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PILOT STUDY COMPLETION REPORT AND FULL-SCALE IMPLEMENTATION PLAN  
ENHANCED REDUCTIVE DECHLORINATION AREA  
OF CONCERN 607 (AOC 607) ZONE F CNC CHARLESTON SC  
7/1/2005  
CH2M HILL

PILOT STUDY COMPLETION REPORT AND FULL-SCALE IMPLEMENTATION PLAN

# Enhanced Reductive Dechlorination AOC 607, Zone F



**Charleston Naval Complex  
North Charleston, South Carolina**

SUBMITTED TO  
**U.S. Navy Southern Division  
Naval Facilities Engineering Command**

**PREPARED BY  
CH2M-Jones**

**July 2005  
Contract N62467-99-C-0960**

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January 26, 2005

Mr. David Scaturo  
South Carolina Department of Health and  
Environmental Control  
Bureau of Land and Waste Management  
2600 Bull Street  
Columbia, SC 29201

Re: Pilot Study Completion Report and Full-Scale Implementation Plan - Enhanced  
Reductive Dechlorination (Revision 0) - AOC 607, Zone F

Dear Mr. Scaturo:

Enclosed please find two copies of the Pilot Study Completion Report and Full-Scale Implementation Plan - Enhanced Reductive Dechlorination (Revision 0) for AOC 607 in Zone F of the Charleston Naval Complex (CNC). This report has been prepared pursuant to agreements by the CNC BRAC Cleanup Team for completing the RCRA Corrective Action process.

Please contact me at 352/335-5877, ext. 2280, if you have any questions or comments.

Sincerely,

CH2M HILL

Dean Williamson, P.E.

cc: Dann Spariosu/USEPA, w/att  
Rob Harrell/Navy, w/att  
Gary Foster/CH2M HILL, w/att

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# Enhanced Reductive Dechlorination AOC 607, Zone F



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North Charleston, South Carolina***

SUBMITTED TO  
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PREPARED BY  
***CH2M-Jones***

*July 2005*

*Revision 1  
Contract N62467-99-C-0960  
158814.ZF.EX.05*

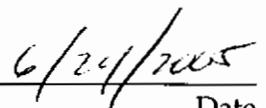
# Certification Page for Pilot Study Completion Report and Full-Scale Implementation Plan – Enhanced Reductive Dechlorination (Revision 1) – AOC 607, Zone F

I, Dean Williamson, certify that this report has been prepared under my direct supervision. The data and information are, to the best of my knowledge, accurate and correct, and the report has been prepared in accordance with current standards of practice for engineering.

South Carolina

Permit No. 21428

  
\_\_\_\_\_  
Dean Williamson, P.E.

  
\_\_\_\_\_  
Date

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# 1 Acronyms and Abbreviations

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2	AOC	area of concern
3	BRAC	Base Realignment and Closure
4	CO <sub>2</sub>	carbon dioxide
5	CA	Corrective Action
6	CMS	Corrective Measures Study
7	CNC	Charleston Naval Complex
8	COC	chemical of concern
9	CSAP	Confirmatory Sampling and Analysis Plan
10	CVOC	chlorinated volatile organic compound
11	DCE	dichloroethene
12	DHE	Dehalococcoides etheneogenes
13	DMP	Data Management Plan
14	DNAPL	dense non-aqueous phase liquid
15	DO	dissolved oxygen
16	DPT	direct-push technology
17	EnSafe	EnSafe Inc.
18	EOS	emulsified oil substrate
19	EPA	U.S. Environmental Protection Agency
20	ERD	enhanced reductive dechlorination
21	ERH	electrical resistance heating
22	ESDSOPQAM	Environmental Services Division <i>Standard Operating Procedures and</i>
23		<i>Quality Assurance Manual</i>
24	ft bls	foot below land surface
25	gnms/g	genomes per gram
26	gnms/mL	genomes per milliliter
27	IM	interim measure
28	MCL	maximum contaminant level

# 1 Acronyms and Abbreviations, Continued

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2	MCS	media cleanup standard
3	µg/L	microgram per liter
4	mg/L	milligrams per liter
5	MEE	methane, ethane, and ethane
6	MNA	monitored natural attenuation
7	mV	millivolt
8	NAVBASE	Naval Base
9	ORP	oxygen reduction potential
10	PCE	tetrachloroethene
11	QAP	Quality Assurance Plan
12	RCRA	Resource Conservation and Recovery Act
13	RFI	RCRA Facility Investigation
14	SCDHEC	South Carolina Department of Health and Environmental Control
15	TCE	trichloroethene
16	TOC	total organic carbon
17	VC	vinyl chloride
18	VFA	volatile fatty acid
19	VOC	volatile organic compound

**Section 1.0**

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# 1 1.0 Introduction

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2 In 1993, Naval Base (NAVBASE) Charleston was added to the list of bases scheduled for  
3 closure as part of the Defense Base Realignment and Closure (BRAC) Act, which regulates  
4 closure and transition of property to the community. The Charleston Naval Complex (CNC)  
5 was formed as a result of the dis-establishment of the Charleston Naval Shipyard and  
6 NAVBASE on April 1, 1996.

7 CNC Corrective Action (CA) activities are being conducted under the Resource  
8 Conservation and Recovery Act (RCRA). The South Carolina Department of Health and  
9 Environmental Control (SCDHEC) is the lead agency for CA activities at the site. All RCRA  
10 CA activities are performed in accordance with the Final Permit (Permit No. SC0 170  
11 022 560).

12 In April 2000, CH2M-Jones was awarded a contract to provide environmental investigation  
13 and remediation services at the CNC. This submittal presents a Pilot Study Completion  
14 Report and Full-Scale Implementation Plan using enhanced reductive dechlorination (ERD)  
15 for Area of Concern (AOC) 607 in Zone F at the CNC. Figure 1-1 presents the location of  
16 AOC 607 within Zone F.

## 17 1.1 Purpose of the Pilot Study Completion Report and Full- 18 Scale Implementation Plan

19 This document contains two submittals: (1) Pilot Study Completion Report, and (2) Full-  
20 Scale Implementation Plan using ERD to address chlorinated solvents in the surficial aquifer  
21 at AOC 607. The Pilot Study Completion Report summarizes the results of the pilot test of  
22 ERD for remediating chlorinated solvents, which was performed from June through  
23 December 2004 at AOC 607. As described in this report, the pilot test demonstrated that  
24 ERD can effectively stimulate in situ biodegradation of the volatile organic compounds  
25 (VOCs) at AOC 607 and that the aquifer characteristics are amenable to this treatment  
26 method.

27 Based on this success, a Full-Scale Implementation Plan using ERD, implemented as an  
28 interim measure (IM), is included with this Pilot Study Completion Report. This plan  
29 presents the design approach for full-scale implementation of ERD at AOC 607.

## 1.2 Background

AOC 607 consists of a former dry cleaning facility, Building 1189, that supported the former local seamen's housing from 1942 to 1986. Building 225, a former Naval Lodge, is located immediately west of AOC 607. Toward the end of its operational period, the dry cleaning facility was used as a general purpose laundry with two industrial washers and dryers. Tetrachloroethene (PCE), a typical dry-cleaning solvent, was one of the primary materials that was used, stored, disposed of, and accidentally released at the site. Trichloroethene (TCE), cis-1,2-dichloroethene (cis-1,2-DCE), trans-1,2-dichloroethene (trans-1,2-DCE), and vinyl chloride (VC), which are sequential dechlorination products of PCE, were also detected in soil and groundwater samples collected at AOC 607 during the RCRA Facility Investigation (RFI) conducted by EnSafe Inc. (EnSafe) in 1996 and 1997. These investigation activities are summarized in the *Zone F RFI Report, Revision 0* (EnSafe, 1997). Figure 1-2 presents an aerial photograph of AOC 607.

Based on the information presented in the RFI report and subsequent investigations, PCE released at AOC 607 appeared to have migrated vertically downward as a dense non-aqueous phase liquid (DNAPL) through fill and shallow subsurface soils, until it encountered a clay unit at approximately 10 to 11 feet below land surface (ft bls). The PCE DNAPL appeared to have accumulated on top of the clay layer, providing a residual source for the dissolved-phase chlorinated solvents that contaminate the shallow groundwater. Left in that state, this DNAPL source area would be expected to contribute dissolved phase contamination to the shallow groundwater for at least several decades into the future.

In order to address this long-term source area, an IM using electrical resistance heating (ERH) was conducted in 2001 and 2002. This IM achieved a significant reduction in the PCE source area mass. Dissolved phase groundwater concentrations were significantly decreased after the ERH IM but were still above the target cleanup levels (drinking water maximum contaminant levels [MCLs]). The ERD pilot test was implemented to assess the effectiveness of ERD for accomplishing further remediation of the chlorinated solvents in groundwater at AOC 607.

The pilot test was completed in accordance with the Pilot Study Work Plan (CH2M-Jones, 2003), which was reviewed and approved by SCDHEC prior to implementing the pilot test.

## 1 **1.3 Report Organization**

2 This report consists of the following sections, including this introductory section:

3 **1.0 Introduction**—Presents the purpose and scope of the Pilot Study Completion Report  
4 and Full-Scale Implementation Plan using ERD.

5 **2.0 Pilot Study Results**—Presents the results of the pilot test to assess the effectiveness of  
6 ERD in further remediating chlorinated solvents in groundwater at AOC 607.

7 **3.0 Full-Scale Implementation Plan**—Presents the approach for the proposed full-scale  
8 implementation of ERD at AOC 607.

9 **4.0 References**—Lists the references used in this document.

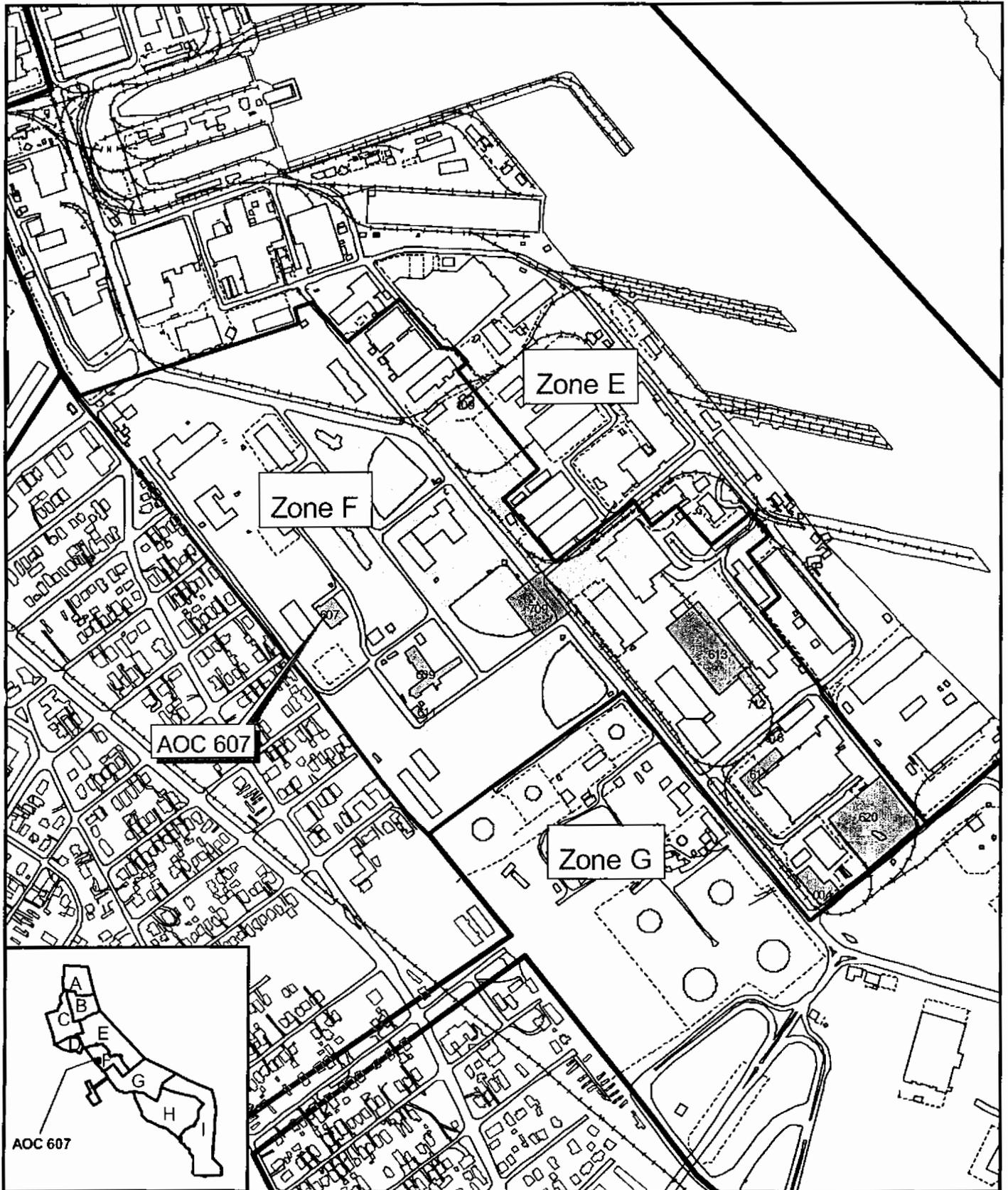
10 **Appendix A** contains well construction, development, and purge logs for the two wells  
11 installed as part of the pilot test.

12 **Appendix B** contains analytical data summaries.

13 **Appendix C** contains the results of the microbiological analysis of the soil and groundwater  
14 samples.

15 **Appendix D** contains data validation worksheets and flagged analytical results (provided  
16 on CD).

17 All tables and figures appear at the end of their respective sections.



-  Zone F Boundary
-  SWMU/AOC Within Zone F Boundary



0 800 1600 Feet

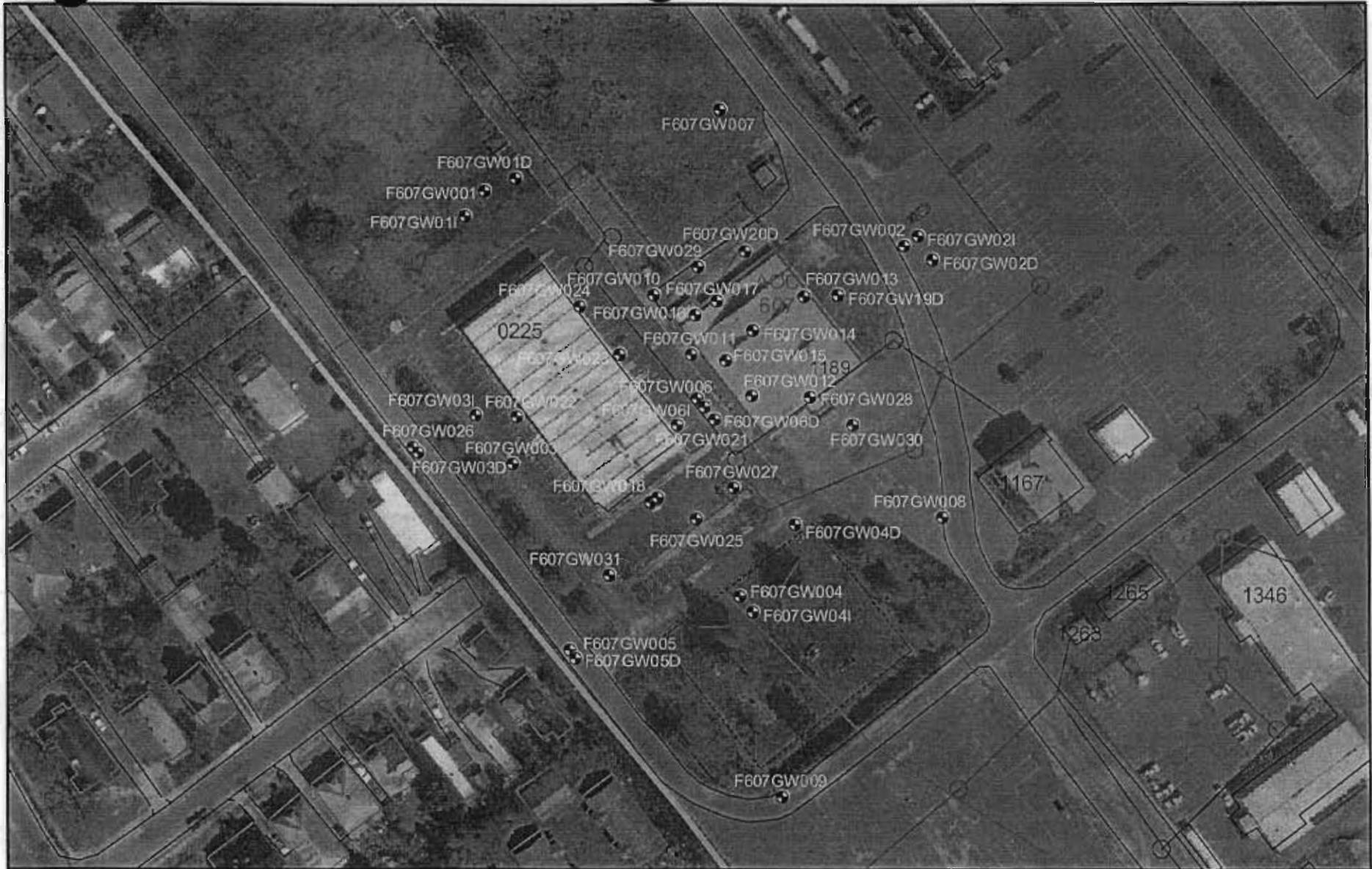


1 inch = 800 feet

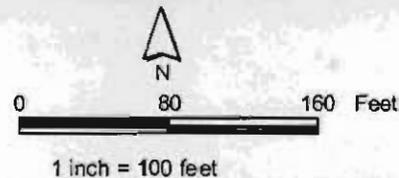
**Figure 1-1**  
 Location of AOC 607 in Zone F  
 AOC 607, Zone F  
 Charleston Naval Complex

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NOTE: Aerial photo is 1997  
 NOTE: Color was added in color



- Monitoring Well
- ▬ Fence
- ▬ Roads
- ▬ STORM-LINE/MANHOLE
- ▬ SEWER-LINE/MANHOLE
- ▭ AOC Boundary
- ▭ Buildings
- ▭ Zone Boundary



**Figure 1-2**  
 Site Location Map  
 AOC 607, Zone F  
 Charleston Naval Complex

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**Section 2.0**

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## 2.0 Pilot Study Results

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This section presents a summary of the pilot study conducted at AOC 607. Discussions of site geology, hydrogeology and the risk assessment were provided in the *Zone F RFI Report, Revision 0* (EnSafe, 1997); groundwater chemicals of concern (COCs) identified in the shallow interval of the surficial aquifer and the overall approach to remediating the site were previously discussed in the *Corrective Measures Study (CMS) Report/Pilot Study Work Plan, Revision 0* (CH2M-Jones, 2003). The CMS Report/Pilot Study Work Plan also identifies the remedial action objectives and proposed media cleanup standards.

### 2.1 Pilot Study Objectives and Goals

The purpose of the pilot study was to evaluate the viability of using ERD to stimulate bioremediation of chlorinated volatile organic compounds (CVOCs) in the shallow portion of the surficial aquifer at AOC 607. The primary goals of the pilot study were to:

- Assess the effectiveness of lactate as an organic substrate (electron donor) for the site;
- Assess the degree to which the naturally present bacterial consortium in the aquifer can effectively degrade PCE and its daughter products; and
- Determine the required frequency of injection, necessary dosage of substrate, approximate radius of influence of the injection well, and overall substrate migration rate within the aquifer in this area.

This information was used to evaluate the overall viability and costs for full-scale implementation.

### 2.2 Pilot Study Approach

Key activities for the pilot study included:

1. Installation of performance monitoring wells with soil sample collection and analysis;
2. Baseline characterization (sampling and analysis) of microbiological and geochemical indicators and groundwater VOC concentrations;
3. Implementation of substrate injection pilot test; and
4. Post-injection monitoring.

Each of these key activities is described below.

## 2.2.1 Monitoring Well Installation

In May 2004, two new monitoring wells, identified as F607GW032 and F607GW033, were installed to monitor performance during the pilot study. These wells were installed within about 10 feet hydraulically downgradient of wells F607GW028 and F607GW025, respectively. Groundwater data from these wells were used to evaluate changes in overall biological activity and effect of the substrate injection on the degree of biodegradation of the VOCs in the pilot test area. Locations of the wells at AOC 607 are presented in Figure 2-1.

The monitoring wells were constructed of 2-inch PVC casing with 5 feet of 0.01-inch slotted well screen installed to approximately the same depth intervals as the injection wells they were intended to monitor (from 6 to 11 ft bls for well F607GW025 and from 8 to 13 ft bls for well F607GW028). Termination depths were at the top of the competent clay layer. Well construction diagrams for the new monitoring wells are included in Appendix A.

## 2.2.2 Baseline Characterization Sampling and Analysis

Baseline sampling and analysis of groundwater from the new wells were conducted on June 2 and 9, 2004. Groundwater samples were collected from monitoring wells F607GW025, F607GW028, F607GW032, F607GW033, F607GW006, F607GW011, F607GW012, and F607GW027. Field parameters, pH, dissolved oxygen (DO), conductivity, oxidation-reduction potential (ORP), and temperature were measured in all of these wells. The four key pilot study wells (F607GW025, F607GW028, F607GW032, F607GW033) were also analyzed for VOCs, alkalinity, bromide, dissolved gases (methane, ethane, and ethane [MEE]), sulfate, sulfide, total organic carbon (TOC), volatile fatty acids (VFAs), and several dissolved metals (potassium, iron, and manganese).

Table 2-1 presents a summary of the sampling and injection events that occurred during the pilot study. Results of the baseline sampling and subsequent sampling data are presented in Table 2-2. Analytical data summaries are presented in Appendix B.

## 2.2.3 Substrate Injection Pilot Test

The overall approach to the pilot test involved the injection of a fermentable substrate (lactate) into the shallow aquifer via two wells (F607GW025 and F607GW028) located in the area of the site containing the highest levels of total VOCs. Injection of lactate into the aquifer stimulates the ERD process because as the lactate ferments, it releases hydrogen gas, which is used as the electron donor by many bacteria, especially those involved in the anaerobic biodegradation of chlorinated solvents. Lactate typically first degrades to pyruvate, releasing a molecule of hydrogen. Pyruvate then typically degrades to acetate,

1 releasing another molecule of hydrogen. Thus, one molecule of lactate provides two  
2 molecules of hydrogen, which then become available for dehalorespiring bacteria.

3 Approximately 38 gallons of 60-percent potassium lactate solution were diluted with 190  
4 gallons of tap water to make an approximately 10 percent lactate solution for the injectate.  
5 Approximately 230 gallons of this solution was injected into each well (F607GW025 and  
6 F607GW028) on June 9 and 10, 2004. Bromide, at a concentration of 500 milligrams per liter  
7 (mg/L), was also added to the injectate to assess the migration and dilution of this  
8 conservative tracer over time. Sodium bicarbonate was also added to the injectate to provide  
9 pH buffering capability to maintain the pH in the range optimal for biodegradation.

10 Following 3 months of performance monitoring that indicated successful results in  
11 sustaining anaerobic conditions and ongoing reductive dechlorination of the parent  
12 compound PCE, a second injection event was performed. This second injection event was  
13 performed on October 13, 2004, with approximately 230 gallons of a 3-percent lactate  
14 solution (by volume) pumped into each well.

15 A small, low pressure pump was used to inject the lactate solution. Following the injection,  
16 approximately 20 gallons of clean water were injected to flush the wells and push the lactate  
17 solution out into the aquifer.

## 18 **2.2.4 Post-Injection Monitoring**

19 Post-injection monitoring measured the response of the aquifer and groundwater quality  
20 downgradient of the injection. Water quality was measured in two newly installed  
21 downgradient monitoring wells (F607GW032 and F607GW033) to assess changes in overall  
22 biological activity and degree of biodegradation of the VOCs.

23 Monitoring was performed on a monthly basis after the initial injection event. Field  
24 parameters (DO, ORP, temperature, pH, conductance), VFAs, TOC, MEE, and VOCs were  
25 measured monthly in both pilot test monitoring wells. Bimonthly (months 2 and 4)  
26 parameters included alkalinity, bromide, sulfate, iron, manganese, potassium, and the  
27 bacteria *dehalococcoides etheneogenes* (DHE). Table 2-1 presents a summary of the post-  
28 injection monitoring events.

29 Groundwater sampling was completed using a low-flow groundwater sampling technique  
30 to minimize disruption of groundwater and accumulated sediment in order to collect  
31 accurate field parameters (particularly DO and ORP) and more representative samples for  
32 dissolved gases. The groundwater sampling was performed in accordance with the

1 procedures found in the approved Comprehensive Sampling and Analysis Plan (CSAP)  
2 portion of the RFI Work Plan (EnSafe, Inc./Allen & Hoshall, 1994). The CSAP outlines all  
3 monitoring procedures to be performed to characterize the environmental setting, source,  
4 and releases of hazardous constituents. In addition, the CSAP includes the Quality  
5 Assurance Plan (QAP) and Data Management Plan (DMP), which contain procedures on  
6 verifying that all information and data are valid and properly documented. Unless  
7 otherwise noted, the sampling strategy and procedures were performed in accordance with  
8 the U.S. Environmental Protection Agency (EPA) Environmental Services Division *Standard*  
9 *Operating Procedures and Quality Assurance Manual* (ESDSOPQAM) (1996).

## 10 **2.3 Pilot Study Results**

11 The results of the pilot study sampling are described below for each of the two pilot test  
12 monitoring wells. Many of the analytical results as measured in wells F607GW032 and  
13 F607GW033 are illustrated graphically in Figures 2-2 and 2-3, respectively.

### 14 **2.3.1 F607GW032 Results**

15 Monitoring well F607GW032 was installed downgradient of well F607GW028, located inside  
16 the former dry cleaner building. The total VOC concentrations in monitoring well  
17 F607GW032 during the baseline sampling in June 2004 were approximately 18,000  
18 micrograms per liter ( $\mu\text{g}/\text{L}$ ). Significant concentrations of PCE (8,090  $\mu\text{g}/\text{L}$ ) were detected  
19 during the baseline sampling for this well. Results from the October 2004 sampling event  
20 show a total VOC concentration of approximately 10,687  $\mu\text{g}/\text{L}$ , a reduction of about 40  
21 percent compared to the baseline concentration in June 2004. PCE concentrations in this well  
22 were reduced from 8,090  $\mu\text{g}/\text{L}$  to about 100  $\mu\text{g}/\text{L}$ , an approximately 99 percent reduction.  
23 VC, a reductive dechlorination daughter product of the ERD process, increased in  
24 concentration compared to the baseline sampling, but VC concentrations are decreasing.  
25 This increase and subsequent decrease in VC is expected as part of the ERD process and  
26 indicates that ERD is successfully progressing. Concentrations of cis-1,2-DCE have  
27 fluctuated during the first three performance monitoring periods and are lower than the  
28 initial baseline conditions. The detected concentrations of cis-1,2-DCE indicate that  
29 additional ERD would likely be beneficial in this area.

30 VFAs are produced as a result of bacterial degradation of organic substrates. Several species  
31 of VFAs were sporadically detected in the post-injection performance monitoring samples at  
32 F607GW032, as shown in Table 2-1, but the VFA concentrations are relatively low overall.

1 This may indicate that the substrate was being effectively consumed and that further  
2 substrate addition would be beneficial in this area.

3 The dissolved gasses ethane and ethene are produced as chlorinated alkenes are reduced via  
4 reductive dechlorination. The presence of methane is indicative of strongly reducing  
5 conditions, which is necessary for reductive dechlorination. The dissolved gasses MEE were  
6 detected at low concentrations in the baseline samples and increased between 1 and 2 orders  
7 of magnitude during the performance monitoring period. Baseline methane concentrations  
8 of 25  $\mu\text{g}/\text{L}$  in June 2004 increased to 996  $\mu\text{g}/\text{L}$  in November 2004. This indicates that  
9 methanogenic conditions have been created within the target pilot test. This highly reducing  
10 condition is conducive to the ERD process.

11 Ethene, a final dechlorination byproduct of the VOCs, increased from a baseline  
12 concentration of 10  $\mu\text{g}/\text{L}$  to a remarkably high value of 29,562  $\mu\text{g}/\text{L}$  during the November  
13 2004 sampling event, indicating the presence of a highly effective ERD process.

14 ORP readings decreased from 80 millivolts (mV), which is indicative of mildly reducing  
15 conditions, to as low as -189 mV, further confirming that strongly reducing conditions were  
16 effectively achieved in this area.

17 Sulfate concentrations decreased from 231 mg/L during baseline conditions to 102 mg/L in  
18 August 2004, indicating that sulfate reduction was readily occurring. Dissolved iron was  
19 detected at a concentration of 35,800  $\mu\text{g}/\text{L}$  during baseline conditions, indicating that  
20 significant iron reduction was occurring in the aquifer. In August 2004, the dissolved iron  
21 concentration was 26,900  $\mu\text{g}/\text{L}$ , indicating that iron reduction was still occurring to some  
22 degree, but possibly to a lesser degree than during baseline conditions.

23 In addition to the presence of reducing conditions, the presence of DHE has also been found  
24 necessary for the complete transformation of chlorinated alkenes to ethane and/or ethane.  
25 The baseline analysis of soil collected during installation of well F607GW032 (using genomic  
26 analytical methods) indicated the presence of DHE at 1,800 genomes per gram (gnms/g).  
27 The baseline groundwater sample collected from well F607GW032 did not have detectable  
28 DHE. However, during the August 2004 sampling event, the DHE concentration in  
29 groundwater from well F607GW032 was measured at 726,000 genomes/mL (gnms/mL), an  
30 increase of 5 to 6 orders of magnitude from the baseline results. Based on these data, the  
31 bacterial strain DHE is not only present at AOC 607 but also is responding readily to the  
32 ERD stimulation.

1 Overall, the analytical data obtained from well F607GW032 indicate that the pilot test of  
2 ERD has achieved significant success in reducing VOC concentrations and stimulating rapid  
3 growth in the native dechlorinating bacterial consortium.

#### 4 **2.3.2 F607GW033 Results**

5 Monitoring well F607GW033 was installed downgradient of well F607GW025, which was  
6 used as the injection well for this portion of the pilot test. Total VOC concentrations in  
7 monitor well F607GW033 measured during baseline sampling in June 2004 were  
8 approximately 860  $\mu\text{g}/\text{L}$ , with cis-1,2-DCE and PCE present in the greatest concentrations.  
9 Total VOCs measured in November 2004 were 140  $\mu\text{g}/\text{L}$ , a reduction of approximately 83  
10 percent. Most of the VOC present in the November 2004 sampling was VC, which, as was  
11 noted above for well F607GW032, initially increased but is now decreasing, as is expected as  
12 part of the ERD process. PCE concentrations in well F607GW003 have been non-detect since  
13 the August 2004 sampling event.

14 VFAs were not detected in the baseline sampling event. A more diverse variety of VFAs  
15 were detected in the post-injection performance monitoring samples at well F607GW032  
16 than were detected at well F607GW033. These data indicate that the lactate injection has  
17 stimulated microbial population growth at well F607GW033 but that the fermentative  
18 environment at F607GW033 is not yet as robust as at well F607GW032.

19 The dissolved gasses ethane and ethene were not detected in the baseline samples. Ethane  
20 was not detected in any of the performance monitoring samples. Ethene was detected in the  
21 first monthly sampling event, but was not detected in subsequent sampling events. Methane  
22 was detected in the baseline sampling event and increased approximately 1 order of  
23 magnitude during the performance monitoring period. Significantly greater methane was  
24 detected at well F607GW032 than at well F607GW033, indicating greater methanogenic  
25 bacterial activity at well F607GW032 compared to well F607GW033.

26 ORP readings decreased from -76 mV during the baseline period, which is indicative of  
27 slightly reducing conditions, to as low as -246 mV, which indicates strongly reducing  
28 conditions.

29 Sulfate concentrations decreased from 243 mg/L for baseline conditions to 14 mg/L in  
30 August 2004, indicating that sulfate reduction was readily occurring. Dissolved iron was  
31 detected at a concentration of 30,600  $\mu\text{g}/\text{L}$  during baseline conditions, indicating that  
32 significant iron reduction was occurring in the aquifer. In August 2004, the dissolved iron

1 concentration had increased to 111,000  $\mu\text{g/L}$ , indicating that iron reduction had been  
2 significantly stimulated.

3 The baseline analysis of soil collected during installation of well F607GW033 indicated the  
4 presence of DHE at 1,100  $\text{gnms/g}$ . The baseline groundwater sample collected from well  
5 F607GW033 detected only trace levels of DHE. However, during the August 2004 sampling  
6 event, the DHE concentration in groundwater from well F607GW033 was measured at  
7 41,600  $\text{gnms/mL}$ , an increase of 4 to 5 orders of magnitude. Based on these data, the  
8 bacterial strain DHE is not only present at AOC 607 but also is responding readily to the  
9 ERD stimulation.

10 Overall, the analytical data obtained from well F607GW033 indicate that the pilot test of  
11 ERD has achieved significant success in reducing VOC concentrations and stimulating rapid  
12 growth in the native dechlorinating bacterial consortium.

### 13 **2.3.3 Total Organic Carbon and Bromide Monitoring Results**

14 The TOC concentration in well F607GW032 during the baseline sampling was  
15 approximately 16  $\text{mg/L}$ . TOC increased to 112  $\text{mg/L}$  and 535  $\text{mg/L}$  in July and August  
16 2004, respectively, before declining to 35  $\text{mg/L}$  in September 2004. The TOC concentration  
17 in well F607GW033 during the baseline sampling was approximately 7  $\text{mg/L}$ . TOC  
18 increased to 794  $\text{mg/L}$  in July and decreased to 41  $\text{mg/L}$  in August 2004. Thus, the effective  
19 duration of the lactate injection was about 2 to 3 months at well F607GW032 and about 1 to 2  
20 months at well F607GW033.

21 Bromide concentrations measured in wells F607GW032 and F607GW033 were both low, on  
22 the order of 1 to 2  $\text{mg/L}$ , indicating that the injectate was generally well distributed in the  
23 aquifer and that the results measured in the two monitoring wells were not significantly  
24 impacted by dilution by the injectate.

## 25 **2.4 Conclusions**

26 Based on the pilot study data, the following conclusions were reached regarding the effect  
27 of substrate injection at AOC 607:

- 28 • The substrate injections significantly stimulated indigenous bacteria to degrade the  
29 COCs,
- 30 • The native bacterial consortium is capable of fully degrading PCE to ethene without  
31 requiring biostimulation,

- 1 • Lactate provided an effective substrate for stimulating the ERD process and achieving  
2 subsurface conditions conducive for reductive dechlorination,
  - 3 • The injections were able to impact groundwater concentrations within at least 10 feet of  
4 the injection well within only a few months,
  - 5 • The lactate has an effective life in the range of 1 to 3 months, and
  - 6 • The existing monitoring wells can be effectively used as injection wells for substrate  
7 addition.
- 8 The data presented in this pilot study report indicate that the pilot scale ERD test was  
9 successful. Full-scale implementation of ERD is recommended for AOC 607.

**TABLE 2-1**  
 Pilot Study Sampling  
 AOC 607, Zone F, Charleston Naval Complex

Date	<i>Dehalococcoides</i> etheneogenes	Alkalinity	Bromide	Methane/ Ethane/ Ethene	Sulfate/ Sulfide	Total Organic Carbon	Volatile Fatty Acids	Metals	Volatile Organic Compounds	Nutrient Injection	Injection Volume (gal)
06/02/2004		F607GW027	F607GW027	F607GW027	F607GW027	F607GW027	F607GW027	F607GW027	F607GW006		
		F607GW028	F607GW028	F607GW028	F607GW028	F607GW028	F607GW028	F607GW028	F607GW011		
		F607GW032	F607GW032	F607GW032	F607GW032	F607GW032	F607GW032	F607GW032	F607GW012		
		F607GW033	F607GW033	F607GW033	F607GW033	F607GW033	F607GW033	F607GW033	F607GW027 F607GW028 F607GW032 F607GW033		
06/09/2004		F607GW025	F607GW025		F607GW025	F607GW025		F607GW025	F607GW025		
									F607GW025	200	
06/10/2004									F607GW028	200	
07/06/2004				F607GW032		F607GW032	F607GW032		F607GW032		
				F607GW033		F607GW033	F607GW033		F607GW033		
08/19/2004	F607GW032	F607GW032	F607GW032	F607GW032	F607GW032	F607GW032	F607GW032	F607GW032	F607GW032		
	F607GW033	F607GW033	F607GW033	F607GW033	F607GW033	F607GW033	F607GW033	F607GW033	F607GW033		
10/01/2004				F607GW032		F607GW032	F607GW032		F607GW032		
				F607GW033		F607GW033	F607GW033		F607GW033		
10/13/2004										F607GW025	230
										F607GW028	230
10/19/2004									F607GW003		
									F607GW006		
									F607GW011		
									F607GW012		
									F607GW014 F607GW015		

**TABLE 2-1**  
 Pilot Study Sampling  
 AOC 607, Zone F, Charleston Naval Complex

Date	<i>Dehalococcoides</i> etheneogenes	Alkalinity	Bromide	Methane/ Ethane/ Ethene	Sulfate/ Sulfide	Total Organic Carbon	Volatile Fatty Acids	Metals	Volatile Organic Compounds	Nutrient Injection	Injection Volume (gal)
10/19/2004									F607GW021		
									F607GW022		
									F607GW023		
									F607GW025		
									F607GW027		
									F607GW028		
									F607GW029		
									F607GW031		
									F607GW061		
									F607GW06D		
10/20/2004									F607GW18D		
									F607GW004		
									F607GW013		
									F607GW016		
									F607GW030		
									F607GW032		
11/18/2004				F607GW032		F607GW032	F607GW032		F607GW032		
				F607GW033		F607GW033	F607GW033		F607GW033		

**TABLE 2-2**  
 Pilot Study COC and Monitored Natural Attenuation (MNA) Results  
 AOC 607, Zone F, Charleston Naval Complex

Station ID	Date Collected	1,1-Dichloroethene (µg/L)	1,2-Dichloroethene (total) (µg/L)	cis-1,2- Dichloroethene (µg/L)	trans-1,2- Dichloroethene (µg/L)	Trichloroethene (TCE) (µg/L)	Tetrachloroethene (PCE) (µg/L)	Vinyl chloride (µg/L)	Acetic Acid (mg/L)	Butyric Acid (mg/L)	Formic Acid (mg/L)	Lactic Acid (C3) (mg/L)	Propionic Acid (C3) (mg/L)	Pyruvic Acid (C3) (mg/L)	Alkalinity, Total (as CaCO3) (mg/L)	Bromide (mg/L)	METHANE (µg/L)
F607GW003	10/19/2004	5 U	5 U	5 U	5 U	5 U	5 U	10 U	-	-	-	-	-	-	-	-	-
F607GW004	10/20/2004	5 U	13.8 =	13.8 =	5 U	1.5 J	5 U	10 U	-	-	-	-	-	-	-	-	-
F607GW006	06/02/2004	4.3 J	1870 =	1860 =	8.6 =	2380 =	1420 =	8.2 J	-	-	-	-	-	-	-	-	-
F607GW006	10/19/2004	6 J	1480 J	1480 J	8.7 J	533 J	301 J	27.6 J	-	-	-	-	-	-	-	-	-
F607GW011	06/02/2004	3.2 J	1960 J	1950 J	6.7 J	774 J	76 J	3.5 J	-	-	-	-	-	-	-	-	-
	10/19/2004	50 U	733 J	733 J	50 U	162 J	64 J	5.7 J	-	-	-	-	-	-	-	-	-
F607GW012	06/02/2004	5 U	35 J	35 J	5 U	3.1 J	2 J	10 U	-	-	-	-	-	-	-	-	-
	10/19/2004	5 U	13.9 J	13.9 J	5 U	0.52 J	0.97 J	10 U	-	-	-	-	-	-	-	-	-
F607GW013	10/20/2004	5 U	1.2 J	1.2 J	5 U	1.1 J	1.1 J	10 U	-	-	-	-	-	-	-	-	-
F607GW014	10/19/2004	4.2 J	1970 J	1970 J	4.6 J	448 J	199 J	0.58 J	-	-	-	-	-	-	-	-	-
F607GW015	10/19/2004	5 U	12.2 J	12.2 J	5 U	3.7 J	5.1 J	10 U	-	-	-	-	-	-	-	-	-
F607GW016	10/20/2004	5 U	22.2 J	22.2 J	5 U	5 U	5 U	4.1 J	-	-	-	-	-	-	-	-	-
F607GW021	10/19/2004	5 U	9.5 J	9.5 J	5 U	3.5 J	16.6 J	10 U	-	-	-	-	-	-	-	-	-
F607GW022	10/19/2004	5 U	5 U	5 U	5 U	5 U	5 U	10 U	-	-	-	-	-	-	-	-	-
F607GW023	10/19/2004	1.2 J	-	203 J	0.82 J	68.8 J	48.8 J	1 J	-	-	-	-	-	-	-	-	-
F607GW025	06/09/2004	5.7 =	2020 =	2020 =	5 U	1240 =	4310 =	5.4 J	-	-	-	-	-	-	46.8 =	0.843 =	-
F607GW025	10/19/2004	25 U	238 J	230 J	8 J	4.5 J	11.1 J	94.6 J	-	-	-	-	-	-	-	-	-
F607GW027	06/02/2004	1.6 J	518 =	518 =	1.8 J	130 =	201 =	10 U	1 U	1 U	1 U	1 U	1 U	4 U	79 J	1.62 =	9900 =
	10/19/2004	50 U	560 J	560 J	50 U	236 J	202 J	6.1 J	-	-	-	-	-	-	-	-	-
F607GW028	06/02/2004	31.4 =	18400 J	18400 J	28.4 =	4.6 J	3.9 J	305 J	1 U	1 U	1 U	1 U	1 U	4 U	84.8 J	0.732 =	610 =

**TABLE 2-2**  
 Pilot Study COC and Monitored Natural Attenuation (MNA) Results  
 AOC 607, Zone F, Charleston Naval Complex

Station ID	Date Collected	1,1-Dichloroethene (µg/L)	1,2-Dichloroethene (total) (µg/L)	cis-1,2- Dichloroethylene (µg/L)	trans-1,2- Dichloroethene (µg/L)	Trichloroethylene (TCE) (µg/L)	Tetrachloroethylene (PCE) (µg/L)	Vinyl chloride (µg/L)	Acetic Acid (mg/L)	Butyric Acid (mg/L)	Formic Acid (mg/L)	Lactic Acid (C3) (mg/L)	Propionic Acid (C3) (mg/L)	Pyruvic Acid (C3) (mg/L)	Alkalinity, Total (as CaCO <sub>3</sub> ) (mg/L)	Bromide (mg/L)	METHANE (µg/L)
	10/19/2004	50 U	523 J	504 J	19.2 J	50 U	8.5 J	211 J	-	-	-	-	-	-	-	-	-
F607GW029	10/19/2004	5 U	0.74 J	0.74 J	5 U	0.49 J	0.54 J	10 U	-	-	-	-	-	-	-	-	-
F607GW030	10/20/2004	5 U	5 U	5 U	5 U	5 U	5 U	10 U	-	-	-	-	-	-	-	-	-
F607GW031	10/19/2004	5 U	5 U	5 U	5 U	5 U	5 U	10 U	-	-	-	-	-	-	-	-	-
F607GW032	06/02/2004	23.2 J	14300 J	14300 J	36.8 J	3480 J	8090 J	151 J	1 U	1 U	1 U	1 U	1 U	4 U	101 J	0.443 =	25 =
	07/06/2004	13.8 J	6000 =	5940 =	58.3 J	10.2 J	3.3 J	452 =	135.5 =	1 U	1 U	1 U	70.5 =	4 U	-	-	27.42 =
	08/19/2004	13.4 J	11700 J	11600 J	60.3 J	71.4 J	14.1 J	1050 J	1 U	1 U	1.9 =	1 U	1 U	4 U	249 =	1.11 =	91.5 =
	10/01/2004	250 U	5230 =	5230 =	34.3 J	147 J	41.3 J	1920 =	16.5 =	1 U	1 U	1 U	5.1 =	4 U	-	-	447 =
	10/20/2004	500 U	6350 J	6310 J	40.9 J	280 J	107 J	1360 J	1 U	1 U	1 U	1 U	1 U	4 U	-	-	-
	11/18/2004	500 U	9010 =	9010 =	500 U	383 J	104 J	1190 =	-	-	-	-	-	-	-	-	996 =
F607GW033	06/02/2004	0.86 J	546 =	546 =	0.9 J	79.7 =	219 =	13.3 =	1 U	1 U	1 U	1 U	1 U	4 U	96.5 J	0.363 =	16600 =
	07/06/2004	1.4 J	469 =	469 =	1.4 J	5.1 =	6.2 =	86.5 =	484.8 =	1 U	10 U	241 =	435.2 =	4 U	-	-	1620 =
	08/19/2004	5 UJ	122 J	118 J	5 J	0.75 J	5 UJ	-	349.4 =	141.4 =	2.6 =	1 U	186 =	4 U	1140 =	2.17 =	14275 =
	10/01/2004	5 U	15.2 =	9.9 =	5.3 =	5 U	5 U	-	60.4 =	6.5 =	1 U	1 U	39.2 =	4 U	-	-	15977 =
	10/20/2004	25 U	19.3 J	14.2 J	5.2 J	25 U	25 U	273 J	864.6 =	240.2 =	10 U	10 U	1756 =	40 U	-	-	-
	11/18/2004	10 U	9.3 J	6.9 J	2.4 J	10 U	10 U	131 =	-	-	-	-	-	-	-	-	286636 =
F607GW06I	10/19/2004	50 U	264 J	264 J	50 U	211 J	440 J	100 U	-	-	-	-	-	-	-	-	-
F607GW06D	10/19/2004	5 U	5 U	5 U	5 U	5 U	5 U	10 U	-	-	-	-	-	-	-	-	-
F607GW18D	10/19/2004	100 U	352 J	352 J	100 U	325 J	1100 J	200 U	-	-	-	-	-	-	-	-	-

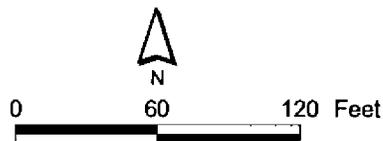
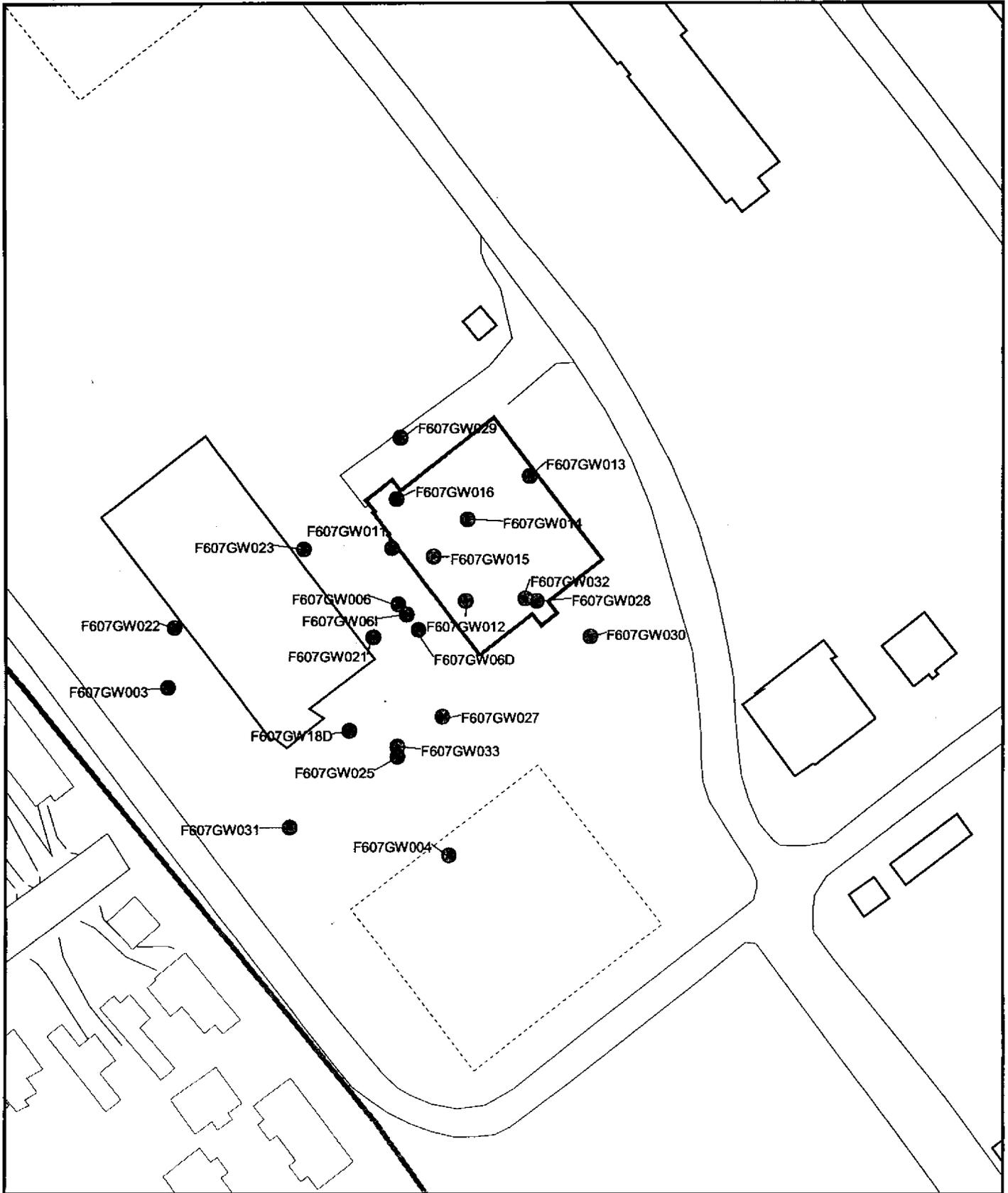
**TABLE 2-2**  
 Pilot Study COC and Monitored Natural Attenuation (MNA) Results  
 AOC 607, Zone F, Charleston Naval Complex

Station ID	Date Collected	ETHANE (µg/L)	ETHENE (µg/L)	Sulfate (as SO4) (mg/L)	Sulfide (mg/L)	Total Organic Carbon (mg/L)	Dehalococoides spp. (Gnms/ML)	Iron (µg/L)	Iron, Dissolved (µg/L)	Manganese (µg/L)	Manganese, Dissolved (µg/L)	Potassium (µg/L)	Potassium, Dissolved (µg/L)	pH (SU)	Conductivity (mS/cm <sup>2</sup> )	Dissolved Oxygen (mg/L)	Oxidation-Reduction Potential
F607GW003	10/19/2004	-	-	-	-	-	-	-	-	-	-	-	-	5.14	0.38	0.22	67
F607GW004	10/20/2004	-	-	-	-	-	-	-	-	-	-	-	-	5.91	3.18	0.97	-1
F607GW006	06/02/2004	-	-	-	-	-	-	-	-	-	-	-	-	5.31	0.84	0.77	60
F607GW006	10/19/2004	-	-	-	-	-	-	-	-	-	-	-	-	5.46	0.705	0.46	4
F607GW011	06/02/2004	-	-	-	-	-	-	-	-	-	-	-	-	5.63	0.837	0.4	-61
	10/19/2004	-	-	-	-	-	-	-	-	-	-	-	-	5.98	0.421	0.32	-84
F607GW012	06/02/2004	-	-	-	-	-	-	-	-	-	-	-	-	6.34	0.54	0.3	75
	10/19/2004	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
F607GW013	10/20/2004	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
F607GW014	10/19/2004	-	-	-	-	-	-	-	-	-	-	-	-	5.67	0.309	0.24	-10
F607GW015	10/19/2004	-	-	-	-	-	-	-	-	-	-	-	-	6.65	0.365	1.98	105
F607GW016	10/20/2004	-	-	-	-	-	-	-	-	-	-	-	-	6.39	0.38	0.7	-144
F607GW021	10/19/2004	-	-	-	-	-	-	-	-	-	-	-	-	5.16	0.282	0.36	62
F607GW022	10/19/2004	-	-	-	-	-	-	-	-	-	-	-	-	6.1	0.616	0.65	-31
F607GW023	10/19/2004	-	-	-	-	-	-	-	-	-	-	-	-	5.61	0.315	0.01	-30
F607GW025	06/09/2004	-	-	191 =	0.0248 UJ	5.85 =	-	24000 =	-	926 =	-	5290 =	-	5.73	0.95	1.42	-55
F607GW025	10/19/2004	-	-	-	-	-	-	-	-	-	-	-	-	6.18	9.12	0	-259
F607GW027	06/02/2004	31.2 U	29.2 U	163 =	0.0248 UJ	5.83 =	-	-	23400 =	-	958 =	4870 J	-	5.91	2.11	0.03	-2
	10/19/2004	-	-	-	-	-	-	-	-	-	-	-	-	5.8	1.74	0	-93

**TABLE 2-2**  
 Pilot Study COC and Monitored Natural Attenuation (MNA) Results  
 AOC 607, Zone F, Charleston Naval Complex

Station ID	Date Collected	ETHANE (µg/L)	ETHENE (µg/L)	Sulfate (as SO4) (mg/L)	Sulfide (mg/L)	Total Organic Carbon (mg/L)	Dehalococoides spp_ (Gnms/ML)	Iron (µg/L)	Iron, Dissolved (µg/L)	Manganese (µg/L)	Manganese, Dissolved (µg/L)	Potassium (µg/L)	Potassium, Dissolved (µg/L)	pH (SU)	Conductivity (mS/cm <sup>2</sup> )	Dissolved Oxygen (mg/L)	Oxidation-Reduction Potential
F607GW028	06/02/2004	45 =	41 =	264 =	0.0248 UJ	15.5 =			16400 =		430 =	4420 J	-	5.61	1.46	1.58	-42
	10/19/2004	-	-	-	-	-	-	-	-	-	-	-	-	6.35	17.7	0	-170
F607GW029	10/19/2004	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
F607GW030	10/20/2004	-	-	-	-	-	-	-	-	-	-	-	-	5.79	1.01	0.41	-54
F607GW031	10/19/2004	-	-	-	-	-	-	-	-	-	-	-	-	5.88	0.421	0.27	-58
F607GW032	06/02/2004	4 =	10 =	231 =	0.0506 J	15.8 =			35800 =		838 =	6420 =	-	5.79	1.15	1.13	84
	07/06/2004	13.73 U	13.73 =			112 =								6.22	1.16	1.24	-152
	08/19/2004	3.12 U	66.62 =	102 =	0.0968 J	535 =	726000 =		26900 =		445 =		25300 =	6.2	1.03	0	-149
	10/01/2004	3.12 U	915 =	-	-	35.2 =	-	-	-	-	-	-	-	6.17	1.05	0.09	-122
	10/20/2004	-	-	-	-	-	-	-	-	-	-	-	-	6.23	1.09	0.32	-189
	11/18/2004	210 =	29562 =	-	-	24.7 =	-	-	-	-	-	-	-	6.54	0.862	0.69	-159
F607GW033	06/02/2004	31.2 U	29.2 U	243 =	0.0248 UJ	7.25 =		30600 =		644 =		6670 =	-	5.98	1.24	0.94	-76
	07/06/2004	31.2 U	8.58 =			794 =								6.04	3.2	1.73	-151
	08/19/2004	3.12 U	2.92 U	14.3 =	0.186 J	40.6 =	41600 =		111000 =		1480 =		843000 =	6.39	3.5	0	-246
	10/01/2004	3.12 U	2.92 U	-	-	27.3 =	-	-	-	-	-	-	-	6.49	1.54	0.07	-176
	10/20/2004	-	-	-	-	-	-	-	-	-	-	-	-	6.31	2.52	0.31	-190
	11/18/2004	156 U	146 U	-	-	30.1 =	-	-	-	-	-	-	-	6.42	6.46	0.29	-191
F607GW06I	10/19/2004	-	-	-	-	-	-	-	-	-	-	-	-	6.51	3.67	0.21	-99
F607GW06D	10/19/2004	-	-	-	-	-	-	-	-	-	-	-	-	8.61	1.2	0.81	-76
F607GW18D	10/19/2004	-	-	-	-	-	-	-	-	-	-	-	-	7.19	1.01	0.42	-95

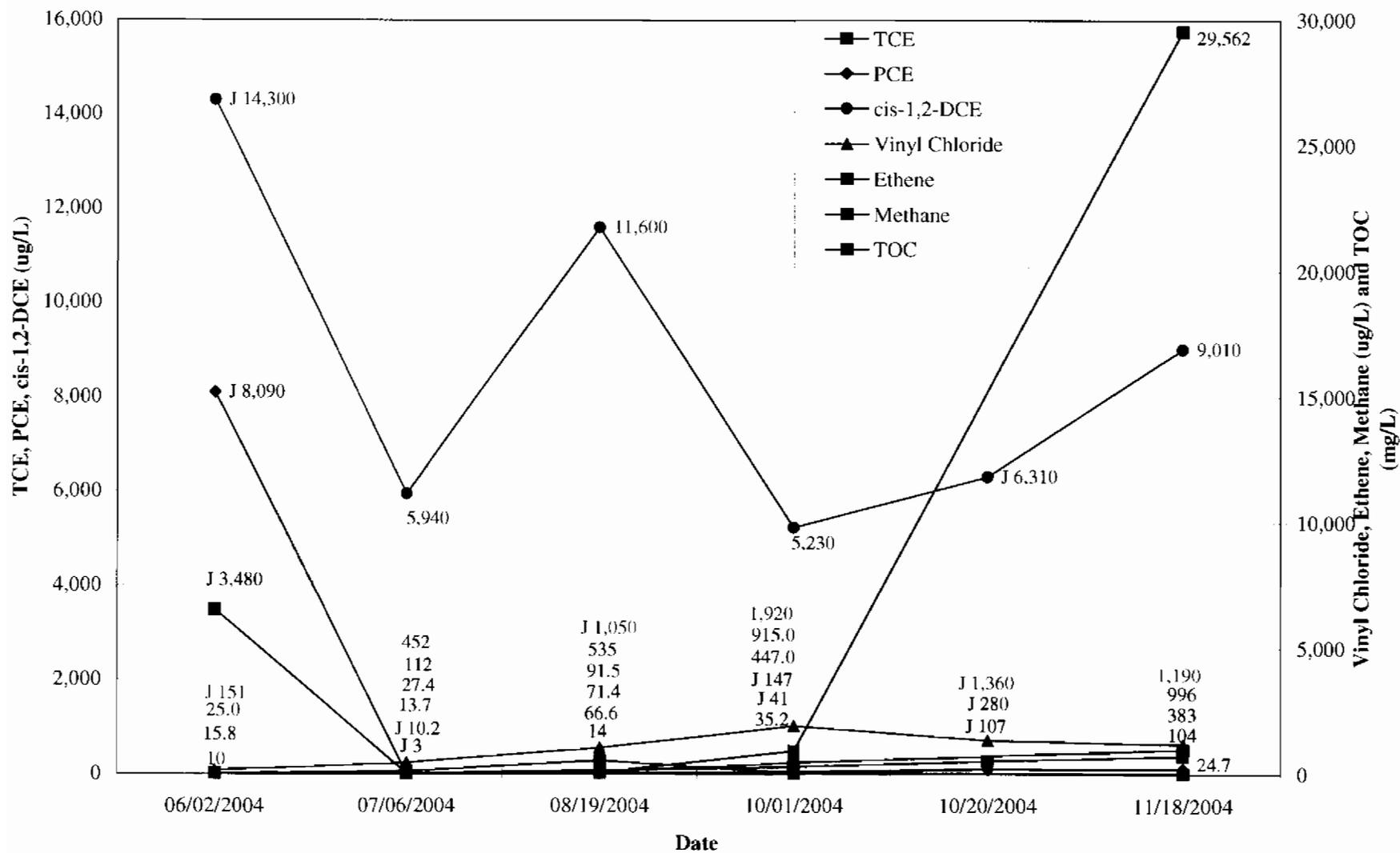
NOTE: Original figure created in color



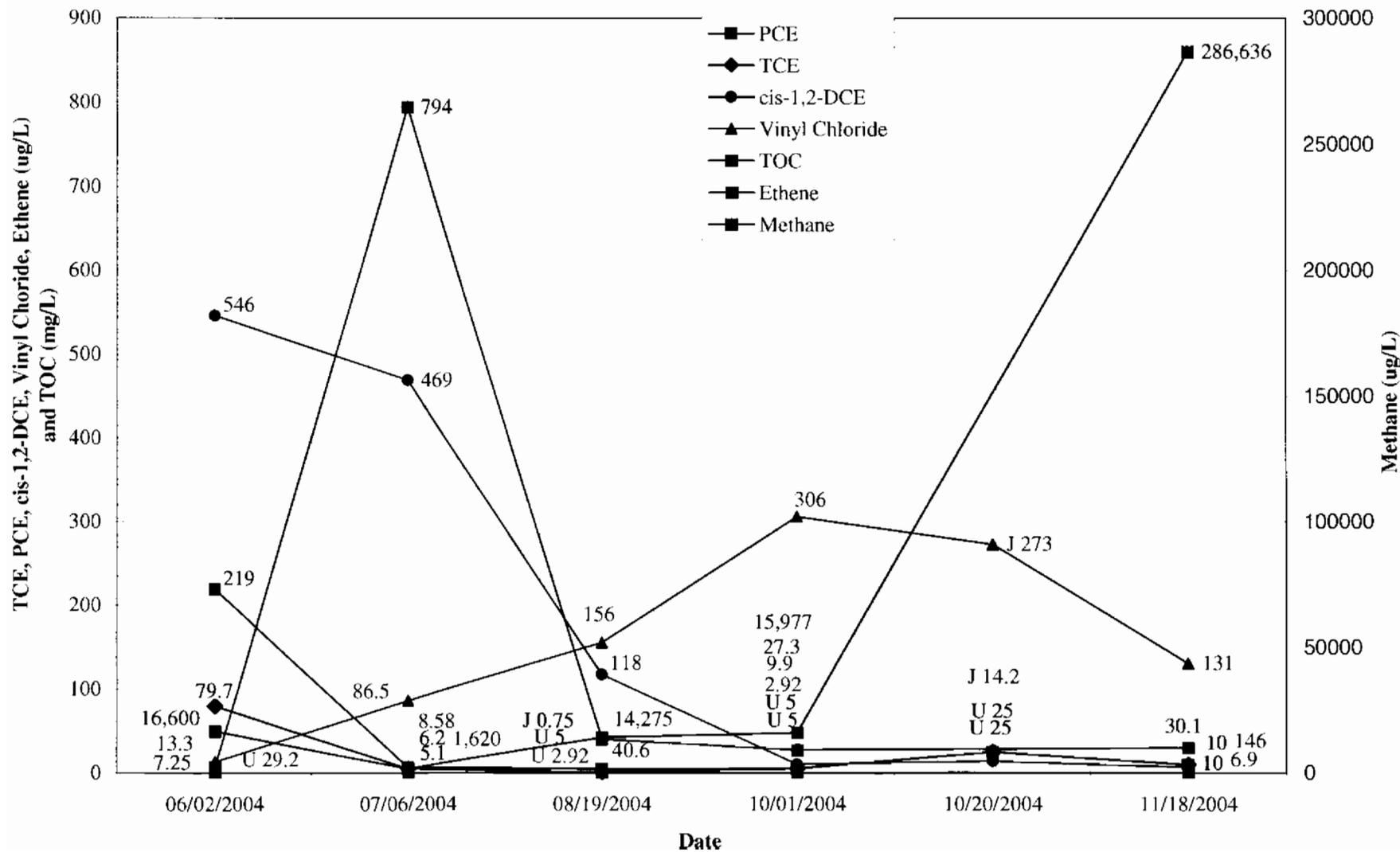
1 inch = 78.5556 feet

**Figure 2-1**  
Monitoring Well Locations  
AOC 607, Zone F  
Charleston Naval Complex

Figure 2-2. AOC 607 Enhanced Biodegradation Pilot Study  
F607GW032 - Performance Monitoring Results



**Figure 2-3. AOC 607 Enhanced Biodegradation Pilot Study  
F607GW033 - Performance Monitoring Results**



**Section 3.0**

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## 1 **3.0 Full-Scale Implementation Plan**

---

2 Based on the success of the pilot study, full-scale implementation of the remedial action is  
3 recommended at AOC 607. This section presents the approach for the proposed full-scale  
4 implementation. The current groundwater conditions with regard to COC concentrations  
5 are presented first, followed by the overall approach for ERD implementation.

### 6 **3.1 Current Groundwater Conditions**

7 VOC data from the annual groundwater monitoring event conducted in October 2004 at  
8 AOC 607 are presented on Figures 3-1 through 3-4 for PCE, TCE, 1,2-cis-DCE, and VC,  
9 respectively. The most recent sampling indicates that overall VOC concentrations have  
10 continued to decrease across the site over the past year. Several wells, such as F607GW006,  
11 F607GW06I, F607GW014, F607GW018D, and F607GW027, continue to have VOCs at  
12 concentrations well above their respective MCLs. However, several wells within the area in  
13 which the ERH was performed, such as F607GW015, F607GW016, and F607GW029, have  
14 PCE and TCE concentrations below or nearly at their respective cleanup levels (MCLs).  
15 Other wells, such as F607GW021 and F607GW023, have PCE and TCE concentrations well  
16 below 100 µg/L. Thus, significant progress has been made in remediating the site, but there  
17 are some areas where further treatment would be beneficial.

### 18 **3.2 Overall Approach for ERD Implementation**

19 The overall proposed approach for implementing ERD is to focus on the areas in which  
20 VOC concentrations currently exceed their target cleanup levels.

#### 21 **3.2.1 Injection Well Construction and Locations**

22 Three new injection wells will be used to impact VOC contamination in the shallow portion  
23 of the surficial aquifer in the immediate area of existing wells F607GW006, F607GW011, and  
24 F607GW027. These wells will be constructed with a 5-foot polyvinyl chloride (PVC)  
25 continuously-wrapped well screen terminated at the top of the clay layer located  
26 approximately 10 to 12 ft bls. The continuously-wrapped well screen with a 0.01-inch slot  
27 opening size offers a greater open area for a given slot size compared to a standard  
28 machine-slotted well screen. The greater open area allows for higher volumetric flow rate  
29 for delivery.

1 Two deep injection wells are recommended in the deep portion of the surficial aquifer to  
2 ensure adequate treatment in the vicinity of existing well F607GW18D. The deep wells will  
3 be terminated at the top of the Ashley formation and will be constructed with a 10-foot  
4 continuously wrapped well screen, with a 0.01-inch slot opening. The screen interval for the  
5 deep injection wells mirrors the screen interval for F60GW18D.

6 In addition to the five new injection wells, existing wells F607GW025 and F607GW028 used  
7 during the pilot test will be retained as injection wells for the full-scale ERD  
8 implementation. The injection and performance monitoring network is shown on Figure 3-5.

9 During full-scale ERD implementation, substrate will be injected in the five new and two  
10 existing wells to stimulate ERD.

11 Currently, F607GW021 and F607GW023 are not identified as injection wells since a  
12 reduction trend in contaminant concentration has been observed since January 2001. This  
13 observed trend in both wells will continue to be evaluated during full-scale implementation.  
14 In the event future analytical results show a deviation in the trend, subsequent substrate  
15 injections in these wells may be required.

### 16 **3.2.2 Substrate Selection**

17 Lactate was demonstrated to be highly effective at this site for stimulating the  
18 biodegradation of the COCs. Therefore, lactate (either potassium or sodium based) will be  
19 the primary substrate initially used for full-scale ERD implementation. Other complex  
20 substrates including high-fructose corn syrup and whey are also viable alternatives and may  
21 be used during full-scale implementation.

22 In addition, the use of an emulsified oil substrate (EOS) is proposed for at least one of the  
23 areas to be treated to evaluate its effectiveness at the site. EOS is a patented, engineered,  
24 food-grade, emulsified soybean oil mixed with lactate and trace nutrients. It has been found  
25 to be effective in promoting ERD, both in the laboratory environment and in field settings.  
26 Although it is more expensive than lactate, it has the advantage of lasting many times as  
27 long as lactate before requiring re-injection and thus can be less expensive than lactate on a  
28 life-cycle cost basis. Well F607GW014 has been identified as a candidate test injection  
29 location for EOS. Additional information about the proposed evaluation of EOS is provided  
30 in Section 3.5.

### 1 **3.2.3 Injection Approach**

2 Based on the success of the pilot test, the use of the existing shallow monitoring wells (see  
3 Section 3.2.1) as injection wells is proposed. The overall approach for injection during the  
4 pilot test (injection of approximately 230 gallons of a 3 to 5 percent lactate solution) has been  
5 modified to use a larger volume of injectate containing a more dilute substrate  
6 concentration. The revised approach will allow a broader and more uniform distribution of  
7 injectate. An injectate volume adequate to achieve a target radius of influence of  
8 approximately 5 to 10 feet radially from the injection well, with a less-concentrated lactate  
9 solution (0.5 to 1 percent) will be used. Based on the results observed during the pilot test, it  
10 is expected that significant improvements in the overall rate of reductive dechlorination of  
11 the COCs at the site will be observed within a 6 to 12 month period using this modified  
12 approach.

13 Injection of lactate is expected to be performed approximately every 2 months for 6 to 9  
14 months. If EOS is found to be a suitable substrate at the site, additional injections of this  
15 substrate may be conducted following the lactate injections.

## 16 **3.3 Performance Monitoring**

17 Performance monitoring will be conducted in a manner similar to that used during the pilot  
18 test. All performance monitoring wells will be monitored for field parameters (ORP, DO,  
19 pH, temperature, turbidity) on a monthly basis. TOC, alkalinity, and VFAs will also be  
20 monitored on a monthly basis for the first 3 months, then bimonthly to track the longevity of  
21 the substrate and assess the degree to which a robust fermentation environment is being  
22 created and maintained.

23 On a bimonthly basis, VOCs and dissolved gasses (MEE) will be measured to track the  
24 degree of ERD being achieved.

25 It is expected that after 6 to 12 months, several of the monitoring wells may indicate that the  
26 COCs are near or below the target media cleanup standards (MCSs). Once the data for a  
27 particular well consistently indicate that the COCs are below the MCSs, additional injections  
28 in the vicinity of that well may be postponed and those wells will continue to be monitored  
29 on a periodic basis to determine whether adequate treatment has occurred or whether  
30 additional injections should be considered. Further treatment of these wells with a long-  
31 lasting substrate such as EOS may also be performed.

## 3.4 Reporting

After the first 6 months following initiation of substrate injections, a semiannual report will be provided to SCDHEC that summarizes the results through the first 6 months and provides recommendations for continuing and optimizing the ERD process.

After the first year following substrate injection, an annual report will be provided that summarizes the results to date and provides recommendations for continuing and optimizing the ERD process as needed to achieve the site remediation objectives.

## 3.5 Evaluation of EOS

As noted above, EOS, an emulsified food-grade soybean oil product, is gaining acceptance as a cost-effective substrate for achieving ERD. Its chief advantage over substrates such as lactate is that it lasts much longer and therefore requires less frequent injections. Testing in the laboratory has found that it can be effective for up to 3 years, although it is not known whether it can last that long in a field setting. However, it is likely that EOS may last up to a year in the field before requiring additional injections.

To evaluate the effectiveness of EOS at AOC 607, EOS is proposed to be injected into well F607GW014 in a manner similar to that used for lactate injection. One new well will be installed in the shallow portion of the surficial aquifer inside Building 1189 to evaluate the impact from the EOS injection in well F607GW014. The well will be constructed using a 5-foot, Schedule 40 PVC well screen with standard 0.01-inch slot size openings. The new monitoring well will be terminated at the top of the clay layer, approximately 10 to 12 ft bbs.

Monitoring will be completed using the same method proposed for other wells. An initial monitoring period of 6 months is proposed to determine whether EOS can achieve results similar to those observed for wells injected with lactate. If EOS is found to be effective, its use in other wells at the site may be proposed.

## 3.6 Direct-Push Technology Investigation

Five temporary direct-push technology (DPT) groundwater monitoring locations at AOC 607, shown on Figure 3-6, will be advanced south of Building 225 and within the former footprint of the ERH IM. The purpose of these borings is to evaluate the impact to the shallow VOC plume from the ERH IM, completed in 2001 and 2002, in areas of the site that are not directly monitored through wells. The DPT borings will be advanced to the top of

1 the shallow clay layer (i.e., 10 to 12 ft bls) and one groundwater sample will be collected  
2 from each DPT boring at that location and analyzed for VOCs using EPA Method 8260B.  
3 The analytical results will be evaluated to determine if additional injection and monitoring  
4 wells not identified in this full-scale implementation plan are required.

## 5 **3.7 Permitting**

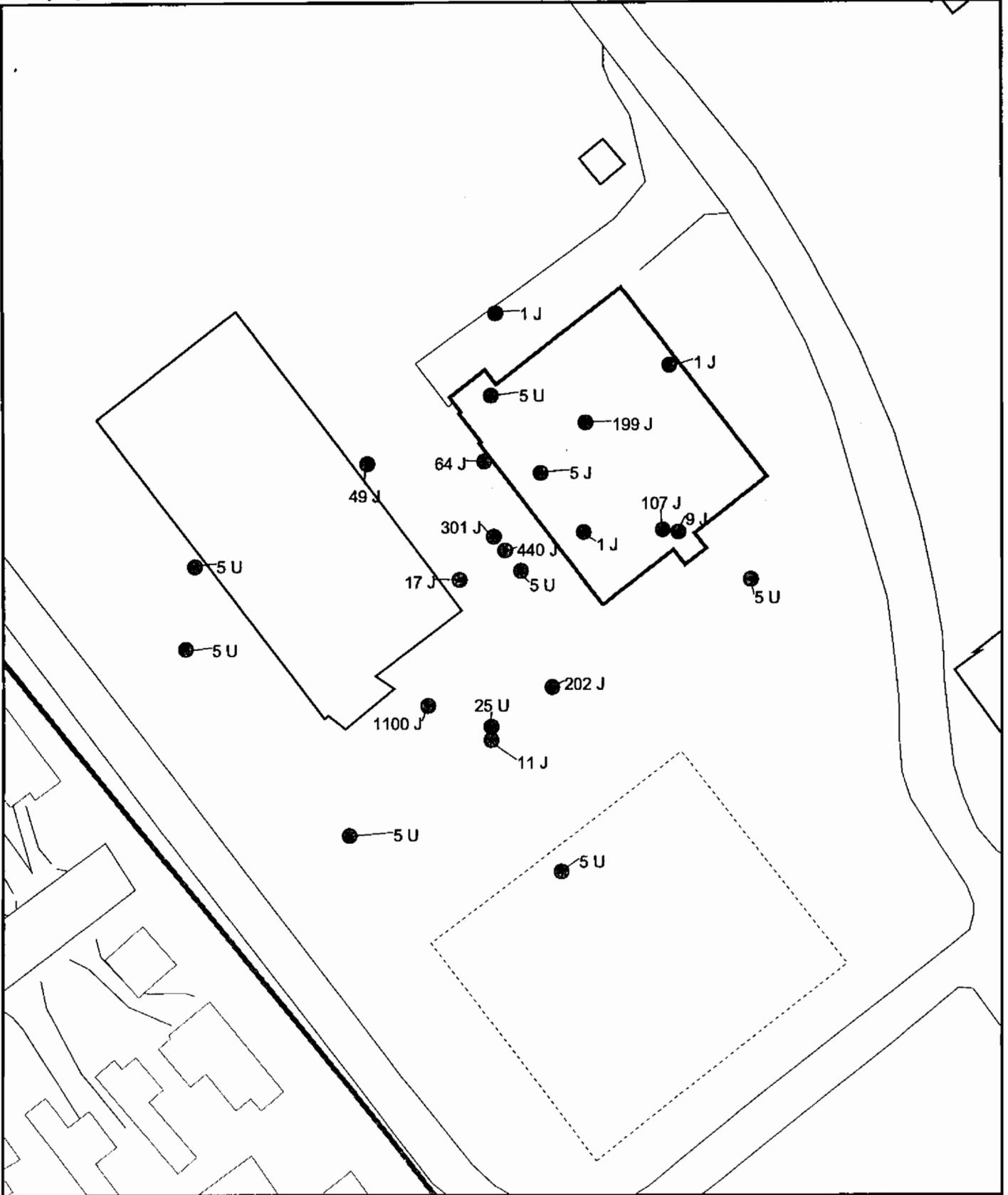
### 6 **3.7.1 SCDHEC Well Installation Request**

7 In accordance with R.61-79.265 Subpart F of the South Carolina Hazardous Waste  
8 Management Regulations and R.61-71 of the South Carolina Well Standards and  
9 Regulations, a request for the advancement of any additional monitoring wells or Geoprobe  
10 borings is required to be submitted to SCDHEC 2 weeks prior to the scheduled activity. The  
11 written request describes the purpose of the monitoring wells, injection wells, and Geoprobe  
12 boring activities and consists of construction details, if required, as well as a map depicting  
13 the proposed locations.

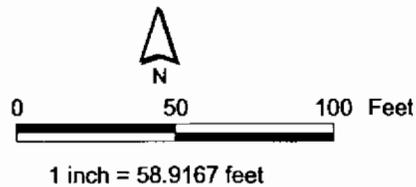
### 14 **3.7.2 SCDHEC Underground Injection Control Permit Application**

15 An underground injection control (UIC) permit addendum to the original Zone F UIC  
16 permit obtained prior to the pilot test will be prepared and submitted to SCDHEC for  
17 approval. The abbreviated addendum will include a description of the enhanced in situ  
18 anaerobic biodegradation technology, injection method, and site figure depicting the  
19 injection and monitoring well locations. Fieldwork consisting of substrate injection will be  
20 initiated after the UIC permit application is approved by SCDHEC.

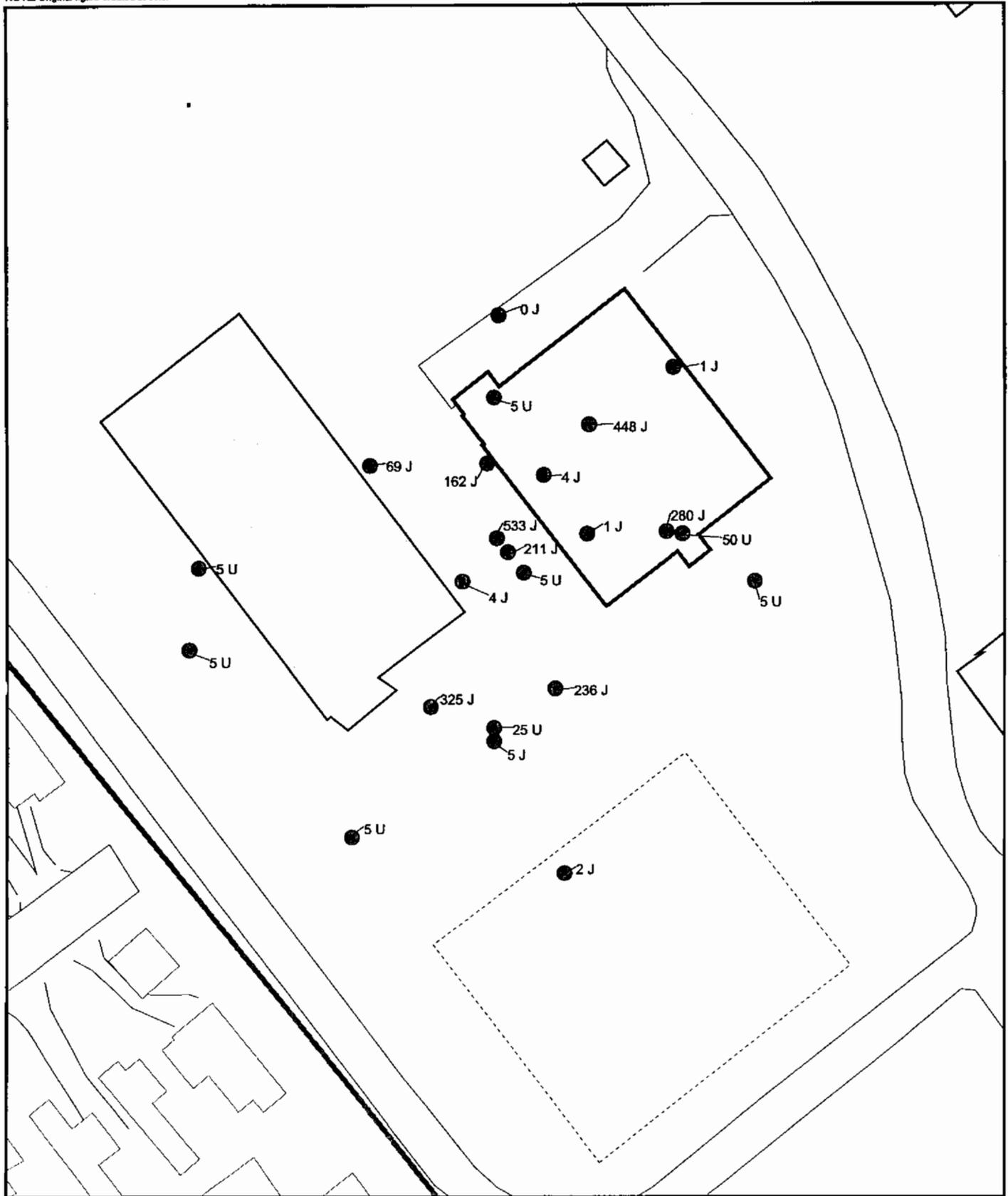
NOTE: Original figure created in color



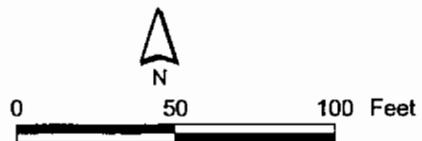
**Figure 3-1**  
PCE in Groundwater  
October 2004; AOC 607  
Charleston Naval Complex



NOTE: Original figure created in color

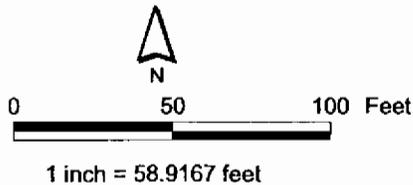
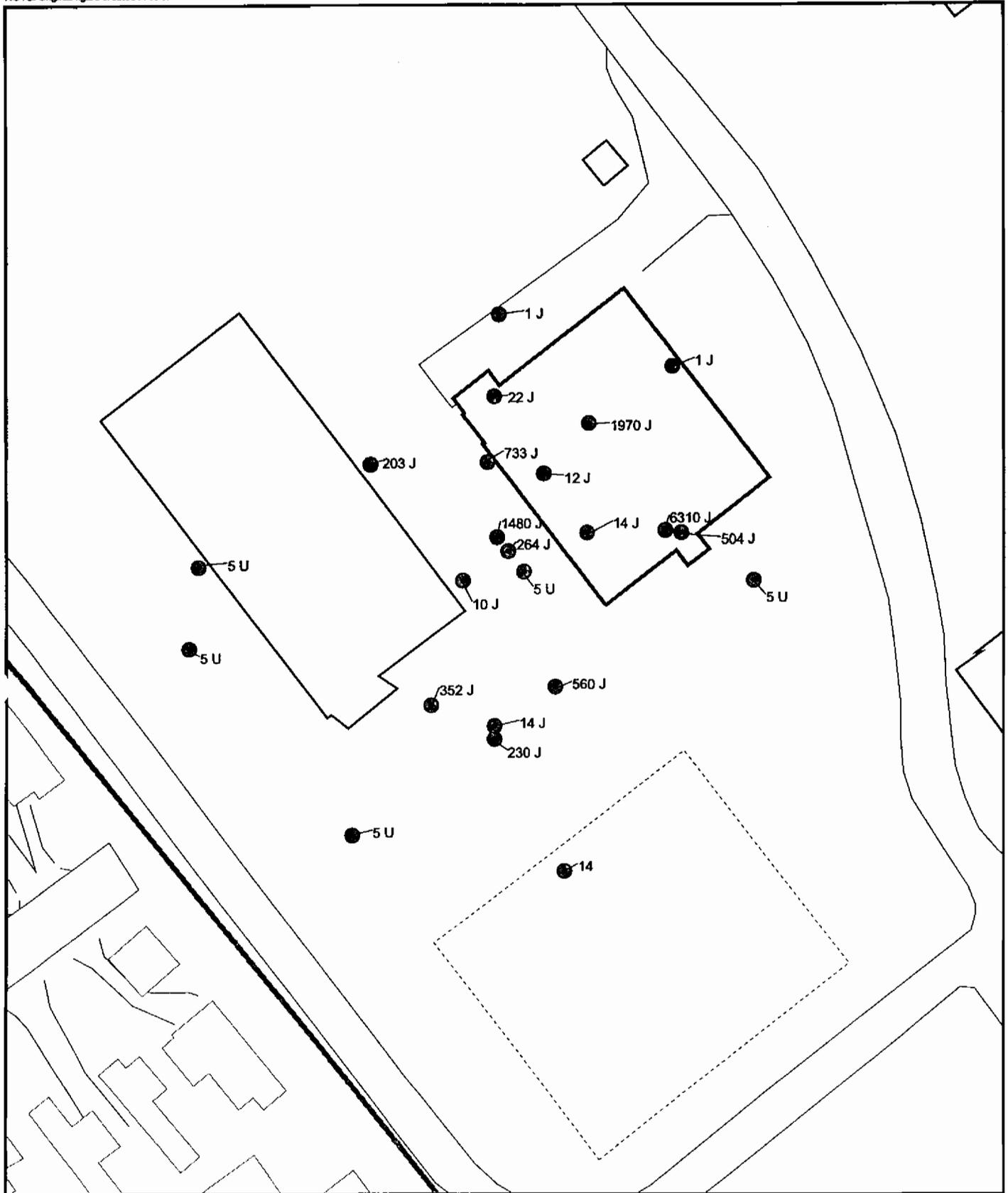


**Figure 3-2**  
TCE in Groundwater  
October 2004, AOC 607  
Charleston Naval Complex



1 inch = 58.9167 feet

NOTE: Original figure created in color



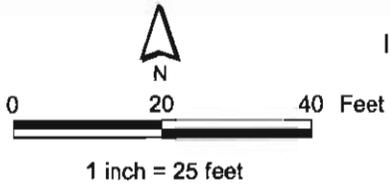
**Figure 3-3**  
1,2-cis-DCE in Groundwater  
October 2004, AOC 607  
Charleston Naval Complex



NOTE: Aerial Photo Date is 1997  
NOTE: Original figure created in color



-  Injection Well
-  Performance Monitoring Well
-  Groundwater Well - Abandoned
-  Groundwater Well - Active
-  AOC Boundary
-  Buildings

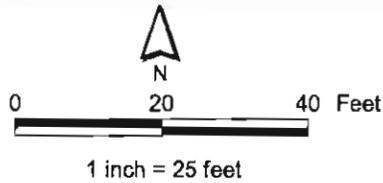


**Figure 3-5**  
Injection and Performance Monitoring Well Locations  
Zone F, AOC 607  
Charleston Naval Complex

NOTE: Aerial Photo Date is 1997  
NOTE: Original figure created in color



- DPT Groundwater Sample
- Groundwater Probe
- Groundwater Well - Abandoned
- Groundwater Well - Active
- AOC Boundary
- Buildings



**Figure 3-6**  
DPT Groundwater Sampling Locations  
Zone F, AOC 607  
Charleston Naval Complex

## **Section 4.0**

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## 1 4.0 References

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- 2 CH2M-Jones. *Corrective Measures Study Report/Pilot Study Work Plan, AOC 607, Zone F,*  
3 *Revision 0.* October 2003.
- 4 CH2M-Jones. *Phase I Interim Measure Work Plan, Groundwater Investigation, AOC 607, Zone F.*  
5 *Revision 0.* March 27, 2001a.
- 6 CH2M-Jones. *Phase II Interim Measure Work Plan, PCE Source Area Delineation, Area of Concern*  
7 *607, Zone F.* Revision 0. May 18, 2001b.
- 8 CH2M-Jones. *Phase III Interim Measure Work Plan, Electrical Resistance Heating – Source Area*  
9 *Remediation, AOC 607, Zone F.* Revision 0. August 24, 2001c.
- 10 EnSafe Inc. *Zone F RFI Report, NAVBASE Charleston.* Revision 0. December 31, 1997.

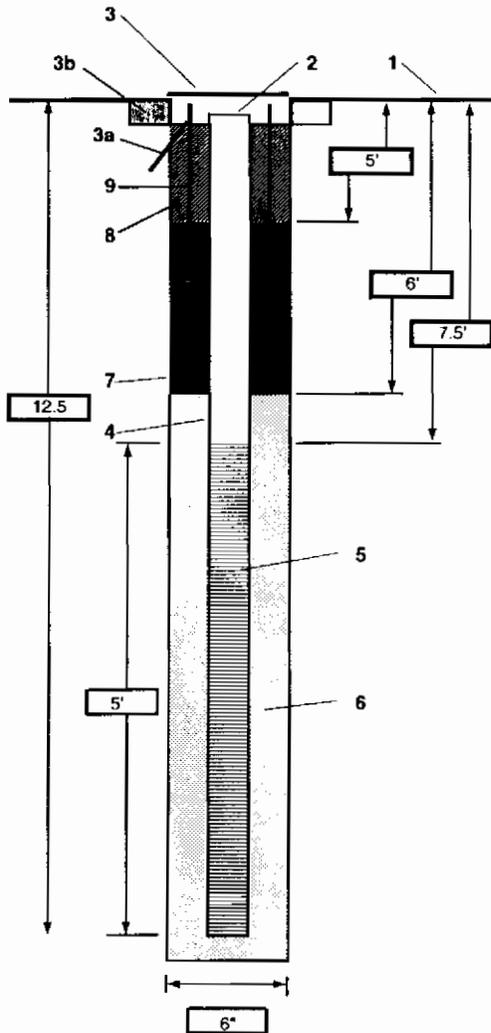
**Appendix A**

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PROJECT NUMBER <b>158814</b>	WELL NUMBER <b>F607GW032</b>	SHEET 1 OF 1
<b>WELL COMPLETION DIAGRAM</b>		

PROJECT : Charleston Naval Complex, AOC 607      LOCATION : Charleston, South Carolina      Northing 374018.288  
 DRILLING CONTRACTOR : Prosonic Corporation License # 1435      Easting 2317839.435  
 DRILLING METHOD AND EQUIPMENT USED : Geoprobe/hollow stem auger  
 WATER LEVELS : 6.3      START : 05/26/2004      END : 05/26/2004      LOGGER : Darryl Gates



1- Ground elevation at well	Not obtained
2- Top of casing elevation	8.61'
3- Wellhead protection cover type	Flush-mounted bolt-down manhole
a) drain tube?	no
b) concrete pad dimensions	3' x 3'
4- Dia./type of well casing	2 inch PVC
5- Type/slot size of screen	2 inch PVC, 0.010" slot screen
6- Type screen filter	20/30 silica sand
a) Quantity used	3.5 - 50 lb bags of sand
7- Type of seal	3/8" barroid bentonite chips, hydrated thr.
a) Quantity used	1/4 (50 lb) bucket
8- Grout	Type I Portland cement w/5% bentonite
a) Grout mix used	Trimee through tunnel
b) Method of placement	
c) Vol. of well casing grout	
9- CPVC sleeve	Not applicable
Development method	Surge block / submersable pump
Development time	68 minutes
Estimated purge volume	13 gallons

Comments    Grout weight = >14lb/gallon  
 Total Depth (BTOC) = +/- 2.5'

Final field parameters collected during well development on 5-27-04

Time/	pH	Cond	Temp	Turb (NTUs)
1045	6.03	1.11	22.1	18
1054	6.05	1.11	22.0	12
1104	6.02	.976	22	7

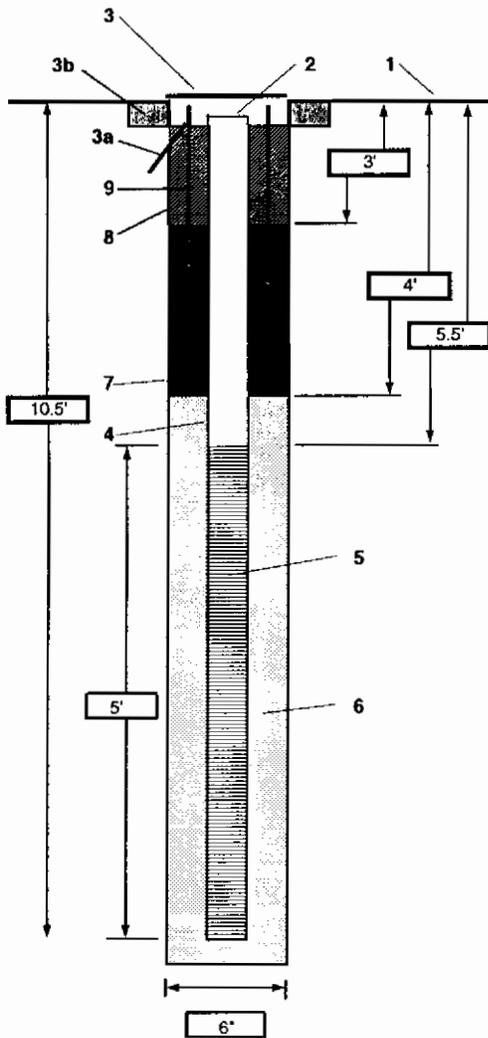
Note: Diagram not to scale.

Due to high turbidity, 10 gallons purged prior to taking readings.  
 Start surge at 1000 End Surge at 1008  
 Start Development at 1009 complete at 1104



PROJECT NUMBER <b>158814</b>	WELL NUMBER <b>F607GW033</b>	SHEET 1 OF 1
<b>WELL COMPLETION DIAGRAM</b>		

PROJECT : Charleston Naval Complex, AOC 607      LOCATION : Charleston, South Carolina      Northing 373931.969  
 DRILLING CONTRACTOR : Prosonic Corporation License # 1435      Easting 2317763.310  
 DRILLING METHOD AND EQUIPMENT USED : Geoprobe/hollow stem auger  
 WATER LEVELS : 4.9      START : 05/25/2004      END : 05/25/2004      LOGGER : Darryl Gates



Note: Diagram not to scale.

1- Ground elevation at well	Not obtained
2- Top of casing elevation	6.58'
3- Wellhead protection cover type	Flush-mounted bolt-down manhole
a) drain tube?	no
b) concrete pad dimensions	3' x 3' x 6"
4- Dia./type of well casing	2 inch PVC
5- Type/slot size of screen	2 inch PVC, 0.010" slot screen
6- Type screen filter	20/30 silica sand
a) Quantity used	3.5 - 50 lb bags of sand
7- Type of seal	3/8" baroid bentonite chips, hydrated 1hr.
a) Quantity used	1/4 (50 lb) bucket
8- Grout	Type I Portland cement w/5% bentonite
a) Grout mix used	
b) Method of placement	Trimee through funnel
c) Vol. of well casing grout	
9- CPVC sleeve	Not applicable
Development method	Surge block / submersible pump
Development time	82 minutes
Estimated purge volume	33 gallons

Comments    Grout weight = >14lb/gallon  
 Total Depth (BTOC) = +/- 2.5 inches

Final field parameters collected during well development on 5-27-04

Time	pH	Cond	Temp	Turb (NTUs)
1239	5.89	.93	27.4	20
1245	5.90	.820	27.4	10
1252	5.89	.820	27.3	8

Due to high turbidity, 30 gallons purged prior to taking readings.  
 Start surge at 1120 End Surge at 1128  
 Start Development at 1130 complete at 1252



**CH2MHILL**

**WELL PURGE AND SAMPLING FIELD SHEET**

**WELL NUMBER:** 607GW032 **SITE:** AOC 607

**FIELD CREW:** Andrew O'Conor / Darryl Gates

DEPTH TO WATER (FT):	6.32	CASING DIAMETER		GAL/FT OF CASING	
WELL DEPTH (FT):	12.1	2 IN.		0.1632	
WATER COLUMN (FT):	5.78	4 IN.		0.6528	
GAL/FT OF CASING	0.1632	6 IN.		1.4688	
CASING VOLUME (GAL)	0.94	8 IN.		2.611	
NO. OF VOLUMES min.(3)	3	10 IN.		4.0797	
PURGE VOLUME (GAL)	2.82	12 IN.		5.8748	

**METHOD OF PURGING**

<b>PUMP:</b> Peristaltic	<b>OTHER:</b>	<b>BAILER :</b> TEFLON, SS ,OTHER:
TIME ON: 1552		BAILER VOL.. (gal) .25 / .33
FLOW RATE (gpm): 0.18		REQUIRED PULLS:
PUMP TIME (min): 15		VOL. PURGED (gals):
VOL. PURGED (gals): 2.82		OTHER:

FIELD PARAMETERS	FIELD MEASUREMENTS					
	Initial	1st	2nd	3rd	5th	6th
TIME	1552	1556	1601	1607		
VOL. (gal)		1	2	3		
pH (s.units)	6.18	5.85	5.84	5.79		
COND.(S/m)	1.12	1.11	1.11	1.15		
TURBIDITY(NTUs)	51.1	62.9	26.5	6.2		
TEMP.(C)	21.96	22.06	21.89	21.86		
DO.(mg/L)	5	2.14	2.47	1.13		
ORP(mV)	72	96	82	84		

**OBSERVATIONS**

**COLOR:**

**ODOR:**

**COMMENTS:**

**SAMPLE DATE/ TIME:** 6-2-04 / 1608

**CH2MHILL****WELL PURGE AND SAMPLING FIELD SHEET****WELL NUMBER:** 607GW033 **SITE:** AOC 607**FIELD CREW:** Andrew O'Connor / Darryl Gates

	DEPTH TO WATER (FT):	CASING DIAMETER	GAL/FT OF CASING
	4.9		
WELL DEPTH (FT):	9.92	2 IN.	0.1632
WATER COLUMN (FT):	5.02	4 IN.	0.6528
GAL/FT OF CASING	0.1632	6 IN.	1.4688
CASING VOLUME (GAL)	0.81	8 IN.	2.611
NO. OF VOLUMES min.(3)	3	10 IN.	4.0797
PURGE VOLUME (GAL)	2.45	12 IN.	5.8748

**METHOD OF PURGING**

<b>PUMP:</b> Peristaltic	<b>OTHER:</b>	<b>BAILER :</b> TEFLON, SS ,OTHER:
TIME ON: 1444		BAILER VOL.. (gal) .25 / .33
FLOW RATE (gpm): 0.16		REQUIRED PULLS:
PUMP TIME (min): 15		VOL. PURGED (gals):
VOL. PURGED (gals): 2.45		OTHER:

FIELD PARAMETERS	FIELD MEASUREMENTS					
	Initial	1st	2nd	3rd	5th	6th
TIME	1445	1450	1455	1500		
VOL. (gal)		1	2	3		
pH (s.units)	6.08	5.9	5.98	5.98		
COND.(S/m)	1.43	1.24	1.24	1.24		
TURBIDITY(NTUs)	5.4	13.2	10.4	9		
TEMP.(C)	28.45	28.37	28.38	28.39		
DO.(mg/L)	5.45	0.65	1	0.94		
ORP(mV)	-85	-65	-73	-76		

**OBSERVATIONS****COLOR:****ODOR:****COMMENTS:****SAMPLE DATE/ TIME:** 6-2-04 / 1502

**Appendix B**

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Analytical Data Summary

01/17/2005 2:00 PM

Location Sample Date Collected SDG Number	F607GW003 607GW003P6 October 19, 2004 124076	F607GW004 607GW004P6 October 20, 2004 124076-1	F607GW006 607GW006P2 June 2, 2004 114093	F607GW006 607GW006P6 October 19, 2004 124076	
Chloromethane	ug/L		10	U	
Vinyl chloride	ug/L	10	U	8.2	J
Bromomethane	ug/L			10	U
Chloroethane	ug/L			10	U
1,1-Dichloroethene	ug/L	5	U	4.3	J
Acetone	ug/L			3.2	J
Carbon Disulfide	ug/L			5	U
Methylene Chloride	ug/L			5	U
trans-1,2-Dichloroethene	ug/L	5	U	8.6	=
1,1-Dichloroethane	ug/L			5	U
Vinyl acetate	ug/L			10	UJ
Methyl ethyl ketone (2-Butanone)	ug/L			10	U
cis-1,2-Dichloroethylene	ug/L	5	U	13.8	=
1,2-Dichloroethene (total)	ug/L	5	U	13.8	=
Chloroform	ug/L			5	U
1,1,1-Trichloroethane	ug/L			5	U
Carbon Tetrachloride	ug/L			5	U
1,2-Dichloroethane	ug/L			5	U
Benzene	ug/L			5	U
Trichloroethylene (TCE)	ug/L	5	U	1.5	J
1,2-Dichloropropane	ug/L			5	U
Bromodichloromethane	ug/L			5	U
2-Chloroethyl vinyl ether	ug/L			10	U
cis-1,3-Dichloropropene	ug/L			5	U
Methyl isobutyl ketone (4-Methyl-2-pentanone)	ug/L			10	U
Toluene	ug/L			0.56	J
trans-1,3-Dichloropropene	ug/L			5	U
1,1,2-Trichloroethane	ug/L			5	U
2-Hexanone	ug/L			10	U
Tetrachloroethylene (PCE)	ug/L	5	U	5	U
Dibromochloromethane	ug/L			1420	=
Chlorobenzene	ug/L			5	U

Analytical Data Summary

01/17/2005 2:00 PM

	Location Sample Date Collected SDG Number	F607GW003 607GW003P6 October 19, 2004 124076	F607GW004 607GW004P6 October 20, 2004 124076-1	F607GW006 607GW006P2 June 2, 2004 114093	F607GW006 607GW006P6 October 19, 2004 124076
Ethylbenzene	ug/L			5	U
o-Xylene	ug/L			5	U
m+p Xylene	ug/L			5	U
Xylenes, Total	ug/L			5	U
Styrene	ug/L			5	U
Bromoform	ug/L			5	U
1,1,2,2-Tetrachloroethane	ug/L			5	U
1,3-Dichlorobenzene	ug/L			5	U
1,4-Dichlorobenzene	ug/L			5	U
1,2-Dichlorobenzene	ug/L			5	U
1,2,4-Trichlorobenzene	ug/L			5	U
1,2,3-Trichlorobenzene	ug/L			5	U

## Analytical Data Summary

01/17/2005 2:00 PM

Location Sample Date Collected SDG Number	F607GW011 607GW011P2 June 2, 2004 114093		F607GW011 607GW011P6 October 19, 2004 124076		F607GW012 607GW012P2 June 2, 2004 114093		F607GW012 607GW012P6 October 19, 2004 124076		
	Chloromethane	ug/L	10	UJ			10	U	
Vinyl chloride	ug/L	3.5	J	5.7	J	10	U	10	U
Bromomethane	ug/L	10	UJ			10	U		
Chloroethane	ug/L	10	UJ			10	U		
1,1-Dichloroethene	ug/L	3.2	J	50	U	5	U	5	U
Acetone	ug/L	3.7	J			3.4	J		
Carbon Disulfide	ug/L	5	UJ			5	U		
Methylene Chloride	ug/L	5	UJ			5	U		
trans-1,2-Dichloroethene	ug/L	6.7	J	50	U	5	U	5	U
1,1-Dichloroethane	ug/L	5	UJ			5	U		
Vinyl acetate	ug/L	10	UJ			10	U		
Methyl ethyl ketone (2-Butanone)	ug/L	10	UJ			10	U		
cis-1,2-Dichloroethylene	ug/L	1950	J	733	J	35	J	13.9	J
1,2-Dichloroethene (total)	ug/L	1960	J	733	J	35	J	13.9	J
Chloroform	ug/L	5	UJ			5	U		
1,1,1-Trichloroethane	ug/L	5	UJ			5	U		
Carbon Tetrachloride	ug/L	5	UJ			5	U		
1,2-Dichloroethane	ug/L	5	UJ			5	U		
Benzene	ug/L	5	UJ			5	U		
Trichloroethylene (TCE)	ug/L	774	J	162	J	3.1	J	0.52	J
1,2-Dichloropropane	ug/L	5	UJ			5	U		
Bromodichloromethane	ug/L	5	UJ			5	U		
2-Chloroethyl vinyl ether	ug/L	10	UJ			10	U		
cis-1,3-Dichloropropene	ug/L	5	UJ			5	U		
Methyl isobutyl ketone (4-Methyl-2-pentanone)	ug/L	10	UJ			10	U		
Toluene	ug/L	1	J			5	U		
trans-1,3-Dichloropropene	ug/L	5	UJ			5	U		
1,1,2-Trichloroethane	ug/L	5	UJ			5	U		
2-Hexanone	ug/L	10	UJ			10	U		
Tetrachloroethylene (PCE)	ug/L	76	J	64	J	2	J	0.97	J
Dibromochloromethane	ug/L	5	UJ			5	U		
Chlorobenzene	ug/L	5	UJ			5	U		

Analytical Data Summary

01/17/2005 2:00 PM

	Location Sample Date Collected SDG Number	F607GW011 607GW011P2 June 2, 2004 114093	F607GW011 607GW011P6 October 19, 2004 124076	F607GW012 607GW012P2 June 2, 2004 114093	F607GW012 607GW012P6 October 19, 2004 124076
Ethylbenzene	ug/L	5 UJ		5 U	
o-Xylene	ug/L	5 UJ		5 U	
m+p Xylene	ug/L	5 UJ		5 U	
Xylenes, Total	ug/L	5 UJ		5 U	
Styrene	ug/L	5 UJ		5 U	
Bromoform	ug/L	5 UJ		5 U	
1,1,2,2-Tetrachloroethane	ug/L	5 UJ		5 U	
1,3-Dichlorobenzene	ug/L	5 UJ		5 U	
1,4-Dichlorobenzene	ug/L	5 UJ		5 U	
1,2-Dichlorobenzene	ug/L	5 UJ		5 U	
1,2,4-Trichlorobenzene	ug/L	5 UJ		5 U	
1,2,3-Trichlorobenzene	ug/L	5 UJ		5 U	

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Location Sample Date Collected SDG Number	F607GW013 607GW013P6 October 20, 2004 124076-1	F607GW014 607GW014P6 October 19, 2004 124076	F607GW015 607GW015P6 October 19, 2004 124076	F607GW016 607GW016P6 October 20, 2004 124076
Chloromethane	ug/L			
Vinyl chloride	ug/L	10 U	0.58 J	10 U 4.1 J
Bromomethane	ug/L			
Chloroethane	ug/L			
1,1-Dichloroethene	ug/L	5 U	4.2 J	5 U 5 U
Acetone	ug/L			
Carbon Disulfide	ug/L			
Methylene Chloride	ug/L			
trans-1,2-Dichloroethene	ug/L	5 U	4.6 J	5 U 5 U
1,1-Dichloroethane	ug/L			
Vinyl acetate	ug/L			
Methyl ethyl ketone (2-Butanone)	ug/L			
cis-1,2-Dichloroethylene	ug/L	1.2 J	1970 J	12.2 J 22.2 J
1,2-Dichloroethene (total)	ug/L	1.2 J	1970 J	12.2 J 22.2 J
Chloroform	ug/L			
1,1,1-Trichloroethane	ug/L			
Carbon Tetrachloride	ug/L			
1,2-Dichloroethane	ug/L			
Benzene	ug/L			
Trichloroethylene (TCE)	ug/L	1.1 J	448 J	3.7 J 5 U
1,2-Dichloropropane	ug/L			
Bromodichloromethane	ug/L			
2-Chloroethyl vinyl ether	ug/L			
cis-1,3-Dichloropropene	ug/L			
Methyl isobutyl ketone (4-Methyl-2-pentanone)	ug/L			
Toluene	ug/L			
trans-1,3-Dichloropropene	ug/L			
1,1,2-Trichloroethane	ug/L			
2-Hexanone	ug/L			
Tetrachloroethylene (PCE)	ug/L	1.1 J	199 J	5.1 J 5 U
Dibromochloromethane	ug/L			
Chlorobenzene	ug/L			

Analytical Data Summary

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	Location Sample Date Collected SDG Number	F607GW013 607GW013P6 October 20, 2004 124076-1	F607GW014 607GW014P6 October 19, 2004 124076	F607GW015 607GW015P6 October 19, 2004 124076	F607GW016 607GW016P6 October 20, 2004 124076
Ethylbenzene	ug/L				
o-Xylene	ug/L				
m+p Xylene	ug/L				
Xylenes, Total	ug/L				
Styrene	ug/L				
Bromoform	ug/L				
1,1,2,2-Tetrachloroethane	ug/L				
1,3-Dichlorobenzene	ug/L				
1,4-Dichlorobenzene	ug/L				
1,2-Dichlorobenzene	ug/L				
1,2,4-Trichlorobenzene	ug/L				
1,2,3-Trichlorobenzene	ug/L				

Analytical Data Summary

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	Location Sample Date Collected SDG Number	F607GW021 607GW021P6 October 19, 2004 124076	F607GW022 607GW022P6 October 19, 2004 124076-1	F607GW023 607GW023P6 October 19, 2004 124076	F607GW025 607GW025P2 June 9, 2004 114667
Chloromethane	ug/L				10 U
Vinyl chloride	ug/L	10 U	10 U	1 J	5.4 J
Bromomethane	ug/L				10 U
Chloroethane	ug/L				10 U
1,1-Dichloroethene	ug/L	5 U	5 U	1.2 J	5.7 =
Acetone	ug/L				10 U
Carbon Disulfide	ug/L				5 U
Methylene Chloride	ug/L				5 U
trans-1,2-Dichloroethene	ug/L	5 U	5 U	0.82 J	5 U
1,1-Dichloroethane	ug/L				5 U
Vinyl acetate	ug/L				10 U
Methyl ethyl ketone (2-Butanone)	ug/L				10 U
cis-1,2-Dichloroethylene	ug/L	9.5 J	5 U	203 J	2020 =
1,2-Dichloroethene (total)	ug/L	9.5 J	5 U	203 J	2020 =
Chloroform	ug/L				5 U
1,1,1-Trichloroethane	ug/L				5 U
Carbon Tetrachloride	ug/L				5 U
1,2-Dichloroethane	ug/L				5 U
Benzene	ug/L				5 U
Trichloroethylene (TCE)	ug/L	3.5 J	5 U	68.8 J	1240 =
1,2-Dichloropropane	ug/L				5 U
Bromodichloromethane	ug/L				5 U
2-Chloroethyl vinyl ether	ug/L				10 U
cis-1,3-Dichloropropene	ug/L				5 U
Methyl isobutyl ketone (4-Methyl-2-pentanone)	ug/L				10 U
Toluene	ug/L				5 U
trans-1,3-Dichloropropene	ug/L				5 U
1,1,2-Trichloroethane	ug/L				5 U
2-Hexanone	ug/L				10 U
Tetrachloroethylene (PCE)	ug/L	16.6 J	5 U	48.8 J	4310 =
Dibromochloromethane	ug/L				5 U
Chlorobenzene	ug/L				5 U

Analytical Data Summary

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	Location Sample Date Collected SDG Number	F607GW021 607GW021P6 October 19, 2004 124076	F607GW022 607GW022P6 October 19, 2004 124076-1	F607GW023 607GW023P6 October 19, 2004 124076	F607GW025 607GW025P2 June 9, 2004 114667
Ethylbenzene	ug/L				0.22 J
o-Xylene	ug/L				5 U
m+p Xylene	ug/L				5 U
Xylenes, Total	ug/L				5 U
Styrene	ug/L				5 U
Bromoform	ug/L				5 U
1,1,2,2-Tetrachloroethane	ug/L				5 U
1,3-Dichlorobenzene	ug/L				5 U
1,4-Dichlorobenzene	ug/L				0.3 J
1,2-Dichlorobenzene	ug/L				5 U
1,2,4-Trichlorobenzene	ug/L				5 U
1,2,3-Trichlorobenzene	ug/L				5 U

Analytical Data Summary

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Location Sample Date Collected SDG Number	F607GW025 607GW025P6 October 19, 2004 124076	F607GW027 607GW027P2 June 2, 2004 114093	F607GW027 607GW027P6 October 19, 2004 124076	F607GW028 607GW028P2 June 2, 2004 114093
Chloromethane	ug/L	10 U		10 U
Vinyl chloride	ug/L	94.6 J	10 U	6.1 J 305 J
Bromomethane	ug/L		10 U	10 U
Chloroethane	ug/L		10 U	1.4 J
1,1-Dichloroethene	ug/L	25 U	1.6 J	50 U 31.4 =
Acetone	ug/L		2.9 J	3.5 J
Carbon Disulfide	ug/L		5 U	5 U
Methylene Chloride	ug/L		5 U	5 U
trans-1,2-Dichloroethene	ug/L	8 J	1.8 J	50 U 28.4 =
1,1-Dichloroethane	ug/L		5 U	5 U
Vinyl acetate	ug/L		10 UJ	10 UJ
Methyl ethyl ketone (2-Butanone)	ug/L		10 U	10 U
cis-1,2-Dichloroethylene	ug/L	230 J	518 =	560 J 18400 J
1,2-Dichloroethene (total)	ug/L	238 J	518 =	560 J 18400 J
Chloroform	ug/L		5 U	5 U
1,1,1-Trichloroethane	ug/L		5 U	5 U
Carbon Tetrachloride	ug/L		5 U	5 U
1,2-Dichloroethane	ug/L		5 U	5 U
Benzene	ug/L		5 U	5 U
Trichloroethylene (TCE)	ug/L	4.5 J	130 =	236 J 4.6 J
1,2-Dichloropropane	ug/L		5 U	5 U
Bromodichloromethane	ug/L		5 U	5 U
2-Chloroethyl vinyl ether	ug/L		10 U	10 U
cis-1,3-Dichloropropene	ug/L		5 U	5 U
Methyl isobutyl ketone (4-Methyl-2-pentanone)	ug/L		10 U	10 U
Toluene	ug/L		5 U	2 J
trans-1,3-Dichloropropene	ug/L		5 U	5 U
1,1,2-Trichloroethane	ug/L		5 U	5 U
2-Hexanone	ug/L		10 U	10 U
Tetrachloroethylene (PCE)	ug/L	11.1 J	201 =	202 J 3.9 J
Dibromochloromethane	ug/L		5 U	5 U
Chlorobenzene	ug/L		5 U	5 U

Analytical Data Summary

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	Location Sample Date Collected SDG Number	F607GW025 607GW025P6 October 19, 2004 124076	F607GW027 607GW027P2 June 2, 2004 114093	F607GW027 607GW027P6 October 19, 2004 124076	F607GW028 607GW028P2 June 2, 2004 114093
Ethylbenzene	ug/L		5 U		5 U
o-Xylene	ug/L		5 U		5 U
m+p Xylene	ug/L		5 U		5 U
Xylenes, Total	ug/L		5 U		5 U
Styrene	ug/L		5 U		5 U
Bromoform	ug/L		5 U		5 U
1,1,2,2-Tetrachloroethane	ug/L		5 U		5 U
1,3-Dichlorobenzene	ug/L		5 U		5 U
1,4-Dichlorobenzene	ug/L		5 U		5 U
1,2-Dichlorobenzene	ug/L		5 U		5 U
1,2,4-Trichlorobenzene	ug/L		5 U		5 U
1,2,3-Trichlorobenzene	ug/L		5 U		5 U

## Analytical Data Summary

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	Location Sample Date Collected SDG Number	F607GW028 607GW028P6 October 19, 2004 124076	F607GW029 607GW029P6 October 19, 2004 124076	F607GW030 607GW030P6 October 20, 2004 124076-1	F607GW031 607GW031P6 October 19, 2004 124076-1
Chloromethane	ug/L				
Vinyl chloride	ug/L	211 J	10 U	10 U	10 U
Bromomethane	ug/L				
Chloroethane	ug/L				
1,1-Dichloroethene	ug/L	50 U	5 U	5 U	5 U
Acetone	ug/L				
Carbon Disulfide	ug/L				
Methylene Chloride	ug/L				
trans-1,2-Dichloroethene	ug/L	19.2 J	5 U	5 U	5 U
1,1-Dichloroethane	ug/L				
Vinyl acetate	ug/L				
Methyl ethyl ketone (2-Butanone)	ug/L				
cis-1,2-Dichloroethylene	ug/L	504 J	0.74 J	5 U	5 U
1,2-Dichloroethene (total)	ug/L	523 J	0.74 J	5 U	5 U
Chloroform	ug/L				
1,1,1-Trichloroethane	ug/L				
Carbon Tetrachloride	ug/L				
1,2-Dichloroethane	ug/L				
Benzene	ug/L				
Trichloroethylene (TCE)	ug/L	50 U	0.49 J	5 U	5 U
1,2-Dichloropropane	ug/L				
Bromodichloromethane	ug/L				
2-Chloroethyl vinyl ether	ug/L				
cis-1,3-Dichloropropene	ug/L				
Methyl isobutyl ketone (4-Methyl-2-pentanone)	ug/L				
Toluene	ug/L				
trans-1,3-Dichloropropene	ug/L				
1,1,2-Trichloroethane	ug/L				
2-Hexanone	ug/L				
Tetrachloroethylene (PCE)	ug/L	8.5 J	0.54 J	5 U	5 U
Dibromochloromethane	ug/L				
Chlorobenzene	ug/L				

Analytical Data Summary

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	Location Sample Date Collected SDG Number	F607GW028 607GW028P6 October 19, 2004 124076	F607GW029 607GW029P6 October 19, 2004 124076	F607GW030 607GW030P6 October 20, 2004 124076-1	F607GW031 607GW031P6 October 19, 2004 124076-1
Ethylbenzene	ug/L				
o-Xylene	ug/L				
m+p Xylene	ug/L				
Xylenes, Total	ug/L				
Styrene	ug/L				
Bromoform	ug/L				
1,1,2,2-Tetrachloroethane	ug/L				
1,3-Dichlorobenzene	ug/L				
1,4-Dichlorobenzene	ug/L				
1,2-Dichlorobenzene	ug/L				
1,2,4-Trichlorobenzene	ug/L				
1,2,3-Trichlorobenzene	ug/L				

## Analytical Data Summary

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Location Sample Date Collected SDG Number		F607GW032 607GW032P2 June 2, 2004 114093		F607GW032 607GW032P3 July 6, 2004 116262		F607GW032 607GW032P4 August 19, 2004 119494		F607GW032 607GW032P4a October 1, 2004 122703	
Chloromethane	ug/L	10	UJ	10	U	10	UJ	500	U
Vinyl chloride	ug/L	151	J	452	=	1050	J	1920	=
Bromomethane	ug/L	10	UJ	10	U	10	UJ	500	U
Chloroethane	ug/L	2.3	J	3.5	J	0.81	J	500	U
1,1-Dichloroethene	ug/L	23.2	J	13.8	J	13.4	J	250	U
Acetone	ug/L	9.9	J	10	U	10	UJ	500	U
Carbon Disulfide	ug/L	5	UJ	5	U	5	UJ	250	U
Methylene Chloride	ug/L	5	UJ	5	U	5	UJ	250	U
trans-1,2-Dichloroethene	ug/L	36.8	J	58.3	J	60.3	J	34.3	J
1,1-Dichloroethane	ug/L	5	UJ	5	U	5	UJ	250	U
Vinyl acetate	ug/L	10	UJ	10	U	10	UJ	500	U
Methyl ethyl ketone (2-Butanone)	ug/L	10	UJ	6.1	J	10	UJ	500	U
cis-1,2-Dichloroethylene	ug/L	14300	J	5940	=	11600	J	5230	=
1,2-Dichloroethene (total)	ug/L	14300	J	6000	=	11700	J	5230	=
Chloroform	ug/L	5	UJ	5	U	5	UJ	250	U
1,1,1-Trichloroethane	ug/L	5	UJ	5	U	5	UJ	250	U
Carbon Tetrachloride	ug/L	5	UJ	5	U	5	UJ	250	U
1,2-Dichloroethane	ug/L	5	UJ	5	U	5	UJ	250	U
Benzene	ug/L	5	UJ	5	U	5	UJ	250	U
Trichloroethylene (TCE)	ug/L	3480	J	10.2	J	71.4	J	147	J
1,2-Dichloropropane	ug/L	5	UJ	5	U	5	UJ	250	U
Bromodichloromethane	ug/L	5	UJ	5	U	5	UJ	250	U
2-Chloroethyl vinyl ether	ug/L	10	UJ	10	U	10	UJ	500	U
cis-1,3-Dichloropropene	ug/L	5	UJ	5	U	5	UJ	250	U
Methyl isobutyl ketone (4-Methyl-2-pentanone)	ug/L	10	UJ	10	U	10	UJ	500	U
Toluene	ug/L	2.4	J	2.6	J	2.1	J	250	U
trans-1,3-Dichloropropene	ug/L	5	UJ	5	U	5	UJ	250	U
1,1,2-Trichloroethane	ug/L	0.51	J	5	U	5	UJ	250	U
2-Hexanone	ug/L	10	UJ	10	U	10	UJ	500	U
Tetrachloroethylene (PCE)	ug/L	8090	J	3.3	J	14.1	J	41.3	J
Dibromochloromethane	ug/L	5	UJ	5	U	5	UJ	250	U
Chlorobenzene	ug/L	5	UJ	5	U	5	UJ	250	U

Analytical Data Summary

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	Location Sample Date Collected SDG Number	F607GW032 607GW032P2 June 2, 2004 114093	F607GW032 607GW032P3 July 6, 2004 116262	F607GW032 607GW032P4 August 19, 2004 119494	F607GW032 607GW032P4a October 1, 2004 122703
Ethylbenzene	ug/L	5 UJ	5 U	5 UJ	250 U
o-Xylene	ug/L	5 UJ	5 U	5 UJ	250 U
m+p Xylene	ug/L	5 UJ	5 U	5 UJ	250 U
Xylenes, Total	ug/L	5 UJ	5 U	5 UJ	250 U
Styrene	ug/L	5 UJ	5 U	5 UJ	250 U
Bromoform	ug/L	5 UJ	5 U	5 UJ	250 U
1,1,2,2-Tetrachloroethane	ug/L	5 UJ	5 U	5 UJ	250 U
1,3-Dichlorobenzene	ug/L	5 UJ	5 U	5 UJ	250 U
1,4-Dichlorobenzene	ug/L	5 UJ	5 U	5 UJ	250 U
1,2-Dichlorobenzene	ug/L	5 UJ	5 U	5 UJ	250 U
1,2,4-Trichlorobenzene	ug/L	5 UJ	5 U	5 UJ	250 U
1,2,3-Trichlorobenzene	ug/L	5 UJ	5 U	5 UJ	250 U

Analytical Data Summary

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Location		F607GW032	F607GW032	F607GW033	F607GW033
Sample		607GW032P6	607GW032P6a	607GW033P2	607GW033P3
Date Collected		October 20, 2004	November 18, 2004	June 2, 2004	July 6, 2004
SDG Number		124076	125902	114093	116262
Chloromethane	ug/L		1000 U	10 U	10 U
Vinyl chloride	ug/L	1360 J	1190 =	13.3 =	86.5 =
Bromomethane	ug/L		1000 U	10 U	10 U
Chloroethane	ug/L		1000 U	10 U	10 U
1,1-Dichloroethene	ug/L	500 U	500 U	0.86 J	1.4 J
Acetone	ug/L		1000 U	4 J	31 U
Carbon Disulfide	ug/L		500 U	5 U	5 U
Methylene Chloride	ug/L		500 U	5 U	5 U
trans-1,2-Dichloroethene	ug/L	40.9 J	500 U	0.9 J	1.4 J
1,1-Dichloroethane	ug/L		500 U	5 U	5 U
Vinyl acetate	ug/L		1000 U	10 U	10 U
Methyl ethyl ketone (2-Butanone)	ug/L		1000 U	10 U	92.6 =
cis-1,2-Dichloroethylene	ug/L	6310 J	9010 =	546 =	469 =
1,2-Dichloroethene (total)	ug/L	6350 J	9010 =	546 =	469 =
Chloroform	ug/L		500 U	5 U	5 U
1,1,1-Trichloroethane	ug/L		500 U	5 U	5 U
Carbon Tetrachloride	ug/L		500 U	5 U	5 U
1,2-Dichloroethane	ug/L		500 U	5 U	5 U
Benzene	ug/L		500 U	5 U	5 U
Trichloroethylene (TCE)	ug/L	280 J	383 J	79.7 =	5.1 =
1,2-Dichloropropane	ug/L		500 U	5 U	5 U
Bromodichloromethane	ug/L		500 U	5 U	5 U
2-Chloroethyl vinyl ether	ug/L		1000 U	10 U	10 U
cis-1,3-Dichloropropene	ug/L		500 U	5 U	5 U
Methyl isobutyl ketone (4-Methyl-2-pentanone)	ug/L		1000 U	10 U	10 U
Toluene	ug/L		500 U	5 U	5 U
trans-1,3-Dichloropropene	ug/L		500 U	5 U	5 U
1,1,2-Trichloroethane	ug/L		500 U	5 U	5 U
2-Hexanone	ug/L		1000 U	10 U	10 U
Tetrachloroethylene (PCE)	ug/L	107 J	104 J	219 =	6.2 =
Dibromochloromethane	ug/L		500 U	5 U	5 U
Chlorobenzene	ug/L		500 U	5 U	5 U

Analytical Data Summary

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	Location Sample Date Collected SDG Number	F607GW032 607GW032P6 October 20, 2004 124076	F607GW032 607GW032P6a November 18, 2004 125902	F607GW033 607GW033P2 June 2, 2004 114093	F607GW033 607GW033P3 July 6, 2004 116262
Ethylbenzene	ug/L		500 U	5 U	5 U
o-Xylene	ug/L		500 U	5 U	5 U
m+p Xylene	ug/L		500 U	5 U	5 U
Xylenes, Total	ug/L		500 U	5 U	5 U
Styrene	ug/L		500 U	5 U	5 U
Bromoform	ug/L		500 U	5 U	5 U
1,1,2,2-Tetrachloroethane	ug/L		500 U	5 U	5 U
1,3-Dichlorobenzene	ug/L		500 U	5 U	5 U
1,4-Dichlorobenzene	ug/L		500 U	5 U	5 U
1,2-Dichlorobenzene	ug/L		500 U	5 U	5 U
1,2,4-Trichlorobenzene	ug/L		500 U	5 U	5 U
1,2,3-Trichlorobenzene	ug/L		500 U	5 U	5 U

Analytical Data Summary

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Location Sample Date Collected SDG Number	F607GW033 607GW033P4 August 19, 2004 119494	F607GW033 607GW033P4a October 1, 2004 122703	F607GW033 607GW033P6 October 20, 2004 124076	F607GW033 607GW033P6a November 18, 2004 125902
Chloromethane	ug/L 10 UJ	10 U		20 U
Vinyl chloride	ug/L 156 J	306 =	273 J	131 =
Bromomethane	ug/L 10 UJ	10 UJ		20 U
Chloroethane	ug/L 10 UJ	10 U		20 U
1,1-Dichloroethene	ug/L 5 UJ	5 U	25 U	10 U
Acetone	ug/L 35 UJ	10.2 J		52.9 =
Carbon Disulfide	ug/L 5 UJ	5 U		10 U
Methylene Chloride	ug/L 5 UJ	5 U		10 U
trans-1,2-Dichloroethene	ug/L 5 J	5.3 =	5.2 J	2.4 J
1,1-Dichloroethane	ug/L 5 UJ	5 U		10 U
Vinyl acetate	ug/L 10 UJ	10 U		20 U
Methyl ethyl ketone (2-Butanone)	ug/L 116 J	20.1 =		288 =
cis-1,2-Dichloroethylene	ug/L 118 J	9.9 =	14.2 J	6.9 J
1,2-Dichloroethene (total)	ug/L 122 J	15.2 =	19.3 J	9.3 J
Chloroform	ug/L 5 UJ	5 U		10 U
1,1,1-Trichloroethane	ug/L 5 UJ	5 U		10 U
Carbon Tetrachloride	ug/L 5 UJ	5 U		10 U
1,2-Dichloroethane	ug/L 5 UJ	5 U		10 U
Benzene	ug/L 5 UJ	5 U		10 U
Trichloroethylene (TCE)	ug/L 0.75 J	5 U	25 U	10 U
1,2-Dichloropropane	ug/L 5 UJ	5 U		10 U
Bromodichloromethane	ug/L 5 UJ	5 U		10 U
2-Chloroethyl vinyl ether	ug/L 10 UJ	10 U		20 U
cis-1,3-Dichloropropene	ug/L 5 UJ	5 U		10 U
Methyl isobutyl ketone (4-Methyl-2-pentanone)	ug/L 10 UJ	10 U		20 U
Toluene	ug/L 5 UJ	5 U		10 U
trans-1,3-Dichloropropene	ug/L 5 UJ	5 U		10 U
1,1,2-Trichloroethane	ug/L 5 UJ	5 U		10 U
2-Hexanone	ug/L 10 UJ	10 U		20 U
Tetrachloroethylene (PCE)	ug/L 5 UJ	5 U	25 U	10 U
Dibromochloromethane	ug/L 5 UJ	5 U		10 U
Chlorobenzene	ug/L 5 UJ	5 U		10 U

Analytical Data Summary

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	<b>Location Sample Date Collected SDG Number</b>	<b>F607GW033 607GW033P4 August 19, 2004 119494</b>	<b>F607GW033 607GW033P4a October 1, 2004 122703</b>	<b>F607GW033 607GW033P6 October 20, 2004 124076</b>	<b>F607GW033 607GW033P6a November 18, 2004 125902</b>
Ethylbenzene	ug/L	5 UJ	5 U		10 U
o-Xylene	ug/L	5 UJ	5 U		10 U
m+p Xylene	ug/L	5 UJ	5 U		10 U
Xylenes, Total	ug/L	5 UJ	5 U		10 U
Styrene	ug/L	5 UJ	5 U		10 U
Bromoform	ug/L	5 UJ	5 U		10 U
1,1,2,2-Tetrachloroethane	ug/L	5 UJ	5 U		10 U
1,3-Dichlorobenzene	ug/L	5 UJ	5 U		10 U
1,4-Dichlorobenzene	ug/L	5 UJ	5 U		10 U
1,2-Dichlorobenzene	ug/L	5 UJ	5 U		10 U
1,2,4-Trichlorobenzene	ug/L	5 UJ	5 U		10 U
1,2,3-Trichlorobenzene	ug/L	5 UJ	5 U		10 U

Analytical Data Summary

01/17/2005 2:00 PM

	Location Sample Date Collected SDG Number	F607GW06D 607GW06DP6 October 19, 2004 124076	F607GW06I 607GW06IP6 October 19, 2004 124076	F607GW18D 607GW18DP6 October 19, 2004 124076
Chloromethane	ug/L			
Vinyl chloride	ug/L	10 U	100 U	200 U
Bromomethane	ug/L			
Chloroethane	ug/L			
1,1-Dichloroethene	ug/L	5 U	50 U	100 U
Acetone	ug/L			
Carbon Disulfide	ug/L			
Methylene Chloride	ug/L			
trans-1,2-Dichloroethene	ug/L	5 U	50 U	100 U
1,1-Dichloroethane	ug/L			
Vinyl acetate	ug/L			
Methyl ethyl ketone (2-Butanone)	ug/L			
cis-1,2-Dichloroethylene	ug/L	5 U	264 J	352 J
1,2-Dichloroethene (total)	ug/L	5 U	264 J	352 J
Chloroform	ug/L			
1,1,1-Trichloroethane	ug/L			
Carbon Tetrachloride	ug/L			
1,2-Dichloroethane	ug/L			
Benzene	ug/L			
Trichloroethylene (TCE)	ug/L	5 U	211 J	325 J
1,2-Dichloropropane	ug/L			
Bromodichloromethane	ug/L			
2-Chloroethyl vinyl ether	ug/L			
cis-1,3-Dichloropropene	ug/L			
Methyl isobutyl ketone (4-Methyl-2-pentanone)	ug/L			
Toluene	ug/L			
trans-1,3-Dichloropropene	ug/L			
1,1,2-Trichloroethane	ug/L			
2-Hexanone	ug/L			
Tetrachloroethylene (PCE)	ug/L	5 U	440 J	1100 J
Dibromochloromethane	ug/L			
Chlorobenzene	ug/L			

Analytical Data Summary

01/17/2005 2:00 PM

	Location Sample Date Collected SDG Number	F607GW06D 607GW06DP6 October 19, 2004 124076	F607GW06I 607GW06IP6 October 19, 2004 124076	F607GW18D 607GW18DP6 October 19, 2004 124076
Ethylbenzene	ug/L			
o-Xylene	ug/L			
m+p Xylene	ug/L			
Xylenes, Total	ug/L			
Styrene	ug/L			
Bromoform	ug/L			
1,1,2,2-Tetrachloroethane	ug/L			
1,3-Dichlorobenzene	ug/L			
1,4-Dichlorobenzene	ug/L			
1,2-Dichlorobenzene	ug/L			
1,2,4-Trichlorobenzene	ug/L			
1,2,3-Trichlorobenzene	ug/L			

Analytical Data Summary

01/17/2005 2:00 PM

Location		F607GW025	F607GW027	F607GW028	F607GW032	F607GW033
Sample		607GW025P2	607GW027P2	607GW028P2	607GW032P2	607GW033P2
Date Collected		June 9, 2004	June 2, 2004	June 2, 2004	June 2, 2004	June 2, 2004
SDG Number		114667	114093	114093	114093	114093
Iron	ug/L	24000 =				30600 =
Manganese	ug/L	926 =				644 =
Potassium	ug/L	5290 =	4870 J	4420 J	6420 =	6670 =

Analytical Data Summary

01/17/2005 2:00 PM

	Location Sample Date Collected SDG Number	F607GW025 607GW025P2 June 9, 2004 114667	F607GW027 607GW027P2 June 2, 2004 114093	F607GW027 607GW027P2 June 2, 2004 12BF	F607GW028 607GW028P2 June 2, 2004 114093	F607GW028 607GW028P2 June 2, 2004 12BF
ETHANE	UG/L			31.2 U		45 =
ETHENE	UG/L			29.2 U		41 =
Formic Acid	MG/L			1 U		1 U
METHANE	UG/L			9900 =		610 =
Acetic Acid	MG/L					
Alkalinity, Total (as CaCO3)	mg/L	46.8 =	79 J		84.8 J	
Butyric Acid	MG/L					
Dehalococcoides spp_	Gnms/ML					
Pyruvic Acid (C3)	MG/L			4 U		4 U
Lactic Acid (C3)	MG/L			1 U		1 U
Acetic Acid (C2)	MG/L			1 U		1 U
Sulfate (as SO4)	mg/L	191 =	163 =		264 =	
Sulfide	mg/L	0.0248 UJ	0.0248 UJ		0.0248 UJ	
Propionic Acid (C3)	MG/L			1 U		1 U
Total Organic Carbon	mg/L	5.85 =	5.83 =		15.5 =	
Butyric Acid (C4)	MG/L			1 U		1 U
Bromide	mg/L	0.843 =	1.62 =		0.732 =	

Analytical Data Summary

01/17/2005 2:00 PM

Location Sample Date Collected SDG Number	F607GW032 607GW032P2 June 2, 2004 114093	F607GW032 607GW032P2 June 2, 2004 12BF	F607GW032 607GW032P3 July 6, 2004 07BG	F607GW032 607GW032P3 July 6, 2004 116262	F607GW032 607GW032P4 August 19, 2004 119494
ETHANE	UG/L	4 =	13.73 U		
ETHENE	UG/L	10 =	13.73 =		
Formic Acid	MG/L	1 U	1 U		
METHANE	UG/L	25 =	27.42 =		
Acetic Acid	MG/L				
Alkalinity, Total (as CaCO3)	mg/L	101 J			249 =
Butyric Acid	MG/L				
Dehalococcoides spp_	Gnms/ML				
Pyruvic Acid (C3)	MG/L	4 U	4 U		
Lactic Acid (C3)	MG/L	1 U	1 U		
Acetic Acid (C2)	MG/L	1 U	135.5 =		
Sulfate (as SO4)	mg/L	231 =			102 =
Sulfide	mg/L	0.0506 J			0.0968 J
Propionic Acid (C3)	MG/L	1 U	70.5 =		
Total Organic Carbon	mg/L	15.8 =		112 =	535 =
Butyric Acid (C4)	MG/L	1 U	1 U		
Bromide	mg/L	0.443 =			1.11 =

Analytical Data Summary

01/17/2005 2:00 PM

Location Sample Date Collected SDG Number	F607GW033 607GW033P2 June 2, 2004 114093	F607GW033 607GW033P2 June 2, 2004 12BF	F607GW033 607GW033P3 July 6, 2004 07BG	F607GW033 607GW033P3 July 6, 2004 116262	F607GW033 607GW033P4 August 19, 2004 119494
ETHANE	UG/L	31.2 U	31.2 U		
ETHENE	UG/L	29.2 U	8.58 =		
Formic Acid	MG/L	1 U	10 U		
METHANE	UG/L	16600 =	1620 =		
Acetic Acid	MG/L				
Alkalinity, Total (as CaCO3)	mg/L	96.5 J			1140 =
Butyric Acid	MG/L				
Dehalococcoides spp_	Gnms/ML				
Pyruvic Acid (C3)	MG/L	4 U	4 U		
Lactic Acid (C3)	MG/L	1 U	241 =		
Acetic Acid (C2)	MG/L	1 U	484.8 =		
Sulfate (as SO4)	mg/L	243 =			14.3 =
Sulfide	mg/L	0.0248 UJ			0.186 J
Propionic Acid (C3)	MG/L	1 U	435.2 =		
Total Organic Carbon	mg/L	7.25 =		794 =	40.6 =
Butyric Acid (C4)	MG/L	1 U	1 U		
Bromide	mg/L	0.363 =			2.17 =

Analytical Data Summary

01/17/2005 2:00 PM

	Location Sample Date Collected SDG Number	F607GW033 607GW033P4 August 19, 2004 29BH	F607GW033 607GW033P4a October 1, 2004 006BJ	F607GW033 607GW033P4a October 1, 2004 122703	F607GW033 607GW033P6a November 18, 2004 053BK	F607GW033 607GW033P6a November 18, 2004 125902
ETHANE	UG/L	3.12 U	3.12 U		156 U	
ETHENE	UG/L	2.92 U	2.92 U		146 U	
Formic Acid	MG/L	2.6 =	1 U		10 U	
METHANE	UG/L	14275 =	15977 =		286636 =	
Acetic Acid	MG/L		60.4 =		864.6 =	
Alkalinity, Total (as CaCO3)	mg/L					
Butyric Acid	MG/L		6.5 =		240.2 =	
Dehalococcoides spp_	Gnms/ML	41600 =				
Pyruvic Acid (C3)	MG/L	4 U	4 U		40 U	
Lactic Acid (C3)	MG/L	1 U	1 U		10 U	
Acetic Acid (C2)	MG/L	349.4 =				
Sulfate (as SO4)	mg/L					
Sulfide	mg/L					
Propionic Acid (C3)	MG/L	186 =	39.2 =		1756 =	
Total Organic Carbon	mg/L			27.3 =		30.1 =
Butyric Acid (C4)	MG/L	141.4 =				
Bromide	mg/L					

Analytical Data Summary

01/25/2005 1:11 PM

	Location Sample Date Collected SDG Number	F607GW027 607GW027P2 June 2, 2004 114095	F607GW028 607GW028P2 June 2, 2004 114095	F607GW032 607GW032P2 June 2, 2004 114095	F607GW032 607GW032P4 August 19, 2004 119494	F607GW033 607GW033P4 August 19, 2004 119494
Iron, Dissolved	ug/L	23400 =	16400 =	35800 =	26900 =	111000 =
Manganese, Dissolved	ug/L	958 =	430 =	838 =	445 =	1480 =
Potassium, Dissolved	ug/L				25300 =	843000 =





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# Microbial Analysis Report

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**Client:** Herb Kelly  
CH2M Hill  
3011 SW Williston Road  
Gainesville, FL 32608

**Phone:** 352-335-5877

**Fax:** 352-271-4811

**MI Identifier:** 46BE    **Date Rec.:** 05/27/04    **Report Date:** 05/28/04

**Analysis Requested:** BDC

**Project:** Charleston Navy Complex

**Comments:**

All samples within this data package were analyzed under U.S. EPA Good Laboratory Practice Standards: Toxic Substances Control Act (40 CFR part 790). All samples were processed according to standard operating procedures. Test results submitted in this data package meet the quality assurance requirements established by Microbial Insights, Inc.

**Reported by:**

**Reviewed by:**

---

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## Bio-Dechlor CENSUS

### Overview of Approach

Nucleic acid technology allows for specific, sensitive detection of microorganisms from a variety of environments. Information can be obtained about the kinds of organisms present (phylogenetic assessment) and also about the specific capabilities of the organisms present (functional assessment). Thus, this technology has become an invaluable tool for detecting specific organisms and/or their functional genes. A limitation of one widely used nucleic acid technology, PCR, was that it was not quantitative. As technology advanced, this limitation has been overcome, and quantitative (real-time) PCR is now possible through the combined use of specialized PCR reagents (e.g., TaqMan) and refined instrumentation. Q-PCR is particularly useful for the bioremediation field because the population size (i.e., the number of particular organisms) can be determined, and so population changes can be tracked over time or in response to a treatment.

For this sample set, DNA was extracted from each sample using MoBio DNA extraction kits and analyzed for the following.

Target group/organism	Acronym	Description
Dehalococcoides spp.	DHC	Determines the concentration of a known dechlorinating bacteria

The results are presented in Table 1.

## CENSUS Results:

**Table 1.** Quantitative Real time PCR (Q-PCR) was used to determine the number of *Dehalococcoides* spp. gene copies in DNA extracted from each sample.

Sample Name	Date Sampled	Dechlorinating Bacteria
		<i>Dehalococcoides</i> spp. <sup>C,F</sup>
		Abundance 16S rRNA genomes/bead
607GW03203	05/26/04	1.8 E+03
607GW03303	05/26/04	1.1 E+03
<b>QA/QC Controls</b>		
Positive Control		2.57 E+07
Negative Control		Not Detected

<sup>C</sup> Assuming *Dehalococcoides ethenogenes* contains 1 rRNA operon per genome, the value given also may represent the number of cells per mL or g of sample for bacteria in this phylogenetic group.

<sup>F</sup> The practical quantitation limit (PQL) is  $\sim 5 \times 10^2$  16S rRNA gene copies per sample.

ND = Not Detected

J = Estimated gene copies below PQL but above LQL

I = Inhibited

<sup>1</sup> Bio-Dechlor Census technology was developed by Dr. Loeffler and colleagues at Georgia Institute of Technology and was licensed for use through Regensis.



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# Microbial Analysis Report

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**Client:** Herb Kelly  
CH2M Hill  
3011 SW Williston Road  
Gainesville, FL 32608

**Phone:** 352-335-5877

**Fax:** 352-271-4811

**MI Identifier:** 12BF      **Date Rec.:** 06/03/04      **Report Date:** 06/07/04

**Analysis Requested:** BDC

**Project:** Charleston Navy Complex

**Comments:**

All samples within this data package were analyzed under U.S. EPA Good Laboratory Practice Standards: Toxic Substances Control Act (40 CFR part 790). All samples were processed according to standard operating procedures. Test results submitted in this data package meet the quality assurance requirements established by Microbial Insights, Inc.

**Reported by:**

**Reviewed by:**

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## Bio-Dechlor CENSUS

### Overview of Approach

Nucleic acid technology allows for specific, sensitive detection of microorganisms from a variety of environments. Information can be obtained about the kinds of organisms present (phylogenetic assessment) and also about the specific capabilities of the organisms present (functional assessment). Thus, this technology has become an invaluable tool for detecting specific organisms and/or their functional genes. A limitation of one widely used nucleic acid technology, PCR, was that it was not quantitative. As technology advanced, this limitation has been overcome, and quantitative (real-time) PCR is now possible through the combined use of specialized PCR reagents (e.g., TaqMan) and refined instrumentation. Q-PCR is particularly useful for the bioremediation field because the population size (i.e., the number of particular organisms) can be determined, and so population changes can be tracked over time or in response to a treatment.

For this sample set, DNA was extracted from each sample using MoBio DNA extraction kits and analyzed for the following.

Target group/organism	Acronym	Description
Dehalococcoides spp.	DHC	Determines the concentration of a known dechlorinating bacteria

The results are presented in Table 1.

**CENSUS Results:**

Table 1. Quantitative Real time PCR (Q-PCR) was used to determine the number of *Dehalococcoides* spp. gene copies in DNA extracted from each sample.

Sample Name	Date Sampled	Dechlorinating Bacteria
		Abundance 16S rRNA genomes/ mL
607GW027P2	06/03/04	ND
607GW028P2	06/03/04	6.34 E+01
607GW0132P2	06/03/04	ND
607GW033P2	06/03/04	J (<1)
<b>QA/QC Controls</b>		
Positive Control		1.36 E+06
Negative Control		Not Detected

<sup>c</sup> Assuming *Dehalococcoides ethenogenes* contains 1 rRNA operon per genome, the value given also may represent the number of cells per mL or g of sample for bacteria in this phylogenetic group.

<sup>f</sup> The practical quantitation limit (PQL) is  $\sim 5 \times 10^2$  16S rRNA gene copies per sample.

ND = Not Detected

J = Estimated gene copies below PQL but above LQL

I = Inhibited

<sup>†</sup> Bio-Dechlor Census technology was developed by Dr. Loeffler and colleagues at Georgia Institute of Technology and was licensed for use through Regeneration.



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# Microbial Analysis Report

---

**Client:** Tom Beisel  
CH2M Hill  
115 Perimeter Center Place  
Suite 700  
Atlanta, GA 30346

**Phone:** (770) 604-9182 x367

**Fax:**

**Email:**

**MI Identifier:** 029BH    **Date Rec.:** 08/20/04    **Report Date:** 09/28/04

**Analysis Requested:** PLFA, DHE, VFA, MEE

**Project:** Charleston Navy Complex

**Comments:**

A copy of this report will be sent to Herb Kelly at the CH2M Hill Office in Gainesville, FL.

All samples within this data package were analyzed under U.S. EPA Good Laboratory Practice Standards: Toxic Substances Control Act (40 CFR part 790). All samples were processed according to standard operating procedures. Test results submitted in this data package meet the quality assurance requirements established by Microbial Insights, Inc.

**Reported by:**

**Reviewed by:**

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## Microbial Analysis Report

### Results and Discussion

The microbial communities of two groundwater samples from the Charleston Navy Complex were characterized according to their phospholipid fatty acid content (PLFA Analysis). The quantification of *Dehalococcoides spp.* was also determined using Real-Time PCR (qPCR). These samples were also assayed for the presence of volatile fatty acids (VFA) and methane, ethane, ethane (MEE). Results from these analyses revealed the following key observations:

- Estimated viable biomass, as determined by total PLFA concentrations, was  $\sim 4.0E+05$  cells/mL for 607GW032P4 and  $\sim 5.8E+05$  cells/mL for 607GW-33P4. In comparison with typical groundwater samples these are moderate levels of biomass. (Figure 1, Table 2)
- The PLFA profiles of the samples showed that the microbial communities had similarly diverse community structures, which had large proportions of biomarkers for Firmicutes (as shown by terminally branched saturated PLFA) and Proteobacteria (monoenoic PLFA). Proportions of Firmicute biomarkers (which include *Clostridia*-like fermenting bacteria) accounted for  $\sim 29\%$  of the total PLFA in 607GW032P4 while being  $\sim 23\%$  of the total PLFA in 607GW033P4. High proportions of Firmicutes are important at contaminated sites due to their ability to produce the hydrogen needed for reductive dechlorination. Biomarkers for Gram negative Proteobacteria were  $\sim 30\%$  of the total PLFA in 607GW032P4 and in 607GW033P4 these biomarkers were the most prominent accounting for  $\sim 38\%$  of the total PLFA. High proportions of Proteobacteria are of interest at contaminated sites due to their ability to utilize a wide range of carbon sources and to quickly adapt to environmental conditions. Anaerobic metal reducers (as shown by branched monoenoic PLFA) and sulfate reducers (mid-chain branched saturated PLFA) were present in 607GW032P4 at  $\sim 5\%$  and  $\sim 7\%$  of the total PLFA, respectively while in 607GW033P4 these biomarkers were seen at  $\sim 4\%$  of the total PLFA each. Eukaryotic biomarkers (polyenoic PLFA) were not detected in either sample at notable proportions. (Figure 2, Table 2)
- Physiologic status ratios for starvation and microbial response to environmentally induced stress showed that the Gram negative population was experiencing low levels of stress in both samples. Physiologic ratios for starvation revealed that 607GW032P4 was experiencing a higher level of starvation than 607GW033P4. It is important to note that starvation is a comparative measure of the growth rate of microbes, i.e., a higher starvation ratio indicates a slower growth rate. Although this ratio does not directly correlate to the log or stationary phases of growth it can be useful in comparing samples within an event or over time. (Figure 3, Table 2)
- Volatile fatty acid analysis (VFA) results showed that high levels of acetic, propionic and butyric acids in sample 607GW033P4. (Table 3)
- Results of the Metabolic Gases analysis (MEE) showed high levels of Methane in both samples while only 607GW032P4 also had notable levels of Ethene. (Table 4)
- The presence of *Dehalococcoides spp.* was quantified using Real-Time PCR (qPCR) and was seen at  $\sim 10^{4-5}$  cells/mL for both samples. (Table 5)

## Overview of Approach

Examining the phospholipid fatty acids (PLFA) in environmental samples is an effective tool for monitoring microbial responses to their environment. They are essential components of the membranes of all cells (except for the Archea, a minor component of most environments), so their sum includes all important members of most microbial communities. There are three different types of information in PLFA profiles: biomass; community structure; and physiological status.

**Biomass:** PLFA analysis is the most reliable and accurate method available for the determination of viable microbial biomass. Phospholipids break down rapidly upon cell death (21, 23), so the PLFA biomass does not contain 'fossil' lipids of dead cells. The sum of the PLFA, expressed as picomoles (1 picomole =  $1 \times 10^{-12}$  mole), is proportional to the number of cells. The proportion used in this report, 20,000 cells/pmol, is taken from cells grown in laboratory media, and varies somewhat with type of organism and environmental conditions. Starving bacterial cells have the lowest cells/pmol, and healthy eukaryotic cells have the highest.

**Community Structure:** The PLFA in an environmental sample is the sum of the microbial community's PLFA, and reflects the proportions of different organisms in the sample. PLFA profiles are routinely used to classify bacteria and fungi (19) and are one of the characteristics used to describe new bacterial species (25). Broad phylogenic groups of microbes have different fatty acid profiles, making it possible to distinguish among them (4, 5, 22, 24). Table 1 describes the six major structural groups employed in this report.

Table 1. Description of PLFA structural groups.

PLFA Structural Group	General classification
Monoenoic (Monos)	Abundant in Proteobacteria (Gram negative bacteria), typically fast growing, utilize many carbon sources, and adapt quickly to a variety of environments.
Terminally Branched Saturated (TerBrSats)	Characteristic of Firmicutes (Low G+C Gram-positive bacteria), and also found in Bacteriodes, and some Gram-negative bacteria (especially anaerobes).
Branched Monoenoic (BrMonos)	Found in the cell membranes of micro-aerophiles and anaerobes, such as sulfate- or iron-reducing bacteria
Mid-Chain Branched Saturated (MidBrSats)	Common in Actinobacteria (High G+C Gram-positive bacteria), and some metal-reducing bacteria.
Normal Saturated (Nsats)	Found in all organisms.
Polyenoic	Found in eukaryotes such as fungi, protozoa, algae, higher plants, and animals.

**Physiological status:** The membrane of a microbe adapts to the changing conditions of its environment, and these changes are reflected in the PLFA. Toxic compounds or environmental conditions that disrupt the membrane cause some bacteria to make *trans* fatty acids from the usual *cis* fatty acids (7). Many Proteobacteria and other microbes respond to starvation or highly toxic conditions by making cyclopropyl (7) or mid-chain branched fatty acids (20). The physiological status biomarkers for Toxic Stress and for Starvation/Toxicity are formed by dividing the amount of the fatty acid induced by starvation and/or stress, by the amount of its biosynthetic precursor.

PLFA were analyzed by extraction of the total lipid (21) and then separation of the polar lipids by column chromatography (6). The polar lipid fatty acids were derivatized to fatty acid methyl esters, which were quantified using gas chromatography (15). Fatty acid structures were verified by chromatography/mass spectrometry and equivalent chain length analysis.

## Volatile Fatty Acids

The volatile fatty acids (VFA) pyruvate, lactate, formate, acetate, propionate, and butyrate are used as biomarkers of anaerobic metabolism. Anaerobic bacteria produce these compounds by fermentation, while under aerobic conditions these compounds are rapidly oxidized for carbon and energy by aerobic bacteria. The VFA are analyzed by ion chromatography.

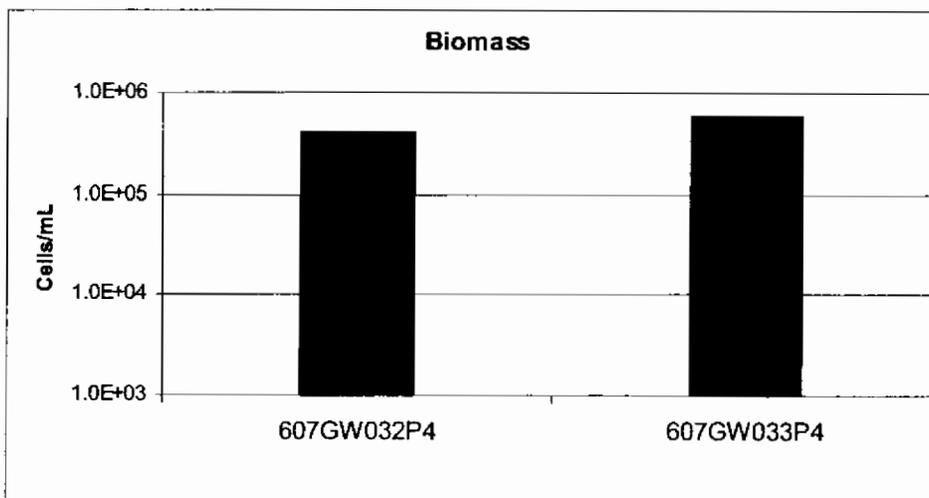
## Quantitative *Dehalococcoides*

Nucleic acid technology allows for specific, sensitive detection of microorganisms from a variety of environments. Information can be obtained about the kinds of organisms present (phylogenetic assessment) and also about the specific capabilities of the organisms present (functional assessment). Thus, this technology has become an invaluable tool for detecting specific organisms and/or their functional genes. A limitation of one widely used nucleic acid technology, PCR, was that it was not quantitative. As technology advanced, this limitation has been overcome, and quantitative (real-time) PCR is now possible through the combined use of specialized PCR reagents (e.g., TaqMan) and refined instrumentation. qPCR is particularly useful for the bioremediation field because the population size (i.e., the number of particular organisms) can be determined, and so population changes can be tracked over time or in response to a treatment.

For this sample set, DNA was extracted from each and the number of 16S rRNA gene copies for *Dehalococcoides* spp. was determined using Bio-Dechlor Census technology<sup>1</sup>. The results from this analysis are presented in Table 5.

## Figures and Tables

### Phospholipid Fatty Acid Analysis



**Figure 1.** Biomass content is presented as a cell equivalent based on the total amount of phospholipid fatty acids (PLFA) extracted from a given sample. Total biomass is calculated based upon PLFA attributed to bacterial and eukaryotic biomass (associated with higher organisms).

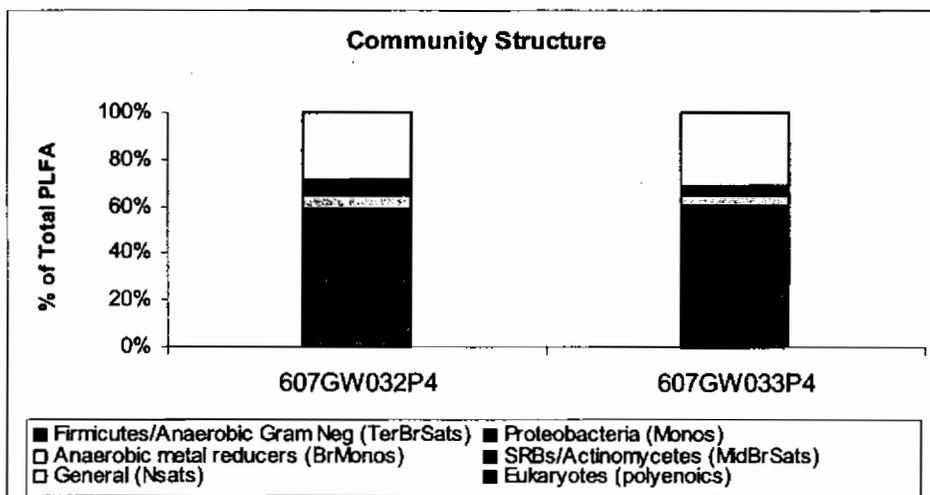


Figure 2. Relative percentages of total PLFA structural groups in the samples analyzed. Structural groups are assigned according to PLFA chemical structure, which is related to fatty acid biosynthesis. See Table 1 for detailed descriptions of structural groups.

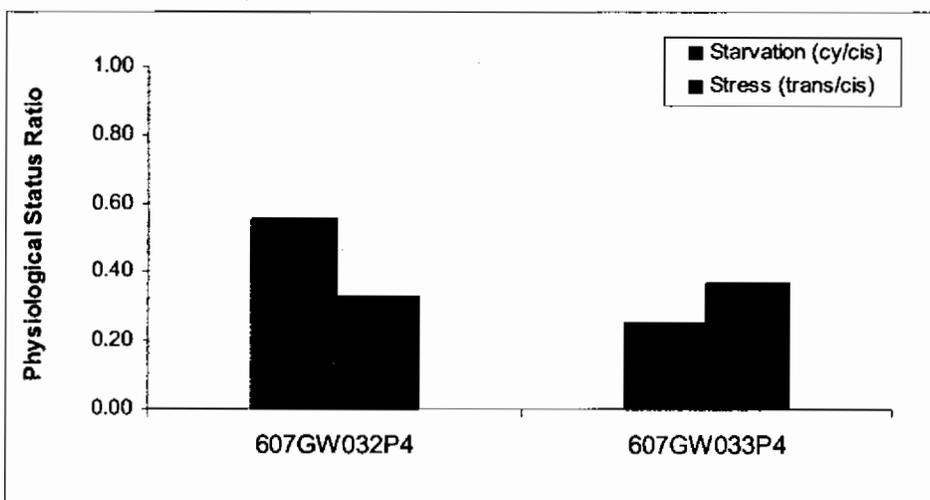


Figure 3. Microbial physiological stress markers. The starvation biomarker for the Gram-negative bacterial community is assessed by the ratios of cyclopropyl fatty acids to their metabolic precursors. An adaptation of the Gram-negative community to toxic stress is determined by the ratio of  $\omega 7/\omega 7c$  fatty acids. Gram-negative bacteria generate *trans* fatty acids to minimize the permeability of their cellular membranes as an adaptation to a less favorable environment. Ratios (16:1 $\omega 7/16:1\omega 7c$  and 18:1 $\omega 7/18:1\omega 7c$ ) greater than 0.2 have been shown to indicate an adaptation to a toxic or stressful environment, resulting in decreased membrane permeability.

Table 2. Values below are: viable microbial biomass (based on total PLFA content) is expressed as cells per mL of sample; fatty acid structural groups as percent of total PLFA; and physiological status biomarkers as mole ratio.

Sample		Biomass	Community Structure (% of total PLFA)						Physiological Status	
Sample Name	Sample Date	Cells/mL	Firmicutes Anaerobic Gram Neg/ (TerBrSats)	Proteobacteria (Monos)	Anaerobic metal reducers (BrMonos)	SRBs/ Actinomyces (MidBrSats)	General (Nsats)	Eukaryotes (polyenoics)	Starved cy/cis	Membrane Stress, trans/cis
607GW032P4	8/19/04	4.04E+05	29.3	29.8	5.3	7.1	28.0	0.4	0.55	0.33
607GW033P4	8/19/04	5.81E+05	23.1	37.5	4.4	4.3	30.7	0.1	0.25	0.37

**Volatile Fatty Acids & Metabolic Gases**

Table 3. Results from the analysis for Volatile fatty acids.

Sample Name	Condition			Metabolic Acids (mg/L)					
	Date Sampled	Date Received	Arrival Condition	Pyruvic	Lactic	Formic	Acetic	Propionic	Butyric
607GW032P4	08/19/04	08/20/04	Good, Cold, Intact	<4	<1	1.9	<1	<1	<1
607GW033P4	08/19/04	08/20/04	Good, Cold, Intact	<4	<1	2.6	349.4	186.4	141.4

Table 4. Results from the analysis for Metabolic Gases: Methane, Ethene, Ethane.

Sample Name	Condition			Metabolic Gases (ug/L)		
	Date Sampled	Date Received	Arrival Condition	Methane	Ethene	Ethane
607GW032P4	08/19/04	08/20/04	Good, Cold, Intact	91.50	66.62	<3.12
607GW033P4	08/19/04	08/20/04	Good, Cold, Intact	14275	<2.92	<3.12

**CENSUS Results:**

Table 5. Quantitative Real time PCR (Q-PCR) was used to determine the number of *Dehalococcoides* spp. gene copies in DNA extracted from each sample.

Sample Name	Date Sampled	Dechlorinating Bacteria
		<i>Dehalococcoides</i> spp. <sup>C,F</sup>
		Abundance
		16S rRNA genomes/mL
607GW032P4	08/19/04	7.26E+05
607GW033P4	08/19/04	4.16E+04
<b>QA/QC Controls</b>		
Positive Control		4.42E+07
Negative Control		Not Detected

<sup>C</sup> Assuming *Dehalococcoides ethenogenes* contains 1 rRNA operon per genome, the value given also may represent the number of cells per mL or g of sample for bacteria in this phylogenetic group.

<sup>F</sup> The practical quantitation limit (PQL) is  $-5 \times 10^2$  16S rRNA gene copies per sample.

ND = Not Detected

J = Estimated gene copies below PQL but above LQL

I = Inhibited

<sup>1</sup> Bio-Dechlor Census technology was developed by Dr. Loeffler and colleagues at Georgia Institute of Technology and was licensed for use through Regenesis

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## **Appendix D**

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