.

10. Stability and Reactivity

Stability: Stable under ordinary conditions of use and storage.
Reactivity: Not reactive under ordinary conditions.
Hazardous Decomposition Products: Carbon dioxide and carbon monoxide may form when heated to decomposition.
Hazardous Polymerization: Will not occur.
Incompatibilities: Strong oxidizers, acids.
Conditions to Avoid: Incompatibles. Isolate from heat and open flame.

11. Toxicological Information

Soybean Oil: No information found on toxicology. It is not a carcinogen listed by IARC, NTP, NIOSH, OSHA, or ACGIH.
Emulsifier/Nutrient Mixture: No information found on toxicology. It is not a carcinogen listed by IARC, NTP, NIOSH, OSHA, or ACGIH.
Sodium Lactate: Oral rat LD50: 2,000 mg/kg. 100 mg caused mild irritation to rabbit eye in Draize test. This compound is not listed as a carcinogen by IARC, NRP, NIOSH, OSHA, or ACGIM.
SRS-SD: The toxicity of the mixture has not been measured.

12. Ecological Information

Environmental Fate: No information found.
Environmental Toxicity: No information found.
Degradability: This product is completely biodegradable under both aerobic and anaerobic conditions.
Soil Mobility: This compound will move with groundwater until the adsorbed onto the soil. Degradation products may be mobile.
Bioaccumulation Potential: No information found.

13. Disposal Considerations

Whatever cannot be saved for recovery or recycling should be managed in an appropriate and approved waste disposal facility. Processing, use or contamination of this product may change the waste management options. State and local disposal regulations may differ from federal disposal regulations. Dispose of container and unused contents in accordance with federal, state and local requirements.

14. Transport Information

Not regulated.

15. Regulatory Information

OSHA STATUS: This product is not hazardous under the criteria of the Federal OSHA hazard Communication Standard 29 CFR 1910.1200. However, thermal processing and decomposition fumes from this product may be hazardous as noted in Section 10.

TSCA STATUS: No component of this product is listed on the TSCA inventory.

CERCLA (Comprehensive Response Compensation, and Liability Act): Not reportable.

SARA TITLE III (Superfund Amendments and Reauthorization Act)
Section 312 Extremely Hazardous Substances: None
Section 311/312 Hazard Categories: Non-hazardous Under Section 311/312
Section 313 Toxic Chemicals: None

RCRA STATUS: If discarded in its purchased form, this product would not be a hazardous waste either by listing or by characteristic. However, under RCRA, it is the responsibility of the product user to determine at the time of disposal, whether a material containing the product or derived from the product should be classified as a hazardous waste. (40 CFR 261.20-24)

CALIFORNIA PROPOSITION 65: The following statement is made in order to comply with the California safe Drinking Water and Toxic Enforcement Act of 1986. The product contains no chemicals known to the State of California to cause cancer.

16. Other Information

NFPA Ratings:	Health: **1** Flammability: **1** Reactivity: **1**
Date Prepared:	September 11, 2019
Revision Information:	SDS Section(s) changed since last revision of document include: Updated Section 3 Composition/Information on Ingredients.
Disclaimer:	Terra Systems, Inc. provides the information contained herein in good faith but makes no representation as to its comprehensiveness or accuracy. This document is intended only as a guide to the appropriate precautionary handling of the material by a properly trained person using this product. Individuals receiving the information must exercise their independent judgment in determining its appropriateness for a particular purpose. TERRA SYSTEMS, INC. MAKES NO REPRESENTATIONS OR WARRANTIES, EITHER EXPRESS OR IMPLIED, INCLUDING WITHOUT LIMITATION ANY WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE WITH RESPECT TO THE INFORMATION SET FORTH HEREIN OR THE PRODUCT TO WHICH THE INFORMATION REFERS. ACCORDINGLY, TERRA SYSTEMS, INC. WILL NOT BE RESPONSIBLE FOR

DAMAGES RESULTING FROM USE OF OR RELIANCE UPON THIS INFORMATION.

Prepared by: Terra Systems, Inc.
Phone Number: (302) 798-9553 (U.S.A.)

SAFETY DATA SHEET

1. CHEMICAL IDENTIFICATION AND COMPANY INFORMATION

Product Name: **KB-1® PLUS**

Company Info:
SiREM
130 Stone Rd. W. Guelph, ON, N1G3Z2
Phone: 519-822-2265
Toll Free, North America: 1-866-251-1747
Fax: 888-635-3470
www.siremlab.com

Emergency Phone Number: 519-822-2265 (for 24/7 assistance, contact poison center hotline in your jurisdiction).

Description: Microbial inoculum (non-pathogenic, non-hazardous) in growth media consisting of a dilute aqueous solution of mineral salts and nutrients.

Recommended Use: Bioremediation of contaminated groundwater.

Restrictions on Use: KB-1® PLUS product intended for laboratory research and field applications for cleanup of contaminated groundwater. Products are not intended to be used as human or animal therapeutics, cosmetics, agricultural or pesticide products, food additives, or as household chemicals.

2. HAZARDS IDENTIFICATION

GHS Classification: Not classified as "hazardous" per OSHA 29 CFR 1910.1200, "Hazard Communication".

GHS Label elements, including hazard and precautionary statements: Not Applicable.

HMIS Rating:	**Health**	**Flammability**	**Physical Hazard**	**Personal Protection**
	1	0	0	B*
NFPA Rating:	**Health**	**Flammability**	**Reactivity**	**Special Hazard**
	1	0	0	N/A

* B = Safety Glasses, Gloves.

A review of available data indicates minimal potential for health effects related to normal use of this product. Microbial components are non-pathogenic. The product is not expected to be a health hazard as a result of inhalation of mists, ingestion or skin contact. Eye contact may result in mild irritation/redness. Normal hygiene precautions should be observed, including eye protection, skin protection, and hand washing. The potential exists for individuals with hypersensitivity to biological materials to exhibit allergic sensitivity to biological components of this product (see Section 4, "First Aid Measures").

3. COMPOSITION/INFORMATION ON INGREDIENTS

KB-1® PLUS is a microbial culture grown in an aqueous dilute solution of mineral salts and nutrients classified as non-hazardous in accordance with provisions of OSHA 29 CFR 1910.1200, "Hazard Communication."

The microbial composition of KB-1® PLUS, as determined by phylogenetic analysis, includes:

Dehalococcoides sp.
Geobacter sp.
Methanomethylovorans sp.
Dehalobacter sp.
Dehalogenimonas sp.

Identification of organisms was obtained by matching 16S rRNA gene sequence of organisms in KB-1® PLUS to other known organisms. The characteristics of related organisms can be used to identify potential or likely characteristics of organisms in KB-1® PLUS.

4. FIRST AID MEASURES

Avoid direct contact with skin and eyes. In any case of any exposure which elicits a response, a physician should be consulted immediately.

Route of Entry	Symptoms	First Aid Procedures
Ingestion	Upset stomach, irritation of digestive tract	Do not induce vomiting. Drink several cups of water. Seek medical attention.
Skin contact	Skin irritation – reddening, itching or inflammation.	Remove contaminated clothes. Wash skin with plenty of water and soap. Seek medical attention if irritation develops or open wounds are present.
Eye contact	Eye irritation – redness, tearing, blurred vision.	Rinse immediately with plenty of water for 15 – 20 minutes, lifting lower and upper eyelids occasionally (remove contact lenses if easily possible). Seek medical attention if undue irritation or redness occurs.
Inhalation of mist	Respiratory irritation, coughing, breathing difficulty.	Remove victim to fresh air. Administer first aid as appropriate for symptoms. Seek medical attention if serious symptoms occur.

5. FIRE FIGHTING MEASURES

General:	This material is non-flammable, consisting primarily of water, and poses no special hazards if involved in a fire situation.
Suitable extinguishing media:	If material is involved in fire situation, use extinguishing media suitable for surrounding fire.
Special protective equipment and precautions for firefighters:	No special equipment necessary; use equipment appropriate for surrounding fire.
Hazardous combustion products:	Not applicable.
Toxic gases produced:	Not applicable.
Shock/impact sensitivity:	Not shock sensitive.

6. ACCIDENTAL RELEASE MEASURES

Method of containment and cleanup: Spilled KB-1® PLUS should be soaked up with sorbent and saturated with a 10% bleach solution (prepared by making a one in ten dilution of diluted standard bleach [normally sold at a strength of 5.25% sodium hypochlorite] to disinfect affected surfaces. Sorbent should be double

bagged and disposed of as indicated in Section 13. After removal of sorbent, area should be washed with 10% bleach solution to disinfect. If liquid from the culture vessel is present on the fittings, non-designated tubing or exterior of the stainless steel pressure vessel liquid should be wiped off and the area washed with 10% bleach solution.

Ventilation: No special ventilation is required in the event of the spill, as the material consists of water and non-volatile constituents. If the potential for generation of mist exists, open windows and provide adequate ventilation. If high levels of mist are encountered, use personal protective equipment indicated below.

Eye/skin protection: Have eye-washing facilities readily available where eye contact can occur. Wash skin with soap and water. Use appropriate protective gloves when handling. Showering and changing into street clothes after work is recommended.

Protective equipment for airborne mist: A NIOSH/MSHA approved dust mask or air purifying respirator with dust/mist filter is recommended where elevated concentrations of airborne mist are expected.

7. HANDLING AND STORAGE

Handling and storage precautions: Use personal protective equipment (eye & skin protection) and hygiene measures (hand washing) to minimize contact with the material.

KB-1® PLUS is shipped in stainless steel pressure vessels and connected to injection lines and inert gas is used to pressurize the vessel to displace the contents. KB-1® PLUS should be handled with care to avoid any spillage. Vessels are shipped with 1 to 5 pound per square inch (psi) pressure; valves should not be opened until connections to appropriate lines for subsurface injection are in place.

During storage, avoid exposing stainless steel pressure vessels to undue temperature extremes (i.e., temperatures less than 0°C or greater than 30°C may result in harm to the microbial cultures and damage to the vessels). All valves should be in the closed position when the vessel is not pressurized to prevent the escape of gases and to maintain anaerobic conditions in the vessel.

Incompatibilities: Avoid exposure of the culture to air as the presence of oxygen will kill the microbes.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

OSHA Permissible Exposure Limits (PELs):

ACHIH Threshold Limit Values (TLVs): No occupational exposure limits are established for microbial constituents. Mixture is not classified as “hazardous” in accordance with 29 CFR 1910.1200 “Hazard Communication,” exceedance of exposure limits is not anticipated either under normal conditions of use, or as the result of an accidental release.

Engineering controls: Generally not required under normal conditions of use. If method of use will result in significant mist generation, use under conditions of adequate ventilation.

Work practices: Use good hygiene practices, avoid mist generation, and minimize contact with the material as a general precautionary measure.

Personal protective equipment:	Under normal conditions of use, wear safety glasses, protective gloves (latex, vinyl or nitrile) and steel toed footwear as general precautionary measures, particularly when opening pressure vessel valves or when pressurizing vessels to inject contents into the subsurface environment. For laboratory use, also wear lab coat. For higher risk of eye contact, wear safety goggles or face shield, as appropriate. Respiratory protection is not required under normal conditions of use (see Section 6, "Accidental Release Measures."

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance, physical state:	Aqueous liquid, dark grey, slightly turbid under anaerobic conditions, pink if exposed to air (oxygen).
Odor:	Pungent ("skunky") odor.
Solubility:	Soluble in water.
pH:	6.5 – 7.5
Melting range	Not determined, approximately equivalent to water.
Vapor density:	Not determined, approximately equivalent to water.
Vapor pressure:	Not determined, approximately equivalent to water.
Relative density:	Not determined, approximately equivalent to water.
Evaporation rate:	Not determined, approximately equivalent to water.
Initial Boiling point, boiling range	Not determined, approximately equivalent to water.
Flammability	Not flammable.
Partition coefficient	Not Applicable.
Auto-ignition temperature	Not Applicable.
Decomposition temperature:	No data, bacterial contents will decompose by heating.
Flash point	Not Applicable.
Flammable limits	Not Applicable.

10. STABILITY AND REACTIVITY

Chemical stability and reactivity:	Stable and non-reactive.
Possibility of hazardous reactions:	Stable. Spontaneous hazardous chemical reactions / decomposition will not occur.
Conditions to avoid:	Maintain under anaerobic conditions to preserve product integrity (exposure to air/oxygen will kill microbes).
Incompatible materials:	Strong oxidizers, acids, water reactive materials.
Hazardous decomposition products:	Not applicable.
Shock sensitivity:	Not shock sensitive; will not decompose and form shock sensitive compounds.

11. TOXICOLOGICAL INFORMATION

Potential for pathogenicity: KB-1® PLUS has tested **negative** (i.e., the organisms are not present) for a variety of pathogenic organisms indicated below:

Pathogenic Organisms	Disease(s) Caused	Test Results
Salmonella sp.	Typhoid fever, gastroenteritis	Not Detected
Listeria monocytogenes	Listerioses	"
Vibrio sp.,	Cholera, gastroenteritis	"
Campylobacter sp.,	Bacterial diarrhea	"
Clostridia sp.,	Food poisoning, botulism, tetanus, gas gangrene	"
Bacillus anthracis	Anthrax	"
Pseudomonas aeruginosa	Wound infection	"
Yersinia sp.,	Bubonic plague, intestinal infection	"
Yeast and Mold	Candidiasis, yeast infection, etc.	"
Fecal coliforms	Indicator organisms for many human pathogens diarrhea, urinary tract infections	"
Enterococci	Various opportunistic infections	"

While there is no evidence that virulent pathogenic organisms are present in KB-1® PLUS, there is potential that certain organisms in KB-1® PLUS may have the potential to act as opportunistic (mild) pathogens, particularly in individuals with open wounds and/or compromised immune systems. For this reason standard hygienic procedures such as hand washing after use should be observed.

12. ECOLOGICAL INFORMATION

This product is not rated as "hazardous" as either an acute or chronic ecological hazard, in accordance with the OSHA Hazard Communication standard, 29 CFR 1910.1200.

13. DISPOSAL CONSIDERATION

Material must be disinfected or sterilized prior to disposal. Consult local regulations prior to disposal.

14. TRANSPORT INFORMATION

U.S. (D.O.T.):	Proper Shipping Name:	Culture of Micro-organisms
	Hazard Class:	Not Applicable
	UN/NA:	Not Applicable
	Labels:	Not Applicable
Canada (T.D.G.)	Proper Shipping Name:	Culture of Micro-organisms
	Hazard Class:	Not Applicable
	UN/NA:	Not Applicable
	Labels:	Not Applicable

International:		
IMDG:	Proper Shipping Name:	Culture of Micro-organisms
	Hazard Class:	Not Applicable
	UN/NA:	Not Applicable
	Labels:	Not Applicable
IATA:	Proper Shipping Name:	Culture of Micro-organisms
	Hazard Class:	Not Applicable
	UN/NA:	Not Applicable
	Labels:	Not Applicable

15. REGULATORY INFORMATION

TSCA:	No

SARA TITLE III

Section 302 (EHS) Ingredients:	No
Section 313 Ingredients:	No
Section 304 (EHS/CERCLA) Ingredients:	No

SARA TITLE III NOTIFICATION INFORMATION

Acute Health Hazard:	No
Chronic Health Hazard:	No
Fire Hazard:	No
Sudden Release of Pressure Hazard:	No

16. OTHER INFORMATION

SiREM provides the information contained herein for hazard communication and safety planning purposes, based on existing information on each of the product components available in the literature; no independent testing was conducted on the final product. The above information is intended to be used only as a guide to the appropriate precautionary handling of this material by a properly trained person.

SAFETY DATA SHEET

KB-1® Primer

Prepared according to U.S. OSHA, CMA, ANSI, Canadian WHMIS, Australian WorkSafe, Japanese Industrial Standard JIS Z 7250:2000, and European Union REACH Regulations

SECTION 1 - PRODUCT AND COMPANY IDENTIFICATION

1.1 PRODUCT NAME:	**KB-1® Primer**
PRODUCT CODE:	N/A
CHEMICAL FAMILY NAME:	Mixture
U.N. NUMBER:	None
U.N. DANGEROUS GOODS CLASS:	Not Regulated
1.2 PRODUCT USE:	For preparation of anaerobic water for use in groundwater remediation. KB-1® products are intended for laboratory research and field applications for groundwater remediation, and are not intended to be used as human or animal therapeutics, cosmetics, agricultural or pesticidal products, food additives, or as household chemicals.
1.3 SUPPLIER/MANUFACTURER'S NAME:	**SiREM**
ADDRESS:	130 Stone Road, West, Guelph, Ontario Canada N1G 3Z2
1.4 EMERGENCY PHONE:	519-515-0840
BUSINESS PHONE:	519-515-0840 (Product Information)
WEB SITE:	www.siremlab.com
1.5 DATE OF PREPARATION:	December 05, 2018
DATE OF LAST REVISION:	New

SECTION 2 - HAZARDS IDENTIFICATION

2.1 Classification of the mixture:

This product does meet the definition of a hazardous substance or preparation as defined by 29 CFR 1910. 1200 AND the European Union Council Directives 67/548/EEC, 1999/45/EC, 1272/2008/EC, 2015/830/EU and subsequent Directives.

Component(s) Contributing to Classification(s)

L-Cysteine

2.2 GHS Label elements, including precautionary statements:

Pictogram(s):

None applicable.

Signal Word:

Warning!

GHS Hazard Classification(s):

Acute Toxicity Category 5 (Oral)

Hazard Statement(s):

H303: May be harmful if swallowed

Prevention Statement(s):

None Applicable

Response Statement(s):

P312: Call a POISON CENTER/doctor if you feel unwell.

Storage Statement(s):

None Applicable

Disposal Statement(s):

None Applicable.

2.3 Other Hazards:

This mixture does not meet the criteria for PBT or vPvB in accordance with Annex VII.

SECTION 3 - COMPOSITION and INFORMATION ON INGREDIENTS

3.1 Substances: Not applicable

3.2 Mixtures:

HAZARDOUS INGREDIENTS:	CAS #	EINECS #	Index #	WT %	GHS CLASSIFICATION
L-Cysteine	52-90-4	200-158-2	Not Listed	1-10%	ACUTE TOX. CAT 4 (ORAL)
Balance of other ingredients are non-hazardous or hazardous below the applicable cut-off level.					

Additional Information: See SECTION 16 for full classification phrases.

SECTION 4 - FIRST-AID MEASURES

4.1 Description of first aid measures:

Contaminated individuals of chemical exposure must be taken for medical attention if any adverse effect occurs. Rescuers should be taken for medical attention, if necessary. Take copy of label and SDS to health professional with contaminated individual.

EYE CONTACT: If product enters the eyes, open eyes while under gentle running water for at least 15 minutes. Seek medical attention if irritation persists.

SKIN CONTACT: Wash skin thoroughly after handling. Seek medical attention if irritation develops and persists. Remove contaminated clothing. Launder before re-use.

INHALATION: If breathing becomes difficult, remove victim to fresh air. If necessary, use artificial respiration to support vital functions. Seek medical attention.

INGESTION: If product is swallowed, call physician or poison control center for most current information. If professional advice is not available, do not induce vomiting. Never induce vomiting or give diluents (milk or water) to someone who is unconscious, having convulsions, or who cannot swallow. Seek medical advice. Take a copy of the label and/or SDS with the victim to the health professional.

4.2 Most important symptoms and effects, both acute and delayed:

May be harmful if swallowed. See section 11 for additional information.

MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE: Pre-existing skin problems may be aggravated by prolonged or repeated contact.

4.3 Indication of immediate medical attention and special treatment needed:

Treat symptoms and reduce over-exposure.

SECTION 5 - FIRE-FIGHTING MEASURES

5.1 Extinguishing media:

Use media suitable for surrounding area. Carbon dioxide, foam, dry chemical, halon, water spray.

5.2 Specific hazards arising from the chemical:

No data available for this product.

Explosion Sensitivity to Mechanical Impact:	Not Sensitive.
Explosion Sensitivity to Static Discharge:	Not Sensitive
Minimum Ignition Energy (M.I.E.)	No Data at this time

5.3 Special firefighting Procedure:

Incipient fire responders should wear eye protection. Structural firefighters must wear Self-Contained Breathing Apparatus and full protective equipment. Isolate materials not yet involved in the fire and protect personnel. Move containers from fire area if this can be done without risk; otherwise, cool with carefully applied water spray. If possible, prevent runoff water from entering storm drains, bodies of water, or other environmentally sensitive areas.

SECTION 6 - ACCIDENTAL RELEASE MEASURES

6.1 Personal precautions, protective equipment and emergency procedures:
No action shall be taken involving any personal risk or without suitable training. Do not touch or walk through spilled material. Avoid breathing dust. Provide adequate ventilation. Use appropriate respirator when ventilation is inadequate and use personal protective clothing as described in Section 8 of this safety data sheet. See section 11 for additional information on health hazards.

6.2 Environmental precautions:
No specific data available for this product.

6.3 Methods and material for containment and cleaning up:
Wear suitable protective clothing. Avoid dust formation. Avoid breathing dust. Carefully sweep up and remove. Place material in a dry container and cover. Remove from the area. Flush spill area with water. Do not let products enter drains. Dispose of in accordance with applicable Federal, State, and local procedures (see Section 13, Disposal Considerations).

SECTION 7 - HANDLING and STORAGE

7.1 Precautions for safe handling:
As with all chemicals, avoid getting this product ON YOU or IN YOU. Wash thoroughly after handling this product. Do not eat, drink, smoke, or apply cosmetics while handling this product. Use in a well-ventilated location. Remove contaminated clothing immediately

7.2 Conditions for safe storage, including any incompatibilities:
Store in a tightly sealed container in a cool, dry and well-ventilated place. Store away from direct light. Avoid generation of dust. Do not breathe dust. Wash thoroughly after handling. In case of contact with eyes, rinse immediately with plenty of water and seek medical advice. Wear suitable protective clothing. Segregate from strong oxidizing agents, acids, bases.

7.3 Specific end uses:
See section 1.2.

SECTION 8 - EXPOSURE CONTROLS - PERSONAL PROTECTION

8.1. Control parameters:

EXPOSURE LIMITS/GUIDELINES: None established for this product.

8.2 Exposure Controls:
Currently, International exposure limits are not established for the components of this product. Please check with competent authority in each country for the most recent limits in place.

VENTILATION AND ENGINEERING CONTROLS: Generally not required under normal conditions of use. If method of use will result in significant dust generation, use in lab hood or under conditions of adequate ventilation.
The following information on appropriate Personal Protective Equipment is provided to assist employers in complying with OSHA regulations found in 29 CFR Subpart I (beginning at 1910.132) or equivalent standard of Canada, or standards of EU member states (including EN 149 for respiratory PPE, and EN 166 for face/eye protection), and those of Japan. Please reference applicable regulations and standards for relevant details.

RESPIRATORY PROTECTION: Maintain airborne contaminant concentrations below guidelines listed above, if applicable. If necessary, use only respiratory protection authorized in the U.S. Federal OSHA Respiratory Protection Standard (29 CFR 1910.134), equivalent U.S. State standards, Canadian CSA Standard Z94.4-93, the European Standard EN149, or EU member states.

EYE PROTECTION: Safety glasses or chemical goggles as appropriate to prevent eye contact. If necessary, refer to U.S. OSHA 29 CFR 1910.133 or appropriate Canadian Standards.

HAND PROTECTION: Use chemical resistant gloves to prevent skin contact. If necessary, refer to U.S. OSHA 29 CFR 1910.138 or appropriate Standards of Canada.

BODY PROTECTION: Use body protection appropriate to prevent contact (e.g. lab coat, overalls). If necessary, refer to appropriate Standards of Canada, or appropriate Standards of the EU, Australian Standards, or relevant Japanese Standards.

SECTION 9 - PHYSICAL and CHEMICAL PROPERTIES

9.1 Information on basic physical and chemical properties:

PHYSICAL STATE:	Solid (Granules)
APPEARANCE:	White to off-white powder or granules
ODOR:	Odorless
ODOR THRESHOLD (PPM):	Not Available
pH:	6-8 (aqueous solution)
MELTING / FREEZING POINT (C°):	Not Available
BOILING POINT (C°):	Not Available
FLASH POINT:	Not Available
EVAPORATION RATE (nBuAc = 1):	Not Available
FLAMMABILITY (solid, gas):	Not Available
FLAMMABLE LIMITS (in air by volume, %):	Not Available
VAPOR PRESSURE (mmHg):	Not Available
VAPOR DENSITY (AIR=1):	Not Available
RELATIVE DENSITY	2.4 to 2.6 g/cm3, depending on formulation
SOLUBILITY IN WATER (%)	Soluble
PARTITION COEFFICIENT: N-OCTANOL/WATER:	Not Available
AUTOIGNITION TEMPERATURE:	Not Available
DECOMPOSITION TEMPERATURE:	Not Available
VISCOSITY:	Not Available
EXPLOSIVE PROPERTIES:	Not Available
OXIDISING PROPERTIES:	Not Available

9.2 Other Information:

PACKING DENSITY:	Not Available
VOC:	Not Available

SECTION 10 - STABILITY and REACTIVITY

10.1 Reactivity: See section 10.5.
10.2 Chemical Stability: Product is stable.
10.3 Possibility of Hazardous Reactions: Under normal conditions of storage and use, hazardous reactions will not occur.
10.4 Conditions to avoid: Contact with incompatibles, exposure to light, and moist air.
10.5 Incompatible materials: Strong oxidizing agents, bases.
10.6 Hazardous Decomposition Products: Carbon monoxide, carbon dioxide, nitrogen oxides, sulfur oxides, potassium oxides.

SECTION 11 - TOXICOLOGICAL INFORMATION

11.1 Information on Toxicological Effects:

TOXICITY DATA:

L-Cysteine CAS# 52-90-4
Oral LD50 1890 mg/kg Rat
Oral LD50 660 mg/kg Mouse

11.1.2 Mixtures:

Acute toxicity	Acute Toxicity Category 5 (Oral)
Skin corrosion / irritation	Based on available data, the classification criteria are not met
Serious eye damage / irritation	Based on available data, the classification criteria are not met
Respiratory or skin sensitization	Based on available data, the classification criteria are not met
Germ cell mutagenicity	Based on available data, the classification criteria are not met
Carcinogenicity	Based on available data, the classification criteria are not met
Reproductive toxicity	Based on available data, the classification criteria are not met
STOT-single exposure	Based on available data, the classification criteria are not met
STOT-repeated exposure	Based on available data, the classification criteria are not met
Aspiration hazard	Based on available data, the classification criteria are not met

Other Information

POTENTIAL HEALTH HAZARDS OR RISKS FROM EXPOSURE:

ACUTE:

EYE CONTACT: Eye exposure may produce irritation.

SKIN CONTACT: Prolonged or repeated skin exposure may cause irritation.

INHALATION HAZARDS: Inhalation of dusts may cause irritation.

INGESTION HAZARDS: May be harmful if swallowed. May cause gastrointestinal tract irritation.

CHRONIC: None Known

TARGET ORGANS: ACUTE: Organs CHRONIC: None Known

CARCINOGENICITY: None of the ingredients are found on the following lists: FEDERAL OSHA Z LIST, NTP, CAL/OSHA, IARC and therefore are not considered to be, nor suspected to be a cancer-causing agent by these agencies.

IRRITANCY OF PRODUCT: Contact with this product can be irritating to skin and eyes.

SENSITIZATION OF PRODUCT: This product is not considered a skin sensitizer.

REPRODUCTIVE TOXICITY INFORMATION: No information concerning the effects of this product and its components on the human reproductive system.

MUTAGENICITY INFORMATION: This product does not contain a component that is suspected to be a mutagenicity hazard.

SPECIFIC TARGET ORGAN TOXICITY – SINGLE EXPOSURE: Data not sufficient for classification.

SPECIFIC TARGET ORGAN TOXICITY – REPEATED EXPOSURE: Data not sufficient for classification.

ASPIRATION HAZARD: Not applicable

SECTION 12 - ECOLOGICAL INFORMATION

ALL WORK PRACTICES MUST BE AIMED AT ELIMINATING ENVIRONMENTAL CONTAMINATION.

12.1 Toxicity:

No specific data available on this product.

12.2 Persistence and Degradability:

No specific data available on this product.

12.3 Bioaccumulative Potential:

No specific data available on this product.

12.4 Mobility in Soil:

No specific data available on this product.

12.5 Results of PBT and vPvB Assessment:

No specific data available on this product.

12.6 Other Adverse Effects:

No specific data available on this product.

12.7 Water Endangerment Class:

Not believed to be water endangering in accordance with EU Guideline 91/155-EWG. At present there are no ecotoxicological assessments for this product.

SECTION 13 - DISPOSAL CONSIDERATIONS

13.1 Waste Treatment Methods:
Waste disposal must be in accordance with appropriate Federal, State, and local regulations, those of Canada, Australia, EU Member States and Japan.

SECTION 14 - TRANSPORTATION INFORMATION

14.1 Transport Information:

US DOT; IATA; IMO; ADR:

THIS PRODUCT IS NOT CLASSIFIED AS DANGEROUS GOODS AS DEFINED BY 49 CFR 172.101 BY THE U.S. DEPARTMENT OF TRANSPORTATION.

PROPER SHIPPING NAME: None
HAZARD CLASS NUMBER and DESCRIPTION: Not Regulated
UN IDENTIFICATION NUMBER: None
PACKING GROUP: None
DOT LABEL(S) REQUIRED: None
NORTH AMERICAN EMERGENCY RESPONSE GUIDEBOOK NUMBER (2016): None
MARINE POLLUTANT: This product does not contain ingredients that are classified by the DOT as a Marine Pollutant (as defined by 49 CFR 172.101, Appendix B)

TRANSPORT CANADA, TRANSPORTATION OF DANGEROUS GOODS REGULATIONS:
This product is not classified as Dangerous Goods, per regulations of Transport Canada

INTERNATIONAL AIR TRANSPORT ASSOCIATION (IATA):
This product is not classified as Dangerous Goods, by rules of IATA:

INTERNATIONAL MARITIME ORGANIZATION SHIPPING and MARITIME DANGEROUS GOODS CODE SHIPPING INFORMATION (IMO / IMDG):
This product is not classified as Dangerous Goods.

EUROPEAN AGREEMENT CONCERNING THE INTERNATIONAL CARRIAGE OF DANGEROUS GOODS BY ROAD (ADR):
This product is not classified by the United Nations Economic Commission for Europe to be dangerous goods.

SECTION 15 - REGULATORY INFORMATION

15.1 Safety, Health and Environmental Regulations/Legislation Specific for the Substance or Mixture:

UNITED STATES REGULATIONS

SARA REPORTING REQUIREMENTS: This product is not subject to the reporting requirements of Sections 302, 304 and 313 of Title III of the Superfund Amendments and Reauthorization Act., as follows: None

TSCA: All components in this product are listed on the US Toxic Substances Control Act (TSCA) inventory of chemicals.

SARA 311/312:

Acute Health: No Chronic Health: No Fire: No Reactivity: No

U.S. SARA THRESHOLD PLANNING QUANTITY: There are no specific Threshold Planning Quantities for this product. The default Federal SDS submission and inventory requirement filing threshold of 10,000 lb (4,540 kg) may apply, per 40 CFR 370.20.

U.S. CERCLA REPORTABLE QUANTITY (RQ): None

CALIFORNIA SAFE DRINKING WATER AND TOXIC ENFORCEMENT ACT (PROPOSITION 65): None of the ingredients are on the California Proposition 65 lists.

CANADIAN REGULATIONS:

CANADIAN DSL/NDSL INVENTORY STATUS: All of the components of this product are on the DSL Inventory

CANADIAN ENVIRONMENTAL PROTECTION ACT (CEPA) PRIORITIES SUBSTANCES LISTS: No component of this product is on the CEPA First Priorities Substance Lists.

CANADIAN WHMIS CLASSIFICATION and SYMBOLS: This product is categorized as per WHMIS 2015 Hazardous Product Regulations.

EUROPEAN ECONOMIC COMMUNITY INFORMATION:

EU LABELING AND CLASSIFICATION:

Classification of the mixture according to Regulation (EC) No1272/2008. See section 2 for details.

AUSTRALIAN INFORMATION FOR PRODUCT:

AUSTRALIAN INVENTORY OF CHEMICAL SUBSTANCES (AICS) STATUS: Components of this product are listed on the AICS.

STANDARD FOR THE UNIFORM SCHEDULING OF DRUGS AND POISONS: Not applicable.

JAPANESE INFORMATION FOR PRODUCT:

JAPAN INDUSTRIAL SAFETY AND HEALTH LAW: This product has been classified per the Japan Industrial Safety and Health Law. See Section 2 for the GHS Classification.

KOREA ACT ON REGISTRATION AND EVALUATION OF CHEMICAL SUBSTANCES (K-REACH): This product has been classified per K-REACH. See Section 2 for the GHS Classification.

INTERNATIONAL CHEMICAL INVENTORIES:

Listing of the components on individual country Chemical Inventories is as follows:

Asia-Pac:	Listed
Australian Inventory of Chemical Substances (AICS):	Listed
Korean Existing Chemicals List (ECL):	Listed
Japanese Existing National Inventory of Chemical Substances (ENCS):	Listed
Philippines Inventory if Chemicals and Chemical Substances (PICCS):	Listed
Swiss Giftliste List of Toxic Substances:	Listed
U.S. TSCA:	Listed

15.2 Chemical Safety Assessment:

A chemical safety assessment has not been performed on this product.

SECTION 16 - OTHER INFORMATION

HMIS Rating (Scale 0-4)	**NFPA Rating (Scale 0-4)**
Health hazard: 1	Health hazard: 1
Flammability: 0	Flammability: 0
Physical Hazard: 0	Physical Hazard: 0

Caution: HMIS and NFPA ratings are based on a 0-4 rating scale

0= Minimal Hazard
1= Slight
2= Moderate
3= High
4= Extreme

Abbreviations and acronyms

ACGIH	*American Conference of Governmental Industrial Hygienists*
CFR	*Code of Federal Regulations*
DOT	*Federal Department of Transportation*
GHS	*The Globally Harmonized System of Classification and Labelling of Chemicals*
HMIS	*Hazardous Material Identification System*
HCS	*Hazard Communication Standard*
IARC	*International Agency for Research on Cancer*
IATA	*The International Air Transport Association*
ICAO	The *International Civil Aviation Organization*
IMDG	*International Maritime Dangerous Goods*
IMO	*International Maritime Organization*
LD50/LC50	*Lethal Concentration/Dose, 50 percent*
NFPA	*National Fire Protection Association*
NIOSH	*National Institute for Occupational Safety and Health*

NTP	*National Toxicology Program*
OSHA	*Occupational Safety and Health*
PEL	*OSHA Permissible Exposure Limit*
SARA	*Superfund Amendments and Reauthorization Act*
TLV	*ACGIH Threshold Limit Value*
TWA	*Time-Weighted Average*
Acute Tox	*Acute Toxicity*
Skin Corr	*Skin Corrosion*

PREPARED BY: Chris Eigbrett MSDS to GHS Compliance

History Log:
December 05, 2018 - Document creation

End of SDS Sheet

SODIUM BICARBONATE
Safety Data Sheet

1. Product Identification

Synonyms: Sodium Hydrogen Carbonate, Baking Soda
CAS No: 144-55-8
Chemical Formula: $NaHCO_3$
Recommended Use: Food ingredient, pharmaceutical, water treatment
Supplier: Terra Systems, Inc.
130 Hickman Road, Suite 1
Claymont, Delaware 19703
Telephone (302) 798-9553
Fax (302) 798-9554
www.terrasystems.net

2. Hazards Identification

Emergency Overview
Caution: None
Health Rating: 0 - None
Flammability Rating: 0 - None
Reactivity Rating: 0 - None
Contact Rating: 0 - None
Protective Equipment: Goggles; Proper Gloves
Storage Color Code: Green (General Storage)
Potential Health Effects
Inhalation: Not expected to be a health hazard. If heated, may produce vapors or mists that irritate the mucous membranes and cause irritation, dizziness, and nausea. Remove to fresh air. Possible irritant.
Ingestion: Not expected to be a health hazard via ingestion. Material is practically non-toxic. Small amounts (1-2 tablespoonfuls) swallowed during normal handling operations are not likely to cause injury as long as the stomach is not overly full; swallowing larger amounts may cause injury.
Skin Contact: Not a skin irritant.
Eye Contact: Not an eye irritant.

Chronic Exposure: Based on published studies on its effects in animals and humans, sodium bicarbonate is not teratogenic or genotoxic. Only known subchronic effect is that of a marked systemic alkalosis. Not classified as carcinogenic by NTP, IARC, OSHA, ACGIH or NIOSH.

Aggravation of Pre-existing Conditions: No information found.

3. Composition/Information on Ingredients

Ingredient	Synonyms	CAS #	Percent	Hazardous
Sodium Bicarbonate	Baking soda	144-5-8	100	No

White crystalline powder; no odor.

4. First Aid Measures

Inhalation: Not expected to require first aid measures. Remove to fresh air. Get medical attention for any breathing difficulty.

Ingestion: If large amounts were swallowed, do not induce vomiting. Give water to drink if person is conscious and get medical advice.

Skin Contact: Not expected to require first aid measures. Wash exposed area with soap and water. Get medical advice if irritation develops.

Eye Contact: Check for and remove contacts. Immediately flush eyes with plenty of water for at least 15 minutes, lifting upper and lower eyelids occasionally. Get medical attention if irritation persists.

Note to Physician: Large doses may produce systemic alkalosis and expansion in extracellular fluid volume with edema.

5. Fire Fighting Measures

Fire: Not combustible. Not considered to be a fire hazard. Isolate from heat and open flame.

Explosion: Not considered to be an explosion hazard.

Fire Extinguishing Media: Use extinguishing media suitable against surrounding fire or the cause of the fire.

Special Information: Carbon Dioxide may be generated making necessary the use of a self-contained breathing apparatus (SCBA) and full protective equipment (Bunker Gear). Carbon dioxide is an asphyxiant at levels over 5% w/w. Sodium oxide, another thermal decomposition product existing at temperatures above

1564°F is a respiratory, eye, and skin irritant. Avoid inhalation, eye and skin contact with sodium oxide dusts

6. Accidental Release Measures

Scoop up into dry, clean containers. Wash away small uncontaminated amounts of residue with water.

7. Handling and Storage

Keep in a tightly closed container, stored in a cool, dry, ventilated area. Protect against physical damage. Containers of this material are not hazardous when empty since they do vapors or harmful substances; observe all warnings and precautions listed for the product. Do not store above 49 C (120 F). Keep container tightly closed and upright when not in use to prevent leakage.

8. Exposure Controls/Personal Protection

Airborne Exposure Limits:	None established.
Ventilation System:	Not expected to require any special ventilation.
Personal Respirators (NIOSH Approved):	Dust mask required if total dust level exceeds 10 mg/m3.
Skin Protection:	Wear protective gloves and clean body-covering clothing.
Eye Protection:	Use chemical safety glasses when handling bulk material or when dusts can be generated. Provide readily accessible eye wash stations and safety showers.

9. Physical and Chemical Properties

Appearance:	White crystalline.
Molecular Weight:	84.02
Odor:	None.
Solubility:	86 g/L at 20 C.
Bulk Density:	9.94 g/cm^3 or 62 pounds/ft^3
pH:	8.2 (1% aqueous solution)
% Volatiles by volume @ 21C (70F):	Negligible.
Boiling Point:	Not applicable.
Melting Point:	Not applicable.
Flash Point (F):	Not applicable.
Autoignition Temperature:	Not flammable, will not support combustion.
Decomposition Temperature:	50 C.
Vapor Density (Air=1):	No information found.

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For More Information Call Michael Free at 302-798-9553 or Email: mfree@terrasystems.net

Vapor Pressure (mm Hg):	Not applicable.
Evaporation Rate (BuAc=1):	No information found.
Partition Coefficient (octanol/water):	No information found.

10. Stability and Reactivity

Stability:	Stable under ordinary conditions of use and storage.
Reactivity:	Not reactive under ordinary conditions. Reacts with acids to yield carbon dioxide.
Hazardous Decomposition Products:	Carbon dioxide may form when heated to decomposition at >100 C. If heated to >850 C, yields sodium oxide which should inhalation, eye and skin contact should be avoided.
Hazardous Polymerization:	Will not occur.
Incompatibilities:	Strong acids.
Conditions to Avoid:	Incompatibles. Isolate from heat and open flame.

11. Toxicological Information

Toxic Dose:	4,220 mg/kg (oral rat).
Inhalation:	High concentrations of dust may cause transient irritation to upper respiratory tract.
Ingestion:	Ingestion of small amounts is unlikely to cause any adverse effects. Ingestion of (excessive amounts) may cause vomiting, nausea, convulsions
Skin:	Repeated or prolonged contact may cause mild irritation and/or drying (defatting) of skin.
Eyes:	The material was minimally irritating to unwashed eyes and practically non-irritating to washed eyes (rabbits).

12. Ecological Information

Environmental Fate:	No information found.
Environmental Toxicity:	4,100 mg/L EC50 Daphnids. 7.100 mg/L LC50 Bluegills. 7,700 mg/L: LCt0 Rainbow trout.
Persistence:	This product is expected to persist in the environment. It is inorganic and not subject to biodegradation.
Soil Mobility:	This compound will move with groundwater until it reacts with acid.
Bioaccumulation Potential:	This product is not expected to bioaccumulate

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For More Information Call Michael Free at 302-798-9553 or Email: mfree@terrasystems.net

13. Disposal Considerations

Bury in a secured landfill in accordance with all local, state and federal environmental regulations. Empty containers may be incinerated or discarded as general trash.

14. Transport Information

Not regulated.

15. Regulatory Information

CLEAN AIR ACT SECTION 611: Material neither contains nor is it manufactured with ozone depleting substances (ODS).
FEDERAL WATER POLLUTION CONTROL ACT (40 CFR 401.15): Material contains no intentionally added or detectable (contaminant) levels of EPA priority toxic pollutants.
FOOD AND DRUG ADMINISTRATION: Generally Recognized As Safe (GRAS) direct food additive (21 CFR 184.1736).
US DEPARTMENT OF AGRICULTURE: List of Proprietary Substances - Permitted Use Codes 3A, J1, A1, G1, and L1.
CERCLA REPORTABLE QUANTITY: None
OSHA: Not hazardous under 29 CFR 1910.1200
RCRA: Not a hazardous material or a hazardous waste by listing or characteristic.
SARA TITLE III:
Section 302, Extremely Hazardous Substances: None
Section 311/312, Hazardous Categories: Non-hazardous
Section 313, Toxic Chemicals: None
Sodium Bicarbonate is reported in the EPA TSCA Inventory List.
Contains no VOCs.
NSF STANDARD 60: Corrosion and Scale Control in Potable Water. Max use 200 mg/l.

16. Other Information

NFPA Ratings:	Health: **0** Flammability: **0** Reactivity: **0**
Date Prepared:	July 18, 2014
Revision Information:	SDS Section(s) changed since last revision of document include: None.
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Prepared by: Terra Systems, Inc.
Phone Number: (302) 798-9553 (U.S.A.)

APPENDIX D

Injection Design Calculations

Dosage Calculations				
		Shallower Interval	**Deeper Interval**	**Total**
Injection Area and Injection Design Assumptions	Treatment Interval	70-82.5 ft bgs	82.5-95 ft bgs	70-95 ft bgs
		12.5	12.5	25
	Target COPC	Chloroform and methlyene chloride	Chloroform and methlyene chloride	Chloroform and methlyene chloride
	Number of Injection Locations	18	18	36
	Anticipated Radius of Influence (ROI) [ft]	15	15	15
	Treatment Area for 15-ft ROI [ft^2] [1]	707	707	707
	Treatment Volume for 15-ft ROI [ft^3] [2]	8840	8840	17680
	Assumed Total Porosity	30%	30%	30%
	Assumed Effective Porosity	25%	25%	25%
	Total Pore Volume per Location [gal] [3]	19837	19837	39674
	Total Effective Pore Volume per Location [gal] [4]	16523	16523	33046
EVO [5] Demand Calculation	Target Oil in the Pore Volume [g/L]	8	8	8
	Mass of Oil per Location [lbs] [6]	1320	1320	2639
	Mass of 60% EVO per location [lbs] [7]	2200	2200	4400
	Volume of 60% EVO per location [gal] [8]	280	280	560
	Volume of 60% EVO per foot of treatment interval [gal] [9]	22.4	22.4	22.4
	Total Volume of 60% EVO [gal] [10]	5040	5040	10080
Buffer Demand	Target Buffer Addition [g/L $NaHCO_3$]	2	2	2
	Mass of $NaHCO_3$ per location [lbs] [11]	330	330	660
	Total Mass of $NaHCO_3$ [lbs] [12]	5939	5939	11877

Notes:

COPC - chemical of potential concern
ROI - radius of influence
EVO - emulsified vegetable oil
ft - feet
gal - gallons
g/L - grams per liter
lbs - pounds
$NaHCO_3$ - sodium bicarbonate
ft bgs - feet below ground surface
% - percentage
L - liters

1 - Treatment Area for 15-ft ROI in ft^2 equals to π * (ROI in ft)^2
2 - Treatment Volume for 15-ft ROI in ft^3 equals to (Treatment Area for 15-ft ROI in ft^2) * (Treatment Interval in ft)
3 - Total Pore Volume per Location in gal equals to (Treatment Volume for 15-ft ROI in ft^3) * (7.48 gal/ft^3) * (Assumed Total Porosity)
4 - Total Effective Pore Volume per Location in gal equals to (Treatment Volume for 15-ft ROI in ft^3) * (7.48 gallon/ft^3) * (Assumed Effective Porosity)
5 - Terra Systems, Inc's EVO (SRS®-FRL), which has 60% by weight EVO.
6 - Mass of Oil per Location in lbs equals to (Total Pore Volume per Location in gal) * (3.78 L/gal) * (Target Oil in the Pore Volume in g/L) * (0.0022 lbs/g)
7 - Mass of 60% EVO per location in lbs equals to (Mass of Oil per Location in lbs) / 60%
8 - Volume of 60% EVO per location in gal equals to (Mass of 60% EVO per location in lbs) / (Density of 60% EVO 8.09 in lbs/gal)
9 - Volume of 60% EVO per foot of treatment interval in gal equals to (Volume of 60% EVO per location in gal) / (Treatment Interval in ft)
10 - Total Volume of 60% EVO in gal equals to (Volume of 60% EVO per location in gal) * (Number of Injection Locations)
11 - Mass of $NaHCO_3$ per Location in lbs equals to (Total Pore Volume per Location in gal) * (3.78 L/gal) * (Target Buffer Addition in g/L $NaHCO_3$) * (0.0022 lbs/g)
12 - Total Mass of $NaHCO_3$ in lbs equals to (Mass of $NaHCO_3$ per Location in lbs) * (Number of Injection Locations)

Bioaugmentation Culture Calculations				
		Shallower Treatment Zone	**Deeper Treatment Zone**	**Total**
Injection Area and Treatment Volume Assumptions	Injection Interval	70-82.5 ft bgs	82.5-95 ft bgs	70-95 ft bgs
		12.5	12.5	25
	Target COPC	Chloroform and methlyene chloride	Chloroform and methlyene chloride	Chloroform and methlyene chloride
	Number of Injection Locations	18	18	36
	Anticipated Radius of Influence (ROI) [ft]	15	15	15
	Treatment Area for 15-ft ROI [ft^2] [1]	707	707	707
	Treatment Volume for 15-ft ROI [ft^3] [2]	8840	8840	17680
	Assumed Total Porosity	30%	30%	30%
	Assumed Effective Porosity	25%	25%	25%
	Total Pore Volume per Location [gal] [3]	19837	19837	39674
	Total Effective Pore Volume per Location [gal] [4]	16523	16523	33046
KB-1 [5] Plus Demand Calculation	Target *Dhb* in the Pore Volume [cells/mL]	1.00E+07	1.00E+07	--
	Dhb in KB-1 Plus Culture [cells/mL]	1.00E+11	1.00E+11	--
	Volume of KB-1 Plus per location [L] [6]	7.5	7.5	15.0
	Total Volume of KB-1 Plus per location [L] [7]	135	135	270

Notes:

COPC - chemical of potential concern
ROI - radius of influence
ft - feet
gal - gallons
cells/mL - cells per milliliter
L - liter
ft bgs - feet below ground surface
% - percentage
"--" - not applicable

1 - Treatment Area for 15-ft ROI in ft^2 equals to π * (ROI in ft)^2
2 - Treatment Volume for 15-ft ROI in ft^3 equals to (Treatment Area for 15-ft ROI in ft^2) * (Treatment Interval in ft)
3 - Total Pore Volume per Location in gal equals to (Treatment Volume for 15-ft ROI in ft^3) * (7.48 gal/ft^3) * (Assumed Total Porosity)
4 - Total Effective Pore Volume per Location in gal equals to (Treatment Volume for 15-ft ROI in ft^3) * (7.48 gallon/ft^3) * (Assumed Effective Porosity)
5 - KB-1® Plus is a SiREM's commercial microbial culture, which can degrade chloroform and methylene chloride.
6 - Volume of KB-1 Plus per location in L equals to (Total Pore Volume per Location in gal) * (3.78 L/gal) * (Target *Dhb* in the Pore Volume in cells/mL)/(*Dhb* in KB-1 Plus Culture in cells/mL)
7 - Total Volume of KB-1 Plus per location in L equals to (Total Volume of KB-1 Plus per location in L) * (Number of Injection Locations)

Injection Volume Calculations				
		Shallower Treatment Zone	**Deeper Treatment Zone**	**Total**
Injection Area and Treatment Volume Assumptions	Injection Interval	70-82.5 ft bgs	82.5-95 ft bgs	70-95 ft bgs
		12.5	12.5	25
	Target COPC	Chloroform and methlyene chloride	Chloroform and methlyene chloride	Chloroform and methlyene chloride
	Number of Injection Locations	18	18	36
	Anticipated Radius of Influence (ROI) [ft]	15	15	15
	Treatment Area for 15-ft ROI [ft^2] [1]	707	707	707
	Treatment Volume for 15-ft ROI [ft^3] [2]	8840	8840	17680
	Assumed Total Porosity	30%	30%	30%
	Assumed Effective Porosity	25%	25%	25%
	Total Pore Volume per Location [gal] [3]	19837	19837	39674
	Total Effective Pore Volume per Location [gal] [4]	16523	16523	33046
Injection Volume Calculations	Target Injection Volume per Location (25% Effective Pore Volume) [gal] [5]	4131	4131	--
	Total Injection Volume [gal] [6]	74353	74353	148705
Deoxygneating Reagent(KB-1 Primer [7]) Calculation	Total KB-1 Primer [lbs] - 7 lbs per 1000 gallons anaerobic water [8]	485	485	970

Notes:

COPC - chemical of potential concern
ROI - radius of influence
ft - feet
gal - gallons
lbs - pounds
ft bgs - feet below ground surface
% - percentage
"--" - not applicable

1 - Treatment Area for 15-ft ROI in ft^2 equals to π * (ROI in ft)^2
2 - Treatment Volume for 15-ft ROI in ft^3 equals to (Treatment Area for 15-ft ROI in ft^2) * (Treatment Interval in ft)
3 - Total Pore Volume per Location in gal equals to (Treatment Volume for 15-ft ROI in ft^3) * (7.48 gal/ft^3) * (Assumed Total Porosity)
4 - Total Effective Pore Volume per Location in gal equals to (Treatment Volume for 15-ft ROI in ft^3) * (7.48 gallon/ft^3) * (Assumed Effective Porosity)
5 - Target Injection Volume per Location (25% Effective Pore Volume) in gal equals to (Total Effective Pore Volume per Location in gal) * 0.25
6 - Total Injection Volume in gal equals to (Target Injection Volume per Location (25% Effective Pore Volume) in gal) * (Number of Injection Locations)
7 - KB-1® Primer, which contains amino acids (50-70%), potassium bicarbonate (25-50%) and sodium sulfite (5-20%), will be used to generate anaerobic water.
8 - Total KB-1 Primer in lbs equals to [(Total Injection Volume in gal) - (Total Volume of 60% EVO in gal)] * (7 lbs KB-1 Primer/1000 gal anaerobic water)