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October 23, 2018

**SITE ASSESSMENT  
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Ms. Regan Rahn  
South Carolina Department of Health and Environmental Control  
Bureau of Land and Waste Management  
2600 Bull Street  
Columbia, South Carolina 29201

## SCANNED

Dear Ms. Rahn:

**Re: Bench Scale Study Report  
Bluewater Thermal Solutions LLC  
VCC # 14-6226  
Fountain Inn, South Carolina**

GHD is providing the attached Bench Scale Study Report for the Former Bluewater Thermal Solutions (Bluewater) Site located at 100 Hunts Bridge Road in Fountain Inn, South Carolina. The report presents the procedures and results from the bench scale testing to determine the effectiveness, optimal oxidant and dosage for in situ chemical oxidation (ISCO) treatment of the impacted groundwater. It also presents the proposed injection plan. Upon completion of the ISCO injection, performance groundwater monitoring will be conducted after 3 months and 6 months and the results will be incorporated in the Feasibility Study (FS) Report to support the final remedy.

An Underground Injection Control (UIC) permit application will be submitted to DHEC for obtaining permit to construct and operate the proposed injection.

Attached are two hard copies and one electronic copy (compact disk) of the report.

Please contact the undersigned or Mr. Richard Scherer with Lippes Mathias Wexler Friedman LLP for any comments or questions on the report.

We appreciate your input during the review of this report.

Sincerely,

GHD

Terefe Mazengia, PG.

TM/tb/3

Encl.

cc: Richard Scherer, Lippes Mathis Wexler Friedman, LLP  
Steven Wilsey, GHD



PM Copy

# Bench Scale Study Report

Former Bluewater Thermal Solutions  
100 Hunts Bridge Road  
Fountain Inn, South Carolina

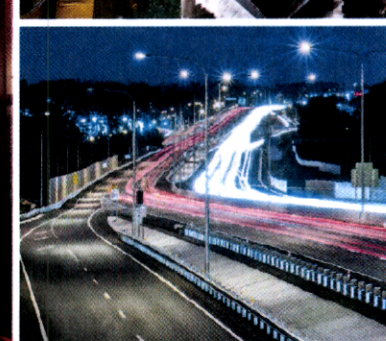
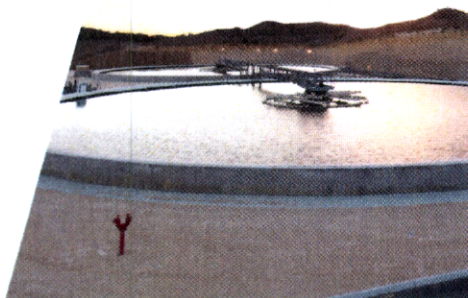
Voluntary Cleanup Contract #14-6226-RP

Lippes Mathias Wexler Friedman LLPC

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## 1. Introduction

Chlorinated volatile organic compounds (CVOC) are present in groundwater at the Bluewater Thermal Solutions Site located at 100 Hunts Bridge Road, Fountain Inn, South Carolina (Site). Bench scale testing in GHD's Innovative Technology Group (ITG) laboratory was performed to determine the effectiveness, optimal oxidant and dosage for in situ chemical oxidation (ISCO) treatment of the impacted groundwater. Treatment of the CVOC impacted groundwater will be based on the results of the bench scale testing. This report contains the results from the bench scale testing and proposed injection plan.

## 2. Technology Descriptions

ISCO is an effective method for treating localized high concentrations of a wide range of organic compounds, including CVOC. In an oxidation reaction, the oxidizing agent breaks the carbon bonds in the compounds and converts them into nonhazardous compounds, primarily carbon dioxide and water. Commonly used oxidizing reagents include potassium permanganate (KMnO<sub>4</sub>), Fenton's Reagent (hydrogen peroxide in a solution of ferrous salts), catalyzed sodium persulfate, and ozone.

KMnO<sub>4</sub> and Fenton's Reagent and catalyzed sodium persulfate are effective when delivered in an aqueous solution and react with a wide range of organic compounds. They are inexpensive and readily available in large quantities. ISCO is Site specific, and successful treatment is typically a function of the effectiveness of the delivery system (being able to deliver sufficient amounts of oxidant to the impacted soil and groundwater and making sufficient "contact") and subsequent transport of the oxidant within the soil and groundwater. The treatment performance is dependent to a great extent on the soil chemistry. A critical factor in the evaluation of ISCO treatment is determining the dosages of oxidant that are required to effectively oxidize the hydrocarbon compounds present (referred to as stoichiometric demand) as well as the competing reactions. The competing reactions are typically caused by the presence of natural organic materials such as humates and fulvates, as well as reduced metal species. The consumption of oxidants by these non-target compounds is defined as natural oxidant demand (NOD). In order to determine the optimum dosage, treatability studies are required. Large quantities of oxidizing chemicals require regulated handling and may pose health and safety concerns. Chemical oxidation may cause mobilization of metals and possible formation of toxic byproducts, heat, gas, and biological perturbation.

Fenton's Reagent is effective for the treatment of volatile organic compounds (VOC). However, the Fenton's Reagent reaction is exothermic, and the heat generated can cause volatilization of compounds. It also requires a pH of 5 pH units and ferrous sulfate catalyst. Base catalyzed sodium persulfate can be injected at concentrations up to 30 percent. It can oxidize a wide range of organic compounds including chlorobenzenes and will continue to oxidize organic material for up to a month.

Sodium persulfate and KMnO<sub>4</sub> were selected as the oxidant for testing in this study because they are effective for treatment of the compounds present at the Site, are easy to handle and can be injected at fairly high concentrations.



### 3. **Treatability Study Objectives**

The primary objectives of this laboratory study were to gather the data necessary to:

- i) Determine effectiveness of chemical oxidation for the treatment of CVOC
- ii) Assess the total oxidant demand (TOD) of the soil
- iii) Assess the potential of the chemical oxidants to solubilize metals into groundwater
- iv) Determine the most effective oxidant and dose for chemical oxidation

### 4. **Treatability Study**

#### 4.1 **Sample Acquisition**

The treatability study was conducted using representative groundwater samples collected from monitoring well MW-1 and soil samples collected from the immediate vicinity of MW-1 below the water table. Three gallons of groundwater and 29 pounds (lb) of soil were collected from the Site. These samples were shipped to the GHD laboratory in Niagara Falls, New York and received on August 23, 2018. Soil and groundwater sample locations are shown on Figure 1.

#### 4.2 **Task 1: Initial Characterization**

Upon receipt by the laboratory, the groundwater and soil samples were analyzed for:

- pH USEPA SW846 9040C (Water) USEPA SW846 9045D (Soil)
- CVOC USEPA SW846 8260B/5030B (Water) USEPA SW846 8260B/5035 (Soil)

The soil and groundwater analytical results provided characterization of the baseline conditions for the treatability study.

In the groundwater, tetrachloroethene (PCE) was present at 4,090 micrograms per liter ( $\mu\text{g/L}$ ), trichloroethene (TCE) present at 113  $\mu\text{g/L}$ , cis 1,2 dichloroethene (cis 1,2 DCE) present at 8.82  $\mu\text{g/L}$ , chloroform present at 2.7  $\mu\text{g/L}$ , and 1,1 dichloroethene (1,1 DCE) present at 2.14  $\mu\text{g/L}$ . The pH was at 4.55 standard units (S.U.). These data are shown in Table 1.

In the soil, PCE was present at 354 micrograms per kilogram ( $\mu\text{g/kg}$ ) and TCE was estimated at 24.5  $\mu\text{g/kg}$ . All other CVOC were below their analytical detection limit. The pH was 5.22 S.U. These data are shown in Table 2.

#### 4.3 **Task 2: Chemical Oxidation Microcosm Tests**

A series of batch microcosm tests were performed using the groundwater and soil samples. The tests were designed to assess the effectiveness of chemical oxidation for treatment of soil and groundwater and to determine the most effective concentration of the oxidant to be used for the full scale application.





In order to determine the amount of sodium hydroxide (NaOH) required to adjust the groundwater to 11.5 S.U., the groundwater was titrated to a pH of 11.5 S.U. with NaOH. The groundwater sample required 0.20 gram (g) of NaOH per liter of groundwater to reach a pH of 11.5 S.U. In order to determine the amount of NaOH required to adjust the pH of the soil to 11.5 S.U., the soils were titrated to a pH of 11.5 S.U. with NaOH. The soil sample required 0.875 g of NaOH per kilogram of soil.

The groundwater microcosm tests consisted of placing 100 milliliters (mL) of groundwater in 125 mL serum bottles and mixing with 10 mL of sodium persulfate solution. The sodium persulfate solutions contained sodium persulfate at concentrations of 1 percent, 5 percent, and 10 percent. A second set of groundwater microcosm tests were set up using KMnO<sub>4</sub>. These solutions were made up and added to the groundwater at 0.5 percent, 1 percent, and 2 percent. No catalyst was added to the KMnO<sub>4</sub> microcosms. Control tests were prepared similarly but without the use of an oxidizing agent solution. The bottles were sealed immediately to prevent the loss of chemicals by volatilization and incubated in the dark at 20°C for 3 weeks.

The soil microcosm tests consisted of placing 100 g of soil in 4 ounce (oz.) glass jars and mixing with 25 mL of catalyzed sodium persulfate solutions. The sodium persulfate solutions contained sodium persulfate at concentrations of 1 percent, 5 percent, and 10 percent. The tests received NaOH as a catalyst. NaOH was added to adjust the soil pH to 11.5, and 2 moles of NaOH were added for every mole of sodium persulfate added. A second set of soil microcosm tests were set up using KMnO<sub>4</sub>. These solutions were made up and added to the soil at 1 percent, 2 percent, and 3 percent. No catalyst was added to the KMnO<sub>4</sub> microcosms. Control tests were prepared similarly but without the use of an oxidizing agent solution. The bottles were sealed immediately to prevent the loss of chemicals by volatilization and incubated in the dark at 20°C for 3 weeks.

The results from the analyses of groundwater microcosms that received NaOH catalyzed sodium persulfate showed 1,1 DCE cis 1,2 DCE, chloroform, and TCE being treated to below their analytical detection limits at all concentrations of sodium persulfate. Greater than 82 percent removal of PCE was observed at all concentrations of sodium persulfate. Treatment with sodium persulfate at a loading rate of 10 grams per liter (g/L) resulted in the lowest concentration of PCE at 3.22 µg/L. These data are shown in Table 3.

The results from the analyses of groundwater microcosms that received KMnO<sub>4</sub> showed 1,1 DCE cis 1,2 DCE, TCE, and PCE being treated to below their analytical detection limits at all concentrations of KMnO<sub>4</sub>. Chloroform concentrations were similar to the control at all concentrations of KMnO<sub>4</sub> resulting in 2.14 µg/L of chloroform remaining after 2 percent KMnO<sub>4</sub> treatment. These data are shown in Table 4.

The results from the analyses of soil microcosms that received NaOH catalyzed sodium persulfate and KMnO<sub>4</sub> showed treatment of PCE to below its analytical detection limit at all concentrations of either product. Therefore, the lowest loading rate used of 2.5 g of sodium persulfate or KMnO<sub>4</sub> per kilogram of soil were effective for the removal of PCE to below its detection limit. These data are shown in Tables 5 and 6.



#### 4.4 Task 3: Total Oxidant Demand

The TOD of the soil samples was assessed by placing 50 g of soil in 4 oz. jars and adding 100 mL of NaOH catalyzed sodium persulfate and  $\text{KMnO}_4$  as described above.

The initial oxidant concentrations in the jars were measured and recorded. After 1 week, the jars were sampled again, and the residual oxidant concentrations were measured and recorded.

The assessed TOD of the sample was 55 g/kg for NaOH catalyzed sodium persulfate and 13 g/kg for  $\text{KMnO}_4$ . These data are shown in Table 7.

#### 4.5 Task 4: Metals Leaching Test

In order to assess the potential for solubilization of metals as a result of the chemical oxidation treatment, metals leaching tests were conducted. The tests were conducted on soil samples in 8 oz. glass reactor jars. Fifty grams of soil were placed in a reactor, followed by 100 mL of a 1 percent (w/w) solution sodium persulfate catalyzed by NaOH and  $\text{KMnO}_4$  as described above. The control tests were prepared similarly by using distilled water instead of oxidizing agent. The supernatant samples were analyzed for dissolved metals.

Treatment with NaOH catalyzed sodium persulfate resulted in the solubilization of aluminum, chromium, and manganese. Treatment with  $\text{KMnO}_4$  resulted in the solubilization of aluminum, barium, chromium, nickel, selenium, and thallium. These data are shown in Table 8.

These results represent a worst case scenario because the oxidant concentrations in the tests were significantly higher than would be encountered in the field. Also, GHD's experience with metals solubilization during chemical oxidation has been that the solubilization of metals from soil is temporary and that metals do not migrate out of the treatment area. Once the highly oxidizing conditions in the treatment area have been exhausted, the solubilized metals reprecipitate immediately.

It is expected that any metals solubilized by the proposed ISCO injection will attenuate within a year of the final ISCO injection and that metals will not be transported out of the injection area.

## 5. Summary

### *Chemical Oxidation Microcosm Tests*

- Treatment with both base-catalyzed sodium persulfate and  $\text{KMnO}_4$  were effective for treatment of most of the CVOC in groundwater and soil; however, treatment with base-catalyzed sodium persulfate resulted in treatment of all CVOC including chloroform.
- The TOD for NaOH catalyzed sodium persulfate was 55 g/kg and 13 g/kg for  $\text{KMnO}_4$ .
- Treatment with NaOH catalyzed sodium persulfate resulted in the solubilization of aluminum, chromium, and manganese. Treatment with  $\text{KMnO}_4$  resulted in the solubilization of aluminum, barium, chromium, nickel, selenium, and thallium. These metals are expected to reprecipitate once the highly oxidizing conditions abate.



## 6. Conclusion

The results of the ISCO testing showed that ISCO was an effective treatment for reducing the concentrations of PCE and its daughter products in the groundwater and soil. NaOH catalyzed sodium persulfate would be the recommended oxidant as it was found to be effective for all CVOC present in the groundwater during the treatability study. The TOD of the soil for base catalyzed sodium persulfate was 55 g/kg. The results of the study suggest that the entire TOD for the soil will not need to be met in order for successful treatment to occur. The results suggest that only 10 percent of the TOD will need to be met in order for successful treatment to occur.

## 7. Injection

The injection will consist of one application of the oxidant to the CVOC plume area.

In order to treat the area between MW-5-16 and BH-3 (approximate area of 500 µg/L contour), it would be necessary to treat an area of approximately 13,500 square feet. A 20 foot radius of influence (ROI) in the saprolite material is expected; therefore, 13 direct push technology (DPT) injection locations would be required. Injections would be made between 19 and 34 feet below ground surface (bgs). Proposed DPT injection locations are shown on Figure 2.

For treatment with sodium persulfate, 2,680 gallons of a 15 percent sodium persulfate solution containing 3,580 lb of sodium persulfate will be mixed immediately before injection with 800 gallons of 25 percent NaOH and injected at each location during the injection event.

### 7.1 Reagent and Injection

Design of the treatment consists of 13 DPT injection points each with a potential ROI of 20 feet, and a 15 foot saturated thickness (between 19 and 34 feet bgs) of groundwater where treatment is planned. The aquifer has an estimated porosity of 30 percent. A conservative factor of 10 percent of the pore volume is used in the calculation in order to prevent disruption of aquifer flow, potential mounding of the water table, and the potential for mobilizing the impacted groundwater plume. As per the calculation below, the total volume of reagent that the aquifer can accept at one time is approximately 4,230 gallons:

Conversion to dose per volume

5.5 g/kg soil = 2.5 g/lb of soil

1 cubic yard of soil weighs 3024 lb

Therefore, the dose for 1 cubic yard of soil is 7560 g of sodium persulfate = 7.56 kg of sodium persulfate = 16.6 lb of sodium persulfate

Therefore the theoretical volume to be treated by each injection point is:

$20 \text{ ft} * 20 \text{ ft} * 3.14 * 15 \text{ ft} = 18,840 \text{ cubic feet} = 698 \text{ cubic yards}$





The total volume of reagent that can be injected at one time is approximately 4,230 gallons per injection point as shown below:

$$20 \text{ ft} * 20 \text{ ft} * 3.14 * 15 \text{ ft} = 18840 \text{ cubic feet} = 141,017 \text{ gallons}$$

$$\text{Using a 30 percent porosity, pore volume} = 141,017 * 0.3 = 42,305 \text{ gallons}$$

$$10 \text{ percent of pore volume} = 42,277 \text{ gallons} * 0.1 = 4,230 \text{ gallons}$$

Based on 90 percent of the above, the solution to be initially injected into each injection point will consist of approximately 2,680 gallons of 15 percent sodium persulfate. NaOH solution will be injected to activate the sodium persulfate. Approximately 800 gallons of 25 percent NaOH solution will be injected into each injection point.

Injection point installation, reagent mixing and injection will be conducted by qualified experienced contractors under the direct supervision of GHD. During the injection event, volume, flow rate, and pressure will be monitored at the injection points and the monitoring wells will be monitored to evaluate field parameters and water levels at the time of injection. Recommended injection flow rates may not exceed 10 gallons per minute (gpm) and pressures will be maintained to 25 psi or less.

## **7.2 Performance Groundwater Monitoring**

Groundwater monitoring will be conducted at monitoring wells MW-1S-16, MW-5-16 and two proposed temporary monitoring wells which will be installed downgradient of the plume in the vicinity of the former TW-3 and TW-8 wells. The two temporary monitoring wells will be constructed with the same total depth to MW-1S-16 and with standard 1-inch diameter PVC casing with 10-foot machine slotted #10, schedule 40 PVC screen. Proposed temporary well locations and groundwater performance sampling locations are shown on Figure 3.

Groundwater monitoring will be conducted three months and six months following completion of the injection. The sampling frequency may be adjusted depending on results and data variability.

Pre-injection and during injection monitoring will be limited to water level and field parameter measurements in select monitoring wells (MW-1S-16, MW-2-16 and MW-5-16).

Post injection monitoring will include the following parameters at monitoring wells MW-1S-16, MW-5-16 and the two proposed temporary monitoring wells:

- CVOC (USEPA Method 8260B);
- Residual Persulfate (field test kit);
- Sulfate (USEPA Method 9056)
- pH (field instrument);
- Dissolved Oxygen (DO) (field instrument);
- Oxygen Reduction Potential (ORP) (field instrument);
- Conductivity (field instrument); and
- Static water level.



## **8. Certification**

In accordance with Section 3 (RESPONSE ACTION) of the VCC 14-6226-RP, this Groundwater Treatability Report is signed as sealed below by a Professional Geologist duly-licensed in the State of South Carolina.



## Professional Geologist Statement

I certify that I am a qualified groundwater scientist who has received a baccalaureate or postgraduate degree in the natural sciences or engineering, and have sufficient training and experience in groundwater hydrology and related fields, as demonstrated by state registration and completion of accredited university courses, that enable me to make sound professional judgments regarding groundwater monitoring and contaminant fate and transport. I further certify that this Groundwater Bench Scale Study Report was prepared in conjunction with others working under my direction.



Terefe Mazengia, PG # 2573

Printed Name (Professional Geologist)

Signature (Professional Geologist)

# Figures



figure 1  
TREATABILITY SAMPLE LOCATIONS  
BLUEWATER THERMAL SOLUTIONS  
*Fountain Inn, South Carolina*



SOURCE:  
ARCADIS SITE PLAN FIGURE 2

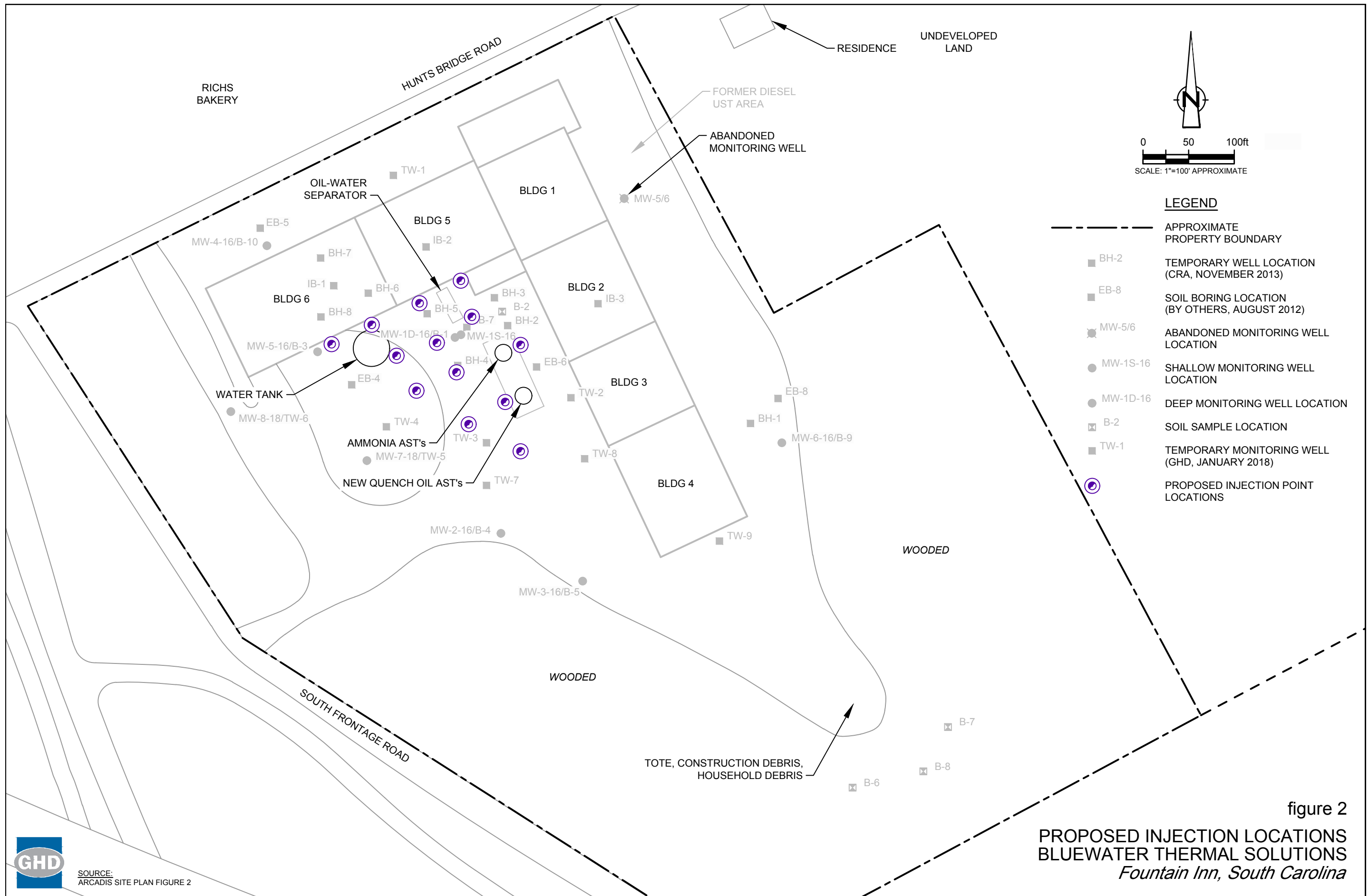
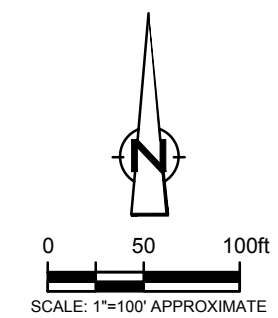
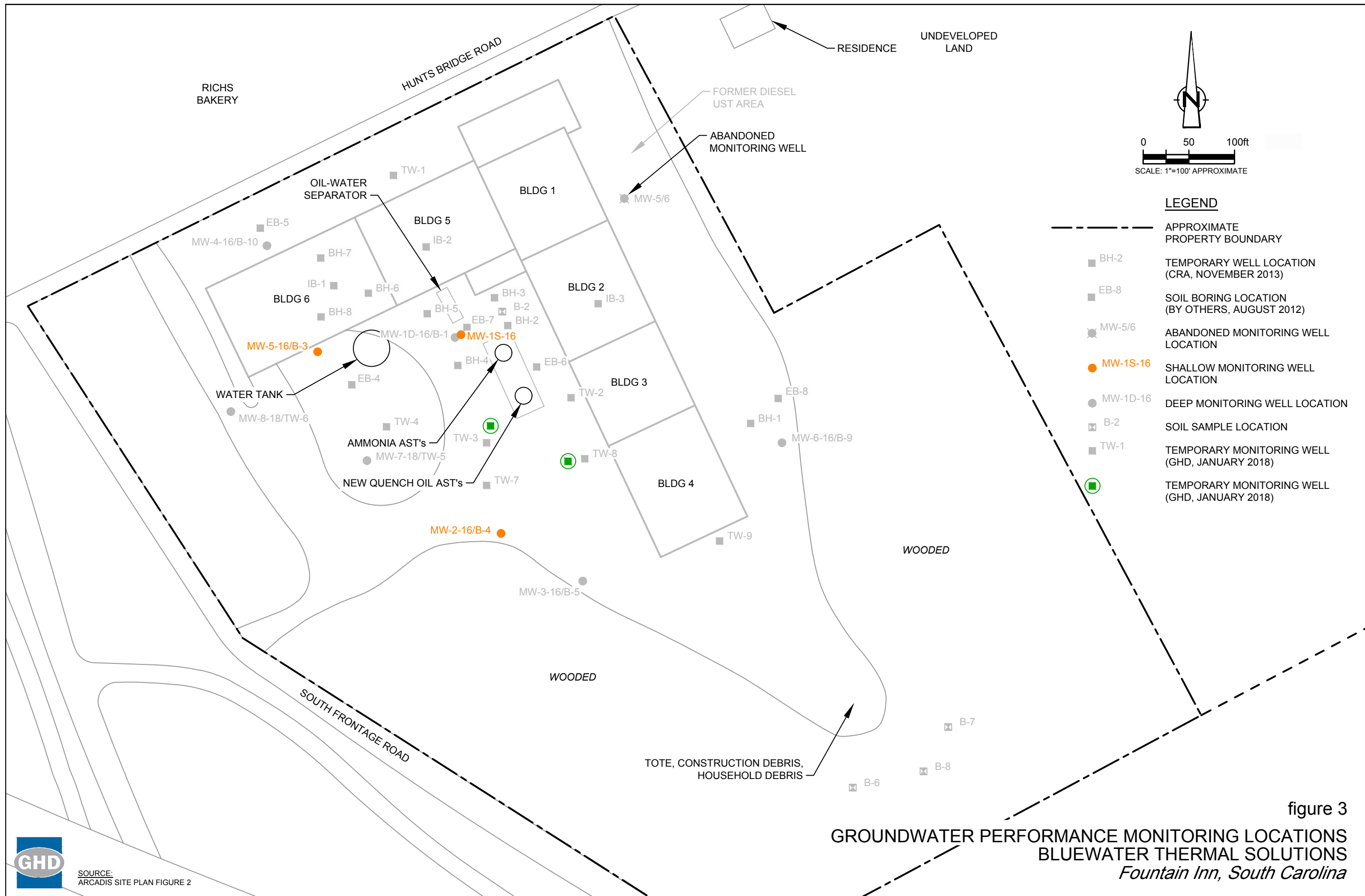


figure 2  
**PROPOSED INJECTION LOCATIONS**  
**BLUEWATER THERMAL SOLUTIONS**  
*Fountain Inn, South Carolina*



SOURCE:  
 ARCADIS SITE PLAN FIGURE 2





- LEGEND**
- APPROXIMATE PROPERTY BOUNDARY
  - BH-2 TEMPORARY WELL LOCATION (CRA, NOVEMBER 2013)
  - EB-8 SOIL BORING LOCATION (BY OTHERS, AUGUST 2012)
  - MW-5/6 ABANDONED MONITORING WELL LOCATION
  - MW-1S-16 SHALLOW MONITORING WELL LOCATION
  - MW-1D-16 DEEP MONITORING WELL LOCATION
  - ⊠ B-2 SOIL SAMPLE LOCATION
  - TW-1 TEMPORARY MONITORING WELL (GHD, JANUARY 2018)
  - TEMPORARY MONITORING WELL (GHD, JANUARY 2018)

figure 3  
**GROUNDWATER PERFORMANCE MONITORING LOCATIONS**  
**BLUEWATER THERMAL SOLUTIONS**  
*Fountain Inn, South Carolina*



SOURCE:  
 ARCADIS SITE PLAN FIGURE 2

# Tables

**Table 1**

**Initial Groundwater Sample Characterization  
Bench Scale Study Report  
Bluewater Thermal Solutions  
Fountain Inn, South Carolina**

<b>Parameters</b>	<b>Units</b>	<b>Water</b>
<b>General Chemistry</b>		
pH	S.U.	4.55
<b>Volatile Organic Compounds (VOCs)</b>		
1,1-Dichloroethene	µg/L	2.14
cis-1,2-Dichloroethene	µg/L	8.82
Chloroform	µg/L	2.7
Tetrachloroethene	µg/L	4090
Trichloroethene	µg/L	113

**Notes:**

S.U. - Standard Units

**Table 2**

**Initial Soil Sample Characterization  
Bench Scale Study Report  
Bluewater Thermal Solutions  
Fountain Inn, South Carolina**

<b>Parameters</b>	<b>Units</b>	<b>Soil</b>
<b>General Chemistry</b>		
pH	S.U.	5.22
<b>Volatile Organic Compounds (VOCs)</b>		
1,1-Dichloroethene	µg/kg	ND (50)
cis-1,2-Dichloroethene	µg/kg	ND (50)
Chloroform	µg/kg	ND (50)
Tetrachloroethene	µg/kg	354
Trichloroethene	µg/kg	24.5 J

## Notes:

- J - Estimated value  
 S.U. - Standard Units  
 ND (x) - Not detected at reporting limit

Table 3

**Treatment of Groundwater with Sodium Hydroxide Catalyzed Sodium Persulfate  
Bench Scale Study Report  
Bluewater Thermal Solutions  
Fountain Inn, South Carolina**

Parameter	Units	Control	1% S <sub>2</sub> O <sub>8</sub>	5% S <sub>2</sub> O <sub>8</sub>	10% S <sub>2</sub> O <sub>8</sub>
Loading Rates	g/L	0.00	1.0	5.0	10.0
<b>Volatile Organic Compounds</b>					
1,1-Dichloroethene	µg/L	1.61 J / 1.5 J	ND (2) / ND (2)	ND (2) / ND (2)	ND (2) / ND (2)
cis-1,2-Dichloroethene	µg/L	7.24 / 6.94	ND (2) / ND (2)	ND (2) / ND (2)	ND (2) / ND (2)
Chloroform	µg/L	2.24 / 2.53	ND (2) / ND (2)	ND (2) / ND (2)	ND (2) / ND (2)
Tetrachloroethene	µg/L	2430 / 2330	454 / 418	13.7 / 12.1	4.15 / 3.49
Trichloroethene	µg/L	82.9 / 79.2	ND (2) / ND (2)	ND (2) / ND (2)	ND (2) / ND (2)
Amount of NaOH used	mL	0.00	0.08	0.08	0.08
% Removal of 1,1-Dichloroethene			>36	>36	>36
% Removal of cis-1,2-Dichloroethene			>86	>86	>86
% Removal of Chloroform			>58	>58	>58
% Removal of Tetrachloroethene			81.7	99.5	99.8
% Removal of Trichloroethene			>98	>98	>98

## Notes:

ND (x) - Not detected at reporting limit

J - Estimated value

x/x - Duplicate analysis

NaOH - Sodium Hydroxide

Table 4

**Treatment of Groundwater with Potassium Permanganate  
Bench Scale Study Report  
Bluewater Thermal Solutions  
Fountain Inn, South Carolina**

Parameter	Units	Control	0.5% KMnO <sub>4</sub>	1% KMnO <sub>4</sub>	2% KMnO <sub>4</sub>
Loading Rates	g/L	0.00	0.5	1.0	2.0
<b>Volatile Organic Compounds</b>					
1,1-Dichloroethene	µg/L	1.61 J / 1.5 J	ND (2) / ND (2)	ND (2) / ND (2)	ND (2) / ND (2)
cis-1,2-Dichloroethene	µg/L	7.24 / 6.94	ND (2) / ND (2)	ND (2) / ND (2)	ND (2) / ND (2)
Chloroform	µg/L	2.24 / 2.53	2.53 / 2.29	2.32 / 2.24	2.12 / 2.16
Tetrachloroethene	µg/L	2430 / 2330	ND (2) / ND (2)	ND (2) / ND (2)	ND (2) / ND (2)
Trichloroethene	µg/L	82.9 / 79.2	ND (2) / ND (2)	ND (2) / ND (2)	ND (2) / ND (2)
% Removal of 1,1-Dichloroethene			>36	>36	>36
% Removal of cis-1,2-Dichloroethene			>86	>86	>86
% Removal of Chloroform			<1	4.4	10.3
% Removal of Tetrachloroethene			>99	>99	>99
% Removal of Trichloroethene			>98	>98	>98

## Notes:

ND (x) - Not detected at reporting limit

J - Estimated value

x/x - Duplicate analysis



Table 5

**Treatment of Soil with Sodium Hydroxide Catalyzed Sodium Persulfate  
Bench Scale Study Report  
Bluewater Thermal Solutions  
Fountain Inn, South Carolina**

Parameter	Units	Control	1% S <sub>2</sub> O <sub>8</sub>	5% S <sub>2</sub> O <sub>8</sub>	10% S <sub>2</sub> O <sub>8</sub>
Loading Rates	g/kg	0.00	2.5	12.5	25.0
<b>Volatile Organic Compounds</b>					
1,1-Dichloroethene	µg/kg	ND (50) / ND (50)	ND (50) / ND (50)	ND (50) / ND (50)	ND (50) / ND (50)
cis-1,2-Dichloroethene	µg/kg	ND (50) / ND (50)	ND (50) / ND (50)	ND (50) / ND (50)	ND (50) / ND (50)
Chloroform	µg/kg	ND (50) / ND (50)	ND (50) / ND (50)	ND (50) / ND (50)	ND (50) / ND (50)
Tetrachloroethene	µg/kg	47.3 J / 37.4 J	ND (50) / ND (50)	ND (50) / ND (50)	ND (50) / ND (50)
Trichloroethene	µg/kg	ND (50) / ND (50)	ND (50) / ND (50)	ND (50) / ND (50)	ND (50) / ND (50)
Amount of NaOH used	mL	0.00	0.35	0.35	0.35
% Removal of Tetrachloroethene			>41	>41	>41

## Notes:

ND (x) - Not detected at reporting limit

J - Estimated value

x/x - Duplicate analysis

NaOH - Sodium Hydroxide

Table 6

**Treatment of Soil with Potassium Permanganate  
Bench Scale Study Report  
Bluewater Thermal Solutions  
Fountain Inn, South Carolina**

Parameter	Units	Control	1% KMnO <sub>4</sub>	2% KMnO <sub>4</sub>	3% KMnO <sub>4</sub>
Loading Rates	g/kg	0.00	2.5	5.0	7.5
<b>Volatile Organic Compounds</b>					
1,1-Dichloroethene	µg/kg	ND (50) / ND (50)	ND (50) / ND (50)	ND (50) / ND (50)	ND (50) / ND (50)
cis-1,2-Dichloroethene	µg/kg	ND (50) / ND (50)	ND (50) / ND (50)	ND (50) / ND (50)	ND (50) / ND (50)
Chloroform	µg/kg	ND (50) / ND (50)	ND (50) / ND (50)	ND (50) / ND (50)	ND (50) / ND (50)
Tetrachloroethene	µg/kg	47.3 J / 37.4 J	ND (50) / ND (50)	ND (50) / ND (50)	ND (50) / ND (50)
Trichloroethene	µg/kg	ND (50) / ND (50)	ND (50) / ND (50)	ND (50) / ND (50)	ND (50) / ND (50)
% Removal of Tetrachloroethene			>41	>41	>41

## Notes:

ND (x) - Not detected at reporting limit

J - Estimated value

x/x - Duplicate analysis

Table 7

**Analysis of Soil Total Oxidant Demand  
Bench Scale Study Report  
Bluewater Thermal Solutions  
Fountain Inn, South Carolina**

<b>Parameters</b>	<b>Units</b>	<b>Soil S<sub>2</sub>O<sub>8</sub></b>	<b>Soil MnO<sub>4</sub></b>
Sodium Persulfate Concentration at T=0	g/L	115	-
Sodium Persulfate Concentration at T=14 days	g/L	94	-
Amount of Sodium Persulfate Consumed by TOD per kg of soil after 7 days	g/kg	54.8	-
Sodium Permanganate Concentration T = 0	g/L	-	8.9
Sodium Permanganate Concentration T = 7 days	g/L	-	8.5
Amount of Sodium Permanganate Consumed by per kg of soil after 7 days	g/kg	-	13
Amount of 25% NaOH Used	mL	0.175	-

## Notes:

NaOH - Sodium Hydroxide

TOD - Total Oxidant Demand

- - Not applicable

Table 8

**Metals Leaching Tests  
Bench Scale Study Report  
Bluewater Thermal Solutions  
Fountain Inn, South Carolina**

<b>Parameters</b>	<b>Units</b>	<b>Control</b>	<b>S<sub>2</sub>O<sub>8</sub></b>	<b>MnO<sub>4</sub></b>
Aluminum	µg/L	ND (50)	4120	4190
Antimony	µg/L	ND (50)	ND (50)	ND (50)
Arsenic	µg/L	ND (50)	ND (50)	40 J
Barium	µg/L	ND (50)	ND (50)	1160
Beryllium	µg/L	ND (25)	ND (25)	ND (25)
Cadmium	µg/L	ND (25)	ND (25)	ND (25)
Calcium	µg/L	ND (500)	ND (500)	12900
Chromium	µg/L	ND (25)	80	29
Cobalt	µg/L	ND (50)	ND (50)	33 J
Copper	µg/L	ND (50)	ND (50)	ND (50)
Iron	µg/L	ND (100)	ND (100)	ND (100)
Lead	µg/L	ND (50)	49.9 J	46.8 J
Magnesium	µg/L	ND (200)	ND (200)	3870
Manganese	µg/L	ND (25)	76.2	804000 E
Nickel	µg/L	ND (50)	ND (50)	77.5
Potassium	µg/L	750	4150	607000 E
Selenium	µg/L	ND (100)	ND (100)	415
Silver	µg/L	ND (50)	ND (50)	95
Sodium	µg/L	3370	1260000 E	6120
Thallium	µg/L	ND (100)	ND (100)	1250
Vanadium	µg/L	ND (50)	ND (50)	ND (50)
Zinc	µg/L	ND (50)	ND (50)	35.8
Amount of 25% NaOH Added	mL	-	0.175	-

## Notes:

- ND (x) - Not detected at reporting limit
- J - Estimated value
- E - Results Above Calibration Range
- NaOH - Sodium Hydroxide
- - Not applicable



## about GHD

GHD is one of the world's leading professional services companies operating in the global markets of water, energy and resources, environment, property and buildings, and transportation. We provide engineering, environmental, and construction services to private and public sector clients.

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