2016

Bioremediation of a Trichloroethene DNAPL Source Zone Utilizing a Partitioning Electron Donor - Field Implementation

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BIOREMEDIATION OF A TRICHLOROETHENE DNAPL SOURCE ZONE UTILIZING A PARTITIONING ELECTRON DONOR – FIELD IMPLEMENTATION

by

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A thesis submitted in partial fulfillment of the requirements
for the degree of Master of Science in Environmental Engineering
in the Department of Civil, Environmental, Construction Engineering
in the College of Engineering & Computer Science
at the University of Central Florida
Orlando, Florida

Fall Term
2016

Major Professor: Andrew Randall

ABSTRACT

Trichloroethene (TCE) is a chlorinated volatile organic compound (CVOC) that can be found in industrial and household products. It is typically used as a solvent or degreaser. TCE can have detrimental health impacts and is known to be carcinogenic to humans. Federal and state regulatory drivers determine the need to assess and remediate soil and groundwater contaminated with CVOCs. There are many different methods for remediation; however, bioremediation has the ability to breakdown TCE all the way to harmless gasses (ethene and ethane).

Bioremediation requires dechlorinating microbes (indigenous or augmented), electron donor (food source), and an electron acceptor (CVOCs). Electron donors are typically injected into the target area and are distributed naturally throughout the subsurface. A partitioning electron donor (PED) has the ability to partition from the dissolved phase into low permeability zones and/or dense non-aqueous phase liquids (DNAPLs) (i.e. source zones), and then be slowly released and readily metabolized at the DNAPL:water interface.

This thesis summarizes the first field scale PED implementation with the main research objective of evaluating whether utilizing a PED for bioremediation of a TCE source zone is achievable. Based on laboratory studies, n-butyl acetate (nBA) was selected as the PED for application in a TCE source area, selected at Cape Canaveral Air Force Station’s Launch Complex 34, identified as Hot Spot 1. Hot Spot 1 has a zone of high concentration TCE in a low permeability clay layer at a depth of approximately 40 feet below land surface (ft BLS). Implementation included the

recirculation of groundwater above and below the clay layer without PED injection for comparative analysis (baseline flux), then with PED injection in, above, and below the clay layer (system operation phase). The groundwater was recirculated using a solar powered recirculation system, which consisted of a pair of extraction wells in the center of the treatment area, screened above and below the low permeability layer, and a set of five peripheral injection well pairs, similarly screened, used to create an inward hydraulic gradient and promote horizontal flow across the top and base of the clay layer. Groundwater concentrations in the treatment area were monitored using three monitoring well clusters (each with six depth intervals ranging from 23 to 61 ft BLS) and existing monitoring wells in the treatment area.

The groundwater recirculation system was operated, without addition of PED, for approximately four weeks to establish the baseline flux condition. PED was then introduced to the subsurface by injecting 34,000 gallons of a solution containing nBA (3,000 mg/L) and conservative tracers (bromide and/or iodide) using direct push technology (DPT) at 20 locations from approximately 23 to 62 ft BLS. Confirmation sampling (DPT groundwater and monitoring well sampling) was conducted to assess the PED distribution after injection activities. The recirculation system remained off after PED injection for approximately four weeks to allow the PED to partition into the DNAPL and to facilitate the acclimation and establishment of biomass within the treatment area. The recirculation system was then restarted and operated for approximately one year. Groundwater sampling was performed regularly to assess mass flux and microbial reductive dechlorination.

PED amendment was successfully injected above, in, and below the low permeability layer, as evidenced by positive detections of nBA from soil and groundwater sampling within the treatment area immediately following the injection event. The implementation was also successful in reducing contaminant mass from both soil and groundwater.

CVOC mass removed during the baseline flux phase (pre-PED injection; 14 March 2011 to 18 April 2011) was calculated based on groundwater sampling data and totaled 14 pounds (lbs). All of the mass removed during the baseline flux phase was from the high permeability layer, indicating that mass removed was dissolved phase mass above and below the clay layer. Mass removal was likely a result of extraction and dilution from operation of the recirculation system. The mass removal rate during the baseline flux phase was approximately 0.40 pounds per day (lbs/day).

CVOC mass removed during the system operation phase (post-PED injection; 9 August 2011 to 11 September 2012) was calculated based on groundwater and soil sampling data and totaled 110 lbs. Of the 110 lbs removed, 78 lbs of CVOC mass was removed from the high permeability layer and 32 lbs was removed from the low permeability layer, indicating that not only dissolved phase mass in the high permeability layer was removed, but source zone material sorbed into the low permeability layer was removed as well. Mass removed from the low permeability layer was likely a result degredation (ie. reductive dechlorination) at and around the DNAPL:water interface. The mass removal rate during the system operation phase was approximately 0.28 lbs/day. The higher rate of removal during the baseline flux phase is likely due to the initial removal of a significant amount of dissolved phase CVOCs and not the mass sorbed into the low permeability layer.

In general, TCE and *cis*-1,2-dichloroethene (cDCE) concentrations decreased during the baseline flux phase with no increase in vinyl chloride (VC) concentration, indicating removal via extraction and dilution and not reductive dechlorination. Following the PED injection, TCE and cDCE concentrations generally decreased with increases observed in VC concentrations, indicative of reductive dechlorination.

Ethene concentration was monitored to assess complete dechlorination from TCE to ethene. Average ethene concentration detected in samples collected from treatment zone monitoring wells increased from 52.8 micrograms per liter (µg/L) (pre-injection; April 2011) to 408 µg/L (September 2012), indicating complete dechlorination of CVOCs was occurring.

In addition, dechlorinating microbial biomass increased significantly, as evidenced by increases in average *Dhc* (dechlorinating microbial culture) and *vcrA* (specific gene of culture responsible for breaking down VC through to ethene) concentrations detected in samples collected from treatment zone monitoring wells; *Dhc* increased from 8.5×10^6 gene copies/L (pre-injection; April 2011) to 5.0×10^7 gene copies/L (September 2012) and *vcrA* increased from 5.0×10^3 gene copies/L (April 2011) to 6.8×10^7 gene copies/L (September 2012).

TOC concentration was shown to generally increase following the injection activities, then decrease through the system operation period, indicating the electron donor was successfully injected into the subsurface, and was being utilized by the indigenous dechlorinating microbial population. Remaining TOC at the site was minimal, with an average TOC concentration of 21 mg/L (September 2012) detected in samples collected from treatment zone monitoring wells, decreasing from 250 mg/L (August 2011) just following injection. If reductive dechlorination were to continue to occur, more electron donor would be needed.

The reduction of CVOC concentrations at the site are likely due to reductive dechlorination as a result of the PED amendment injection, as evidenced by: (i) the production of daughter products relative to the degradation of TCE; (ii) the production of ethene; (iii) the production of dechlorinating microbial mass; and (iv) the reduction of electron donor.

Although effective, nBA was utilized and depleted quicker than an industry electron donor would be expected to last, depleting within 12 months, as opposed to two to three years. Based on this alone, it appears that nBA would not be a good candidate for full scale implementation at this or other sites; however, to provide a true comparative analysis, side-by-side test plots would be recommended at the site, one utilizing nBA and one utilizing a standard substrate. This would ensure both electron donor options are being subjected to the same geophysical and geochemical settings and the same or similar contaminant concentrations.

ACKNOWLEDGMENTS

I would like to thank Dr. Andrew Randall, Dr. Debra Reinhart, Dr. Dingbao Wang, and Dr. Rebecca Daprato for serving on my thesis defense committee and for their guidance through my graduate studies.

The data presented in this thesis was obtained from field activities carried out by Geosyntec Consultants in collaboration with National Aeronautics and Space Administration (NASA) at Cape Canaveral Air Force Station, Florida. I played a major role in the execution of the project field work, data analysis, and interpretation of results. Parts of this thesis have previously been presented in NASA's 2013 Report *Launch Complex 34, SWMU CC054, Hot Spot 1 Interim Measures Implementation Report: Partitioning Electron Donor Demonstration*; a report which I authored under the supervision of committee member Dr. Daprato.

Accordingly, I would like to thank Geosyntec Consultants for allowing me the opportunity and support to pursue higher education while maintaining a working career and NASA's Kennedy Space Center Remediation Team for allowing me and Geosyntec the opportunity to perform and share this pioneering work.

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LIST OF ABBREVIATIONS

CCAFS	Cape Canaveral Air Force Station
CVOC	chlorinated volatile organic compound
cDCE	*cis*-1,2-dichloroethene
Dhc	dehalococcoides ethenogenes
DNAPL	dense non-aqueous phase liquid
DPT	direct push technology
EOS	Emulsified Oil Substrate
ESB	engineering support building
ft BLS	feet below land surface
ft/d	feet per day
F.A.C.	Florida Administrative Code
FDEP	Florida Department of Environmental Protection
f_{oc}	fraction of organic carbon
gene copies/L	gene copies per liter
gpm	gallons per minute
GAC	granular activated carbon
GCTL	groundwater cleanup target level
HDPE	high density polyethylene
HRC	Hydrogen Release Compound
HSA	hollow stem auger

I	associated result is between the laboratory MDL and PQL
in	inch
kg	kilogram
K_{oc}	organic carbon-water partitioning coefficient
lbs	pounds
lbs/day	pounds per day
LC34	Launch Complex 34
IARC	International Agency for Research on Cancer
MCL	maximum contaminant level
MCLG	MCL goals
MDL	method detection limit
MEE	methane, ethane, and ethene
µg/L	micrograms per liter
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mM	millimolar
mV	millivolt
NADC	natural attenuation default concentration
NASNI	Naval Air Station North Island
nBA	n-butyl acetate
nHEX	n-hexonal
O&M	operation and maintenance
PED	partitioning electron donor

PCE	tetrachloroethene
PID	photoionization detector
P&ID	process and instrumentation diagram
ppb	parts per billion
PQL	practical quantitation limit
psi	pounds per square inch
PVC	polyvinyl chloride
ROI	radius of influence
SABRE	Source Area Bioremediation
SCTL	soil cleanup target level
SRS™	Slow Release Substrate
SU	standard unit
SWMU	Solid Waste Management Unit
TCE	trichloroethene
TOC	total organic carbon
UIC	underground injection control
U.S. EPA	United States Environmental Protection Agency
VC	vinyl chloride
vcrA	vinyl chloride reductase A
VFA	volatile fatty acid

CHAPTER 1: INTRODUCTION

Overview

Trichloroethene (TCE) is a material that can be found in industrial and household products, which if directly exposed to, can be have negative impacts on human health. Because of this, regulatory drivers have been established which drives the need to cleanup, or remediate, existing groundwater or soil impacts. Of the different remedial strategies available, bioremediation, utilizing microorganisms to breakdown targeted compounds, is capable of degrading TCE to a harmless gas (ethene). Bioremediation of high concentration TCE source areas is not typical; however, is achievable by utilizing the correct microorganisms and electron donor, or substrate. This project focuses on the utilization of a partitioning electron donor to facilitate the bioremediation of a TCE source zone as implemented in the field.

Research Objectives

The purpose of this project is to evaluate whether utilizing a partitioning electron donor (PED) for bioremediation of a TCE source zone is achievable. Success criteria is based on confirmation of successful injection of PED into the treatment area (above, in, and below a low-permeability zone), observable reduction in contaminant concentrations in both soil and groundwater, observable utilization of electron donor, and observable complete dechlorination of TCE to ethene.

CHAPTER 2: BACKGROUND

Trichloroethene

TCE is a chlorinated solvent that is a colorless liquid, at room temperature, and is characterized as having a sweet odor and sweet, burning taste. TCE was developed to replace its more flammable predecessors and is now mainly used as a degreasing agent for industrial metal parts, although it can be found in some household items such as paint removers, adhesives, and spot removers (ATSDR 1997). The structure of TCE and its daughter products is shown in Figure 1.

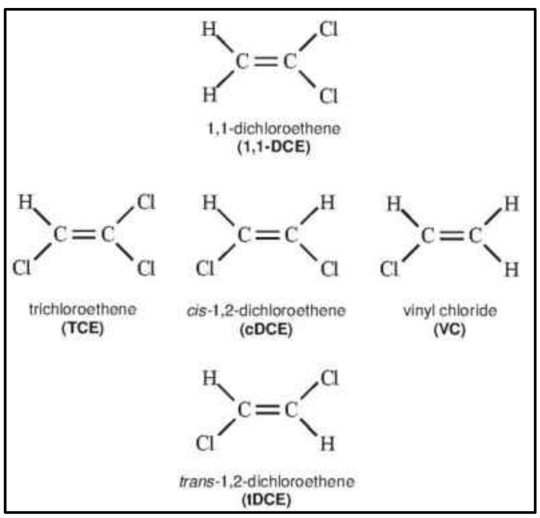


Figure 1: Structure of TCE and Daughter Products (Roberts 2008)

TCE can enter the environment through evaporation from factories that conduct degreasing activities, from chemical waste disposal sites, or from accidental spills. Total on and off site disposal and other releases reported to the United States Environmental Protection Agency (U.S. EPA) have decreased from greater than 57 million pounds (lbs) in 1988 to about 2.3 million lbs reported in 2012 (U.S. EPA 2014a). The fate and transport of TCE and other chlorinated solvents is dependent upon physical and chemical characteristics of the compounds, including aqueous solubility, liquid density, and the soil organic carbon-water partitioning coefficient (K_{oc}) which determine how the compound reacts with the surrounding matrix. Physical properties of TCE and its daughter products are provided in Table 1.

Table 1: Properties of TCE and Daughter Products (U.S. EPA 1996, Pankow and Cherry 1996)

Compound	Molecular Weight (g/mol)	Aqueous Solubility (mg/L)	Density (g/cm^3)	K_{oc} (L/kg)
Trichloroethene (TCE)	131.4	1,100	1.46	166
cis-1,2-dichloroethene (cDCE)	96.9	3,500	1.28	35.5
Vinyl Chloride (VC)	62.5	2,700	0.9	18.6

The low aqueous solubility of TCE causes the compound to often serve as a recalcitrant source for dissolved phase groundwater contamination for many years in the form of a dense, nonaqueous-phase liquid (DNAPL) (ITRC 2003). DNAPL travels downward through the pore spaces of soil, moving more readily through a soil with high hydraulic conductivity, such as loose sands or gravels, and tending to pool on top of, or slowing partition into, soils with low hydraulic conductivity, such as silts or clay confining units, as presented in Figure 2. These pools serve as a DNAPL source zone where dissolved plumes can originate from. These pools contain DNAPL that can occupy up to 70 percent of the pore space (Keuper et al. 2003).

The distribution of DNAPL through the subsurface is not uniform due to the pore size distribution and other physical characteristics of the soil matrix. As it is traveling downward, some DNAPL will be retained within pore spaces, held by capillary forces and interfacial tensions caused by the DNAPLs hydrophobic properties and groundwater interaction. This trapped DNAPL is known as ganglia or residual DNAPL and, much like the pools, can also be characterized as a source zone. However, unlike the DNAPL pools, residual DNAPL saturation typically ranges from 5 to 15 percent of the pore space (ITRC 2003).

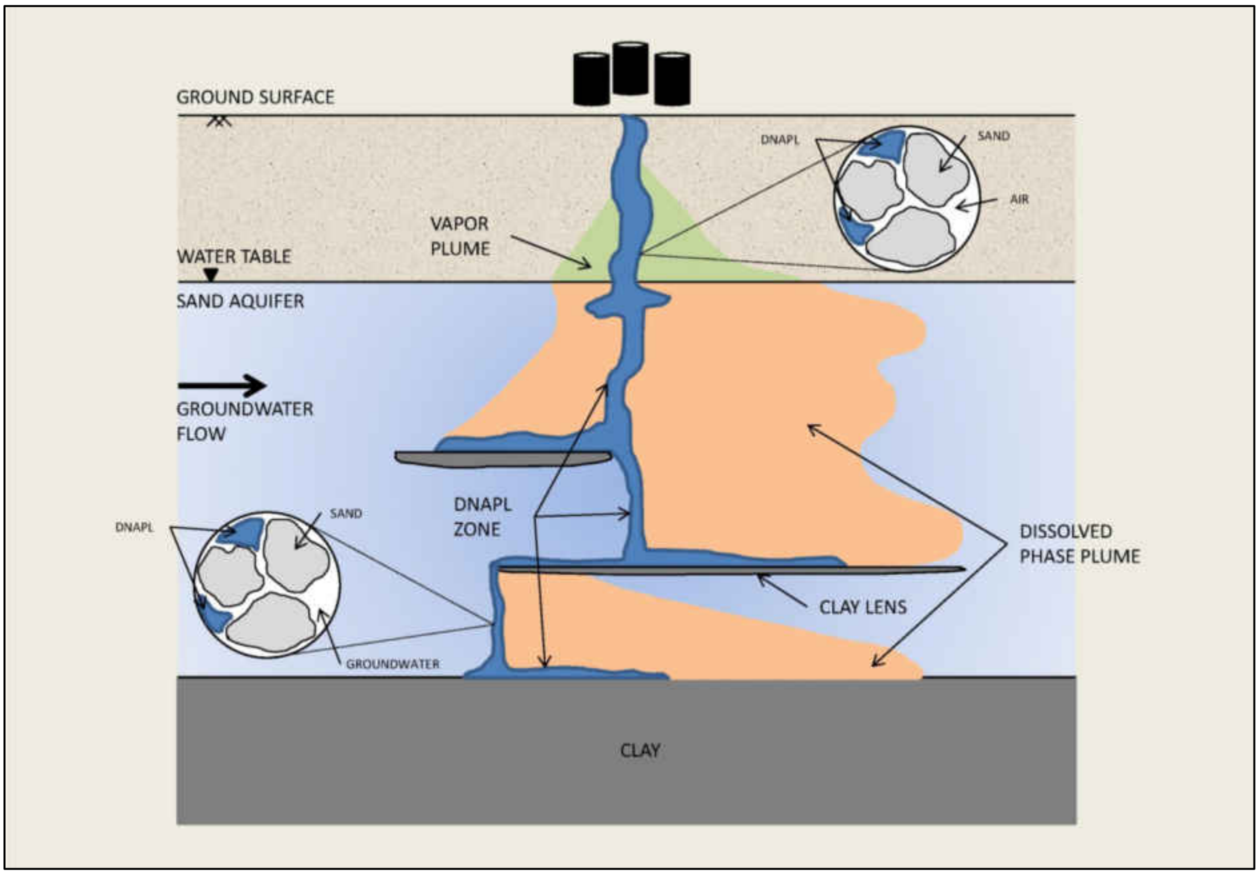


Figure 2: Conceptual Model of the Migration and Fate of DNAPL (ITRC 2003)

Aqueous phase plumes originate from the source zones relatively readily due to the low K_{oc} of the chlorinated solvents. A low K_{oc} indicates that the compound will not strongly sorb to the soil matrix and are therefore, not significantly retard with respect to groundwater flow. The rapid rate of chlorinated solvent DNAPL migration and low degree of sorption both contribute in creating a formidable groundwater contaminant issue in need of accurate assessment and proper remediation.

Regulatory Drivers

TCE has been shown to negatively affect the health of humans who have been exposed to it, either by inhalation, absorption, or ingestion, and thus is a cause for concern when discovered in the environment. As recent as 2012, the International Agency for Research on Cancer (IARC) has classified TCE as "carcinogenic to humans" (Chiu et al 2013). TCE is also a non-cancer toxicity health hazard. Exposure to skin can develop into rashes, inhalation of TCE may cause dizziness, or drowsiness, and headaches, and ingestion of TCE from contaminated drinking water may lead to birth defects and complications with the central nervous system, kidney, liver, immune system, and reproductive systems (ITRC 2003, Chiu et al 2013).

Because of the detrimental health affects TCE has, the U.S. EPA has set the maximum contaminant level goals (MCLG) for TCE at zero. The MCLG is a non-enforceable goal advised to prevent potential health problems. The enforceable regulation for TCE, the maximum contaminant level (MCL), is set at 5 micrograms per liter (µg/L), or parts per billion (ppb). The MCL is a federal drinking water standard and is set as close to the MCLG as possible, while considering feasibility, cost of detection, and method of removal (U.S. EPA 2014b). Each state can impose its own regulatory standard equal or less than the federal MCL. The Florida Department of Environmental Protection (FDEP) has developed and implemented the groundwater cleanup target levels (GCTLs), natural attenuation default concentration (NADC), and soil cleanup target levels (SCTLs) per Florida Administrative Code (F.A.C.) Chapter 66-777. The FDEP GCTLs, NADCs, and SCTLs for TCE and its daughter products are provided in Table 2.

Table 2: Regulatory Criteria for TCE and Daughter Products (FDEP 2005)

Compound	MCL (U.S. EPA) (µg/L)	GCTL (µg/L)	NADC (µg/L)	SCTL (mg/kg)	
				Residential	Industrial
TCE	5	3	300	6.4	9.3
cDCE	70	70	700	33	180
VC	2	1	100	0.2	0.8

Bioremediation

Although there are many options for remediating chlorinated solvent contaminants (e.g. pump and treat, chemical oxidation, air sparging, etc.), bioremediation has the potential to reduce chlorinated contaminants all the way to harmless gasses (ethane and ethane). Bioremediation utilizes microorganisms (i.e. bacteria) to degrade contaminants in groundwater and soil. If the proper microorganisms are indigenous to the site, electron donors and/or nutrients can be added (biostimulation) to enhance the rate of degradation. If the proper microorganisms are not present, they can be introduced to the subsurface to initiate treatment (bioaugmentation). Bioremediation can occur aerobically (requiring oxygen), anaerobically (absence of oxygen), or cometabolicaly (degradation through side reaction) depending on the type of contaminant and site conditions. Typically, bioremediation of chlorinated solvents is most effective in anaerobic-reducing conditions (U.S. EPA 2014c).

Reductive Dechlorination

In an anaerobic-reducing environment, chlorinated solvents can be degraded through the reductive dechlorination process. This process follows a step-wise replacement of chlorine atoms with hydrogen atoms, as shown in Figure 3. In this process, TCE is dechlorinated to its daughter products: *cis*-1,2-dichloroethene (cDCE) and vinyl chloride (VC), then completing the chlorine replacement process as ethene and ethane. The dechlorination process was first demonstrated in the laboratory by Freedman and Gossett in 1989 (ESTCP 2005).

Reductive dechlorination can occur directly or co-metabolically. Direct reductive dechlorination occurs when chlorine atoms are replaced with hydrogen on a chlorinated ethene molecule and the bacteria gain energy and grow as a result, sometimes referred to as “dehalorespiration”. In this instance, hydrogen is typically supplied by fermentation of organic substrates or can be introduced using direct injection techniques. Complete reductive dechlorination typically occurs under cometabolic reactions, in which chlorinated ethenes are reduced by enzymes produced by bacteria during metabolism of a substrate. In this instance, the bacteria do not gain any energy, only serving to mediate the reaction, and maintain energy for growth from the sufficient available substrate (ITRC 2008).

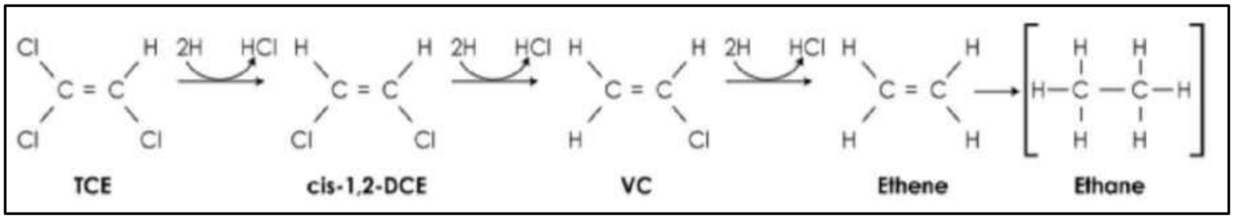


Figure 3: Biodegredation Pathway for TCE Under Anaerobic Conditions (U.S. EPA 2004)

Dechlorinating Bacteria

Not all dechlorinating bacteria are capable of dechlorinating TCE all the way to the non-toxic end product of ethene, typically stalling at cDCE. Complete dechlorination requires both the proper microbial population capable of completing each step and proper environmental conditions suitable to facilitate the dechlorination process (ITRC 2008). The only microorganisms that have demonstrated the ability to carry out dechlorination from cDCE completely to ethene belong to the genus *Dehalococcoides ethenogenes* (*Dhc*); however, not all *Dhc* species are capable of this, so it is important to know what type of *Dhc* strain is present at the site. Within the *Dhc* species, the strain containing the vinyl chloride reductase A gene (vcrA) was identified as producing the correct enzyme necessary to convert VC to ethene (Muller et al. 2004). A survey of 24 contaminated sites was conducted in 2002 by Hendrickson et al. which provided compelling evidence for the role of *Dhc* in the bioremediation of chlorinated solvents. *Dhc* microbes were discovered at all sites where dechlorination proceeded beyond cDCE to VC and ethene (21 of 24 sites) and the *Dhc* microbes were absent at sites that stalled at cDCE (3 of 24 sites) (ESTCP 2005).

Electron Donors

Hydrogen is recognized as the direct electron donor necessary for reductive dechlorination to occur. The hydrogen is typically generated by organisms that ferment organic substrates. The substrates most commonly used for anaerobic bioremediation include lactate, molasses, and vegetable oils (AFCEE et al. 2004). The type of electron donor to be selected depends on the application and site conditions. For example, a more soluble substrate, such as lactate, has improved dispersion qualities; however, it has to be reapplied more frequently (i.e. continuously or monthly). A more viscous substrate, such as vegetable oils, will not disperse as readily, and will provide a long-lasting source of organic carbon, only requiring reapplication every two to three years (ARCEE et al. 2004).

The production of hydrogen does not necessarily guarantee that it will be available to dechlorinating bacteria exclusively. For dechlorination to occur, dechlorinators must compete with other microbes that also utilize hydrogen as an electron donor, such as denitrifiers, iron-reducers, sulfate-reducers, methanogens, and other bacteria (ACREE et al. 2004). Substrate application is crucial because of this competition and it is important to try and reduce the amount of electron donor consumption by non-dechlorinating microbes.

Partitioning Electron Donors

Soluble electron donors that would partition directly into DNAPL source zones (ie. olive oil, pentanol, and oleate) were investigated further by Yang and McCarty (2002), which led to more focused investigation of partitioning electron donors (PEDs). The goal of a PED is to increase the concentration of electron donor at or near the source zone (DNAPL), thereby promoting dechlorinating biomass growth within close proximity to the DNAPL. PEDs should be selected based on having similar physical and chemical properties (i.e. solubility, density, K_{ow}, etc.) as the contaminant of concern. This allows for a similar fate and transport of the PED toward and into the source zone. This increases the likelihood of the electron donor being utilized exclusively by dechlorinating bacteria. Traditionally, soluble electron donors are consumed as they travel towards the source zone, leaving low concentrations of electron donor near the DNAPL. Ideal PEDs, if effectively applied to the subsurface near the source zone, will partition directly into the DNAPL and decrease in aqueous phase concentration. The DNAPL-phase PED will then slowly, based on PED concentration gradient between the DNAPL and the surrounding groundwater, partition back into the aqueous phase, as shown in Figure 4, providing a much higher concentration of electron donor at the DNAPL:water interface than existing electron donor delivery methods (Cápiro et al. 2011).

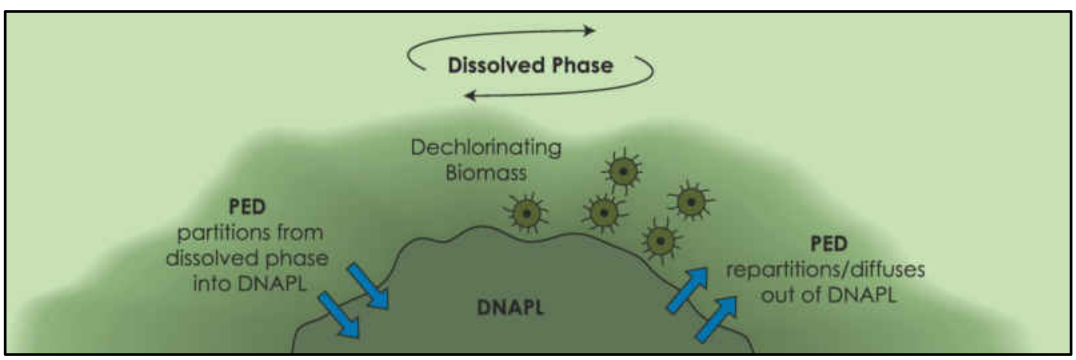


Figure 4: Conceptual Model of PED Partitioning Into and Out of DNAPL (Lebron et al. 2011)

n-Butyl Acetate

The PED that was utilized in this demonstration is n-butyl acetate (nBA) ($C_6H_{12}O_2$). nBA is an industrial solvent mainly used in the production of lacquers. It is a clear, volatile, and flammable liquid that has a sweet odor. The material safety data sheet (MSDS) for nBA is provided in Appendix A. As an electron donor, once exposed to water, nBA hydrolizes to form n-butanol and acetic acid. The n-butanol is then utilized by fermenting organisms, forming butyric acid, acetic acid, and hydrogen (electron donor). nBA was chosen as the PED based on the results of the U.S. EPAs Remediation Technologies Development Forum Source Area Bioremediation (SABRE) program bench scale microcosm study, column test study, and a bench scale treatability study that were conducted with the goal of systematically attempting to quantify the effectiveness of bioremediation to treat TCE DNAPL by using slow release electron donors and PEDs. The solubility of nBA was determined to be approximately 6,000 milligrams per liter (mg/L) with an octonal-water partition coefficient (K_{ow}) of 1.82 (Roberts 2008).

Microcosm Study

A microcosm study was performed at four laboratories (DuPont, GE, Terra Systems, and SiREM) and evaluated six electron donors (lactate, acetate, methanol, slow release substrate [SRS™ - proprietary small droplet, emulsified vegetable soil substrate], n-hexanol [nHEX], and nBA). Reductive dechlorination from TCE to ethene was observed in all cases and at high concentrations (800 mg/L), which would be encountered at DNAPL source zones. Out of the six electron donors, SRS supported the fastest dechlorination and nBA supported the most complete dechlorination to ethene. nBA partitioned most readily into the TCE DNAPL, with an average partitioning coefficient calculated at 458 +/- 32. A toxicity experiment was also conducted with nBA to determine the threshold of nBA that would inhibit successful dechlorination. Concentrations of nBA at 2,000 mg/L (approximately half of nBA solubility) and higher were observed to inhibit dechlorination (Roberts 2008).

Column Study

Column studies were performed to compare the partitioning behavior and mass transfer/dissolution rates of the DNAPL using SRS™, nHEX, and nBA as PEDs. Studies were conduct at SiREM laboratories in Guelph, Canada (nBA and SRS™) and at Georgia Institute of Technology (nBA and nHEX). For all tests, TCE DNAPL pore space saturation ranged from 9 to 14 percent. SRS™ demonstrated the largest amount of mass removed (68 percent); however, it did not exhibit favorable partitioning characteristics. Again, nBA demonstrated greater partitioning into the DNAPL and slower mass transfer back into the aqueous phase indicating it was a longer lasting source of electron donor (Roberts 2008, Cápiro et al. 2011, Lebron 2008).

Treatability Study

A treatability study was conducted at a TCE DNAPL site at Operable Unit – 11 test site at Naval Air Station North Island (NASNI), Coronado, California. The pilot test was conducted to ensure nBA partitioning behavior was consistent with laboratory observations prior to full scale implementation. The results of the test suggested adequate physical-chemical partitioning and verified that nBA was a suitable PED (Lebron 2008).

Bioremediation of DNAPLs

The goal of bioremediating a DNAPL source zone is to increase the concentration gradient at the DNAPL:water interface, which in turn increases the rate of DNAPL dissolution. The time it takes to remove the DNAPL is a function of how quickly the contaminant mass can be transferred to the aqueous phase. Bioremediation of DNAPL works by enhancing and accelerating dissolution rates through three mechanisms: (i) decreasing aqueous phase concentration near the DNAPL:water interface by encouraging a robust dechlorinating microbe population near the DNAPL, so parent contaminants are rapidly degraded after they dissolve into the groundwater, thus increasing the concentration gradient; (ii) increasing concentrations of reductive daughter products that are more soluble than parent compounds, producing more moles in aqueous phase when degradation is occurring, encouraging higher rates of dechlorination through dehalorespiration; and (iii) electron donors have the ability to abiotically increase effective solubility of DNAPL through reductions in interfacial tensions, encouraging increased dissolution rates (ITRC 2008).

Bioremediation is a proven technology for dissolved-phase plume treatment and is becoming more acceptable as a treatment technology for DNAPL source zones. It was previously thought that higher concentrations of contaminants, such as those found in DNAPL source zone areas, were toxic to the microorganisms necessary for dechlorination. Yang and McCarty (2000) observed that at a tetrachloroethene (PCE) concentration of 0.3 millimolar (mM) (PCE solubility is 0.9 mM) methanogenesis (methane production) and homoacetogenesis (acetate production) was inhibited. Another example of inhibition was demonstrated by Yu et al. (2005), observing that higher concentrations in more chlorinated ethenes (i.e. PCE and TCE) was inhibitory to dechlorination of less chlorinated ethenes (i.e. cDCE and VC) due to competitive inhibitions.

Alternatively, there have been field and bench scale demonstrations with chlorinated solvent DNAPLs, or with concentrations close to solubility, that have been successfully remediated to ethene. One such case is at the Launch Complex 34 (LC34) site at Cape Canaveral Air Force Station (CCAFS), in close proximity to the site used in this thesis, where a test plot, containing TCE DNAPL under the former engineering support building (ESB), was bioaugmented (KB-1™ culture from SiREM Laboratories, Inc.) and biostimulated (ethanol) successfully. Pre-demonstration in-situ TCE mass (dissolved and free-phase) was calculated to be approximatley 25.5 kilograms (kg) and post-demonstration TCE mass was 0.4 kg (U.S. EPA 2004). In the Yang and McCarty (2000) study, PCE, at concentrations above solubility (0.9 mM) and TCE up to 2.26 mM (TCE solubility is 8.4 mM) were both successfully dechlorinated. There are a number of other field applications where bioremediation of source areas was successful, as summarized in examples listed below (ITRC 2007).

- Test Area North, Idaho – A TCE plume with maximum concentrations greater than 20 mg/L was being contained by a pump and treat system. Five technologies were evaluated to enhance or replace the pump and treat system. A nine-month full scale field evaluation of bioremediation enhanced with electron donor (lactate) injections resulted in complete biodegradation of the TCE source area.

- Dover National Test Site, Delaware – A test cell contained 100 L of PCE DNAPL in a porous media that was operated under different phases of investigation; (i) under enhanced extraction conditions; (ii) under biostimulation with sodium lactate and ethanol conditions; and (iii) under biostiumlation plus bioaugmentation (using KB-1™) conditions. During the first phase, results indicated that the indigenous microbial community was not capable of dechlorinating the PCE DNAPL. During the second phase, high PCE concentrations continued to persist, making up 99 percent of the total ethenes. During the third phase, bioaugmentation coupled with biostimulation, after 20 months of operation, ethene represented 70 percent of total ethenes, demonstrating that the PCE DNAPL was successfully dechlorinated.

- Portland, Oregon Dry Cleaner Site – A hydrogen release compound (HRC) was selected for a pilot test study to determine if the same approach could be used to treat both the PCE source area (maximum PCE concentration of 150 mg/L) and the dissolved plume. A year after injecting 1,900 lbs of HRC, PCE concentrations were reduced by 99.9 percent and TCE concentrations were reduced by 99.4 percent. Sampling three years later revealed parent compound concentrations remained low, indicating rebound has not occurred.

- Tarheel Army Missile Plant, North Carolina – An emulsified oil substrate was used in a pilot test to remediate a TCE source area with a maximum concentration of 2,600 µg/L. Following injection, TCE and PCE concentrations dropped, subsequently followed by the rise, then fall of cDCE and VC concentrations. VC concentrations remained higher than final remedial goals, possibly due to insufficient amount of available electron donor.

As enhanced bioremediation becomes increasingly applied to source zones, more innovative techniques are investigated. Adamson and Newell (2009) modeled and tested the use of biomass decay in and around the DNAPL as a source of electron donor recycling, long after the introduced electron donor has been exhausted. Such efficiencies in design are likely to be implemented as the use of bioremediation becomes an accepted treatment for DNAPL source zones.

The use of PEDs, nor the use of nBA as substrate, for bioremediation could not be found in literature, aside from the SABRE microcosm, column, and treatability studies previously mentioned.

There are several disadvantages that may complicate bioremediation of DNAPL using traditional electron donors (eg. emulsified oil substrate), including: (i) DNAPL typically exists as a separate phase, heterogeneously in the subsurface, in the form of non-uniform ganglia, so substrate delivery near the DNAPL surface can be difficult; (ii) microbial growth near the DNAPL surface can cause a quantifiable reduction in hydraulic conductivity over time, potentially causing microbial clogging; and (iii) gas production and entrapment, as a results of microbial activity, particularly methanogenesis, can result in clogging and flow dispersion around DNAPL (Yang and McCarty 2002). Utilizing PEDs can help successfully overcome many of these complications. PEDs readily partition into DNAPL, providing a steady flow of electron donor at or near the DNAPL:water interface, thereby reducing the need for pinpoint application. The high contaminant concentrations near the DNAPL surface, where most of the dechlorinating processes will be taking place due to the PED, inhibit the growth of methanogens (Yang and McCarty 2000), therefore reducing the potential for methane gas production and entrapment. Other advantages of PEDs include: (i) they are water soluble, readily dispersing throughout the source area and into the DNAPL; (ii) they are relatively inexpensive, when compared to proprietary electron donors, such as SRS™ or HRC™; and (iii) they are slowly metabolized, therefore they can be efficiently dispersed without premature losses due to microbial consumption (Roberts 2008, ESTCP 2011).

Site Selection

The site selected to perform the ESTCP PED demonstration/validation was at National Aeronautics and Space Administration's (NASA) LC34 site located at CCAFS on the east-central Atlantic coast of Florida in Brevard County (Figure 5), designated as Solid Waste Management Unit (SWMU) CC054. Hot Spot 1 (Figure 6) was selected as a suitable test site based on the following criteria (ESTCP 2011):

- A known TCE DNAPL source zone, or "hot spot", exists on site that is relatively shallow (<50 feet below land surface [ft BLS]);
- An extensive conceptual site model existed, including characterization data, delineation of the DNAPL source zone and donwgradient dissolved plume, site hydrogeology and lithology, and site groundwater geochemistry;

- A regulatory environment that will allow re-injection of amended groundwater still containing contaminants and the use of PEDs;
- Evidence that indigenous microbial population are present suitable for effective reductive dechlorination based on a successful pilot test at the ESB, located approximately 500 ft west of Hot Spot 1;
- Existing monitoring wells within the source area and downgradient areas to supplement the performance monitoring network;
- Availability of local support staff for monitoring and sampling events; and
- Reasonable site access.

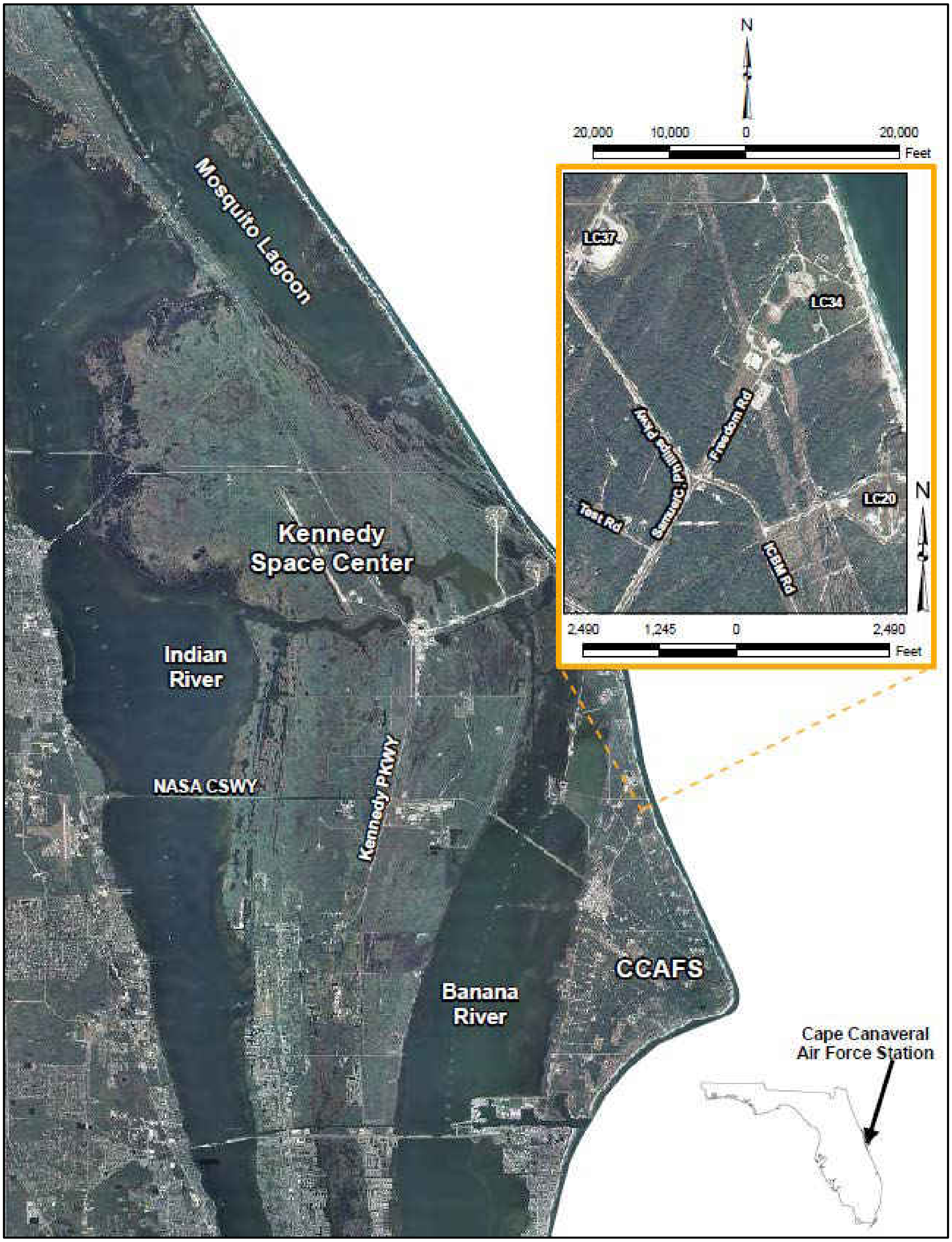


Figure 5: Launch Complex 34 Location Map (NASA 2010)

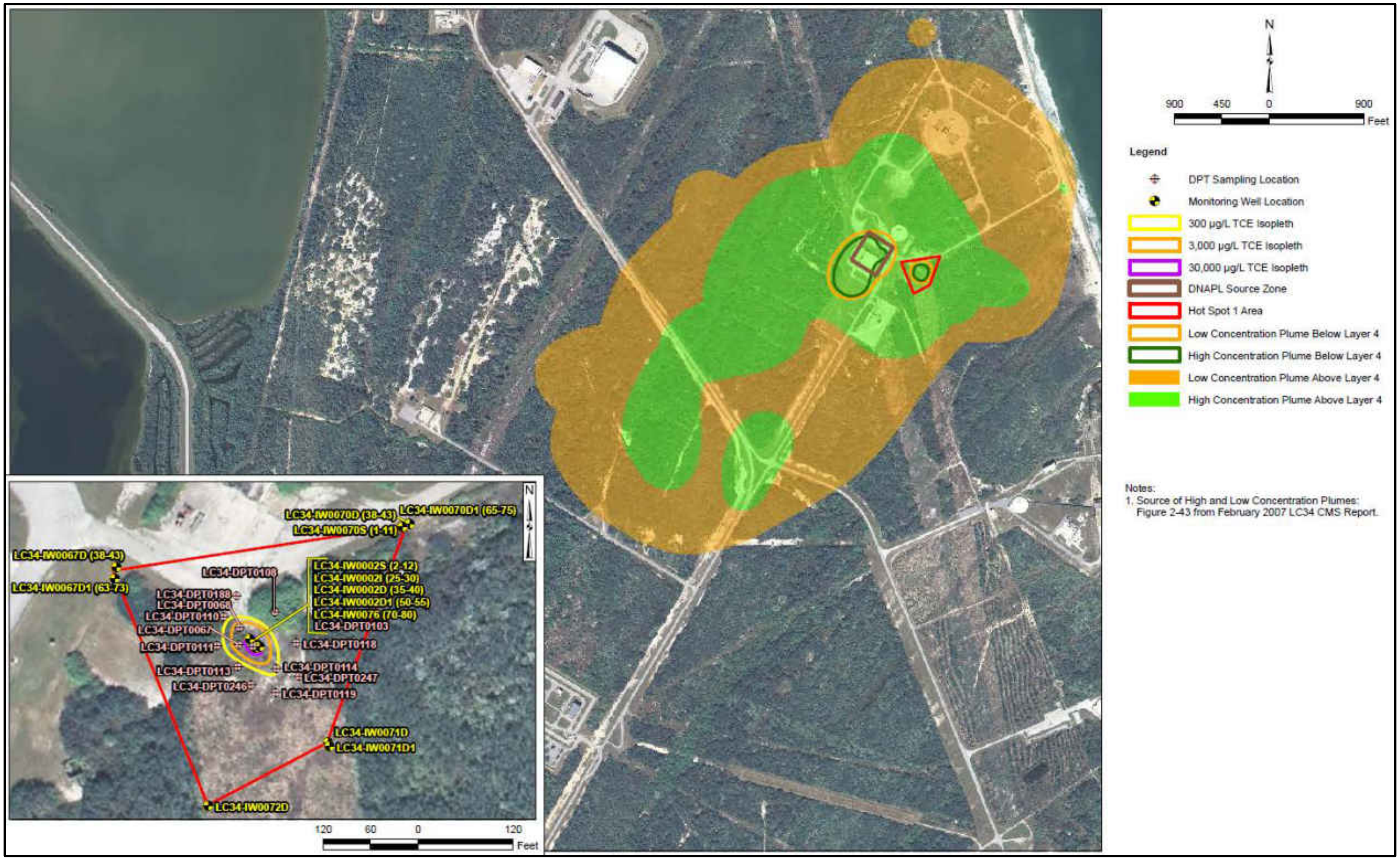


Figure 6: Hot Spot 1 Location Map (NASA 2010)

Summary of Site Geology and Hydrogeology

Site geology and lithology were characterized during previous investigations. A description of the general site geology and lithology is provided below and presented on Figure 7.

- Land surface to 42 ft BLS: varying brown, tan, and gray fine sand with varying amount of shell fragments with a hydraulic conductivity of approximately 30 feet per day (ft/d);
- 42 to 48 ft BLS: Semi-confining unit composed of gray silty clay with minor amount of shell fragments with a hydraulic conductivity of approximately 1.7 x 10^{-4} ft/d;
- 48 to 54 ft BLS: gray fine sand with silt and varying amount of shell fragments with a hydraulic conductivity of approximately 2.8 ft/d;
- 54 to 55 ft BLS: gray silty clay lenses/stringers;
- 55 to 80 ft BLS: varying black and gray fine sand with silt and varying shell fragments with a hydraulic conductivity of approximately 2.8 ft/d.

Two large water bodies, the Atlantic Ocean and the Banana River, are located approximately 0.25 miles to the east and 1 mile to the west of the site, respectively. Groundwater flow at the site is generally sluggish (e.g. less than 5 ft/year) and is tidally influenced by the large surface water bodies near the site. The primary direction of groundwater flow is directed toward the coastal margins of the site.

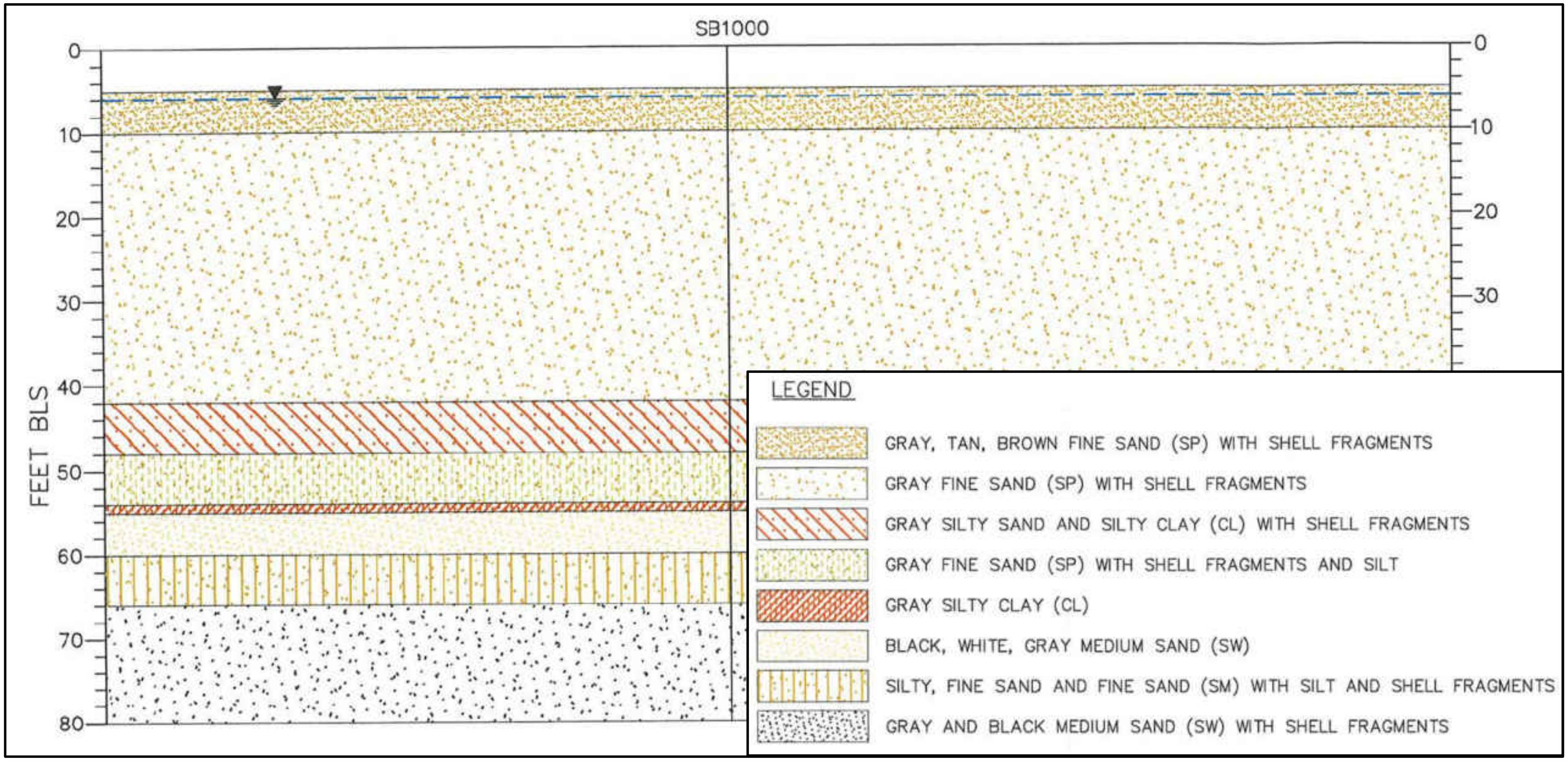


Figure 7: Hot Spot 1 Generalized Lithology (NASA 2010)

CHAPTER 3: FIELD IMPLEMENTATION

Overview

This section summarizes the field activities that were performed to accomplish the research objectives, including: (i) installation; (ii) baseline groundwater sampling; (iii) baseline flux measurement phase; (iv) PED injection; (v) biomass growth phase; (vi) system operation phase; and (vii) post system operation groundwater sampling.

Installation

Installation activities for the LC34 PED demonstration commenced on 19 January 2011, which included installation of: (i) recirculation extraction and injection wells; (ii) performance monitoring bundle wells; and (iii) the recirculation system (recirculation equipment and piping). Locations of existing wells and the proposed well installations are provided in Figure 8. The various wells were installed using different drilling techniques, such as direct push technology (DPT), hollow stem auger (HSA), and mud rotary, which are described in further detail in Appendix B and referenced to in the following sections.

Figure 8: Recirculation Extraction, Recirculation Injection, and Monitoring Well Locations (NASA 2013)

Baseline Soil Sampling

Prior to installing the wells, four soil cores (SB1001 through SB1004) were collected using a direct push technology (DPT) drill rig and 5-ft macro-core® samplers at locations corresponding to performance monitoring bundle wells BW0001, BW0002, and BW0003 and recirculation extraction well RW0008. Soil cores were visually logged to document soil lithology and to confirm the depth of the semi-confining unit. Samples were collected from the soil cores based on lithology (i.e. more samples collected from clay semi-confining unit) and based on photoionization detector (PID) screening. PID response correlates directly to presence of chlorinated volatile organic compound (CVOC); therefore, samples were collected from locations that exhibited the highest PID responses and laboratory analyzed for CVOCs to verify presence, and for nBA to verify absence. Additionally, select soil samples were analyzed for total organic carbon (TOC) and the fraction of organic carbon (f_{oc}). Samples were analyzed by Columbia Analytical Services.

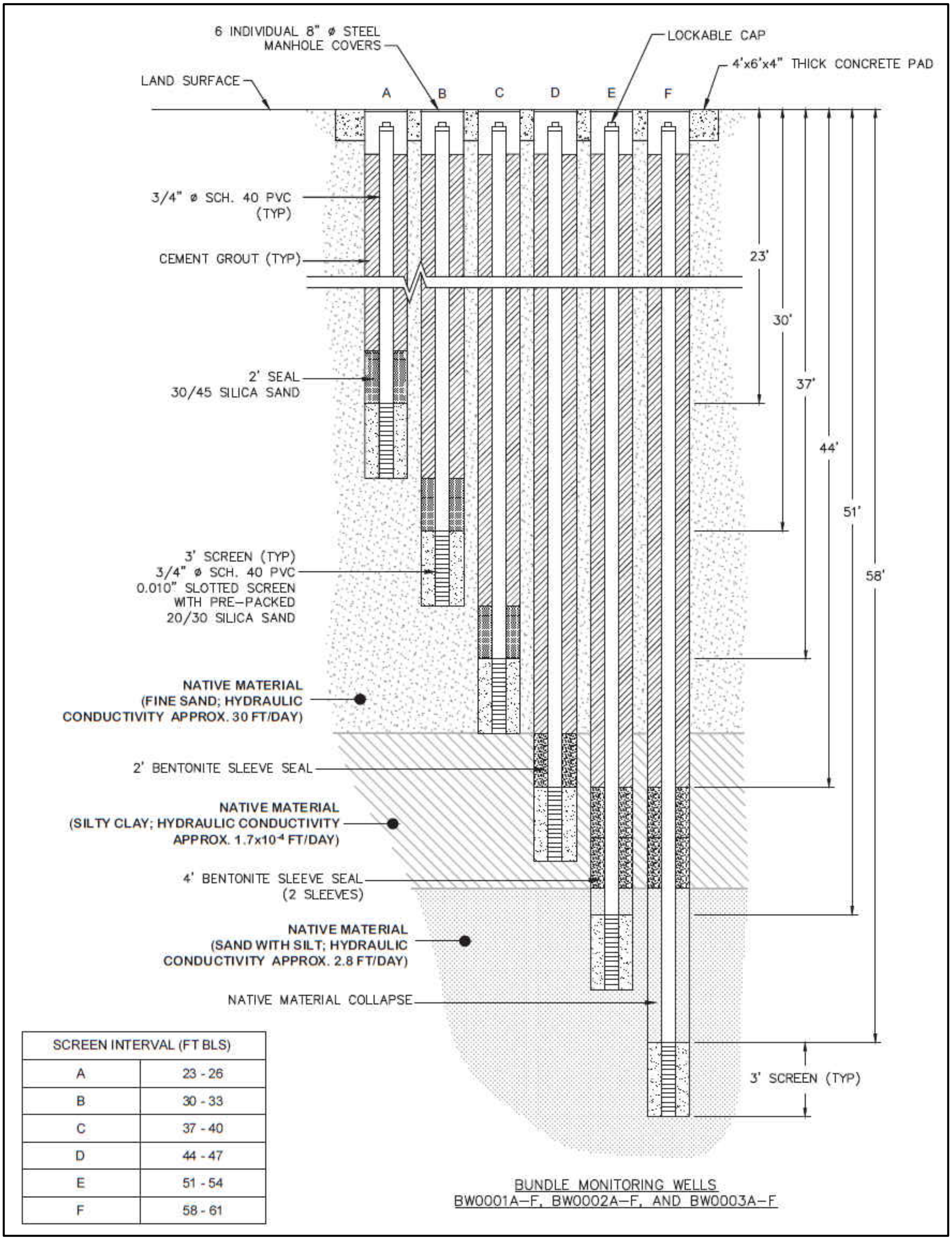
Recirculation Extraction and Injection Well Installation

Two recirculation extraction wells (RW0007 and RW0008) were installed close to the center of Hot Spot 1, as depicted in Figure 8. Extraction well RW0007 was installed using a hollow stem auger (HSA) drill rig to a total depth of 42 ft BLS (screen interval of 35 to 42 ft BLS), above the clay, semi-confining unit. For recirculation extraction well RW0008, HSA tooling was installed to 45 ft BLS, and set into the clay layer, as a temporary surface casing to seal off the aquifer above the clay, semi-confining unit, then used mud rotary drilling techniques to drill through the casing and install the well at a total depth of 57 ft BLS (screen interval of 47 to 57 ft BLS), below the clay. The diameter of the borehole for both wells was 14-inch (in). Both wells were constructed of 6-in schedule 40 polyvinyl chloride (PVC) with a 0.020-in slotted screen. The 4-in annular space around the well screen was filled with a 6/20 sand filter pack, extending 1-ft above the top of the screen, followed by 5-ft of bentonite seal, followed by cement grout to surface. Both wells were completed with an 18-in by 18-in steel vault box and a 3-ft by 3-ft by 4-in thick concrete pad.

Five recirculation injection well clusters (a pair of injection wells per cluster) (IJ0013 to IJ0022) were installed around the periphery of Hot Spot 1, as depicted in Figure 8, using HSA techniques. Each cluster has one injection wells screened above the clay layer (32 to 42 ft BLS) and one injection well screened below the clay layer (47 to 57 ft BLS). Both injection wells were installed in the same 10-in diameter borehole. Injection wells were constructed of 2-in scheduled 40 PVC with a 0.020-in slotted screen. The 4-in annular space around the well was filled with a 6/20 sand filter pack, extending 1-ft above the top of the screen, followed by 2-ft of bentonite seal, followed by cement grout to the surface. All injection well clusters were completed with an 18-in by 18-in steel vault box and a 3-ft by 3-ft by 4-in thick concrete pad.

Monitoring Bundle Well Installation

Three bundle monitoring wells (BW0001A-F, BW0002A-F, and BW0003A-F) were installed using DPT techniques at the locations depicted on Figure 8. Each bundle well included six individual monitoring wells with the following screen intervals: 23 to 26 (A), 30 to 33 (B), 37 to 40 (C), 44 to 47 (D), 51-54 (E), and 58 to 61 (F) ft BLS. The wells were constructed of ¾-in schedule 40 PVC with a 0.010-in slotted screen with a pre-packed 20/30 sand filter. Instead of filling the annular space around the well screen with a sand filer, pre-packed screens come from the manufacturer with a sand filter pack around the screen held in place by a porous mesh that is securely strapped to the screen material. Wells screened above the clay layer (A through C) received a 2-ft 30/45 sand seal above the pre-packed filter, followed by grout to surface. Wells screened in the clay layer (D) received a 2-ft bentonite seal above the screen, sealing off the clay layer between the upper and lower aquifers, followed by grout to the surface. Wells screened below the clay layer (E and F) received a 4-ft of bentonite seal at the clay layer, to seal off upper and lower units, followed by grout to surface. Each bundle well was completed with a 4-ft by 6-ft by 4-in thick concrete pad, containing six individual 8-in steel manhole covers for each monitoring well. Bundle monitoring well construction details, showing general lithology and hydraulic conductivity in relation to screened intervals, is provided on Figure 9.



SCREEN INTERVAL (FT BLS)	
A	23 - 26
B	30 - 33
C	37 - 40
D	44 - 47
E	51 - 54
F	58 - 61

Figure 9: Bundle Monitoring Well Construction Details (NASA 2013)

Recirculation System Installation

The recirculation system consisted of a solar powered recirculation pumping system, which was enclosed in a mobile utility trailer, and the recirculation system piping, which routed the groundwater from the extraction wells to the injection wells.

The equipment trailer housed two 12-volt batteries that were charged by solar panels mounted to the roof of the trailer. The batteries powered two 4.25-in diameter submersible pumps (one in each recirculation extraction well) that were capable of extracting groundwater at a rate of 2.5 gallons per minute (gpm). The pumps were placed at mid-screen depth and held in place with a steel cable connected to the vault box at grade. Timers were programed to operate the pumps on a 40 minutes on and 20 minutes off cycle. Other components housed in the equipment trailer included in-line sediment filters, flow totalizers for each extraction well, a piping manifold including individual flow meters for the ten injection wells, in-line sampling ports, and system operational hour meters. A process and instrumentation diagram (P&ID) of the equipment trailer and recirculation system is provided in Figure 10.

The recirculation system was piped above grade with ¾-in diameter high density polyethylene (HDPE) tubing run through 2-in diameter schedule 40 PVC, serving as secondary containment. Groundwater originated from the extraction well, traveling to the equipment trailer, through the in-line appurtenances, to the manifold, where the groundwater flow was split into ten individual flow streams. Flow from extraction well RW0007 (above the clay) was split evenly between the five injection wells screened above the clay layer and flow from extraction well RW0008 (below the clay layer) was split evenly and distributed to the five injection wells screened below the clay layer. Flow rate to each injection well was designed to be approximately 0.5 gpm. The groundwater was discharged into the injection wells from system piping that was placed approximately 2-ft below the water table.

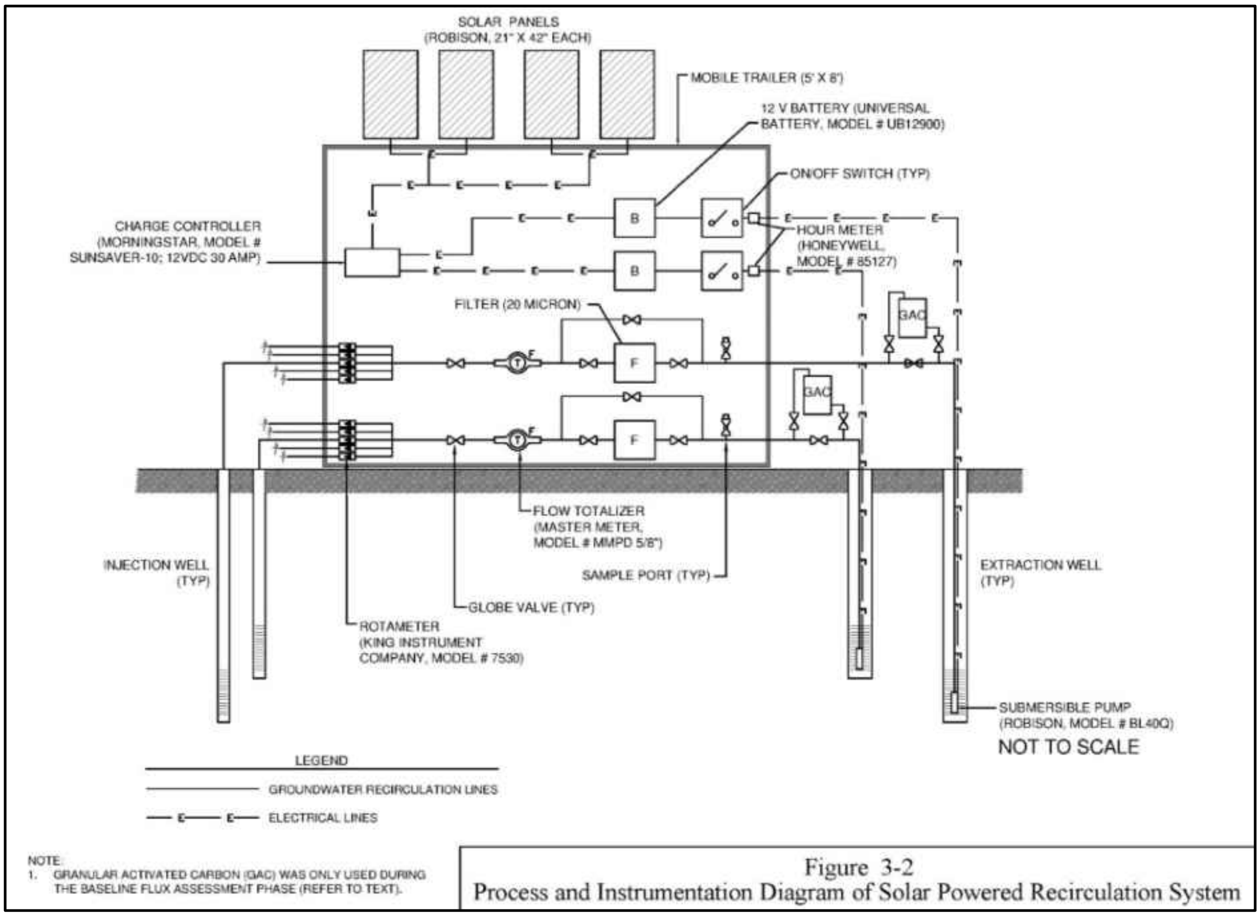


Figure 10: Process and Instrumentation Diagram of Solar Powered Recirculation System (NASA 2013)

Baseline Groundwater Sampling

Baseline groundwater sampling was performed from 1 through 3 February 2011 and included the collection of groundwater samples from 28 site monitoring wells, two recirculation extraction wells, and four recirculation injection wells. Samples were laboratory analyzed for CVOCs and nBA, using EPA Method 8260C, to establish pre-demonstration conditions groundwater conditions and to confirm CVOC delineation within the treatment zone.

Baseline Flux Measurement Phase

The baseline flux measurement phase took place from 14 March to 18 April 2011, approximately four weeks. The recirculation system was operated with no electron donor injected in the subsurface, with the objective of observing the baseline mass flux prior to the PED injection. The extracted groundwater was treated with granular activated carbon (GAC) before being injected into the subsurface to ensure impacted water was not being re-injected. During this phase, operation and maintenance (O&M), groundwater sampling, and GAC effluent sampling activities were performed to assess operations.

Baseline Flux System O&M

The system was started on 14 March 2011 and ran for the four-week baseline flux measurement period. O&M events were conducted weekly for the four-week period and included the following activities:

- inspected wiring and piping for leaks/damages;
- cleaned sediment filters, solar panels, and flow meters as needed;
- measured flow rates and volume produced from recirculation extraction wells;
- measured flow rates, initial and adjusted, to recirculation injection wells;
- measured voltage and percent charged from batteries; and

- addressed any operational abnormalities with corrective action.

Baseline Flux Groundwater Sampling

Select site monitoring wells and the two recirculation extraction wells were sampled during the first three weeks of the baseline flux measurement phase (22, 28, and 29 March and 7 April 2011). The samples were analyzed for parameters listed in Table 3.

Table 3: Baseline Flux Measurement Sampling Plan (NASA 2013)

Sampling Location	Screen Interval (ft BLS)	Analysis							
		VOCs by EPA Method 8260B	VFAs by EPA Method 300-modified	Bromide and Iodide by EPA Method 300.0	TOC by EPA Method 9060A	Sulfide by EPA Method 376.1	MEEs by EPA Method RSK 175	Anions by EPA Method 300.0	Alkalinity by EPA Method 310.1
Upper Treatment Zone									
RW0007	35 to 42	X	X	X	X	X	X	X	X
IW0002I	25 to 30	X							
IW0002D	35 to 40	X							
BW0001A	23 to 26								
BW0001B	30 to 33								
BW0001C	37 to 40	X							
BW0001D	44 to 47								
BW0002A	23 to 26								
BW0002B	30 to 33								
BW0002C	37 to 40	X							
BW0002D	44 to 47								
BW0003A	23 to 26								
BW0003B	30 to 33								
BW0003C	37 to 40	X							
BW0003D	44 to 47								
Lower Treatment Zone									
RW0008	47 to 57	X	X	X	X	X	X	X	X
IW0002DI	50 to 55	X							
BW0001E	51 to 54	X							
BW0001F	58 to 61								
BW0002E	51 to 54								
BW0002F	58 to 61								
BW0003E	51 to 54	X							
BW0003F	58 to 61								

Notes:
1. ft BLS indicates feet below land surface.
2. VOCs indicate volatile organic compounds and includes analysis for n-butyl acetate and n-butanol.
3. EPA indicates Environmental Protection Agency.
4. VFAs indicate volatile fatty acids.
5. TOC indicates total organic carbon.
6. MEEs indicate methane, ethane, ethene.
7. Anions include analysis for chloride, sulfate, nitrate and nitrite.
8. Analysis of groundwater samples for VOCs, n-butanol, VFAs, bromide and TOC will occur weekly.
9. Analysis of groundwater samples for sulfide, MEEs, anions and alkalinity will occur bi-weekly.

Baseline Flux GAC Effluent Sampling

GAC effluent samples were collected from the system, prior to reinjection of the groundwater into the subsurface, to ensure that CVOCs were removed. Samples were collected from sampling ports located inside the recirculation trailer (post-GAC and pre-sediment filters) on 1, 7, and 18 April 2011 and were laboratory analyzed for CVOCs using EPA Method 8260C. After completion of this phase, the GAC vessels were removed from the system and staged onsite for proper offsite disposal.

Post-Baseline Flux Groundwater Sampling

The baseline flux measurement phase ended on 18 April 2011. The system was subsequently shutdown and a comprehensive post baseline flux measurement groundwater sampling event was conducted to serve as both a final assessment of the baseline flux measurement phase and a baseline event prior to the injection activities. The samples were collected and analyzed for the parameters presented in Table 4.

Table 4: Post Baseline Mass Flux Measurement Sampling Plan (NASA 2013)

Sampling Location	Screen Interval (ft BLS)	Analysis										
		VOCs by EPA Method 8260B	VFAs by EPA Method 300-modified	Bromide and Iodide by EPA Method 300.0	TOC by EPA Method 9060A	Sulfide by EPA Method 376.1	MEEs by EPA Method RSK 175	Anions by EPA Method 300.0	Alkalinity by EPA Method 310.1	Dissolved Metals by EPA Method 6010B	*Dhc* by Gene-Trac® Dhc	*vcrA* by Gene-Trac® VC
Upper Treatment Zone												
RW0007	35 to 42	X	X	X	X	X	X	X	X	X	X	X
IW0002I	25 to 30	X	X	X	X	X	X	X	X	X		
IW0002D	35 to 40	X	X	X	X	X	X	X	X	X		
BW0001A	23 to 26	X	X	X	X	X	X	X	X	X		
BW0001B	30 to 33	X	X	X	X	X	X	X	X	X		
BW0001C	37 to 40	X	X	X	X	X	X	X	X	X	X	X
BW0001D	44 to 47	X	X	X	X	X	X	X	X	X		
BW0002A	23 to 26	X	X	X	X		X					
BW0002B	30 to 33	X	X	X	X		X					
BW0002C	37 to 40	X	X	X	X	X	X	X	X			
BW0002D	44 to 47	X	X	X	X		X					
BW0003A	23 to 26	X	X	X	X		X					
BW0003B	30 to 33	X	X	X	X		X					
BW0003C	37 to 40	X	X	X	X	X	X	X	X		X	X
BW0003D	44 to 47	X	X	X	X		X					
Lower Treatment Zone												
RW0008	47 to 57	X	X	X	X	X	X	X	X	X	X	X
IW0002DI	50 to 55	X	X	X	X	X	X	X	X	X		
BW0001E	51 to 54	X	X	X	X	X	X	X	X	X	X	X
BW0001F	58 to 61	X	X	X	X	X	X	X	X	X		
BW0002E	51 to 54	X	X	X	X		X					
BW0002F	58 to 61	X	X	X	X		X					
BW0003E	51 to 54	X	X	X	X		X				X	X
BW0003F	58 to 61	X	X	X	X		X					
Outside Treatment Area												
IW0076 (below treatment area)	70 to 80	X	X	X	X		X			X		
IW0067D (UIC monitoring wel	38 to 43	X			X							
IW0067D1 (UIC monitoring w	63 to 73	X			X							
IW0070D (UIC monitoring wel	38 to 43	X			X							
IW0070D1 (UIC monitoring w	65 to 75	X			X							
IW0071D (UIC monitoring wel	38 to 43	X			X							
IW0071D1 (UIC monitoring w	65 to 75	X			X							

<u>Notes:</u>

1. ft BLS indicates feet below land surface.
2. VOCs indicate volatile organic compounds and include analysis for n-butyl acetate and n-butanol.
3. EPA indicates Environmental Protection Agency.
4. VFAs indicate volatile fatty acids.
5. TOC indicates total organic carbon.
6. MEEs indicate methane, ethane, ethene.
7. Anions include analysis for chloride, sulfate, nitrate and nitrite.
8. Dissolved metals include analysis for iron, manganese and arsenic.
9. *Dhc* indicates *Dehalococcoides* and is the quantitative analysis for the 16S rRNA gene.
10. *vcrA* indicates the vinyl chloride reductase gene and is a quantitative analysis.

PED Injection

The PED injection was performed from 20 to 28 June 2011, utilizing the Vironex (contractor based out of Washington, D.C.) injection platform. The goal was to inject approximately 0.2 percent of the pore volume with nBA. Given the area of the target area was approximately 655 ft^2, the treatment interval was from 23 to 62 ft BLS, and an assumed porosity of 0.30, 115 gallons of nBA was required. The nBA was diluted to 3,000 mg/L (approximately half aqueous solubility), generating 34,000 gallons of nBA solution (Table 5). The nBA injection concentration was chosen close to the solubility to create a concentration gradient to force nBA to partition into the low permeability confining unit.

The 34,000 gallons of nBA solution was injected into 20 temporary DPT injection points (IP01 through IP20) at the locations depicted on Figure 11. The nBA solution was injected through a 2-foot injection tool at 2-foot intervals above, in, and below the low permeability confining unit. Therefore, approximately 1,700 gallons of nBA solution was injected per point and 85 gallons of nBA solution was injected per interval. Based on the injection interval volumes, a radius of influence (ROI) of approximately 4 ft was expected (Table 6). Injection flow rates ranged from 6 to 8 gpm at pressures ranging from 30 to 45 pounds per square inch (psi). Photographs of the injection activities are provided in Appendix C (NASA 2013). An Injection Services Report, prepared by Vironex, which outlines injection activities, is provided in Appendix D (NASA 2013).

Table 5: Electron Donor Dosing and Injection Volume Calculations (NASA 2013)

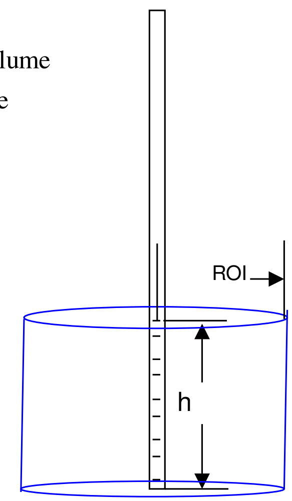
Treatment Interval	Number of Injection Points	Porosity	Injection Interval	Number of Injection Intervals	Volume of Injection Area	Pore Volume of Injection Area	Volume of nBA Based on 0.2% pore volume	Mass of nBA Reqired	Volume of nBA Solution (3,000 mg/L nBA concentration)	Volume of nBA Solution per Location	Volume nBA Solution per Injection Interval
					Area (~655 ft^2) * Injection interval (BASED ON TARGET AREA)	Volume * Porosity * 7.480519 gal/ft^3	pore volume *0.002	Volume nBA * Density (882.5 g nBA/L)	Mass nBA / 3,000 mg /L * 3.7854 gal/L	Volume nBA Solution / Number of Injection Points	Volume of nBA Solution per Location / Number of Injection Intervals
(ft BLS)			(feet)		(ft^3)	(gal)	(gal)	(grams)	(gal)	(gal)	(gal)
23 to 62	20	0.3	2	20	25,545	57,327	115	383,015	34,000	1,700	85

Notes:

1. ft BLS indicates feet below land surface.
2. ROI indicates radius of influence.
3. ft^2 indicates square feet.
4. ft^3 indicates cubic feet.
5. gal indicates gallons.

Table 6: Radius of Influence Calculations for Individual Injection Intervals (NASAS 2013)

Treatment Interval	23 to 26	ft BLS	
V_{nBA}	85	gal	nBA Solution Inj Volume
V_{water}	0	gal	Chase Water Volume
V_{total}	85	gal	Total Inj. Volume
V_{total}	11.4	ft^3	Total Inj. Volume
h	2	ft	screen length
π	3.14		pi
n	0.1		effective porosity
ROI = sqrt(V/π*n*h)			
ROI	4.3	ft	



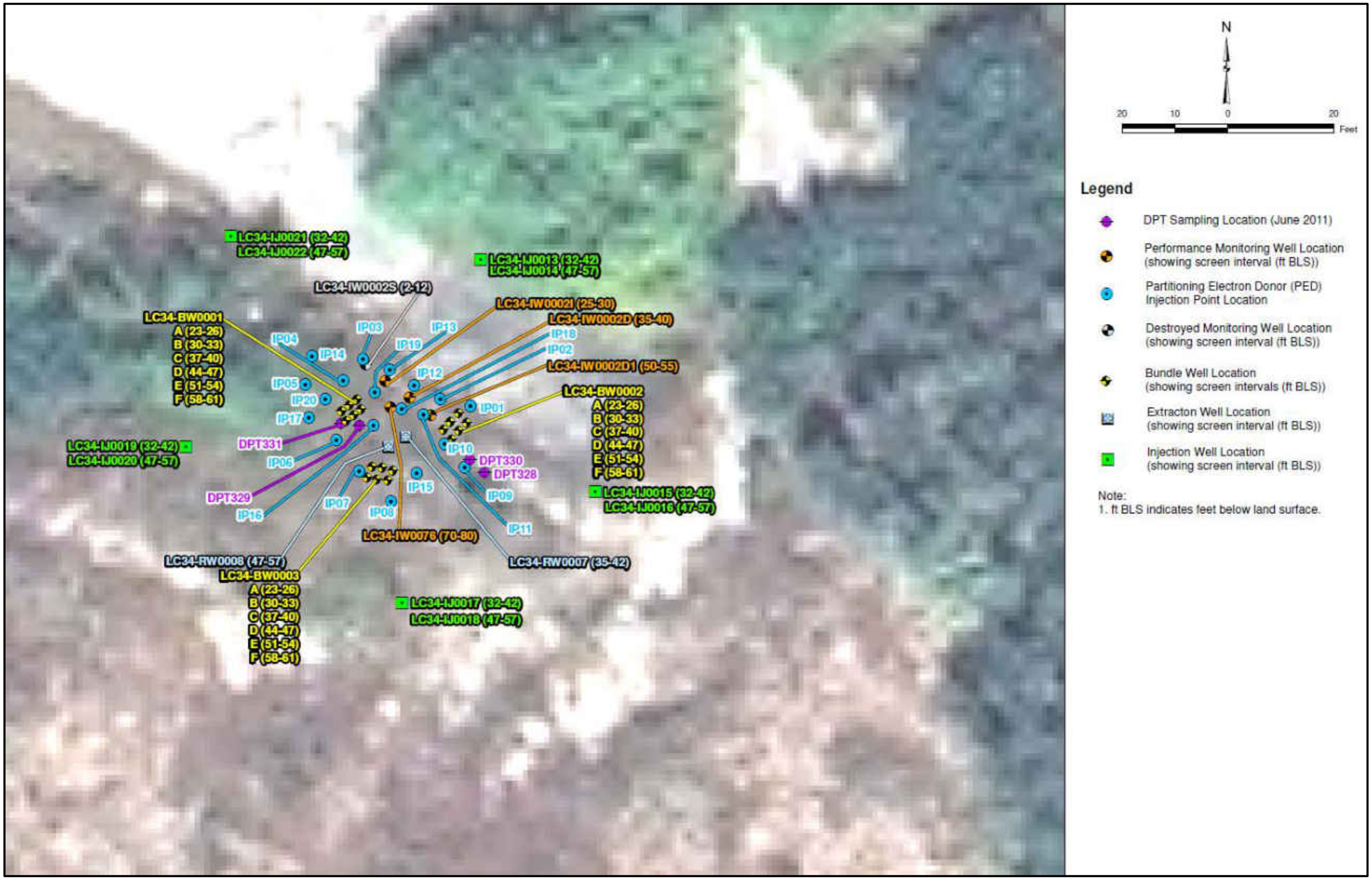


Figure 11: PED Injection and DPT Groundwater Sampling Locations (NASA 2013)

In addition to the nBA, two conservative tracers (potassium bromide [KBr] and potassium iodide [KI]) were added to the nBA solution to evaluate overall amendment distribution, flow paths, and degree of hydraulic connection across the confining unit layer. Approximately 12 kgs of KBr and 12 kgs of KI was used. The amendment injected above the clay (23 to 42 ft BLS) consisted of dilution water, nBA, KBr, and KI and the amendment injected in and below the clay layer (42 to 62 ft BLS) consisted of water, nBA, and KBr. Batches of nBA solution were mixed for a minimum of 15 minutes prior to being injected.

PED Injection Amendment Batch Sampling

In order to ensure that batches of amendment were being properly prepared and mixed, batch samples were collected from a sample port located on the Vironex platform and were laboratory analyzed for CVOCs and nBA (EPA Method 8260C) and bromide and iodide (EPA Method 300.0). Batches were mixed in two 250-gallon poly-tanks that were staged inside of a spill barrier and were covered to prevent excessive heat due to direct sunlight exposure. A total of 155 batches were prepared and injected into the subsurface. Two to three batches a day were randomly sampled for quality assurance (a total of 17 batches were sampled).

Post-PED Injection Groundwater Sampling

Groundwater samples were collected following the injection event to aid in the evaluation of the amendment distribution and ROI. Groundwater samples were collected using both DPT and monitoring well sampling techniques.

Post injection DPT groundwater sampling activities occurred on 30 June 2011, one day after injection activities were completed. Two sample locations were within 2 feet of the nearest injection point (DPT330 and DPT331) and two sample locations were within 4 feet of the nearest injection point (DPT 328 and DPT329), as depicted on Figure 11. A total of 18 samples were collected (4 to 5 samples per location) from 8 to 59 ft BLS and were analyzed by a mobile laboratory for CVOCs and nBA (EPA Method 8260C).

Post injection monitoring well groundwater sampling activities occurred on 7 July 2011, one week after injection activities were completed. Eleven site monitoring wells and both recirculation extraction wells (BW0001C through D, BW0002C through D, BW0003C through D, RW0007, and RW0008) were sampled and laboratory analyzed for CVOCs, nBA, n-butanol (EPA Method 8260C), and bromide and iodide (EPA Method 300.0).

Biomass Growth Phase

Following the injection activities, the recirculation system remained off for four weeks to allow time for the nBA to partition into the DNAPL source zone and for biomass growth. After the four-week biomass growth phase, additional groundwater and soil samples were collected to further assess the distribution of nBA and CVOCs.

Biomass Growth Phase Groundwater Sampling

Biomass growth phase groundwater monitoring well sampling was performed from 1 through 2 August 2011 and included collecting samples from 24 site monitoring wells. Collected samples were laboratory analyzed for parameters listed in Table 7.

Table 7: Biomass Growth Phase Sampling Plan (NASA 2013)

Sampling Location	Screen Interval (ft BLS)	Analysis								
		VOCs by EPA Method 8260B	VFAs by EPA Method 300-modified	Bromide and Iodide by EPA Method 300.0	TOC by EPA Method 9060A	Sulfide by EPA Method 376.1	MEEs by EPA Method RSK 175	Anions by EPA Method 300.0	Alkalinity by EPA Method 310.1	Dissolved Metals by EPA Method 6010B
Upper Treatment Zone										
RW0007	35 to 42	X	X	X	X	X	X	X	X	X
IW0002I	25 to 30	X	X	X	X	X	X	X	X	X
IW0002D	35 to 40	X	X	X	X	X	X	X	X	X
BW0001A	23 to 26	X	X	X	X	X	X	X	X	X
BW0001B	30 to 33	X	X	X	X	X	X	X	X	X
BW0001C	37 to 40	X	X	X	X	X	X	X	X	X
BW0001D	44 to 47	X	X	X	X	X	X	X	X	X
BW0002A	23 to 26	X	X	X	X		X			
BW0002B	30 to 33	X	X	X	X		X			
BW0002C	37 to 40	X	X	X	X	X	X	X	X	
BW0002D	44 to 47	X	X	X	X		X			
BW0003A	23 to 26	X	X	X	X		X			
BW0003B	30 to 33	X	X	X	X		X			
BW0003C	37 to 40	X	X	X	X	X	X	X	X	
BW0003D	44 to 47	X	X	X	X		X			
Lower Treatment Zone										
RW0008	47 to 57	X	X	X	X	X	X	X	X	X
IW0002DI	50 to 55	X	X	X	X	X	X	X	X	X
BW0001E	51 to 54	X	X	X	X	X	X	X	X	X
BW0001F	58 to 61	X	X	X	X	X	X	X	X	X
BW0002E	51 to 54	X	X	X	X		X			
BW0002F	58 to 61	X	X	X	X		X			
BW0003E	51 to 54	X	X	X	X		X			
BW0003F	58 to 61	X	X	X	X		X			
Outside Treatment Area										
IW0076 (below treatment area)	70 to 80	X	X	X	X		X			
IW0067D (UIC monitoring wel	38 to 43									
IW0067D1 (UIC monitoring w	63 to 73									
IW0070D (UIC monitoring wel	38 to 43									
IW0070D1 (UIC monitoring w	65 to 75									
IW0071D (UIC monitoring wel	38 to 43									
IW0071D1 (UIC monitoring w	65 to 75									

Notes:

1. ft BLS indicates feet below land surface.
2. VOCs indicate volatile organic compounds and include analysis for n-butyl acetate and n-butanol.
3. EPA indicates Environmental Protection Agency.
4. VFAs indicate volatile fatty acids.
5. TOC indicates total organic carbon.
6. MEEs indicate methane, ethane, ethene.
7. Anions include analysis for chloride, sulfate, nitrate and nitrite.
8. Dissolved metals include analysis for iron, manganese and arsenic.

Biomass Growth Phase Soil Sampling

Biomass growth phase soil sampling was performed on 3 August 2011 and included collection three soil cores (DPT0332, DPT0333, and DPT0334) using DPT techniques at the locations presented on Figure 12. A total of 17 soil samples were collected based on PID screening responses and based on lithology (i.e. more samples collected from clay layer). The samples were laboratory analyzed for CVOCs and nBA (EPA Method 8260C). In addition, the soil cores were logged to document soil lithology.

System Operation Phase

Following the biomass growth phase, the recirculation system was restarted on 9 August 2011. The system operated for a duration of approximately 12 months and was shut down on 11 September 2012. During system operation, frequent groundwater sampling events and semi-annual soil sampling events were performed to monitor the effectiveness of the nBA field implementation demonstration. In addition, O&M activities were conducted regularly to ensure proper operation of the recirculation system.

Figure 12: Biomass Growth Phase, Month 6, and Month 12 Soil Sampling Locations (NASA 2013)

System O&M

O&M events were conducted weekly for the first six month of operation and were conducted biweekly thereafter. O&M events included the following activities:

- inspected wiring and piping for leaks/damages;
- cleaned sediment filters, solar panels, and flow meters as needed;
- measured flow rates and volume produced from recirculation extraction wells;
- measured flow rates, initial and adjusted, to recirculation injection wells;
- measured voltage and percent charged from batteries; and
- addressed any operational abnormalities with corrective action.

System Operation Phase Groundwater Sampling

Groundwater samples were collected from both recirculation extraction wells (RW0007 and RW0008) on a weekly basis for the first month of operation. The sampling frequency was reduced to biweekly sampling from month 2 to month 6 and monthly sampling from month 7 to month 12. Samples collected from month 1 to month 6 were laboratory analyzed for parameters listed in Table 8. Samples collected from month 7 to month 12 were laboratory analyzed for parameters listed in Table 9.

Groundwater samples were collected from select site monitoring wells on a quarterly basis (Month 3 – October 2011, Month 6 – February 2012, Month 9 – June 2012, and Month 12 – September 2012). During month 3 and month 6 sampling events, collected samples were laboratory analyzed for the parameters listed in Table 8. During month 9 and month 12 sampling events, collected samples were laboratory analyzed for parameters listed in Table 9.

Underground injection control (UIC) sampling was performed during the baseline sampling event, at the end of the baseline flux phase, and during the first two quarterly system operation sampling events (month 3 and month 6). Groundwater samples were collected from the designated UIC monitoring wells (IW0067, IW0070, and IW0071) and were laboratory analyzed for the parameters listed in Table 8.

Table 8: System Operation Sampling Plan – Startup to Month 6 (NASA 2013)

Sampling Location	Screen Interval (ft BLS)	Analysis: VOCs by EPA Method 8260B	VFAs by EPA Method 300-modified	Bromide and Iodide by EPA Method 300.0	TOC by EPA Method 9060A	Sulfide by EPA Method 376.1	MEEs by EPA Method RSK 175	Anions by EPA Method 300.0	Alkalinity by EPA Method 310.1	Dissolved Metals by EPA Method 6010B	*Dhc* by Gene-Trac® Dhc	*vcrA* by Gene-Trac® VC
Upper Treatment Zone												
RW0007	35 to 42	X	X	X	X	X	X	X	X	X	X	X
IW0002I	25 to 30	X	X	X	X	X	X	X	X	X		
IW0002D	35 to 40	X	X	X	X	X	X	X	X	X		
BW0001A	23 to 26	X	X	X	X	X	X	X	X	X		
BW0001B	30 to 33	X	X	X	X	X	X	X	X	X		
BW0001C	37 to 40	X	X	X	X	X	X	X	X	X	X	X
BW0001D	44 to 47	X	X	X	X		X	X	X	X		
BW0002A	23 to 26	X	X	X	X		X					
BW0002B	30 to 33	X	X	X	X		X					
BW0002C	37 to 40	X	X	X	X	X	X	X	X			
BW0002D	44 to 47	X	X	X	X		X					
BW0003A	23 to 26	X	X	X	X		X					
BW0003B	30 to 33	X	X	X	X		X					
BW0003C	37 to 40	X	X	X	X	X	X	X	X		X	X
BW0003D	44 to 47	X	X	X	X		X					
Lower Treatment Zone												
RW0008	47 to 57	X	X	X	X	X	X	X	X	X	X	X
IW0002DI	50 to 55	X	X	X	X	X	X	X	X	X		
BW0001E	51 to 54	X	X	X	X	X	X	X	X	X	X	X
BW0001F	58 to 61	X	X	X	X	X	X	X	X	X		
BW0002E	51 to 54	X	X	X	X		X					
BW0002F	58 to 61	X	X	X	X		X					
BW0003E	51 to 54	X	X	X	X		X				X	X
BW0003F	58 to 61	X	X	X	X		X					
Outside Treatment Area												
IW0076 (below treatment area)	70 to 80	X	X	X	X		X			X		
IW0067D (UIC monitoring wel	38 to 43	X			X							
IW0067D1 (UIC monitoring we	63 to 73	X			X							
IW0070D (UIC monitoring wel	38 to 43	X			X							
IW0070D1 (UIC monitoring we	65 to 75	X			X							
IW0071D (UIC monitoring wel	38 to 43	X			X							
IW0071D1 (UIC monitoring we	65 to 75	X			X							

Notes:

1. ft BLS indicates feet below land surface.
2. VOCs indicate volatile organic compounds and include analysis for n-butyl acetate and n-butanol.
3. EPA indicates Environmental Protection Agecny.
4. VFAs indicate volatile fatty acids.
5. TOC indicates total organic carbon.
6. MEEs indicate methane, ethane, ethene.
7. Anions include analysis for chloride, sulfate, nitrate and nitrite.
8. Dissolved metals include analysis for iron, manganese and arsenic.
9. *Dhc* indicates *Dehalococcoides* and is the quantitative analysis for the 16S rRNA gene.
10. *vcrA* indicates the vinyl chloride reductase gene and is a quantitative analysis.
11. Extraction wells (RW0007 and RW0008) were sampled weekly for the first month and bi-weekly for remaining five months. Analysis of samples for *Dhc* and *vcrA* occurred quarterly.
12. Monitoring wells were sampled at month 3 and month 6 of operation.

Table 9: System Operation Sampling Plan – Month 7 to Month 12 (NASA 2013)

Sampling Location	Screen Interval (ft BLS)	Analysis				
		VOCs by EPA Method 8260B	TOC by EPA Method 9060A	MEEs by EPA Method RSK 147	*Dhc* by Gene-Trac® Dhc	*vcrA* by Gene-Trac® VC
Upper Treatment Zone						
RW0007	35 to 42	X	X	X	X	X
IW0002I	25 to 30	X	X	X		
IW0002D	35 to 40	X	X	X		
BW0001A	23 to 26	X	X	X		
BW0001B	30 to 33	X	X	X		
BW0001C	37 to 40	X	X	X	X	X
BW0001D	44 to 47	X	X	X		
BW0002A	23 to 26	X	X	X		
BW0002B	30 to 33	X	X	X		
BW0002C	37 to 40	X	X	X		
BW0002D	44 to 47	X	X	X		
BW0003A	23 to 26	X	X	X		
BW0003B	30 to 33	X	X	X		
BW0003C	37 to 40	X	X	X	X	X
BW0003D	44 to 47	X	X	X		
Lower Treatment Zone						
RW0008	47 to 57	X	X	X	X	X
IW0002DI	50 to 55	X	X	X		
BW0001E	51 to 54	X	X	X	X	X
BW0001F	58 to 61	X	X	X		
BW0002E	51 to 54	X	X	X		
BW0002F	58 to 61	X	X	X		
BW0003E	51 to 54	X	X	X	X	X
BW0003F	58 to 61	X	X	X		
Outside Treatment Area						
IW0076 (below treatment area)	70 to 80	X	X	X		
IW0067D (UIC monitoring well)	38 to 43					
IW0067D1 (UIC monitoring well)	63 to 73					
IW0070D (UIC monitoring well)	38 to 43					
IW0070D1 (UIC monitoring well)	65 to 75					
IW0071D (UIC monitoring well)	38 to 43					
IW0071D1 (UIC monitoring well)	65 to 75					

Notes:

1. ft BLS indicates feet below land surface.
2. VOCs indicate volatile organic compounds and include analysis for n-butyl acetate and n-butanol.
3. EPA indicates Environmental Protection Agency.
4. TOC indicates total organic carbon.
5. MEEs indicate methane, ethane, ethene.
6. *Dhc* indicates *Dehalococcoides* and is the quantitative analysis for the 16S rRNA gene.
7. *vcrA* indicates the vinyl chloride reductase gene and is a quantitative analysis.
8. Extraction wells (RW0007 and RW0008) were sampled monthly from month 7 to month 12 and samples were analyzed for VOCs only and were sample quarterly for the constituents noted above.
9. Monitoring wells were sampled at month 9 and month 12 of operation.

System Operation Phase Soil Sampling

Three soil cores (DPT0346, DPT0347, and DPT0348) were collected during the month 6 sampling event and three soil cores (DPT0349, PDT0350, and DPT0351) were collected during the month 12 sampling event using DPT techniques at the locations presented on Figure 12. Sample intervals were selected based on PID screening responses and based on lithology. A total of 24 soil samples were collected during the month 6 event and 22 soil samples were collected from the month 12 event. Collected soil samples were laboratory analyzed for CVOCs and nBA (EPA Method 8260C and select soil samples were analyzed for *Dhc* and *vcrA*. In addition, the cores were visually logged to document soil lithology.

Post System Operation Groundwater Sampling

Six month following the recirculation system shutdown (i.e. through March 2013 [Month 18]), selected site monitoring wells were sampled to assess the availability of remaining electron donor and to evaluate CVOC concentrations. Samples were collected from monitoring wells BW0001B, BW0001C, and BW0001D and were laboratory analyzed for CVOCs and nBA (EPA Method 8260C) and methane, ethane, and ethene (EPA Method RSK 175).

Recirculation System Removal

Following the month 18 groundwater sampling event, the recirculation system and piping were removed on 20 May 2013. The temporary construction fencing, above ground secondary containment piping (2-in schedule 40 PVC), injection piping (3/4-in HDPE), submersible recirculation pumps, and the recirculation trailer were all removed from the site.

CHAPTER 4: RESULTS

Overview

This section summarizes the results from sampling activities associated with the PED injection demonstration. Sampling activities occurred from January 2011 (baseline sampling) through March 2013 (post system operation sampling) and included soil sampling, groundwater sampling, GAC effluent sampling, and PED injection batch sampling. Sampling was performed to assess the effectiveness of the PED injection as a viable bioremediation alternative. This section is organized by the phases of implementation operation, including: (i) baseline sampling; (ii) baseline flux measurement phase; (iii) injection phase; (iv) biomass growth phase; (v) system operation phase; and (vi) post system operation phase. All result tables are provided at the end of the section for coherence.

Baseline Sampling Results

Baseline sampling included collecting soil and groundwater samples from locations in and around the treatment area. Samples were collected to confirm constituent delineation and to establish pre-implementation groundwater conditions within the vicinity of the treatment area.

Baseline Soil Sampling Results

CVOC and nBA results for baseline soil sampling are presented in Table 10. A total of 19 soil samples were collected from four locations at intervals ranging from 24 to 55 ft BLS. The maximum TCE concentration detected at each location was as follows:

- 22 milligrams per kilogram (mg/kg) at soil boring location SB1003 (location of bundle well BW0001), at a depth of 44 ft BLS;
- 0.03 mg/kg at soil boring location SB1002 (location of bundle well BW0002) at a depth of 46.5 ft BLS;
- 5.4 mg/kg at soil boring location SB1004 (location of bundle well BW0003) at a depth of 45 ft BLS; and
- 5.7 mg/kg at SB1001 (location of recirculation extraction well RW0008) at a depth of 44.5 ft BLS.

The maximum TCE concentrations were all detected within the silty/clay layer (low hydraulic conductivity semi-confining layer). nBA was not detected in any soil samples collected, as expected.

TOC and f_{oc} results for baseline soil sampling are presented in Table 11. TOC and f_{oc} samples were collected from soil borings SB1002 (location of bundle well BW0002) and SB1003 (location of bundle well BW0001). The average values for the clay layer were 2,850 mg/kg TOC and 0.003 f_{oc}.

Baseline Groundwater Sampling CVOC Results

CVOC and nBA results for baseline groundwater sampling are presented in Table 12. Groundwater samples were collected from 28 monitoring wells, including six UIC wells, two recirculation extraction wells, and four injection wells. Maximum TCE concentration (150,000 µg/L) was observed in the sample collected from monitoring well BW0001D, screened within the clay layer. The groundwater sampling results confirm the soil sampling results – the highest TCE concentrations are in the area of monitoring well BW0001 and within the clay layer. Maximum cDCE concentration (87,000 µg/L) was observed in the sample collected from monitoring well BW0002C, just above the clay layer. Maximum VC concentration (13,000 µg/L) was observed in the sample collected from monitoring well BW0003A (above the clay layer). No CVOCs were detected in samples collected from the UIC monitoring wells, which are located outside of the treatment zone. nBA was not detected in any of the samples collected, as expected. Freon 113 was detected in 13 of the 34 wells sampled and the maximum concentration detected (130,000 µg/L) was observed in the sample collected from monitoring well BW0001B.

Baseline Groundwater Sampling Field Geochemical Parameter Results

Field geochemical parameters collected during the baseline groundwater sampling event were used to evaluate whether aquifer conditions are favorable for the reductive dechlorination of CVOCs and are presented in Table 13.

The optimal pH range for *Dhc* is between 6 and 8 standard units (SU). The pH reported within the treatment zone during the February 2011 baseline sampling event ranged from 7.3 SU to 8.8

SU, with an average of 7.6 SU. This indicates that the pH in the treatment area was generally within the optimum range for dechlorinating bacteria.

The absence of DO in groundwater is an indication that conditions are favorable for anaerobic reductive dechlorination of CVOCs. Negative ORP values indicate a reducing groundwater environment and are also indicative of groundwater conditions favorable for anaerobic reductive dechlorination of CVOCs. The DO reported from monitoring wells within the treatment zone during the February 2011 baseline sampling event ranged from 0.16 mg/L to 0.61 mg/L, with an average of 0.33 mg/L. The ORP reported during the February 2011 baseline sampling event ranged from negative 197 millivolts (mV) to 6.5 mV, with an average of negative 138 mV. The ORP of 6.5 mV was from the groundwater at recirculation extraction well RW0007, which was the only well in the treatment area with an ORP that was positive (all other values were less than negative 90 mV). The average DO and ORP concentrations presented are indicative of a reducing, anaerobic environment conducive to the reductive dechlorination of CVOCs.

Baseline Flux Measurement Phase Results

During the baseline flux phase, the recirculation system was operated for four weeks (March through April 2011) prior to injection of the PED with a goal of measuring mass removal without PED enhancement. The recirculation extraction wells, along with select site monitoring wells, were sampled weekly. The results from the recirculation extraction wells were mainly used to evaluate the effects of the recirculation system operation without PED enhancement. The post baseline flux sampling event occurred at the end of week 4, which serves as the baseline data for all future sampling events. GAC effluent was sampled as well to monitor for breakthrough prior to reinjection.

Baseline Flux Measurement Groundwater Sampling CVOC Results

CVOC results for the baseline flux measurement phase are presented in Table 12. Data from the recirculation extraction wells indicate that TCE and cDCE concentrations in the area of the recirculation extraction wells decreased during the baseline flux measurement phase. A summary of the data is provided below.

Samples collected from recirculation extraction well RW0007 yielded a decrease in TCE concentration from 54,000 µg/L to 12,000 µg/L, a decrease in cDCE concentration from 50,000 µg/L to 25,000 µg/L, and an increase in VC concentration from non-detect to 990 I µg/L (I indicates concentration detected between the method detection limit [MDL] and the practical quantitation limit [PQL]). Samples collected from recirculation extraction well RW0008 yielded a decrease in TCE concentration from 4,900 µg/L to 1,000 µg/L, a decrease in cDCE concentration from 3,300 µg/L to 510 µg/L, and stable VC concentrations that remained below detectable limits.

During the baseline flux phase, select monitoring wells were sampled which included wells screened above the clay (BW0001C, BW0002C, BW0003C, IW0002I, IW0002D) and wells screened below the clay (BW0001E, BW00003E, IW0002D1). The highest TCE, cDCE and VC concentrations were observed in samples collected from monitoring well BW0001C, BW0002C, and BW0003C, respectively. CVOC concentrations in the samples collected from the monitoring wells were generally the same order of magnitude as the concentrations observed during the baseline sampling, with the following exceptions:

- TCE concentrations in samples collected from monitoring well IW0002D decreased from 17,000 µg/L to 490 I µg/L;
- cDCE concentrations in samples collected from monitoring well IW0002D decreased from 57,000 µg/L to 26,000 µg/L;
- cDCE concentrations in samples collected from monitoring well BW0003C decreased from 36,000 µg/L to 6,000 µg/L;
- and cDCE concentrations in samples collected from monitoring well BW0001C decreased from 47,000 µg/L to 25,000 µg/L.

In general, the data suggests that the operation of the recirculation system alone impacted groundwater within the treatment area, initially decreasing CVOC concentrations. The decreases observed from samples collected from treatment zone monitoring wells are likely attributed to dilution from recirculation system influences, as evidenced by the similar relative decreases observed in both TCE and daughter product concentrations. If concentration decreases were attributed to reductive dechlorination, an increase in daughter products would be expected following a decrease in TCE concentrations.

Baseline Flux Measurement Groundwater Sampling nBA, TOC, and VFA Results

nBA results are presented in Table 12 and TOC and volatile fatty acids (VFAs) results are presented in Table 14. During the baseline flux measurement phase, groundwater collected from the recirculation extraction wells were analyzed for nBA, TOC, and VFAs weekly for four weeks and select site monitoring wells were sampled during the week four event (results to serve as baseline sampling event for next phase). Sample results from the recirculation extraction wells remained stable during the baseline flux measurement phase; therefore, the results below focus on the week four sampling event.

Groundwater samples were analyzed for nBA during the baseline flux measurement phase to ensure nBA was not present in the groundwater prior to its injection. There were no detections of nBA in any of the samples collected during the baseline flux measurement phase.

The purpose of analyzing groundwater samples for TOC and VFAs (including acetic acid, butanoic acid (ie. butyric acid), lactic acid, propionic acid, and pyruvic acid) during the baseline flux measurement phase was to obtain a baseline value of TOC and VFAs prior to PED injection. During the baseline flux measurement phase, acetic acid and lactic acid were the only VFAs detected. Average detected TOC, acetic acid, and lactic acid concentrations observed in samples collected from recirculation extraction wells and select site and UIC monitoring wells are summarized below:

- TOC ranged from 2.9 mg/L to 7.5 mg/L, with an average of 4.0 mg/L;
- acetic acid ranged from 1.0 µg/L to 65 µg/L, with an average of 11 µg/L; and
- lactic acid concentrations ranged from 1.1 µg/L to 2.3 µg/L, with an average of 1.5 µg/L.

Baseline Flux Measurement Groundwater Sampling *Dhc* and *vcrA* Results

Results for *Dhc* and *vcrA* analyses are presented in Table 15. Samples were analyzed for *Dhc* and *vcrA* during the last week of the baseline flux measurement phase in order to establish a baseline concentration. *Dhc* was detected in 5 of the 6 wells sampled with a concentration that ranged from 1.0 x 10^3 J (estimated value between the detection limit and the quantitation limit) gene copies per liter (gene copies/L) to 5.0 x 10^7 gene copies/L. Analysis for *vcrA* was performed on the samples collected from the recirculation extraction wells (RW0007 and RW0008). A *vcrA* concentration of 5.0 x 10^3 gene copies/L was detected in samples collected from recirculation extraction well RW0007 and no *vcrA* was detected in samples collected from recirculation extraction well RW0008.

Baseline Flux Measurement Groundwater Sampling Geochemical Results

Results for geochemical parameters are presented in Table 16 and include concentrations of MEEs, nitrate, nitrite, sulfate, sulfide, chloride, alkalinity, and bromide and iodide (tracers). During the baseline flux measurement phase, groundwater collected from the recirculation extraction wells were analyzed for geochemical parameters during week two and week four and select site monitoring wells were sampled during the week four event (results to serve as baseline sampling event for next phase). Sample results from the recirculation extraction wells remained stable during the baseline flux measurement phase; therefore, the results below focus on the week four sampling event.

Dissolved Gases Evaluation

Methane is produced by methanogenic bacteria from the conversion of acetate or the reduction of carbon dioxide under anaerobic conditions. Methanogens and dechlorinating organisms thrive under similar conditions; therefore, the production of methane in groundwater is a good indicator that favorable conditions exist for reductive dechlorination. Methane concentrations detected in samples collected during the week four of the baseline flux measurement phase ranged from 5.8 µg/L to 110 µg/L, with an average of 45 µg/L.

Ethene is the final dechlorination product of TCE, cDCE, and VC. Ethene concentrations ranged from 2.9 µg/L to 260 µg/L, with an average of 53 µg/L. Ethane was not detected. This data suggests that complete dechlorination is naturally occurring.

Nitrate and Nitrite Evaluation

Nitrate is reduced to nitrite under anaerobic conditions by bacteria that contain nitrate reductase (enzyme responsible for nitrate reduction). The nitrate reducing bacteria can compete for electron donor with dechlorinating organisms (e.g., *Dhc*). Both nitrate and nitrite were not detected in any samples collected during the baseline flux phase. These results suggest that nitrate is not present in site groundwater and therefore, the bacteria responsible for nitrate reduction will not be present to compete with the dechlorinating organisms for electron donor.

Sulfate and Sulfide Evaluation

Sulfate is transformed to sulfide under anaerobic conditions by sulfate reducers and these organisms can compete for electron donor with dechlorinating organisms (e.g., *Dhc*). Sulfate concentrations have been observed as high as 960 mg/L without showing inhibitions, whereas sulfide inhibition to *Dhc* begins at concentrations between 32 and 160 mg/L (He 2005). Sulfate concentrations detected in samples collected during the baseline flux measurement phase ranged from 27 mg/L to 112 mg/L, with an average of 64 mg/L, which is below inhibitory concentrations. Sulfide was only detected in recirculation extraction well RW0007 at a concentration of 1.0 mg/L, which is below inhibitory concentrations.

<u>Chloride and Alkalinity Evaluation</u>

Chloride is produced during the reductive dechlorination of TCE, cDCE, and VC. Groundwater samples were analyzed for chloride during the last week of the baseline flux measurement phase to obtain baseline data for the remainder of the PED implementation. Chloride concentrations ranged from 73 mg/L to 780 mg/L, with an average of 464 mg/L.

Groundwater samples were analyzed for alkalinity during the baseline flux phase to evaluate the general groundwater geochemistry at the site prior to PED injection activities. The alkalinity ranged from 166 mg/L to 341 mg/L as $CaCO_3$, with an average of 245 mg/L as $CaCO_3$.

<u>Bromide and Iodide (Tracers) Evaluation</u>

The purpose of sampling for bromide and iodide during the baseline flux measurement phase was to obtain a baseline value for the tracer concentrations prior to injection event. During the four weeks of the baseline flux measurement phase, bromide concentration detected in samples collected from recirculation extraction wells and select site and UIC monitoring wells ranged from 1.1 mg/L to 2.1 mg/L, with an average of 1.5 mg/L. Iodide was not detected in any samples collected during the baseline flux measurement phase.

Baseline Flux Measurement Groundwater Sampling Dissolved Metals Results

Dissolved metals were monitored for mobilization during implementation. Groundwater samples were analyzed for dissolved metals, including arsenic, iron, and manganese, during the last week of the baseline flux measurement phase to obtain baseline values for the remainder of the PED implementation and results are presented in Table 17. Arsenic was not detected in samples collected during the baseline flux measurement phase. Iron concentrations detected (nine out of 12 wells sampled) in samples collected during the baseline flux measurement phase ranged from 110 µg/L to 230 µg/L, and manganese concentrations ranged (detected in all wells sampled) from 10 µg/L to 34 µg/L.

Baseline Flux Measurement Groundwater Sampling Field Geochemical Results

Field geochemical parameters collected during the baseline flux measurement phase were used to evaluate whether aquifer conditions remain favorable for the reductive dechlorination of CVOCs and are presented in Table 13.

The pH reported from monitoring wells within the treatment zone during the baseline flux measurement phase ranged from 7.3 SU to 7.8 SU, with an average of 7.6 SU. This indicates that the pH in the target area remains within the optimum range for reductive dechlorination.

The DO reported from monitoring wells within the treatment zone during the baseline flux measurement phase ranged from 0.08 mg/L to 1.7 mg/L, with an average of 0.41 mg/L. The

ORP observed during the baseline flux measurement phase ranged from negative 211 mV to negative 53 mV, with an average of negative 143 mV. While it appears the site DO was occasionally above the levels where site groundwater is considered anaerobic (0.5 mg/L) [Wiedemeier 2005], the ORP concentrations observed are indicative of a reducing, anaerobic environment conducive to the reductive dechlorination of CVOCs.

Baseline Flux Measurement GAC Effluent Results

Effluent from the GAC vessels was sampled to assure that the CVOCs were removed from the groundwater prior to reinjection. CVOCs were not detected in any GAC effluent samples collected, indicating that all CVOCs were removed from the groundwater prior to reinjection.

Baseline Flux Measurement Recirculation System Operation Summary

The recirculation system operated for four weeks during the baseline flux measurement phase and a summary of recirculation system operation data collected during O&M activities (Appendix E) is provided below.

- Average flow rates
    - Approximately 2.3 gpm from recirculation extraction well RW0007, slightly less than design flow rate of 2.5 gpm;
    - approximately 2.4 gpm from recirculation extraction well RW0008, slightly less than design flow rate of 2.5 gpm; and
    - approximately 0.4 gpm to 0.5 gpm to individual recirculation injection wells.
- Total groundwater recirculated

- Approximately 58,700 gallons from recirculation extraction well RW0007; and
- approximately 44,000 gallons from recirculation extraction well RW0008.

- Operational percentage
  - The system was designed to operate on for 40 minutes, then off for 20 minutes. Therefore, the system was anticipated to operate for 16 hours per day;
  - recirculation extraction well RW0007 operated for approximately 78 percent of the time; and
  - recirculation extraction well RW0008 operated for approximately 57 percent of the time.

No repairs or adjustments to the recirculation system were necessary during the baseline flux measurement phase. The reduced operational percentage was mainly due to the undersized solar panel recharging network and did not impact the baseline flux phase evaluation.

PED Injection Sampling Results

The PED injection took place from 20 through 28 June 2011. During the injection, PED solution batches were sampled to ensure proper preparation. Following the injection, DPT groundwater sampling and monitoring well sampling was conducted to ensure proper delivery of the PED to the subsurface.

PED Injection Amendment Batch Sampling Results

The PED amendment batches were sampled prior to injection to compare against design criteria. The PED amendment batch sampling results are presented in Table 18. The nBA concentration observed in samples collected from random batches during the June 2011 injection event ranged from 1,100 mg/L to 7,700 mg/L, with an average of 3,000 mg/L, which was the same as the design concentration (3,000 mg/L). The bromide concentration observed in samples collected from batches during the injection event ranged from 17 mg/L to 111 mg/L, with an average of 72 mg/L, which was slightly higher than the design concentration of 60 mg/L. The iodide concentration observed in samples collected from batches during the injection event ranged from 27 mg/L to 150 mg/L, with an average of 107 mg/L, which was less than the design concentration of 140 mg/L.

PED Injection DPT Groundwater Sampling Results

Post-injection DPT groundwater sampling results are presented in Table 19 and were collected at the locations presented on Figure 11 to aid in the evaluation of the ROI obtained during injection activities. The DPT groundwater sampling was conducted one day after completion of the PED injection activities. Two feet away from the nearest injection point, the maximum nBA concentration detected from samples collected during the post-injection DPT groundwater sampling was 1,700 mg/L (DPT0329), approximately half of the design concentration of 3,000 mg/L. Four feet away from the nearest injection point, the maximum nBA concentration detected was 490 mg/L. It is likely that the nBA hydrolyzed into n-butanol and acetate more quickly than anticipated. The collected samples were analyzed using an on-site mobile laboratory; therefore, n-butanol data was not available to verify if hydrolysis of nBA occurred.

PED Injection Monitoring Well Groundwater Sampling Results

Post-injection monitoring well groundwater sampling, which occurred on 7 July 2011, was conducted to aid in the evaluation of the ROI obtained during injection activities. CVOC, nBA, and n-butanol results are presented in Table 12 and tracer results are presented in Table 16. Maximum TCE concentration detected during the post-injection monitoring well groundwater sampling event during July 2011 was 170,000 µg/L in samples collected from monitoring well BW0001D. Maximum cDCE concentration detected was 51,000 µg/L in samples collected from monitoring well BW0002C, and maximum VC concentration detected was 2,400 I µg/L in samples collected from monitoring well BW0003C.

nBA concentrations detected in samples collected during the post-injection monitoring well groundwater sampling (detected at all wells sampled) ranged from 49 I µg/L to 1,500 mg/L (maximum concentration detected at BW0003E; approximately four feet from nearest injection point), with an average of 403 mg/L. n-butanol concentrations detected (detected in 10 of 11 wells sampled) in samples collected during the sampling event ranged from 1.5 I mg/L to 520 mg/L (maximum concentration detected at BW0003E), with an average of 168 mg/L. The detection of n-butanol suggests that the nBA is undergoing hydrolysis in the subsurface.

Bromide was detected in all samples collected during the July 2011 post-injection monitoring well groundwater sampling. Iodide was detected in samples collected from wells screened above the clay layer (BW0001C, BW0002C, BW0003C, and RW0007) as expected since iodide was only injected above the clay. Bromide and iodide detections indicate that the nBA solution was successfully delivered to the subsurface within the treatment area.

Recirculation extraction well RW0007 is the location that is furthest away from the injection points and nBA, bromide, and iodide were observed in samples collected from recirculation extraction well RW0007. Therefore, the estimated achieved ROI was up to 5 ft.

Biomass Growth Results

During the biomass growth phase, the recirculation system remained off for approximately four weeks to allow the nBA to partition into the DNAPL and to allow time for biomass growth. Groundwater sampling occurred on 1 and 2 August 2011 and soil sampling occurred on 3 August 2011 to evaluate site conditions after biomass growth phase.

Biomass Growth Groundwater Sampling CVOC Results

Biomass growth phase CVOC results are presented in Table 12. TCE concentrations in samples collected during the biomass growth phase in August 2011 ranged from 1.3 I µg/L to 120,000 µg/L (BW0001D), cDCE concentrations ranged from 4.0 I µg/L to 43,000 µg/L (BW0002C), and VC concentrations ranged from 1.3 I µg/L to 14,000 µg/L (BW0003B). When compared to results from week four of the baseline flux measurement phase (April 2011), maximum TCE and cDCE concentrations were within the same order of magnitude, with the maximum concentrations occurring in samples collected from the same monitoring wells (BW0001D and BW0002C, respectively), while the maximum VC concentration was observed to increase from 5,700 µg/L (April 2011; BW0003A) to 14,000 µg/L (August 2011; BW0003B). The increase in VC concentration can be attributed to the degradation of TCE into daughter products.

Biomass Growth Groundwater Sampling nBA, TOC, AND VFA Results

nBA results are presented in Table 12 and TOC and VFA results are presented in Table 14. A summary of the results collected during the biomass growth phase in August 2011 is provided below.

- nBA concentrations detected averaged 71 mg/L, decreasing from average nBA concentration observed in July 2011 (403 mg/L);
- n-butanol concentrations detected averaged 157 mg/L, remaining stable from average n-butanol concentration observed in July 2011 (168 mg/L);
- TOC concentrations detected ranged from 3.7 mg/L to 1,130 mg/L, with an average of 250 mg/L, increasing from the average concentration observed in April 2011 (4.0 mg/L);
- acetic acid concentrations detected ranged from 2.8 µg/L to 1,100 µg/L, with an average of 272 µg/L, increasing from the average concentration observed in April 2011 (11 µg/L);
- butanoic acid concentrations detected ranged from 3.7 µg/L to 1,200 µg/L, with an average of 143 µg/L, increasing from non-detect (April 2011);
- lactic acid concentrations ranged from 1.1 µg/L to 1.7 µg/L, with an average of 1.3 µg/L, which is similar to concentration observed in April 2011 (1.5 µg/L); and
- propionic acid concentrations ranged from 1.1 µg/L to 21 µg/L, with an average of 9.8 µg/L, increasing from non-detect (April 2011).

n-butanol detection indicated that nBA is being hydrolyzed in the subsurface. The increase in acetic and butanoic acid indicates n-butanol is being broken down in the subsurface and providing essential electron donor.

Biomass Growth Groundwater Sampling Tracer Results

Bromide and iodide results are presented in Table 16. Bromide concentrations detected in samples collected during the biomass growth phase in August 2011 ranged from 1.0 mg/L to 58 mg/L and iodide concentrations ranged from 2.3 mg/L to 64 mg/L. No iodide was detected below the semi-confining unit, as expected, since no iodide was injection below it.

Biomass Growth Groundwater Sampling Geochemical Results

Results for geochemical parameters are presented in Table 16 and are summarized below.

<u>Dissolved Gases Evaluation</u>

A summary of the results is provided below.

- Methane concentrations detected in samples collected during the biomass growth phase ranged from 4.3 µg/L to 5,600 µg/L, with an average of 361 µg/L;
- ethane concentrations detected ranged from 1.3 µg/L to 140 µg/L, with an average of 41 µg/L;
- ethene concentrations detected ranged from 1.5 µg/L to 410 µg/L, with an average of 67 µg/L; and

- methane and ethane average concentrations increased from concentrations detected in April 2011, which were 45 µg/L and non-detect, respectively, while the ethene concentration was similar to the concentration observed in April 2011 (53 µg/L).

The increase in the average concentration of methane indicates that the injection of PED has created an environment that is suitable for the reductive dechlorination of CVOCs. The increase in ethane concentrations indicates that ethene is being reduced to ethane. The observed stable concentration of ethene is likely due to conversion to ethane.

Sulfate and Sulfide Evaluation

Sulfate concentrations detected in samples collected during the biomass growth phase ranged from 2.3 mg/L to 79 mg/L, with an average of 23 mg/L, decreasing from the average concentrations detected in April 2011 (64 mg/L). Sulfide concentrations detected in samples collected ranged from 1.2 mg/L to 15 mg/L, with an average of 5.0 mg/L. Sulfide was detected in samples collected from 12 monitoring wells, which is an increase from the one well detected in during April 2011 sampling; however, sulfide concentrations remain below inhibitory concentrations.

Nitrate and Nitrite Evaluation

Nitrate and nitrite were not detected in any samples collected during the biomass growth phase, similar to results from April 2011.

Chloride and Alkalinity Evaluation

Chloride concentrations ranged from 137 mg/L to 670 mg/L, with an average of 428 mg/L, which is similar to the concentration observed in April 2011 (464 mg/L). Alkalinity ranged from 183 mg/L as $CaCO_3$ to 1,150 mg/L as $CaCO_3$ with an average of 497 mg/L as $CaCO_3$, which is the similar to the concentration observed in April 2011 (245 mg/L as $CaCO_3$).

Biomass Growth Groundwater Sampling Dissolved Metals Results

Results for dissolved metals are presented in Table 17. Arsenic was not detected in samples collected during the biomass growth phase, which is consistent with the results from April 2011. Iron concentrations detected (six of 12 wells) in samples collected during the biomass growth phase ranged from 120 µg/L to 3,500 µg/L (IW0002I). Four of the iron detections were greater than the FDEP GCTLs (BW0001F, IW0002D, RW0007 and RW0008) and one iron detection was greater than the FDEP NADC (IW0002I). Manganese concentrations detected (11 of 12 wells) ranged from 17 µg/L to 198 µg/L (IW0002D). Five of the detections were greater than the FDEP GCTL (IW0002I, IW0002D, IW0002D1, RW0007, RW0008). The detection of metal concentrations suggest that metals were mobilized during injection or recirculation activities within the treatment zone.

Biomass Growth Groundwater Sampling Field Geochemical Results

Field geochemical parameters collected during the biomass growth phase are presented in Table 13 and are summarized below.

The pH reported from monitoring wells located within the treatment zone during the biomass growth phase ranged from 6.6 SU to 7.9 SU, with an average of 7.4 SU, similar to April 2011 (7.6 SU). This indicates that the pH in the treatment area remains within the optimum range for reductive dechlorination.

The DO reported from monitoring wells within the treatment zone during the biomass growth phase ranged from 0.23 mg/L to 1.25 mg/L, with an average of 0.64 mg/L, increasing from April 2011 (0.41 mg/L). The ORP observed during the biomass growth phase ranged from negative 275 mV to negative 2.9 mV, with an average of negative 119 mV, increasing slightly from April 2011 (negative 143 mV).

The pH, DO and ORP are all the same order of magnitude as those reported in April 2011 (prior to injection). This was expected, since this data was collected only approximately four weeks after injection activities.

Biomass Growth Soil Sampling Results

CVOC and nBA results for biomass growth phase soil sampling are presented in Table 10 and the results for the TCE and nBA are summarized below.

- DPT0332 – TCE concentration detected in soil samples collected during the biomass growth phase ranged from 0.0098 mg/kg to 70 mg/kg (43.5 ft BLS). nBA concentration detected in collected soil samples ranged from 0.0047 I mg/kg to 38 mg/kg (43.5 ft BLS).

- DPT0333 – TCE concentration detected in soil samples collected during the biomass growth phase ranged from 0.0095 mg/kg to 65 mg/kg (44 ft BLS). nBA concentration detected in collected soil samples ranged from 0.00087 I mg/kg to 24 mg/kg (37 ft BLS).
- DPT0334 – TCE concentration detected in soil samples collected during the biomass growth phase ranged from 0.006 J (estimated value) mg/kg to 31 mg/kg (47 ft BLS). nBA concentration detected in collected soil samples ranged from 0.056 I mg/kg to 7.0 mg/kg (53 ft BLS).

Based on soil samples collected during the biomass growth phase, the highest TCE concentrations were detected in the clay layer (as expected) and the TCE concentrations were higher than those observed in the baseline soil sampling. These results suggest that the CVOC mass distribution is heterogeneous within the clay layer. nBA was observed in all soil samples collected and the highest concentrations were observed in the clay layer, which indicates that the nBA was distributed within the low permeability zone. The CVOC and nBA concentrations detected from samples collected during the biomass growth phase serve as a comparative baseline for later soil sampling events occurring at the same locations.

System Operation Results

Following the biomass growth phase, the recirculation system was restarted on 9 August 2011 and the system operated for approximately twelve months. During system operation, regular groundwater sampling was conducted to monitor effectiveness of the PED. Site wide sampling events took place quarterly during month 3, month 6, month 9, and month 12 of operation. In addition, O&M activities were performed regularly to ensure proper operation of the recirculation system.

System Operation Groundwater Sampling CVOC Results

CVOC results for the system operation phase are presented in Table 12 and are summarized below.

Extraction Well Sampling Results

The recirculation extraction wells were sampled weekly the first month of operation, biweekly from month 2 to month 6 and monthly from month 6 to month 12. A summary of the results is provided below (August 2011 to September 2012).

- Recirculation Extraction Well RW0007
  - TCE concentration ranged from 120 I µg/L to 10,000 µg/L, with an average of 3,188 µg/L;
    - the maximum TCE concentration (10,000 µg/L) was observed in August 2011 and decreased through September 2012 (210 µg/L);
  - cDCE concentration ranged from 2,300 µg/L to 26,000 µg/L, with an average of 12,281 µg/L;
    - the maximum cDCE concentration (26,000 µg/L) was observed in August 2011 and concentrations decreased through September 2012 (2,300 µg/L);

    - VC concentration ranged from 1,400 µg/L to 10,000 µg/L, with an average of 5,305 µg/L; and
        - the maximum VC concentration (10,000 µg/L) was observed in January 2012 and concentrations decreased through September 2012 (2,000 µg/L).

- <u>Recirculation Extraction Well RW0008</u>
    - TCE concentration ranged from 56 µg/L to 2,000 µg/L, with an average of 1,015 µg/L;
        - the maximum TCE concentration (2,000 µg/L) was observed in November 2011 and the concentration decreased through September 2012 (56 µg/L);
    - cDCE concentration ranged from 610 µg/L to 2,300 µg/L, with an average of 1,210 µg/L;
        - the maximum cDCE concentration (2,300 µg/L) was observed in December 2011 and concentrations decreased through September 2012 (750 µg/L);
    - VC concentration ranged from 94 µg/L to 1,100 µg/L, with an average of 633 µg/L; and
        - the maximum VC concentration (1,100 µg/L) was observed in April 2012 and concentrations decreased through September 2012 (710 µg/L).

A decrease in concentrations of CVOCs indicates that reductive dechlorination was occurring and mass was being removed from the treatment area.

Monitoring Well Sampling Results

Monitoring wells were sampled quarterly during the system operations phase and a summary of the data is provided below (October 2011 to September 2012).

- Treatment Zone Monitoring Wells
  - TCE concentration ranged from 0.35 I µg/L to 150,000 µg/L, with an average of 6,746 µg/L;
    - the maximum TCE concentration (150,000 µg/L; BW0001D) was observed in October 2011 and the concentration decreased through September 2012 (43,000 µg/L);
  - cDCE concentration ranged from 0.34 I µg/L to 66,000 µg/L, with an average of 8,823 µg/L;
    - the maximum cDCE concentration (66,000 µg/L; BW0002C) was observed in October 2011 and concentrations decreased through September 2012 (11,000 µg/L);
  - VC concentration ranged from 0.91 I µg/L to 14,000 µg/L, with an average of 2,353 µg/L; and
    - the maximum VC concentration (14,000 µg/L; BW0003C) was observed in February 2012 and concentrations decreased through September 2012 (5,100 µg/L).

- Vertical Extent Monitoring well (IW0076)
  - The TCE concentrations were below the FDEP GCTL in all sampling events;

- cDCE detected concentration ranged from 110 µg/L to 5,000 µg/L, with an average of 1,763 µg/L;
    - the maximum cDCE concentration (5,000 µg/L) was observed in June 2012 and concentrations decreased through September 2012 (non-detect);
- VC concentration ranged from 3.5 I µg/L to 170 µg/L, with an average of 47 µg/L; and
    - the maximum VC concentration (170 µg/L) was observed in June 2012 and concentrations decreased through September 2012 (3.5 I µg/L).

The results suggest that cDCE and VC were pushed below the treatment area during the PED implementation or were mobilized during drilling activities; however, during the last sampling event, only VC was above the GCTL (3.5 I µg/L).

System Operation Groundwater Sampling nBA, TOC, AND VFA Results

nBA and n-butanol results for the system operation phase are presented in Table 12 and TOC and VFA concentrations are presented in Table 14 and are summarized below.

Recirculation Extraction Well Sampling

nBA was detected in samples collected from both recirculation extraction wells during initial sampling of the system operation phase (12 August 2011) with concentrations of 33 mg/L (RW0007) and 8.1 mg/L (RW0008) and n-butanol was detected with concentrations of 230 mg/L (RW0007) and 120 mg/L (RW0008). No nBA was detected in samples collected from RW0007 after 12 August 2011 and no n-butanol was detected after 26 October 2011. No nBA was detected in samples collected from RW0008 after 12 August 2011 and no n-butanol was detected after 18 August 2011.

TOC concentration increased after injection and remained elevated (above baseline concentrations) throughout system operation. TOC concentration detected in samples collected from RW0007 during initial sampling of the system operation phase (12 August 2011) was 191 mg/L, decreasing to 9.6 mg/L (13 September 2012) and TOC concentration in RW0008 decreased from 203 mg/L (12 August 2011) to 27 mg/L (13 September 2012), all the while, remaining above the baseline (April 2011) average (4.0 mg/L).

The only VFAs detected in samples collected from recirculation extraction wells RW0007 and RW0008 were acetic, butanoic, and propionic acids. Acetic acid detected in samples collected from both recirculation extraction wells ranged from 91 µg/L to 380 µg/L, with an average of 203 µg /L, which is similar to the average concentration (310 µg/L) observed during the biomass growth phase (August 2011). Butanoic acid detected in samples collected from both recirculation extraction wells ranged from 4.8 µg/L to 350 µg/L, with an average of 123 µg/L, which is similar to the average concentration (256 µg/L) observed during the biomass growth phase (August 2011). Propionic acid detected in samples collected from both recirculation extraction wells ranged from 1.2 µg/L to 22 µg/L, with an average of 8.7 µg/L, which is similar to the average concentration (9.8 µg/L) observed during the biomass growth phase (August 2011).

Monitoring Well Sampling

nBA and n-butanol concentrations in samples collected from monitoring wells generally remained non-detect after the month 3 sampling event (October 2011), with the exception of samples collected from BW0001D (non-detect after month 6 sampling event [February 2012]) and BW0003E (concentrations detected through month 12 sampling event [September 2012; nBA detected at 30 µg/L]).

TOC concentration detected in samples collected from monitoring wells during the system operation phase ranged from 2.3 mg/L to 760 mg/L, with an average of 63 mg/L, decreasing from the average observed during the biomass growth phase (275 mg/L; August 2011). A majority of the remaining TOC detected during the month 12 sampling event was observed in the monitoring wells with a designation of D, which are screened within the clay layer.

The VFAs detected in samples collected during the system operation phase (VFA data only collected during month 3 and month 6 sampling events) were acetic, butanoic, lactic (only detected once during once during month 3 sampling event at a low concentration [1.1 µg/L; BW0002C]), and propionic acids. Acetic acid concentration detected in samples collected during the system operation phase ranged from 1.6 µg/L to 970 µg/L, with an average of 147 µg/L, decreasing from an average of 310 µg/L observed during the biomass growth phase (August 2011). Butanoic acid concentration detected in samples collected during the system operation phase ranged from 2.7 µg/L to 810 µg/L, with an average of 114 µg/L, decreasing from an average of 256 µg/L, observed during the biomass growth phase (August 2011). Propionic acid concentration detected in samples collected during the system operation phase ranged from 1.5 µg/L to 49 µg/L, with an average of 10 µg/L, which is similar to the concentration observed (9.8 µg/L) during the biomass growth phase (August 2011).

System Operation Groundwater Sampling Tracer Results

Results for tracer concentrations, including bromide and iodide, are presented in Table 16. Bromide concentrations detected in samples collected during the system operation phase (data collected during month 3 and month 6 sampling events) from the monitoring wells and the recovery wells ranged from 1.5 mg/L to 51 mg/L and iodide concentrations ranged from 2.2 mg/L to 89 mg/L. Bromide was detected in samples collected from above, in, and below the semi-confining unit. Iodide, injected above the semi-confining unit only, was detected in one sample collected below the semi-confining unit from monitoring well IW0002D1 at a concentration of 2.2 mg/L during the month 6 (February 2012) event. Because this is the only detection of iodide in the deep zone, it can be concluded that no, or very little, mixing occurred between the shallow and deep zones.

System Operation Groundwater Sampling *Dhc* and *vcrA* Results

Results for *Dhc* and *vcrA* analyses are presented in Table 15 and are summarized for the system operation phase below.

Select samples collected from monitoring wells above and below the clay layer and from the recirculation extraction wells were analyzed for *Dhc* and *vcrA*. *Dhc* concentrations observed in samples collected during the system operation phase ranged from $1x10^6$ gene copies/L to $5x10^8$

gene copies/L, with an average of $9.5x10^7$ gene copies/L, increasing from the average observed during the baseline flux phase (April 2011; $8.5x10^6$ gene copies/L). *vcrA* concentrations observed in samples collected during the system operation phase ranged from $2x10^6$ gene copies/L to $2x10^8$ gene copies/L, with an average of $4.5x10^7$ gene copies/L. This average concentration is higher than the single detection of *vcrA* observed in April 2011 ($5.0x10^3$ gene copies/L). Samples collected from wells screened above the clay layer were observed to generally have higher *Dhc* and *vcrA* concentrations (within 10^8 gene copies/L order of magnitude) as expected since CVOC concentrations were higher above the clay layer.

Operation Groundwater Sampling Geochemical Results

Results for geochemical parameters are presented in Table 13 and summarized below.

Dissolved Gases Evaluation

A summary of the results is provided below.

- Methane concentrations detected in samples collected during the system operation phase ranged from 8.2 µg/L to 2,700 µg/L, with an average of 511 µg/L;
- ethane concentrations detected ranged from 1.1 µg/L to 110 µg/L, with an average of 18 µg/L;
- ethene concentrations detected ranged from 3.1 µg/L to 1,600 µg/L, with an average of 265 µg/L; and

- methane and ethene average concentrations increased from concentrations detected in August 2011, which were 361 µg/L and 67 µg/L, respectively, and ethane average concentration decreased from concentration detected in August 2011 (41 µg/L).

The increase in average concentration of methane indicates that the treatment area remained a suitable environment for the reductive dechlorination of CVOCs during system operation. The increase in ethene concentrations indicates that CVOCs are being completely reduced and the decrease in ethane concentrations suggest that the rate of ethene to ethane reduction has slowed.

<u>Sulfate and Sulfide Evaluation</u>

Sulfate concentrations detected in samples collected during the system operation phase ranged from 2.1 mg/L to 103 mg/L, with an average of 25 mg/L, which is similar to the concentrations detected in August 2011 (23 mg/L). Sulfide concentrations detected in samples collected ranged from 1.1 mg/L to 17 mg/L, with an average of 7.4 mg/L, which is similar to the concentration observed in August 2011 (5.0 mg/L). Sulfide concentrations remained below inhibitory concentrations.

<u>Nitrate and Nitrite Evaluation</u>

Both nitrate and nitrite were not detected in any samples collected during the system operation phase, similar to results from August 2011 (biomass growth phase).

Chloride and Alkalinity Evaluation

Chloride concentrations detected in samples collected during the system operation phase ranged from 51 mg/L to 751 mg/L, with an average of 370 mg/L, which is similar to the average concentration observed in August 2011 (428 mg/L). Alkalinity ranged from 169 mg/L as $CaCO_3$ to 880 mg/L as $CaCO_3$, with an average of 368 mg/L as $CaCO_3$, which is similar to the average concentration observed in August 2011 (497 mg/L as $CaCO_3$).

System Operation Groundwater Sampling Dissolved Metals Results

Results for dissolved metals are presented in Table 17. The results presented in this section are for both the monitoring wells and the recirculation extraction wells. Arsenic was not detected in samples collected during the system operation phase. Iron concentrations detected in samples collected ranged from 120 µg/L to 550 µg/L (IW0002I). Manganese concentrations detected in collected samples ranged from 12 µg/L to 100 µg/L (IW0002I). During the final sampling event (February 2012; dissolved metals not analyzed for after month 6 sampling event) all metal concentrations were below their GCTLs, with the exception of the manganese concentration detected in the samples collected from monitoring wells (IW0002I [69 µg/L], IW0002D [57 µg/L], and BW0001C [57 µg/L]). The results suggest that iron and arsenic were not mobilized during the PED implementation, but that the potential exists for manganese mobilization, which should be considered during future implementation.

System Operation Groundwater Sampling Field Geochemical Results

Field geochemical parameters collected during the system operation phase are presented in Table 13 and summarized below.

The pH reported from monitoring wells located within the treatment zone during the system operation phase ranged from 6.4 SU to 7.9 SU, with an average of 7.3 SU, similar to average pH during August 2011 (7.4 SU). This indicates that the pH within the treatment zone was within the optimum range for reductive dechlorination.

The DO reported from monitoring wells within the treatment zone during the system operation phase ranged from 0.07 mg/L to 1.67 mg/L, with an average of 0.38 mg/L, decreasing from August 2011 (0.64 mg/L). The ORP observed during the system operation phase ranged from negative 538 mV to 72 mV, with an average of negative 248 mV, decreasing from August 2011 (negative 119 mV). The average DO and ORP concentrations observed suggest conditions were favorable for reductive dechlorination for the duration of system operation.

UIC Monitoring Well Sampling Results

nBA was not detected in any samples collected from UIC monitoring wells during all sampling events (February 2011 [baseline], April 2011 [baseline flux], October 2011 [month 3], February 2012 [month 6], and June 2012 [month 9]). Sampling of UIC monitoring wells was discontinued after month 9 sampling event since nBA concentrations were below FDEP GCTLs for at least two consecutive sampling events.

System Operation Soil Sampling Results

CVOC and nBA results for system operation phase soil sampling are presented in Table 10. *Dhc* and *vcrA* results for the month 12 sampling event are presented in Table 20. System operation soil sampling results, which are focused on the parent compound (TCE) and nBA, are summarized below.

- Month 6 (13 February 2012)
    - DPT0346 (same location as DPT0332) – TCE detected in soil samples collected during month 6 of operation ranged from 0.0024 I mg/kg to 8.0 mg/kg (48 ft BLS), decreasing from the maximum detected in August 2011 (70 mg/kg at 43.5 ft BLS). nBA was only detected at a sample depth of 46.5 ft BLS at 0.00087 I mg/kg, decreasing from the maximum detected in August 2011 (38 mg/kg at 43.5 ft BLS).
    - DPT0347 (same location as DPT0333) – TCE detected in soil samples collected during month 6 of operation ranged from 0.0016 I mg/kg to 73 mg/kg (47 ft BLS), increasing slightly and at a deeper depth interval from the maximum detected in August 2011 (65 mg/kg at 44 ft BLS). nBA was only detected at a sample depth of 45.5 ft BLS at 0.0011 I mg/kg, decreasing from the maximum detected in August 2011 (24 mg/kg at 37 ft BLS).
    - DPT0348 (same location as DPT0334) – TCE detected in soil samples collected during month 6 of operation ranged from 0.001 I mg/kg to 75 mg/kg (48.5 ft BLS), increasing and at a slightly deeper sample depth from the maximum detected in August 2011 (31 mg/kg at 47 ft BLS). nBA detected in collected soil

samples ranged from 0.00071 I mg/kg to 0.0025 I (45.4 ft BLS), decreasing from the maximum detected in August 2011 (7.0 mg/kg at 53 ft BLS).

- Month 12 (10 September 2012)
  - DPT0349 (same as location DPT0346) – TCE detected in soil samples collected during month 12 of operation ranged from 0.0018 I mg/kg to 30 mg/kg (46.5 ft BLS), increasing and at a shallower sample depth from the maximum detected in February 2012 (8.0 mg/kg at 48 ft BLS). nBA was not detected in any collected soil samples during month 12 of operation. *Dhc* concentration detected in samples collected during month 12 of operation ranged from 2.0 X 10^3 I gene copies per gram (gene copies/g) to 3.0 x 10^3 I gene copies/g (48 ft BLS), and *vcrA* was not detected in collected samples.
  - DPT0350 (same as location DPT0347) – TCE detected in soil samples collected during month 12 of operation ranged from 0.0049 I mg/kg to 75 mg/kg (45.5 ft BLS), increasing slightly and at a shallower depth interval from the maximum detected in February 2012 (73 mg/kg at 47 ft BLS). nBA was not detected in any collected soil samples during month 12 of operation. *Dhc* detected in samples collected during month 12 of operation ranged from 4.0 X 10^3 I gene copies/g to 1.0 x 10^6 gene copies/g (50 ft BLS), and *vcrA* was only detected at a depth interval of 50 ft BLS at 1.0 x 10^6 gene copies/g.
  - DPT0351 (same as location DPT0348) – TCE detected in soil samples collected during month 12 of operation ranged from 0.01 mg/kg to 6.4 mg/kg (45.5 ft BLS), decreasing and at a shallower sample depth from the maximum detected in February 2012 (75 mg/kg at 48.5 ft BLS). nBA was detected in only one

collected soil sample at 0.00078 I mg/kg at a sample depth of 53 ft BLS. *Dhc* detected in samples collected during month 12 of operation ranged from 3.0 X 10^4 gene copies/g to 7.0 x 10^5 gene copies/g (45.5 ft BLS), and *vcrA* detected in collected samples ranged from 6.0 x 10^4 gene copies/g to 1.0 x 10^6 gene copies/g (45.5 ft BLS).

Recirculation System Operation Summary

The recirculation system operated for approximately twelve months during the system operation phase. O&M activities (Appendix E) are summarized below.

- Average flow rates
  - Approximately 2.5 gpm from recirculation extraction well RW0007, similar to design flow rate of 2.5 gpm;
  - approximately 2.6 gpm from recirculation extraction well RW0008, slightly more than design flow rate of 2.5 gpm; and
  - approximately 0.4 gpm to 0.5 gpm to recirculation injection wells.
- Total groundwater recirculated
  - Approximately 543,000 gallons from recirculation extraction well RW0007; and
  - approximately 505,000 gallons from recirculation extraction well RW0008.
- Operational percentage
  - The system was designed to operate on for 40 minutes, then off for 20 minutes. Therefore, the system was anticipated to operate for 16 hours per day;

- recirculation extraction well RW0007 operated for approximately 53 percent of the time; and
- recirculation extraction well RW0008 operated for approximately 50 percent of the time.

Loss of operational time was due to undersized solar panel recharging network and downed pumps. The pumps reached the end of their useful life most likely due to biofouling/biomass accumulation from reductive dechlorination reactions and/or biofilm build up in the pipe system and the pumps themselves. The pump for recirculation extraction well RW0007 was replaced, under manufacturer's warranty, on 5 January 2012, 15 March 2012, and again on 21 June 2012. The pump for recirculation extraction well RW0008 was replaced on 21 June 2012.

The total volume of groundwater recirculated represents approximately 4.2 pore volumes of the treatment area. Due to the reduced operational time, the initial goal of recirculating at least 6 pore volumes was not achieved; however, treatment area groundwater was still sufficiently mixed and PED injection amendments distributed.

Post System Operation Groundwater Sampling Results

Select site monitoring wells (the well with the highest TCE concentration [BW0001D] and select wells screened above the clay in that cluster [BW0001B and BW0001C]) were sampled six months after the recirculation system was turned off. CVOC and nBA results are presented in Table 12 and MEE results are presented in Table 16. Results are summarized below.

- Monitoring Well BW0001B
  - The TCE concentration (370 I µg/L) was similar to the concentration observed in September 2012 (month 12) (350 I µg/L). cDCE concentration (16,000 µg/L) was the same order of magnitude as the concentration detected in the September 2012 sampling event (19,000 µg/L) and the VC concentration remained the same at 1,100 I µg/L. TCE concentration was reduced by 99 percent since baseline sampling (February 2011).
  - nBA and n-butanol were not detected in samples collected during month 18 sampling event.
  - Methane (63 µg/L), ethane (18 µg/L), and ethene (26 µg/L) concentrations detected in the sample collected during month 18 were relatively stable when compared to MEEs collected during the September 2012 (month 12) sampling event (71 µg/L, 6.3 µg/L, and 31 µg/L, respectively).

- Monitoring Well BW0001C
  - The TCE concentration (400 I µg/L) was similar to concentration observed in September 2012 (month 12) (130 I µg/L). The cDCE concentration (24,000 µg/L) and the VC concentration (1,600 I µg/L) were the same order of magnitude as the concentration observed in the September 2012 sampling event (cDCE = 20,000 µg/L; VC = 1,900 µg/L).
  - nBA and n-butanol were not detected in samples collected during month 18 sampling event.

- Methane (120 µg/L) and ethane (61 µg/L) concentrations remained stable compared to the month 12 sampling event (methane 180 µg/L; ethane 61 µg/L). The ethene concentration (60 µg/L) decreased compared to month 12 sampling event (200 µg/L).

- <u>Monitoring Well BW0001D</u>
  - The TCE concentration (41,000 µg/L) was similar to concentration observed in September 2012 (month 12) (43,000 µg/L). The cDCE concentration (24,000 µg/L) and the VC concentration (1,900 I µg/L) were the same order of magnitude as the concentrations observed in September 2012 (cDCE 12,000 µg/L; VC 990 I µg/L.
  - nBA and n-butanol were not detected in samples collected during month 18 sampling event.
  - Methane (310 µg/L), ethane (98 µg/L), and ethene (98 µg/L) concentrations were similar to those observed during the September 2012 sampling event (160 µg/L, 93 µg/L, and 43 µg/L, respectively).

The absence of nBA and n-butanol and the relatively stable CVOC concentrations suggest that the electron donor within the treatment area has likely been utilized.

Table10: Summary of Soil Sampling Results: Chlorinated Volatile Organic Compounds (NASA 2013)

Location	Sample Date	Sample Depth (ft BLS)	Concentration (mg/kg)				
			Trichloroethene	cis-1,2-Dichloroethene	trans-1,2-Dichloroethene	Vinyl Chloride	n-Butyl Acetate
LC34-SB1001	01/19/2011	24.0	0.02	1.4 L	0.03	0.05	0.05 U
		35.5	3.2	2.0	0.10 U	0.10 U	0.50 U
		41.0	2.6	4.2	0.10 U	0.10 U	0.50 U
		44.5	5.7	1.4	0.10 U	0.10 U	0.50 U
LC34-SB1002	01/19/2011	44.5	0.01 U	0.06	0.01 U	0.01 U	0.05 U
		46.5	0.03	0.55	0.01 U	0.01 U	0.05 U
		49.5	0.01 U	0.02	0.01 U	0.01 U	0.05 U
		55.0	0.01 U	0.01 U	0.01 U	0.01 U	0.05 U
LC34-SB1003	01/19/2011	37.5	3.7	7.0	0.10 U	0.10 U	0.50 U
		43.0	7.3	0.36 I	0.50 U	0.50 U	2.5 U
		44.0	22	0.76	0.50 U	0.50 U	2.5 U
		46.0	6.8	1.1	0.10 U	0.10 U	0.50 U
		49.5	7.2	2.0	0.10 U	0.10 U	0.50 U
LC34-SB1004	01/19/2011	34.5	0.77	2.0	0.10	0.05 I	0.50 U
		37.0	0.50 U	15	0.50 U	0.22 I	2.5 U
		43.0	3.4	0.98	0.10 U	0.10 U	0.50 U
		45.0	5.4	3.8	0.10 U	0.10 U	0.50 U
		46.5	0.35	2.0	0.10 U	0.10 U	0.50 U
		50.0	0.01 U	0.02	0.01 U	0.01 U	0.05 U
LC34-DPT0332	08/03/2011	37.0	15	6.8	0.055 I	0.16 I	8.3
		43.5	70	4.5	0.11 U	0.13 U	38
		45.0	3.4	1.8	0.04 U	0.048 U	7.7
		48.0	1.8	1.5	0.037 U	0.046 U	1.1
		53.0	0.0098	0.0042 I	0.00042 U	0.00052 U	0.0047 I
LC34-DPT0333	08/03/2011	37.0	46	6.5	0.083 I	0.075 U	24
		44.0	65	1.1 I	0.24 U	0.29 U	6.4
		45.5	64	3.3	0.064 I	0.062 U	4.9
		47.0	37	2.0	0.049 U	0.059 U	0.29 I
		48.5	5.7 L	0.73 L	0.0042 I	0.0015 I	0.16
		53.0	0.0095	0.002 I	0.00044 U	0.00054 U	0.00087 I

Location	Sample Date	Sample Depth (ft BLS)	Concentration (mg/kg)				
			Trichloroethene	cis-1,2-Dichloroethene	trans-1,2-Dichloroethene	Vinyl Chloride	n-Butyl Acetate
LC34-DPT0334	08/03/2011	34.5	4.8	2.7	0.05 I	0.033 U	0.490 I
		37.0	6.8	7.1	0.042 I	0.30 I	0.057 I
		45.5	5.7 L	4.0 L	0.078	0.0028 I	1.7 L
		47.0	31	5.7	0.093 I	0.065 U	0.056 I
		48.5	5.3	1.4	0.034 U	0.041 U	0.03 U
		53.0	0.006 J	0.003	0.00032 U	0.00039 U	7.0
LC34-DPT0346	02/13/2012	37.0	0.62 I	6.1	0.099 I	1.7	0.032 U
		40.0	0.42 I	14	0.34 I	0.67 I	0.071 U
		43.5	4.9	6.3	0.053 I	1.6	0.038 U
		45.0	4.3	6.2	0.071 U	1.7	0.0062 U
		46.5	0.0024 I	0.0075	0.00089 I	0.0065	0.00087 I
		48.0	8.0	23	0.13 I	0.11 I	0.043 U
		53.0	0.00063 U	0.00059 I	0.00077 I	0.0098	0.00056 U
		55.0	0.0005 U	0.001 I	0.0006 I	0.0033 I	0.00044 U
LC34-DPT0347	02/13/2012	37.0	4.4	0.84	0.034 U	0.85	0.029 U
		40.0	2.6	0.68	0.030 U	0.69	0.026 U
		45.5	0.17	0.13	0.0023 I	0.022	0.0011 I
		47.0	73	7.5	0.12 U	0.17 I	0.11 U
		50.0	69	3.6 I	0.17 U	0.21 U	0.15 U
		50.5	0.0016 I	0.0017 I	0.00042 U	0.013	0.00049 U
		53.0	0.0016 I	0.0014 I	0.00052 I	0.012	0.00047 U
LC34-DPT0348	02/13/2012	34.5	0.062 I	5.8	0.12 I	0.29 I	0.026 U
		37.0	0.030 I	0.26 I	0.052 I	3.7	0.023 U
		40.0	0.670 I	2.5	0.033 U	0.90	0.028 U
		45.4	0.19	0.031	0.00062 U	0.00091 I	0.0025 I
		45.5	0.16 I	0.56 I	0.056 U	0.59 I	0.067 U
		45.6	3.4 L	1.3 L	0.014	0.39 L	0.0011 I
		47.0	41	23	0.27 I	0.14 U	0.098 U
		48.5	75	27	0.24 I	0.093 U	0.067 U
		53.0	0.001 I	0.0039 I	0.00041 U	0.0032 I	0.00071 I

Location	Sample Date	Sample Depth (ft BLS)	Concentration (mg/kg)				
			Trichloroethene	cis-1,2-Dichloroethene	trans-1,2-Dichloroethene	Vinyl Chloride	n-Butyl Acetate
LC34-DPT0349	09/10/2012	37.0	2.9	7.2	0.16 I	1.7	0.047 U
		40.0	0.11 I	0.67 I	0.057 U	0.73 I	0.035 U
		43.5	1.5	1.2	0.042 U	1.3	0.026 U
		45.0	1.5	3.7	0.074 I	2.1	0.029 U
		46.5	30	11	0.09 U	0.20 I	0.055 U
		47.0	10	14	0.061 I	0.17 I	0.029 U
		48.0	0.59 I	19	0.092 I	0.19 I	0.029 U
		53.0	0.0018 I	0.0025 I	0.0016 I	0.067	0.00091 U
LC34-DPT0350	09/10/2012	37.0	5.0	4.2	0.11 I	2.1	0.026 U
		40.0	1.1	0.73	0.047 U	0.96	0.028 U
		44.0	4.8	3.3	0.07 I	2.2	0.033 U
		45.5	75	2.7	0.17 U	0.14 U	0.11 U
		47.0	48	5.1	0.11 U	0.092 U	0.066 U
		48.5	38	4.7	0.12 U	0.094 U	0.067 U
		53.0	0.0049 I	0.0072	0.00095 U	0.011	0.00091 U
LC34-DPT0351	09/10/2012	34.5	0.021 U	0.85	0.04 U	0.05 I	0.024 U
		37.0	0.01	0.03	0.03	0.65	0.00067 U
		40.0	0.01	0.10	0.043	0.033	0.00085 U
		45.5	6.4	8.9	0.061 I	1.2	0.03 U
		47.0	0.12 I	21	0.094 I	0.61 I	0.049 U
		48.5	0.13 I	17	0.079 I	1.3	0.04 U
		53.0	0.0009 U	0.0015	0.00077 U	0.0027 I	0.00078 I

Notes:

1. ft BLS indicates feet below land surface.
2. mg/kg indicates milligrams per kilogram.
3. U indicates result not detected above method detection limit (MDL).
4. I indicates the result is between the MDL and the practical quantitation limit.
5. J indicates estimated value.
6. L indicates concentration exceeded upper limit of calibration range, estimated value.

Table 11: Summary of Soil Sampling Results: Total Organic Carbon and Fraction Organic Carbon (NASA 2013)

Location	Sample Date	Sample Depth (ft BLS)	Total Organic Carbon (mg/kg)	Fraction Organic Carbon
LC34-SB1002	01/19/2011	28	1,110	0.00111
LC34-SB1002	01/19/2011	34	990	0.00099
LC34-SB1002	01/19/2011	47	2630	0.00263
LC34-SB1002	01/19/2011	53	860	0.00086
LC34-SB1003	01/19/2011	28	1,410	0.00141
LC34-SB1003	01/19/2011	34	440	0.00044
LC34-SB1003	01/19/2011	47	3,070	0.00307
LC34-SB1003	01/19/2011	53	650	0.00065

Notes:

1. ft BLS indicates feet below land surface.
2. mg/kg indicates milligram per kilogram.

Table 12: Summary of Groundwater Sampling Results: Chlorinated Volatile Organic Compounds (NASA 2013)

Location	Sample Date	Screen Interval (ft BLS)	Concentration (µg/L)					
			Trichloroethene	cis-1,2-Dichloroethene	trans-1,2-Dichloroethene	Vinyl Chloride	n-Butyl Acetate	n-Butanol
Groundwater Cleanup Target Level (µg/L)			3	70	100	1	43	700
Natural Attenuation Default Concentration (µg/L)			300	700	1,000	100	430	7,000
LC34-BW0001A	02/01/2011	23 to 26	**300 I**	**31,000**	**640**	**4,700**	30 U	670 U
	04/18/2011		**150 U**	**39,000**	**830 I**	**2,200 I**	**150 U**	**3,400 U**
	08/01/2011		**300 I**	**36,000**	**690 I**	**4,000**	**340 I**	**5,300 U**
	08/01/2011*		**470 I**	**39,000**	**680 I**	**5,200**	**670 I**	**49,000 I**
	10/25/2011		**130 I**	**45,000**	**1,100 I**	**2,400**	53 U	**2,700 U**
	02/16/2012		**120 U**	**11,000**	**290 I**	**840 I**	**110 U**	**5,300 U**
	06/26/2012		**120 U**	**6,200**	**220 I**	**770 I**	**110 U**	**5,300 U**
	09/13/2012		**500 U**	**1,700**	60 I	**200 I**	39 U	**1,800 U**
LC34-BW0001B	02/01/2011	30 to 33	**27,000**	**6,600**	**150 I**	**160 I**	60 U	1,400 U
	04/18/2011		**14,000**	**28,000**	**470 I**	**1,800 I**	**300 U**	**6,700 U**
	08/01/2011		**19,000**	**14,000**	**270 I**	**600 I**	**1,000 I**	**11,000 U**
	10/25/2011		**3,200**	**12,000**	**260 I**	**1,100 I**	**56,000**	**1,400,000**
	02/16/2012		**1,400 I**	**38,000**	**920 I**	**2,200 I**	**210 U**	**11,000 U**
	06/26/2012		**720 I**	**28,000**	**750 I**	**1,500 I**	**210 U**	**11,000 U**
	09/13/2012		**350 I**	**19,000**	**510 I**	**1,100 I**	**98 U**	**4,400 U**
	03/19/2013		**370 I**	**16,000**	**480 I**	**1,100 I**	**390 U**	**18,000 U**
LC34-BW0001C	02/01/2011	37 to 40	**53,000**	**47,000**	**280 I**	**150 U**	**150 U**	**3,400 U**
	03/22/2011		**48,000**	**28,000**	**240 I**	**420 I**	75 U	**1,700 U**
	03/29/2011		**48,000**	**26,000**	**290 I**	**380 I**	60 U	1,400 U
	04/07/2011		**54,000**	**29,000**	**280 I**	**570 I**	75 U	**1,700 U**
	04/18/2011		**45,000**	**25,000**	**260 I**	**630 I**	**150 U**	**3,400 U**
	07/07/2011		**52,000**	**21,000**	**270 I**	**510 I**	**420,000**	**320,000**
	08/01/2011		**27,000**	**31,000**	**210 I**	**480 I**	**95,000**	**280,000**
	10/25/2011		**12,000**	**22,000**	**270 I**	**1,300 I**	**110 U**	**200,000**
	02/16/2012		**1,400**	**26,000**	**390 I**	**3,700**	53 U	**2,700 U**
	06/26/2012		**370 I**	**22,000**	**460 I**	**3,800**	53 U	**2,700 U**
	09/13/2012		**130 I**	**20,000**	**420 I**	**1,900**	**98 U**	**4,400 U**
	03/19/2013		**400 I**	**24,000**	**630 I**	**1,600 I**	**200 U**	**8,700 U**

Location	Sample Date	Screen Interval (ft BLS)	Concentration (µg/L)					
			Trichloroethene	cis-1,2-Dichloroethene	trans-1,2-Dichloroethene	Vinyl Chloride	n-Butyl Acetate	n-Butanol
Groundwater Cleanup Target Level (µg/L)			3	70	100	1	43	700
Natural Attenuation Default Concentration (µg/L)			300	700	1,000	100	430	7,000
LC34-BW0001D	02/01/2011	44 to 47	**150,000**	**5,200**	150 U	**150 U**	**150 U**	**3,400 U**
	04/18/2011		**180,000**	**6,100**	**300 U**	**300 U**	**300 U**	**6,700 U**
	07/07/2011		**170,000**	**5,600**	200 U	**230 U**	**60,000**	**23,000 I**
	08/01/2011		**120,000**	**4,300 I**	200 U	**230 U**	**71,000**	**15,000 I**
	08/01/2011*		**170,000**	**5,900**	200 U	**230 U**	**84,000**	**22,000 I**
	10/25/2011		**150,000**	**3,000 I**	200 U	**230 U**	**270,000**	**310,000**
	02/16/2012		**110,000**	**5,100**	200 U	**230 U**	**210 U**	**36,000 I**
	06/26/2012		**64,000**	**7,400**	200 U	**990 I**	**210 U**	**11,000 U**
	09/13/2012		**43,000**	**12,000**	170 U	**990 I**	**200 U**	**8,700 U**
	03/19/2013		**41,000**	**24,000**	170 U	**1,900 I**	**200 U**	**8,700 U**
LC34-BW0001E	02/01/2011	51 to 54	**1,600**	**220**	3.0 U	**3.0 U**	3.0 U	67 U
	03/22/2011		**590**	**79**	1.5 U	1.5 U	1.5 U	34 U
	03/29/2011		**400**	**71**	0.75 U	0.83 I	0.75 U	17 U
	04/07/2011		**380**	60	0.75 U	0.75 U	0.75 U	17 U
	04/18/2011		**490**	**74**	0.60 U	0.86 I	0.60 U	14 U
	07/07/2011		**330**	**1,500**	11 I	**4.7 U**	**3,500**	**1,500 I**
	08/01/2011		**32 I**	**1,400**	8.9 I	**23 I**	4.6 I	**730 I**
	10/25/2011		**230**	**470**	3.6 I	**110**	1.1 U	53 U
	02/16/2012		1.2 I	2.5 I	1.0 I	**27**	0.21 U	11 U
	06/26/2012		0.50 I	59	12	**600**	0.21 U	11 U
	09/13/2012		2.4 I	13	2.5 I	**23**	0.98 U	44 U
LC34-BW0001F	02/01/2011	58 to 61	**3.5 I**	0.79 I	0.30 U	0.30 U	0.30 U	6.7 U
	04/18/2011		1.1 I	0.41 I	0.30 U	0.30 U	0.30 U	6.7 U
	08/01/2011		**1,200 U**	**1,000 U**	**1,000 U**	**1,200 U**	**900,000**	**620,000 I**
	10/25/2011		1.1 I	0.34 I	0.20 U	0.23 U	0.21 U	150 I
	02/16/2012		**5.1**	53	0.20 U	**81**	0.21 U	11 U
	06/26/2012		1.2 I	0.99 I	0.20 U	**13**	0.21 U	11 U
	09/13/2012		1.4 I	0.50 I	0.33 U	**3.8 I**	0.40 I	18 U
LC34-BW0002A	02/01/2011	23 to 26	**530 I**	**36,000**	**690 I**	**110 I**	60 U	1,400 U
	04/19/2011		**140 I**	**41,000**	**820 I**	**1,900**	75 U	**1,700 U**
	04/19/2011*		**140 I**	**38,000**	**790 I**	**1,800**	75 U	**1,700 U**
	08/02/2011		**300 I**	**32,000**	**610 I**	**820 I**	**150 I**	**11,000 I**
	10/26/2011		**31 I**	**13,000**	**330 I**	**850**	21 U	1,100 U
	02/15/2012		**51 I**	**46,000**	**380 I**	**7,800**	21 U	1,100 U
	06/26/2012		**4.7 I**	**260**	34	**410**	0.53 U	27 U
	09/11/2012		**5.6**	49	13	**130**	0.39 U	18 U

Location	Sample Date	Screen Interval (ft BLS)	Concentration (µg/L)					
			Trichloroethene	cis-1,2-Dichloroethene	trans-1,2-Dichloroethene	Vinyl Chloride	n-Butyl Acetate	n-Butanol
Groundwater Cleanup Target Level (µg/L)			3	70	100	1	43	700
Natural Attenuation Default Concentration (µg/L)			300	700	1,000	100	430	7,000
LC34-BW0002B	02/01/2011	30 to 33	**17,000**	**44,000**	**390 I**	**230 I**	75 U	**1,700 U**
	04/19/2011		**1,100 I**	**48,000**	**850 I**	**750 I**	75 U	**1,700 U**
	08/02/2011		**2,500**	**42,000**	**580 I**	**470 I**	**130 I**	**2,700 U**
	10/26/2011		**320 I**	**36,000**	**720 I**	**1,300**	53 U	**2,700 U**
	02/15/2012		**41 I**	**4,900**	**170**	**1,800**	5.3 U	270 U
	06/26/2012		**16 I**	**1,100**	67	**820**	2.1 U	110 U
	09/11/2012		**9.8 I**	**170**	23	**330**	0.98 U	44 U
LC34-BW0002C	02/01/2011	37 to 40	**620 I**	**87,000**	**510 I**	**700 I**	75 U	**1,700 U**
	03/22/2011		**2,900**	**66,000**	**430 I**	**2,500**	75 U	**1,700 U**
	03/29/2011		**5,300**	**75,000**	**460 I**	**2,300 I**	**150 U**	**3,400 U**
	04/07/2011		**3,000**	**79,000**	**450 I**	**2,300 I**	**150 U**	**3,400 U**
	04/19/2011		**1,800 I**	**74,000**	**490 I**	**2,100 I**	**150 U**	**3,400 U**
	07/07/2011		**2,000 I**	**51,000**	**360 I**	**2,200 I**	**490,000**	**120,000 I**
	08/02/2011		**380 I**	**43,000**	**280 I**	**6,100**	**42,000**	**210,000**
	10/26/2011		**530 I**	**66,000**	**320 I**	**3,800**	53 U	**2,700 U**
	02/14/2012		2.1 I	**580**	54	**620**	1.1 U	53 U
	06/26/2012		**5.7 I**	**30,000**	**250**	**13,000**	1.1 U	53 U
	09/11/2012		**22 U**	**11,000**	**280 I**	**11,000**	39 U	**1,800 U**
LC34-BW0002D	02/01/2011	44 to 47	**39 I**	**4,200**	29 I	**52 I**	7.5 U	170 U
	04/19/2011		**38 I**	**7,500**	49 I	**410**	7.5 U	170 U
	04/19/2011*		**44 I**	**7,900**	49 I	**360**	7.5 U	170 U
	07/07/2011		**41 I**	**8,000**	58 I	**1,300**	**49 I**	530 U
	08/02/2011		**43 I**	**8,800**	59 I	**1,500**	**86 I**	530 U
	08/02/2011 *		**41 I**	**8,100**	63 I	**1,100**	**81 I**	**4,300 I**
	10/26/2011		**29 I**	**16,000**	**110 I**	**3,900**	11 U	530 U
	02/14/2012		**29 I**	**13,000**	**120 I**	**6,500**	21 U	1,100 U
	06/26/2012		**23 U**	**5,100**	**110 I**	**12,000**	21 U	1,100 U
	09/11/2012		**11 U**	40 I	79 I	**9,100**	20 U	870 U
LC34-BW0002E	02/01/2011	51 to 54	0.78 I	9.3	0.30 U	0.30 U	0.30 U	6.7 U
	04/19/2011		0.64 I	19	0.30 U	**2.0 I**	0.30 U	6.7 U
	07/07/2011		4.7 U	62 I	4.0 U	**4.7 U**	**3,300**	**2,000 I**
	08/02/2011		1.3 I	51	0.29 I	**3.4 I**	43	150 I
	10/26/2011		0.35 I	15	0.64 I	**69**	0.21 U	11 U
	02/14/2012		0.23 U	2.3 I	0.62 I	**22**	0.21 U	11 U
	06/26/2012		0.23 U	0.71 I	0.75 I	**15**	0.21 U	11 U
	09/11/2012		2.6 I	8.1	1.2 I	**23**	0.39 U	18 U

Location	Sample Date	Screen Interval (ft BLS)	Concentration (µg/L)					
			Trichloroethene	cis-1,2-Dichloroethene	trans-1,2-Dichloroethene	Vinyl Chloride	n-Butyl Acetate	n-Butanol
Groundwater Cleanup Target Level (µg/L)			3	70	100	1	43	700
Natural Attenuation Default Concentration (µg/L)			300	700	1,000	100	430	7,000
LC34-BW0002F	02/01/2011	58 to 61	**10 I**	**880**	5.0 I	**28**	1.5 U	34 U
	04/19/2011		**4.7 I**	**80**	2.1 I	**67**	0.30 U	6.7 U
	04/19/2011*		**5.3**	**58**	1.4 I	**38**	0.30 U	6.7 U
	08/02/2011		**5.1**	**150**	4.6 I	**440**	0.41 I	11 U
	08/02/2011*		**2.1 I**	**100**	2.7 I	**370**	0.53 U	27 U
	10/26/2011		0.50 I	8.2	0.63 I	**35**	0.21 U	11 U
	02/14/2012		0.23 U	0.84 I	0.40 I	**6.3**	0.21 U	11 U
	06/26/2012		0.23 U	1.6 I	4.6 I	**160**	0.21 U	11 U
	09/11/2012		**6.4**	40	5.1	**130**	0.39 U	18 U
LC34-BW0003A	02/01/2011	23 to 26	**60 U**	**37,000**	60 U	**13,000**	60 U	1,400 U
	04/19/2011		**60 U**	**45,000**	**970 I**	**5,700**	60 U	1,400 U
	08/02/2011		**58 U**	**33,000**	**760 I**	**12,000**	53 U	**2,700 U**
	10/26/2011		**58 U**	**30,000**	**790 I**	**2,100**	53 U	**2,700 U**
	02/15/2012		**12 U**	**6,800**	**220 I**	**1,100**	11 U	530 U
	06/27/2012		**12 U**	**5,200**	**220 I**	**560**	11 U	530 U
	09/11/2012		2.4 I	**1,600**	55	**210**	4.0 U	180 U
LC34-BW0003B	02/01/2011	30 to 33	**30 U**	**16,000**	30 U	**5,300**	30 U	670 U
	04/19/2011		**30 U**	**46,000**	**600**	**5,500**	30 U	670 U
	04/19/2011 *		**30 U**	**52,000**	**1,000**	**9,500**	30 U	670 U
	08/02/2011		**23 U**	**6,700**	**310 I**	**14,000**	**88 I**	1,100 U
	10/27/2011		**120 U**	**48,000**	**1,300 I**	**6,900**	**110 U**	**5,300 U**
	02/15/2012		**12 U**	**8,600**	**360**	**1,900**	11 U	530 U
	06/27/2012		**12 U**	**6,600**	**270**	**1,000**	11 U	530 U
	09/11/2012		4.4 U	**2,100**	82 I	**350**	7.9 U	350 U
LC34-BW0003C	02/02/2011	37 to 40	**140 I**	**36,000**	**240 I**	**2,900**	30 U	670 U
	03/22/2011		**65 I**	**12,000**	**110 I**	**3,200**	30 U	670 U
	03/29/2011		**36 I**	**12,000**	**160 I**	**3,500**	30 U	670 U
	04/07/2011		**32 I**	**9,800**	**150 I**	**4,700**	15 U	340 U
	04/19/2011		**15 U**	**6,000**	**120 I**	**4,500**	15 U	340 U
	07/07/2011		**230 U**	**4,300 I**	200 U	**2,400 I**	**640,000**	**360,000**
	08/02/2011		**21 I**	**2,500**	67 I	**3,100**	**290**	**190,000**
	10/27/2011		**12 U**	**1,800**	**180 I**	**9,400**	11 U	530 U
	02/15/2012		**12 U**	**16,000**	**600**	**14,000**	11 U	530 U
	06/27/2012		**23 U**	**22,000**	**840**	**8,600**	21 U	1,100 U
	09/13/2012		**22 U**	**17,000**	**560**	**5,100**	39 U	**1,800 U**

Location	Sample Date	Screen Interval (ft BLS)	Concentration (µg/L)					
			Trichloroethene	cis-1,2-Dichloroethene	trans-1,2-Dichloroethene	Vinyl Chloride	n-Butyl Acetate	n-Butanol
Groundwater Cleanup Target Level (µg/L)			3	70	100	1	43	700
Natural Attenuation Default Concentration (µg/L)			300	700	1,000	100	430	7,000
LC34-BW0003D	02/02/2011	44 to 47	**7,800**	**17,000**	79 I	**410 I**	30 U	670 U
	04/19/2011		**650**	**6,800**	33 I	**400**	15 U	340 U
	04/19/2011 *		**500**	**5,700**	27 I	**340**	15 U	340 U
	07/07/2011		**1,300 I**	**7,700**	200 U	**400 I**	**830,000**	**350,000**
	08/02/2011		**1,100 I**	**7,500**	200 U	**740 I**	**170,000**	**510,000**
	10/26/2011		**96 I**	**3,500**	27 I	**1,900**	6.5 I	270 U
	02/15/2012		**28 I**	**3,200**	51 I	**2,900**	5.3 U	270 U
	06/27/2012		5.8 U	**360**	65 I	**4,000**	5.3 U	270 U
	09/13/2012		4.4 U	**86 I**	61 I	**2,600**	7.9 U	350 U
LC34-BW0003E	02/01/2011	51 to 54	0.30 U	23	0.30 U	0.30 U	0.30 U	6.7 U
	03/22/2011		0.30 U	0.62 I	0.30 U	0.30 U	0.30 U	6.7 U
	03/22/2011*		0.30 U	1.5 I	0.3 U	0.3 U	0.30 U	6.7 U
	03/29/2011		0.43 I	1.2 I	0.30 U	0.30 U	0.30 U	6.7 U
	04/07/2011		0.30 U	0.56 I	0.30 U	0.30 U	0.30 U	6.7 U
	04/19/2011		0.30 U	0.72 I	0.30 U	0.30 U	0.30 U	6.7 U
	07/07/2011		**980 I**	**1,300 I**	200 U	**230 U**	**1,500,000**	**520,000**
	08/02/2011		**13,000 U**	**1,700 I**	**500 U**	**580 U**	**420,000**	**890,000**
	10/27/2011		2.9 I	20	0.41 I	**110**	0.40 I	70 I
	02/15/2012		0.48 I	40	1.7 I	**61**	7.4	11 U
	06/27/2012		0.23 U	4.2 I	4.8 I	**66**	27	11 U
	09/13/2012		3.1 I	58	9.4 I	**270**	30	44 U
LC34-BW0003F	02/01/2011	58 to 61	0.30 U	0.30 U	0.30 U	0.30 U	0.30 U	6.7 U
	04/19/2011		0.30 U	0.94 I	0.30 U	0.39 I	0.30 U	6.7 U
	08/02/2011		2.7 I	13 I	0.50 U	1.3 I	**93**	**18,000**
	10/27/2011		0.50 I	**210**	1.1 I	**190**	0.21 U	11 U
	02/15/2012		0.23 U	0.81 I	4.3 I	**190**	0.21 U	11 U
	06/27/2012		**26**	15	0.43 I	0.91 I	0.21 U	11 U
	09/13/2012		0.82 I	3.6 I	2.7 I	**90**	0.39 U	18 U

Location	Sample Date	Screen Interval (ft BLS)	Concentration (µg/L)					
			Trichloroethene	cis-1,2-Dichloroethene	trans-1,2-Dichloroethene	Vinyl Chloride	n-Butyl Acetate	n-Butanol
Groundwater Cleanup Target Level (µg/L)			3	70	100	1	43	700
Natural Attenuation Default Concentration (µg/L)			300	700	1,000	100	430	7,000
LC34-IW0002I	02/03/2011	25 to 30	**370 I**	**27,000**	**510**	**630**	30 U	670 U
	03/22/2011		**200 I**	**27,000**	**550 I**	**1,100 I**	**150 U**	**3,400 U**
	03/29/2011		**110 I**	**23,000**	**500**	**980**	15 U	340 U
	04/07/2011		**150 U**	**23,000**	**510 I**	**1,100 I**	**150 U**	**3,400 U**
	04/18/2011		**180 I**	**21,000**	**430 I**	**1,000 I**	**150 U**	**3,400 U**
	08/01/2011		**280 I**	**13,000**	**220 I**	**270 I**	**11,000**	**630,000**
	08/01/2011 *		**310 I**	**14,000**	**260 I**	**370 I**	**33,000**	**590,000**
	10/26/2011		**57 I**	**15,000**	**320 I**	**930**	21 U	1,100 U
	02/15/2012		**46 U**	**3,500**	**140 I**	**300 I**	42 U	**2,100 U**
	06/26/2012		**46 U**	**970 I**	40 I	**110 I**	42 U	**2,100 U**
	09/13/2012		5.5 I	**500**	17 I	**43**	2.0 U	87 U
LC34-IW0002D	02/02/2011	35 to 40	**17,000**	**57,000**	**390 I**	**170 I**	30 U	670 U
	03/22/2011		**3,100**	**25,000**	**260 I**	**1,300 I**	75 U	**1,700 U**
	03/28/2011		**1,600**	**28,000**	**320 I**	**1,900**	60 U	1,400 U
	04/07/2011		**1,100 I**	**28,000**	**360 I**	**2,800**	75 U	**1,700 U**
	04/18/2011		**490 I**	**26,000**	**370 I**	**3,500**	75 U	**1,700 U**
	08/01/2011		**74 I**	**22,000**	**170 I**	**2,200**	**110 I**	**200,000**
	10/26/2011		**73 I**	**16,000**	**290 I**	**4,000**	21 U	**2,700 I**
	02/16/2012		**26 I**	**4,700**	**300**	**9,400**	11 U	530 U
	06/26/2012		**12 I**	**3,400**	**190**	**3,800**	5.3 U	270 U
	09/13/2012		5.6 I	**1,300**	**110**	**2,400**	7.9 U	350 U
LC34-IW0002D1	02/02/2011	50 to 55	**760**	**1,200**	6.3 I	**6.4 I**	3.0 U	67 U
	03/22/2011		**260**	**380**	2.5 I	**3.3 I**	0.75 U	17 U
	03/28/2011		**75**	**350**	3.0 I	**1.9 I**	0.75 U	17 U
	04/07/2011		**59**	**770**	5.7 I	**3.5 I**	0.75 U	17 U
	04/18/2011		**7.7**	24	0.30 U	0.98 I	0.30 U	6.7 U
	08/01/2011		**1,300**	**7,500**	81	**1,900**	31	**2,600**
	10/26/2011		0.81 I	4.3 I	1.5 I	**60**	0.36 I	11 U
	02/16/2012		4.1 I	**250**	35	**2,000**	0.21 U	11 U
	06/26/2012		4.7 U	9.8 I	58 I	**2,000**	4.2 U	210 U
	09/13/2012		4.4 U	48 I	57 I	**2,000**	7.9 U	350 U
LC34-IW0067D	02/02/2011	38 to 43	0.30 U	0.30 U	0.30 U	0.30 U	0.30 U	6.7 U
	04/18/2011		0.30 U	0.30 U	0.30 U	1.1 I	0.30 U	6.7 U
	10/25/2011		0.23 U	0.74 I	0.20 U	**7.4**	0.21 U	11 U
	02/14/2012		0.23 U	0.68 I	0.20 U	**8.4**	0.21 U	11 U
	06/26/2012		0.23 U	1.2 I	0.20 U	**18**	0.21 U	11 U

Location	Sample Date	Screen Interval (ft BLS)	Concentration (µg/L)					
			Trichloroethene	cis-1,2-Dichloroethene	trans-1,2-Dichloroethene	Vinyl Chloride	n-Butyl Acetate	n-Butanol
Groundwater Cleanup Target Level (µg/L)			3	70	100	1	43	700
Natural Attenuation Default Concentration (µg/L)			300	700	1,000	100	430	7,000
LC34-IW0067D1	02/03/2011	63 to 73	0.30 U	0.88 I	0.30 U	0.30 U	0.30 U	6.7 U
	04/18/2011		0.30 U	0.30 U	0.30 U	0.30 U	0.30 U	6.7 U
	10/25/2011		0.23 U	0.20 U	0.20 U	0.23 U	0.21 U	11 U
	02/14/2012		0.23 U	0.20 U	0.20 U	0.23 U	0.21 U	11 U
	06/26/2012		0.23 U	0.20 U	0.20 U	0.23 U	0.21 U	11 U
LC34-IW0070D	02/02/2011	38 to 43	0.30 U	0.30 U	0.30 U	0.3 U	0.3 U	6.7 U
	04/18/2011		0.30 U	0.30 U	0.30 U	0.30 U	0.30 U	6.7 U
	10/25/2011		0.23 U	0.20 U	0.20 U	0.23 U	0.21 U	11 U
	02/15/2012		0.23 U	0.20 U	0.20 U	0.23 U	0.21 U	11 U
	06/26/2012		0.23 U	0.20 U	0.20 U	0.23 U	0.21 U	11 U
LC34-IW0070D1	02/02/2011	65 to 75	0.30 U	0.30 U	0.30 U	0.30 U	0.30 U	6.7 U
	04/18/2011		0.30 U	0.30 U	0.30 U	0.30 U	0.30 U	6.7 U
	10/25/2011		0.23 U	0.20 U	0.20 U	0.23 U	0.21 U	11 U
	02/15/2012		0.23 U	0.20 U	0.20 U	0.23 U	0.21 U	11 U
	06/26/2012		0.23 U	0.20 U	0.20 U	0.23 U	0.21 U	11 U
LC34-IW0071D	02/02/2011	38 to 43	0.30 U	0.30 U	0.30 U	0.30 U	0.30 U	6.7 U
	04/18/2011		0.30 U	0.30 U	0.30 U	0.30 U	0.30 U	6.7 U
	10/25/2011		0.23 U	0.20 U	0.20 U	0.23 U	0.21 U	11 U
	02/15/2012		0.23 U	0.20 U	0.20 U	0.23 U	0.21 U	11 U
	06/26/2012		0.23 U	0.20 U	0.20 U	0.23 U	0.21 U	11 U
LC34-IW0071D1	02/02/2011	65 to 75	0.30 U	0.30 U	0.30 U	0.30 U	0.30 U	6.7 U
	04/18/2011		0.30 U	0.30 U	0.30 U	0.30 U	0.30 U	6.7 U
	10/25/2011		0.23 U	0.20 U	0.20 U	0.23 U	0.21 U	11 U
	02/14/2012		0.23 U	0.20 U	0.20 U	0.23 U	0.21 U	11 U
	06/26/2012		0.23 U	0.20 U	0.20 U	0.23 U	0.21 U	11 U
LC34-IW0076	02/02/2011	70 to 80	0.30 U	0.40 I	0.30 U	0.30 U	0.30 U	6.7 U
	04/18/2011		0.30 U	0.30 U	0.30 U	0.30 U	0.30 U	6.7 U
	08/01/2011		0.46 U	4.0 I	0.40 U	0.46 U	**550**	200 I
	10/25/2011		0.27 I	**110**	4.0 I	**5.0**	0.21 U	90 I
	02/15/2012		0.75 I	**180**	8.1	**8.4**	0.21 U	11 U
	06/26/2012		2.7 I	**5,000**	81	**170**	0.21 U	**960**
	09/13/2012		0.49 I	5.0 U	3.9 I	**3.5 I**	0.39 U	18 U

Location	Sample Date	Screen Interval (ft BLS)	Concentration (µg/L)					
			Trichloroethene	cis-1,2-Dichloroethene	trans-1,2-Dichloroethene	Vinyl Chloride	n-Butyl Acetate	n-Butanol
Groundwater Cleanup Target Level (µg/L)			3	70	100	1	43	700
Natural Attenuation Default Concentration (µg/L)			300	700	1,000	100	430	7,000
	02/02/2011		**54,000**	**50,000**	**300 I**	**60 U**	60 U	1,400 U
	03/22/2011		**14,000**	**27,000**	**210 I**	**610 I**	75 U	**1,700 U**
	03/28/2011		**17,000**	**31,000**	**200 I**	**740 I**	60 U	1,400 U
	03/28/2011*		**16,000**	**32,000**	**200 I**	**810 I**	60 U	1,400 U
	04/07/2011		**14,000**	**33,000**	**290 I**	**1,000 I**	75 U	**1,700 U**
	04/19/2011		**12,000**	**25,000**	**170 I**	**990 I**	75 U	**1,700 U**
	04/19/2011 *		**12,000**	**23,000**	**160 I**	**900 I**	60 U	1,400 U
	07/07/2011		**21,000**	**20,000**	**150 I**	**690 I**	**410,000**	**140,000**
	08/01/2011		**2,400**	**31,000**	**130 I**	**770 I**	53 U	**180,000**
	08/01/2011 *		**3,300**	**36,000**	**130 I**	**850 I**	**130 I**	**230,000**
	08/12/2011		**3,300**	**26,000**	50 U	**58 U**	**33,000**	**230,000**
	08/18/2011		**7,100**	**23,000**	50 U	**1,400**	53 U	**130,000**
	08/24/2011		**10,000**	**21,000**	**130 I**	**1,700**	42 U	**26,000 I**
	08/31/2011		**10,000**	**20,000**	**150 I**	**2,000**	21 U	**29,000**
	09/15/2011		**8,400**	**19,000**	**150 I**	**3,100**	21 U	1,100 U
LC34-RW0007	09/28/2011	35 to 42	**5,700**	**15,000**	**140 I**	**3,700**	21 U	**2,700 I**
	10/13/2011		**4,300**	**15,000**	**190 I**	**4,300**	21 U	**2,900 I**
	10/26/2011		**3,900**	**16,000**	**170 I**	**4,800**	21 U	**1,800 I**
	11/10/2011		**3,500**	**16,000**	**200 I**	**6,400**	21 U	1,100 U
	11/22/2011		**3,200**	**14,000**	**160 I**	**4,900**	21 U	1,100 U
	12/15/2011		**1,500**	**11,000**	**180 I**	**6,000**	21 U	1,100 U
	01/05/2012		**160 I**	**4,500**	**200 I**	**6,200**	11 U	530 U
	01/26/2012		**1,700**	**15,000**	**250 I**	**10,000**	0.21 U	11 U
	02/14/2012		**560**	**8,900**	**250 I**	**6,400**	11 U	530 U
	02/14/2012 *		**1,100**	**9,100**	**210 I**	**7,600**	11 U	530 U
	03/15/2012		**120 I**	**3,600**	**160**	**3,000**	5.3 U	270 U
	04/19/2012		**650**	**7,200**	**200**	**8,100**	5.3 U	270 U
	05/17/2012		**520**	**6,000**	**190 I**	**8,700**	11 U	530 U
	06/26/2012		**820**	**5,500**	**250**	**8,100**	11 U	530 U
	07/19/2012		**640**	**4,600**	**260 I**	**7,900**	21 U	1,100 U
	08/16/2012		**660**	**4,300**	**190 I**	**7,400**	20 U	870 U
	09/13/2012		**210**	**2,300**	100	**2,000**	7.9 U	350 U

Location	Sample Date	Screen Interval (ft BLS)	Concentration (µg/L)					
			Trichloroethene	cis-1,2-Dichloroethene	trans-1,2-Dichloroethene	Vinyl Chloride	n-Butyl Acetate	n-Butanol
Groundwater Cleanup Target Level (µg/L)			3	70	100	1	43	700
Natural Attenuation Default Concentration (µg/L)			300	700	1,000	100	430	7,000
LC34-RW0008	02/02/2011	47 to 57	**4,900**	**3,300**	20 I	**18 I**	7.5 U	170 U
	03/22/2011		**1,300**	**450**	3.0 I	**34 I**	3.0 U	67 U
	03/28/2011		**840**	**280**	1.9 I	**14 I**	1.5 U	34 U
	04/07/2011		**790**	**360**	1.9 I	**13 I**	1.5 U	34 U
	04/19/2011		**1,000**	**510**	3.0 I	**24 I**	3.0 U	67 U
	04/19/2011 *		**1,100**	**500**	3.3 I	**23 I**	3.0 U	67 U
	07/07/2011		**1,100**	**4,000**	40 U	**140 I**	**81,000**	**8,700 I**
	08/01/2011		**3.5 I**	55	19	**2,600**	4.0 I	63 B,J
	08/01/2011*		**3.2 I**	47	17	**2,900**	4.3 I	220 I
	08/12/2011		**1,900**	**1,700**	4.0 U	**4.7** U	**8,100**	**120,000**
	08/18/2011		**1,700**	**890**	2.0 U	**94**	2.1 U	**9,300**
	08/24/2011		**1,500**	**830**	3.9 I	**160**	2.1 U	110 U
	08/31/2011		**940**	**610**	3.2 I	**150**	1.1 U	53 U
	09/15/2011		**970**	**860**	5.4 I	**310**	1.1 U	53 U
	09/28/2011		**1,100**	**1,100**	7.6 I	**410**	1.1 U	53 U
	10/13/2011		**1,300**	**1,300**	10 I	**610**	2.1 U	110 U
	10/26/2011		**1,900**	**1,700**	12 I	**630**	2.1 U	110 U
	11/10/2011		**2,000**	**2,000**	14 I	**640**	2.1 U	110 U
	11/22/2011		**1,100**	**1,600**	12 I	**580**	2.1 U	110 U
	12/15/2011		**1,500**	**2,300**	17 I	**820**	4.2 U	210 U
	01/05/2012		**1,100**	**1,400**	12 I	**560**	2.1 U	110 U
	01/26/2012		**940**	**1,700**	22 I	**1,000**	2.1 U	110 U
	02/14/2012		**570**	**1,100**	14 I	**670**	2.1 U	110 U
	03/15/2012		**620**	**1,100**	17 I	**900**	2.1 U	110 U
	04/19/2012		**290**	**870**	17 I	**1,100**	2.1 U	110 U
	05/17/2012		**300**	**1,300**	18 I	**870**	2.1 U	110 U
	06/26/2012		**620**	**970**	21 I	**990**	1.1 U	53 U
	07/19/2012		**450**	**640**	23 I	**870**	1.1 U	53 U
	08/16/2012		**460**	**700**	13 I	**600**	2.0 U	87 U
	09/13/2012		**56**	**750**	14 I	**710**	2.0 U	87 U

Location	Sample Date	Screen Interval (ft BLS)	Concentration (µg/L)					
			Trichloroethene	cis-1,2-Dichloroethene	trans-1,2-Dichloroethene	Vinyl Chloride	n-Butyl Acetate	n-Butanol
Groundwater Cleanup Target Level (µg/L)			3	70	100	1	43	700
Natural Attenuation Default Concentration (µg/L)			300	700	1,000	100	430	7,000
LC34-IJ0015	02/03/2011	32 to 42	**3,400**	**70,000**	**320 I**	**3,300**	**150 U**	**3,400 U**
LC34-IJ0016	02/03/2011	47 to 57	**600 I**	**37,000**	**180 I**	**400 I**	60 U	1,400 U
LC34-IJ0019	02/03/2011	32 to 42	**15 U**	**6,400**	**180 I**	**5,500**	15 U	340 U
LC34-IJ0020	02/03/2011	47 to 57	3.0 U	**1,400**	30 I	**410**	3.0 U	67 U

Notes:

1. ft BLS indicates feet below land surface.
2. µg/L indicates micrograms per liter.
3. * indicates duplicate sample.
4. U indicates result not detected above method detection limit (MDL).
5. I indicates the result is between the MDL and the practical quantitation limit.
6. Bold text indicates an exceedance of the FDEP Groundwater Cleanup Target Level.
7. Shaded cell indicates an exceedance of the FDEP Natural Attenuation Default Concentration.
8. B indicates detected in associated method blank.
9. J indicates estimated value.

Table 13: Summary of Groundwater Sampling Results: Field Geochemical Parameters (NASA 2013)

Location	Sample Date	Screen Interval (ft BLS)	Temperature (°C)	pH (S.U.)	Conductivity (mS/cm)	Turbidity (NTU)	Oxidation-Reduction Potential (mV)	Dissolved Oxygen (mg/L)	Total Dissolved Solids (g/L)	Color
LC34-BW0001A	02/01/2011	23 to 26	23.8	7.45	1.20	5.7	-154	0.40	0.80	Clear
	04/18/2011		24.2	7.43	0.78	1.9	-156	0.38	0.51	Clear
	08/01/2011		26.9	7.67	1.16	2.0	-30.9	0.41	0.75	Clear
	10/25/2011		25.5	7.26	0.86	1.7	-146	0.46	0.56	Clear
	02/16/2012		24.2	7.75	0.77	2.8	-111	0.45	0.50	Clear
	06/26/2012		24.0	6.91	0.70	1.1	-116	0.60	0.45	Clear
	09/13/2012		26.2	7.41	0.89	0.5	-141	1.36*	0.58	Clear
LC34-BW0001B	02/01/2011	30 to 33	24.0	7.49	2.31	9.9	-146	0.33	1.53	Clear
	04/18/2011		24.8	7.55	1.39	2.3	-159	0.24	0.91	Clear
	08/01/2011		26.4	7.62	1.81	6.5	-48.2	0.28	1.17	Clear
	10/25/2011		25.8	7.03	2.37	0.70	-175	0.39	1.54	Clear
	02/16/2012		24.8	7.60	0.99	2.5	-254	0.23	0.64	Clear
	06/26/2012		24.2	7.06	0.82	0.72	-119	0.24	0.53	Clear
	09/13/2012		26.3	7.59	1.06	0.60	-164	1.21*	0.69	Clear
	03/19/2013		23.5	7.59	0.76	4.2	-200	1.13	0.49	Clear
LC34-BW0001C	02/01/2011	37 to 40	24.4	7.52	2.88	8.2	-150	0.28	1.90	Clear
	03/22/2011		24.6	7.34	2.59	4.8	-163	0.53	1.69	Clear
	03/29/2011		24.6	7.50	2.09	4.9	-59.0	0.49	1.34	Clear
	04/07/2011		25.3	7.47	2.47	2.2	-141	0.17	1.61	Clear
	04/18/2011		24.9	7.43	2.06	12	-146	0.54	1.35	Clear
	07/07/2011		26.1	7.15	2.59	1.6	-125	0.23	1.68	Clear
	08/01/2011		26.3	7.81	2.14	1.3	-52.7	0.23	1.38	Clear
	10/25/2011		25.7	7.07	2.38	0.82	-274	0.10	1.55	Clear
	02/16/2012		24.2	7.25	1.03	3.9	-229	0.30	0.89	Clear
	06/26/2012		24.5	6.72	1.45	0.62	-167	0.16	0.95	Clear
	09/13/2012		26.4	7.61	0.99	5.6	-16.0	0.41	0.65	Clear
	03/19/2013		23.7	7.39	1.00	1.0	-227	1.03	0.65	Clear
LC34-BW0001D	02/01/2011	44 to 47	25.2	7.36	3.19	4.9	-122	0.36	2.07	Clear
	04/18/2011		25.6	7.37	2.75	3.9	-123	0.32	1.79	Clear
	07/07/2011		25.6	7.33	2.96	4.5	-101	0.24	1.92	Clear
	08/01/2011		27.0	7.64	2.00	4.2	-37.1	0.24	1.32	Clear
	10/25/2011		25.7	7.10	2.76	4.4	-302	0.35	1.79	Clear
	02/16/2012		25.4	6.73	2.92	7.9	-251	0.36	1.90	Clear
	06/26/2012		24.5	6.85	2.67	0.97	-223	0.16	1.73	Clear
	09/13/2012		25.7	6.99	3.79	17	-283	1.62*	2.46	Cloudy
	03/19/2013		23.6	7.16	2.38	2.9	-325	1.28	1.55	Clear

Location	Sample Date	Screen Interval (ft BLS)	Temperature (°C)	pH (S.U.)	Conductivity (mS/cm)	Turbidity (NTU)	Oxidation-Reduction Potential (mV)	Dissolved Oxygen (mg/L)	Total Dissolved Solids (g/L)	Color
LC34-BW0001E	02/01/2011	51 to 54	24.9	7.69	2.71	9.7	-150	0.37	1.76	Clear
	03/22/2011		24.5	7.60	2.39	5.7	-155	0.35	1.55	Clear
	03/29/2011		25.1	7.64	2.57	8.7	-65.0	0.41	1.61	Clear
	04/07/2011		24.8	7.71	2.51	5.1	-139	0.15	1.63	Clear
	04/18/2011		24.7	7.69	2.37	12	-154	0.33	1.54	Clear
	07/07/2011		25.6	7.60	2.58	3.9	-145	0.17	1.68	Clear
	08/01/2011		27.4	7.32	1.99	4.5	-32.0	1.25	1.25	Clear
	10/25/2011		25.8	7.48	2.69	0.48	-281	0.20	1.75	Clear
	02/16/2012		25.2	7.47	2.52	2.3	-300	0.26	1.64	Clear
	06/26/2012		24.7	7.13	2.39	1.4	-215	0.21	1.55	Clear
	09/13/2012		26.2	7.54	3.34	7.1	-274	1.43*	2.17	Cloudy
LC34-BW0001F	02/01/2011	58 to 61	24.9	7.64	2.81	8.6	-152	0.37	1.83	Clear
	04/18/2011		25.0	7.65	2.47	3.9	-119	0.49	1.61	Clear
	08/01/2011		26.0	7.80	2.05	4.2	-43.2	0.89	1.32	Clear
	10/25/2011		25.6	7.49	2.67	1.4	-188	0.30	1.74	Clear
	02/16/2012		25.1	7.25	2.53	0.93	-287	0.30	1.64	Clear
	06/26/2012		24.7	7.05	2.44	0.62	-167	0.27	1.53	Clear
	09/13/2012		26.2	7.15	2.52	6.6	-175	0.47	1.65	Clear
LC34-BW0002A	02/01/2011	23 to 26	24.7	7.44	1.28	1.4	-170	0.19	0.84	Clear
	04/19/2011		24.5	7.49	0.67	8.4	-175	0.20	0.43	Clear
	08/02/2011		26.4	7.87	1.00	4.7	-11.0	0.65	0.65	Clear
	10/26/2011		25.8	7.18	1.30	2.5	-184	0.31	0.85	Clear
	02/15/2012		25.4	7.37	2.11	4.5	-299	0.17	1.39	Clear
	06/26/2012		25.1	7.35	0.68	2.7	-189	0.23	0.44	Clear
	09/11/2012		26.2	7.13	0.96	0.56	72.2	0.70*	0.63	Clear
LC34-BW0002B	02/01/2011	30 to 33	24.7	7.56	2.11	3.7	-183	0.30	1.38	Clear
	04/19/2011		25.0	7.50	0.90	5.8	-186	0.20	0.59	Clear
	08/02/2011		26.5	7.50	1.61	9.7	-13.0	1.04	1.04	Clear
	10/26/2011		25.5	7.34	1.19	3.2	-237	0.35	0.77	Clear
	02/15/2012		25.4	7.26	0.79	6.5	-213	0.22	0.48	Clear
	06/26/2012		25.2	7.46	0.70	2.0	-253	0.20	0.46	Clear
	09/11/2012		26.0	7.23	0.95	1.0	-19.6	0.30	0.61	Cloudy

Location	Sample Date	Screen Interval (ft BLS)	Temperature (°C)	pH (S.U.)	Conductivity (mS/cm)	Turbidity (NTU)	Oxidation-Reduction Potential (mV)	Dissolved Oxygen (mg/L)	Total Dissolved Solids (g/L)	Color
LC34-BW0002C	02/01/2011	37 to 40	24.7	7.69	2.62	0.0	-197	0.37	1.71	Clear
	03/22/2011		24.6	7.71	2.56	7.5	-210	0.36	1.66	Clear
	03/29/2011		23.6	7.31	2.49	5.1	-60.2	0.62	1.62	Clear
	04/07/2011		24.8	7.75	2.48	12	-149	0.25	1.62	Clear
	04/19/2011		25.2	7.60	2.10	5.3	-203	0.27	1.37	Clear
	07/07/2011		26.5	7.53	2.42	6.1	-255	0.16	1.58	Clear
	08/02/2011		26.2	7.24	2.61	4.3	-15.3	0.97	1.77	Clear
	10/26/2011		25.4	7.38	2.52	0.80	-330	0.15	1.64	Clear
	02/14/2012		25.2	7.45	0.66	1.2	-161	0.10	0.43	Clear
	06/26/2012		26.0	7.28	2.11	2.4	-364	0.19	1.35	Clear
	09/11/2012		25.9	7.44	2.49	0.94	-251	0.30	1.62	Clear
LC34-BW0002D	02/01/2011	44 to 47	24.3	7.61	2.68	0.0	-154	0.35	1.77	Clear
	04/19/2011		25.1	7.68	2.05	2.6	-211	0.24	1.33	Clear
	07/07/2011		26.4	7.39	2.43	12	-161	0.20	1.58	Clear
	08/02/2011		26.4	7.68	2.37	1.2	-12.8	0.24	1.21	Clear
	10/26/2011		25.3	7.56	2.76	0.72	-338	0.77	1.80	Clear
	02/14/2012		25.2	7.41	2.67	1.4	-288	0.09	1.74	Clear
	06/26/2012		26.0	7.30	2.58	4.3	-361	0.10	1.65	Clear
	09/11/2012		26.9	7.69	3.31	5.5	-325	1.77*	2.19	Cloudy
LC34-BW0002E	02/01/2011	51 to 54	23.7	7.58	2.60	7.5	-154	0.41	1.74	Clear
	04/19/2011		25.3	7.66	2.06	19	-187	0.08	1.34	Clear
	07/07/2011		25.6	7.77	2.58	5.6	-229	0.12	1.68	Clear
	08/02/2011		26.9	7.61	2.04	13	-2.90	0.33	1.34	Clear
	10/26/2011		26.1	7.77	2.66	1.8	-251	0.20	1.73	Clear
	02/14/2012		25.4	7.65	2.55	1.0	-266	0.09	1.66	Clear
	06/26/2012		25.1	7.61	2.40	1.3	-274	0.15	1.60	Clear
	09/11/2012		26.2	7.74	3.21	2.7	-236	1.44*	2.09	Cloudy
LC34-BW0002F	02/01/2011	58 to 61	22.9	7.37	2.68	2.2	-109	0.52	1.82	Clear
	04/19/2011		25.2	7.63	2.14	2.2	-155	0.16	1.39	Clear
	08/02/2011		26.6	7.71	2.19	7.0	-15.5	0.54	1.45	Clear
	10/26/2011		26.3	7.69	2.73	0.4	-220	0.24	1.78	Clear
	02/14/2012		25.0	7.71	2.59	0.75	-204	0.11	1.68	Clear
	06/26/2012		24.9	7.57	2.53	1.4	-258	0.12	1.64	Clear
	09/11/2012		26.2	7.82	3.30	1.9	-286	0.71*	2.15	Clear
LC34-BW0003A	02/01/2011	23 to 26	24.3	7.43	1.44	10	-152	0.35	0.95	Clear
	04/19/2011		24.4	7.43	0.72	0.5	-180	1.16	0.47	Clear
	08/02/2011		25.8	7.86	1.30	2.9	-170	2.13*	0.85	Clear
	10/26/2011		26.4	7.23	0.85	1.8	-252	0.80	0.56	Clear
	02/15/2012		24.8	7.47	0.76	2.1	-150	0.18	0.49	Clear
	06/27/2012		24.5	7.52	0.71	0.36	-175	0.61	0.46	Clear
	09/11/2012		26.6	7.41	0.90	0.4	-87.1	2.32*	0.58	Clear

Location	Sample Date	Screen Interval (ft BLS)	Temperature (°C)	pH (S.U.)	Conductivity (mS/cm)	Turbidity (NTU)	Oxidation-Reduction Potential (mV)	Dissolved Oxygen (mg/L)	Total Dissolved Solids (g/L)	Color
LC34-BW0003B	02/01/2011	30 to 33	24.4	7.66	1.89	13	-196	0.22	1.25	Clear
	04/19/2011		24.5	7.48	0.82	3.8	-176	0.34	0.53	Clear
	08/02/2011		25.8	7.53	1.83	1.0	-167	2.35*	1.19	Clear
	10/27/2011		25.2	7.30	0.95	1.4	-238	0.78	0.61	Clear
	02/15/2012		25.2	7.52	0.80	2.4	-161	0.21	0.52	Clear
	06/27/2012		24.4	7.54	0.73	0.49	-169	0.21	0.47	Clear
	09/11/2012		26.0	7.28	0.89	0.62	-104	1.49*	0.58	Clear
LC34-BW0003C	02/02/2011	37 to 40	23.9	7.73	2.42	7.0	-143	0.20	1.60	Clear
	03/22/2011		24.2	7.56	2.20	2.7	-181	0.24	1.43	Clear
	03/29/2011		23.6	7.50	2.50	8.9	-92.3	0.42	1.62	Clear
	04/07/2011		24.7	7.70	2.16	2.8	-168	0.12	1.40	Clear
	04/19/2011		24.8	7.56	1.60	6.1	-177	0.19	1.04	Clear
	07/07/2011		25.2	7.26	2.02	18	-123	0.21	1.31	Clear
	08/02/2011		26.2	6.88	3.07	3.2	-276	1.26*	1.99	Clear
	10/27/2011		25.6	7.32	1.75	2.7	-282	0.36	1.14	Clear
	02/15/2012		25.0	7.50	1.19	7.9	-199	0.17	0.84	Clear
	06/27/2012		24.6	7.61	1.09	0.48	-248	0.30	0.71	Clear
	09/13/2012		25.6	7.65	1.16	1.6	-141	3.09*	0.76	Clear
LC34-BW0003D	02/02/2011	44 to 47	24.0	7.71	2.59	5.1	-115	0.21	1.71	Clear
	04/19/2011		24.8	7.51	1.86	11	-177	0.31	1.21	Clear
	07/07/2011		25.7	5.74	2.12	13	13.2	0.42	1.41	Clear
	08/02/2011		27.1	6.95	2.98	5.0	-268	1.24*	1.94	Clear
	10/26/2011		25.8	6.43	2.61	6.8	-292	0.60	1.70	Clear
	02/15/2012		25.0	6.90	2.53	5.1	-314	0.19	1.65	Clear
	06/27/2012		25.1	7.28	2.42	7.8	-346	0.56	1.57	Clear
	09/13/2012		25.8	7.28	3.13	1.3	-268	1.35*	2.03	Cloudy
LC34-BW0003E	02/01/2011	51 to 54	24.2	7.65	2.63	2.9	-149	0.32	1.74	Clear
	03/22/2011		24.4	7.56	2.37	5.9	-159	0.25	1.54	Clear
	03/29/2011		24.0	7.71	2.12	6.6	-94.0	0.65	1.41	Clear
	04/07/2011		25.0	7.74	2.48	4.9	-136	0.17	1.61	Clear
	04/19/2011		24.6	7.59	1.87	5.0	-158	0.25	1.22	Clear
	07/07/2011		25.0	6.94	1.97	7.0	-128	0.22	1.28	Clear
	08/02/2011		25.6	7.10	2.94	1.2	-265	0.97	1.90	Clear
	10/26/2011		25.8	6.43	2.61	6.8	-292	0.60	1.70	Clear
	02/15/2012		25.1	6.84	2.56	2.3	-300	0.19	1.67	Clear
	06/27/2012		25.0	7.37	2.60	0.95	-289	0.70	1.69	Clear
	09/13/2012		25.7	7.33	3.36	0.92	-238	1.73*	2.18	Cloudy

Location	Sample Date	Screen Interval (ft BLS)	Temperature (°C)	pH (S.U.)	Conductivity (mS/cm)	Turbidity (NTU)	Oxidation-Reduction Potential (mV)	Dissolved Oxygen (mg/L)	Total Dissolved Solids (g/L)	Color
LC34-BW0003F	02/01/2011	58 to 61	24.3	7.61	2.80	2.4	-142	0.24	1.85	Clear
	04/19/2011		24.6	7.56	2.01	2.2	-133	0.22	1.30	Clear
	08/02/2011		25.6	7.80	2.78	1.3	-248	1.25	1.80	Clear
	10/27/2011		26.0	7.32	2.73	1.4	-287	0.34	1.78	Clear
	02/15/2012		24.9	6.88	2.61	0.96	-270	0.18	1.7	Clear
	06/27/2012		25.1	7.54	2.59	1.1	-285	0.33	1.69	Clear
	09/13/2012		25.8	7.54	3.46	5.3	-262	1.63*	2.25	Cloudy
LC34-IW0002I	02/03/2011	25 to 30	24.0	7.30	1.25	10	-137	0.61	0.83	Clear
	03/22/2011		25.2	7.26	0.88	3.7	-146	0.61	0.57	Clear
	03/29/2011		24.8	7.63	2.35	4.7	-52.9	0.45	1.31	Clear
	04/07/2011		24.5	7.40	0.85	6.1	-138	0.35	0.55	Clear
	04/18/2011		24.4	7.44	0.73	5.1	-141	0.29	0.48	Clear
	08/01/2011		27.0	6.57	1.95	4.3	-143	0.91	1.27	Clear
	10/26/2011		26.0	6.99	0.78	9.5	-291	0.52	0.51	Clear
	02/15/2012		24.8	7.32	0.66	4.1	-729	0.86	0.43	Clear
	06/26/2012		25.3	6.86	0.60	3.2	-80.4	0.32	0.39	Clear
	09/13/2012		26.4	7.63	0.51	11	-118	0.77	0.33	Clear
LC34-IW0002D	02/02/2011	35 to 40	24.6	7.38	2.81	6.0	-95	0.42	1.84	Clear
	03/22/2011		24.8	7.40	1.96	7.2	-144	0.48	1.28	Clear
	03/28/2011		23.3	7.46	1.90	5.5	-149	0.69	1.23	Clear
	04/07/2011		24.6	7.58	1.81	1.7	-153	0.27	1.18	Clear
	04/18/2011		25.9	7.80	1.24	3.8	-162	0.36	0.81	Clear
	08/01/2011		26.9	6.83	3.66	4.7	-211	0.76	2.38	Clear
	10/26/2011		26.5	6.92	2.29	1.6	-312	0.61	1.40	Clear
	2/16/2012		25.4	6.99	1.25	4.0	-243	0.33	0.81	Clear
	06/26/2012		25.3	7.32	0.88	1.5	-307	0.29	0.60	Clear
	09/13/2012		26.1	7.76	0.72	6.6	-157	0.56	0.50	Clear
LC34-IW0002D1	02/02/2011	50 to 55	24.6	7.70	2.94	6.2	-90.0	0.49	1.93	Clear
	03/22/2011		24.6	7.56	2.50	8.3	-121	0.39	1.62	Clear
	03/28/2011		23.8	7.59	2.63	7.5	-109	0.43	1.71	Clear
	04/07/2011		24.1	7.68	2.59	5.2	-127	0.29	1.69	Clear
	04/18/2011		25.2	7.83	1.97	6.8	-119	0.39	1.28	Clear
	08/01/2011		26.5	7.11	2.90	15	-250	0.53	1.89	Clear
	10/26/2011		26.6	7.57	2.73	7.1	-302	0.27	1.77	Clear
	02/16/2012		25.1	7.07	2.59	3.8	-308	0.31	1.69	Clear
	06/26/2012		25.5	7.29	2.37	2.3	-364	0.27	1.56	Clear
	09/13/2012		26.0	7.77	2.34	2.9	-276	0.23	1.59	Clear
LC34-IW0067D	02/02/2011	38 to 43	25.0	7.74	3.00	4.1	-249	0.32	1.95	Clear
	04/18/2011		25.8	7.89	1.94	5.4	-272	0.35	1.26	Clear
	10/25/2011		26.0	7.51	2.61	7.3	-245	0.09	1.70	Clear
	02/14/2012		24.3	8.52 *	2.54	1.6	-240	0.33	1.65	Clear
	06/26/2012		25.5	7.52	2.66	3.0	-298	0.17	1.73	Clear

Location	Sample Date	Screen Interval (ft BLS)	Temperature (°C)	pH (S.U.)	Conductivity (mS/cm)	Turbidity (NTU)	Oxidation-Reduction Potential (mV)	Dissolved Oxygen (mg/L)	Total Dissolved Solids (g/L)	Color
LC34-IW0067D1	02/03/2011	63 to 73	24.6	7.53	2.73	14	-98.8	0.30	1.79	Clear
	04/18/2011		25.9	7.76	1.96	17	-154	0.38	1.28	Clear
	10/25/2011		25.9	7.50	2.66	75	-142	0.13	1.73	Cloudy
	02/14/2012		24.1	7.63 *	2.58	9.7	-60.2	0.39	1.67	Clear
	06/26/2012		25.2	7.41	2.67	125	-146	0.14	1.74	White and cloudy
LC34-IW0070D	02/02/2011	38 to 43	25.1	7.74	3.08	2.4	-242	0.46	2.00	Clear
	04/18/2011		25.3	7.83	1.90	6.0	-220	0.43	1.24	Clear
	10/25/2011		26.2	7.64	2.67	4.3	-281	0.08	1.74	Clear
	02/15/2012		25.2	7.73	2.54	5.7	-170	0.30	1.65	Clear
	06/26/2012		25.4	7.49	2.71	3.8	-281	0.42	1.77	Clear
LC34-IW0070D1	02/02/2011	65 to 75	24.7	7.69	3.10	3.5	-151	0.38	2.03	Clear
	04/18/2011		25.7	7.80	2.02	14	-123	0.47	1.31	Clear
	10/25/2011		26.1	7.56	2.69	8.0	-185	0.10	1.75	Clear
	02/15/2012		25.0	7.67	2.57	3.0	-24.4	0.31	1.67	Clear
	06/26/2012		25.0	7.42	2.69	3.1	-90.1	0.42	1.75	Clear
LC34-IW0071D	02/02/2011	38 to 43	23.1	7.54	2.33	1.0	-137	0.17	1.57	Clear
	04/18/2011		24.7	7.91	1.84	0.7	-172	0.68	1.19	Clear
	10/25/2011		24.3	7.54	2.39	1.1	-222	0.12	1.56	Clear
	02/15/2012		23.4	7.66	2.28	0.57	-87.9	0.31	1.48	Clear
	06/26/2012		24.0	7.42	2.49	1.6	-242	0.13	1.62	Clear
LC34-IW0071D1	02/02/2011	65 to 75	23.0	7.65	2.47	0.7	-112	0.19	1.67	Clear
	04/18/2011		25.0	7.82	1.92	7.6	-124	0.34	1.25	Clear
	10/25/2011		24.5	7.58	2.55	4.2	-161	0.09	1.66	Clear
	02/14/2012		23.2	7.63	2.49	1.8	-73.4	0.27	1.62	Clear
	06/26/2012		24.0	7.42	2.63	1.6	-151	0.15	1.71	Clear
LC34-IW0076	02/02/2011	70 to 80	24.3	7.69	2.95	16	0.40	1.95	1.95	Clear
	04/18/2011		25.2	7.83	2.38	7.9	-182	0.22	1.55	Clear
	08/01/2011		25.9	7.78	2.53	14	-152	1.79	1.64	Clear
	10/25/2011		27.0	7.43	2.60	39	-200	0.07	1.69	Cloudy
	02/15/2012		24.6	7.12	2.39	16	-62.8	0.51	1.56	Clear
	06/26/2012		28.2	6.60	2.34	5.9	-207	0.48	1.55	Clear
	09/13/2012		26.3	7.80	2.54	6.9	-140	0.49	1.67	Clear

Location	Sample Date	Screen Interval (ft BLS)	Temperature (°C)	pH (S.U.)	Conductivity (mS/cm)	Turbidity (NTU)	Oxidation-Reduction Potential (mV)	Dissolved Oxygen (mg/L)	Total Dissolved Solids (g/L)	Color
LC34-RW0007	02/02/2011	35 to 42	24.1	7.90	2.69	10	6.5	0.16	1.78	Clear
	03/22/2011		24.2	7.40	2.28	3.0	-109	2.34*	1.48	Clear
	03/28/2011		23.2	7.43	2.60	3.7	-136	1.69	1.69	Clear
	04/07/2011		24.2	7.57	2.35	0.79	-154	0.38	1.52	Clear
	04/19/2011		24.7	7.42	1.90	1.4	-166	0.41	1.24	Clear
	07/07/2011		25.3	7.22	2.20	4.3	-124	0.27	1.43	Clear
	08/01/2011		26.6	6.98	2.74	3.6	-208	0.39	1.78	Clear
	08/12/2011		26.5	8.21*	1.83	4.8	-238	0.14	1.16	Clear
	08/18/2011		26.5	6.80	2.39	7.8	-280	0.49	1.55	Clear
	08/24/2011		26.7	6.75	2.73	1.8	-252	0.63	1.77	Clear
	08/31/2011		26.5	7.34	2.58	1.6	-290	0.17	1.63	Clear
	09/15/2011		27.1	7.06	2.66	0.8	-303	1.67	1.73	Clear
	09/28/2011		26.4	7.11	2.45	1.6	-284	0.66	1.60	Clear
	10/13/2011		25.7	7.15	2.49	2.3	-315	0.20	1.62	Clear
	10/26/2011		25.3	7.04	1.22	0.62	-314	1.19	0.79	Clear
	11/10/2011		25.3	7.26	2.45	1.5	-333	0.21	1.59	Clear
	11/22/2011		25.6	7.19	2.46	0.77	-539	0.15	1.60	Clear
	12/15/2011		25.0	7.18	2.06	0.99	-320	0.12	1.34	Clear
	01/05/2012		23.2	7.11	1.40	3.0	-255	0.50	0.91	Clear
	01/26/2012		24.5	7.23	1.99	0.83	-260	1.06	1.29	Clear
	02/14/2012		24.0	8.84*	2.03	0.69	-252	0.53	1.32	Clear
	03/15/2012		25.7	7.78	0.79	5.6	-222	0.32	0.52	Clear
	04/19/2012		24.7	7.46	2.04	3.6	-234	1.10	1.33	Clear
	05/17/2012		24.1	10.54*	2.09	1.3	-312	1.58*	1.36	Clear
	06/26/2012		26.7	7.12	2.07	3.1	-286	0.33	1.35	Clear
	07/19/2012		25.6	7.39	1.94	0.08	-324	0.38	1.26	Clear
	08/16/2012		26.2	7.42	2.81	1.2	-324	0.09	1.83	Clear
	09/13/2012		26.5	7.85	0.92	2.9	-241	0.25	0.60	Clear

Location	Sample Date	Screen Interval (ft BLS)	Temperature (°C)	pH (S.U.)	Conductivity (mS/cm)	Turbidity (NTU)	Oxidation-Reduction Potential (mV)	Dissolved Oxygen (mg/L)	Total Dissolved Solids (g/L)	Color
LC34-RW0008	02/02/2011	47 to 57	24.5	8.76	2.30	11	-91.1	0.16	1.51	Clear
	03/22/2011		24.5	7.56	2.40	4.1	-102	1.02	1.56	Clear
	03/28/2011		23.2	7.60	2.56	7.9	-117	0.55	1.66	Clear
	04/07/2011		24.2	7.68	2.46	0.8	-113	0.61	1.60	Clear
	04/19/2011		25.2	7.68	1.93	1.9	-156	0.40	1.25	Clear
	07/07/2011		25.2	7.35	2.35	8.7	-209	0.27	1.53	Clear
	08/01/2011		26.3	7.32	2.53	3.3	-226	0.25	1.64	Clear
	08/12/2011		26.2	8.11*	2.87	8.3	-262	0.26	1.82	Clear
	08/18/2011		26.5	6.98	2.66	3.7	-246	0.34	1.73	Clear
	08/24/2011		27.3	7.01	2.73	3.1	-250	0.52	1.78	Clear
	08/31/2011		26.6	7.80	2.65	2.5	-294	0.07	1.67	Clear
	09/15/2011		26.8	7.21	2.66	0.9	-320	1.03	1.73	Clear
	09/28/2011		26.4	7.21	2.47	1.3	-275	0.59	1.61	Clear
	10/13/2011		25.6	7.34	2.65	1.7	-305	0.21	1.72	Clear
	10/26/2011		24.9	7.20	2.66	1.7	-323	0.31	1.73	Clear
	11/10/2011		35.1	7.42	2.59	1.4	-349	0.21	1.68	Clear
	11/22/2011		25.7	7.31	2.58	0.79	-346	0.14	1.68	Clear
	12/15/2011		24.6	7.42	2.55	1.4	-329	0.15	1.66	Clear Grey
	01/05/2012		23.0	7.26	2.42	0.80	-284	0.50	1.57	Clear
	01/26/2012		24.5	7.36	2.35	0.59	-293	0.80	1.53	Clear
	02/14/2012		24.0	8.82*	2.54	0.64	-255	0.49	1.65	Clear
	03/15/2012		25.9	7.52	2.49	0.76	-232	0.38	1.62	Clear
	04/19/2012		24.5	7.65	2.42	0.96	-220	1.08	1.57	Clear
	05/17/2012		23.8	10.69*	2.47	2.4	-320	1.55*	1.60	Clear
	06/26/2012		25.5	7.07	2.70	2.5	-270	0.38	1.75	Clear
	07/19/2012		25.8	7.51	2.51	0.09	-306	0.32	1.63	Clear
	08/16/2012		25.7	7.64	3.64	1.6	-341	0.36	2.37	Clear
	09/13/2012		26.7	7.77	2.56	5.2	-240	0.40	1.67	Clear

Location	Sample Date	Screen Interval (ft BLS)	Temperature (°C)	pH (S.U.)	Conductivity (mS/cm)	Turbidity (NTU)	Oxidation-Reduction Potential (mV)	Dissolved Oxygen (mg/L)	Total Dissolved Solids (g/L)	Color
LC34-IJ0015	02/03/2011	32 to 42	24.1	7.56	2.65	15	-162	0.26	1.76	Clear
LC34-IJ0016	02/03/2011	47 to 57	24.2	7.63	2.78	14	-133	0.28	1.84	Clear
LC34-IJ0019	02/03/2011	32 to 42	24.1	7.64	1.97	12	-160	0.31	1.30	Clear
LC34-IJ0020	02/03/2011	47 to 57	23.4	7.68	2.36	13	-121	0.35	1.58	Clear

Notes:

1. ft BLS indicates feet below land surface.
2. °C indicates degree Celsius.
3. pH indicates hydrogen ion concentration.
4. S.U. indicates standard units.
5. mS/cm indicates milliSiemens per centimeter.
6. NTU indicates Nephelometric Turbidity Unit.
7. mV indicates millivolts.
8. mg/L indicates milligram per liter.
9. g/L indicates gram per liter.
10. * indicates malfunctioning of probe.

Table 14: Summary of Groundwater Sampling Results: TOC and VFAs (NASA 2013)

Location	Sample Date	Screen Interval (ft BLS)	Concentration (mg/L)	Concentration (µg/L)				
			TOC	Acetic Acid	Butanoic Acid	Lactic Acid	Propionic Acid	Pyruvic Acid
LC34-BW0001A	04/18/2011	23 to 26	3.2	1.7	0.56 U	0.072 U	0.13 U	0.018 U
	08/01/2011		4.2	0.073 U	0.56 U	0.072 U	0.13 U	0.018 U
	10/25/2011		7.2	11	0.56 U	0.072 U	0.13 U	0.018 U
	02/16/2012		2.8	1.6	0.56 U	0.072 U	0.13 U	0.018 U
	02/16/2012 *		3.0	NA	NA	NA	NA	NA
	06/26/2012		2.6	NA	NA	NA	NA	NA
	09/13/2012		2.3	NA	NA	NA	NA	NA
LC34-BW0001B	04/18/2011	30 to 33	5.7	27	0.56 U	2.3	0.13 U	0.018 U
	08/01/2011		8.0	0.073 U	0.56 U	1.7	0.13 U	0.018 U
	10/25/2011		760	970	180	0.72 U	1.3 U	0.18 U
	02/16/2012		32	47	17	0.072 U	0.13 U	0.018 U
	06/26/2012		4.9	NA	NA	NA	NA	NA
	09/13/2012		3.4	NA	NA	NA	NA	NA
LC34-BW0001C	04/18/2011	37 to 40	7.3	65	0.56 U	1.2	0.13 U	0.018 U
	08/01/2011		301	370	120	0.15 U	0.26 U	0.036 U
	08/01/2011*		304	NA	NA	NA	NA	NA
	10/25/2011		511	480	530	0.36 U	12	0.09 U
	02/16/2012		504	390	440	0.36 U	13	0.09 U
	06/26/2012		120	NA	NA	NA	NA	NA
	09/13/2012		10	NA	NA	NA	NA	NA
LC34-BW0001D	04/18/2011	44 to 47	7.5	50	0.56 U	1.1	0.13 U	0.018 U
	08/01/2011		37	21	4.0	1.2	0.13 U	0.018 U
	10/25/2011		241	340	29	0.15 U	0.26 U	0.036 U
	02/16/2012		176	200	140	0.15 U	0.26 U	0.036 U
	06/26/2012		99	NA	NA	NA	NA	NA
	09/13/2012		92	NA	NA	NA	NA	NA
LC34-BW0001E	04/18/2011	51 to 54	3.3	0.073 U	0.56 U	0.072 U	0.13 U	0.018 U
	08/01/2011		8.3	10	0.56 U	0.072 U	0.13 U	0.018 U
	10/25/2011		79	140	34	0.072 U	3.5	0.018 U
	02/16/2012		11	17	0.56 U	0.072 U	0.13 U	0.018 U
	06/26/2012		21	NA	NA	NA	NA	NA
	09/13/2012		9.0	NA	NA	NA	NA	NA
LC34-BW0001F	04/18/2011	58 to 61	3.3	0.073 U	0.56 U	0.072 U	0.13 U	0.018 U
	08/01/2011		606	590	30	0.36 U	0.64 U	0.09 U
	10/25/2011		4.4	1.7	0.56 U	0.072 U	0.13 U	0.018 U
	02/16/2012		17	32	0.56 U	0.072 U	0.13 U	0.018 U
	06/26/2012		3.9	NA	NA	NA	NA	NA
	09/13/2012		3.5	NA	NA	NA	NA	NA

Location	Sample Date	Screen Interval (ft BLS)	Concentration (mg/L)	Concentration (µg/L)				
			TOC	Acetic Acid	Butanoic Acid	Lactic Acid	Propionic Acid	Pyruvic Acid
LC34-BW0002A	04/19/2011	23 to 26	3.0	2.4	0.56 U	0.072 U	0.13 U	0.018 U
	04/19/2011*		NA	2.4	0.56 U	0.072 U	0.13 U	0.018 U
	08/02/2011		3.7	13	0.56 U	0.072 U	0.13 U	0.018 U
	10/26/2011		178	370	57	0.15 U	0.26 U	0.036 U
	02/15/2012		41	100	0.56 U	0.072 U	0.13 U	0.018 U
	06/26/2012		2.7	NA	NA	NA	NA	NA
	09/11/2012		2.5	NA	NA	NA	NA	NA
LC34-BW0002B	04/19/2011	30 to 33	4.1	18	0.56 U	0.072 U	0.13 U	0.018 U
	08/02/2011		13	48	3.7	1.1	0.13 U	0.018 U
	08/02/2011*		14	NA	NA	NA	NA	NA
	10/26/2011		107	230	30	0.15 U	2.4	0.036 U
	02/15/2012		11	19	0.56 U	0.072 U	0.13 U	0.018 U
	06/26/2012		3.0	NA	NA	NA	NA	NA
	09/11/2012		2.7	NA	NA	NA	NA	NA
LC34-BW0002C	04/19/2011	37 to 40	4.3	36	0.56 U	0.072 U	0.13 U	0.018 U
	08/02/2011		354	350	290	0.36 U	0.64 U	0.09 U
	10/26/2011		78	160	43	1.1	2	0.018 U
	02/14/2012		2.5	0.073 U	0.56 U	0.072 U	0.13 U	0.018 U
	06/26/2012		49	NA	NA	NA	NA	NA
	09/11/2012		78	NA	NA	NA	NA	NA
LC34-BW0002D	04/19/2011	44 to 47	4.0	3.3	0.56 U	0.072 U	0.13 U	0.018 U
	04/19/2011*		4.0	3.3	0.56 U	0.072 U	0.13 U	0.018 U
	08/02/2011		4.1	3.3	0.56 U	0.072 U	0.13 U	0.018 U
	10/26/2011		102	130	61	0.072 U	13	0.018 U
	02/14/2012		88	190	20	0.072 U	2.1	0.018 U
	06/26/2012		104	NA	NA	NA	NA	NA
	09/11/2012		87	NA	NA	NA	NA	NA
LC34-BW0002E	04/19/2011	51 to 54	3.2	0.073 U	0.56 U	0.072 U	0.13 U	0.018 U
	08/02/2011		4.4	2.8	0.56 U	0.072 U	0.13 U	0.018 U
	10/26/2011		4.0	1.8	0.56 U	0.072 U	0.13 U	0.018 U
	02/14/2012		4.6	4.3	0.56 U	0.072 U	0.13 U	0.018 U
	06/26/2012		5.3	NA	NA	NA	NA	NA
	09/11/2012		4.9	NA	NA	NA	NA	NA
LC34-BW0002F	04/19/2011	58 to 61	3.1	0.073 U	0.56 U	0.072 U	0.13 U	0.018 U
	08/02/2011		7.1	11	0.56 U	0.072 U	0.13 U	0.018 U
	10/26/2011		3.5	0.073 U	0.56 U	0.072 U	0.13 U	0.018 U
	02/14/2012		3.1	0.073 U	0.56 U	0.072 U	0.13 U	0.018 U
	06/26/2012		3.4	NA	NA	NA	NA	NA
	09/11/2012		3.3	NA	NA	NA	NA	NA

Location	Sample Date	Screen Interval (ft BLS)	Concentration (mg/L)	Concentration (µg/L)				
			TOC	Acetic Acid	Butanoic Acid	Lactic Acid	Propionic Acid	Pyruvic Acid
LC34-BW0003A	04/19/2011	23 to 26	2.9	0.073 U	0.56 U	0.072 U	0.13 U	0.018 U
	08/02/2011		7.2	12	0.56 U	0.072 U	0.13 U	0.018 U
	10/26/2011		5.7	9.0	0.56 U	0.072 U	0.13 U	0.018 U
	02/15/2012		2.6	0.073 U	0.56 U	0.072 U	0.13 U	0.018 U
	06/27/2012		2.4	NA	NA	NA	NA	NA
	09/11/2012		2.3	NA	NA	NA	NA	NA
LC34-BW0003B	04/19/2011	30 to 33	3.3	0.073 U	0.56 U	0.072 U	0.13 U	0.018 U
	04/19/2011*		3.2	NA	NA	NA	NA	NA
	08/02/2011		89	120	95	0.072 U	2.1	0.018 U
	08/02/2011*		99	NA	NA	NA	NA	NA
	10/27/2011		11	16	2.7	0.072 U	0.13 U	0.018 U
	02/15/2012		2.7	0.073 U	0.56 U	0.072 U	0.13 U	0.018 U
	06/27/2012		2.6	NA	NA	NA	NA	NA
	09/11/2012		2.3	NA	NA	NA	NA	NA
LC34-BW0003C	04/19/2011	37 to 40	3.8	8.1	0.56 U	0.072 U	0.13 U	0.018 U
	08/02/2011		671	680	630	0.36 U	15	0.09 U
	10/27/2011		15	25	0.56 U	0.072 U	0.13 U	0.018 U
	02/15/2012		6.2	6.8	0.56 U	0.072 U	0.13 U	0.018 U
	06/27/2012		4.2	NA	NA	NA	NA	NA
	09/13/2012		3.2	NA	NA	NA	NA	NA
LC34-BW0003D	04/19/2011	44 to 47	4.1	4.8	0.56 U	0.072 U	0.13 U	0.018 U
	08/02/2011		603	640	320	0.36 U	0.64 U	0.09 U
	08/02/2011*		NA	620	310	0.36 U	0.64 U	0.09 U
	10/26/2011		169	250	99	0.36 U	24	0.09 U
	02/15/2012		98	190	17	0.072 U	5.0	0.018 U
	06/27/2012		59	NA	NA	NA	NA	NA
	09/13/2012		50	NA	NA	NA	NA	NA
LC34-BW0003E	04/19/2011	51 to 54	3.4	0.073 U	0.56 U	0.072 U	0.13 U	0.018 U
	08/02/2011		905	870	360	0.36 U	0.64 U	0.09 U
	10/27/2011		56	57	29	0.072 U	2.7	0.018 U
	02/15/2012		34	73	2.9	0.072 U	0.13 U	0.018 U
	06/27/2012		42	NA	NA	NA	NA	NA
	09/13/2012		38	NA	NA	NA	NA	NA
LC34-BW0003F	04/19/2011	58 to 61	3.2	0.073 U	0.56 U	0.072 U	0.13 U	0.018 U
	08/02/2011		107	140	58	0.072 U	13	0.018 U
	10/27/2011		30	65	4.6	0.072 U	0.13 U	0.018 U
	02/15/2012		20	39	0.56 U	0.072 U	0.13 U	0.018 U
	06/27/2012		4.5	NA	NA	NA	NA	NA
	09/13/2012		4.9	NA	NA	NA	NA	NA

Location	Sample Date	Screen Interval (ft BLS)	Concentration (mg/L)	Concentration (µg/L)				
			TOC	Acetic Acid	Butanoic Acid	Lactic Acid	Propionic Acid	Pyruvic Acid
LC34-IW0002I	04/18/2011	25 to 30	3.3	2.3	0.56 U	0.072 U	0.13 U	0.018 U
	08/01/2011		487	610	210	0.36 U	0.64 U	0.09 U
	08/01/2011*		NA	620	200	0.36 U	0.64 U	0.09 U
	10/26/2011		31	55	13	0.072 U	2.7	0.018 U
	02/15/2012		4.0	3.6	0.56 U	0.072 U	0.13 U	0.018 U
	02/15/2012 *		NA	3.7	2 U	0.072 U	0.13 U	0.018 U
	06/26/2012		3.0	NA	NA	NA	NA	NA
	09/13/2012		2.3	NA	NA	NA	NA	NA
LC34-IW0002D	04/18/2011	35 to 40	5.1	24	0.56 U	0.072 U	0.13 U	0.018 U
	08/01/2011		1,130	1,100	1,200	0.72 U	11	0.18 U
	08/01/2011*		NA	1,100	1,200	0.72 U	1.3 U	0.18 U
	10/26/2011		590	390	810	0.36 U	49	0.09 U
	02/16/2012		124	230	38	0.15 U	7.7	0.036 U
	06/26/2012		23	NA	NA	NA	NA	NA
	09/13/2012		8.7	NA	NA	NA	NA	NA
LC34-IW0002D1	04/18/2011	50 to 55	3.1	0.073 U	0.56 U	0.072 U	0.13 U	0.018 U
	08/01/2011		587	450	2.8 U	0.36 U	21	0.09 U
	10/26/2011		43	93	5.0	0.072 U	0.13 U	0.018 U
	02/16/2012		58	110	9.9	0.072 U	1.5	0.018 U
	06/26/2012		49	NA	NA	NA	NA	NA
	09/13/2012		37	NA	NA	NA	NA	NA
LC34-IW0067D	04/18/2011	38 to 43	3.6	NA	NA	NA	NA	NA
	02/14/2012		3.6	NA	NA	NA	NA	NA
LC34-IW0067D1	04/18/2011	63 to 73	3.3	NA	NA	NA	NA	NA
	02/14/2012		3.0	NA	NA	NA	NA	NA
LC34-IW0070D	04/18/2011	38 to 43	4.1	NA	NA	NA	NA	NA
	02/15/2012		4.1	NA	NA	NA	NA	NA
LC34-IW0070D1	04/18/2011	65 to 75	3.2	NA	NA	NA	NA	NA
	02/15/2012		3.1	NA	NA	NA	NA	NA
LC34-IW0071D	04/18/2011	38 to 43	3.6	NA	NA	NA	NA	NA
	02/15/2012		3.4	NA	NA	NA	NA	NA
LC34-IW0071D1	04/18/2011	65 to 75	3.3	NA	NA	NA	NA	NA
	02/14/2012		3.1	NA	NA	NA	NA	NA
LC34-IW0076	04/18/2011	70 to 80	3.3	0.073 U	0.56 U	0.072 U	0.13 U	0.018 U
	08/01/2011		3.7	0.073 U	0.56 U	0.072 U	0.13 U	0.018 U
	10/25/2011		4.7	12	13	0.072 U	0.13 U	0.018 U
	02/15/2012		7.3	2.8	3.3	0.072 U	0.13 U	0.018 U
	06/26/2012		3.3	NA	NA	NA	NA	NA
	09/13/2012		3.1	NA	NA	NA	NA	NA

Location	Sample Date	Screen Interval (ft BLS)	Concentration (mg/L)	Concentration (µg/L)				
			TOC	Acetic Acid	Butanoic Acid	Lactic Acid	Propionic Acid	Pyruvic Acid
LC34-RW0007	03/22/2011	35 to 42	5.3	33	0.56 U	1.2	0.13 U	0.018 U
	03/28/2011		4.9	0.073 U	0.56 U	0.072 U	0.13 U	0.018 U
	04/07/2011		5.3	24	0.56 U	0.072 U	0.13 U	0.018 U
	04/19/2011		4.4	22	0.56 U	0.072 U	0.13 U	0.018 U
	04/19/2011*		4.5	22	0.56 U	0.072 U	0.13 U	0.018 U
	08/01/2011		327	350	230	0.15 U	5.2	0.036 U
	08/12/2011		191	260	68	0.36 U	0.64 U	0.09 U
	08/18/2011		363	380	320	0.36 U	11	0.09 U
	08/18/2011*		358	NA	NA	NA	NA	NA
	08/24/2011		322	320	350	0.36 U	18	0.09 U
	08/31/2011		280	290	310	0.36 U	17	0.09 U
	09/15/2011		219	250	250	0.36 U	16	0.09 U
	09/28/2011		242	260	250	0.36 U	18	0.09 U
	10/13/2011		262	280	300	0.36 U	22	0.09 U
	10/26/2011		246	270	270	0.36 U	17	0.09 U
	11/10/2011		222	270	240	0.36 U	16	0.09 U
	11/22/2011		174	240	170	0.15 U	12	0.036 U
	12/15/2011		172	230	130	0.15 U	9.7	0.036 U
	01/05/2012		153	220	54	0.36 U	8.9	0.09 U
	01/26/2012		113	170	50	0.36 U	5.3	0.09 U
	02/14/2012		108	170	49	0.072 U	4.9	0.018 U
	06/26/2012		63	NA	NA	NA	NA	NA
	09/13/2012		9.6	NA	NA	NA	NA	NA

Location	Sample Date	Screen Interval (ft BLS)	Concentration (mg/L)	Concentration (µg/L)				
			TOC	Acetic Acid	Butanoic Acid	Lactic Acid	Propionic Acid	Pyruvic Acid
LC34-RW0008	03/22/2011	47 to 57	3.6	0.073 U	0.56 U	0.072 U	0.13 U	0.018 U
	03/28/2011		3.5	0.073 U	0.56 U	0.072 U	0.13 U	0.018 U
	04/07/2011		3.5	0.073 U	0.56 U	0.072 U	0.13 U	0.018 U
	04/19/2011		3.4	1.0	0.56 U	0.072 U	0.13 U	0.018 U
	08/01/2011		73.1	130	28	0.072 U	1.1	0.018 U
	08/12/2011		203	220	150	0.15 U	5.5	0.036 U
	08/18/2011		177	230	150	0.36 U	12	0.09 U
	08/24/2011		147	220	100	0.36 U	NA	0.09 U
	08/31/2011		122	210	72	0.36 U	15	0.09 U
	09/15/2011		80	140	34	0.072 U	5.1	0.018 U
	09/28/2011		64	140	12	0.072 U	2.2	0.018 U
	10/13/2011		61	130	16	0.072 U	1.8	0.018 U
	10/26/2011		65	130	19	0.072 U	1.4	0.018 U
	11/10/2011		59	120	22	0.072 U	1.4	0.018 U
	11/22/2011		56	120	18	0.072 U	1.6	0.018 U
	12/15/2011		56	120	13	0.072 U	1.6	0.018 U
	01/05/2012		51	96	8.5	0.072 U	1.4	0.018 U
	01/26/2012		48	100	7.1	0.072 U	1.2	0.018 U
	02/14/2012		44	91	4.8	0.072 U	1.2	0.018 U
	06/26/2012		37	NA	NA	NA	NA	NA
	09/13/2012		27	NA	NA	NA	NA	NA

Notes:

1. ft BLS indicates feet below land surface.
2. µg/L indicates micrograms per liter.
3. mg/L indicates milligrams per liter.
4. U indicates result not detected above method detection limit (MDL).
5. TOC indicates total organic carbon.
6. VFA indicates volatile fatty acid.
7. NA indicates not analyzed.

Table 15: Summary of Groundwater Sampling Results: *Dehalococcoides and Vinyl Chloride Reductase* (NASA 2013)

Location	Sample Date	Screen Interval (ft BLS)	*Dehalococcoides* (gene copies/L)	*Vinyl Chloride Reductase* (gene copies/L)
LC34-BW0001C	04/18/2011	37 to 40	7.0E+05	NA
	10/25/2011		6.0E+06	NA
	02/16/2012		6.0E+06	NA
	06/26/2012		1.0E+08	1.0E+08
	09/13/2012		1.0E+08	2.0E+08
LC34-BW0001E	04/18/2011	51 to 54	4.0E+03 U	NA
	10/25/2011		7.0E+06	NA
	02/16/2012		3.0E+07	NA
	06/26/2012		2.0E+07	2.0E+07
	09/13/2012		2.0E+07	3.0E+07
LC34-BW0003C	04/19/2011	37 to 40	5.0E+07	NA
	10/27/2011		5.0E+08	NA
	02/15/2012		3.0E+08	NA
	06/27/2012		2.0E+08	9.0E+07
	09/13/2012		1.0E+08	1.0E+08
LC34-BW0003E	04/19/2011	51 to 54	1.0E+03 J	NA
	10/27/2011		2.0E+06	NA
	02/15/2012		1.0E+06	NA
	06/27/2012		3.0E+06	8.0E+06
	09/13/2012		2.0E+06	5.0E+06
LC34-RW0007	04/19/2011	35 to 42	1.0E+05	5.0E+03
	10/26/2011		1.0E+08	2.0E+06
	02/14/2012		2.0E+08	3.0E+07
	06/26/2012		2.0E+07	2.0E+07
	09/13/2012		2.0E+07	1.0E+07
LC34-RW0008	04/19/2011	47 to 57	3.0E+04	4.0E+03 U
	10/26/2011		3.0E+08	5.0E+07
	02/14/2012		1.0E+08	3.0E+07
	06/26/2012		9.0E+07	1.0E+08
	09/13/2012		6.0E+07	6.0E+07

Notes:

1. ft BLS indicates feet below land surface.
2. Gene copies/L indicates gene copies per liter.
3. U indicates not detected above method detection limit.
4. J indicates values is between the method detection limit and the quantitation limit.

Table 16: Summary of Groundwater Sampling Results: Geochemical Parameters (NASA 2013)

Location	Sample Date	Screen Interval (ft BLS)	Concentration (µg/L)			Concentration (mg/L)							
			Ethane	Ethene	Methane	Nitrate-N	Nitrite-N	Sulfate	Sulfide	Chloride	Alkalinity	Bromide	Iodide
LC34-BW0001A	04/18/2011	23 to 26	0.29 U	30	76	0.07 U	0.05 U	49	0.48 U	84	270	0.30 U	0.20 U
	08/01/2011		15	27	92	0.20 U	0.30 U	54	0.20 U	137	293	0.60 U	0.20 U
	10/25/2011		3.9	35	83	0.20 U	0.10 U	50	0.20 U	76	299	0.60 U	0.20 U
	02/16/2012		3.0	26	64	0.20 U	0.004 U	56	0.20 U	66	241	0.60 U	0.20 U
	06/26/2012		3.2	25	89	NA	NA	NA	NA	NA	NA	NA	NA
	09/13/2012		1.2	12	46	NA	NA	NA	NA	NA	NA	NA	NA
LC34-BW0001B	04/18/2011	30 to 33	0.29 U	17	85	0.07 U	0.30 U	44	0.48 U	258	329	0.30 U	0.20 U
	08/01/2011		51	30	100	0.20 U	1.0 U	38	4.5	322	350	0.60 U	0.20 U
	10/25/2011		6.5	12	23	0.20 U	0.20 U	20	2.1	119	880	51	89
	02/16/2012		16	30	83	0.20 U	0.004 U	32	3.4	96	328	3.2	0.20 U
	02/16/2012 *		NA	NA	NA	NA	NA	NA	3.2	NA	NA	NA	NA
	06/26/2012		7.3	30	70	NA	NA	NA	NA	NA	NA	NA	NA
	09/13/2012		6.3	31	71	NA	NA	NA	NA	NA	NA	NA	NA
	03/19/2013		18	26	63	NA	NA	NA	NA	NA	NA	NA	NA
LC34-BW0001C	04/18/2011	37 to 40	1.0 U	9.5	62	0.07 U	0.50 U	27	0.50 U	570	341	0.30 U	0.20 U
	07/07/2011		NA	NA	NA	NA	NA	NA	NA	NA	NA	15	22
	08/01/2011		130	16	47	0.20 U	2.0 U	2.3	6.2	500	408	23	18
	10/25/2011		57	10	64	0.20 U	0.50 U	0.50 U	9.0	287	718	40	40
	02/16/2012		59	53	600	0.20 U	0.004 U	0.50 U	5.8	247	760	29	41
	02/16/2012 *		NA	NA	NA	NA	NA	NA	NA	NA	NA	37	0.20 U
	06/26/2012		50	660	1,600	NA	NA	NA	NA	NA	NA	NA	NA
	09/13/2012		23	200	180	NA	NA	NA	NA	NA	NA	NA	NA
	03/19/2013		61	60	120	NA	NA	NA	NA	NA	NA	NA	NA
LC34-BW0001D	04/18/2011	44 to 47	0.29 U	5.3	14	0.07 U	0.50 U	76	0.50 U	780	251	0.30 U	0.20 U
	07/07/2011		NA	NA	NA	NA	NA	NA	NA	NA	NA	3.6	0.20 U
	08/01/2011		140	5.4	19	0.20 U	2.0 U	79	1.2	670	250	2.9	0.20 U
	08/01/2011*		NA	NA	NA	NA	NA	NA	NA	NA	245	NA	NA
	10/25/2011		99	3.5	13	0.20 U	1.0 U	69	2.8	568	436	13	0.20 U
	02/16/2012		100	4.6	27	0.20 U	0.004 U	16	16	751	465	8.9	0.20 U
	06/26/2012		89	25	110	NA	NA	NA	NA	NA	NA	NA	NA
	09/13/2012		93	43	160	NA	NA	NA	NA	NA	NA	NA	NA
	03/19/2013		98	98	310	NA	NA	NA	NA	NA	NA	NA	NA
LC34-BW0001E	04/18/2011	51 to 54	0.29 U	0.30 U	6.8	0.07 U	0.90 U	95	0.50 U	600	167	1.2	0.20 U
	07/07/2011		NA	NA	NA	NA	NA	NA	NA	NA	NA	2.2	0.20 U
	08/01/2011		10	2.1	9.9	0.20 U	2.0 U	77	1.5	595	183	1.4	0.20 U
	08/01/2011*		NA	NA	NA	NA	NA	NA	1.5	NA	NA	NA	0.20 U
	10/25/2011		6.9	110	95	0.20 U	1.0 U	17	9.3	625	299	4.8	0.20 U
	02/16/2012		3.7	110	620	0.20 U	0.004 U	25	8.9	603	239	2.9	0.20 U
	06/26/2012		13	610	2,200	NA	NA	NA	NA	NA	NA	NA	NA
	09/13/2012		7.3 U	390	2,700	NA	NA	NA	NA	NA	NA	NA	NA
LC34-BW0001F	04/18/2011	58 to 61	0.29 U	0.30 U	5.8	0.07 U	0.90 U	112	0.50 U	636	166	1.1	0.20 U
	08/01/2011		0.29 U	0.30 U	4.3	0.20 U	2.0 U	46	5.8	409	504	26.9	0.20 U
	08/01/2011*		NA	NA	NA	0.20 U	2.0 U	45	NA	406	NA	26.3	0.20 U
	10/25/2011		0.29 U	0.30 U	51	0.20 U	1.0 U	103	1.1	670	169	1.6	0.20 U
	02/16/2012		1.8	58	270	0.20 U	0.004 U	37	6.7	619	250	3.0	0.20 U
	06/26/2012		1.5 U	56	440	NA	NA	NA	NA	NA	NA	NA	NA
	09/13/2012		1.5 U	99	300	NA	NA	NA	NA	NA	NA	NA	NA

Location	Sample Date	Screen Interval (ft BLS)	Concentration (µg/L)			Concentration (mg/L)							
			Ethane	Ethene	Methane	Nitrate-N	Nitrite-N	Sulfate	Sulfide	Chloride	Alkalinity	Bromide	Iodide
LC34-BW0002A	04/19/2011	23 to 26	0.29 U	33	75	NA	NA	NA	NA	NA	NA	0.30 U	0.20 U
	04/19/2011*		0.29 U	32	80	NA	NA	NA	NA	NA	NA	NA	NA
	08/02/2011		32	18	86	NA	NA	NA	NA	NA	NA	0.60 U	0.20 U
	10/26/2011		3.0	46	660	NA	NA	NA	NA	NA	NA	12	14
	02/15/2012		98	140	410	NA	NA	NA	NA	NA	NA	2.7	2.6
	02/15/2012 *		96	150	410	NA	NA	NA	NA	NA	NA	NA	NA
	06/26/2012		0.58 U	97	92	NA	NA	NA	NA	NA	NA	NA	NA
	09/11/2012		0.29 U	42	39	NA	NA	NA	NA	NA	NA	NA	NA
LC34-BW0002B	04/19/2011	30 to 33	0.29 U	12	93	NA	NA	NA	NA	NA	NA	0.30 U	0.20 U
	08/02/2011		82	14	130	NA	NA	NA	NA	NA	NA	0.60 U	0.20 U
	10/26/2011		15	27	82	NA	NA	NA	NA	NA	NA	6.8	7.4
	02/15/2012		4.5	110	150	NA	NA	NA	NA	NA	NA	0.60 U	0.20 U
	06/26/2012		0.58 U	100	230	NA	NA	NA	NA	NA	NA	NA	NA
	09/11/2012		0.58 U	44	140	NA	NA	NA	NA	NA	NA	NA	NA
LC34-BW0002C	04/19/2011	37 to 40	0.29 U	8.0	58	0.07 U	0.90 U	48	0.48 U	687	247	0.30 U	0.20 U
	07/07/2011		NA	NA	NA	NA	NA	NA	NA	NA	NA	24	14
	08/02/2011		69	21	52	0.20 U	1.0 U	0.50 U	11	539	480	7.6	13
	08/02/2011*		NA	NA	NA	0.20 U	0.10 U	0.50 U	NA	53	NA	8.6	NA
	10/26/2011		110	31	170	0.20 U	1.0 U	4.2	11	548	366	2.9	6.6
	02/14/2012		0.58 U	170	140	0.20 U	0.004 U	26	2.4	51	233	0.60 U	0.20 U
	02/14/2012 *		NA	NA	NA	0.20 U	0.004 U	26	NA	47	NA	NA	NA
	06/26/2012		65	430	690	NA	NA	NA	NA	NA	NA	NA	NA
	09/11/2012		52	890	1,800	NA	NA	NA	NA	NA	NA	NA	NA
LC34-BW0002D	04/19/2011	44 to 47	0.29 U	2.9	9.0	NA	NA	NA	NA	NA	NA	1.3	0.20 U
	07/07/2011		NA	NA	NA	NA	NA	NA	NA	NA	NA	2.2	0.20 U
	08/02/2011		17	14	290	NA	NA	NA	NA	NA	NA	1.1	0.20 U
	08/02/2011*		NA	NA	NA	NA	NA	NA	NA	NA	NA	1.0	0.20 U
	10/26/2011		27	21	65	NA	NA	NA	NA	NA	NA	11.7	0.20 U
	02/14/2012		41	180	110	NA	NA	NA	NA	NA	NA	6.5	2.8
	06/26/2012		42	560	1,400	NA	NA	NA	NA	NA	NA	NA	NA
	09/11/2012		36	1,000	1,600	NA	NA	NA	NA	NA	NA	NA	NA
LC34-BW0002E	04/19/2011	51 to 54	0.29 U	0.30 U	6.8	NA	NA	NA	NA	NA	NA	0.30 U	0.20 U
	07/07/2011		NA	NA	NA	NA	NA	NA	NA	NA	NA	2.5	0.20 U
	08/02/2011		0.29 U	0.30 U	8.4	NA	NA	NA	NA	NA	NA	1.4	0.20 U
	10/26/2011		0.29 U	3.3	17	NA	NA	NA	NA	NA	NA	2.2	0.20 U
	02/14/2012		1.7	90	46	NA	NA	NA	NA	NA	NA	2.0	0.20 U
	06/26/2012		3.3	160	78	NA	NA	NA	NA	NA	NA	NA	NA
	09/11/2012		3.4	160	77	NA	NA	NA	NA	NA	NA	NA	NA
LC34-BW0002F	04/19/2011	58 to 61	0.29 U	0.30 U	6.4	NA	NA	NA	NA	NA	NA	0.30 U	0.20 U
	08/02/2011		1.3	1.5	14	NA	NA	NA	NA	NA	NA	2.3	0.20 U
	10/26/2011		0.29 U	7.2	8.6	NA	NA	NA	NA	NA	NA	2.3	0.20 U
	02/14/2012		0.29 U	6.9	8.2	NA	NA	NA	NA	NA	NA	2.0	0.20 U
	06/26/2012		1.2	65	19	NA	NA	NA	NA	NA	NA	NA	NA
	09/11/2012		1.6	110	22	NA	NA	NA	NA	NA	NA	NA	NA
LC34-BW0003A	04/19/2011	23 to 26	0.29 U	110	94	NA	NA	NA	NA	NA	NA	0.30 U	0.20 U
	08/02/2011		12	240	110	NA	NA	NA	NA	NA	NA	0.60 U	0.20 U
	08/02/2011*		12	250	110	NA	NA	NA	NA	NA	NA	NA	NA
	10/26/2011		1.9	53	94	NA	NA	NA	NA	NA	NA	0.60 U	0.20 U
	02/15/2012		0.29 U	5.4	15	NA	NA	NA	NA	NA	NA	0.60 U	0.20 U
	06/27/2012		1.1	24	82	NA	NA	NA	NA	NA	NA	NA	NA
	09/11/2012		0.29 U	11	110	NA	NA	NA	NA	NA	NA	NA	NA

Location	Sample Date	Screen Interval (ft BLS)	Concentration (µg/L)			Concentration (mg/L)							
			Ethane	Ethene	Methane	Nitrate-N	Nitrite-N	Sulfate	Sulfide	Chloride	Alkalinity	Bromide	Iodide
LC34-BW0003B	04/19/2011	30 to 33	0.29 U	160	97	NA	NA	NA	NA	NA	NA	0.30 U	0.20 U
	08/02/2011		24	410	85	NA	NA	NA	NA	NA	NA	7.7	9.6
	10/27/2011		2.3	99	95	NA	NA	NA	NA	NA	NA	1.2	0.20 U
	02/15/2012		0.29 U	11	24	NA	NA	NA	NA	NA	NA	0.60 U	0.20 U
	06/27/2012		0.29 U	20	76	NA	NA	NA	NA	NA	NA	NA	NA
	09/11/2012		0.29 U	12	99	NA	NA	NA	NA	NA	NA	NA	NA
LC34-BW0003C	04/19/2011	37 to 40	0.29 U	260	96	0.07 U	0.90 U	34	0.48 U	490	279	0.30 U	0.20 U
	07/07/2011		NA	NA	NA	NA	NA	NA	NA	NA	NA	36	58
	08/02/2011		15	150	710	0.20 U	0.80 U	3.4	14.6	329	760	52	64.1
	08/02/2011*		NA	NA	NA	NA	NA	NA	14.7	NA	746	NA	NA
	10/27/2011		12	770	300	0.20 U	0.80 U	13	4.9	360	313	1.5	0.20 U
	02/15/2012		2.9 U	640	240	0.20 U	0.004 U	35	4.2	237	308	0.60 U	0.20 U
	02/15/2012 *		NA	NA	NA	NA	NA	NA	NA	NA	310	NA	NA
	06/27/2012		13	620	210	NA	NA	NA	NA	NA	NA	NA	NA
	09/13/2012		9.6	410	180	NA	NA	NA	NA	NA	NA	NA	NA
LC34-BW0003D	04/19/2011	44 to 47	0.29 U	4.5	44	NA	NA	NA	NA	NA	NA	1.3	0.20 U
	04/19/2011*		1.0 U	4.3	43	NA	NA	NA	NA	NA	NA	NA	NA
	07/07/2011		NA	NA	NA	NA	NA	NA	NA	NA	NA	24	0.20 U
	08/02/2011		20	5.5	18	NA	NA	NA	NA	NA	NA	38	0.20 U
	10/26/2011		11	35	1,800	NA	NA	NA	NA	NA	NA	11	0.20 U
	02/15/2012		7.3 U	310	1,700	NA	NA	NA	NA	NA	NA	5.7	3.3
	06/27/2012		26	910	1,400	NA	NA	NA	NA	NA	NA	NA	NA
	09/13/2012		26	1,200	1,400	NA	NA	NA	NA	NA	NA	NA	NA
LC34-BW0003E	04/19/2011	51 to 54	0.29 U	0.30 U	6.5	NA	NA	NA	NA	NA	NA	1.3	0.20 U
	07/07/2011		NA	NA	NA	NA	NA	NA	NA	NA	NA	45	0.20 U
	08/02/2011		0.29 U	1.7	30	NA	NA	NA	NA	NA	NA	58	0.20 U
	10/27/2011		0.29 U	4.1	2,000	NA	NA	NA	NA	NA	NA	8.8	0.20 U
	02/15/2012		6.1	310	390	NA	NA	NA	NA	NA	NA	3.2	0.20 U
	06/27/2012		18	850	680	NA	NA	NA	NA	NA	NA	NA	NA
	09/13/2012		21	1,000	920	NA	NA	NA	NA	NA	NA	NA	NA
LC34-BW0003F	04/19/2011	58 to 61	0.29 U	0.03 U	7.0	NA	NA	NA	NA	NA	NA	1.4	0.20 U
	08/02/2011		0.29 U	0.30 U	750	NA	NA	NA	NA	NA	NA	2.5	0.20 U
	08/02/2011*		0.29 U	0.30 U	850	NA	NA	NA	NA	NA	NA	NA	NA
	10/27/2011		1.5	5.1	170	NA	NA	NA	NA	NA	NA	3.1	0.20 U
	02/15/2012		7.8	450	570	NA	NA	NA	NA	NA	NA	2.7	0.20 U
	06/27/2012		10 U	85	1,300	NA	NA	NA	NA	NA	NA	NA	NA
	09/13/2012		20 U	290	1,100	NA	NA	NA	NA	NA	NA	NA	NA
LC34-IW0002I	04/18/2011	25 to 30	0.29 U	19	61	0.07 U	0.05 U	51	0.50 U	73	250	0.30 U	0.20 U
	08/01/2011		23	7.1	44	0.20 U	0.30 U	0.50 U	1.3	138	632	35	45
	10/26/2011		6.2	29	69	0.20 U	0.10 U	31	2.7	65	285	2.7	2.5
	02/15/2012		3.8	9.2	51	0.20 U	0.004 U	44	0.20 U	52	228	0.60 U	0.20 U
	06/26/2012		1.6	5.5	35	NA	NA	NA	NA	NA	NA	NA	NA
	09/13/2012		1.6	3.1	24	NA	NA	NA	NA	NA	NA	NA	NA
LC34-IW0002D	04/18/2011	35 to 40	0.29 U	110	110	0.07 U	0.30 U	32	0.48 U	301	318	0.30 U	0.20 U
	08/01/2011		48	28	43	0.20 U	1.0 U	0.50 U	3.4	352	1,150	9.1	42
	10/26/2011		48	120	230	0.20 U	0.60 U	8.0	11	227	642	20	18
	02/16/2012		13	44	660	0.20 U	0.004 U	0.50 U	7.6	97	420	11	11
	06/26/2012		40	920	970	NA	NA	NA	NA	NA	NA	NA	NA
	09/13/2012		24	670	310	NA	NA	NA	NA	NA	NA	NA	NA

Location	Sample Date	Screen Interval (ft BLS)	Concentration (µg/L)			Concentration (mg/L)							
			Ethane	Ethene	Methane	Nitrate-N	Nitrite-N	Sulfate	Sulfide	Chloride	Alkalinity	Bromide	Iodide
LC34-IW0002D1	04/18/2011	50 to 55	0.29 U	0.30 U	8.6	0.07 U	0.90 U	105	0.48 U	628	167	1.6	0.20 U
	08/01/2011		20	29	5,600	0.20 U	2.0 U	0.50 U	6.2	451	660	9.0	5.1
	08/01/2011*		22	31	5,800	NA	NA	NA	NA	NA	NA	NA	NA
	10/26/2011		2.9	140	390	0.20 U	1.0 U	43	9.1	650	244	3.5	0.20 U
	02/16/2012		7.6	370	240	0.20 U	0.004 U	5.1	14.4	572	301	4.7	2.2
	06/26/2012		32	1,400	1,300	NA	NA	NA	NA	NA	NA	NA	NA
	09/13/2012		30	1,600	2,700	NA	NA	NA	NA	NA	NA	NA	NA
LC34-IW0076	04/18/2011	70 to 80	0.29 U	0.30 U	5.8	NA	NA	NA	NA	NA	NA	0.30 U	0.20 U
	08/01/2011		0.29 U	0.30 U	7.7	NA	NA	NA	NA	NA	NA	1.2	0.20 U
	10/25/2011		0.29 U	0.30 U	790	NA	NA	NA	NA	NA	NA	2.5	0.20 U
	02/15/2012		2.9 U	3.0 U	780	NA	NA	NA	NA	NA	NA	1.9	0.20 U
	06/26/2012		2.9 U	3.0 U	980	NA	NA	NA	NA	NA	NA	NA	NA
	09/13/2012		0.73 U	6.7	210	NA	NA	NA	NA	NA	NA	NA	NA
LC34-RW0007	03/22/2011	35 to 42	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.7	0.20 U
	03/28/2011		80	8.6	40	0.07 U	0.50 U	59	1.1	664	227	0.30 U	0.20 U
	04/07/2011		NA	NA	NA	NA	NA	NA	NA	NA	NA	1.3	0.20 U
	04/19/2011		0.29 U	11	47	0.07 U	0.90 U	61	1.0	642	223	1.5	0.20 U
	04/19/2011*		0.29 U	11	47	0.07 U	0.90 U	61	0.48 U	645	221	NA	NA
	07/07/2011		NA	NA	NA	NA	NA	NA	NA	NA	NA	17	2.1
	08/01/2011		61	9.8	35	0.20 U	1.0 U	0.50 U	1.7	519	510	28	2.3
	08/12/2011		55	14	93	0.05 U	0.004 U	18	9.2	264	460	12	15
	08/18/2011		53	14	76	0.20 U	1.0 U	0.50 U	15	421	510	26	17
	08/18/2011*		NA	NA	NA	0.20 U	NA	0.50 U	NA	NA	NA	25	NA
	08/24/2011		50	12	100	0.20 U	1.0 U	0.50 U	25	516	498	20	11
	08/31/2011		49	15	150	0.20 U	1.0 U	2.3	23	487	472	18	11
	09/15/2011		48	33	290	0.20 U	1.0 U	0.50 U	21	512	445	13	10
	09/28/2011		46	53	380	0.20 U	1.0 U	0.50 U	20	509	440	16	12
	10/13/2011		48	86	420	0.20 U	1.0 U	0.50 U	17	433	468	18	15
	10/26/2011		39	110	330	0.20 U	1.0 U	2.1	17	437	468	14	14
	11/10/2011		44	150	520	0.20 U	0.004 U	0.50 U	16	472	470	21	13
	11/22/2011		41	190	510	0.20 U	0.004 U	2.1	18	469	430	14	11
	12/15/2011		46	300	1,100	0.20 U	0.004 U	4.3	14	384	455	13	11
	01/05/2012		30	740	3,200	0.20 U	0.004 U	3.7	14	199	460	7.3	12
	01/26/2012		45	480	1,300	0.20 U	0.004 U	2.2	15	431	368	7.8	7.9
	02/14/2012		37	500	1,100	0.20 U	0.004 U	4.2	15	409	390	8.0	7.2
	06/26/2012		41	1,200	1,700	NA	NA	NA	NA	NA	NA	NA	NA
	09/13/2012		11	370	360	NA	NA	NA	NA	NA	NA	NA	NA

Location	Sample Date	Screen Interval (ft BLS)	Concentration (µg/L)			Concentration (mg/L)							
			Ethane	Ethene	Methane	Nitrate-N	Nitrite-N	Sulfate	Sulfide	Chloride	Alkalinity	Bromide	Iodide
LC34-RW0008	03/22/2011	47 to 57	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.1	0.20 U
	03/28/2011		3.1	0.30 U	7.7	0.07 U	0.50 U	91	0.50 U	665	168	1.8	0.20 U
	04/07/2011		NA	NA	NA	NA	NA	NA	NA	NA	NA	1.4	0.20 U
	04/19/2011		0.29 U	0.30 U	8.8	0.07 U	0.90 U	92	0.50 U	675	173	1.7	0.20 U
	04/19/2011*		0.29 U	11	47	0.07 U	0.90 U	61	0.48 U	645	221	NA	NA
	07/07/2011		NA	NA	NA	NA	NA	NA	NA	NA	NA	4.8	0.20 U
	08/01/2011		16	310	30	0.20 U	2.0 U	0.50 U	2.9	602	279	4.8	0.20 U
	08/01/2011*		NA	NA	NA	0.20 U	1.0 U	0.50 U	NA	629	NA	NA	NA
	08/12/2011		7.8	2.0	120	0.05 U	0.004 U	23	10	594	378	17	0.20 U
	08/18/2011		5.2	7.8	300	0.20 U	1.0 U	3.2	16	641	369	8.4	0.20 U
	08/24/2011		4.3	9.3	370	0.20 U	1.0 U	0.50 U	20	604	368	8.2	0.20 U
	08/31/2011		3.8	23	520	0.20 U	1.0 U	3.7	19	590	329	5.6	0.20 U
	09/15/2011		4.4	26	430	0.20 U	1.0 U	17	15	609	299	4.8	0.20 U
	09/28/2011		5.6	28	410	0.20 U	1.0 U	13	14	633	271	2.8	0.20 U
	10/13/2011		7.4	71	460	0.20 U	1.0 U	16	15	624	287	4.2	0.20 U
	10/26/2011		8.8	95	400	0.20 U	1.0 U	14	15	632	288	4.5	0.20 U
	11/10/2011		10	140	450	0.20 U	0.004 U	7.3	14	652	300	4.5	0.20 U
	11/22/2011		10	190	450	0.20 U	0.004 U	7.3	15	620	294	4.0	0.20 U
	12/15/2011		13	270	600	0.20 U	0.004 U	7.0	14	605	321	5.3	0.20 U
	01/05/2012		13	320	670	0.20 U	0.004 U	3.9	14	679	314	4.5	0.20 U
	01/26/2012		13	370	490	0.20 U	0.004 U	3.5	13	622	288	4.8	0.20 U
	02/14/2012		13	450	510	0.20 U	0.004 U	2.9	13	621	300	4.3	0.20 U
	06/26/2012		23	910	620	NA	NA	NA	NA	NA	NA	NA	NA
	09/13/2012		30	940	760	NA	NA	NA	NA	NA	NA	NA	NA

Notes:

1. ft BLS indicates feet below land surface.
2. µg/L indicates micrograms per liter.
3. mg/L indicates milligrams per liter.
4. U indicates result not detected above method detection limit (MDL).
5. NA indicates not analyzed.
6. * indicates duplicate sample.

Table 17: Summary of Groundwater Sampling Results: Dissolved Metals (NASA 2013)

Location	Sample Date	Screen Interval (ft BLS)	Concentration (µg/L)		
			Arsenic	Iron	Manganese
Groundwater Cleanup Target Level (µg/L)			10	300	50
Natural Attenuation Default Concentration (µg/L)			100	3,000	500
LC34-BW0001A	04/18/2011	23 to 26	4.0 U	230	31
	08/01/2011		2.0 U	20 U	29
	10/25/2011		2.0 U	130	24
	02/16/2012		2.0 U	30 U	18
LC34-BW0001B	04/18/2011	30 to 33	4.0 U	110	25
	08/01/2011		2.0 U	20 U	28
	10/25/2011		2.0 U	**380**	43
	02/16/2012		2.0 U	30 U	17
LC34-BW0001C	04/18/2011	37 to 40	4.0 U	110	17
	08/01/2011		2.0 U	120	30
	10/25/2011		2.0 U	120	39
	02/16/2012		2.0 U	140	**57**
LC34-BW0001D	04/18/2011	44 to 47	4.0 U	110	34
	08/01/2011		2.0 U	20 U	29
	10/25/2011		2.0 U	230	41
	02/16/2012		2.0 U	30 U	47
LC34-BW0001E	04/18/2011	51 to 54	4.0 U	60 U	16
	08/01/2011		2.0 U	20 U	17
	10/25/2011		2.0 U	30 U	18
	02/16/2012		2.0 U	30 U	13
LC34-BW0001F	04/18/2011	58 to 61	4.0 U	110	13
	08/01/2011		2.0 U	**350**	36
	10/25/2011		2.0 U	130	13
	02/16/2012		2.0 U	30 U	12

Location	Sample Date	Screen Interval (ft BLS)	Concentration (µg/L)		
			Arsenic	Iron	Manganese
Groundwater Cleanup Target Level (µg/L)			10	300	50
Natural Attenuation Default Concentration (µg/L)			100	3,000	500
LC34-IW0002I	04/18/2011	25 to 30	4.0 U	60 U	31
	08/01/2011		2.0 U	**3,500**	**126**
	10/26/2011		2.0 U	**550**	**100**
	02/15/2012		2.0 U	30 U	**69**
LC34-IW0002D	04/18/2011	35 to 40	4.0 U	110	11
	08/01/2011		2.0 U	**1,590**	**198**
	10/26/2011		2.0 U	30 U	**98**
	02/16/2012		2.0 U	30 U	**57**
LC34-IW0002D1	04/18/2011	50 to 55	4.0 U	110	13
	08/01/2011		2.0 U	20 U	**60**
	08/01/2011*		2.0 U	20 U	**59**
	10/26/2011		2.0 U	30 U	13
	02/16/2012		2.0 U	30 U	14
LC34-IW0076	04/18/2011	70 to 80	4.0 U	60 U	11
	08/01/2011		2.0 U	20 U	2.0 U
	08/01/2011*		2.0 U	20 U	10
	10/25/2011		2.0 U	30 U	13
	02/15/2012		2.0 U	30 U	14

Location	Sample Date	Screen Interval (ft BLS)	Concentration (µg/L)		
			Arsenic	Iron	Manganese
Groundwater Cleanup Target Level (µg/L)			10	300	50
Natural Attenuation Default Concentration (µg/L)			100	3,000	500
LC34-RW0007	04/19/2011	35 to 42	4.0 U	120	10
	04/19/2011*		4.0 U	60 U	2 U
	08/01/2011		2.0 U	**880**	**91**
	08/12/2011		2.0 U	20 U	12 B
	08/18/2011		2.0 U	20 U	19
	08/24/2011		2.0 U	20 U	25
	08/31/2011		2.0 U	200	23
	09/15/2011		2.0 U	20 U	23
	09/28/2011		2.0 U	140	21
	10/13/2011		2.0 U	20 U	23
	10/26/2011		2.0 U	30 U	20
	11/10/2011		2.0 U	30 U	22
	11/22/2011		2.0 U	30 U	22
	12/15/2011		2.0 U	30 U	15
	01/05/2012		2.0 U	30 U	19
	01/26/2012		2.0 U	30 U	25
	02/14/2012		10 U	100 U	15

Location	Sample Date	Screen Interval (ft BLS)	Concentration (µg/L)		
			Arsenic	Iron	Manganese
Groundwater Cleanup Target Level (µg/L)			10	300	50
Natural Attenuation Default Concentration (µg/L)			100	3,000	500
LC34-RW0008	04/19/2011	47 to 57	4.0 U	120	15
	04/19/2011*		4.0 U	60 U	14
	08/01/2011		2.0 U	**690**	**86**
	08/12/2011		2.0 U	180 B	23 B
	08/18/2011		2.0 U	120	20
	08/24/2011		2.0 U	20 U	22
	08/31/2011		2.0 U	190	21
	09/15/2011		2.0 U	20 U	16
	09/28/2011		2.0 U	140	16
	10/13/2011		2.0 U	20 U	15
	10/26/2011		2.0 U	30 U	15
	11/10/2011		2.0 U	30 U	16
	11/22/2011		2.0 U	30 U	16
	12/15/2011		2.0 U	30 U	12
	01/05/2012		2.0 U	30 U	15
	01/26/2012		2.0 U	30 U	15
	02/14/2012		10 U	100 U	12
	02/14/2012 *		10 U	100 U	12

Notes:

1. ft BLS indicates feet below land surface.
2. µg/L indicates micrograms per liter.
3. B indicates constituent detected in associated method blank.
4. U indicates result not detected above method detection limit (MDL).
5. Bold text indicates an exceedance of the Florida Department of Environmental Protection (FDEP) Groundwater Cleanup Target Level
6. Shaded cell indicates an exceedance of the FDEP Natural Attenuation Default Concentration.
7. *indicates duplicate sample.

Table 18: PED Injection Amendment Sampling Results (NASA 2013)

Batch Number	Sample Date	Concentration		
		µg/L	mg/L	
		n-Butyl Acetate	Bromide	Iodide
BATCH 10	06/21/2011	2,500,000	65	NA
BATCH 17	06/21/2011	1,900,000	111	70
BATCH 26	06/21/2011	2,200,000	109	150
BATCH 29	06/22/2011	2,500,000	71	NA
BATCH 39	06/22/2011	7,700,000	88	NA
BATCH 40	06/22/2011	4,700,000	86	115
BATCH 49	06/22/2011	6,600,000	72	146
BATCH 54	06/23/2011	3,400,000	65	NA
BATCH 57	06/23/2011	2,400,000	65	NA
BATCH 67	06/23/2011	1,700,000	71	102
BATCH 112	06/27/2011	3,800,000	76	100
BATCH 117	06/27/2011	1,800,000	69	145
BATCH 127	06/27/2011	1,100,000	68	NA
BATCH 134	06/27/2011	2,300,000	69	NA
BATCH 136	06/28/2011	2,500,000	63	105
BATCH 144	06/28/2011	1,800,000	17	27
BATCH 152	06/28/2011	2,100,000	64	NA

Notes:

1. µg/L indicates micrograms per liter.
2. mg/L indicates milligrams per liter.
3. NA indicates not analyzed.

Table 19: Summary of DPT Groundwater Sampling Results: Chlorinated Volatile Organic Compounds (NASA 2013)

Location	Sample Date	Sample interval (ft BLS)	Concentration (µg/L)				
			Trichloroethene	cis-1,2-Dichloroethene	trans-1,2-Dichloroethene	Vinyl Chloride	n-Butyl Acetate
Groundwater Cleanup Target Level (µg/L)			3	70	100	1	43
Natural Attenuation Default Concentration (µg/L)			300	700	1,000	100	430
LC34-DPT328	06/30/2011	28 to 32	**4,100**	**45,000**	**500 I**	**240 U,I**	**1,500 J**
	06/30/2011*		**3,800**	**48,000**	**440 I**	**250 I**	**110 U**
	06/30/2011	37 to 41	**1,400**	**52,000**	**330 I**	**1,600**	**19,000**
	06/30/2011*		**1,200 I**	**56,000**	**260 I**	**2,000 I**	**15,000**
	06/30/2011	43 to 47	**2,100**	**34,000**	**210 I**	**120 U,I**	**640 J**
	06/30/2011*		**1,900**	**35,000**	**190 I**	**58 U**	**55 I**
	06/30/2011	49 to 53	**4.5 I**	**250**	10 U	**4.4 I**	26 J
	06/30/2011	55 to 59	1.3	**65**	1.0 U	1.0 U	**440**
LC34-DPT329	06/30/2011	28 to 32	**2,900 U,I**	**4,800 I**	**10,000 U**	**2,400 U,I**	**1,300,000**
	06/30/2011	37 to 41	**11,000**	**11,000**	1,000 U	**240 U,I**	**1,200,000**
	06/30/2011*		**10,000 I**	**14,000 I**	**2,000 U**	**2,300 U**	**1,100,000**
	06/30/2011	43 to 47	**34,000**	**4,900**	**2,000 U**	**480 U,I**	**1,300,000**
	06/30/2011	49 to 53	**9,000**	**5,000 U**	**5,000 U**	**1,200 U,I**	**1,700,000**
LC34-DPT330	06/30/2011	8 to 12	**3.8 I**	**230**	7.0	**12**	**1,600**
	06/30/2011	28 to 32	**1,700**	**38,000**	**510**	**240 I**	**19,000**
	06/30/2011	37 to 41	**640**	**50,000**	**290 I**	**2,300**	**20,000**
	06/30/2011*		**530 I**	**59,000**	**340 I**	**2,500**	**15,000**
	06/30/2011	43 to 47	**3,800**	**20,000**	**2,000 U**	**480 U,I**	**860,000**
	06/30/2011*		**3,500**	**20,000**	**130 I**	**120 U**	**690,000**
	06/30/2011	49 to 53	**58 U,I**	**1,200**	200 U	**48 U,I**	**97,000**
	06/30/2011*		**58 U**	**510 I**	50 U	**58 U**	**76,000**
LC34-DPT331	06/30/2011	14 to 18	**58 U,I**	**14,000**	**390**	**1,000**	**1,700**
	06/30/2011	28 to 32	**24,000**	**15,000**	**2,000 U**	**960 I**	**24,000**
	06/30/2011	37 to 41	**72,000**	**20,000**	**1,000 U**	**240 U,I**	**490,000**
	06/30/2011*		**76,000**	**20,000**	**500 U**	**580 U**	**360,000**
	06/30/2011	43 to 47	**190,000**	**4,700**	**2,000 U**	**480 U,I**	**55,000**
	06/30/2011*		**180,000**	**3,700 I**	**200 U**	**230 U**	**820 I**

Notes:

1. ft BLS indicates feet below land surface.
2. µg/L indicates micrograms per liter.
3. * indicates duplicate sample. All duplicate samples analyzed by fixed base laboratory (CAS), all other samples by mobile laboratory (KB Labs).
4. U indicates result not detected above method detection limit (MDL).
5. I indicates the result is between the MDL and the practical quantitation limit (PQL).
6. J indicates an estimated value; for n-butyl acetate values below PQL are all qualified with J.
7. Bold text indicates an exceedance of the FDEP Groundwater Cleanup Target Level.
8. Shaded cell indicates an exceedance of the FDEP Natural Attenuation Default Concentration.

Table 20: Summary of Soil Sampling Results: *Dehalococcoides and Vinyl Chloride Reductase* (NASA 2013)

Location	Sample Date	Sample Depth (ft BLS)	*Dehalococcoides* (gene copies/g)	*Vinyl Chloride Reductase* (gene copies/g)
LC34-DPT0349	09/10/2012	43.5	2.0E+03 I	6.0E+03 U
	09/10/2012	48	3.0E+03 I	7.0E+03 U
LC34-DPT0350	09/10/2012	37	4.0E+03 I	6.0E+03 U
	09/10/2012	47	7.0E+05 U,I	NA
	09/10/2012	50	1.0E+06	1.0E+06
LC34-DPT0351	09/11/2012	45.5	7.0E+05	1.0E+06
	09/11/2012	47	8.0E+03 U, I	NA
	09/11/2012	48.5	3.0E+04	6.0E+04

Notes:

1. ft BLS indicates feet below land surface.
2. gene copies/g indicates gene copies per gram.
3. U indicates not detected above method detection limit (MDL).
4. I indicates the result is between the MDL and the practical quantitation limit.
5. NA indicates not analyzed.

CHAPTER 5: DISCUSSION AND CONCLUSIONS

Overview

This section summarizes milestones that were achieved as a result of the enhanced bioremediation field implementation, including mass removed and evidence of reductive dechlorination. Additionally, conclusions and recommendations for a path forward for the site and for utilization of nBA as a PED at other sites are provided in the following sections.

Mass Removed and Mass Removal Rates

Mass removal for implementation of enhanced bioremediation using PED was calculated based on groundwater and soil samples collected within the treatment area during the Baseline Flux Phase (pre-PED injection) and System Operation Phase (post-PED injection) to evaluate mass removal and removal rates pre and post PED injection. Furthermore, contaminant mass removal was calculated for the high permeability zone and the low permeability zone separately to compare removal of dissolved phase contaminants in the high permeability zone versus removal of DNAPL source material sorbed in the low permeability zones. Calculations are presented in Appendix F and are summarized in the following sections.

Mass Removed

Baseline Flux Phase (pre-PED Injection; 14 March 2011 to 18 April 2011) – Soil sampling was not conducted pre and post baseline flux phase, per the proposed work plan (NASA 2010);

therefore, mass removal during the baseline flux phase was calculated using groundwater sampling results only. The total CVOC mass present in groundwater in February 2011 (pre-baseline flux) was 112 pounds (lbs) and in April 2011 (post-baseline flux) was 98 lbs; therefore, approximately 14 lbs of CVOCs were removed from the groundwater during the baseline flux phase (12 percent reduction). Of the mass removed, 17 lbs of CVOC mass was calculated to have been removed from the high permeability layer and an increase of 3 lbs was calculated in the low permeability layer, indicating that the mass removed during the baseline flux phase was dissolved phase mass in the high permeability layers above and below the clay. Mass removal was likely a result of extraction and dilution from operation of the recirculation system.

System Operation (post-PED Injection; 9 August 2011 to 11 September 2012) – Groundwater and soil sampling was conducted before and after the system operation phase and the results were used to calculate mass removal during the system operation phase. The total CVOC mass present within the treatment area in August 2011 (pre-system operation) was 248 lbs and in September 2012 (post-system operation) was 138 lbs; therefore, 110 lbs of CVOCs were removed during the system operation phase (44 percent reduction). Of the 110 lbs removed, 78 lbs of CVOC mass was calculated to have been removed from the high permeability layer and 32 lbs was removed from the low permeability layer, indicating that not only dissolved phase mass in the high permeability layer was removed, but source zone material sorbed in the low permeable clay layer was removed as well. Mass removed from the low permeability layer during the system operation phase represented approximately 29 percent of the total mass removed during that phase. Mass removal was likely a result of reductive dechlorination occurring within the treatment area.

Mass Removal Rates

The mass removal rates from the baseline flux and the system operation phases were estimated to compare the mass removal between the system with no PED and with PED (Appendix F). The estimated mass removal rate from the baseline flux phase (recirculation with GAC and no PED injection) was, on average, approximately 0.40 pounds per day (lbs/day) based on mass removed from the baseline sampling to post baseline flux groundwater sampling (February 2011 to April 2011). The estimated mass removal rate for the system operation phase (August 2011 to September 2012) was, on average, approximately 0.28 lbs/day based on groundwater and soil sampling data.

Mass removal rates pre-PED injection (0.40 lbs/day) was greater than that observed during the post-PED injection system operational phase (0.28 lbs/day). The higher mass removal rate observed during baseline flux activities is likely due to the large dissolved CVOC flux available in the subsurface to be immediately extracted by the recirculation system (CVOC mass removal by in-line GAC). Additionally, the baseline flux period was approximately 35 days, versus the system operational period of approximately 399 days. If the baseline flux phase was a longer duration, the removal rate would likely have been less, as the readily available dissolved CVOC mass would be removed and the sorbed mass in the low permeability layers would very slowly desorb. This was demonstrated by the lack of mass removal from the low permeability layer during the baseline flux phase.

<u>**Evidence of Reductive Dechlorination**</u>

Reductions in CVOC concentrations are likely attributed to complete reductive dechlorination as a result of the PED injection, as evidenced by: (i) the production of daughter products relative to the degradation of TCE; (ii) the production of ethene; (iii) the production of dechlorinating microbial mass; and (iv) and reduction of electron donor.

Trend graphs were created for recirculation extraction wells RW0007 and RW0008 and for bundle wells BW0001, BW0002, and BW0003 at depth intervals above, in, and below the clay layer and are provided in Appendix G. These trend graphs were generated showing CVOC concentrations in μg/L to show degradation of TCE and corresponding increases, then degradation, of daughter products as a result of reductive dechlorination.

In general, the baseline sampling results indicated that TCE and cDCE were the CVOCs with the highest concentrations in the monitoring wells and the recirculation extraction wells. In general, TCE and cDCE concentrations decreased during the baseline flux phase (operation of the recirculation system with no electron donor) with no increase in VC concentration (indicating removal via extraction and dilution and not reductive dechlorination). After PED injection and the startup of the recirculation system, TCE and cDCE concentrations generally decreased with an increase in VC concentrations as the degradation process moved forward and increased daughter product production. The highest concentration of TCE was observed in the area around monitoring well BW0001D, which is screened in the clay layer. The trend graph for monitoring well BW0001D shows that TCE decreased throughout the system operation period.

Graphs were also prepared using data from the same wells to demonstrate trends observed between CVOC (molar basis) and TOC concentration reductions and ethene (molar basis) production, indicative of reductive dechlorination (Appendix G).

Average ethene concentration detected in samples collected from treatment zone monitoring wells increased from 52.8 μg/L (pre-injection baseline flux; April 2011) to 408 μg/L (September 2012), indicating complete dechlorination of CVOCs is occurring. In addition, biomass concentration increased significantly, as evidenced by increases in average *Dhc* and *vcrA* concentrations detected in samples collected from treatment zone monitoring wells; *Dhc* increased from $8.5x10^6$ gene copies/L (pre-injection; April 2011) to $5.0x10^7$ gene copies/L (September 2012) and *vcrA* increased from $5.0x10^3$ gene copies/L (April 2011) to $6.8x10^7$ gene copies/L (September 2012).

TOC concentration is shown to generally increase following the injection activities, then decrease through the system operation period, indicating the electron donor was successfully injected into the subsurface, and was being utilized by the indigenous dechlorinating microbial population. Remaining TOC at the site was minimal, with an average TOC concentration of 21 mg/L (September 2012) detected in samples collected from treatment zone monitoring wells, decreasing from 250 mg/L (August 2011) just following injection.

Conclusions and Recommendations

This was the first enhanced bioremediation field implementation using nBA as a PED. nBA was successfully utilized as a PED for bioremediation of the TCE source zone. In reference to the success criteria of the research objective:

- the PED amendment was successfully injected and distributed above, in, and below the low permeability zone, as documented by nBA detections from sampling results (groundwater monitoring well samples, DPT groundwater samples, and DPT soil samples);
- the implementation was successful in reducing contaminant mass in both groundwater and soil, as evidenced by the observed mass removal;
- electron donor was successfully utilized, as evidenced by the observed reductions in TOC; and
- reductions are likely attributed to enhanced reductive dechlorination, as evidenced by corresponding increases in daughter product concentrations, increase in ethene concentration, increase in dechlorinating microbial concentrations, and decreases in TOC.

If reductive dechlorination were to continue to occur at the site on a long term basis, more electron donor would be needed. Based on the low average TOC concentrations at the site following the system operation phase (21 mg/L in September 2012), recommendations were made to perform a second nBA injection in the area where higher concentrations remained (vicinity of bundle well BW0001). Unfortunately, following the conclusion of the PED implementation, Geosyntec no longer performed work at the LC34 site, so it is unknown whether or not a second injection was performed.

This thesis project demonstrated that nBA could successfully be used as a PED to bioremediate a TCE source zone. When compared to other industry electron donors, although effective, nBA was utilized rather quickly, depleting within 12 months, as opposed to two to three years as expected from an electron donor such as a vegetable oil (ARCEE et al. 2004). Based on this alone, it appears that nBA would not be a good candidate for full scale implementation at this or other sites. However, there are many site specific uncertainties that could affect the distribution and utilization rate of electron donor, such as hydraulic conductivity, porosity, and mass distribution (i.e. concentration gradients). To conclude whether or not nBA would be the better option than other industry substrates and provide a true comparative analysis, side-by-side test plots would be recommended at the site, one utilizing nBA and one utilizing a standard substrate. This would ensure both electron donor options are being subjected to the same geophysical and geochemical settings and the same or similar contaminant concentrations.

APPENDIX A: NBA MSDS

Health	1
Fire	3
Reactivity	0
Personal Protection	H

Material Safety Data Sheet
n-Butyl acetate MSDS

Section 1: Chemical Product and Company Identification

Product Name: n-Butyl acetate

Catalog Codes: SLB1183

CAS#: 123-86-4

RTECS: AF7350000

TSCA: TSCA 8(b) inventory: n-Butyl acetate

CI#: Not available.

Synonym:

Chemical Formula: CH3COO(CH2)CH3

Contact Information:

Sciencelab.com, Inc.
14025 Smith Rd.
Houston, Texas 77396

US Sales: **1-800-901-7247**
International Sales: **1-281-441-4400**

Order Online: ScienceLab.com

CHEMTREC (24HR Emergency Telephone), call:
1-800-424-9300

International CHEMTREC, call: 1-703-527-3887

For non-emergency assistance, call: 1-281-441-4400

Section 2: Composition and Information on Ingredients

Composition:

Name	CAS #	% by Weight
{n-}Butyl acetate	123-86-4	100

Toxicological Data on Ingredients: n-Butyl acetate: ORAL (LD50): Acute: 10768 mg/kg [Rat]. DERMAL (LD50): Acute: 17601 mg/kg [Rabbit].

Section 3: Hazards Identification

Potential Acute Health Effects:
Very hazardous in case of ingestion. Hazardous in case of skin contact (irritant), of eye contact (irritant), of inhalation. Slightly hazardous in case of skin contact (permeator).

Potential Chronic Health Effects:
CARCINOGENIC EFFECTS: Not available. MUTAGENIC EFFECTS: Not available. TERATOGENIC EFFECTS: Not available. DEVELOPMENTAL TOXICITY: Not available. The substance is toxic to lungs, the nervous system, mucous membranes. Repeated or prolonged exposure to the substance can produce target organs damage.

Section 4: First Aid Measures

Eye Contact:

Check for and remove any contact lenses. In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. Cold water may be used. Get medical attention.

Skin Contact:
In case of contact, immediately flush skin with plenty of water. Cover the irritated skin with an emollient. Remove contaminated clothing and shoes. Cold water may be used.Wash clothing before reuse. Thoroughly clean shoes before reuse. Get medical attention.

Serious Skin Contact:
Wash with a disinfectant soap and cover the contaminated skin with an anti-bacterial cream. Seek immediate medical attention.

Inhalation:
If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention.

Serious Inhalation: Not available.

Ingestion:
Do NOT induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. Loosen tight clothing such as a collar, tie, belt or waistband. Get medical attention if symptoms appear.

Serious Ingestion: Not available.

Section 5: Fire and Explosion Data

Flammability of the Product: Flammable.

Auto-Ignition Temperature: 421°C (789.8°F)

Flash Points: CLOSED CUP: 23.9°C (75°F). (TAG) OPEN CUP: 37°C (98.6°F) (Cleveland).

Flammable Limits: LOWER: 1.7% UPPER: 7.6%

Products of Combustion: These products are carbon oxides (CO, CO2).

Fire Hazards in Presence of Various Substances:
Flammable in presence of open flames and sparks. Slightly flammable to flammable in presence of oxidizing materials, of acids, of alkalis.

Explosion Hazards in Presence of Various Substances:
Risks of explosion of the product in presence of mechanical impact: Not available. Risks of explosion of the product in presence of static discharge: Not available. Slightly explosive in presence of oxidizing materials, of acids, of alkalis.

Fire Fighting Media and Instructions:
Flammable liquid, soluble or dispersed in water. SMALL FIRE: Use DRY chemical powder. LARGE FIRE: Use alcohol foam, water spray or fog. Cool containing vessels with water jet in order to prevent pressure build-up, autoignition or explosion.

Special Remarks on Fire Hazards: Not available.

Special Remarks on Explosion Hazards: Not available.

Section 6: Accidental Release Measures

Small Spill:
Dilute with water and mop up, or absorb with an inert dry material and place in an appropriate waste disposal container. Finish cleaning by spreading water on the contaminated surface and dispose of according to local and regional authority requirements.

Large Spill:
Flammable liquid. Keep away from heat. Keep away from sources of ignition. Stop leak if without risk. Absorb with DRY earth, sand or other non-combustible material. Do not touch spilled material. Prevent entry into sewers, basements or confined

areas; dike if needed. Be careful that the product is not present at a concentration level above TLV. Check TLV on the MSDS and with local authorities.

Section 7: Handling and Storage

Precautions:
Keep away from heat. Keep away from sources of ignition. Ground all equipment containing material. Do not ingest. Do not breathe gas/fumes/ vapor/spray. Wear suitable protective clothing. In case of insufficient ventilation, wear suitable respiratory equipment. If ingested, seek medical advice immediately and show the container or the label. Avoid contact with skin and eyes.

Storage:
Store in a segregated and approved area. Keep container in a cool, well-ventilated area. Keep container tightly closed and sealed until ready for use. Avoid all possible sources of ignition (spark or flame).

Section 8: Exposure Controls/Personal Protection

Engineering Controls:
Provide exhaust ventilation or other engineering controls to keep the airborne concentrations of vapors below their respective threshold limit value. Ensure that eyewash stations and safety showers are proximal to the work-station location.

Personal Protection:
Splash goggles. Lab coat. Vapor respirator. Be sure to use an approved/certified respirator or equivalent. Gloves.

Personal Protection in Case of a Large Spill:
Splash goggles. Full suit. Vapor respirator. Boots. Gloves. A self contained breathing apparatus should be used to avoid inhalation of the product. Suggested protective clothing might not be sufficient; consult a specialist BEFORE handling this product.

Exposure Limits:
TWA: 150 CEIL: 200 TWA: 710 CEIL: 950 Consult local authorities for acceptable exposure limits.

Section 9: Physical and Chemical Properties

Physical state and appearance: Liquid.

Odor: Not available.

Taste: Not available.

Molecular Weight: 116.16 g/mole

Color: Not available.

pH (1% soln/water): Not available.

Boiling Point: 126.5°C (259.7°F)

Melting Point: -77.9 (-108.2°F)

Critical Temperature: Not available.

Specific Gravity: 0.9 (Water = 1)

Vapor Pressure: 1.3 kPa (@ 20°C)

Vapor Density: 4.01 (Air = 1)

Volatility: Not available.

Odor Threshold: 0.31 ppm

Water/Oil Dist. Coeff.: The product is equally soluble in oil and water; log(oil/water) = 0

Ionicity (in Water): Not available.

Dispersion Properties: See solubility in water.

Solubility: Partially soluble in cold water.

Section 10: Stability and Reactivity Data

Stability: The product is stable.

Instability Temperature: Not available.

Conditions of Instability: Not available.

Incompatibility with various substances: Not available.

Corrosivity: Non-corrosive in presence of glass.

Special Remarks on Reactivity: Not available.

Special Remarks on Corrosivity: Not available.

Polymerization: Will not occur.

Section 11: Toxicological Information

Routes of Entry: Eye contact. Inhalation. Ingestion.

Toxicity to Animals:
WARNING: THE LC50 VALUES HEREUNDER ARE ESTIMATED ON THE BASIS OF A 4-HOUR EXPOSURE. Acute oral toxicity (LD50): 10768 mg/kg [Rat]. Acute dermal toxicity (LD50): 17601 mg/kg [Rabbit]. Acute toxicity of the vapor (LC50): 2000 4 hours [Rat].

Chronic Effects on Humans: Causes damage to the following organs: lungs, the nervous system, mucous membranes.

Other Toxic Effects on Humans:
Very hazardous in case of ingestion. Hazardous in case of skin contact (irritant), of inhalation. Slightly hazardous in case of skin contact (permeator).

Special Remarks on Toxicity to Animals: Not available.

Special Remarks on Chronic Effects on Humans: Not available.

Special Remarks on other Toxic Effects on Humans: Not available.

Section 12: Ecological Information

Ecotoxicity: Not available.

BOD5 and COD: Not available.

Products of Biodegradation:
Possibly hazardous short term degradation products are not likely. However, long term degradation products may arise.

Toxicity of the Products of Biodegradation: The products of degradation are more toxic.

Special Remarks on the Products of Biodegradation: Not available.

Section 13: Disposal Considerations

Waste Disposal:

Section 14: Transport Information

DOT Classification: CLASS 3: Flammable liquid.

Identification: : Butyl acetate UNNA: UN1123 PG: III

Special Provisions for Transport: Not available.

Section 15: Other Regulatory Information

Federal and State Regulations:
Pennsylvania RTK: n-Butyl acetate Massachusetts RTK: n-Butyl acetate TSCA 8(b) inventory: n-Butyl acetate CERCLA: Hazardous substances.: n-Butyl acetate

Other Regulations: OSHA: Hazardous by definition of Hazard Communication Standard (29 CFR 1910.1200).

Other Classifications:

WHMIS (Canada):
CLASS B-2: Flammable liquid with a flash point lower than 37.8°C (100°F). CLASS D-2B: Material causing other toxic effects (TOXIC).

DSCL (EEC):
R10- Flammable. R20- Harmful by inhalation. R36/38- Irritating to eyes and skin.

HMIS (U.S.A.):

- **Health Hazard:** 1
- **Fire Hazard:** 3
- **Reactivity:** 0
- **Personal Protection:** h

National Fire Protection Association (U.S.A.):

- **Health:** 1
- **Flammability:** 3
- **Reactivity:** 0
- **Specific hazard:**

Protective Equipment:
Gloves. Lab coat. Vapor respirator. Be sure to use an approved/certified respirator or equivalent. Wear appropriate respirator when ventilation is inadequate. Splash goggles.

Section 16: Other Information

References: Not available.

Other Special Considerations: Not available.

Created: 10/10/2005 08:15 PM

Last Updated: 05/21/2013 12:00 PM

The information above is believed to be accurate and represents the best information currently available to us. However, we make no warranty of merchantability or any other warranty, express or implied, with respect to such information, and we assume

APPENDIX B: DRILLING TECHNIQUES

DRILLING TECHNIQUES

Overview

As a part of the partitioning electron donor (PED) injection field implementation, recirculation extraction, recirculation injection, and monitoring wells were installed using three different drilling techniques: (i) hollow stem auger (HSA); (ii) mud rotary; and (iii) direct push technology (DPT). These drilling techniques are described in more detail below.

Hollow Stem Auger

As part of the PED injection implementation, HSA drilling was used to install the recirculation extraction and injection wells. HSA drilling involves using hollow drill stems with spiral-shaped flights that are rotated into the ground, using purely mechanical means, for borehole advancement. The tooling typically comes in 5-foot sections which are bolted together above the surface prior to advancing to depth. Soil cuttings are returned to surface as the tooling is advanced and have to be stockpiled and/or containerized as part of drilling activities. Once at depth, the annular space inside of the hollow stem can be utilized for soil or groundwater collection and monitoring well installations. A typical HSA drill rig and tooling is shown in Figure 13.

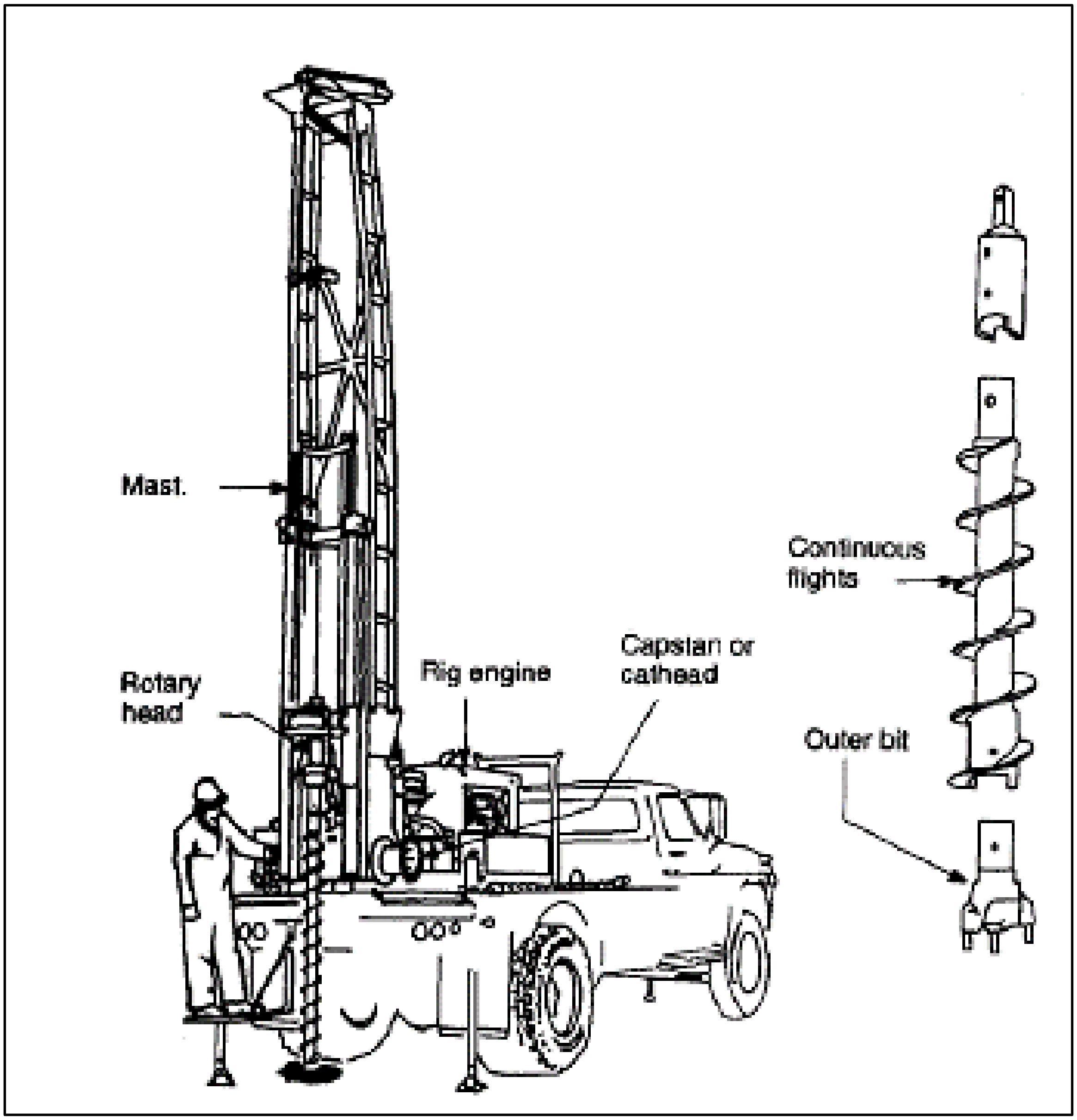


Figure 13: Hollow Stem Auger Rig and Tooling (DSE 2016)

HSA drilling techniques utilize rather simple mechanical components and are relatively cheap rigs to operate, although they generally have a large foot print and tooling can be large and cumbersome (RGC 2016, FDEP 2008). A summary of HSA drilling techniques and advantages and disadvantages is provided in Table 21 below.

Table 21: Hollow Stem Auger Drilling Summary (FDEP 2008)

Method and ASTM Standard	Drilling Principle	Depth Limitation Feet (meters)	Advantages	Disadvantages
Auger, Hollow-Stem and Solid-Stem ASTM D5784, ASTM D1452	Successive 5-foot (1.5m) flights of spiral-shaped drill stem are rotated into the ground to create a borehole. Cuttings are brought to the surface by the rotation of the auger flights	150 (45)	• May be inexpensive • Fairly simple, quick setup time and moderately fast operation • Rigs are highly mobile and can reach most drilling sites • No drilling fluid or lubricants used, eliminating contamination from additives • Can be used to avoid hole caving • Hollow-stem allows formation water to be sampled during drilling via screened auger or advancing a well point ahead of the augers • Small-diameter wells can be built inside hollow-stem flights • Hollow-stem allows the collection of split-spoon samples, continuous sampling possible • Natural gamma-ray logging can be done inside hollow-stem flights	• Limited to unconsolidated or semiconsolidated (weathered rock) materials Compact, gravelly materials may be hard to penetrate • Possible problems controlling heaving sands • Rips and smears borehole wall, creating problems with connecting to the aquifer during well development • Well points yields low rates of water • Small diameter well screen may be hard to develop. Screen may become clogged if thick clays are penetrated • May not be able to run a complete suite of geophysical logs

Mud Rotary

As part of the PED injection implementation, mud rotary drilling was used to install the deep recirculation extraction well (RW0008). HSA tooling was drilled to depth, keying into a semi-confining unit (ie clay layer), as a temporary surface casing, then mud rotary was used to drill through the surface casing to total depth and install the well. Mud rotary drilling involves using a rotating bit to advance tooling while having the soil cuttings removed from the borehole with continuous circulation of a drilling fluid. The drilling fluid is pumped down into the bottom of the borehole through the tooling and out of the bit, then flows upward to surface through the annular space, carrying the soil cuttings with it in suspension. At the surface, the fluids flow through a settling/mud pit, where the soil cutting drop out, and the clean drilling fluids are recirculated into the borehole. The drilling fluid typically consists of a bentonite slurry solution which helps suspend the soil cuttings and maintain borehole integrity during drilling activities (Ruda and Bosscher 2005, FDEP 2008). A typical mud rotary drill rig set up is shown in Figure 14.

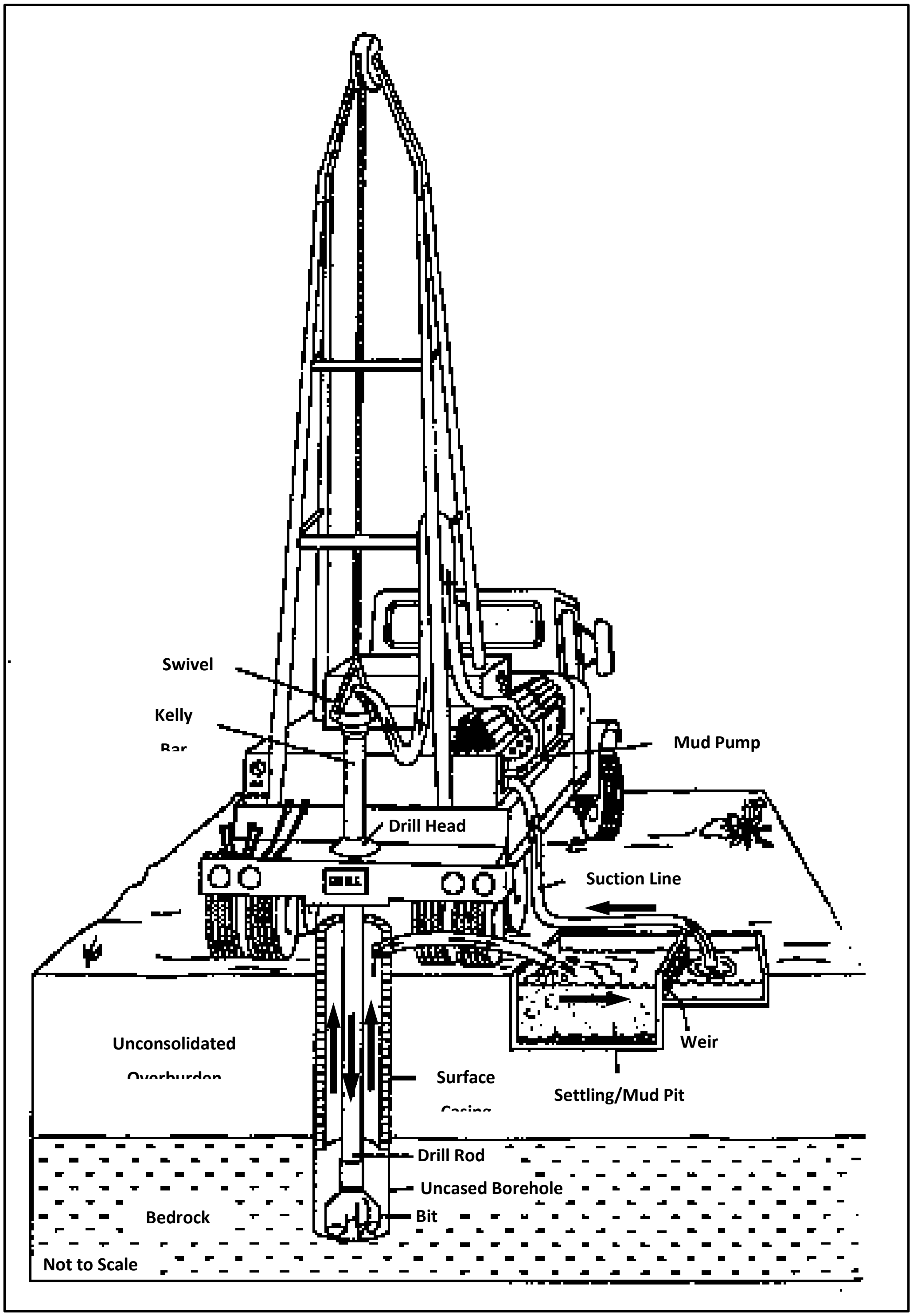


Figure 14: Mud Rotary Technique (Ruda and Bosscher 2005)

Once at depth, the tooling is removed from the uncased, stabilized borehole and can be utilized for soil sampling or well installation. When installing monitoring wells, it is necessary to develop the well until clear to ensure all drilling fluids have been removed (FDEP 2008). A summary of mud rotary drilling techniques and advantages and disadvantages is provided in Table 22 below.

Table 22: Mud Rotary Drilling Summary (FDEP 2008)

Method and ASTM Standard	Drilling Principle	Depth Limitation Feet (meters)	Advantages	Disadvantages
Water/Mud Rotary (Hydraulic Rotary) ASTM D5783	Rotating bit breaks formation; cuttings are brought to the surface by a circulation fluid (mud). Mud (which should be contaminant-free water and bentonite without additives) is forced down the interior of the drill stem, out the bit, and up the annulus between the drill stem and borehole wall. Cuttings are removed by settling in a mud pit at the ground surface and the mud is circulated back down the drill stem.	5,000+ (1,500+)	• Drilling is fairly rapid in all types of geologic materials, unconsolidated and consolidated • Borehole may stay open from formation of a mud wall on the sides of borehole by the circulating mud • Geologic cores can be collected • A complete suite of geophysical logs can be obtained in the open borehole • Many options for well construction. Can use casing-advancement drilling method, or casing may not be required • Smaller rigs can reach most drilling sites • Borehole can be gravel packed and easily grouted	• May be expensive, requires experienced driller and a fair amount of peripheral equipment; overburden casing required • Drilling fluids mix with formation water, may contaminate and can be difficult to remove. • Completed well may be difficult to develop, especially small diameter wells, due to mud cake invading the formation and is difficult to remove • Geological logging by visual inspection is only fair, can miss strata and composition • Location of water-bearing zones during drilling may be difficult to detect • Drilling fluid circulation is often lost and difficult to maintain in fractured rock, and gravel or cavernous zones • Difficult drilling in boulder and cobble zones • Circulation of drilling mud through a contaminated zone can create a hazard a ground surface and cross-contaminate clean zones • Organic drilling fluids can interfere with bacterial and/or organic-related analyses and are not allowed; bentonitic fluids with metal analyses, but may be necessary.

Direct Push Technology

As part of the PED injection implementation, DPT drilling was used to collect soil and groundwater samples and install the monitoring bundle wells. DPT drilling involves pushing tooling (steel rods) into the ground, without the use of drilling to remove soils, to make a path for the tooling. The driving force used to push the tooling into the ground is the static weight of the vehicle combined with percussive blows from a front mounted hydraulic "hammer", as shown in Figure 15.

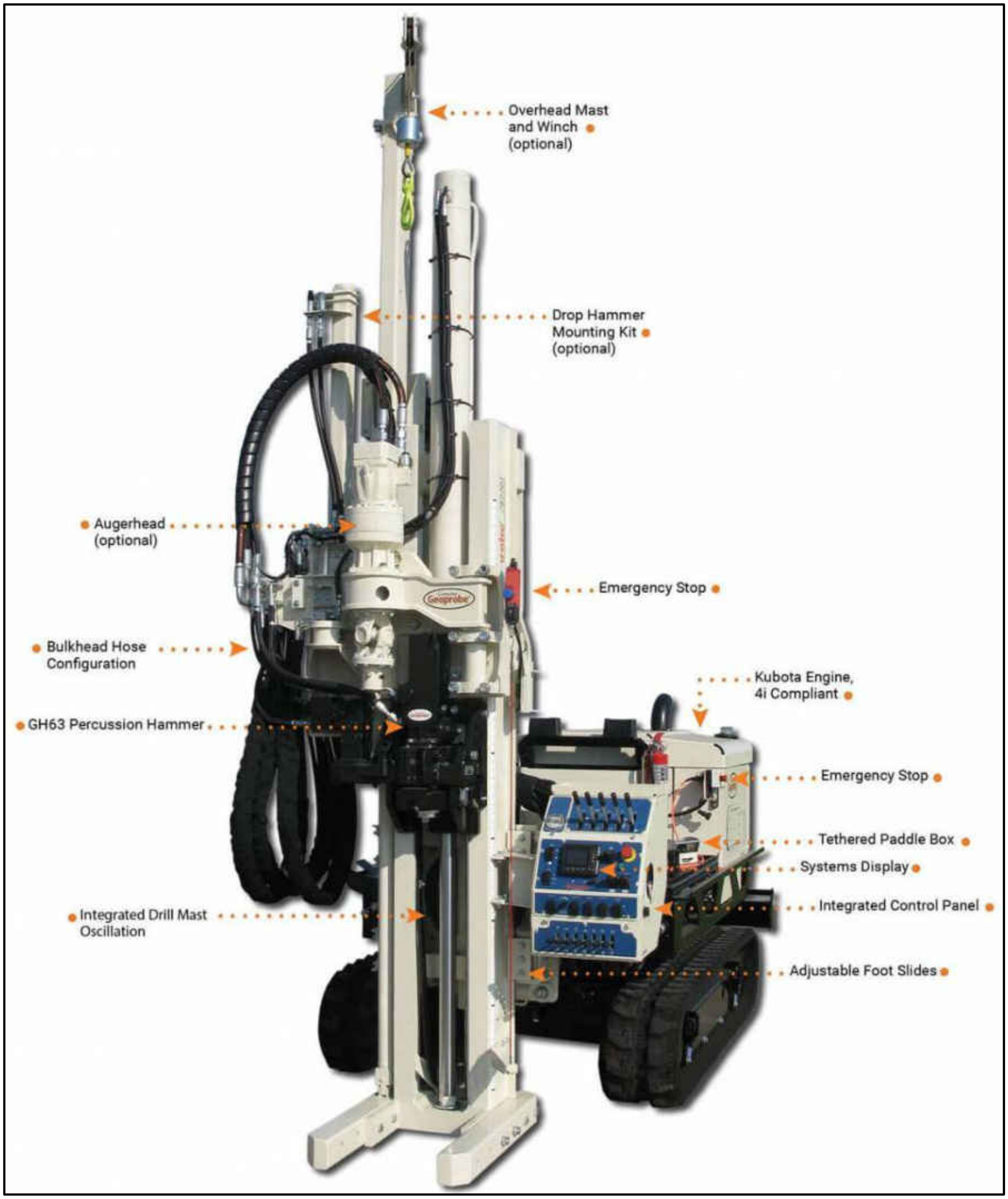


Figure 15: Geoprobe DPT Rig 7822DT (Geoprobe 2016)

DPT drilling can be used for a variety of activities, such as collection of groundwater samples using screens that can be exposed at discrete depths for sampling, collection of continuous soil cores using Geoprobe Macro-cores® (5-foot long by 1.25-inch diameter acetate sleeves that are pushed to depth to collect relatively undisturbed, discrete cores of soil), collection of real-time contaminant and/or hydro-geologic data using specialized probes that can be attached and advanced to depth with the tooling, and installation of wells using hollow casing advanced to depth. Well depth (maximum ~100 feet) and diameter (maximum of 4.5-inch diameter tooling) are limited by DPT rigs' ability to overcome compressive and/or friction forces when advancing tooling into the subsurface, but their small footprint make the machines easy to mobilize and efficient to operate (Geoprobe 2016, FDEP 2008). A table summarizing DPT drilling techniques and advantages and disadvantages is provided in Table 23 below.

Table 23: Direct Push Technology Drilling Summary (FDEP 2008)

Method and ASTM Standard	Drilling Principle	Depth Limitation Feet (meters)	Advantages	Disadvantages
Direct Push ASTM D6724, ASTM D6725	Advances a sampling device into the subsurface by applying static pressure, impacts, or vibrations or any combination thereof to the above ground portion of the sampler extensions until the samples has been advanced its full length into the soil strata.	100 (30)	• Avoids use of drilling fluids and lubricants during drilling • Equipment is highly mobile • Disturbance of geochemical conditions during installation is minimized • Drilling and well screen installation is fast, considerably less labor intensive • Does not produce drill cuttings, reduction of investigation-derived wastes	• Limited to fairly soft materials such as clay, silt, sand and gravel • Compact, gravelly materials may be hard to penetrate • Small diameter well screen may be hard to develop. Screen may become clogged if thick clays are penetrated • The small diameter drive pipe generally precluded conventional borehole geophysical logging • The drive points yield relatively low rates of water

APPENDIX C: PHOTOGRAPHIC RECORD

Geosyntec Consultants Photographic Record		
Client:	NASA	Project Number: FO0552B
Site Name: LC34	Site Location: CCAFS	

Photograph 1	
Date: 1/19/11	
Direction: North	
Comments: Macro-core soil samples were collected, via DPT, prior to installing wells.	
Photograph 2	
Date: 1/19/11	
Direction: East	
Comments: Recovery wells (6″ Sch. 40 PVC) were installed via HSA and bundle wells (3/4″ Sch. 40 PVC) were installed via DPT.	

Geosyntec Consultants
Photographic Record

Client:	NASA	Project Number: FO0552B
Site Name: LC34	Site Location: CCAFS	

Photograph 3	
Date: 1/25/11	
Direction: N/A	
Comments: Recovery wells were completed with an 18″x18″x10″ vault box set in a 36″x36″x4″ concrete pad. Stub outs were installed in the vault box for system piping and electrical conduit.	
Photograph 4	
Date: 1/25/11	
Direction: N/A	
Comments: Injection wells were completed with an 18″x18″x10″ well vault boxes set in a 36″x36″x4″ concrete pad. A stub out was installed in the vault box for system piping.	

Geosyntec Consultants
Photographic Record

Client: NASA Project Number: FO0552B

Site Name: LC34 Site Location: CCAFS

Photograph 5

Date: 1/25/11

Direction: N/A

Comments: Bundle wells were completed with individual 8″ diameter steel manhole covers (6 per bundle well) set in a 6′x6′x4″ concrete pad.

Photograph 6

Date: 3/3/11

Direction: East

Comments: System piping (3/4″ diameter HDPE) was encased in 2″ diameter Sch. 40 PVC and connected the recovery and injection wells to the solar powered recirculation trailer.

Geosyntec Consultants
Photographic Record

Client:	NASA	Project Number: FO0552B
Site Name: LC34	Site Location: CCAFS	

Photograph 7

Date: 3/3/11

Direction: N/A

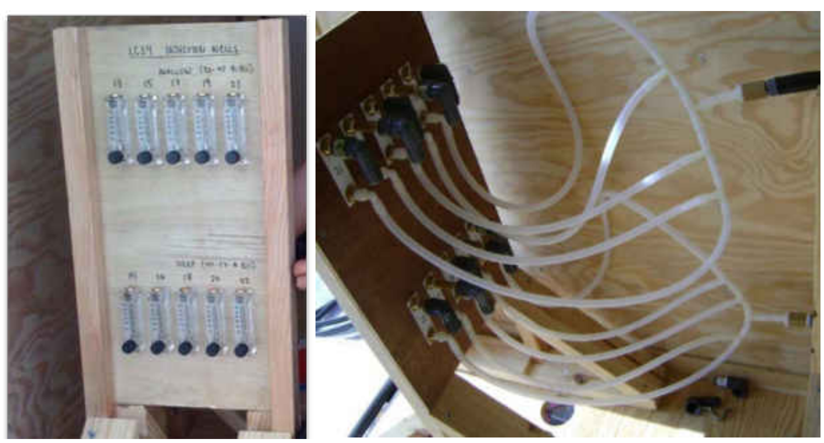
Comments: From the recovery wells, the flow is directed through sediment filters and into flow totalizers, one for each recovery well.

Photograph 8

Date: 3/3/11

Direction: N/A

Comments: From the flow totalizers, the flow is directed into a manifold, splitting it into10 flow streams, 5 to the shallow injection wells and 5 to the deep injection wells.



Geosyntec Consultants
Photographic Record

Client:	NASA	Project Number: FO0552B
Site Name: LC34	Site Location: CCAFS	

Photograph 9

Date: 6/24/11

Direction: South

Comments: 20 injection points were marked with ~5 foot spacing within the treatment zone.

Photograph 10

Date: 6/20/11

Direction: North

Comments: Vironex injection platform was utilized for mixing and injecting the PED amendment.

Geosyntec Consultants
Photographic Record

Client:	NASA	Project Number: FO0552B
Site Name: LC34	Site Location: CCAFS	

Photograph 11

Date: 6/20/11

Direction: West

Comments: n-butyl acetate was added to the PED solution by using a hand crank flow meter for accuracy. All metal components were grounded to reduce the risk of a fire by electrical spark.

Photograph 12

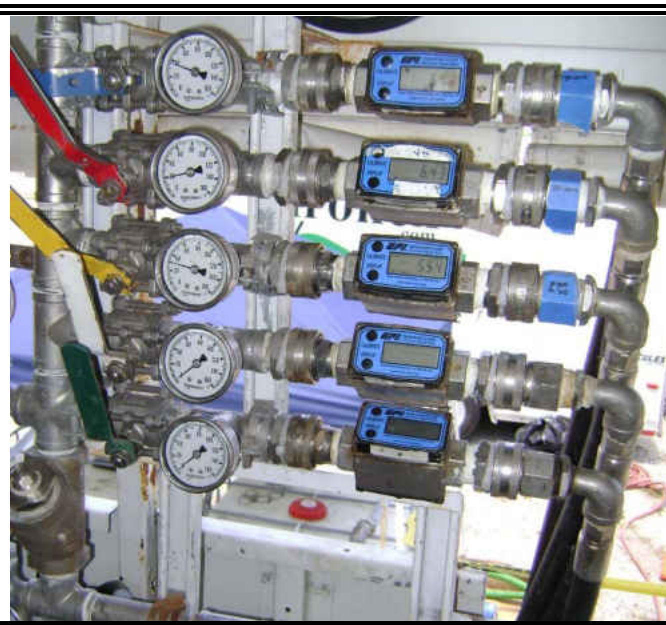
Date: 6/20/11

Direction: East

Comments: The PED solution was mixed, by closed loop recirculation, in batches in 2, 250 gallon totes for 15 minutes each before injection.

Geosyntec Consultants
Photographic Record

Client:	NASA	Project Number: FO0552B
Site Name: LC34	Site Location: CCAFS	

Photograph 13 Date: 6/24/11 Direction: North Comments: The Vironex injection platform was equipped with the necessary pumps, meters, and gauges for injection. The platform was constructed of metal grating over a catch basin to serve as secondary containment in case of a spill.	
Photograph 14 Date: 6/24/11 Direction: East Comments: The injection pressure and flow was metered in real-time to ensure proper distribution of the amendment.	

Geosyntec Consultants
Photographic Record

Client:	NASA	Project Number: FO0552B
Site Name: LC34	Site Location: CCAFS	

Photograph 15

Date: 6/21/11

Direction: North

Comments: From the injection platform, the injection hose was threaded through the DPT tooling prior to drilling.

Photograph 16

Date: 6/21/11

Direction: N/A

Comments: The 2 foot injection tool was demonstrated above grade with water to ensure proper functionality and to measure injection pressure at atmospheric pressure.

APPENDIX D: VIRONEX INJECTION SERVICES REPORT

Injection Services Report

Prepared for:

Geosyntec consultants

Prepared by:

Vironex

LC-34

Cape Canaveral, FL

June 20, 2011 - June 28, 2011

Wilmington, DE • Washington, DC • Denver, CO • Los Angeles, CA • San Francisco, CA
www.vironex.com

Contents

Project Summary

Project Name: LC-34

Project Dates: June 20, 2011 - June 28, 2011

Manpower: Mike Mazzarese (Project Manager); Austin Hittinger (Field Tech); Jacob Haldiman (Field Tech); George Lujan (National Director of Safety)

Equipment: One (1) Custom Vironex Remediation Platform, One (1) Support Truck and Trailer

Proposed SOW: Vironex will inject 34,000 gallons of n-Butyl Acetate solution (3,000 mg/L) into 20 locations over a 40 ft injection interval (23 ft to 63 ft bgs). Potassium Bromide (60 mg/L) and Potassium Iodide (140 mg/L) will be added to the injection solutions as specified in the RFP (Bromide in all injection solutions, Iodide in injection solution below the clay layer only).

Project Summary: Injection services were initiated on Monday June 20, 2011. Upon arrival to the site Vironex set up a containment pad and ran hoses for the remediation platform. The platform and mixing totes were grounded due to the explosiveness of the reagent that was being injected. Prior to the injections, a water test was performed to check the line pressure and ensure that there were no leaks in the remediation system. Vironex sustained flow rates between 6 and 8 gpm while averaging 30 to 45 psi throughout the injection process. During this event there was one location IP – 0018 that had to be slowed down due to rising water levels in a nearby monitoring well (RW – 8). This injection event was successfully completed on Tuesday June 28, 2011 one day ahead of schedule.

Injection Summary

Site LC34 - Cape Canaveral, FL
Injection Summary

	Date	Total nBA Injected (Gal)	Total KBr Injected (g)	Total KI Injected (g)	Total H2O Injected (Gal)	Total Volume Injected (Gal)	Points Completed
Monday	6/20/11	5.8	578.0	1173.0	1694.0	1700.0	1.0
Tuesday	6/21/11	14.4	1445.0	1760.0	4236.0	4250.0	2.5
Wednesday	6/22/11	17.4	1734.0	1759.0	5082.5	5100.0	3.0
Thursday	6/23/11	17.4	1734.0	1759.5	5082.5	5100.0	3.0
Friday	6/24/11	23.1	2318.8	1759.5	6797.0	6820.0	4.0
Monday	6/27/11	20.2	2016.2	1759.0	5910.0	5930.0	3.5
Tuesday	6/28/11	16.7	1734.0	1760.0	5082.0	5100.0	3.0
	Design	115.0	11560.0	11730.0	33885.0	34000.0	20.0
	Injected	115.0	11560.0	11730.0	33884.0	34000.0	20.0
	Daily Average	16.4	1651.4	1675.7	4840.6	4857.1	2.7

Project Photographs

Site Set-up and Tailgate meeting

2 ft Injection tool during water test

Mixing totes and transfer pumps

n Butyl Acetate drum pump in protective vapor shield

Well box locations in the injection area

Injection area

Project Photographs

Injection Rig

Rig Platform

Transfer Line Manifold on top of Progressive Cavity Pump

5 Point Injection Manifold

Gram scale for tracer measurements

Gram Scale

Project Photographs

Copper spike for injection rig grounding wire

Bonding location on injection Rig

Bonding locations on mixing totes

Bonding locations on drum pump and transfer pump

Transfer Pump bonding location

n Butyl Acetate 5 gal. steel drums

Appendix A – Injection Logs

Hot Spot Area One, Launch Complex 34

Cape Canaveral Air Force Station

Vironex Field Data Sheet

Injection Point ID	Start Date	Start Time	End Date	End Time	Tool Length (ft)	Injection Interval	Gal per Interval	Running Total	Average PSI	Average Flow Rate	nBA Injected (gal)	KBr Injected (grams)	KI Injected (grams)	H2O Injected (gal)	Amended Total Gal	Notes
IP-0001	6/20/11	2:06 PM	6/20/11	2:20 PM	2.0	23'-25'	85	85	20	6.0	0.289	28.9	58.7	84.7	85	
	6/20/11	2:20 PM	6/20/11	2:35 PM	2.0	25'-27'	85	170	20	6.0	0.289	28.9	58.7	84.7	85	
	6/20/11	2:35 PM	6/20/11	2:50 PM	2.0	27'-29'	85	255	20	6.0	0.289	28.9	58.7	84.7	85	
	6/20/11	3:35 PM	6/20/11	3:50 PM	2.0	29'-31'	85	340	25	6.0	0.289	28.9	58.7	84.7	85	
	6/20/11	3:50 PM	6/20/11	4:05 PM	2.0	31'-33'	85	425	25	6.0	0.289	28.9	58.7	84.7	85	
Total nBA (gal)	6/20/11	4:05 PM	6/20/11	4:20 PM	2.0	33'-35'	85	510	30	6.0	0.289	28.9	58.7	84.7	85	
5.8	6/20/11	4:20 PM	6/20/11	4:35 PM	2.0	35'-37'	85	595	30	6.0	0.289	28.9	58.7	84.7	85	
	6/20/11	4:35 PM	6/20/201	4:50 PM	2.0	36.5'-38.5'	85	680	30	6.0	0.289	28.9	58.7	84.7	85	Correct the depth error by completing three 1.5 ft pushes to bring the final depth of the day
Total KBr (g)	6/20/11	4:50 PM	6/20/11	5:05 PM	2.0	38'-41'	85	765	35	6.0	0.289	28.9	58.7	84.7	85	to 41.5 feet bgs.
578.0	6/20/11	5:05 PM	6/20/11	5:08 PM	2.0	39.5'-41.5'	85	850	35	6.0	0.289	28.9	58.7	84.7	85	
	6/21/11	7:50 AM	6/21/11	8:05 AM	2.0	42'-44'	85	935	30	5.8	0.289	28.9		84.7	85	First interval with no Potassium Iodide. First push of the day was 2.5ft to get back
Total KI (g)	6/21/11	8:05 AM	6/21/11	8:20 AM	2.0	44'-46'	85	1,020	38	6.0	0.289	28.9		84.7	85	onto the target depth.
586.5	6/21/11	8:20 AM	6/21/11	8:35 AM	2.0	46'-48'	85	1,105	40	6.0	0.289	28.9		84.7	85	
	6/21/11	8:35 AM	6/21/11	8:50 AM	2.0	48'-50'	85	1,190	40	6.0	0.289	28.9		84.7	85	
Total H2O (gal)	6/21/11	8:50 AM	6/21/11	9:05 AM	2.0	50'-52'	85	1,275	50	8.0	0.289	28.9		84.7	85	Increased flow rates.
1694.2	6/21/11	9:05 AM	6/21/11	9:15 AM	2.0	52'-54'	85	1,360	48	8.2	0.289	28.9		84.7	85	
	6/21/11	9:15 AM	6/21/11	9:25 AM	2.0	54'-56'	85	1,445	45	8.0	0.289	28.9		84.7	85	
Total Volume	6/21/11	9:25 AM	6/21/11	9:35 AM	2.0	56'-58'	85	1,530	45	8.0	0.289	28.9		84.7	85	
1700	6/21/11	9:35 AM	6/21/11	9:45 AM	2.0	58'-60'	85	1,615	50	8.0	0.289	28.9		84.7	85	
	6/21/11	9:45 AM	6/21/11	9:55 AM	2.0	60'-62'	85	1,700	40	8.0	0.289	28.9		84.7	85	Successfully completed location. Chased with 10 gal. Flush water.
IP-0002	6/20/11	2:40 PM	6/20/11	3:00 PM	2.0	23'-25'	85	85	18	6.0	0.289	28.9	58.7	84.7	85	
	6/20/11	3:00 PM	6/20/11	3:15 PM	2.0	25'-27'	85	170	20	6.0	0.289	28.9	58.7	84.7	85	
	6/20/11	3:15 PM	6/20/11	3:30 PM	2.0	27'-29'	85	255	20	6.0	0.289	28.9	58.7	84.7	85	
	6/20/11	3:30 PM	6/20/11	3:45 PM	2.0	29'-31'	85	340	20	6.0	0.289	28.9	58.7	84.7	85	
	6/20/11	3:45 PM	6/20/11	4:00 PM	2.0	31'-33'	85	425	22	6.0	0.289	28.9	58.7	84.7	85	
Total nBA (gal)	6/20/11	4:00 PM	6/20/11	4:15 PM	2.0	33'-35'	85	510	25	6.0	0.289	28.9	58.7	84.7	85	
5.8	6/20/11	4:15 PM	6/20/11	4:30 PM	2.0	35'-37'	85	595	30	6.0	0.289	28.9	58.7	84.7	85	
	6/20/11	4:30 PM	6/20/11	4:45 PM	2.0	36.5'-38.5'	85	680	30	6.0	0.289	28.9	58.7	84.7	85	Correct the depth error by completing three 1.5 ft pushes to bring the final depth of the day
Total KBr (g)	6/20/11	4:45 PM	6/20/11	5:00 PM	2.0	38'-41'	85	765	40	6.0	0.289	28.9	58.7	84.7	85	to 41.5 feet bgs.
578.0	6/20/11	5:00 PM	6/20/11	5:08 PM	2.0	39.5'-41.5'	85	850	40	6.0	0.289	28.9	58.7	84.7	85	
	6/21/11	7:50 AM	6/21/11	8:05 AM	2.0	42'-44'	85	935	20	6.0	0.289	28.9		84.7	85	First interval with no Potassium Iodide. First push of the day was 2.5ft to get back
Total KI (g)	6/21/11	8:05 AM	6/21/11	8:20 AM	2.0	44'-46'	85	1,020	15	6.0	0.289	28.9		84.7	85	onto the target depth.
586.5	6/21/11	8:20 AM	6/21/11	8:35 AM	2.0	46'-48'	85	1,105	18	6.0	0.289	28.9		84.7	85	
	6/21/11	8:35 AM	6/21/11	8:50 AM	2.0	48'-50'	85	1,190	20	6.0	0.289	28.9		84.7	85	
Total H2O (gal)	6/21/11	8:50 AM	6/21/11	9:05 AM	2.0	50'-52'	85	1,275	30	8.0	0.289	28.9		84.7	85	Increased flow rates.
1694.2	6/21/11	9:05 AM	6/21/11	9:15 AM	2.0	52'-54'	85	1,360	45	8.3	0.289	28.9		84.7	85	
	6/21/11	9:15 AM	6/21/11	9:25 AM	2.0	54'-56'	85	1,445	45	8.0	0.289	28.9		84.7	85	
Total Volume	6/21/11	9:25 AM	6/21/11	9:35 AM	2.0	56'-58'	85	1,530	40	8.0	0.289	28.9		84.7	85	
1700	6/21/11	9:35 AM	6/21/11	9:45 AM	2.0	58'-60'	85	1,615	45	8.0	0.289	28.9		84.7	85	
	6/21/11	9:45 AM	6/21/11	9:55 AM	2.0	60'-62'	85	1,700	40	8.0	0.289	28.9		84.7	85	Successfully completed location. Chased with 10 gal. Flush water.

Vironex Field Data Sheet

Injection Point ID	Start Date	Start Time	End Date	End Time	Tool Length (ft)	Injection Interval	Gal per Interval	Running Total	Average PSI	Average Flow Rate	nBA Injected (gal)	KBr Injected (grams)	KI Injected (grams)	H2O Injected (gal)	Amended Total Gal	Notes
IP-0003	6/21/11	11:35 AM	6/21/11	11:50 AM	2.0	23'-25'	85	85	22	6.0	0.289	28.9	58.7	84.7	85	
	6/21/11	11:50 AM	6/21/11	12:05 PM	2.0	25'-27'	85	170	25	6.0	0.289	28.9	58.7	84.7	85	
	6/21/11	12:05 PM	6/21/11	12:20 PM	2.0	27'-29'	85	255	25	6.0	0.289	28.9	58.7	84.7	85	Took lunch after this interval.
	6/21/11	1:00 PM	6/21/11	1:10 PM	2.0	29'-31'	85	340	35	8.0	0.289	28.9	58.7	84.7	85	
	6/21/11	1:10 PM	6/21/11	1:20 PM	2.0	31'-33'	85	425	35	8.0	0.289	28.9	58.7	84.7	85	
Total nBA (gal)	6/21/11	1:20 PM	6/21/11	1:30 PM	2.0	33'-35'	85	510	40	8.0	0.289	28.9	58.7	84.7	85	
5.8	6/21/11	1:30 PM	6/21/11	1:40 PM	2.0	35'-37'	85	595	38	8.0	0.289	28.9	58.7	84.7	85	
	6/21/11	1:40 PM	6/21/11	1:50 PM	2.0	37'-39'	85	680	38	8.0	0.289	28.9	58.7	84.7	85	
Total KBr (g)	6/21/11	1:55 PM	6/21/11	3:00 PM	2.0	39'-41'	85	765	35	8.0	0.289	28.9	58.7	84.7	85	
578.0	6/21/11	3:00 PM	6/21/11	3:10 PM	2.0	40'-42'	85	850	35	8.0	0.289	28.9	58.7	84.7	85	1 ft. push to inject in the foot above the clay layer.
	6/22/11	7:40 AM	6/22/11	8:10 AM	2.0	42'-44'	85	935	55	7.5	0.289	28.9		84.7	85	
Total KI (g)	6/22/11	8:10 AM	6/22/11	8:35 AM	2.0	44'-46'	85	1,020	35	5.8	0.289	28.9		84.7	85	
586.5	6/22/11	8:35 AM	6/22/11	8:55 AM	2.0	46'-48'	85	1,105	40	6.0	0.289	28.9		84.7	85	
	6/22/11	8:55 AM	6/22/11	9:20 AM	2.0	48'-50'	85	1,190	40	6.0	0.289	28.9		84.7	85	
Total H2O (gal)	6/22/11	9:20 AM	6/22/11	9:50 AM	2.0	50'-52'	85	1,275	40	6.0	0.289	28.9		84.7	85	
1694.2	6/22/11	9:50 AM	6/22/11	10:25 AM	2.0	52'-54'	85	1,360	40	6.0	0.289	28.9		84.7	85	
	6/22/11	10:25 AM	6/22/11	10:50 AM	2.0	54'-56'	85	1,445	40	6.0	0.289	28.9		84.7	85	
Total Volume	6/22/11	10:50 AM	6/22/11	11:15 AM	2.0	56'-58'	85	1,530	42	6.5	0.289	28.9		84.7	85	
1700	6/22/11	11:15 AM	6/22/11	11:35 AM	2.0	58'-60'	85	1,615	40	6.0	0.289	28.9		84.7	85	
	6/22/11	11:35 AM	6/22/11	12:00 PM	2.0	60'-62'	85	1,700	45	6.0	0.289	28.9		84.7	85	Successfully completed location. Chased with 10 gal. Flush water.
IP-0004	6/21/11	11:35 AM	6/21/11	11:50 AM	2.0	23'-25'	85	85	22	6.0	0.289	28.9	58.7	84.7	85	
	6/21/11	11:50 AM	6/21/11	12:05 PM	2.0	25'-27'	85	170	25	6.0	0.289	28.9	58.7	84.7	85	
	6/21/11	12:05 PM	6/21/11	12:20 PM	2.0	27'-29'	85	255	25	6.0	0.289	28.9	58.7	84.7	85	Took lunch between these intervals.
	6/21/11	1:00 PM	6/21/11	1:10 PM	2.0	29'-31'	85	340	35	8.0	0.289	28.9	58.7	84.7	85	
	6/21/11	1:10 PM	6/21/11	1:20 PM	2.0	31'-33'	85	425	35	8.0	0.289	28.9	58.7	84.7	85	
Total nBA (gal)	6/21/11	1:20 PM	6/21/11	1:30 PM	2.0	33'-35'	85	510	40	8.0	0.289	28.9	58.7	84.7	85	
5.8	6/21/11	1:30 PM	6/21/11	1:40 PM	2.0	35'-37'	85	595	38	8.0	0.289	28.9	58.7	84.7	85	
	6/21/11	1:40 PM	6/21/11	1:50 PM	2.0	37'-39'	85	680	38	8.0	0.289	28.9	58.7	84.7	85	
Total KBr (g)	6/21/11	1:55 PM	6/21/11	3:00 PM	2.0	39'-41'	85	765	35	8.0	0.289	28.9	58.7	84.7	85	
578.0	6/21/11	3:00 PM	6/21/11	3:10 PM	2.0	40'-42'	85	850	35	8.0	0.289	28.9	58.7	84.7	85	1 ft. push to inject in the foot above the clay layer.
	6/22/11	7:40 AM	6/22/11	8:10 AM	2.0	42'-44'	85	935	60	7.0	0.289	28.9		84.7	85	
Total KI (g)	6/22/11	8:10 AM	6/22/11	8:35 AM	2.0	44'-46'	85	1,020	40	5.5	0.289	28.9		84.7	85	
586.5	6/22/11	8:35 AM	6/22/11	8:55 AM	2.0	46'-48'	85	1,105	40	6.0	0.289	28.9		84.7	85	
	6/22/11	8:55 AM	6/22/11	9:20 AM	2.0	48'-50'	85	1,190	40	6.0	0.289	28.9		84.7	85	
Total H2O (gal)	6/22/11	9:20 AM	6/22/11	9:50 AM	2.0	50'-52'	85	1,275	40	6.0	0.289	28.9		84.7	85	
1694.2	6/22/11	9:50 AM	6/22/11	10:25 AM	2.0	52'-54'	85	1,360	40	6.0	0.289	28.9		84.7	85	
	6/22/11	10:25 AM	6/22/11	10:50 AM	2.0	54'-56'	85	1,445	40	6.3	0.289	28.9		84.7	85	
Total Volume	6/22/11	10:50 AM	6/22/11	11:15 AM	2.0	56'-58'	85	1,530	40	6.3	0.289	28.9		84.7	85	
1700	6/22/11	11:15 AM	6/22/11	11:35 AM	2.0	58'-60'	85	1,615	40	6.0	0.289	28.9		84.7	85	
	6/22/11	11:35 AM	6/22/11	12:00 PM	2.0	60'-62'	85	1,700	40	6.0	0.289	28.9		84.7	85	Successfully completed location. Chased with 10 gal. Flush water.

Vironex Field Data Sheet

Injection Point ID	Start Date	Start Time	End Date	End Time	Tool Length (ft)	Injection Interval	Gal per Interval	Running Total	Average PSI	Average Flow Rate	nBA Injected (gal)	KBr Injected (grams)	KI Injected (grams)	H2O Injected (gal)	Amended Total Gal	Notes
IP-0005	6/21/11	3:45 PM	6/21/11	4:30 PM	5.0	23'-28'	213	213	40	8.0	0.724	72.4	147.0	212.3	213	5 ft. injection tool.
	6/21/11	4:30 PM	6/21/11	5:15 PM	5.0	28'-33'	212	425	40	8.0	0.721	72.1	146.3	211.3	212	
	6/21/11	5:15 PM	6/21/11	6:00 PM	5.0	33'-38'	213	637	40	8.0	0.724	72.4	147.0	212.3	213	
	6/21/11	6:00 PM	6/21/11	6:45 PM	5.0	37'-42'	212	850	40	8.0	0.721	72.1	146.3	211.3	212	4 ft. push to inject in the interval above the clay layer.
	6/22/11	7:35 AM	6/22/11	8:35 AM	5.0	42'-47'	213	1,062	55	6.0	0.721	72.1		211.3	212	
Total nBA (gal) 5.8	6/22/11	8:35 AM	6/22/11	9:50 AM	5.0	47'-52'	212	1,275	45	6.5	0.724	72.4		212.3	213	
	6/22/11	9:50 AM	6/22/11	10:50 AM	5.0	52'-57'	213	1,487	50	6.5	0.721	72.1		211.3	212	
	6/22/11	10:50 AM	6/22/11	11:50 AM	5.0	57'-62'	212	1,700	45	6.5	0.724	72.4		212.3	213	Successfully completed location. Chased with 10 gal. Flush water.
Total KBr (g) 578.0																
Total KI (g) 586.5																
Total H2O (gal) 1694.2																
Total Volume 1700																
IP-0006	6/22/11	2:50 PM	6/22/11	3:25 PM	2.0	23'-25'	85	85	10	3.0	0.289	28.9	58.7	84.7	85	Pumped slow to allow the other location to catch up.
	6/22/11	3:25 PM	6/22/11	3:35 PM	2.0	25'-27'	85	170	35	8.0	0.289	28.9	58.7	84.7	85	
	6/22/11	3:35 PM	6/22/11	3:45 PM	2.0	27'-29'	85	255	40	8.0	0.289	28.9	58.7	84.7	85	
	6/22/11	3:45 PM	6/22/11	3:55 PM	2.0	29'-31'	85	340	50	8.0	0.289	28.9	58.7	84.7	85	
	6/22/11	3:55 PM	6/22/11	4:05 PM	2.0	31'-33'	85	425	45	8.0	0.289	28.9	58.7	84.7	85	
Total nBA (gal) 5.8	6/22/11	4:05 PM	6/22/11	4:25 PM	2.0	33'-35'	85	510	40	6.0	0.289	28.9	58.7	84.7	85	
	6/22/11	4:25 PM	6/22/11	4:40 PM	2.0	35'-37'	85	595	40	6.0	0.289	28.9	58.7	84.7	85	
	6/22/11	4:40 PM	6/22/11	4:55 PM	2.0	37'-39'	85	680	35	6.0	0.289	28.9	58.7	84.7	85	
Total KBr (g) 578.0	6/22/11	4:55 PM	6/22/11	5:10 PM	2.0	39'-41'	85	765	55	8.0	0.289	28.9	58.7	84.7	85	
	6/22/11	5:10 PM	6/22/11	5:25 PM	2.0	40'-42'	85	850	55	8.0	0.289	28.9	58.7	84.7	85	1 ft. push to inject in the foot above the clay layer.
	6/23/11	7:40 AM	6/23/11	7:50 AM	2.0	42'-44'	85	935	45	8.5	0.289	28.9		84.7	85	
Total KI (g) 586.5	6/23/11	7:50 AM	6/23/11	8:05 AM	2.0	44'-46'	85	1,020	50	7.0	0.289	28.9		84.7	85	
	6/23/11	8:05 AM	6/23/11	11:50 AM	2.0	46'-48'	85	1,105	35	5.0	0.289	28.9		84.7	85	
	6/23/11	11:50 AM	6/23/11	12:00 PM	2.0	48'-50'	85	1,190	50	8.5	0.289	28.9		84.7	85	
Total H2O (gal) 1694.2	6/23/11	12:00 PM	6/23/11	12:15 PM	2.0	50'-52'	85	1,275	45	7.0	0.289	28.9		84.7	85	
	6/23/11	12:15 PM	6/23/11	12:25 PM	2.0	52'-54'	85	1,360	50	8.5	0.289	28.9		84.7	85	
	6/23/11	12:25 PM	6/23/11	12:35 PM	2.0	54'-56'	85	1,445	50	8.5	0.289	28.9		84.7	85	
Total Volume 1700	6/23/11	12:35 PM	6/23/11	12:45 PM	2.0	56'-58'	85	1,530	50	8.5	0.289	28.9		84.7	85	
	6/23/11	12:45 PM	6/23/11	12:55 PM	2.0	58'-60'	85	1,615	50	8.5	0.289	28.9		84.7	85	
	6/23/11	12:55 PM	6/23/11	1:10 PM	2.0	60'-62'	85	1,700	50	8.0	0.289	28.9		84.7	85	Successfully completed location. Chased with 10 gal. Flush water.

Vironex Field Data Sheet

Injection Point ID	Start Date	Start Time	End Date	End Time	Tool Length (ft)	Injection Interval	Gal per Interval	Running Total	Average PSI	Average Flow Rate	nBA Injected (gal)	KBr Injected (grams)	KI Injected (grams)	H2O Injected (gal)	Amended Total Gal	Notes
IP-0007	6/22/11	3:00 PM	6/22/11	3:25 PM	2.0	23'-25'	85	85	35	8.0	0.289	28.9	58.7	84.7	85	
	6/22/11	3:25 PM	6/22/11	3:35 PM	2.0	25'-27'	85	170	35	8.0	0.289	28.9	58.7	84.7	85	
	6/22/11	3:35 PM	6/22/11	3:45 PM	2.0	27'-29'	85	255	40	8.0	0.289	28.9	58.7	84.7	85	
	6/22/11	3:45 PM	6/22/11	3:55 PM	2.0	29'-31'	85	340	45	8.0	0.289	28.9	58.7	84.7	85	
	6/22/11	3:55 PM	6/22/11	4:05 PM	2.0	31'-33'	85	425	45	8.0	0.289	28.9	58.7	84.7	85	
Total nBA (gal)	6/22/11	4:05 PM	6/22/11	4:25 PM	2.0	33'-35'	85	510	40	6.0	0.289	28.9	58.7	84.7	85	
5.8	6/22/11	4:25 PM	6/22/11	4:40 PM	2.0	35'-37'	85	595	40	6.0	0.289	28.9	58.7	84.7	85	
	6/22/11	4:40 PM	6/22/11	4:55 PM	2.0	37'-39'	85	680	35	6.0	0.289	28.9	58.7	84.7	85	
Total KBr (g)	6/22/11	4:55 PM	6/22/11	5:10 PM	2.0	39'-41'	85	765	55	8.0	0.289	28.9	58.7	84.7	85	
578.0	6/22/11	5:10 PM	6/22/11	5:25 PM	2.0	40'-42'	85	850	55	8.0	0.289	28.9	58.7	84.7	85	1 ft. push to inject in the foot above the clay layer.
	6/23/11	7:40 AM	6/23/11	7:50 AM	2.0	42'-44'	85	935	38	8.0	0.289	28.9		84.7	85	
Total KI (g)	6/23/11	7:50 AM	6/23/11	8:05 AM	2.0	44'-46'	85	1,020	45	7.0	0.289	28.9		84.7	85	
586.5	6/23/11	8:05 AM	6/23/11	11:50 AM	2.0	46'-48'	85	1,105	35	5.0	0.289	28.9		84.7	85	
	6/23/11	11:50 AM	6/23/11	12:00 PM	2.0	48'-50'	85	1,190	50	8.5	0.289	28.9		84.7	85	
Total H2O (gal)	6/23/11	12:00 PM	6/23/11	12:15 PM	2.0	50'-52'	85	1,275	45	7.0	0.289	28.9		84.7	85	
1694.2	6/23/11	12:15 PM	6/23/11	12:25 PM	2.0	52'-54'	85	1,360	50	8.5	0.289	28.9		84.7	85	
	6/23/11	12:25 PM	6/23/11	12:35 PM	2.0	54'-56'	85	1,445	50	8.5	0.289	28.9		84.7	85	
Total Volume	6/23/11	12:35 PM	6/23/11	12:45 PM	2.0	56'-58'	85	1,530	50	8.5	0.289	28.9		84.7	85	
1700	6/23/11	12:45 PM	6/23/11	12:55 PM	2.0	58'-60'	85	1,615	50	8.5	0.289	28.9		84.7	85	
	6/23/11	12:55 PM	6/23/11	1:10 PM	2.0	60'-62'	85	1,700	50	8.0	0.289	28.9		84.7	85	Successfully completed location. Chased with 10 gal. Flush water.
IP-0008	6/22/11	2:40 PM	6/22/11	3:25 PM	5.0	23'-28'	213	213	35	8.0	0.724	72.4	147.0	212.3	213	5 ft. injection tool.
	6/22/11	3:25 PM	6/22/11	3:50 PM	5.0	28'-33'	212	426	45	8.5	0.721	72.1	146.3	211.3	212	
	6/22/11	3:50 PM	6/22/11	4:05 PM	5.0	33'-38'	213	638	50	8.5	0.724	72.4	147.0	212.3	213	
	6/22/11	4:05 PM	6/22/11	4:45 PM	5.0	37'-42'	212	851	50	8.5	0.721	72.1	146.3	211.3	212	4 ft. push to inject in the interval above the clay layer.
	6/23/11	7:40 AM	6/23/11	8:05 AM	5.0	42'-47'	213	1,063	40	8.0	0.721	72.1		211.3	212	
Total nBA (gal)	6/23/11	8:05 AM	6/23/11	12:05 PM	5.0	47'-52'	212	1,276	40	8.5	0.724	72.4		212.3	213	
5.8	6/23/11	12:05 PM	6/23/11	1:00 PM	5.0	52'-57'	212	1,488	8	3.5	0.724	72.4		212.3	213	
	6/23/11	1:00 PM	6/23/11	1:30 PM	5.0	57'-62'	212	1,700	35	7.0	0.721	72.1		211.3	212	Successfully completed location. Chased with 10 gal. Flush water.
Total KBr (g)																
578.0																
Total KI (g)																
586.5																
Total H2O (gal)																
1694.2																
Total Volume																
1700																

Vironex Field Data Sheet

Injection Point ID	Start Date	Start Time	End Date	End Time	Tool Length (ft)	Injection Interval	Gal per Interval	Running Total	Average PSI	Average Flow Rate	nBA Injected (gal)	KBr Injected (grams)	KI Injected (grams)	H2O Injected (gal)	Amended Total Gal	Notes
IP-0009	6/23/11	3:15 PM	6/23/11	3:40 PM	2.0	23'-25'	85	85	40	7.5	0.289	28.9	58.7	84.7	85	
	6/23/11	3:40 PM	6/23/11	3:50 PM	2.0	25'-27'	85	170	38	8.0	0.289	28.9	58.7	84.7	85	
	6/23/11	3:50 PM	6/23/11	4:00 PM	2.0	27'-29'	85	255	42	8.0	0.289	28.9	58.7	84.7	85	
	6/23/11	4:00 PM	6/23/11	4:10 PM	2.0	29'-31'	85	340	50	8.0	0.289	28.9	58.7	84.7	85	
	6/23/11	4:10 PM	6/23/11	4:20 PM	2.0	31'-33'	85	425	45	8.0	0.289	28.9	58.7	84.7	85	
Total nBA (gal)	6/23/11	4:20 PM	6/23/11	4:30 PM	2.0	33'-35'	85	510	45	8.0	0.289	28.9	58.7	84.7	85	
5.8	6/23/11	4:30 PM	6/23/11	4:40 PM	2.0	35'-37'	85	595	45	8.0	0.289	28.9	58.7	84.7	85	
	6/23/11	4:40 PM	6/23/11	4:50 PM	2.0	37'-39'	85	680	45	8.0	0.289	28.9	58.7	84.7	85	
Total KBr (g)	6/23/11	4:50 PM	6/23/11	5:00 PM	2.0	39'-41'	85	765	45	8.0	0.289	28.9	58.7	84.7	85	
578.0	6/23/11	5:00 PM	6/23/11	5:10 PM	2.0	40'-42'	85	850	45	8.0	0.289	28.9	58.7	84.7	85	1 ft. push to inject in the foot above the clay layer.
	6/24/11	7:20 AM	6/24/11	7:35 AM	2.0	42'-44'	85	935	38	6.0	0.289	28.9		84.7	85	
Total KI (g)	6/24/11	7:35 AM	6/24/11	7:50 AM	2.0	44'-46'	85	1,020	40	6.0	0.289	28.9		84.7	85	
586.5	6/24/11	7:50 AM	6/24/11	8:00 AM	2.0	46'-48'	85	1,105	40	6.5	0.289	28.9		84.7	85	
	6/24/11	8:00 AM	6/24/11	8:10 AM	2.0	48'-50'	85	1,190	45	6.0	0.289	28.9		84.7	85	
Total H2O (gal)	6/24/11	8:10 AM	6/24/11	8:20 AM	2.0	50'-52'	85	1,275	50	8.4	0.289	28.9		84.7	85	
1694.2	6/24/11	8:20 AM	6/24/11	8:30 AM	2.0	52'-54'	85	1,360	50	8.5	0.289	28.9		84.7	85	
	6/24/11	8:30 AM	6/24/11	8:40 AM	2.0	54'-56'	85	1,445	50	8.5	0.289	28.9		84.7	85	
Total Volume	6/24/11	8:40 AM	6/24/11	8:50 AM	2.0	56'-58'	85	1,530	45	8.5	0.289	28.9		84.7	85	
1700	6/24/11	8:50 AM	6/24/11	9:00 AM	2.0	58'-60'	85	1,615	45	8.5	0.289	28.9		84.7	85	
	6/24/11	9:00 AM	6/24/11	9:20 AM	2.0	60'-62'	85	1,700	45	8.5	0.289	28.9		84.7	85	Successfully completed location. Chased with 10 gal. Flush water.
IP-0010	6/23/11	3:05 PM	6/23/11	3:45 PM	2.0	23'-25'	85	85	40	7.5	0.289	28.9	58.7	84.7	85	
	6/23/11	3:45 PM	6/23/11	3:55 PM	2.0	25'-27'	85	170	40	8.0	0.289	28.9	58.7	84.7	85	
	6/23/11	3:55 PM	6/23/11	4:05 PM	2.0	27'-29'	85	255	50	8.0	0.289	28.9	58.7	84.7	85	
	6/23/11	4:05 PM	6/23/11	4:15 PM	2.0	29'-31'	85	340	40	8.0	0.289	28.9	58.7	84.7	85	
	6/23/11	4:15 PM	6/23/11	4:25 PM	2.0	31'-33'	85	425	40	8.0	0.289	28.9	58.7	84.7	85	
Total nBA (gal)	6/23/11	4:25 PM	6/23/11	4:35 PM	2.0	33'-35'	85	510	40	8.0	0.289	28.9	58.7	84.7	85	
5.8	6/23/11	4:35 PM	6/23/11	4:45 PM	2.0	35'-37'	85	595	45	8.0	0.289	28.9	58.7	84.7	85	
	6/23/11	4:45 PM	6/23/11	4:55 PM	2.0	37'-39'	85	680	45	8.0	0.289	28.9	58.7	84.7	85	
Total KBr (g)	6/23/11	4:55 PM	6/23/11	5:05 PM	2.0	39'-41'	85	765	45	8.0	0.289	28.9	58.7	84.7	85	
578.0	6/23/11	5:05 PM	6/23/11	5:15 PM	2.0	40'-42'	85	850	45	8.0	0.289	28.9	58.7	84.7	85	1 ft. push to inject in the foot above the clay layer.
	6/24/11	7:20 AM	6/24/11	7:38 AM	2.0	42'-44'	85	935	38	6.0	0.289	28.9		84.7	85	
Total KI (g)	6/24/11	7:38 AM	6/24/11	5:52 AM	2.0	44'-46'	85	1,020	40	6.0	0.289	28.9		84.7	85	
586.5	6/24/11	7:52 AM	6/24/11	8:02 AM	2.0	46'-48'	85	1,105	40	6.0	0.289	28.9		84.7	85	
	6/24/11	8:02 AM	6/24/11	8:12 AM	2.0	48'-50'	85	1,190	45	6.0	0.289	28.9		84.7	85	
Total H2O (gal)	6/24/11	8:12 AM	6/24/11	8:22 AM	2.0	50'-52'	85	1,275	52	8.5	0.289	28.9		84.7	85	
1694.2	6/24/11	8:22 AM	6/24/11	8:32 AM	2.0	52'-54'	85	1,360	50	8.5	0.289	28.9		84.7	85	
	6/24/11	8:32 AM	6/24/11	8:42 AM	2.0	54'-56'	85	1,445	50	8.5	0.289	28.9		84.7	85	
Total Volume	6/24/11	8:42 AM	6/24/11	8:52 AM	2.0	56'-58'	85	1,530	50	8.5	0.289	28.9		84.7	85	
1700	6/24/11	8:52 AM	6/24/11	9:02 AM	2.0	58'-60'	85	1,615	45	8.5	0.289	28.9		84.7	85	
	6/24/11	9:02 AM	6/24/11	9:20 AM	2.0	60'-62'	85	1,700	40	8.5	0.289	28.9		84.7	85	Successfully completed location. Chased with 10 gal. Flush water.

Vironex Field Data Sheet

Injection Point ID	Start Date	Start Time	End Date	End Time	Tool Length (ft)	Injection Interval	Gal per Interval	Running Total	Average PSI	Average Flow Rate	nBA Injected (gal)	KBr Injected (grams)	KI Injected (grams)	H2O Injected (gal)	Amended Total Gal	Notes
IP-0011	6/23/11	3:20 PM	6/23/11	3:50 PM	2.0	23'-25'	85	85	40	7.5	0.289	28.9	58.7	84.7	85	
	6/23/11	3:50 PM	6/23/11	4:00 PM	2.0	25'-27'	85	170	35	8.0	0.289	28.9	58.7	84.7	85	
	6/23/11	4:00 PM	6/23/11	4:10 PM	2.0	27'-29'	85	255	32	8.0	0.289	28.9	58.7	84.7	85	
	6/23/11	4:10 PM	6/23/11	4:20 PM	2.0	29'-31'	85	340	40	8.0	0.289	28.9	58.7	84.7	85	
	6/23/11	4:20 PM	6/23/11	4:30 PM	2.0	31'-33'	85	425	40	8.0	0.289	28.9	58.7	84.7	85	
Total nBA (gal)	6/23/11	4:30 PM	6/23/11	4:40 PM	2.0	33'-35'	85	510	40	8.0	0.289	28.9	58.7	84.7	85	
5.8	6/23/11	4:40 PM	6/23/11	4:50 PM	2.0	35'-37'	85	595	45	8.0	0.289	28.9	58.7	84.7	85	
	6/23/11	4:50 PM	6/23/11	5:00 PM	2.0	37'-39'	85	680	45	8.0	0.289	28.9	58.7	84.7	85	
Total KBr (g)	6/23/11	5:00 PM	6/23/11	5:10 PM	2.0	39'-41'	85	765	45	8.0	0.289	28.9	58.7	84.7	85	
578.0	6/23/11	5:10 PM	6/23/11	5:35 PM	2.0	40'-42'	85	850	45	8.0	0.289	28.9	58.7	84.7	85	1 ft. push to inject in the foot above the clay layer.
	6/24/11	7:25 AM	6/24/11	7:40 AM	2.0	42'-44'	85	935	38	6.0	0.289	28.9		84.7	85	
Total KI (g)	6/24/11	7:40 AM	6/24/11	7:55 AM	2.0	44'-46'	85	1,020	40	6.0	0.289	28.9		84.7	85	
586.5	6/24/11	7:55 AM	6/24/11	8:05 AM	2.0	46'-48'	85	1,105	40	7.0	0.289	28.9		84.7	85	
	6/24/11	8:05 AM	6/24/11	8:20 AM	2.0	48'-50'	85	1,190	30	4.5	0.289	28.9		84.7	85	Slowed down to avoid surfacing from a well 1.5 ft away screened at the same depth.
Total H2O (gal)	6/24/11	8:20 AM	6/24/11	8:30 AM	2.0	50'-52'	85	1,275	50	8.3	0.289	28.9		84.7	85	
1694.2	6/24/11	8:30 AM	6/24/11	8:40 AM	2.0	52'-54'	85	1,360	50	8.5	0.289	28.9		84.7	85	
	6/24/11	8:40 AM	6/24/11	8:50 AM	2.0	54'-56'	85	1,445	45	8.5	0.289	28.9		84.7	85	
Total Volume	6/24/11	8:50 AM	6/24/11	9:00 AM	2.0	56'-58'	85	1,530	45	8.5	0.289	28.9		84.7	85	
1700	6/24/11	9:00 AM	6/24/11	9:10 AM	2.0	58'-60'	85	1,615	40	8.5	0.289	28.9		84.7	85	
	6/24/11	9:10 AM	6/24/11	9:20 AM	2.0	60'-62'	85	1,700	40	8.5	0.289	28.9		84.7	85	Successfully completed location. Chased with 10 gal. Flush water.
IP-0012	6/24/11	11:00 AM	6/24/11	11:15 AM	2.0	23'-25'	85	85	40	8.0	0.289	28.9	58.7	84.7	85	
	6/24/11	11:20 AM	6/24/11	11:30 AM	2.0	25'-27'	85	170	40	7.5	0.289	28.9	58.7	84.7	85	
	6/24/11	11:30 AM	6/24/11	11:40 AM	2.0	27'-29'	85	255	40	8.0	0.289	28.9	58.7	84.7	85	
	6/24/11	11:40 AM	6/24/11	12:15 PM	2.0	29'-31'	85	340	40	8.0	0.289	28.9	58.7	84.7	85	
	6/24/11	12:15 PM	6/24/11	12:25 PM	2.0	31'-33'	85	425	40	8.0	0.289	28.9	58.7	84.7	85	Took lunch during this interval.
Total nBA (gal)	6/24/11	12:25 PM	6/24/11	12:35 PM	2.0	33'-35'	85	510	40	8.5	0.289	28.9	58.7	84.7	85	
5.8	6/24/11	12:35 PM	6/24/11	12:45 PM	2.0	35'-37'	85	595	40	8.5	0.289	28.9	58.7	84.7	85	
	6/24/11	12:45 PM	6/24/11	12:55 PM	2.0	37'-39'	85	680	40	8.5	0.289	28.9	58.7	84.7	85	
Total KBr (g)	6/24/11	12:55 PM	6/24/11	1:05 PM	2.0	39'-41'	85	765	40	8.0	0.289	28.9	58.7	84.7	85	
578.0	6/24/11	1:05 PM	6/24/11	1:15 PM	2.0	40'-42'	85	850	40	8.0	0.289	28.9	58.7	84.7	85	
	6/24/11	1:40 PM	6/24/11	1:50 PM	2.0	42'-44'	85	935	25	6.0	0.289	28.9		84.7	85	
Total KI (g)	6/24/11	1:50 PM	6/24/11	2:47 PM	2.0	44'-46'	85	1,020	20	6.5	0.289	28.9		84.7	85	Stopped pumping to repair a leak in the system.
586.5	6/24/11	2:47 PM	6/24/11	2:57 PM	2.0	46'-48'	85	1,105	20	6.5	0.289	28.9		84.7	85	
	6/24/11	2:57 PM	6/24/11	3:07 PM	2.0	48'-50'	85	1,190	30	7.0	0.289	28.9		84.7	85	
Total H2O (gal)	6/24/11	3:07 PM	6/24/11	3:17 PM	2.0	50'-52'	85	1,275	35	7.0	0.289	28.9		84.7	85	
1694.2	6/24/11	3:17 PM	6/24/11	3:27 PM	2.0	52'-54'	85	1,360	45	8.0	0.289	28.9		84.7	85	
	6/24/11	3:27 PM	6/27/11	7:20 AM	2.0	54'-56'	85	1,445	45	8.0	0.289	28.9		84.7	85	Ended the day early due to Phase 2 lightning warning.
Total Volume	6/27/11	7:20 AM	6/27/11	7:30 AM	2.0	56'-58'	85	1,530	35	8.0	0.289	28.9		84.7	85	
1700	6/27/11	7:30 AM	6/27/11	7:40 AM	2.0	58'-60'	85	1,615	40	7.8	0.289	28.9		84.7	85	
	6/27/11	7:40 AM	6/27/11	3:25 PM	2.0	60'-62'	85	1,700	40	7.8	0.289	28.9		84.7	85	Hit Refusal at 61 ft bgs. Successfully completed location. Chased with 10 gal. flush water.

Vironex Field Data Sheet

Injection Point ID	Start Date	Start Time	End Date	End Time	Tool Length (ft)	Injection Interval	Gal per Interval	Running Total	Average PSI	Average Flow Rate	nBA Injected (gal)	KBr Injected (grams)	KI Injected (grams)	H2O Injected (gal)	Amended Total Gal	Notes
IP-0013	6/24/11	11:05 AM	6/24/11	11:20 AM	2.0	23'-25'	85	85	40	7.0	0.289	28.9	58.7	84.7	85	
	6/24/11	11:20 AM	6/24/11	11:33 AM	2.0	25'-27'	85	170	40	7.5	0.289	28.9	58.7	84.7	85	
	6/24/11	11:33 AM	6/24/11	11:43 AM	2.0	27'-29'	85	255	40	8.0	0.289	28.9	58.7	84.7	85	
	6/24/11	11:43 AM	6/24/11	11:53 AM	2.0	29'-31'	85	340	40	8.0	0.289	28.9	58.7	84.7	85	
	6/24/11	12:15 PM	6/24/11	12:25 PM	2.0	31'-33'	85	425	40	8.0	0.289	28.9	58.7	84.7	85	Took lunch during this interval.
Total nBA (gal) 5.8	6/24/11	12:25 PM	6/24/11	12:35 PM	2.0	33'-35'	85	510	40	8.0	0.289	28.9	58.7	84.7	85	
	6/24/11	12:35 PM	6/24/11	12:45 PM	2.0	35'-37'	85	595	40	8.0	0.289	28.9	58.7	84.7	85	
	6/24/11	12:45 PM	6/24/11	12:55 PM	2.0	37'-39'	85	680	40	8.0	0.289	28.9	58.7	84.7	85	
Total KBr (g) 578.0	6/24/11	12:55 PM	6/24/11	1:05 PM	2.0	39'-41'	85	765	40	8.0	0.289	28.9	58.7	84.7	85	
	6/24/11	1:05 PM	6/24/11	1:15 PM	2.0	40'-42'	85	850	40	8.0	0.289	28.9	58.7	84.7	85	
	6/24/11	1:40 PM	6/24/11	1:50 PM	2.0	42'-44'	85	935	40	6.0	0.289	28.9		84.7	85	
Total KI (g) 586.5	6/24/11	1:50 PM	6/24/11	2:50 PM	2.0	44'-46'	85	1,020	40	6.0	0.289	28.9		84.7	85	Stopped pumping to repair a leak in the system.
	6/24/11	2:50 PM	6/24/11	3:00 PM	2.0	46'-48'	85	1,105	40	6.0	0.289	28.9		84.7	85	
	6/24/11	3:00 PM	6/24/11	3:10 PM	2.0	48'-50'	85	1,190	45	7.0	0.289	28.9		84.7	85	
Total H2O (gal) 1694.2	6/24/11	3:10 PM	6/24/11	3:20 PM	2.0	50'-52'	85	1,275	45	7.0	0.289	28.9		84.7	85	
	6/24/11	3:20 PM	6/24/11	3:30 PM	2.0	52'-54'	85	1,360	45	7.0	0.289	28.9		84.7	85	
	6/24/11	3:30 PM	6/27/11	7:22 AM	2.0	54'-56'	85	1,445	45	7.8	0.289	28.9		84.7	85	Ended the day early due to Phase 2 lightning warning.
Total Volume 1700	6/27/11	7:22 AM	6/27/11	7:32 AM	2.0	56'-58'	85	1,530	45	8.0	0.289	28.9		84.7	85	
	6/27/11	7:32 AM	6/27/11	7:45 AM	2.0	58'-60'	85	1,615	45	7.8	0.289	28.9		84.7	85	
	6/27/11	7:45 AM	6/27/11	8:00 AM	2.0	60'-62'	85	1,700	45	8.0	0.289	28.9		84.7	85	Successfully completed location. Chased with 10 gal. flush water.
IP-0014	6/24/11	11:15 AM	6/24/11	11:27 AM	2.0	23'-25'	85	85	40	7.6	0.289	28.9	58.7	84.7	85	
	6/24/11	11:27 AM	6/24/11	11:37 AM	2.0	25'-27'	85	170	40	8.0	0.289	28.9	58.7	84.7	85	
	6/24/11	11:37 AM	6/24/11	11:47 AM	2.0	27'-29'	85	255	40	8.0	0.289	28.9	58.7	84.7	85	Took lunch during this interval.
	6/24/11	12:15 PM	6/24/11	12:25 PM	2.0	29'-31'	85	340	40	8.0	0.289	28.9	58.7	84.7	85	
	6/24/11	12:25 PM	6/24/11	12:35 PM	2.0	31'-33'	85	425	40	8.0	0.289	28.9	58.7	84.7	85	
Total nBA (gal) 5.8	6/24/11	12:35 PM	6/24/11	12:45 PM	2.0	33'-35'	85	510	40	8.0	0.289	28.9	58.7	84.7	85	
	6/24/11	12:45 PM	6/24/11	12:55 PM	2.0	35'-37'	85	595	40	8.0	0.289	28.9	58.7	84.7	85	
	6/24/11	12:55 PM	6/24/11	1:05 PM	2.0	37'-39'	85	680	40	8.0	0.289	28.9	58.7	84.7	85	
Total KBr (g) 578.0	6/24/11	1:05 PM	6/24/11	1:15 PM	2.0	39'-41'	85	765	40	8.5	0.289	28.9	58.7	84.7	85	
	6/24/11	1:15 PM	6/24/11	1:25 PM	2.0	40'-42'	85	850	40	8.0	0.289	28.9	58.7	84.7	85	
	6/24/11	1:25 PM	6/24/11	1:50 PM	2.0	42'-44'	85	935	40	6.0	0.289	28.9		84.7	85	
Total KI (g) 586.5	6/24/11	1:50 PM	6/24/11	2:55 PM	2.0	44'-46'	85	1,020	40	6.0	0.289	28.9		84.7	85	Stopped pumping to fix a leak in the injection system.
	6/24/11	2:55 PM	6/24/11	3:05 PM	2.0	46'-48'	85	1,105	40	6.5	0.289	28.9		84.7	85	
	6/24/11	3:05 PM	6/24/11	3:15 PM	2.0	48'-50'	85	1,190	40	6.5	0.289	28.9		84.7	85	
Total H2O (gal) 1694.2	6/24/11	3:15 PM	6/24/11	3:25 PM	2.0	50'-52'	85	1,275	45	7.0	0.289	28.9		84.7	85	
	6/24/11	3:25 PM	6/24/11	3:35 PM	2.0	52'-54'	85	1,360	45	7.0	0.289	28.9		84.7	85	
	6/24/11	3:35 PM	6/24/11	7:25 AM	2.0	54'-56'	85	1,445	45	7.5	0.289	28.9		84.7	85	Ended the day early due to Phase 2 lightning warning.
Total Volume 1700	6/27/11	7:25 AM	6/27/11	7:35 AM	2.0	56'-58'	85	1,530	45	7.8	0.289	28.9		84.7	85	
	6/27/11	7:35 AM	6/27/11	7:48 AM	2.0	58'-60'	85	1,615	45	7.8	0.289	28.9		84.7	85	
	6/27/11	7:48 AM	6/27/11	8:00 AM	2.0	60'-62'	85	1,700	45	8.0	0.289	28.9		84.7	85	Successfully completed location. Chased with 10 gal. flush water.

Vironex Field Data Sheet

Injection Point ID	Start Date	Start Time	End Date	End Time	Tool Length (ft)	Injection Interval	Gal per Interval	Running Total	Average PSI	Average Flow Rate	nBA Injected (gal)	KBr Injected (grams)	KI Injected (grams)	H2O Injected (gal)	Amended Total Gal	Notes
IP-0015	6/27/11	9:55 AM	6/27/11	10:20 AM	2.0	23'-25'	85	85	15	4.0	0.289	28.9	58.7	84.7	85	
	6/27/11	10:20 AM	6/27/11	10:31 AM	2.0	25'-27'	85	170	30	7.8	0.289	28.9	58.7	84.7	85	
	6/27/11	10:31 AM	6/27/11	10:43 AM	2.0	27'-29'	85	255	35	8.3	0.289	28.9	58.7	84.7	85	
	6/27/11	10:43 AM	6/27/11	10:53 AM	2.0	29'-31'	85	340	40	8.5	0.289	28.9	58.7	84.7	85	
	6/27/11	10:53 AM	6/27/11	11:12 AM	2.0	31'-33'	85	425	40	8.5	0.289	28.9	58.7	84.7	85	Paused to change out an electrical cable.
Total nBA (gal)	6/27/11	11:12 AM	6/27/11	11:22 AM	2.0	33'-35'	85	510	40	8.5	0.289	28.9	58.7	84.7	85	
5.8	6/27/11	11:22 AM	6/27/11	11:32 AM	2.0	35'-37'	85	595	40	8.5	0.289	28.9	58.7	84.7	85	
	6/27/11	11:32 AM	6/27/11	11:42 AM	2.0	37'-39'	85	680	40	8.5	0.289	28.9	58.7	84.7	85	
Total KBr (g)	6/27/11	11:42 AM	6/27/11	11:52 AM	2.0	39'-41'	85	765	45	8.5	0.289	28.9	58.7	84.7	85	
578.0	6/27/11	11:52 AM	6/27/11	12:02 PM	2.0	40'-42'	85	850	45	8.5	0.289	28.9	58.7	84.7	85	Paused after this interval to take lunch.
	6/27/11	12:40 PM	6/27/11	12:53 PM	2.0	42'-44'	85	935	40	7.2	0.289	28.9		84.7	85	
Total KI (g)	6/27/11	12:53 PM	6/27/11	1:05 PM	2.0	44'-46'	85	1,020	30	6.0	0.289	28.9		84.7	85	
586.5	6/27/11	1:05 PM	6/27/11	1:18 PM	2.0	46'-48'	85	1,105	35	5.8	0.289	28.9		84.7	85	
	6/27/11	1:18 PM	6/27/11	1:30 PM	2.0	48'-50'	85	1,190	35	6.0	0.289	28.9		84.7	85	
Total H2O (gal)	6/27/11	1:32 PM	6/27/11	1:43 PM	2.0	50'-52'	85	1,275	35	5.3	0.289	28.9		84.7	85	
1694.2	6/27/11	1:43 PM	6/27/11	2:05 PM	2.0	52'-54'	85	1,360	35	4.0	0.289	28.9		84.7	85	
	6/27/11	2:05 PM	6/27/11	2:20 PM	2.0	54'-56'	85	1,445	35	4.3	0.289	28.9		84.7	85	
Total Volume	6/27/11	2:20 PM	6/27/11	2:32 PM	2.0	56'-58'	85	1,530	35	4.2	0.289	28.9		84.7	85	
1700	6/27/11	2:32 PM	6/27/11	2:43 PM	2.0	58'-60'	85	1,615	45	7.6	0.289	28.9		84.7	85	
	6/27/11	2:43 PM	6/27/11	2:57 PM	2.0	60'-62'	85	1,700	45	7.7	0.289	28.9		84.7	85	Successfully completed location. Chased with 10 gal. flush water.
IP-0016	6/27/11	10:00 AM	6/27/11	10:25 AM	2.0	23'-25'	85	85	15	4.0	0.289	28.9	58.7	84.7	85	
	6/27/11	10:25 AM	6/27/11	10:36 AM	2.0	25'-27'	85	170	40	7.5	0.289	28.9	58.7	84.7	85	
	6/27/11	10:36 AM	6/27/11	10:46 AM	2.0	27'-29'	85	255	40	8.2	0.289	28.9	58.7	84.7	85	
	6/27/11	10:46 AM	6/27/11	11:05 AM	2.0	29'-31'	85	340	40	8.5	0.289	28.9	58.7	84.7	85	
	6/27/11	10:56 AM	6/27/11	11:13 AM	2.0	31'-33'	85	425	40	8.2	0.289	28.9	58.7	84.7	85	Paused to change out an electrical cable.
Total nBA (gal)	6/27/11	11:13 AM	6/27/11	11:24 AM	2.0	33'-35'	85	510	40	8.4	0.289	28.9	58.7	84.7	85	
5.8	6/27/11	11:24 AM	6/27/11	11:34 AM	2.0	35'-37'	85	595	40	8.4	0.289	28.9	58.7	84.7	85	
	6/27/11	11:34 AM	6/27/11	11:44 AM	2.0	37'-39'	85	680	40	8.5	0.289	28.9	58.7	84.7	85	
Total KBr (g)	6/27/11	11:44 AM	6/27/11	11:54 AM	2.0	39'-41'	85	765	45	8.5	0.289	28.9	58.7	84.7	85	
578.0	6/27/11	11:54 AM	6/27/11	12:04 PM	2.0	40'-42'	85	850	45	8.5	0.289	28.9	58.7	84.7	85	Paused for lunch after this interval.
	6/27/11	12:45 PM	6/27/11	12:58 PM	2.0	42'-44'	85	935	40	7.2	0.289	28.9		84.7	85	
Total KI (g)	6/27/11	12:58 PM	6/27/11	1:10 PM	2.0	44'-46'	85	1,020	40	6.0	0.289	28.9		84.7	85	
586.5	6/27/11	1:10 PM	6/27/11	1:23 PM	2.0	46'-48'	85	1,105	40	5.5	0.289	28.9		84.7	85	
	6/27/11	1:23 PM	6/27/11	1:35 PM	2.0	48'-50'	85	1,190	40	6.1	0.289	28.9		84.7	85	
Total H2O (gal)	6/27/11	1:35 PM	6/27/11	1:55 PM	2.0	50'-52'	85	1,275	45	5.3	0.289	28.9		84.7	85	
1694.2	6/27/11	1:55 PM	6/27/11	2:10 PM	2.0	52'-54'	85	1,360	35	4.0	0.289	28.9		84.7	85	
	6/27/11	2:10 PM	6/27/11	2:25 PM	2.0	54'-56'	85	1,445	30	4.0	0.289	28.9		84.7	85	
Total Volume	6/27/11	2:25 PM	6/27/11	2:37 PM	2.0	56'-58'	85	1,530	30	4.3	0.289	28.9		84.7	85	
1700	6/27/11	2:37 PM	6/27/11	2:50 PM	2.0	58'-60'	85	1,615	45	7.5	0.289	28.9		84.7	85	
	6/27/11	2:50 PM	6/27/11	3:04 PM	2.0	60'-62'	85	1,700	45	7.7	0.289	28.9		84.7	85	Successfully completed location. Chased with 10 gal. flush water.

Vironex Field Data Sheet

Injection Point ID	Start Date	Start Time	End Date	End Time	Tool Length (ft)	Injection Interval	Gal per Interval	Running Total	Average PSI	Average Flow Rate	nBA Injected (gal)	KBr Injected (grams)	KI Injected (grams)	H2O Injected (gal)	Amended Total Gal	Notes
IP-0017	6/27/11	10:10 AM	6/27/11	10:28 AM	2.0	23'-25'	85	85	15	4.0	0.289	28.9	58.7	84.7	85	
	6/27/11	10:28 AM	6/27/11	10:39 AM	2.0	25'-27'	85	170	40	7.7	0.289	28.9	58.7	84.7	85	
	6/27/11	10:39 AM	6/27/11	10:49 AM	2.0	27'-29'	85	255	40	8.5	0.289	28.9	58.7	84.7	85	
	6/27/11	10:49 AM	6/27/11	11:08 AM	2.0	29'-31'	85	340	40	8.5	0.289	28.9	58.7	84.7	85	Paused to change out an electrical cable.
	6/27/11	11:08 AM	6/27/11	11:20 AM	2.0	31'-33'	85	425	40	8.5	0.289	28.9	58.7	84.7	85	
Total nBA (gal)	6/27/11	11:20 AM	6/27/11	11:30 AM	2.0	33'-35'	85	510	40	8.5	0.289	28.9	58.7	84.7	85	
5.8	6/27/11	11:30 AM	6/27/11	11:40 AM	2.0	35'-37'	85	595	40	8.5	0.289	28.9	58.7	84.7	85	
	6/27/11	11:40 AM	6/27/11	11:50 AM	2.0	37'-39'	85	680	40	8.5	0.289	28.9	58.7	84.7	85	
Total KBr (g)	6/27/11	11:50 AM	6/27/11	12:00 PM	2.0	39'-41'	85	765	40	8.5	0.289	28.9	58.7	84.7	85	
578.0	6/27/11	12:00 PM	6/27/11	12:10 PM	2.0	40'-42'	85	850	40	8.5	0.289	28.9	58.7	84.7	85	Paused for lunch after this interval.
	6/27/11	12:00 AM	6/27/11	1:05 PM	2.0	42'-44'	85	935	40	7.1	0.289	28.9		84.7	85	
Total KI (g)	6/27/11	1:05 PM	6/27/11	1:18 PM	2.0	44'-46'	85	1,020	35	6.0	0.289	28.9		84.7	85	
586.5	6/27/11	1:18 PM	6/27/11	1:30 PM	2.0	46'-48'	85	1,105	40	6.0	0.289	28.9		84.7	85	
	6/27/11	1:30 PM	6/27/11	1:43 PM	2.0	48'-50'	85	1,190	40	6.3	0.289	28.9		84.7	85	
Total H2O (gal)	6/27/11	1:43 PM	6/27/11	1:53 PM	2.0	50'-52'	85	1,275	45	8.5	0.289	28.9		84.7	85	
1694.2	6/27/11	1:53 PM	6/27/11	2:03 PM	2.0	52'-54'	85	1,360	45	8.5	0.289	28.9		84.7	85	
	6/27/11	2:03 PM	6/27/11	2:13 PM	2.0	54'-56'	85	1,445	45	8.5	0.289	28.9		84.7	85	
Total Volume	6/27/11	2:13 PM	6/27/11	2:23 PM	2.0	56'-58'	85	1,530	45	8.5	0.289	28.9		84.7	85	
1700	6/27/11	2:23 PM	6/27/11	2:33 PM	2.0	58'-60'	85	1,615	45	8.5	0.289	28.9		84.7	85	
	6/27/11	2:33 PM	6/27/11	2:43 PM	2.0	60'-62'	85	1,700	45	8.5	0.289	28.9		84.7	85	Successfully completed location. Chased with 10 gal. flush water.
IP-0018	6/28/11	8:55 AM	6/28/11	9:10 AM	2.0	23'-25'	85	85	25	6.0	0.280	28.9	58.7	84.7	85	
	6/28/11	9:10 AM	6/28/11	9:28 AM	2.0	25'-27'	85	170	30	7.0	0.280	28.9	58.7	84.7	85	
	6/28/11	9:28 AM	6/28/11	9:38 AM	2.0	27'-29'	85	255	32	8.5	0.280	28.9	58.7	84.7	85	
	6/28/11	9:38 AM	6/28/11	9:48 AM	2.0	29'-31'	85	340	35	8.5	0.280	28.9	58.7	84.7	85	
	6/28/11	9:48 AM	6/28/11	9:58 AM	2.0	31'-33'	85	425	40	8.5	0.280	28.9	58.7	84.7	85	
Total nBA (gal)	6/28/11	9:58 AM	6/28/11	10:10 AM	2.0	33'-35'	85	510	38	8.0	0.280	28.9	58.7	84.7	85	
5.6	6/28/11	10:10 AM	6/28/11	10:22 AM	2.0	35'-37'	85	595	35	8.0	0.280	28.9	58.7	84.7	85	
	6/28/11	10:22 AM	6/28/11	10:34 AM	2.0	37'-39'	85	680	40	8.1	0.280	28.9	58.7	84.7	85	
Total KBr (g)	6/28/11	10:34 AM	6/28/11	10:45 AM	2.0	39'-41'	85	765	45	8.5	0.280	28.9	58.7	84.7	85	
578.0	6/28/11	10:45 AM	6/28/11	10:55 AM	2.0	40'-42'	85	850	45	8.5	0.280	28.9	58.7	84.7	85	Took Lunch after this interval.
	6/28/11	11:30 AM	6/28/11	11:43 AM	2.0	42'-44'	85	935	40	6.0	0.280	28.9		84.7	85	
Total KI (g)	6/28/11	11:43 AM	6/28/11	11:57 AM	2.0	44'-46'	85	1,020	40	6.0	0.280	28.9		84.7	85	
586.5	6/28/11	11:57 AM	6/28/11	12:11 PM	2.0	46'-48'	85	1,105	40	6.0	0.280	28.9		84.7	85	
	6/28/11	12:11 PM	6/28/11	12:21 PM	2.0	48'-50'	85	1,190	45	8.5	0.280	28.9		84.7	85	
Total H2O (gal)	6/28/11	12:21 PM	6/28/11	12:35 PM	2.0	50'-52'	85	1,275	40	6.0	0.280	28.9		84.7	85	Lowered the gpm to slow the rise in water on a well. (RW-8)
1694.4	6/28/11	12:35 PM	6/28/11	12:49 PM	2.0	52'-54'	85	1,360	40	6.3	0.280	28.9		84.7	85	
	6/28/11	12:49 PM	6/28/11	1:00 PM	2.0	54'-56'	85	1,445	43	6.5	0.280	28.9		84.7	85	
Total Volume	6/28/11	1:00 PM	6/28/11	1:13 PM	2.0	56'-58'	85	1,530	40	6.0	0.280	28.9		84.7	85	
1700	6/28/11	1:13 PM	6/28/11	1:26 PM	2.0	58'-60'	85	1,615	35	6.0	0.280	28.9		84.7	85	
	6/28/11	1:26 PM	6/28/11	1:50 PM	2.0	60'-62'	85	1,700	40	6.3	0.280	28.9		84.7	85	Successfully completed location. Chased with 35 gal. chase water.

Vironex Field Data Sheet

Injection Point ID	Start Date	Start Time	End Date	End Time	Tool Length (ft)	Injection Interval	Gal per Interval	Running Total	Average PSI	Average Flow Rate	nBA Injected (gal)	KBr Injected (grams)	KI Injected (grams)	H2O Injected (gal)	Amended Total Gal	Notes
IP-0019	6/28/11	9:00 AM	6/28/11	9:15 AM	2.0	23'-25'	85	85	23	6.0	0.280	28.9	58.7	84.7	85	
	6/28/11	9:15 AM	6/28/11	9:29 AM	2.0	25'-27'	85	170	35	7.2	0.280	28.9	58.7	84.7	85	
	6/28/11	9:29 AM	6/28/11	9:40 AM	2.0	27'-29'	85	255	35	8.2	0.280	28.9	58.7	84.7	85	
	6/28/11	9:40 AM	6/28/11	9:50 AM	2.0	29'-31'	85	340	40	8.5	0.280	28.9	58.7	84.7	85	
	6/28/11	9:50 AM	6/28/11	10:03 AM	2.0	31'-33'	85	425	40	8.0	0.280	28.9	58.7	84.7	85	
Total nBA (gal)	6/28/11	10:03 AM	6/28/11	10:15 AM	2.0	33'-35'	85	510	38	8.0	0.280	28.9	58.7	84.7	85	
5.6	6/28/11	10:15 AM	6/28/11	10:27 AM	2.0	35'-37'	85	595	40	8.0	0.280	28.9	58.7	84.7	85	
	6/28/11	10:27 AM	6/28/11	10:38 AM	2.0	37'-39'	85	680	30	7.8	0.280	28.9	58.7	84.7	85	
Total KBr (g)	6/28/11	10:38 AM	6/28/11	10:48 AM	2.0	39'-41'	85	765	40	8.5	0.280	28.9	58.7	84.7	85	
578.0	6/28/11	10:48 AM	6/28/11	10:58 AM	2.0	40'-42'	85	850	45	8.5	0.280	28.9	58.7	84.7	85	Took lunch after this interval.
	6/28/11	11:32 AM	6/28/11	11:45 AM	2.0	42'-44'	85	935	43	6.0	0.280	28.9		84.7	85	
Total KI (g)	6/28/11	11:45 AM	6/28/11	11:59 AM	2.0	44'-46'	85	1,020	40	6.0	0.280	28.9		84.7	85	
586.5	6/28/11	11:59 AM	6/28/11	12:13 PM	2.0	46'-48'	85	1,105	38	6.0	0.280	28.9		84.7	85	
	6/28/11	12:13 PM	6/28/11	12:23 PM	2.0	48'-50'	85	1,190	45	8.5	0.280	28.9		84.7	85	
Total H2O (gal)	6/28/11	12:23 PM	6/28/11	12:33 PM	2.0	50'-52'	85	1,275	45	8.5	0.280	28.9		84.7	85	
1694.4	6/28/11	12:33 PM	6/28/11	12:43 PM	2.0	52'-54'	85	1,360	45	8.5	0.280	28.9		84.7	85	
	6/28/11	12:43 PM	6/28/11	12:54 PM	2.0	54'-56'	85	1,445	45	8.5	0.280	28.9		84.7	85	
Total Volume	6/28/11	12:54 PM	6/28/11	1:04 PM	2.0	56'-58'	85	1,530	45	8.5	0.280	28.9		84.7	85	
1700	6/28/11	1:06 PM	6/28/11	1:17 PM	2.0	58'-60'	85	1,615	45	8.5	0.280	28.9		84.7	85	
	6/28/11	1:17 PM	6/28/11	1:27 PM	2.0	60'-62'	85	1,700	45	8.5	0.280	28.9		84.7	85	Successfully completed location. Chased with 35 gal. chase water.
IP-0020	6/28/11	9:05 AM	6/28/11	9:25 AM	2.0	23'-25'	85	85	30	7.0	0.280	28.9	58.7	84.7	85	
	6/28/11	9:25 AM	6/28/11	9:35 AM	2.0	25'-27'	85	170	35	8.5	0.280	28.9	58.7	84.7	85	
	6/28/11	9:35 AM	6/28/11	9:45 AM	2.0	27'-29'	85	255	40	8.5	0.280	28.9	58.7	84.7	85	
	6/28/11	9:45 AM	6/28/11	9:55 AM	2.0	29'-31'	85	340	45	8.5	0.280	28.9	58.7	84.7	85	
	6/28/11	9:55 AM	6/28/11	10:07 AM	2.0	31'-33'	85	425	45	8.2	0.280	28.9	58.7	84.7	85	
Total nBA (gal)	6/28/11	10:07 AM	6/28/11	10:19 AM	2.0	33'-35'	85	510	43	8.0	0.280	28.9	58.7	84.7	85	
5.6	6/28/11	10:19 AM	6/28/11	10:30 AM	2.0	35'-37'	85	595	45	8.3	0.280	28.9	58.7	84.7	85	
	6/28/11	10:30 AM	6/28/11	10:40 AM	2.0	37'-39'	85	680	45	8.5	0.280	28.9	58.7	84.7	85	
Total KBr (g)	6/28/11	10:40 AM	6/28/11	10:50 AM	2.0	38'-41'	85	765	45	8.5	0.280	28.9	58.7	84.7	85	
578.0	6/28/11	10:50 AM	6/28/11	11:00 AM	2.0	40'-42'	85	850	45	8.5	0.280	28.9	58.7	84.7	85	Took lunch after this interval.
	6/28/11	11:34 AM	6/28/11	11:47 AM	2.0	42'-44'	85	935	38	6.0	0.280	28.9		84.7	85	
Total KI (g)	6/28/11	11:47 AM	6/28/11	12:00 PM	2.0	44'-46'	85	1,020	40	6.0	0.280	28.9		84.7	85	
586.5	6/28/11	12:00 PM	6/28/11	12:14 PM	2.0	46'-48'	85	1,105	40	6.0	0.280	28.9		84.7	85	
	6/28/11	12:14 PM	6/28/11	12:24 PM	2.0	48'-50'	85	1,190	45	8.0	0.280	28.9		84.7	85	
Total H2O (gal)	6/28/11	12:24 PM	6/28/11	12:34 PM	2.0	50'-52'	85	1,275	45	8.0	0.280	28.9		84.7	85	
1694.4	6/28/11	12:34 PM	6/28/11	12:44 PM	2.0	52'-54'	85	1,360	45	8.0	0.280	28.9		84.7	85	
	6/28/11	12:44 PM	6/28/11	12:54 PM	2.0	54'-56'	85	1,445	45	8.0	0.280	28.9		84.7	85	
Total Volume	6/28/11	12:54 PM	6/28/11	1:04 PM	2.0	56'-58'	85	1,530	45	8.5	0.280	28.9		84.7	85	
1700	6/28/11	1:04 PM	6/28/11	1:14 PM	2.0	58'-60'	85	1,615	45	8.5	0.280	28.9		84.7	85	
	6/28/11	1:14 PM	6/28/201	1:30 PM	2.0	60'-62'	85	1,700	45	7.7	0.280	28.9		84.7	85	Successfully completed location. Chased with 35 gal. chase water.

Avg	Avg	nBA	KBr	KI	H2O	Total Gal	Points Completed
39.7	7.3	115.0	11,560.0	11,730.0	33,885.0	34,000.0	20.0

APPENDIX E: O&M FORMS

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician:	Joe Bartlett	Date:	3/14/2011	Time:	1040

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	No	
System operational on departure (yes/no)	Weekly	Yes	
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	NA	
Collect water levels from injection wells	Monthly	NA	
Clean solar panels	As Needed	NA	
Clean flow meters	As Needed	NA	

Extraction Wells

	Flow Rate (gpm)	Volume Produced (gallons)
RW0007	2.1	87
RW0008	2.3	87

Injection Wells[2]

Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
IJ0013	27	27	IJ0014	26	27
IJ0015	26	27	IJ0016	27	27
IJ0017	26	27	IJ0018	22	27
IJ0019	28	27	IJ0020	28	27
IJ0021	28	27	IJ0022	28	27

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [divide total flow rate by 5 for rate for each well.]

Battery	Voltage (V)	Percent Charge (%)	Task that need to be completed during the next scheduled visit
1a	14.28	100.00	
1b	13.63	100.00	replace PVC carbon bung connector with galvanized cast iron X3
2a	13.52	100.00	1 1/4" male thread - 3/4" female thread
2b	14.48	100.00	

Comments

Recycle Timer - red LED - slow steady blink - system ON; quick, short blink - system OFF

hide-a-key under right side of trailer door.

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: Joe Bartlett	**Date:** 3/21/2011	**Time:** 1700	

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	Yes	
System operational on departure (yes/no)	Weekly	Yes	
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	Yes	
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	NA	
Clean flow meters	As Needed	NA	

Extraction Wells

	Flow Rate (gpm)	Volume Produced (gallons)
RW0007	2.3	16252
RW0008	2.6	14251

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [divide total flow rate by 5 for rate for each well.]

Injection Wells[2]

Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
IJ0013	24	27	IJ0014	30	28
IJ0015	26	27	IJ0016	28	28
IJ0017	26	26	IJ0018	22	27
IJ0019	25	27	IJ0020	31	28
IJ0021	26	27	IJ0022	26	28

Battery	Voltage (V)	Percent Charge (%)
1a	12.54	94.00
1b	12.52	94.00
2a	12.54	96.00
2b	12.57	96.00

Task that need to be completed during the next scheduled visit

Comments

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: Joseph Bartlett	**Date:** 4/1/2011	**Time:** 1436	

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	Yes	
System operational on departure (yes/no)	Weekly	Yes	
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	No	
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	No	

Extraction Wells

	Flow Rate (gpm)	Volume Produced (gallons)
RW0007	2.5	31048
RW0008	2.2	28078

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [divide total flow rate by 5 for rate for each well.]

Injection Wells[2]

Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
IJ0013	28	28	IJ0014	27	28
IJ0015	28	28	IJ0016	28	28
IJ0017	28	28	IJ0018	28	28
IJ0019	27	28	IJ0020	28	28
IJ0021	29	28	IJ0022	26	28

Battery	Voltage (V)	Percent Charge (%)
1a	12.57	92.00
1b	12.56	96.00
2a	12.49	92.00
2b	12.49	92.00

Task that need to be completed during the next scheduled visit

Comments

Carbon Effluent Samples collected at 1450 EW0007 - EF001, EW0008 - EF002

O&M not performed on 28 March due to weather (thunderstorms all week). Flow totalizer reading collected on 3/29/2011: EW0007 - 30723 gal., EW0008 - 27842 gal.

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician:	**Joseph Bartlett**	**Date:** 4/7/2011	**Time:** 1442

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	Yes	
System operational on departure (yes/no)	Weekly	Yes	
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	Yes	
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	No	

Extraction Wells

	Flow Rate (gpm)	Volume Produced (gallons)
RW0007	2.5	40970
RW0008	2.5	35456

Injection Wells[2]

Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
IJ0013	28	28	IJ0014	30	30
IJ0015	28	28	IJ0016	30	30
IJ0017	28	28	IJ0018	30	30
IJ0019	28	28	IJ0020	30	30
IJ0021	28	28	IJ0022	30	30

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [divide total flow rate by 5 for rate for each well.]

Battery	Voltage (V)	Percent Charge (%)
1a	12.48	92.00
1b	12.46	92.00
2a	13.34	100.00
2b	13.20	100.00

Task that need to be completed during the next scheduled visit

Comments

carbon changed

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician:	Joe Bartlett	Date:	4/18/2011	Time:	900

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	Yes	
System operational on departure (yes/no)	Weekly	No	System turned off at 0915 - baseline flux phase complete
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	No	
Collect water levels from injection wells	Monthly	Yes	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	No	

Extraction Wells

	Flow Rate (gpm)	Volume Produced (gallons)
RW0007	2.4	58731
RW0008	2.2	44085

Injection Wells[2]

Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
IJ0013	27	27	IJ0014	24	26
IJ0015	27	27	IJ0016	24	26
IJ0017	28	27	IJ0018	25	26
IJ0019	28	27	IJ0020	25	26
IJ0021	25	27	IJ0022	24	26

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [divide total flow rate by 5 for rate for each well.]

Battery	Voltage (V)	Percent Charge (%)
1a	11.76	93.00
1b	11.74	92.00
2a	12.48	92.00
2b	12.54	94.00

Task that need to be completed during the next scheduled visit

Install hour meters

Comments

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician:	**Joseph Bartlett**	**Date:**	**8/9/2011**	**Time:**	**1100**

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	No	system restarted after being shut down for injection activites
System operational on departure (yes/no)	Weekly	Yes	
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	Yes	new filters installed
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	No	

Extraction Wells				Injection Wells[2]					
	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)	Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
RW0007	2.6	58,771	0	IJ0013	26	28	IJ0014	28	30
RW0008	2.8	44,113	0	IJ0015	30	28	IJ0016	26	30
				IJ0017	30	28	IJ0018	32	30
				IJ0019	26	28	IJ0020	36	30
				IJ0021	28	28	IJ0022	32	30

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Battery	Voltage (V)	Percent Charge (%)	Task that need to be completed during the next scheduled visit
1a	13.98	100	
1b	13.56	100	
2a	13.69	100	
2b	13.85	100	

Comments

installed hour meters

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: Joseph Bartlett | **Date: 08/12/2011** | **Time: 0913**

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	Yes	
System operational on departure (yes/no)	Weekly	Yes	
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	Yes	installed new filters, cleaned used filters off-site (hose bib previously used has been
Collect water levels from injection wells	Monthly	No	removed)
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	Yes	used DI water and pipe cleaner (left on-site)

Extraction Wells				Injection Wells[2]					
	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)	Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
RW0007	2.5	65561	42.7	IJ0013	29	26	IJ0014	26	26
RW0008	2.6	51232	45.6	IJ0015	26	26	IJ0016	25	26
				IJ0017	24	26	IJ0018	28	26
				IJ0019	26	26	IJ0020	26	26
				IJ0021	26	26	IJ0022	25	26

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Battery	Voltage (V)	Percent Charge (%)	Task that need to be completed during the next scheduled visit
1a	11.92	0.00	- 0% charge reading, however pumps are still operation. May be indication of problem with battery meter.
1b	11.92	0.00	
2a	11.79	0.00	
2b	11.80	0.00	

Comments

- significant biofouling (black/smokey colored groundwater) in RW0007 pipe lines

- minor biofouling in RW0008 pipe lines

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: Joseph Bartlett | **Date: 08/18/2011** | **Time: 0916**

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	No	"load disconnect" light on charge controller suggesting battery charge reached 0%,
System operational on departure (yes/no)	Weekly	Yes	causing the system to shut off until 100% charge reached.
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	system forced ON by turning system off, then on using toggle switches and
Clean filters	Weekly	Yes	disconnecting/reconnecting battery terminals
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	Yes	

Extraction Wells			
	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)
RW0007	2.3	74258	103.4
RW0008	2.6	59187	98.9

Injection Wells[2]					
Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
IJ0013	24	24	IJ0014	27	28
IJ0015	24	24	IJ0016	30	28
IJ0017	26	24	IJ0018	27	28
IJ0019	27	24	IJ0020	28	28
IJ0021	20	24	IJ0022	26	28

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Battery	Voltage (V)	Percent Charge (%)
1a	12.08	25.00
1b	12.08	25.00
2a	11.96	6.00
2b	11.96	6.00

Task that need to be completed during the next scheduled visit

charge read at 1130 to observe charging rate:
1a - 12.30 V, 61%
1b - 12.24 V, 51%
2a - 12.04 V, 18%
2b - 12.04 V, 18%

Comments

IDW - pallet #: 183809, drum #: 183866

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: Joseph Bartlett	Date: 08/24/2011	Time: 1040

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	No	load disconnect light on
System operational on departure (yes/no)	Weekly	Yes	forced on by diconnecting/reconnecting battery terminals
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	Yes	
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	No	

Extraction Wells

	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)
RW0007	2.4	82434	161.5
RW0008	2.6	67015	151.5

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Injection Wells[2]

Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
IJ0013	24	24	IJ0014	30	28
IJ0015	24	24	IJ0016	28	28
IJ0017	20	24	IJ0018	28	28
IJ0019	26	24	IJ0020	30	28
IJ0021	28	24	IJ0022	26	28

Battery	Voltage (V)	Percent Charge (%)
1a	12.27	56.00
1b	12.24	51.00
2a	12.19	45.00
2b	12.20	45.00

Task that need to be completed during the next scheduled visit

Comments

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: Joseph Bartlett | **Date: 08/31/2011** | **Time: 0930**

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	No	load disconnect light on - Forced system on
System operational on departure (yes/no)	Weekly	Yes	
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	Yes	
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	Yes	

Extraction Wells

	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)
RW0007	2.4	90012	214.3
RW0008	2.5	74235	199.6

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Injection Wells[2]

Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
IJ0013	26	25	IJ0014	27	27
IJ0015	25	25	IJ0016	27	27
IJ0017	26	25	IJ0018	29	27
IJ0019	26	25	IJ0020	23	27
IJ0021	24	25	IJ0022	30	27

Battery	Voltage (V)	Percent Charge (%)
1a	12.33	66.00
1b	12.33	66.00
2a	12.33	66.00
2b	12.35	66.00

Task that need to be completed during the next scheduled visit

Comments

- collected data logger data
- data logger in RW0008 gone, most likely fell to bottom of well
    - pulled RW0008 pump out, data logger attached
- repaired fencing

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: Joseph Bartlett	Date: 09/08/2011	Time: 0940

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	No	Load disconnect light on - forced on
System operational on departure (yes/no)	Weekly	Yes	
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	Yes	
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	No	

Extraction Wells

	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)
RW0007	2.6	101352	288.8
RW0008	2.6	84039	265.7

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Injection Wells[2]

Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
IJ0013	27	26	IJ0014	28	27
IJ0015	26	26	IJ0016	27	27
IJ0017	30	26	IJ0018	26	27
IJ0019	26	26	IJ0020	26	27
IJ0021	22	26	IJ0022	28	27

Battery	Voltage (V)	Percent Charge (%)
1a	12.17	39.00
1b	12.14	32.00
2a	12.16	39.00
2b	12.17	39.00

Task that need to be completed during the next scheduled visit

need to order more filters soon: Flow max pleated filter cartridge. 2 3/4" dia., 20 micron

Comments

Battery Analyzer: Argus Analyzer, model # AA350.

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: Joseph Bartlett	Date: 09/15/2011	Time: 1422

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	Yes	
System operational on departure (yes/no)	Weekly	Yes	
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	Yes	replaced with cleaned filters.
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	No	

Extraction Wells				Injection Wells[2]					
	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)	Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
RW0007	2.5	112997	365.1	IJ0013	25	28	IJ0014	27	26
RW0008	2.4	94424	335.7	IJ0015	26	28	IJ0016	25	26
				IJ0017	26	28	IJ0018	27	26
				IJ0019	23	27	IJ0020	29	26
				IJ0021	38	28	IJ0022	24	26

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Battery	Voltage (V)	Percent Charge (%)	Task that need to be completed during the next scheduled visit
1a	12.67	94.00	
1b	12.73	96.00	
2a	12.70	96.00	
2b	12.73	98.00	

Comments

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: Joseph Bartlett	Date: 09/22/11	Time: 0952

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	No	load disconnect light on
System operational on departure (yes/no)	Weekly	Yes	forced on
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	Yes	replaced with cleaned filters
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	Yes	

Extraction Wells

	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)
RW0007	2.5	123841	436.4
RW0008	2.6	103828	400

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Injection Wells[2]

Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
IJ0013	28	27	IJ0014	26	27
IJ0015	27	27	IJ0016	27	27
IJ0017	24	26	IJ0018	23	27
IJ0019	26	27	IJ0020	28	27
IJ0021	28	27	IJ0022	27	27

Battery	Voltage (V)	Percent Charge (%)
1a	12.08	25.00
1b	12.11	25.00
2a	12.08	25.00
2b	12.11	25.00

Task that need to be completed during the next scheduled visit

Comments

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: Joseph Bartlett | **Date: 09/28/11** | **Time: 1236**

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	Yes	
System operational on departure (yes/no)	Weekly	Yes	
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	Yes	replaced with cleaned filters
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	No	

Extraction Wells				Injection Wells[2]					
	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)	Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
RW0007	2.5	132387	492.5	IJ0013	25	27	IJ0014	27	27
RW0008	2.6	111063	449.5	IJ0015	30	27	IJ0016	27	27
				IJ0017	26	27	IJ0018	28	27
				IJ0019	32	27	IJ0020	26	27
				IJ0021	22	27	IJ0022	28	27

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Battery	Voltage (V)	Percent Charge (%)	Task that need to be completed during the next scheduled visit
1a	12.48	71.00	
1b	12.48	84.00	
2a	12.43	76.00	
2b	12.46	80.00	

Comments

collected data from data loggers, redeployed

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: Joseph Bartlett	Date: 10/05/11	Time: 0935

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	No	Load disconnect light on
System operational on departure (yes/no)	Weekly	Yes	Forced on
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	Yes	Replaced with cleaned filters
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	No	

Extraction Wells

	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)
RW0007	2.5	144138	569.8
RW0008	2.6	121025	518

Injection Wells[2]

Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
IJ0013	28	27	IJ0014	27	27
IJ0015	24	27	IJ0016	26	27
IJ0017	26	26	IJ0018	26	27
IJ0019	25	27	IJ0020	28	27
IJ0021	29	27	IJ0022	26	27

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Battery	Voltage (V)	Percent Charge (%)
1a	11.96	6.00
1b	11.96	6.00
2a	11.95	2.00
2b	11.95	2.00

Task that need to be completed during the next scheduled visit

Comments

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: Joseph Bartlett | **Date: 10/13/11** | **Time: 1046**

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	Yes	
System operational on departure (yes/no)	Weekly	Yes	
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	No	
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	No	

Extraction Wells				Injection Wells[2]					
	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)	Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
RW0007	2.5	153299	629.2	IJ0013	27	27	IJ0014	26	28
RW0008	2.6	129060	571.8	IJ0015	30	27	IJ0016	28	27
				IJ0017	24	26	IJ0018	28	28
				IJ0019	27	27	IJ0020	27	28
				IJ0021	25	27	IJ0022	28	28

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Battery	Voltage (V)	Percent Charge (%)	Task that need to be completed during the next scheduled visit
1a	12.11	32.00	
1b	12.08	25.00	
2a	12.20	45.00	
2b	12.22	51.00	

Comments

Fence repaired

overcast weather during week

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: Joseph Bartlett	Date: 10/20/11	Time: 1219

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	Yes	
System operational on departure (yes/no)	Weekly	Yes	
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	Yes	replaced with cleaned filters
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	No	

Extraction Wells				Injection Wells[2]					
	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)	Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
RW0007	2.6	160697	676.7	IJ0013	30	29	IJ0014	28	27
RW0008	2.6	135468	612.7	IJ0015	26	29	IJ0016	26	26
				IJ0017	28	28	IJ0018	27	27
				IJ0019	27	29	IJ0020	27	27
				IJ0021	31	29	IJ0022	26	27

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Battery	Voltage (V)	Percent Charge (%)	Task that need to be completed during the next scheduled visit
1a	12.84	100.00	
1b	12.81	100.00	
2a	12.75	98.00	
2b	12.78	100.00	

Comments

overcast weather during week

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: Joseph Bartlett	Date: 10/27/11	Time: 1233

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	Yes	
System operational on departure (yes/no)	Weekly	Yes	
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	Yes	Replaced with cleaned filters
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	No	

Extraction Wells			
	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)
RW0007	2.6	172662	754.6
RW0008	2.6	145857	678.4

Injection Wells[2]					
Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
IJ0013	26	28	IJ0014	26	27
IJ0015	30	28	IJ0016	26	27
IJ0017	24	28	IJ0018	28	27
IJ0019	28	28	IJ0020	28	27
IJ0021	28	28	IJ0022	28	27

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Battery	Voltage (V)	Percent Charge (%)
1a	12.35	66.00
1b	12.35	71.00
2a	12.62	92.00
2b	12.65	94.00

Task that need to be completed during the next scheduled visit

Comments

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: Joseph Bartlett | **Date: 11/03/11** | **Time: 1408**

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	Yes	
System operational on departure (yes/no)	Weekly	Yes	
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	Yes	replaced with new filters
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	No	

Extraction Wells				Injection Wells[2]					
	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)	Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
RW0007	2.5	180418	805.1	IJ0013	30	28	IJ0014	26	27
RW0008	2.6	153165	726.5	IJ0015	27	28	IJ0016	26	27
				IJ0017	26	28	IJ0018	27	27
				IJ0019	30	28	IJ0020	25	27
				IJ0021	26	28	IJ0022	28	27

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Battery	Voltage (V)	Percent Charge (%)	Task that need to be completed during the next scheduled visit
1a	12.16	51.00	
1b	12.24	51.00	
2a	12.27	56.00	
2b	12.27	56.00	

Comments

Water accumulation in IJ17 &18 vault box. Leaking water funneled into vault box through secondary containment tubing. Approx. 5 gallons from vault box poured into IDW drum # 185539. Repaired leak at male-male connector by applying additional hose clamps.

Repaired leaking manifold tubing.

Collected Datalogger data.

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: Joseph Bartlett | **Date: 11/10/11** | **Time: 1155**

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	Yes	
System operational on departure (yes/no)	Weekly	Yes	
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	No	
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	No	

Extraction Wells

	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)
RW0007	2.5	188701	859.9
RW0008	2.6	160793	776.7

Injection Wells[2]

Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
IJ0013	26	26	IJ0014	28	27
IJ0015	26	26	IJ0016	26	27
IJ0017	30	26	IJ0018	28	27
IJ0019	24	26	IJ0020	27	27
IJ0021	26	26	IJ0022	26	27

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Battery	Voltage (V)	Percent Charge (%)
1a	12.86	100.00
1b	12.89	100.00
2a	12.81	100.00
2b	12.81	100.00

Task that need to be completed during the next scheduled visit

Comments

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: Joseph Bartlett	**Date: 11/17/11**	**Time: 0857**

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	No	Load Disconnect' light on
System operational on departure (yes/no)	Weekly	Yes	Forced on
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	Yes	New filters installed
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	No	

Extraction Wells			
	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)
RW0007	2.5	199088	928.0
RW0008	2.6	170200	838.7

Injection Wells[2]					
Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
IJ0013	28	27	IJ0014	28	27
IJ0015	29	27	IJ0016	28	27
IJ0017	26	27	IJ0018	28	27
IJ0019	26	27	IJ0020	25	27
IJ0021	26	27	IJ0022	30	27

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Battery	Voltage (V)	Percent Charge (%)
1a	12.28	56.00
1b	12.28	56.00
2a	12.08	25.00
2b	12.08	25.00

Task that need to be completed during the next scheduled visit

Comments

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: Joseph Bartlett	Date: 11/22/11	Time: 1232

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	Yes	
System operational on departure (yes/no)	Weekly	Yes	
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	Yes	replaced with cleaned filters
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	Yes	

Extraction Wells				Injection Wells[2]					
	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)	Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
RW0007	2.5	205617	970.2	IJ0013	28	27	IJ0014	27	26
RW0008	2.5	175870	876.3	IJ0015	26	27	IJ0016	28	26
				IJ0017	25	26	IJ0018	30	26
				IJ0019	26	27	IJ0020	24	26
				IJ0021	28	27	IJ0022	24	26

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Battery	Voltage (V)	Percent Charge (%)	Task that need to be completed during the next scheduled visit
1a	12.94	100.00	
1b	12.67	94.00	
2a	12.52	87.00	
2b	12.52	84.00	

Comments

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: Joseph Bartlett	Date: 12/1/11	Time: 0920

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	Yes	
System operational on departure (yes/no)	Weekly	Yes	
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	Yes	replaced with cleaned filters
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	No	

Extraction Wells				Injection Wells[2]					
	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)	Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
RW0007	2.5	216612	1043.1	IJ0013	26	27	IJ0014	25	26
RW0008	2.6	185735	940.6	IJ0015	26	27	IJ0016	28	26
				IJ0017	30	27	IJ0018	26	26
				IJ0019	27	27	IJ0020	26	26
				IJ0021	26	27	IJ0022	26	26

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Battery	Voltage (V)	Percent Charge (%)	Task that need to be completed during the next scheduled visit
1a	12.04	11.00	
1b	12.03	11.00	
2a	12.48	84.00	
2b	12.48	84.00	

Comments

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: Joseph Bartlett	Date: 12/7/11	Time: 1007

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	Yes	
System operational on departure (yes/no)	Weekly	Yes	
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	No	
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	No	

Extraction Wells				Injection Wells[2]					
	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)	Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
RW0007	2.5	225042	1097.6	IJ0013	27	28	IJ0014	26	27
RW0008	2.6	193040	987.3	IJ0015	30	28	IJ0016	26	26
				IJ0017	24	27	IJ0018	27	27
				IJ0019	26	28	IJ0020	27	27
				IJ0021	29	28	IJ0022	28	27

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Battery	Voltage (V)	Percent Charge (%)	Task that need to be completed during the next scheduled visit
1a	12.14	39.00	
1b	12.14	39.00	
2a	12.46	80.00	
2b	12.48	80.00	

Comments

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: Joseph Bartlett	Date: 12/15/11	Time: 1202

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	No	"Load Disconnect" light on
System operational on departure (yes/no)	Weekly	Yes	
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	Yes	Replaced with cleaned filters
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	No	

Extraction Wells

	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)
RW0007	2.6	232700	1147.3
RW0008	2.6	199720	1030.0

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Injection Wells[2]

Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
IJ0013	26	26	IJ0014	27	27
IJ0015	26	26	IJ0016	26	26
IJ0017	25	26	IJ0018	27	27
IJ0019	27	26	IJ0020	27	27
IJ0021	27	26	IJ0022	26	27

Battery	Voltage (V)	Percent Charge (%)
1a	12.28	56.00
1b	12.27	56.00
2a	12.27	51.00
2b	12.28	56.00

Task that need to be completed during the next scheduled visit

Comments

Weather - 70s, ovecast

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: Joseph Bartlett	Date: 12/22/11	Time: 1040

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	No	"load disconnect" light on
System operational on departure (yes/no)	Weekly	Yes	
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	Yes	replaced with cleaned filters
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	No	

Extraction Wells				Injection Wells[2]					
	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)	Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
RW0007	2.5	240538	1198.6	IJ0013	28	26	IJ0014	26	27
RW0008	2.5	206694	1074.8	IJ0015	25	26	IJ0016	28	26
				IJ0017	26	26	IJ0018	26	27
				IJ0019	26	26	IJ0020	26	27
				IJ0021	26	26	IJ0022	26	27

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Battery	Voltage (V)	Percent Charge (%)	Task that need to be completed during the next scheduled visit
1a	12.27	56.00	
1b	12.28	56.00	
2a	12.22	51.00	
2b	12.28	56.00	

Comments

data logger data collected

weather: 70s, overcast

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: Joseph Bartlett	Date: 1/5/12	Time: 1534

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	No	RW7 not running; RW8 running
System operational on departure (yes/no)	Weekly	Yes	
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	Yes	replaced with cleaned filters
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	No	

Extraction Wells

	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)
RW0007	2.6	249543	1298.4
RW0008	2.6	222277	1175.3

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Injection Wells[2]

Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
IJ0013	30	28	IJ0014	28	27
IJ0015	28	28	IJ0016	25	26
IJ0017	28	28	IJ0018	27	27
IJ0019	27	28	IJ0020	28	27
IJ0021	28	28	IJ0022	27	27

Battery	Voltage (V)	Percent Charge (%)
1a	13.21	100.00
1b	13.26	100.00
2a	12.56	90.00
2b	12.59	90.00

Task that need to be completed during the next scheduled visit

Comments

- Upon arrival, RW7 pump was not running. Inspected wiring - ok. Switched source wiring, pump was not responsive.

The pump has reached The end of its useful life. Replaced pump for RW7 with spare.

- Repaired construction fencing.

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: Joseph Bartlett	Date: 1/16/12	Time: 0953

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	Yes	
System operational on departure (yes/no)	Weekly	Yes	
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	Yes	replaced with cleaned filters
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	No	

Extraction Wells				Injection Wells[2]					
	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)	Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
RW0007	2.5	265098	1398.5	IJ0013	25	28	IJ0014	26	26
RW0008	2.5	234235	1252.6	IJ0015	29	28	IJ0016	25	24
				IJ0017	26	27	IJ0018	26	26
				IJ0019	28	28	IJ0020	26	26
				IJ0021	26	28	IJ0022	25	26

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Battery	Voltage (V)	Percent Charge (%)	Task that need to be completed during the next scheduled visit
1a	12.11	25.00	
1b	12.09	25.00	
2a	12.01	11.00	
2b	12.03	11.00	

Comments

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: J. Bartlett	Date: 1/26/12	Time: 1230

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	Yes	
System operational on departure (yes/no)	Weekly	Yes	
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	Yes	replaced with cleaned filters
Collect water levels from injection wells	Monthly	Yes	see below
Clean solar panels	As Needed	Yes	
Clean flow meters	As Needed	No	

Extraction Wells				Injection Wells[2]					
	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)	Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
RW0007	2.6	279302	1489.8	IJ0013	32	28	IJ0014	27	27
RW0008	2.6	246358	1332.2	IJ0015	27	28	IJ0016	26	27
				IJ0017	26	28	IJ0018	27	27
				IJ0019	28	28	IJ0020	28	27
				IJ0021	30	28	IJ0022	29	27

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Battery	Voltage (V)	Percent Charge (%)	Task that need to be completed during the next scheduled visit
1a	12.46	80.00	
1b	12.46	80.00	
2a	12.72	96.00	
2b	12.72	96.00	

Comments

Collected data logger levels. Collected groundwater levels manually at time of data logger collection (system was on during time of collection):

RW07: 12.78 ft BTOC @ 1259; RW08: 23.12 ft BTOC @1311; IW2D1: 6.21 ft BTOC @1318; IW2D: 5.85 ft BTOC @ 1325; IJ17: 4.67 ft BTOC @1335

IJ18: 3.77 ft BTOC @ 1342; IJ13: 3.67 ft BTOC @ 1349; IJ14: 5.96 ft BTOC @1400

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: J Bartlett	**Date: 2/6/12**	**Time: 1407**

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	Yes	
System operational on departure (yes/no)	Weekly	Yes	
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	Yes	replaced with cleaned filters
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	No	

Extraction Wells				Injection Wells[2]					
	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)	Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
RW0007	2.6	293427	1580.5	IJ0013	26	28	IJ0014	26	27
RW0008	2.6	258227	1411.1	IJ0015	30	28	IJ0016	26	27
				IJ0017	29	29	IJ0018	27	27
				IJ0019	31	28	IJ0020	27	27
				IJ0021	26	28	IJ0022	27	27

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Battery	Voltage (V)	Percent Charge (%)	Task that need to be completed during the next scheduled visit
1a	12.54	87.00	
1b	12.54	87.00	
2a	12.64	92.00	
2b	12.67	94.00	

Comments

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: J Bartlett	Date: 2/14/12	Time: 0923

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	Yes	
System operational on departure (yes/no)	Weekly	No	system will be restarted 2/17/12
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	No	
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	No	

Extraction Wells				Injection Wells[2]					
	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)	Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
RW0007	2.6	302185	1636.7	IJ0013	30	27	IJ0014	26	26
RW0008	2.5	265760	1461.2	IJ0015	24	27	IJ0016	26	26
				IJ0017	28	27	IJ0018	26	26
				IJ0019	24	27	IJ0020	26	26
				IJ0021	28	27	IJ0022	26	26

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Battery	Voltage (V)	Percent Charge (%)
1a	12.12	32.00
1b	12.11	32.00
2a	12.08	25.00
2b	12.09	25.00

Task that need to be completed during the next scheduled visit

Comments

Data logger data collected 2/16/2012.

Water levels - IJ13: 5.85 ft BTOC @ 0921 (unable to collect data logger data - connection timed out); IJ14: 6.10 ft BTOC @ 1222; IW2D1: 6.28 ft BTOC @ 1231

IW2D: 6.14 ft BTOC @ 1239; RW7: 5.47 ft BTOC @ 1245; RW8: 5.33 ft BTOC @ 1253; IJ17: 5.43 ft BTOC @ 1302; IJ18: 5.70 ft BTOC @1307

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: J Bartlett	Date: 3/2/12	Time: 1030

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	Yes	
System operational on departure (yes/no)	Weekly	Yes	
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	Yes	Replaced with cleaned filters
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	No	

Extraction Wells

	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)
RW0007	2.6	322727	1768.6
RW0008	2.6	283067	1574.2

Injection Wells[2]

Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
IJ0013	26	28	IJ0014	26	27
IJ0015	30	28	IJ0016	26	27
IJ0017	27	28	IJ0018	26	27
IJ0019	29	28	IJ0020	28	27
IJ0021	27	28	IJ0022	28	27

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Battery	Voltage (V)	Percent Charge (%)
1a	12.44	76.00
1b	12.46	80.00
2a	12.56	87.00
2b	12.59	90.00

Task that need to be completed during the next scheduled visit

Comments

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: J. Bartlett | **Date: 3/15/12** | **Time: 1300**

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	No	RW7 not running, RW8 running
System operational on departure (yes/no)	Weekly	Yes	
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	Yes	replaced with cleaned filters
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	No	

Extraction Wells

	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)
RW0007	2.8	328054	1957.4
RW0008	2.6	299640	1681.9

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Injection Wells[2]

Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
IJ0013	29	30	IJ0014	28	28
IJ0015	32	30	IJ0016	28	28
IJ0017	30	30	IJ0018	28	28
IJ0019	30	30	IJ0020	28	28
IJ0021	32	30	IJ0022	28	28

Battery	Voltage (V)	Percent Charge (%)
1a	14.06	100.00
1b	13.72	100.00
2a	12.60	90.00
2b	12.64	92.00

Task that need to be completed during the next scheduled visit

Comments

Replaced pump for RW0007

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: J. Bartlett	**Date: 4/5/12**	**Time: 1300**

Maintenance & Monitoring

Item	**Frequency**	**Completed (yes/no)**	**Comments or Notes**
System operational on arrival (yes/no)[1]	Weekly	No	RW8 pumping; RW7 off
System operational on departure (yes/no)	Weekly	Yes	
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	Yes	Replaced with cleaned filters
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	No	

Extraction Wells			
	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)
RW0007	2.7	347393	2210.5
RW0008	2.6	330755	1881.4

Injection Wells[2]					
Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
IJ0013	30	30	IJ0014	28	28
IJ0015	28	30	IJ0016	28	28
IJ0017	30	29	IJ0018	28	28
IJ0019	30	30	IJ0020	28	28
IJ0021	28	30	IJ0022	28	28

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Battery	Voltage (V)	Percent Charge (%)
1a	13.69	100.00
1b	13.71	100.00
2a	12.76	98.00
2b	12.75	98.00

Task that need to be completed during the next scheduled visit

Comments

Tubing for RW7 had slipped off of 90° located at well top of casing. Will calculate operating time using flow. When reconnected, observed pumping rate to be very slow. Pulled pump, noticed thick cake layer on sediment sock on pump. Washed off and redeployed pump. Flow observed to be normal after cleaning.

Leaking for manifold, replaced cracked tubing segments.

Collected data logger data and removed all data loggers except 2 remaining in RW7 and RW8.

Repaired construction fencing.

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: J. Bartlett	Date: 4/19/12	Time: 1025

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	Yes	
System operational on departure (yes/no)	Weekly	Yes	
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	Yes	replaced with cleaned filters
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	No	

Extraction Wells				Injection Wells[2]					
	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)	Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
RW0007	2.6	368404	2346	IJ0013	26	26	IJ0014	25	26
RW0008	2.5	349626	2001	IJ0015	27	26	IJ0016	25	26
				IJ0017	26	26	IJ0018	25	26
				IJ0019	24	26	IJ0020	26	26
				IJ0021	24	26	IJ0022	26	26

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Battery	Voltage (V)	Percent Charge (%)	Task that need to be completed during the next scheduled visit
1a	12.16	39.00	
1b	12.12	25.00	
2a	12.56	87.00	
2b	12.60	90.00	

Comments

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: J. Bartlett	Date: 5/4/12	Time: 1055

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	Yes	
System operational on departure (yes/no)	Weekly	Yes	
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	Yes	replaced with cleaned filters
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	No	

Extraction Wells				Injection Wells[2]					
	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)	Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
RW0007	2.6	391657	2496.5	IJ0013	26	27	IJ0014	28	27
RW0008	2.6	370668	2135.4	IJ0015	28	27	IJ0016	25	26
				IJ0017	26	27	IJ0018	28	27
				IJ0019	30	27	IJ0020	28	27
				IJ0021	28	27	IJ0022	27	27

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Battery	Voltage (V)	Percent Charge (%)	Task that need to be completed during the next scheduled visit
1a	12.43	80.00	
1b	12.43	76.00	
2a	12.52	84.00	
2b	12.56	87.00	

Comments

repaired cracked manifold hose.

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: J. Bartlett	Date: 5/17/12	Time: 0936

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	Yes	
System operational on departure (yes/no)	Weekly	Yes	
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	Yes	replaced with cleaned filters
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	No	

Extraction Wells				Injection Wells[2]					
	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)	Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
RW0007	2.6	407750	2601.8	IJ0013	26	28	IJ0014	27	27
RW0008	2.5	386050	2234.7	IJ0015	26	28	IJ0016	25	26
				IJ0017	25	27	IJ0018	27	27
				IJ0019	26	28	IJ0020	26	27
				IJ0021	28	28	IJ0022	28	27

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Battery	Voltage (V)	Percent Charge (%)	Task that need to be completed during the next scheduled visit
1a	12.17	45.00	
1b	12.17	39.00	
2a	12.30	66.00	
2b	12.36	71.00	

Comments

- cleaned sediment sock for RW0007 after observing lower than normal flow.
- measurements were collected after cleaning of the sediment sock for RW07

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: J. Bartlett	Date: 6/7/12	Time: 0851

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	No	Load disconnect light on
System operational on departure (yes/no)	Weekly	Yes	
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	No	
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	No	

Extraction Wells

	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)
RW0007	2.5	434684	2778.9
RW0008	2.5	411500	2400.1

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Injection Wells[2]

Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
IJ0013	22	27	IJ0014	26	26
IJ0015	26	27	IJ0016	26	26
IJ0017	24	26	IJ0018	26	27
IJ0019	28	26	IJ0020	28	26
IJ0021	26	26	IJ0022	28	26

Battery	Voltage (V)	Percent Charge (%)
1a	12.27	56.00
1b	12.24	51.00
2a	12.30	66.00
2b	12.33	66.00

Task that need to be completed during the next scheduled visit

Comments

- weather overcast, 70s
- repaired leaking segment of manifold

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: J. Bartlett | **Date: 6/21/12** | **Time: 1230**

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	No	Both pumps down upon arrival
System operational on departure (yes/no)	Weekly	Yes	
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	Yes	replaced with cleaned filters
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	No	

Extraction Wells

	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)
RW0007	2.6	445425	2932.7
RW0008	2.6	420846	2517.7

Injection Wells[2]

Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
IJ0013	26	26	IJ0014	32	28
IJ0015	28	26	IJ0016	30	28
IJ0017	28	27	IJ0018	32	28
IJ0019	26	26	IJ0020	26	28
IJ0021	29	26	IJ0022	28	28

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Battery	Voltage (V)	Percent Charge (%)
1a	12.89	100.00
1b	13.05	100.00
2a	13.61	100.00
2b	13.68	100.00

Task that need to be completed during the next scheduled visit

Comments

- checked wiring for pump RW7, pulled pumps and tested by hooking directly to battery - noise like motor is trying to turn, but jammed. Replaced pump for RW7.
- checked wiring for pump RW8, pulled pump and tested - unresponsive. Replaced pump for RW8
- repaired leaking manifold tubing.
- readings colleced at 1555.

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: J. Bartlett	Date: 7/10/12	Time: 1005

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	No	RW7 running, RW8 not running.
System operational on departure (yes/no)	Weekly	Yes	
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	No	
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	No	

Extraction Wells

	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)
RW0007	2.5	471,010	3106.7
RW0008	2.6	434,550	2681.1

Injection Wells[2]

Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
IJ0013	32	26	IJ0014	28	28
IJ0015	26	26	IJ0016	28	28
IJ0017	24	25	IJ0018	28	28
IJ0019	25	26	IJ0020	28	28
IJ0021	25	26	IJ0022	28	28

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Battery	Voltage (V)	Percent Charge (%)
1a	12.27	61.00
1b	12.28	56.00
2a	12.88	100.00
2b	12.89	100.00

Task that need to be completed during the next scheduled visit

Comments

- Inspected piping in RW8, pipe was disconnected at elbow at TOC of RW. Hose clamp must have rusted through and fell off. Reconnected piping and replaced hose clamp. System operated normally.
- Cleared tall grass and weeds from wells and piping runs.

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: J. Bartlett	Date: 7/19/12	Time: 0926

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	Yes	
System operational on departure (yes/no)	Weekly	Yes	
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	Yes	replaced with cleaned filters
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	Yes	

Extraction Wells

	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)
RW0007	2.4	481880	3180.9
RW0008	2.5	445710	2753.0

Injection Wells[2]

Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
IJ0013	25	25	IJ0014	25	26
IJ0015	24	25	IJ0016	24	26
IJ0017	26	25	IJ0018	26	26
IJ0019	22	25	IJ0020	24	26
IJ0021	27	25	IJ0022	25	26

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Battery	Voltage (V)	Percent Charge (%)
1a	12.38	71.00
1b	12.36	71.00
2a	12.59	90.00
2b	12.62	92.00

Task that need to be completed during the next scheduled visit

Comments

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: J. Bartlett | **Date: 8/2/12** | **Time: 0920**

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	No	"load disconnect" light on
System operational on departure (yes/no)	Weekly	Yes	forced on by disconnecting/reconnecting battery terminals
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	Yes	replaced with cleaned filters
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	No	

Extraction Wells				Injection Wells[2]					
	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)	Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
RW0007	2.4	500950	3311.7	IJ0013	26	25	IJ0014	27	26
RW0008	2.5	464280	2870.3	IJ0015	25	25	IJ0016	25	26
				IJ0017	22	25	IJ0018	26	26
				IJ0019	26	25	IJ0020	26	26
				IJ0021	26	25	IJ0022	26	26

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Battery	Voltage (V)	Percent Charge (%)	Task that need to be completed during the next scheduled visit
1a	12.32	51.00	
1b	12.25	45.00	
2a	12.64	66.00	
2b	12.64	90.00	

Comments

Drums remaining onsite: Pallet 183805 - Drums 183808, 183807; Pallet 185408 - Drums 190485, 188680

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: J. Bartlett	Date: 8/16/12	Time: 1350

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	Yes	
System operational on departure (yes/no)	Weekly	Yes	
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	Yes	Replaced with cleaned filters
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	No	

Extraction Wells				Injection Wells[2]					
	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)	Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
RW0007	2.5	519394	3438.5	IJ0013	25	26	IJ0014	30	29
RW0008	2.6	482120	2981.1	IJ0015	26	26	IJ0016	30	29
				IJ0017	26	26	IJ0018	28	29
				IJ0019	24	26	IJ0020	28	29
				IJ0021	24	26	IJ0022	28	29

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Battery	Voltage (V)	Percent Charge (%)	Task that need to be completed during the next scheduled visit
1a	12.65	94.00	
1b	12.65	92.00	
2a	13.02	100.00	
2b	12.94	92.00	

Comments

Repaired leaking manifold tubing.

Geosyntec consultants

Launch Complex 34 O&M

Launch Complex 34, SWMU CC054
Cape Canaveral Air Force Station, Florida

Technician: J. Bartlett	Date: 09/06/12	Time: 1000

Maintenance & Monitoring

Item	Frequency	Completed (yes/no)	Comments or Notes
System operational on arrival (yes/no)[1]	Weekly	Yes	
System operational on departure (yes/no)	Weekly	Yes	
Inspect wiring and connection	Bi-weekly	Yes	
Inspect piping and connections for leaks	Weekly	Yes	
Clean filters	Weekly	Yes	replaced with cleaned filters
Collect water levels from injection wells	Monthly	No	
Clean solar panels	As Needed	No	
Clean flow meters	As Needed	No	

Extraction Wells			
	Flow Rate (gpm)	Volume Produced (gallons)	Hour Meter Reading (hours)
RW0007	2.4	543077	3605.6
RW0008	2.6	504939	3120.5

Injection Wells[2]					
Shallow (32-42 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final	Deep (47-57 ft BLS)	Flow Rate (gph) Initial	Flow Rate (gph) Final
IJ0013	22	24	IJ0014	28	27
IJ0015	25	24	IJ0016	26	27
IJ0017	23	24	IJ0018	28	27
IJ0019	24	24	IJ0020	28	27
IJ0021	24	24	IJ0022	27	27

1. System on a recycle timer set for 40 min/20 min off. If system is off, make sure system is not in 20 min off period.

2. Use flow meters to distribute flow evenly between injection wells. [multiply total flow rate (gpm) by 12 for rate for each well (gph).]

Battery	Voltage (V)	Percent Charge (%)
1a	12.28	56.00
1b	12.24	51.00
2a	12.59	90.00
2b	12.59	90.00

Task that need to be completed during the next scheduled visit

Comments

repaired leaking manifold tubing

marked locations for 12 mth DPT soil sampling

utility locate with Sean O'Brien and Eddie Crayton

Geosyntec consultants

APPENDIX F: CVOC MASS CALCULATIONS

High Permeability Layer				Low Permeability Layer			
Groundwater Pore Volume				**Groundwater Pore Volume**			
Treatment Area	3,700	sq ft	Based on area of TCE greater than 300 µg/L	Treatment Area	3,700	sq ft	Based area of TCE greater than 300 µg/L
Treatment Interval	33	ft	23 to 42 and 48 to 62 ft BLS for entire treatment area	Treatment Interval	6	ft	42 to 48 ft BLS for entire treatment area
Treatment Volume	122,100	cubic ft	Area X Interval	Treatment Volume	22,200	cubic ft	Area X Interval
Porosity	0.3		Porosity of Sand (Freeze and Cherry 1979)	Porosity	0.4		Porosity of Clay (Freeze and Cherry 1979)
Groundwater Pore Volume	36,630	cubic ft	Volume X Porosity	Groundwater Pore Volume	8,880	cubic ft	Volume X Porosity
	1,037,244	liters			251,453	liters	
Soil Weight				**Soil Weight**			
Treatment Area	3,700	sq ft	Based on area of TCE greater than 300 µg/L	Treatment Area	3,700	sq ft	Based area of TCE greater than 300 µg/L
Treatment Interval	14.5	ft	34.5 to 42 and 48 to 55 ft BLS for treatment area (sampled interval)	Treatment Interval	6	ft	42 to 48 ft BLS for entire treatment area
Treatment Volume	53,650	cubic ft	Area X Interval	Treatment Volume	22,200	cubic ft	Area X Interval
Soil Density	130	lbs/cubic ft, saturated	Saturated unit weight of Sand, dense and uniform (Lindeburg 2001)	Soil Density	110	lbs/cubic ft	Saturated unit weight of Clay dense and uniform (Lindeburg 2001)
	59	kg/cubic ft, saturated			50	kg/cubic ft	
Soil Weight	3,163,577	kg	Soil Density X Treatment Volume	Soil Weight	1,107,423	kg	Soil Density X Treatment Volume

BASELINE FLUX PHASE (14 March 2011 to 18 April 2011)

March_2011 (High Permeability)	Sample Date	Average Groundwater Concentration	Mass		March_2011 (Low Permeability)	Sample Date	Average Groundwater Concentration	Mass	
	1-Feb-11	(µg/L)	(lbs)	Final Biomass Growth		1-Feb-11	(µg/L)	(lbs)	Final Biomass Growth
	TCE	8,864	20			TCE	52,613	29	
	cDCE	24,012	55	Average Conc. X Pore Vol.		cDCE	8,800	5	Average Conc. X Pore Vol.
	VC	1,403	3			VC	179	0.1	
	GROUNDWATER MASS SUBTOTAL		78			GROUNDWATER MASS SUBTOTAL		34	
	Sample Date	Average Soil Concentration	Mass			Sample Date	Average Soil Concentration	Mass	
	n/a	(mg/kg)	(lbs)	Final Biomass Growth		n/a	(mg/kg)	(lbs)	Final Biomass Growth
	TCE	no data	no data	Average Conc. X Soil Wt.		TCE	no data	no data	Average Conc. X Pore Vol.
	cDCE	no data	no data			cDCE	no data	no data	
	SOIL MASS SUBTOTAL		no data			SOIL MASS SUBTOTAL		no data	
HIGH PERMEABILITY MASS SUBTOTAL (March 2011)			78		LOW PERMEABILITY MASS SUBTOTAL (March 2011)			34	
					TOTAL MASS (March 2011)			112	

April_2011 (High Permeability)	Sample Date	Average Groundwater Concentration	Mass		April_2011 (Low Permeability)	Sample Date	Average Groundwater Concentration	Mass	
	18-Apr-16	(µg/L)	(lbs)	Final Biomass Growth		18-Apr-16	(µg/L)	(lbs)	Final Biomass Growth
	TCE	3,817	9			TCE	60,229	33	
	cDCE	21,235	49	Average Conc. X Pore Vol.		cDCE	6,800	4	Average Conc. X Pore Vol.
	VC	1,533	4			VC	320	0	
	GROUNDWATER MASS SUBTOTAL		61			GROUNDWATER MASS SUBTOTAL		37	
	Sample Date	Average Soil Concentration	Mass			Sample Date	Average Soil Concentration	Mass	
	n/a	(mg/kg)	(lbs)	Final Biomass Growth		n/a	(mg/kg)	(lbs)	Final Biomass Growth
	TCE	no data	no data	Average Conc. X Soil Wt.		TCE	no data	no data	Average Conc. X Pore Vol.
	cDCE	no data	no data			cDCE	no data	no data	
	SOIL MASS SUBTOTAL		no data			SOIL MASS SUBTOTAL		no data	
HIGH PERMEABILITY MASS SUBTOTAL (April 2011)			61		LOW PERMEABILITY MASS SUBTOTAL (April 2011)			37	
					TOTAL MASS (April 2011)			98	

MASS REMOVED FROM HIGH PERMEABILITY LAYER SUBTOTAL (April 2011)	17	lbs	MASS REMOVED FROM LOW PERMEABILITY LAYER SUBTOTAL (April 2011)	-3	lbs
			TOTAL MASS REMOVED (Baseline Flux Phase - 14 March 2011 to 18 April 2011)	14	lbs

% Reduction	Days	Removal Rate	
12	35	0.40	lbs removed/day

High Permeability Layer

Groundwater Pore Volume			
Treatment Area	3,700	sq ft	Based on area of TCE greater than 300 µg/L
Treatment Interval	33	ft	23 to 42 and 48 to 62 ft BLS for entire treatment area
Treatment Volume	122,100	cubic ft	Area X Interval
Porosity	0.3		Porosity of Sand (Freeze and Cherry 1979)
Groundwater Pore Volume	36,630	cubic ft	Volume X Porosity
	1,037,244	liters	
Soil Weight			
Treatment Area	3,700	sq ft	Based on area of TCE greater than 300 µg/L
Treatment Interval	14.5	ft	34.5 to 42 and 48 to 55 ft BLS for treatment area (sampled interval)
Treatment Volume	53,650	cubic ft	Area X Interval
Soil Density	130	lbs/cubic ft, saturated	Saturated unit weight of Sand, dense and uniform (Lindeburg 2001)
	59	kg/cubic ft, saturated	
Soil Weight	3,163,577	kg	Soil Density X Treatment Volume

Low Permeability Layer

Groundwater Pore Volume			
Treatment Area	3,700	sq ft	Based area of TCE greater than 300 µg/L
Treatment Interval	6	ft	42 to 48 ft BLS for entire treatment area
Treatment Volume	22,200	cubic ft	Area X Interval
Porosity	0.4		Porosity of Clay (Freeze and Cherry 1979)
Groundwater Pore Volume	8,880	cubic ft	Volume X Porosity
	251,453	liters	
Soil Weight			
Treatment Area	3,700	sq ft	Based area of TCE greater than 300 µg/L
Treatment Interval	6	ft	42 to 48 ft BLS for entire treatment area
Treatment Volume	22,200	cubic ft	Area X Interval
Soil Density	110	lbs/cubic ft	Saturated unit weight of Clay dense and uniform (Lindeburg 2001)
	50	kg/cubic ft	
Soil Weight	1,107,423	kg	Soil Density X Treatment Volume

SYSTEM OPERATION PHASE (9 August 2011 to 11 September 2012)

High Permeability Layer – August_2011

Sample Date	Average Groundwater Concentration	Mass	
1-Aug-11	(µg/L)	(lbs)	Final Biomass Growth
TCE	3,037	7	
cDCE	15,878	36	Average Conc. X Pore Vol.
VC	2,533	6	
GROUNDWATER MASS SUBTOTAL		49	

Sample Date	Average Soil Concentration	Mass	
3-Aug-11	(mg/kg)	(lbs)	Final Biomass Growth
TCE	10	68	Average Conc. X Soil Wt.
cDCE	3	21	
SOIL MASS SUBTOTAL		89	
HIGH PERMEABILITY MASS SUBTOTAL (August 2011)		138	

Low Permeability Layer – August_2011

Sample Date	Average Groundwater Concentration	Mass	
1-Aug-11	(µg/L)	(lbs)	Final Biomass Growth
TCE	40,381	22	
cDCE	6,867	4	Average Conc. X Pore Vol.
VC	785	0.4	
GROUNDWATER MASS SUBTOTAL		27	

Sample Date	Average Soil Concentration	Mass	
3-Aug-11	(mg/kg)	(lbs)	Final Biomass Growth
TCE	32	77	Average Conc. X Pore Vol.
cDCE	3	7	
SOIL MASS SUBTOTAL		84	
LOW PERMEABILITY MASS SUBTOTAL (August 2011)		110	

TOTAL MASS (Aug. 2011): 248

High Permeability Layer – September_2012

Sample Date	Average Groundwater Concentration	Mass	
11-Sep-12	(µg/L)	(lbs)	Final Biomass Growth
TCE	53	0.1	
cDCE	3,882	9	Average Conc. X Pore Vol.
VC	1,401	3	
GROUNDWATER MASS SUBTOTAL		12	

Sample Date	Average Soil Concentration	Mass	
10-Sep-12	(mg/kg)	(lbs)	Final Biomass Growth
TCE	4	27	Average Conc. X Soil Wt.
cDCE	3	21	
SOIL MASS SUBTOTAL		48	
HIGH PERMEABILITY MASS SUBTOTAL (September 2012)		60	

Low Permeability Layer – September_2012

Sample Date	Average Groundwater Concentration	Mass	
11-Sep-12	(µg/L)	(lbs)	Final Biomass Growth
TCE	14,336	8	
cDCE	4,042	2	Average Conc. X Pore Vol.
VC	4,230	2	
GROUNDWATER MASS SUBTOTAL		13	

Sample Date	Average Soil Concentration	Mass	
10-Sep-12	(mg/kg)	(lbs)	Final Biomass Growth
TCE	18	43	Average Conc. X Pore Vol.
cDCE	9	22	
SOIL MASS SUBTOTAL		65	
LOW PERMEABILITY MASS SUBTOTAL (September 2012)		78	

TOTAL MASS (September 2012): 138

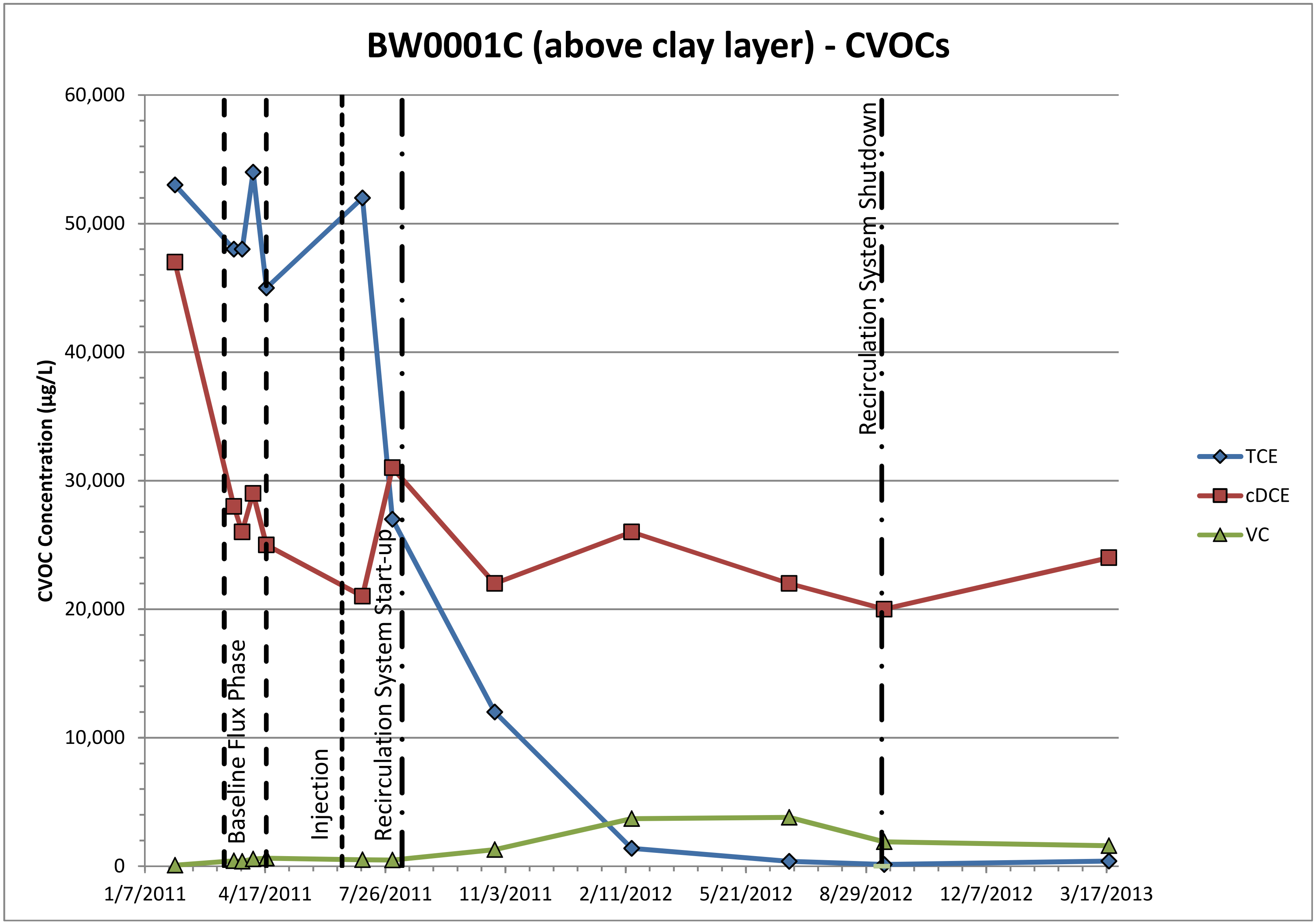
MASS REMOVED FROM HIGH PERMEABILITY LAYER SUBTOTAL (April 2011)	78	lbs
MASS REMOVED FROM LOW PERMEABILITY LAYER SUBTOTAL (April 2011)	32	lbs
TOTAL MASS REMOVED (System Operation Phase - 9 Aug. 2011 to 11 Sept. 2012)	110	lbs

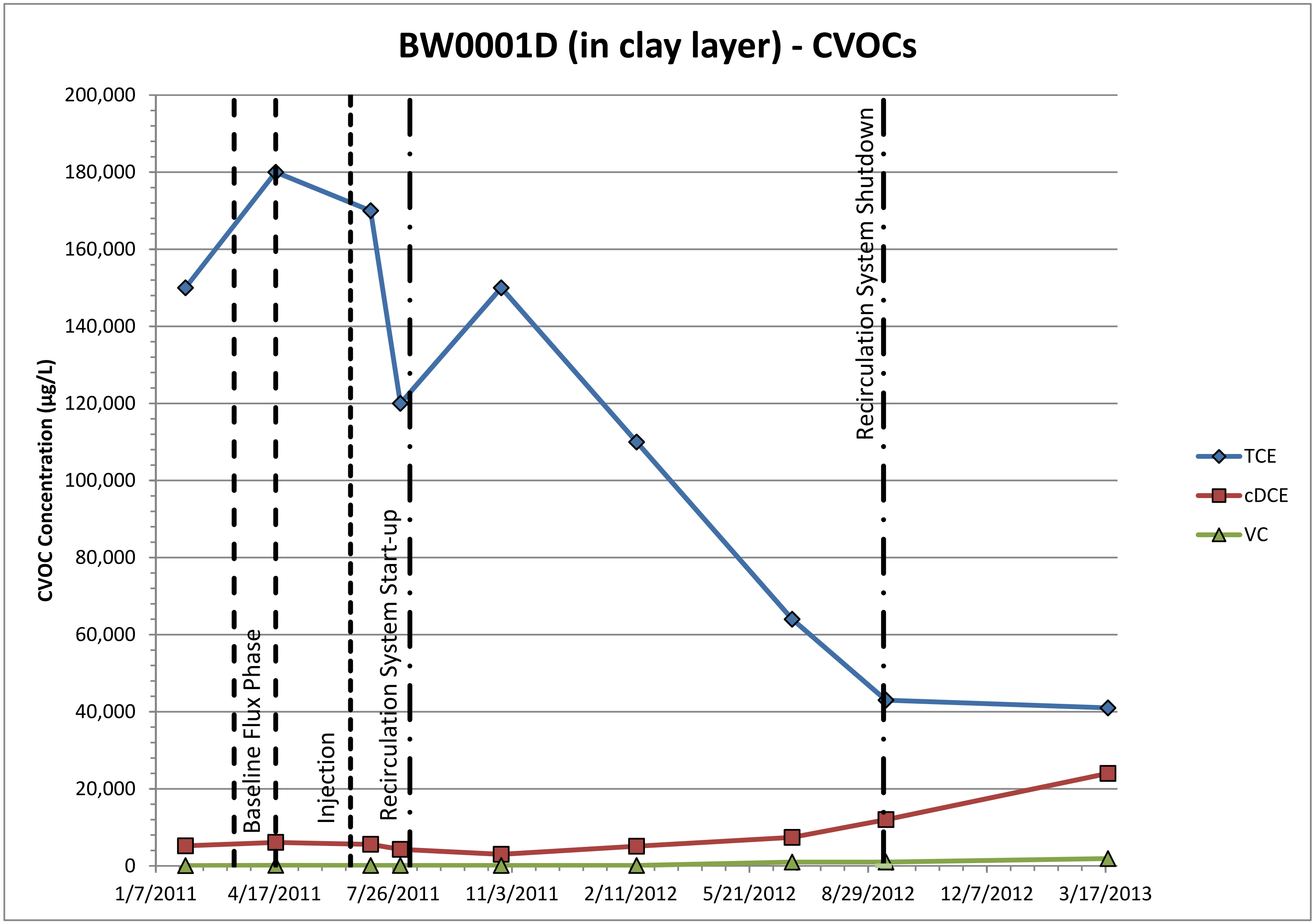
% Reduction	Days	Removal Rate	
44	399	0.28	lbs removed/day

APPENDIX G: TREND GRAPHS

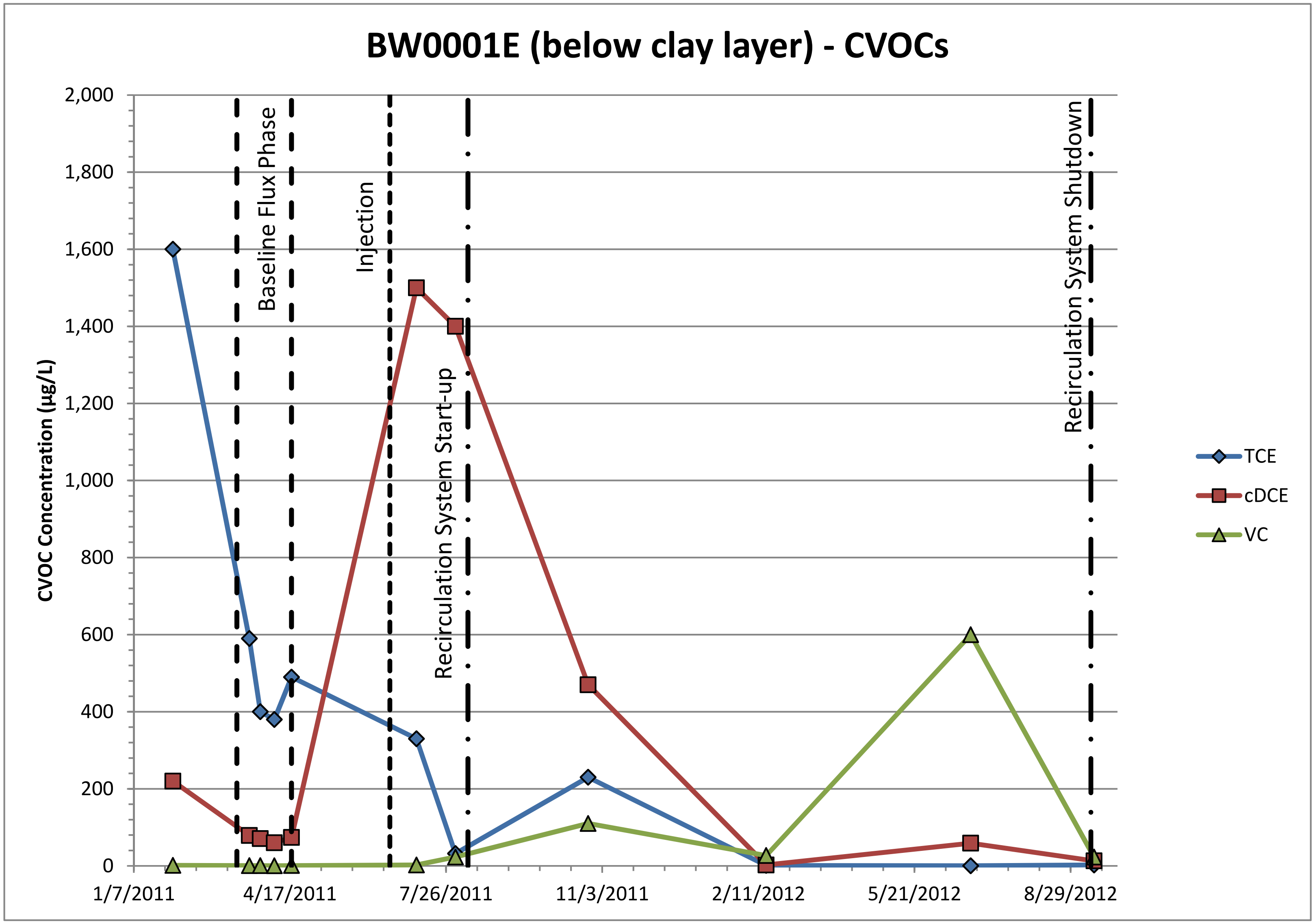
TREND GRAPHS

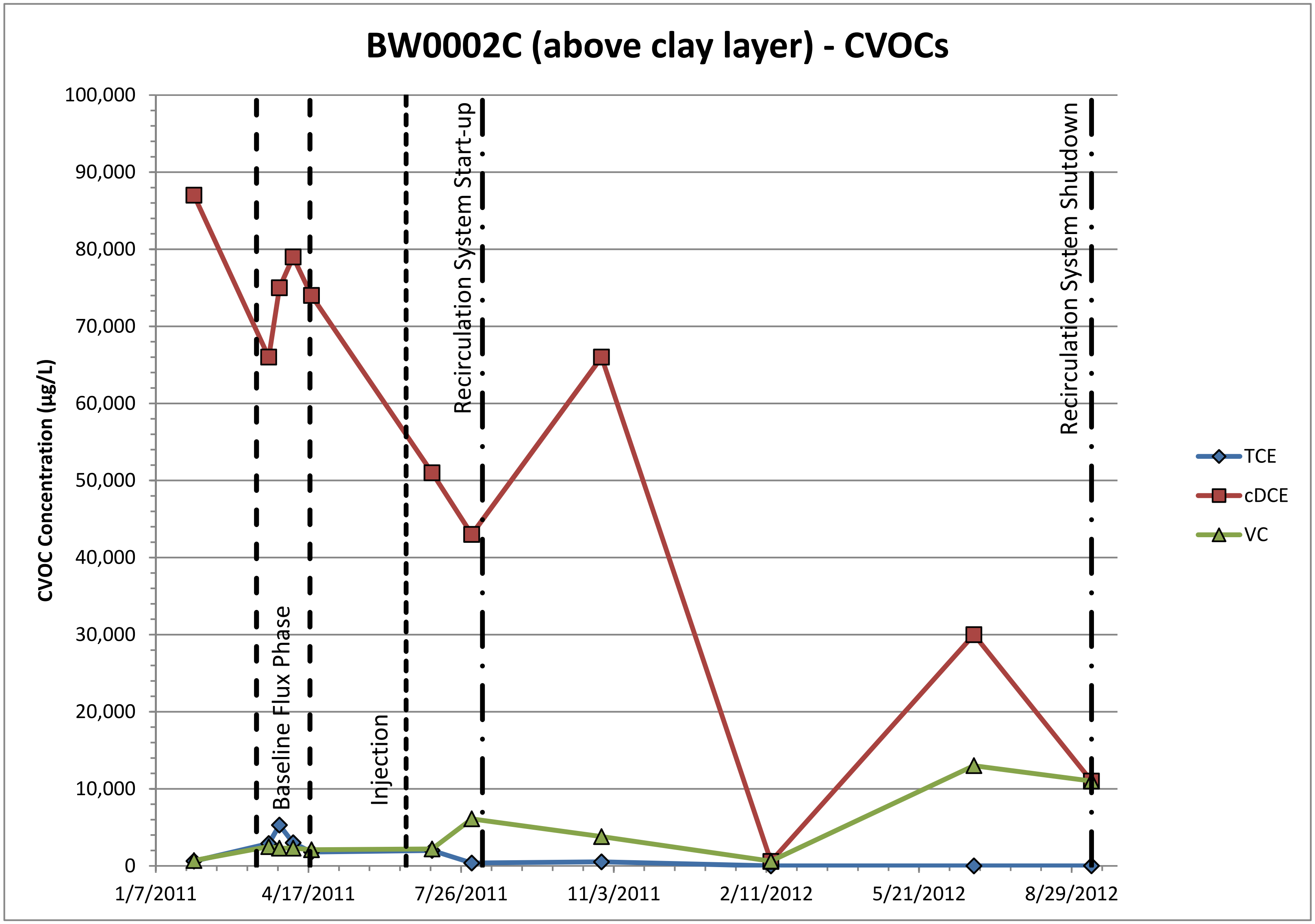
CVOC Concentrations

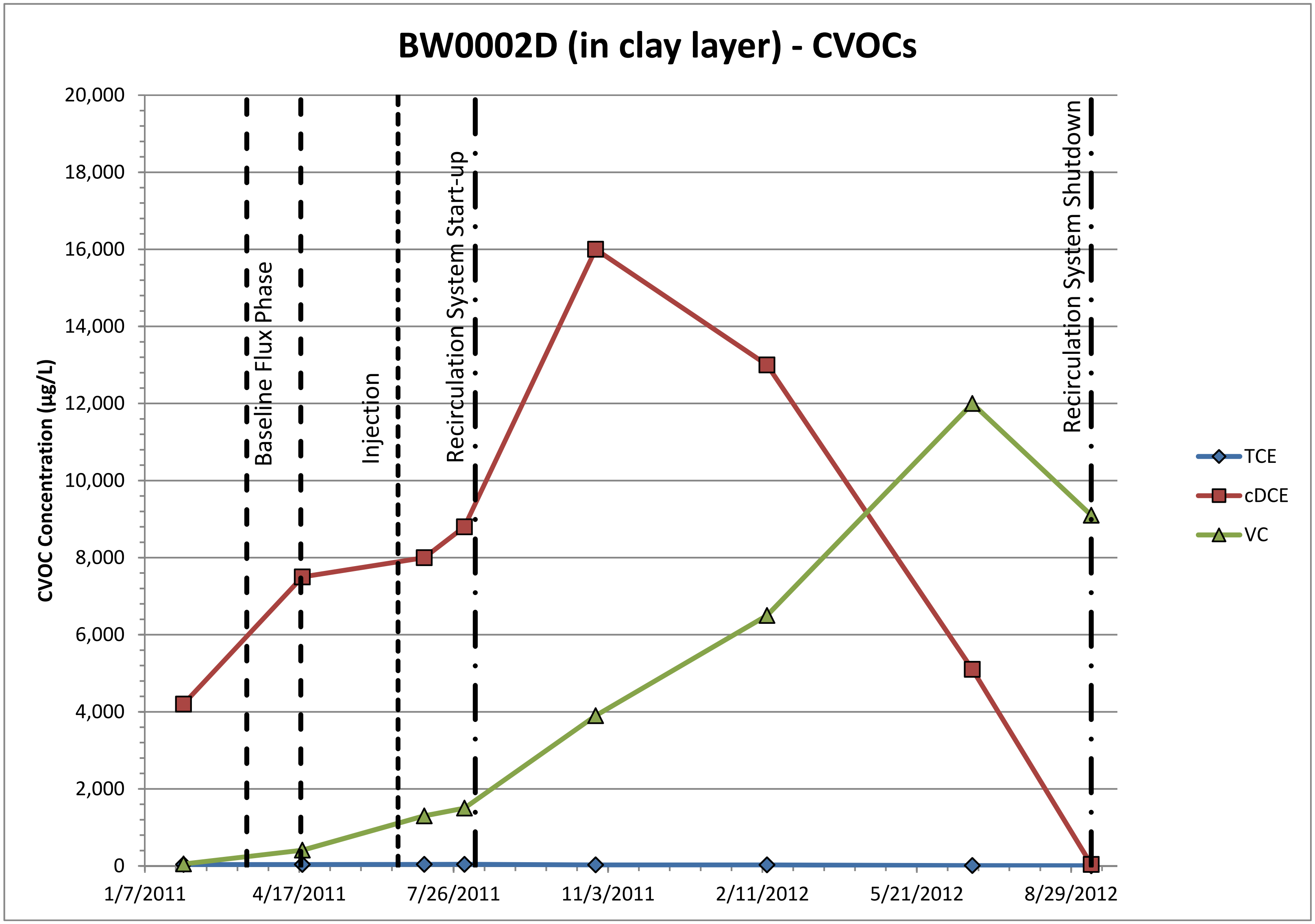

BW0001C (above clay layer) - CVOCs
CVOC Concentration (µg/L)
60,000
50,000
40,000
30,000
20,000
10,000
0
1/7/2011
4/17/2011
7/26/2011
11/3/2011
2/11/2012
5/21/2012
8/29/2012
12/7/2012
3/17/2013
Baseline Flux Phase
Injection
Recirculation System Start-up
Recirculation System Shutdown
TCE
cDCE
VC



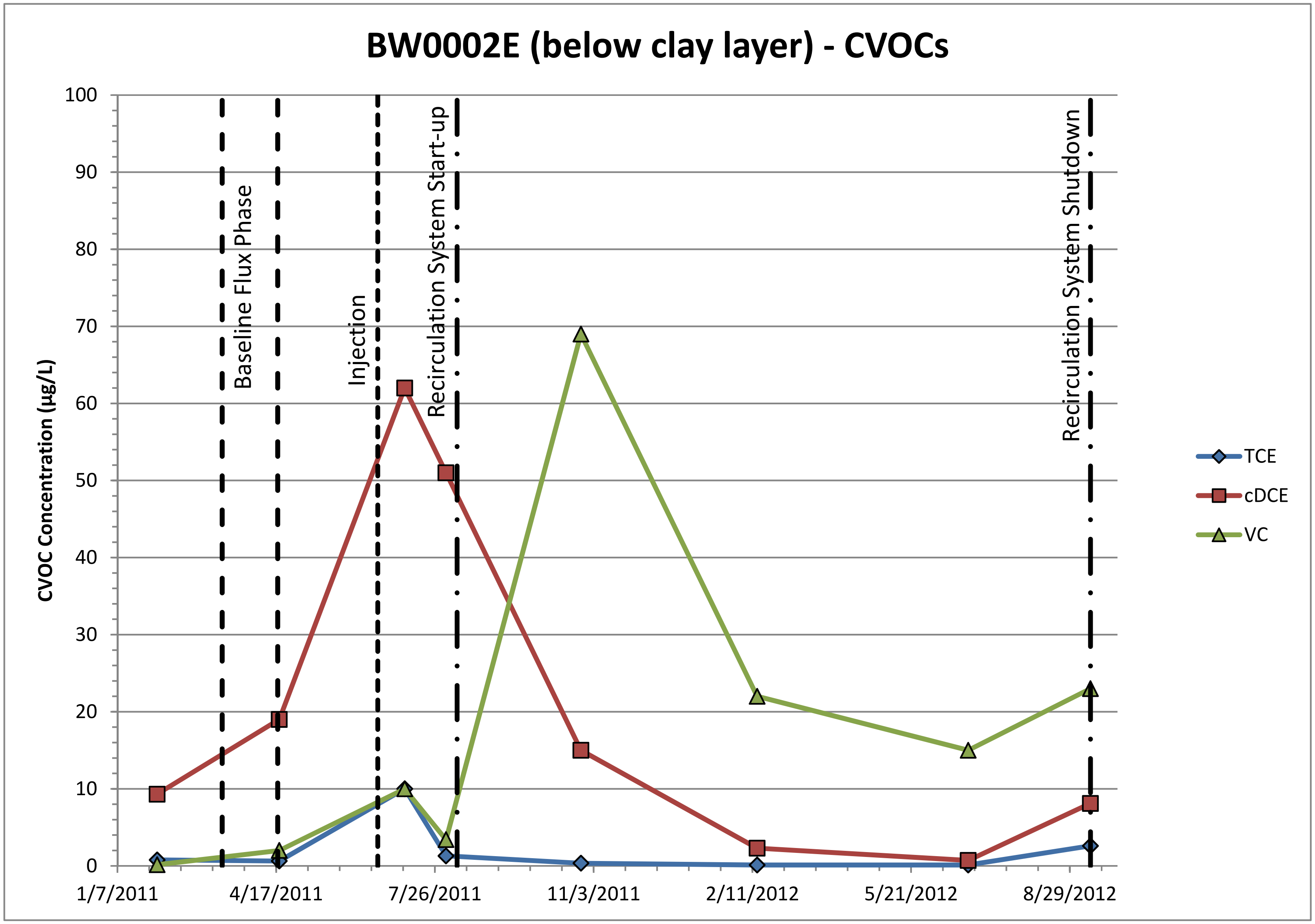
BW0001D (in clay layer) - CVOCs
CVOC Concentration (µg/L)
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
1/7/2011
4/17/2011
7/26/2011
11/3/2011
2/11/2012
5/21/2012
8/29/2012
12/7/2012
3/17/2013
Baseline Flux Phase
Injection
Recirculation System Start-up
Recirculation System Shutdown
TCE
cDCE
VC

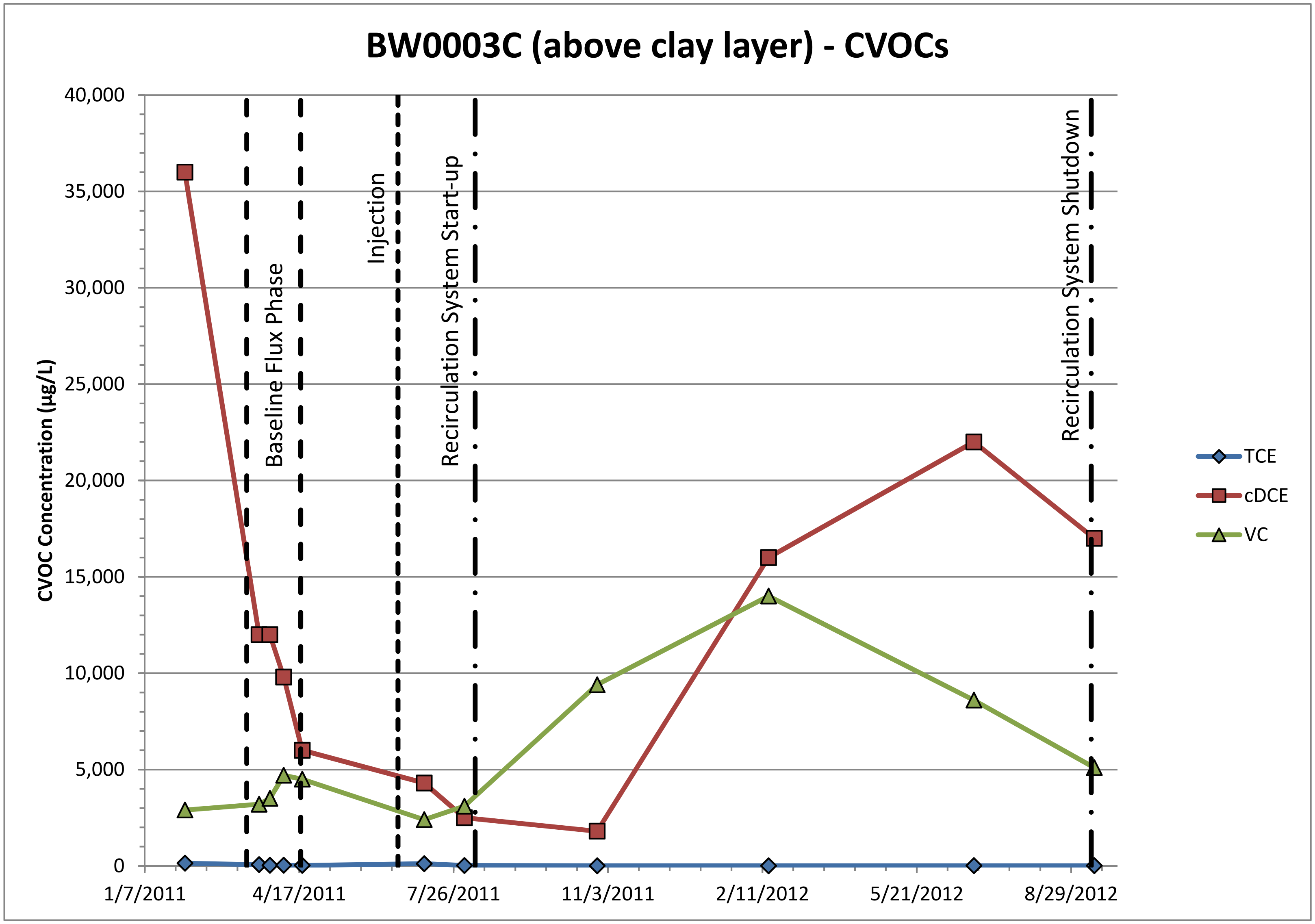

BW0001E (below clay layer) - CVOCs
CVOC Concentration (µg/L)
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
1/7/2011
4/17/2011
7/26/2011
11/3/2011
2/11/2012
5/21/2012
8/29/2012
Baseline Flux Phase
Injection
Recirculation System Start-up
Recirculation System Shutdown
TCE
cDCE
VC

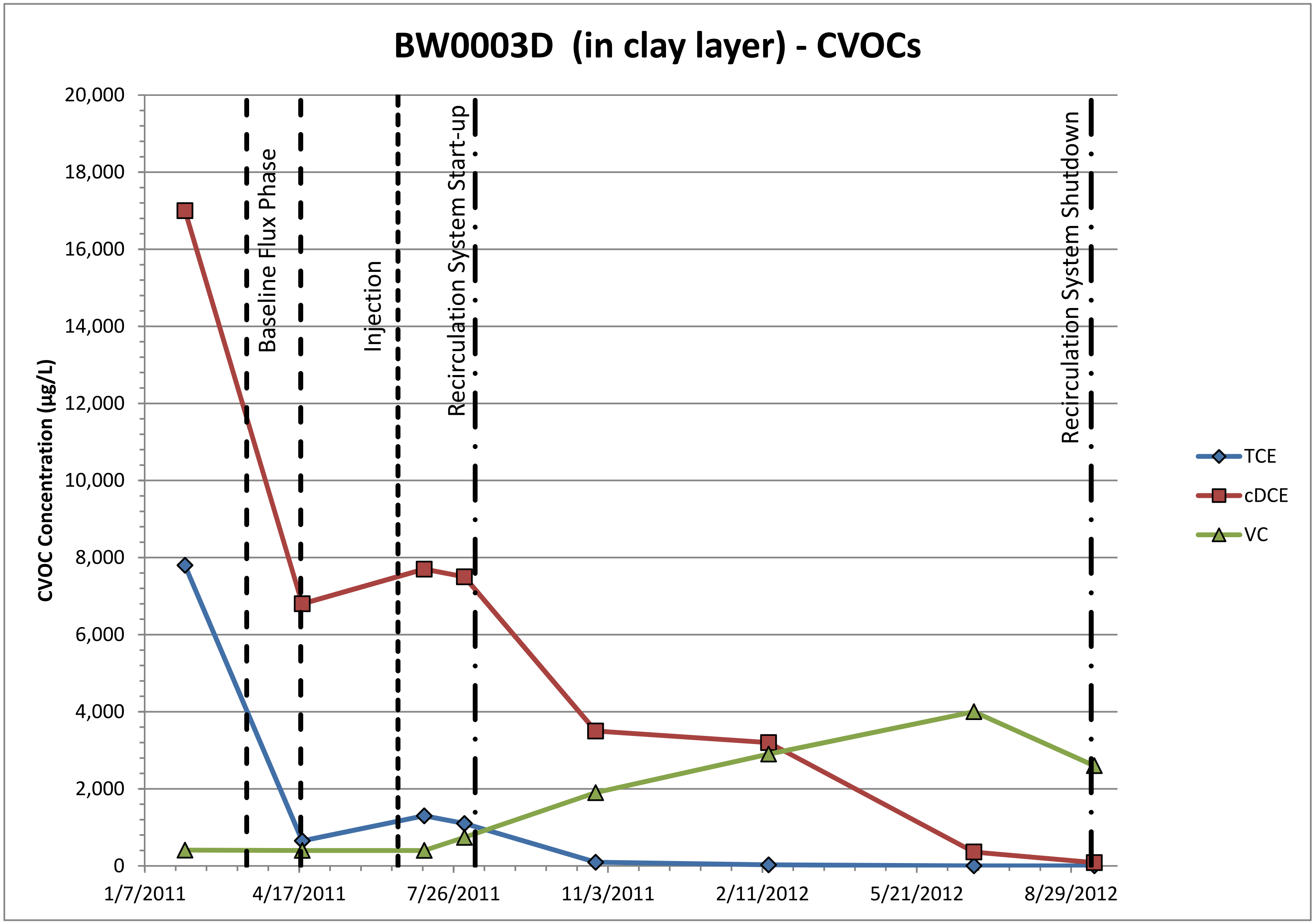

BW0002C (above clay layer) - CVOCs
CVOC Concentration (µg/L)
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
1/7/2011
4/17/2011
7/26/2011
11/3/2011
2/11/2012
5/21/2012
8/29/2012
Baseline Flux Phase
Injection
Recirculation System Start-up
Recirculation System Shutdown
TCE
cDCE
VC



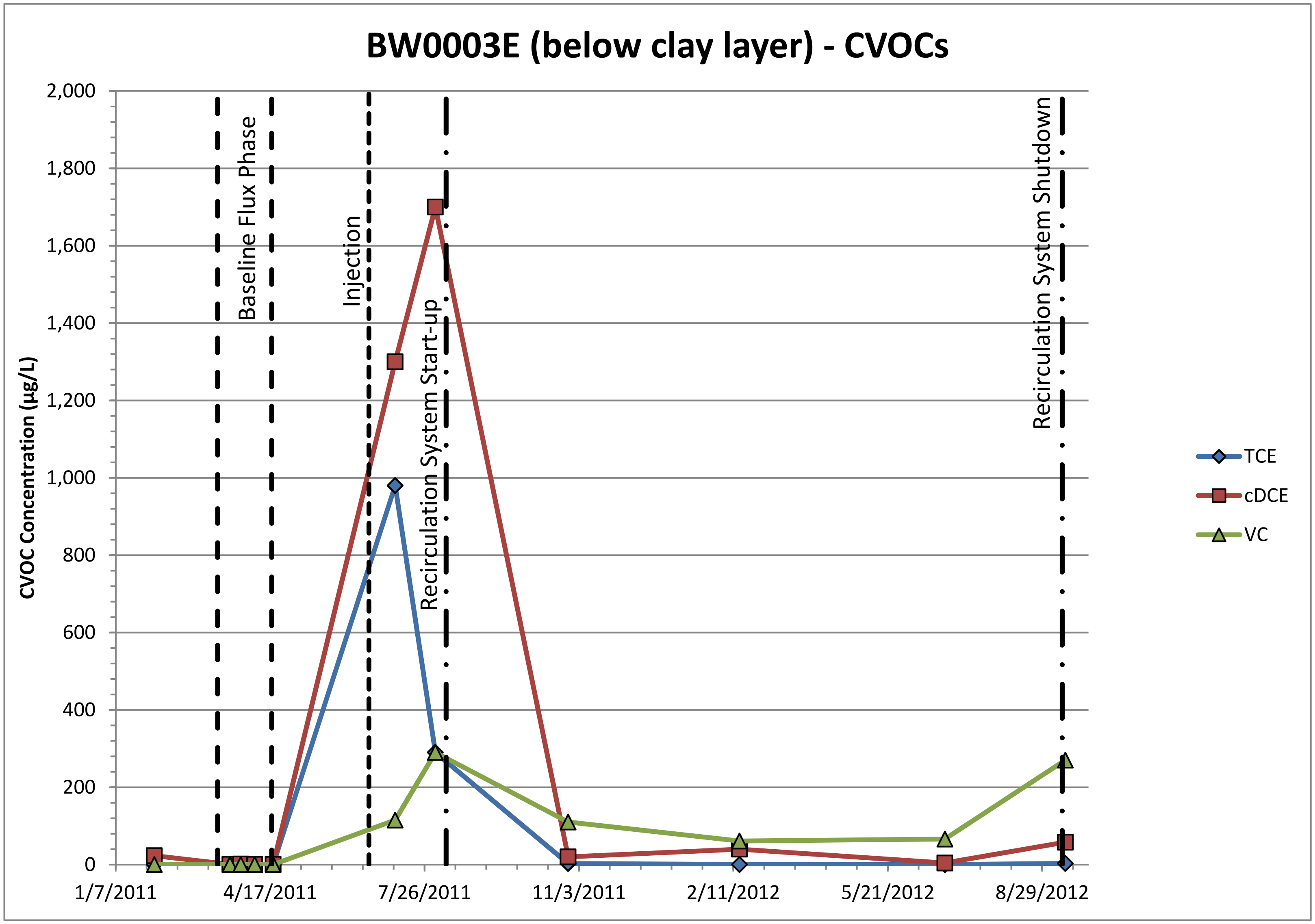
BW0002D (in clay layer) - CVOCs
CVOC Concentration (µg/L)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1/7/2011
4/17/2011
7/26/2011
11/3/2011
2/11/2012
5/21/2012
8/29/2012
Baseline Flux Phase
Injection
Recirculation System Start-up
Recirculation System Shutdown
TCE
cDCE
VC


BW0002E (below clay layer) - CVOCs
CVOC Concentration (µg/L)
100
90
80
70
60
50
40
30
20
10
0
1/7/2011
4/17/2011
7/26/2011
11/3/2011
2/11/2012
5/21/2012
8/29/2012
Baseline Flux Phase
Injection
Recirculation System Start-up
Recirculation System Shutdown
TCE
cDCE
VC

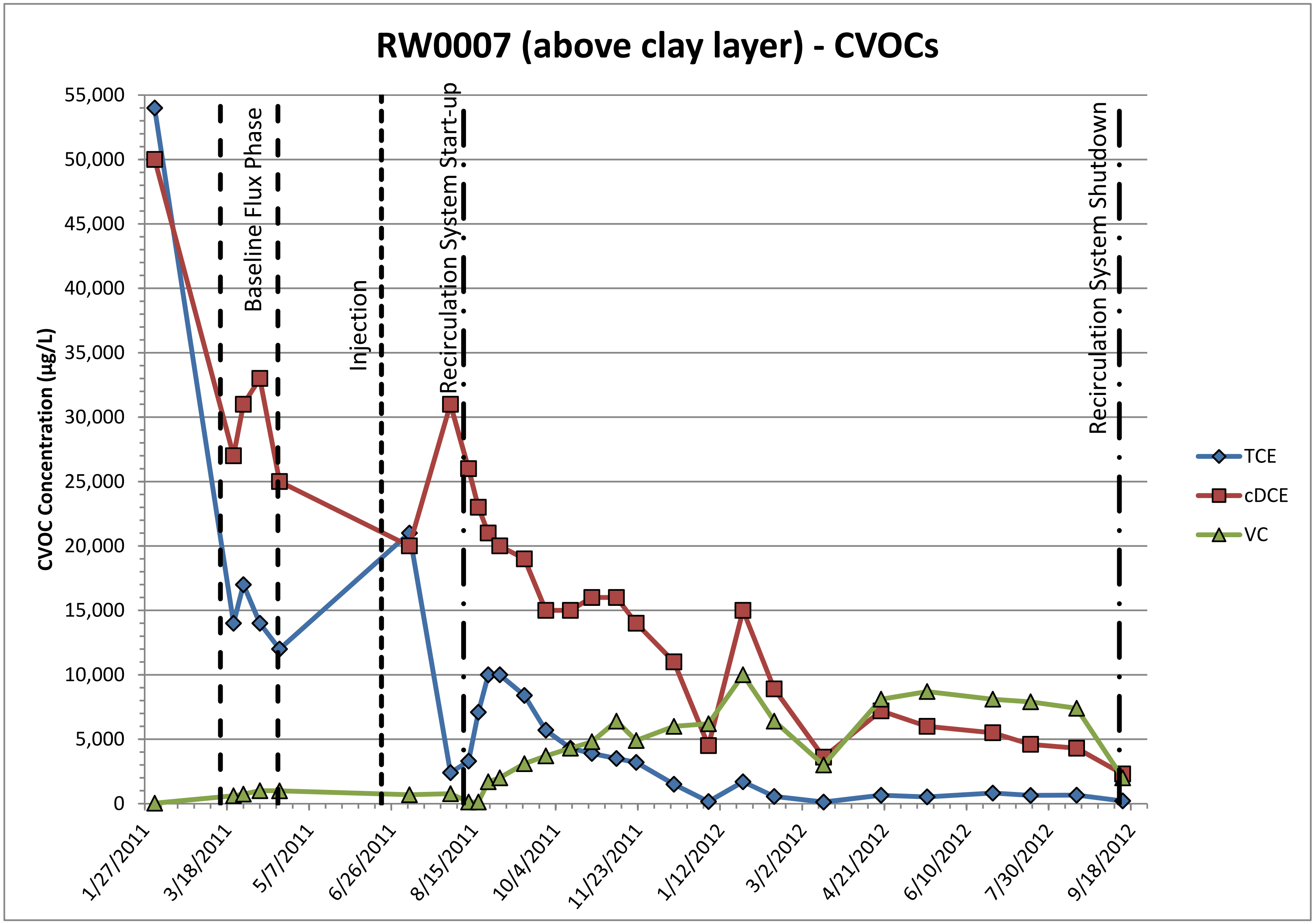

BW0003C (above clay layer) - CVOCs
CVOC Concentration (µg/L)
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
1/7/2011
4/17/2011
7/26/2011
11/3/2011
2/11/2012
5/21/2012
8/29/2012
Baseline Flux Phase
Injection
Recirculation System Start-up
Recirculation System Shutdown
TCE
cDCE
VC

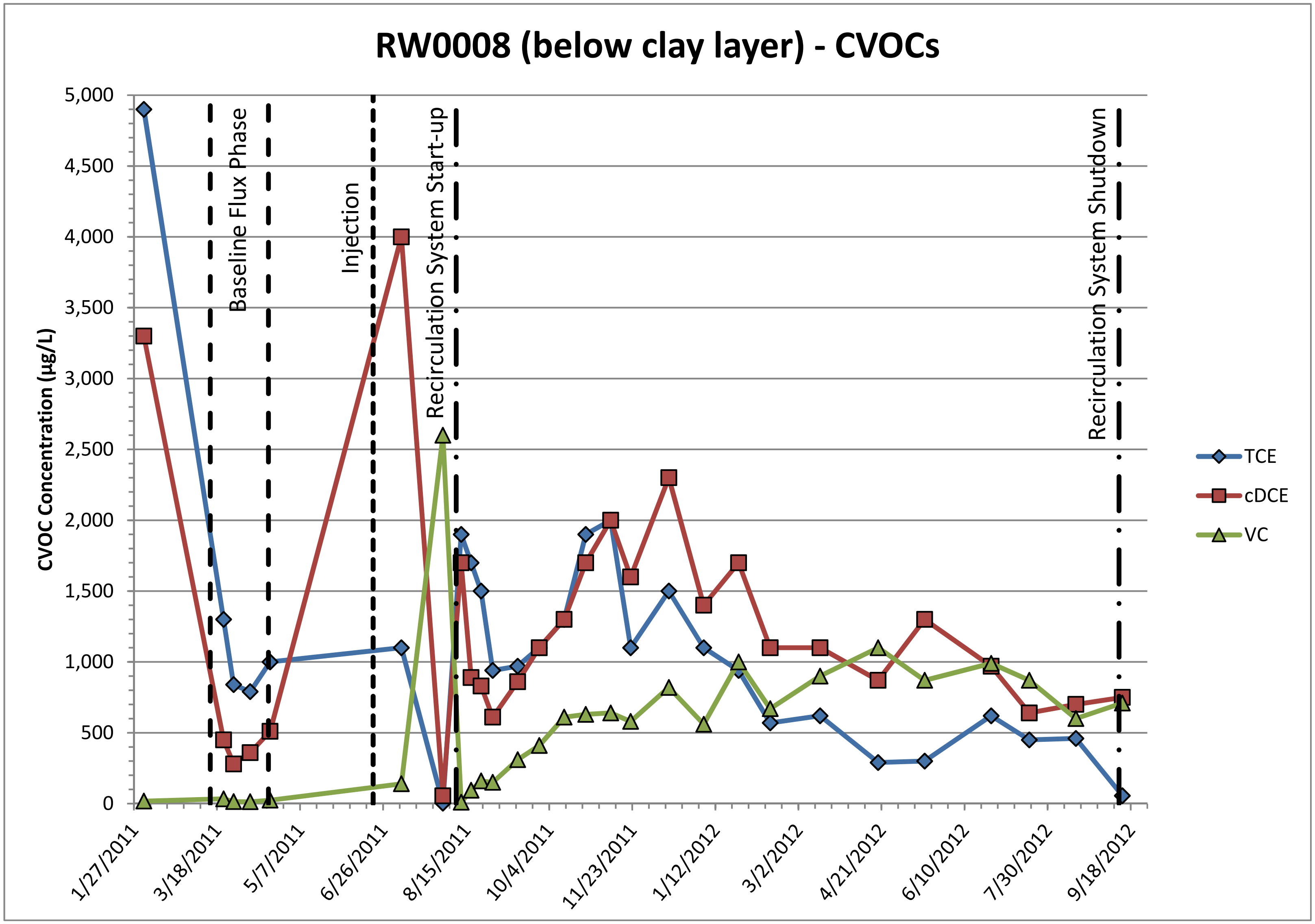


BW0003D (in clay layer) - CVOCs
CVOC Concentration (µg/L)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1/7/2011
4/17/2011
7/26/2011
11/3/2011
2/11/2012
5/21/2012
8/29/2012
Baseline Flux Phase
Injection
Recirculation System Start-up
Recirculation System Shutdown
TCE
cDCE
VC



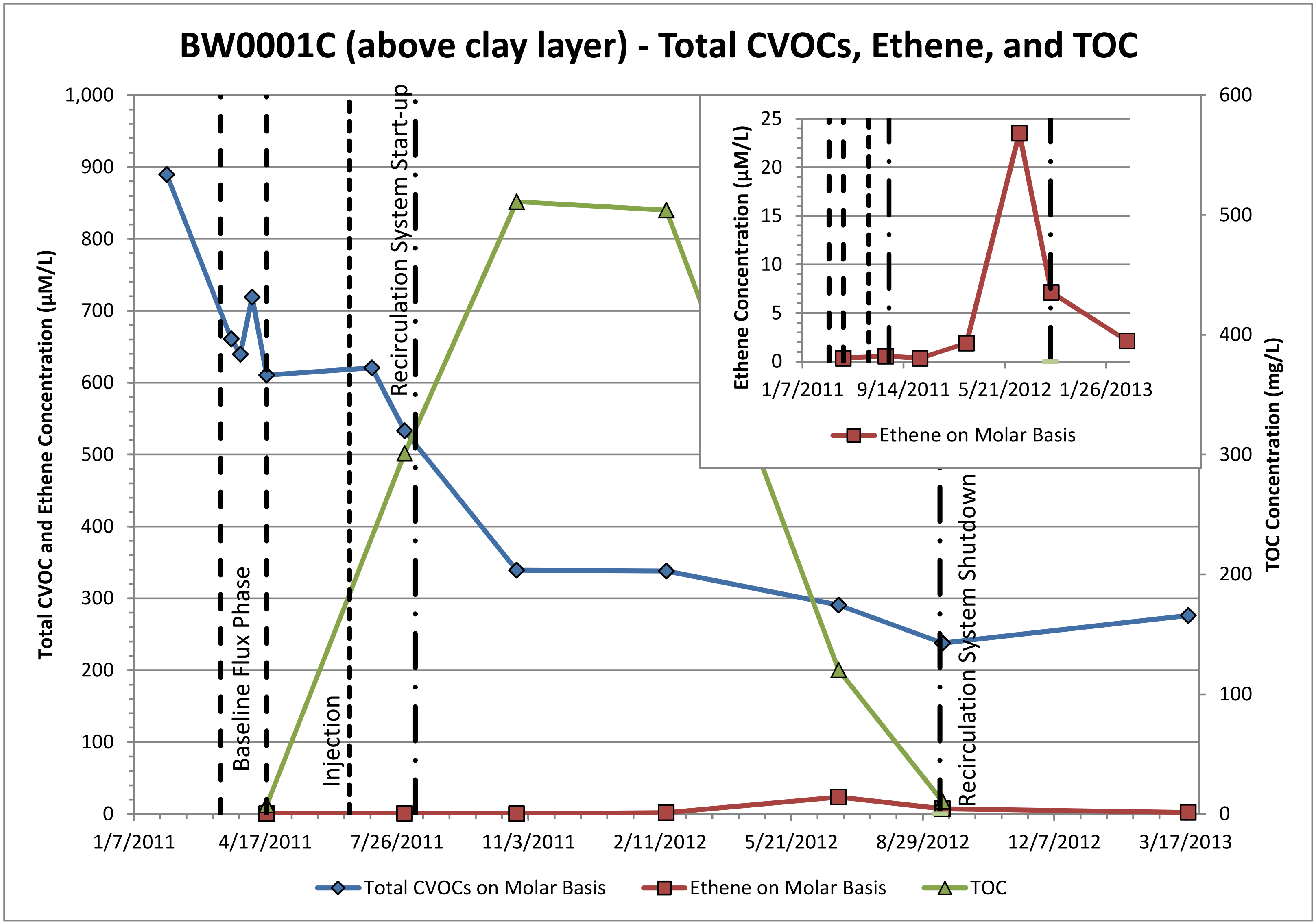
BW0003E (below clay layer) - CVOCs
CVOC Concentration (µg/L)
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
1/7/2011
4/17/2011
7/26/2011
11/3/2011
2/11/2012
5/21/2012
8/29/2012
Baseline Flux Phase
Injection
Recirculation System Start-up
Recirculation System Shutdown
TCE
cDCE
VC

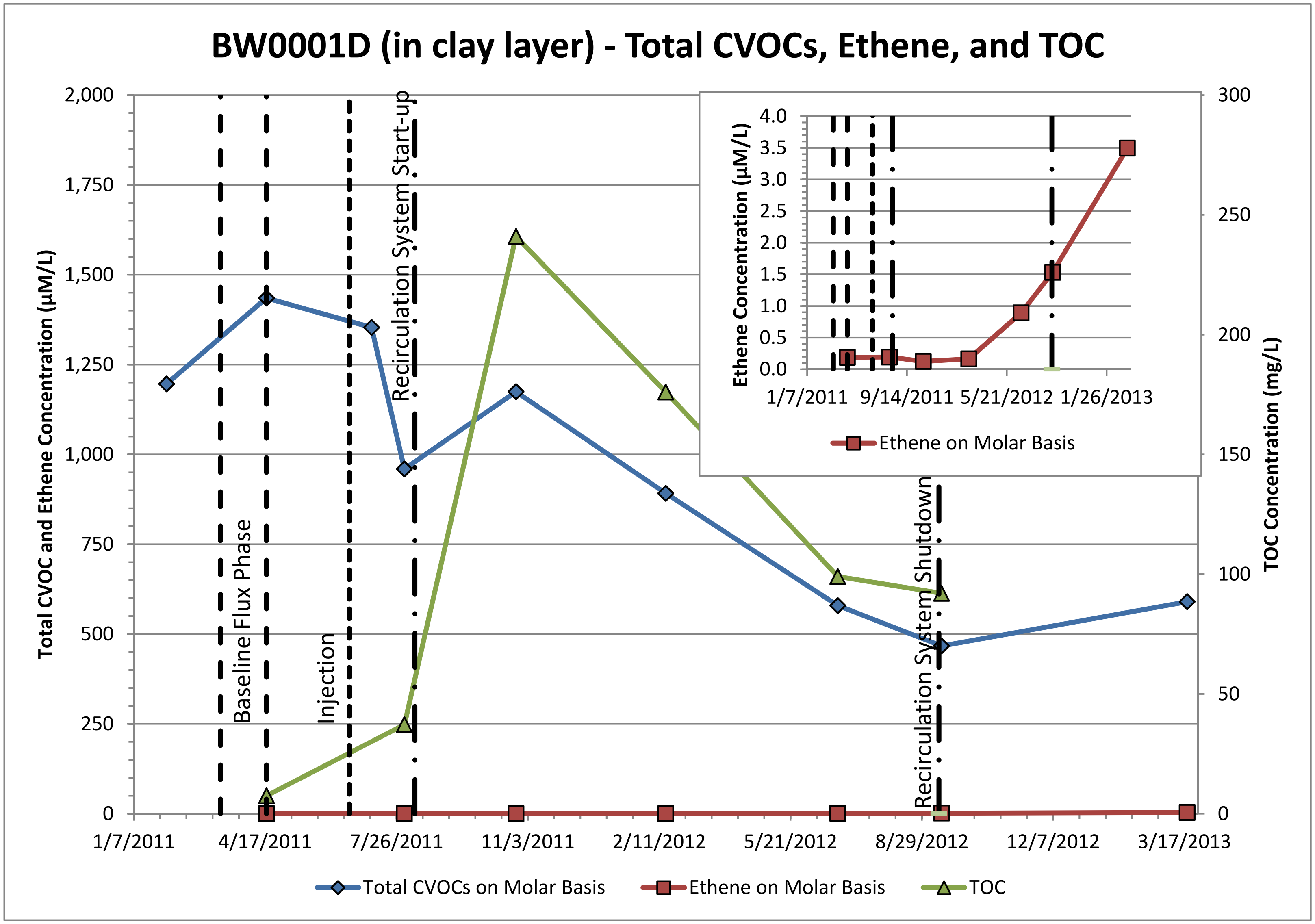

RW0007 (above clay layer) - CVOCs
CVOC Concentration (µg/L)
55,000
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Baseline Flux Phase
Injection
Recirculation System Start-up
Recirculation System Shutdown
1/27/2011
3/18/2011
5/7/2011
6/26/2011
8/15/2011
10/4/2011
11/23/2011
1/12/2012
3/2/2012
4/21/2012
6/10/2012
7/30/2012
9/18/2012
TCE
cDCE
VC

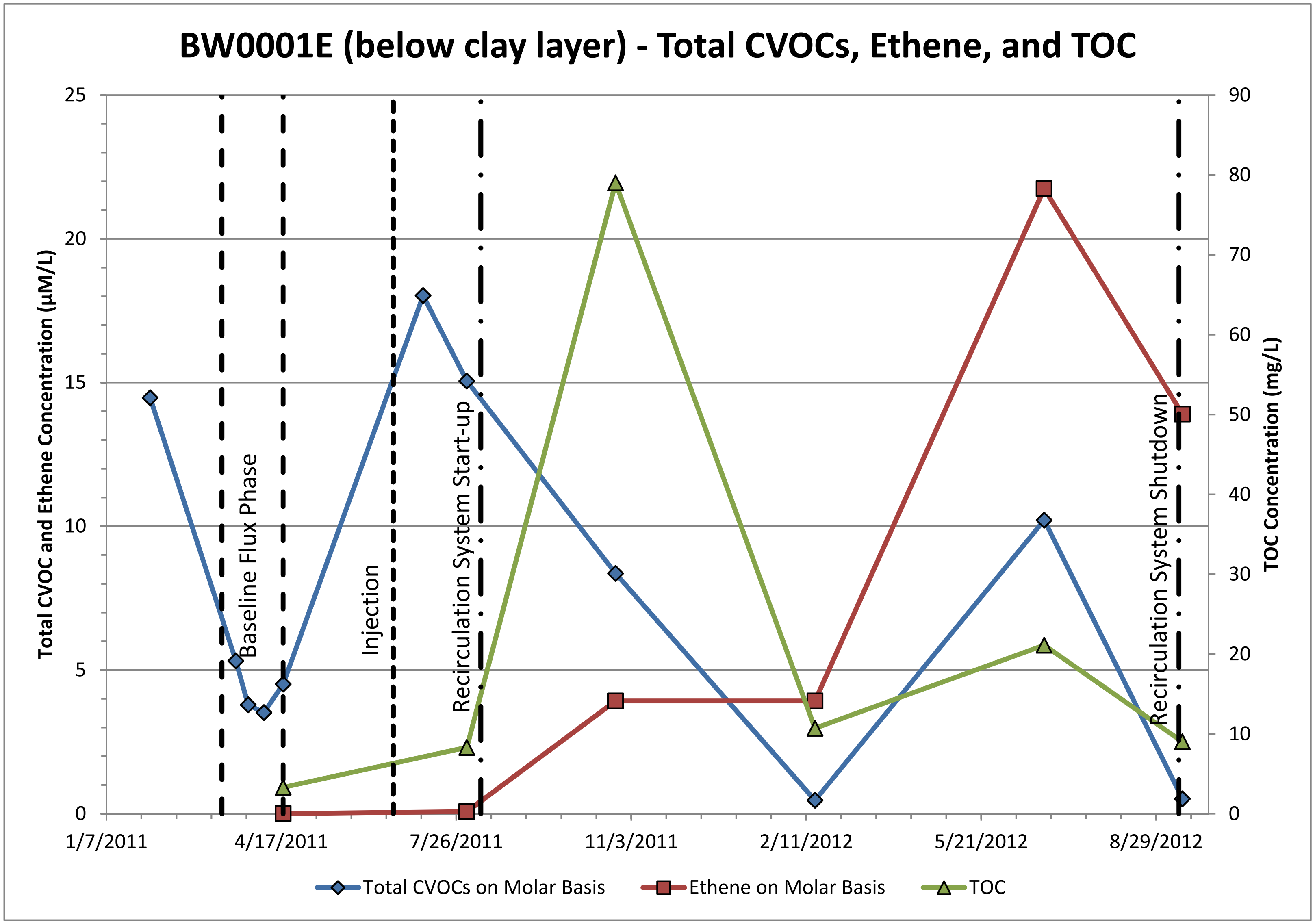

RW0008 (below clay layer) - CVOCs
CVOC Concentration (µg/L)
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Baseline Flux Phase
Injection
Recirculation System Start-up
Recirculation System Shutdown
1/27/2011
3/18/2011
5/7/2011
6/26/2011
8/15/2011
10/4/2011
11/23/2011
1/12/2012
3/2/2012
4/21/2012
6/10/2012
7/30/2012
9/18/2012
TCE
cDCE
VC

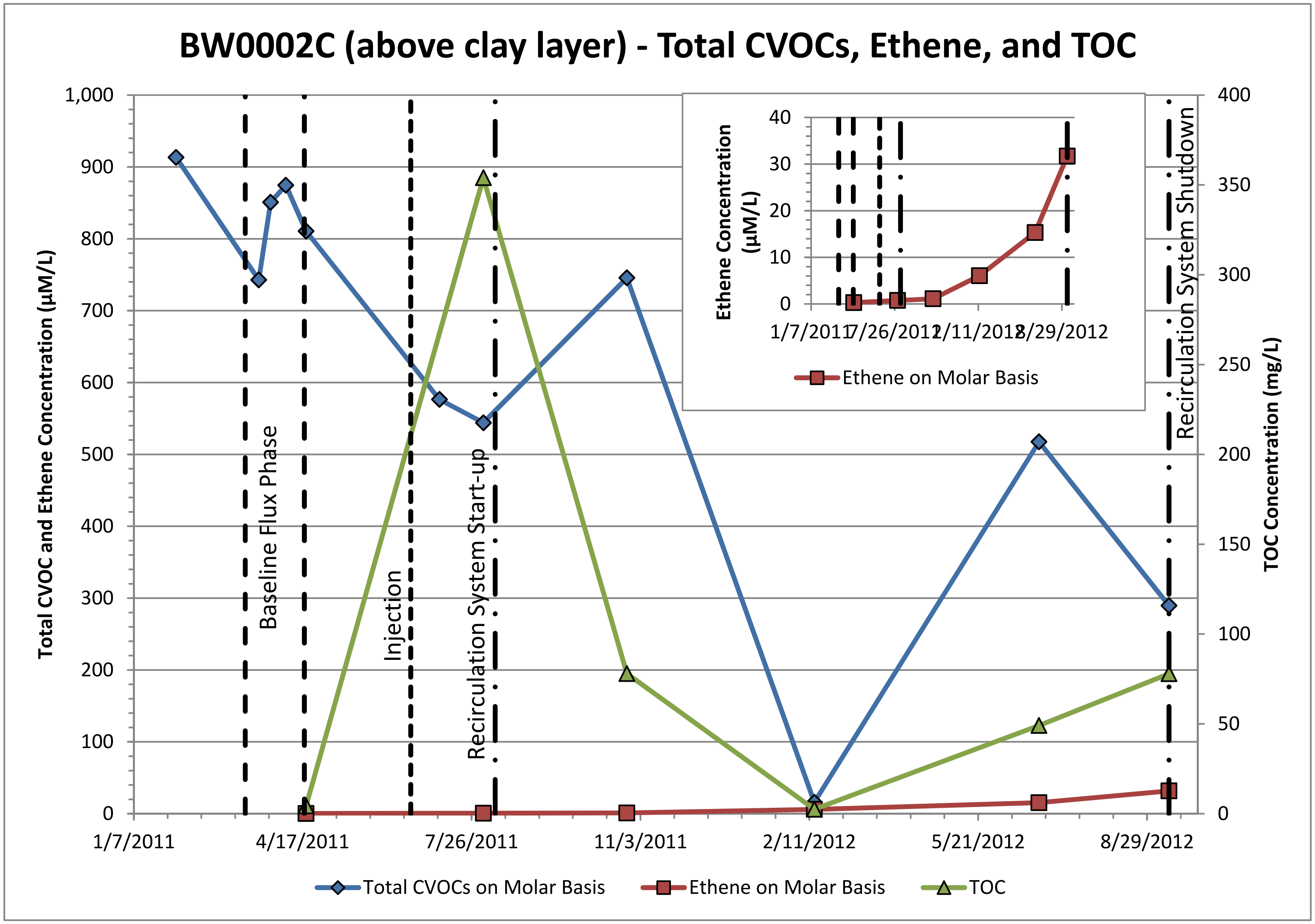
TREND GRAPHS

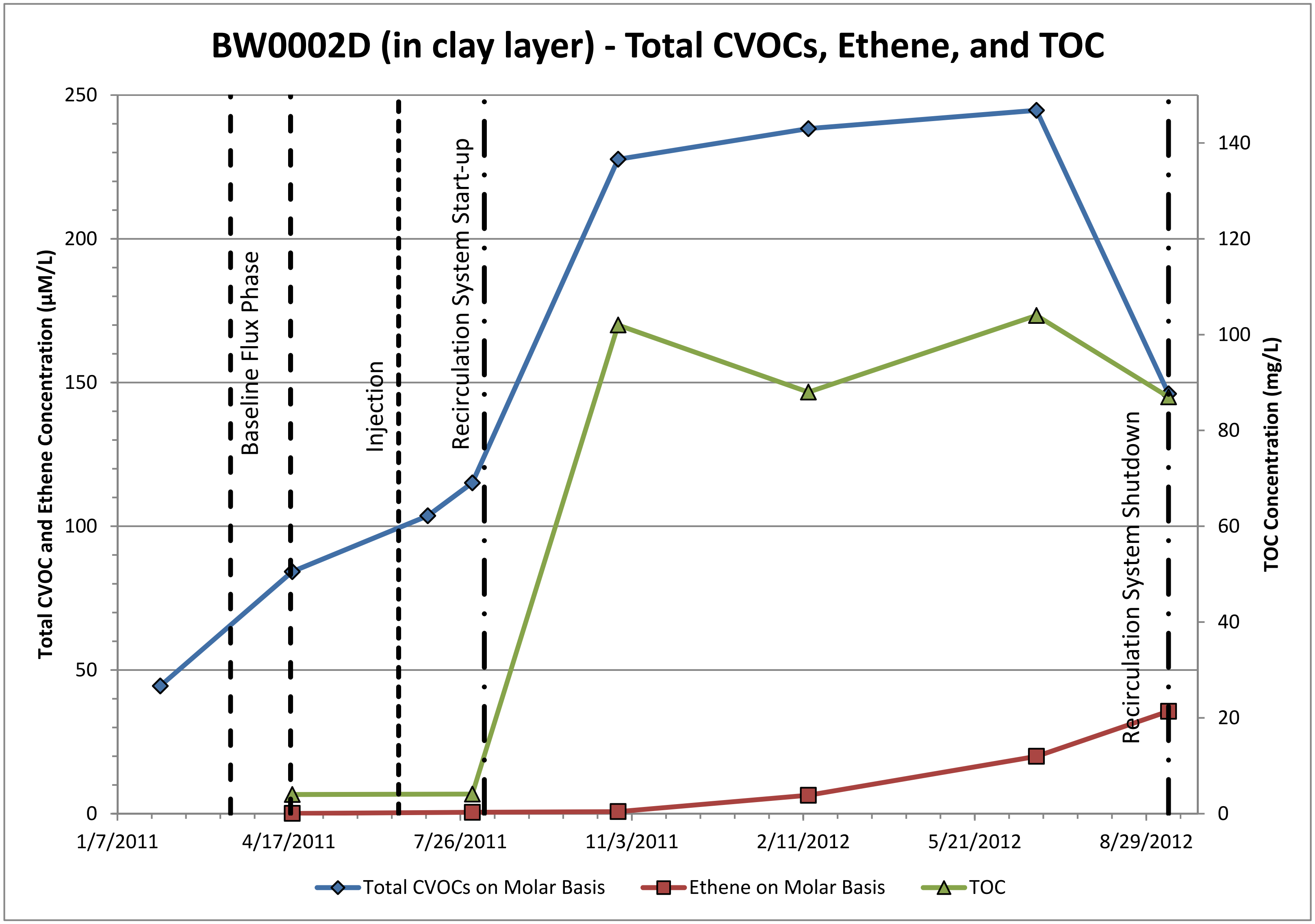
Total CVOCs and Ethene in Molar Basis and TOC Concentration

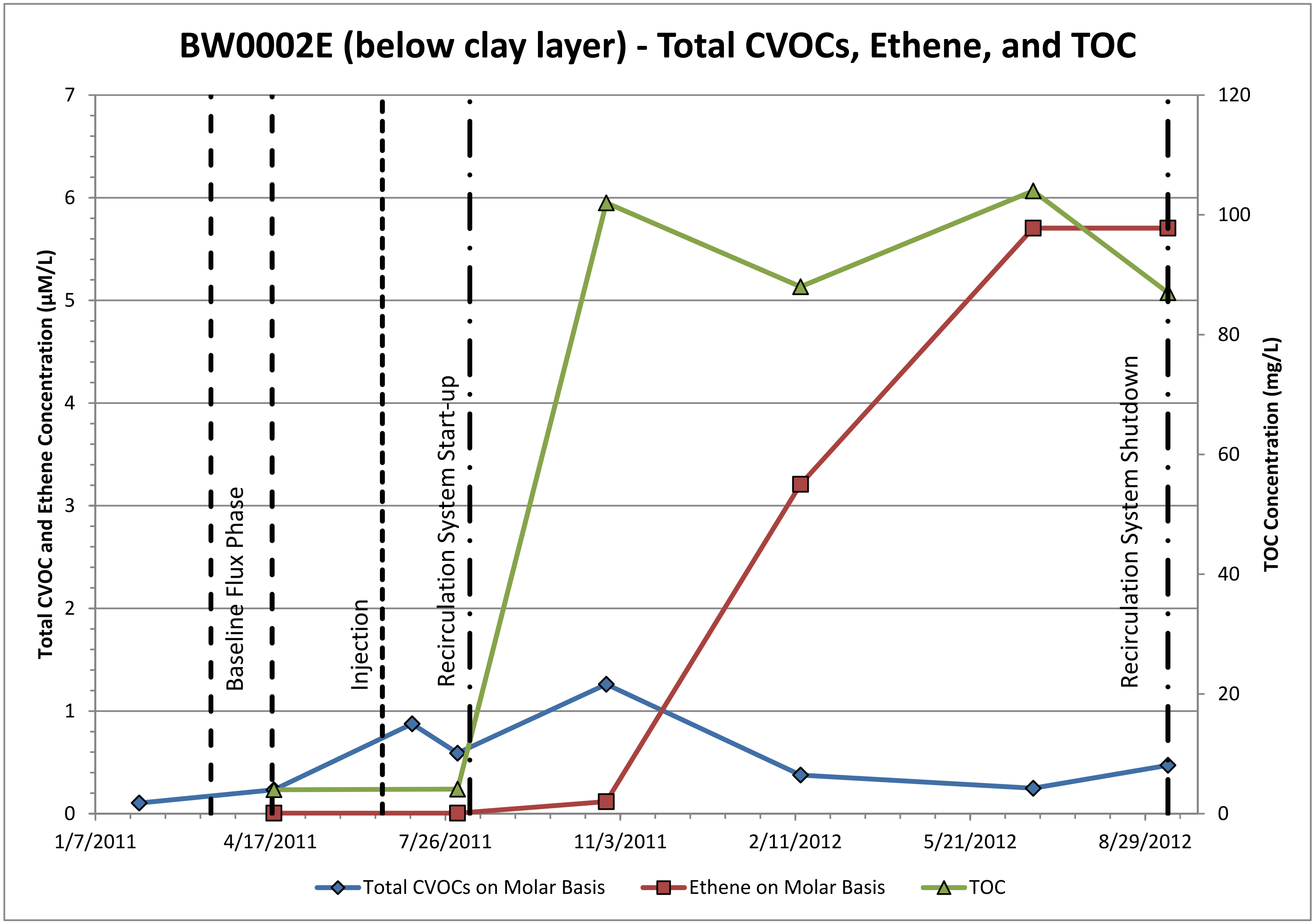

BW0001C (above clay layer) - Total CVOCs, Ethene, and TOC
Total CVOC and Ethene Concentration (µM/L)
TOC Concentration (mg/L)
1,000
900
800
700
600
500
400
300
200
100
0
600
500
400
300
200
100
0
1/7/2011
4/17/2011
7/26/2011
11/3/2011
2/11/2012
5/21/2012
8/29/2012
12/7/2012
3/17/2013
Baseline Flux Phase
Injection
Recirculation System Start-up
Recirculation System Shutdown
Ethene Concentration (µM/L)
25
20
15
10
5
0
1/7/2011
9/14/2011
5/21/2012
1/26/2013
Ethene on Molar Basis
Total CVOCs on Molar Basis
Ethene on Molar Basis
TOC

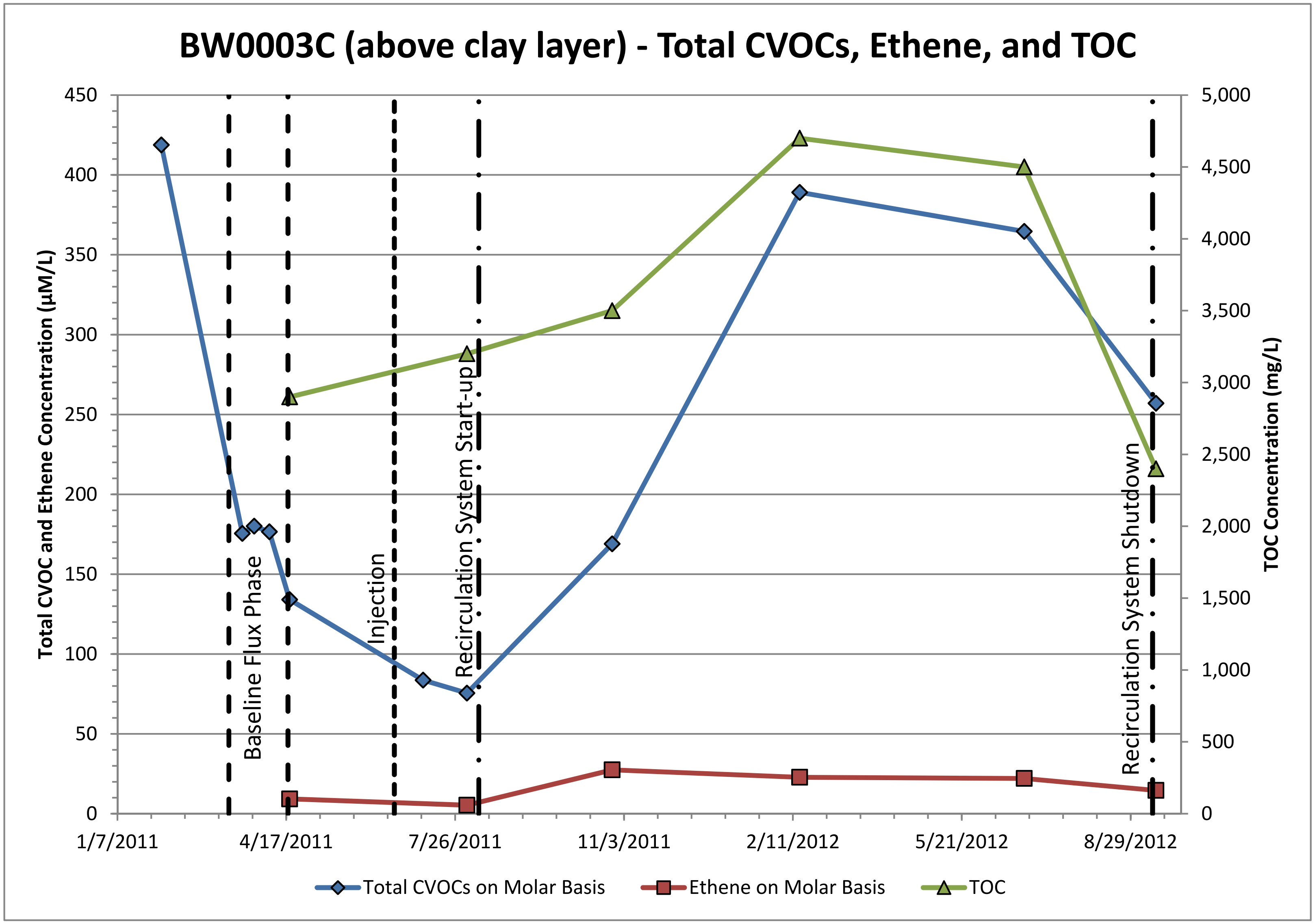

BW0001D (in clay layer) - Total CVOCs, Ethene, and TOC
Total CVOC and Ethene Concentration (µM/L)
TOC Concentration (mg/L)
2,000
1,750
1,500
1,250
1,000
750
500
250
0
300
250
200
150
100
50
0
1/7/2011
4/17/2011
7/26/2011
11/3/2011
2/11/2012
5/21/2012
8/29/2012
12/7/2012
3/17/2013
Baseline Flux Phase
Injection
Recirculation System Start-up
Recirculation System Shutdown
Ethene Concentration (µM/L)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1/7/2011
9/14/2011
5/21/2012
1/26/2013
Ethene on Molar Basis
Total CVOCs on Molar Basis
Ethene on Molar Basis
TOC

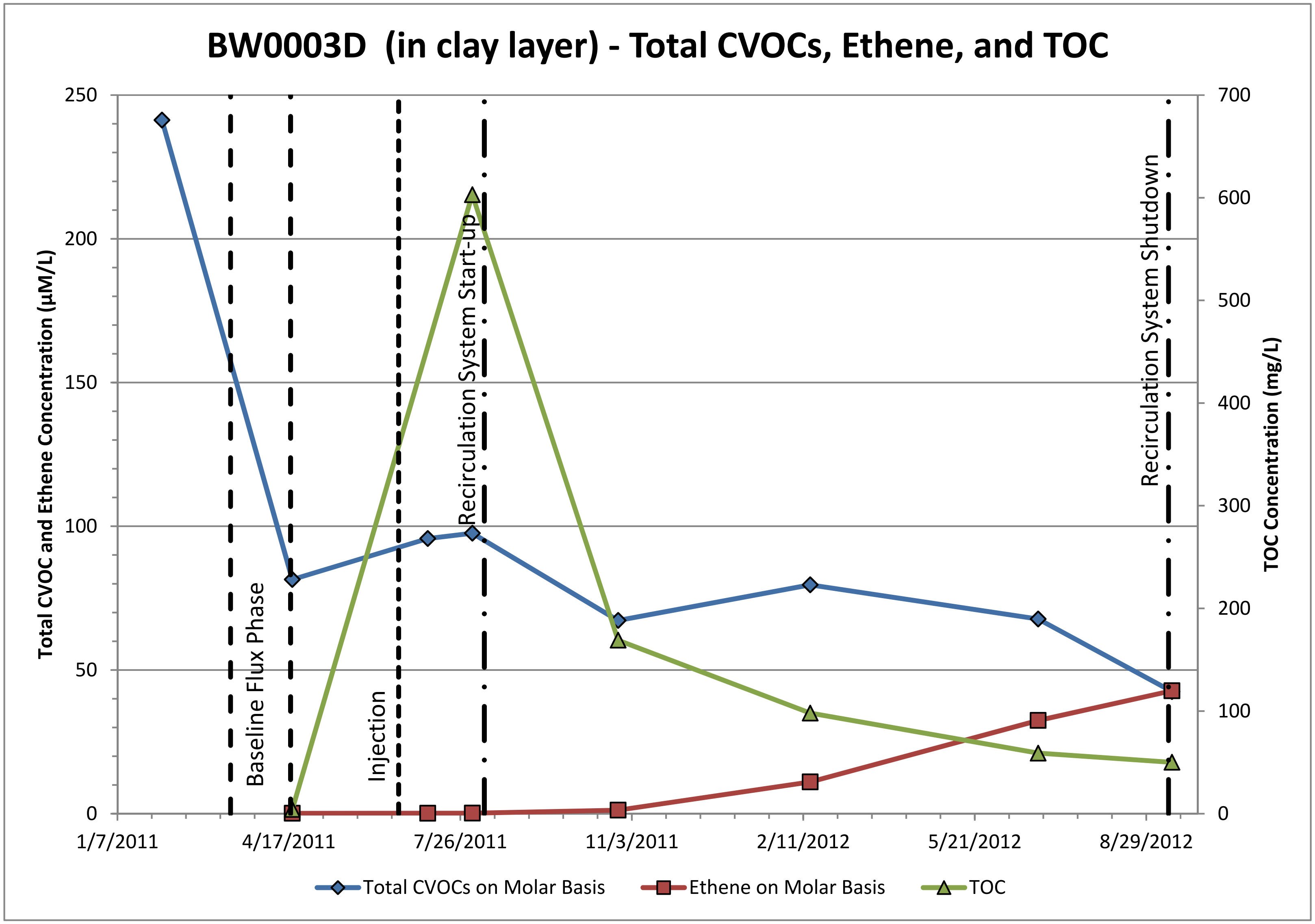

BW0001E (below clay layer) - Total CVOCs, Ethene, and TOC
Total CVOC and Ethene Concentration (µM/L)
TOC Concentration (mg/L)
25
20
15
10
5
0
90
80
70
60
50
40
30
20
10
0
1/7/2011
4/17/2011
7/26/2011
11/3/2011
2/11/2012
5/21/2012
8/29/2012
Baseline Flux Phase
Injection
Recirculation System Start-up
Recirculation System Shutdown
Total CVOCs on Molar Basis
Ethene on Molar Basis
TOC


BW0002C (above clay layer) - Total CVOCs, Ethene, and TOC
Total CVOC and Ethene Concentration (µM/L)
TOC Concentration (mg/L)
1,000
900
800
700
600
500
400
300
200
100
0
400
350
300
250
200
150
100
50
0
1/7/2011
4/17/2011
7/26/2011
11/3/2011
2/11/2012
5/21/2012
8/29/2012
Baseline Flux Phase
Injection
Recirculation System Start-up
Recirculation System Shutdown
Ethene Concentration (µM/L)
40
30
20
10
0
1/7/2011
7/26/2011
2/11/2012
8/29/2012
Ethene on Molar Basis
Total CVOCs on Molar Basis
Ethene on Molar Basis
TOC

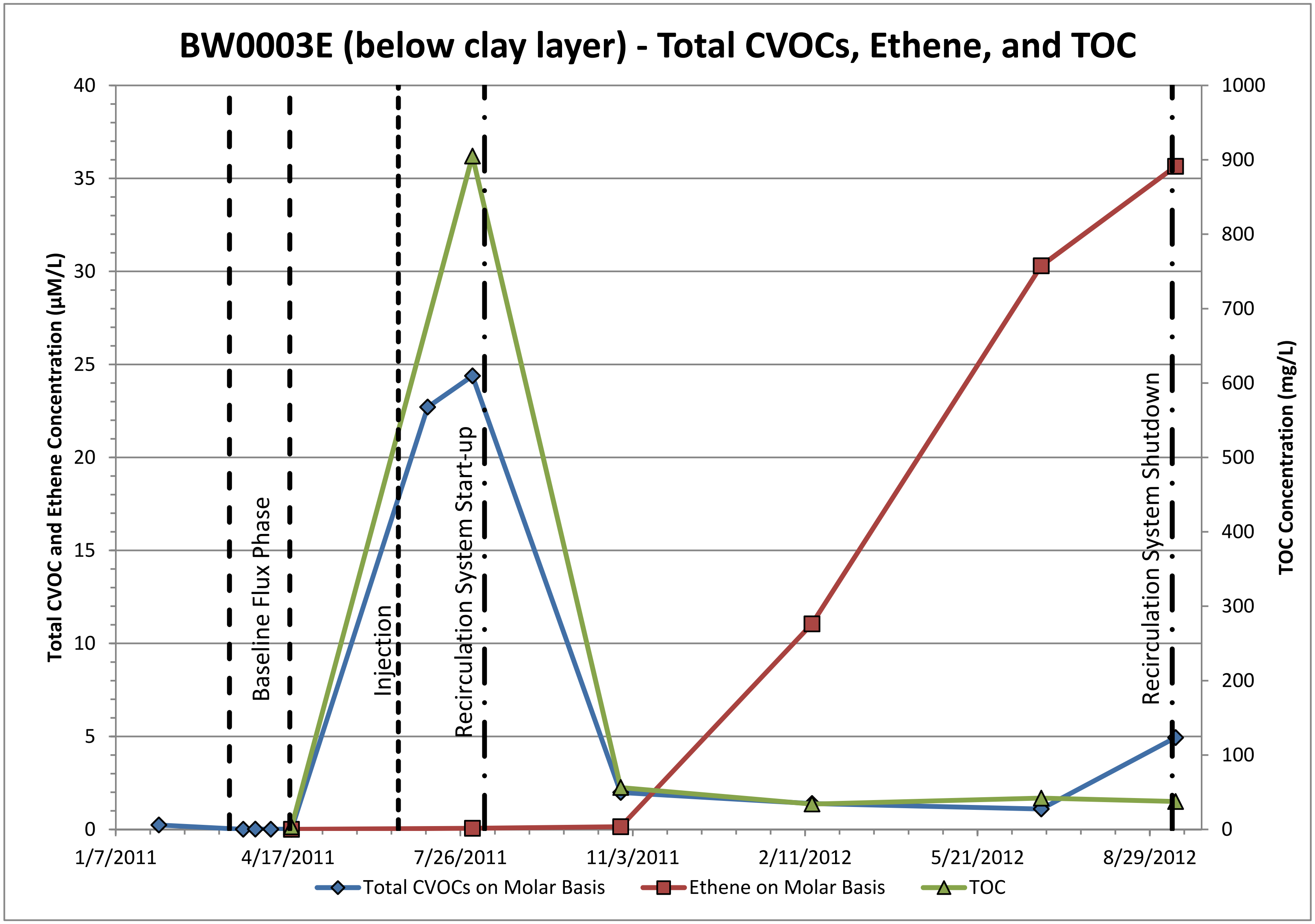

BW0002D (in clay layer) - Total CVOCs, Ethene, and TOC
Total CVOC and Ethene Concentration (µM/L)
TOC Concentration (mg/L)
250
200
150
100
50
0
140
120
100
80
60
40
20
0
1/7/2011
4/17/2011
7/26/2011
11/3/2011
2/11/2012
5/21/2012
8/29/2012
Baseline Flux Phase
Injection
Recirculation System Start-up
Recirculation System Shutdown
Total CVOCs on Molar Basis
Ethene on Molar Basis
TOC


BW0002E (below clay layer) - Total CVOCs, Ethene, and TOC
Total CVOC and Ethene Concentration (µM/L)
TOC Concentration (mg/L)
7
6
5
4
3
2
1
0
120
100
80
60
40
20
0
Baseline Flux Phase
Injection
Recirculation System Start-up
Recirculation System Shutdown
1/7/2011
4/17/2011
7/26/2011
11/3/2011
2/11/2012
5/21/2012
8/29/2012
Total CVOCs on Molar Basis
Ethene on Molar Basis
TOC

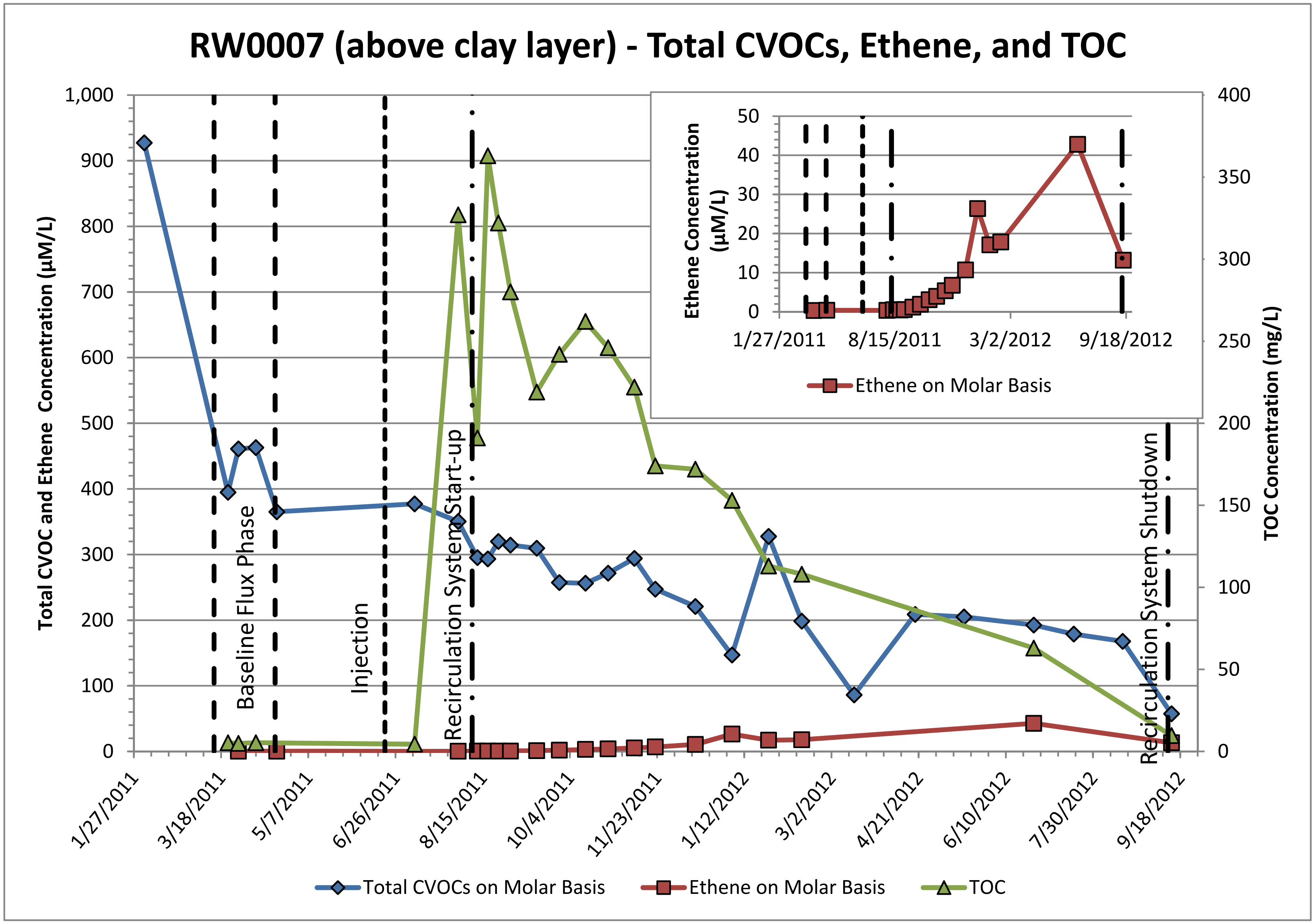

BW0003C (above clay layer) - Total CVOCs, Ethene, and TOC
Total CVOC and Ethene Concentration (µM/L)
TOC Concentration (mg/L)
450
400
350
300
250
200
150
100
50
0
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
1/7/2011
4/17/2011
7/26/2011
11/3/2011
2/11/2012
5/21/2012
8/29/2012
Baseline Flux Phase
Injection
Recirculation System Start-up
Recirculation System Shutdown
Total CVOCs on Molar Basis
Ethene on Molar Basis
TOC

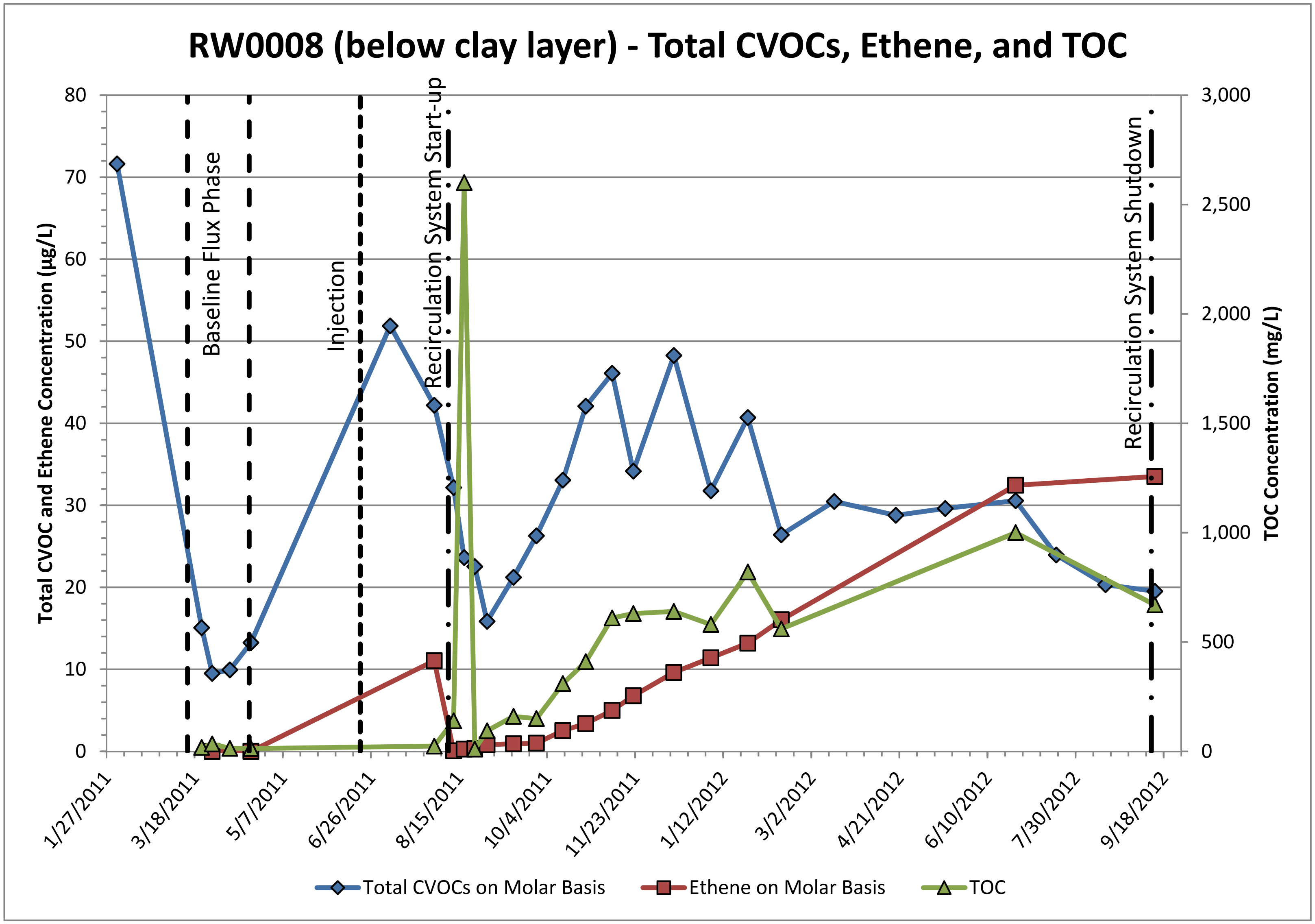


BW0003D (in clay layer) - Total CVOCs, Ethene, and TOC
Total CVOC and Ethene Concentration (µM/L)
TOC Concentration (mg/L)
250
200
150
100
50
0
700
600
500
400
300
200
100
0
1/7/2011
4/17/2011
7/26/2011
11/3/2011
2/11/2012
5/21/2012
8/29/2012
Baseline Flux Phase
Injection
Recirculation System Start-up
Recirculation System Shutdown
Total CVOCs on Molar Basis
Ethene on Molar Basis
TOC



BW0003E (below clay layer) - Total CVOCs, Ethene, and TOC
Total CVOC and Ethene Concentration (µM/L)
TOC Concentration (mg/L)
40
35
30
25
20
15
10
5
0
1000
900
800
700
600
500
400
300
200
100
0
Baseline Flux Phase
Injection
Recirculation System Start-up
Recirculation System Shutdown
1/7/2011
4/17/2011
7/26/2011
11/3/2011
2/11/2012
5/21/2012
8/29/2012
Total CVOCs on Molar Basis
Ethene on Molar Basis
TOC


RW0007 (above clay layer) - Total CVOCs, Ethene, and TOC
Total CVOC and Ethene Concentration (µM/L)
TOC Concentration (mg/L)
Baseline Flux Phase
Injection
Recirculation System Start-up
Recirculation System Shutdown
Ethene Concentration (µM/L)
Ethene on Molar Basis
Total CVOCs on Molar Basis
Ethene on Molar Basis
TOC
1/27/2011
3/18/2011
5/7/2011
6/26/2011
8/15/2011
10/4/2011
11/23/2011
1/12/2012
3/2/2012
4/21/2012
6/10/2012
7/30/2012
9/18/2012



RW0008 (below clay layer) - Total CVOCs, Ethene, and TOC
Total CVOC and Ethene Concentration (µg/L)
TOC Concentration (mg/L)
80
70
60
50
40
30
20
10
0
3,000
2,500
2,000
1,500
1,000
500
0
Baseline Flux Phase
Injection
Recirculation System Start-up
Recirculation System Shutdown
1/27/2011
3/18/2011
5/7/2011
6/26/2011
8/15/2011
10/4/2011
11/23/2011
1/12/2012
3/2/2012
4/21/2012
6/10/2012
7/30/2012
9/18/2012
Total CVOCs on Molar Basis
Ethene on Molar Basis
TOC

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