FINAL REPORT

Providing Additional Support for MNA by Including Quantitative Lines of Evidence for Abiotic Degradation and Co-metabolic Oxidation of Chlorinated Ethylenes

ESTCP Project ER-201584

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14. ABSTRACT
The overarching objectives of the work described herein were to:
(1) Provide a method to readily and inexpensively acquire the magnetic susceptibility data required to evaluate the abiotic degradation of TCE by magnetite in aquifer materials using existing non-metallic groundwater monitoring wells.
(2) Provide a method to readily and inexpensively acquire the data required to evaluate and quantify the rate constant for aerobic biological co-oxidation of TCE.

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Below Ground Surface, radioactive carbon 14, carbon dioxide, Distilled Deionized water, Dissolved Oxygen, Deoxyribonucleic Acid, Filter-Sterilized Groundwater, Nonaqueous-Phase Liquid, Nonstrippable Residue, Polymerase Chain Reaction, Volatile Organic Compound

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ACRONYMS AND ABBREVIATIONS

AFB	Air Force Base
bgs	Below Ground Surface
BSM	Basal Salts Medium
^{14}C	Radioactive Carbon 14
^{14}C-CO_2	Carbon Dioxide labelled with Carbon 14
^{14}C-NSR	Nonstrippable Residue labelled with Carbon 14
^{14}C-TCE	Trichloroethene labelled with Carbon 14
mCi	milli-curie (a unit of radioactivity)
CINN	*trans*-Cinnamonitrile
C_t	Cycle number at threshold (see Definitions)
d	Day
DAPI	4,6-Diamidino-2-phenylindole
*c*DCE	*cis*-1,2-Dichloroethene
*t*DCE	trans-1,2-Dichloroethene
1,1-DCE	1,1-Dichloroethene
DDI	Distilled Deionized water
DEM/VAL	Demonstration and Validation
DNA	Deoxyribonucleic Acid
DO	Dissolved Oxygen
DOD	Department of Defense
dpm	Disintegrations per minute
EAP	Enzyme Activity Probe
EISB	Enhanced *In Situ* Bioremediation
EPA	Environmental Protection Agency
ESTCP	Environmental Security Technology Certification Program
FID	Flame Ionization Detector
FSGW	Filter-Sterilized Groundwater
GC	Gas Chromatograph
GC/FID	Gas Chromatograph with a Flame Ionization Detector
GC/TCD	Gas Chromatograph with a Thermal Conductivity Detector
3HPA	3-Hydroxyphenylacetylene
IDW	Investigation Derived Wastes
IWL	Industrial Waste Lagoon at TEAD
LSC	Liquid Scintillation Cocktail

MBTs	Molecular Biological Tools
MCL	Maximum Contaminant Level
MCRD	Marine Corps Recruit Depot
mmoZ	qPCR Primer for Soluble Methane Monooxygenase Enzyme
MNA	Monitored Natural Attenuation
NAPL	Nonaqueous-Phase Liquid
NSR	Nonstrippable Residue
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
O&M	Operation & Maintenance
OIWL	Old Industrial Wastewater Lagoon at TEAD
PA	Phenylacetylene
PCE	Tetrachloroethene
PCR	Polymerase Chain Reaction
pH	potential of Hydrogen
PHE	qPCR Primer for Phenol Monooxygenase (Phenol Hydrolyase) Enzyme
PNNL	Pacific Northwest National Laboratory (DOE)
POET	Point Of Entry Treatment system
PVC	Poly(Vinyl Chloride)
qPCR	Quantitative Real-Time Polymerase Chain Reaction
RDEG	a qPCR Primer for Ring-Hydroxylating Toluene Monooxygenease Enzyme
RMO	a qPCR Primer for Ring-Hydroxylating Toluene Monooxygenease Enzyme
RPD	Relative Percent Difference
RPM	Remedial Project Manager
SMMO	qPCR Primer for Soluble Methane Monooxygenase Enzyme
T2,3-di	Toluene-2,3-dioxygenase Enzyme
T3-mono	Toluene-3-monooxygenase Enzyme
TEAD	Tooele Army Depot, Utah
1,1,1-TCA	1,1,1-Trichloroethane
TCAAP	Twin Cities Army Ammunition Plant
TCD	Thermal Conductivity Detector
TCE	Trichloroethene
TOL	qPCR Primer for Toluene/Xylene Side Chain Monooxygenase Enzyme
TOD	qPCR Primer for Toluene Dioxygenase Enzyme
USEPA	United States Environmental Protection Agency
VC	Vinyl Chloride
VOC	Volatile Organic Compound

DEFINITIONS

Abiotic Oxidation: Oxidative contaminant transformation without direct involvement of a biological system. Involves the abiotic oxidation of the organic compound of interest to carbon dioxide and other products. For example, He et al. (2009) show that the reaction of cDCE with magnetite results in the production of CO_2 and likely water and chloride. This is consistent with the work of Darlington et al. (2008). This reaction can occur under oxic or anoxic conditions.

Abiotic Reduction: Reductive contaminant transformation without the direct involvement of a biological system. Involves the abiotic reduction of the organic compound of interest to a more reduced compound. For example, Butler and Hayes (1999) and Lee and Batchelor (2002 a, b and 2003) show that TCE is abiotically reduced to chloroacetylene and/or acetylene which is then oxidized to CO_2, water, and chloride. Abiotic transformations of chlorinated organics can occur under oxic or anoxic conditions and can be significant at sites with iron-rich minerals, including iron sulfide, pyrite, fougerite, magnetite, and Fe(II)-containing phyllosilicates.

Aerobic Co-oxidation: Oxygen-dependent oxidation reaction(s) leading to detoxification of chlorinated ethylenes. Involves the biologically-mediated oxidation of organic compounds to produce an enzyme that fortuitously degrades TCE and potentially PCE. This reaction predominantly occurs under oxic to hypoxic conditions.

Aerobic Oxidation: Oxygen-dependent oxidation reaction(s) leading to detoxification. Involves the biologically-mediated oxidation of compounds of interest and occurs when oxygen in used as an electron acceptor and the organic compound is used as the electron donor. For example, during aerobic oxidation, vinyl chloride is oxidized to the nontoxic end-products carbon dioxide, water, and chloride. This reaction predominantly occurs under oxic conditions.

Anaerobic Oxidation: Oxygen-independent oxidation reaction(s) leading to detoxification. Occurs only under anoxic conditions. Involves the biologically-mediated oxidation of compounds of interest and occurs when an electron acceptor other than oxygen is utilized as an electron sink, and the organic compound is used as the electron donor. For example, during anaerobic oxidation under iron-reducing conditions, vinyl chloride is oxidized to the nontoxic end-products carbon dioxide, water, and chloride.

Attenuation: Complement of processes that reduce contaminant concentrations in groundwater. Attenuation processes are dominated by dispersion, sorption, biodegradation and abiotic degradation.

Attenuation Rate Constant: The proportionality constant quantifying the rate of change in the concentration of a contaminant due to the combined processes of dispersion, sorption, and biotic and abiotic degradation.

Bioattenuation: Complement of all biological processes that reduce contaminant concentrations in groundwater.

C_t: The cycle number in a PCR amplification where the fluorescence exceeds the threshold value (background level) and amplification of the DNA is detectable.

Degradation: Degradation involves the breakage of C-C or C-Cl bonds and generates products of lower molecular weight.

Degradation Rate: The rate of change in contaminant concentration due only to the degradation of organic compounds. This rate does not consider the effects of dispersion or sorption and thus quantifies only the rate at which the mass of the parent compound is being removed from the system.

Degradation Rate Constant: The proportionality constant quantifying the rate of change in concentration or mass of a chemical compound over time resulting from the transformation of a contaminant into a degradation product. At the field scale, degradation rate constants are typically described by first-order kinetics.

Enzyme Activity Probe: Enzyme activity probes (EAPs) are chemicals used to detect and quantify specific activities of microorganisms in environmental samples (e.g., soil, water, or sediment). EAPs are compounds that serve as alternative or surrogate substrates for the protein catalysts (enzymes) responsible for the metabolic activities of microorganisms. These surrogate compounds are transformed by target enzymes into distinct and readily detectable products.

Mass Magnetic Susceptibility: The degree of magnetization of a material in response to an applied magnetic field. It is one measure of the magnetic properties of a material. The susceptibility indicates whether a material is attracted into or repelled out of a magnetic field. In most hydrogeologic settings, magnetic susceptibility is a measure of the amount of magnetite present in the system. Magnetic susceptibility sondes measure the volume magnetic susceptibility. The mass magnetic susceptibility of the subsurface material is calculated by dividing the volume magnetic susceptibility by the bulk density of the material being analyzed (kg/m^3).

Monitored Natural Attenuation (MNA): The reliance on natural attenuation processes (within the context of a carefully controlled and monitored site cleanup approach) to achieve site-specific remedial objectives within a time frame that is reasonable compared to other methods. In order for MNA to be considered a viable remediation alternative, regulatory agencies often require evidence of degradation. In the past this degradation has largely been consider to be of strictly biological origin. It is now known that abiotic degradation can contribute to contaminant detoxification.

Reductive Dechlorination (Hydrogenolysis): Replacement of a halogen substituent with hydrogen with the concomitant addition of electrons to the organic molecule. For chlorinated aliphatic hydrocarbons, this process results in the degradation of organic compounds by chemical reduction with release of inorganic chloride ions.

Relative Percent Difference: An expression of the difference between two numbers calculated as the difference expressed as a percent of the average of the two numbers.

Sonde: A Sonde (*Sonde* is French for *probe*) is a water quality monitoring instrument, that may be stationary or may move up and down a water column, measuring water attributes including magnetic susceptibility, temperature, conductivity, salinity, dissolved oxygen, pH, turbidity, and depth.

Volume Magnetic Susceptibility: Volume magnetic susceptibility is a property of space. The volume magnetic susceptibility is the ratio of the magnetization (the magnetic dipole moment per unit volume) measured in amperes per meter divided by the magnetic field strength, measured in amperes per meter. The units for volume magnetic susceptibility cancel out.

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EXECUTIVE SUMMARY

OBJECTIVES

The overarching objectives of the work described herein were to:

(1) Provide a method to readily and inexpensively acquire the magnetic susceptibility data required to evaluate the abiotic degradation of TCE by magnetite in aquifer materials using existing non-metallic groundwater monitoring wells.
(2) Provide a method to readily and inexpensively acquire the data required to evaluate and quantify the rate constant for aerobic biological co-oxidation of TCE.

TECHNOLOGY DESCRIPTION

Using mass magnetic susceptibility to predict abiotic degradation of chlorinated alkenes by magnetite in the aquifer matrix has been shown to be viable, but before the work presented in this report, such evaluation required that a core sample of the aquifer material be submitted for laboratory analysis. This report shows that an inexpensive downhole sonde (probe) can be used in existing 2- and 4-inch PVC groundwater monitoring wells to quantify magnetic susceptibility of aquifer material.

Bacteria that degrade natural organic matter in groundwater contain enzymes (oxygenases) that can aerobically degrade TCE through a process of biological co-oxidation. Bacteria that contain active oxygenase enzymes can be recognized using fluorescent Enzyme Activity Probes (EAP), and the bacteria can be counted under a microscope. There are primers that can be used in the Polymerase Chain Reaction (qPCR) to amplify DNA that codes for selected oxygenase enzymes. A qPCR assay can be used to determine the number of gene copies for these enzymes in a sample of groundwater. Aerobic cooxidation is a promising risk management strategy for large dilute plumes, but its application has been limited because the co-oxidation of TCE in the environment is difficult to quantify by simply measuring changes in the concentration of TCE in the field, and the numbers of bacteria in groundwater that have the oxygenase enzymes has not been directly correlated to field-scale rates of degradation.

Because determining field scale rates for co-oxidation of TCE using concentration data is problematic, a ^{14}C labelled TCE assay was developed to measure rate constants. The utility of EAPs and qPCR assays to evaluate co-oxidation of TCE was determined by comparing the rate constant developed using the ^{14}C-labelled TCE assay to the abundance of cells that react with EAPs or the abundance of gene copies for oxygenase enzymes.

DEMONSTRATION RESULTS

Values for volume magnetic susceptibility were determined in 26 PVC wells using a downhole sonde. The values were converted to mass magnetic susceptibility, and compared to values for mass magnetic susceptibility from laboratory analyses on samples from boreholes that were adjacent to the wells. There was good agreement between the two measurements.

Out of the 19 groundwater samples evaluated using the ^{14}C-TCE assay, TCE co-oxidation could be documented in 8 samples, with first order rate constants ranging from 0.00658 to 2.65 yr^{-1}.

In a particular water sample, the abundance of gene copies of the most common oxygenase was similar to the abundance of cells reacting to the EAPs.

Some oxygenase enzymes were more abundant in groundwater from some wells and other enzymes were more abundant in other wells. Cooxidation of TCE could not be attributed to any one oxygenase enzyme. To further complicate interpretation of the abundance of DNA gene copies, not all the DNA in bacteria is actively transcribed to make enzymes at any one time. If the mRNA transcript for an enzyme is present in a sample, that is evidence that the gene is being transcribed.to make the active enzyme. The total abundance of active DNA gene copies was calculated as the sum of the individual gene copies of oxygenase enzymes for which the mRNA transcript was detected. There was a useful relationship between the total abundance of active DNA gene copies and the rate constants for TCE cooxidation. The 80% prediction interval of a regression of the rate constants on the total abundance of active DNA gene copies is only one order of magnitude wide.

COSTS

The cost to determine volume magnetic susceptibility in one well using a down-hole sonde is approximately $2,000. The cost of the ^{14}C assay of the rate constant of cooxidation of TCE is approximately $476 per well. The cost of the EAP assay is approximately $1,900 per well. The cost of the qPCR analyses is approximately $835 per well.

IMPLEMENTATION ISSUES

Laboratory microcosm studies have shown that some aquifer sediments have appreciable values for mass magnetic susceptibility but no evidence for abiotic degradation of TCE. Values of mass magnetic susceptibility should only be used as a second line evidence to support a rate constant for TCE degradation that is extracted from site characterization data, as is illustrated in the decision logic of Lebrón et al. (2015). Mass magnetic susceptibility should not be used as primary line of evidence to extract a rate constant. Similarly, the abundance of cells that react to an EAP or the abundance of DNA amplified by a qPCR marker for an oxygenase enzyme should be used as a second line evidence to support a rate constant for TCE degradation that is extracted from site characterization data. They should not be used as primary line of evidence to extract a rate constant.

Two other significant implementation issues are the cost of the enzyme activity probe (EAP) analyses and the fact that they can only be completed by the Pacific Northwest National Laboratory (PNNL) and the requirement that the ^{14}C-TCE assay be done in a certified and permitted laboratory. A third implementation issue has to do with the integrity of the PVC monitoring wells; specifically, 2-inch groundwater monitoring wells. If these wells are not sufficiently straight, or if the joints are not flush, then the magnetic susceptibility sonde cannot be lowered into the well, and it will not be possible to obtain mass magnetic susceptibility readings in such wells.

1.0 INTRODUCTION

This section provides a general overview of the project. It is divided into several subsections.

1.1 BACKGROUND

Monitored natural attenuation (MNA) and enhanced bioremediation have gained popularity as remediation approaches at sites contaminated with chlorinated solvents over the past 25 years. ESTCP Project Number ER-201129 developed a quantitative framework to aid in the selection of MNA or bioremediation approaches (biostimulation alone, or biostimulation combined with bioaugmentation) at sites contaminated with chlorinated ethylenes. Upon completion of ER-201129, two shortcomings regarding the current state of the science were identified, including:

- In some cases, the investigator may not want to expend the resources necessary to fully implement the decision framework developed for ER-201129. The most notable example occurs when the investigator has worked through the decision framework and will not be able to proceed without magnetic susceptibility data. Using mass magnetic susceptibility to predict abiotic degradation of chlorinated alkenes by magnetite in an aquifer matrix has been shown to be effective (ESTCP, 2015; He, 2009). However, before the work presented herein, this evaluation required that a core sample from a borehole be submitted for laboratory analysis. Obtaining core samples at many sites is unrealistic because the drilling program has been completed. Thus, general and widespread acceptance of the approach outlined in ER-201129 was limited. As detailed in this report, this project develops and validates a more affordable technique to measure magnetic susceptibility with a sonde (probe) that can be inserted into an existing monitoring well. The use of a downhole sonde that can be used in existing 2-inch or 4-inch inner-diameter non-metallic monitoring wells should increase the implementability and use of the decision framework developed for ER-201129, including BioPIC.
- Bacteria that degrade natural organic matter in groundwater contain enzymes (oxygenases) that can aerobically degrade trichloroethylene (TCE) through co-oxidation. These bacteria use oxygenase enzymes to degrade organic matter in groundwater. Trichloroethylene is fortuitously degraded by the same oxygenase enzymes that are produced during degradation of native organic matter. This degradation mechanism is promising for large dilute plumes, but its application has been limited because the numbers of bacteria in groundwater that have the oxygenase enzymes have not been directly correlated to degradation rates until now. This degradation pathway was not included in ER-201129 because it had not yet been quantified. This report quantifies the relationship between oxygenase enzymes and degradation rates.

A number of studies have demonstrated that remedial goals can be met with significantly reduced environmental impacts, capital investment, and operation and maintenance (O&M) costs by implementing MNA. The results of this project and the results presented in this report should increase the number of sites where MNA is implemented because it allows the Department of Defense (DOD) to better describe the mechanisms and processes that contribute to natural attenuation. This is because degradation by magnetite and aerobic cooxidation have largely been neglected when evaluating MNA in the past, which often has resulted in the misinterpretation of degradation mechanisms and thus, the efficacy of MNA.

For example, when abiotic degradation or aerobic co-oxidative degradation are the predominant degradation mechanisms, the investigator may falsely conclude that degradation has "stalled" at dichloroethylene (DCE), typically *cis*-1,2-DCE (*c*DCE). With the information presented in this report, the DOD and other responsible parties will be able to present State and Federal regulatory agencies with quantitative estimates of the contribution of abiotic degradation by magnetite and aerobic co-oxidation to the overall rate of natural attenuation at DOD sites contaminated with chlorinated ethylenes. An increase in the use of MNA will minimize detrimental environmental impacts, such as greenhouse gas emissions, at sites where unnecessary remediation previously would have taken place. This will reduce both capital and O&M costs to the DOD.

1.2 OBJECTIVES OF THE DEMONSTRATION

The overarching objectives of the work described herein are to:

(1) Provide a method to readily and inexpensively acquire the magnetic susceptibility data required to evaluate the abiotic degradation of chlorinated ethylenes by magnetite in existing non-metallic groundwater monitoring wells.

(2) Provide a method to readily and inexpensively acquire the data required to evaluate and quantify the aerobic co-oxidation of TCE.

Based on the data and information presented in this report, these objectives have been met. It is anticipated that this work will further promote the implementation of MNA where it previously was not implemented because of a lack of understanding of these important degradation processes, and the inability for them to be readily quantified at many sites.

1.3 REGULATORY DRIVERS

Presently, the maximum contaminant levels (MCLs) for the chlorinated ethylenes PCE, TCE, *c*DCE, and vinyl chloride (VC) are 5 micrograms per liter (µg/L), 5 µg/L, 70 µg/L, and 2 µg/L, respectively (http://water.epa.gov/drink/contaminants/index.cfm). At many sites, a risk-based assessment dictates cleanup goals, which often means that MCLs are not the regulatory driver. In any event, some type of remedial action is required at many DOD sites where chlorinated ethylenes are present. This project expands on the elucidation of degradation pathways outlined in ESTCP ER-201129 to allow DOD RPMs to choose the most efficacious remediation approach to meet remedial objectives.

2.0 TECHNOLOGY

This section provides an overview of the technology components demonstrated in this report.

2.1 TECHNOLOGY DESCRIPTION

The results presented in this report allow the efficacy of MNA to be evaluated more efficiently and accurately than it has been in the past using tools that had already been developed but had not been adequately tested for environmental applications. Specifically, the techniques described and quantified in this report benchmark abiotic degradation by magnetite and aerobic co-oxidation at sites contaminated with chlorinated ethylenes. Figure 2.1.1 is a process schematic showing integration of key components of the demonstration.

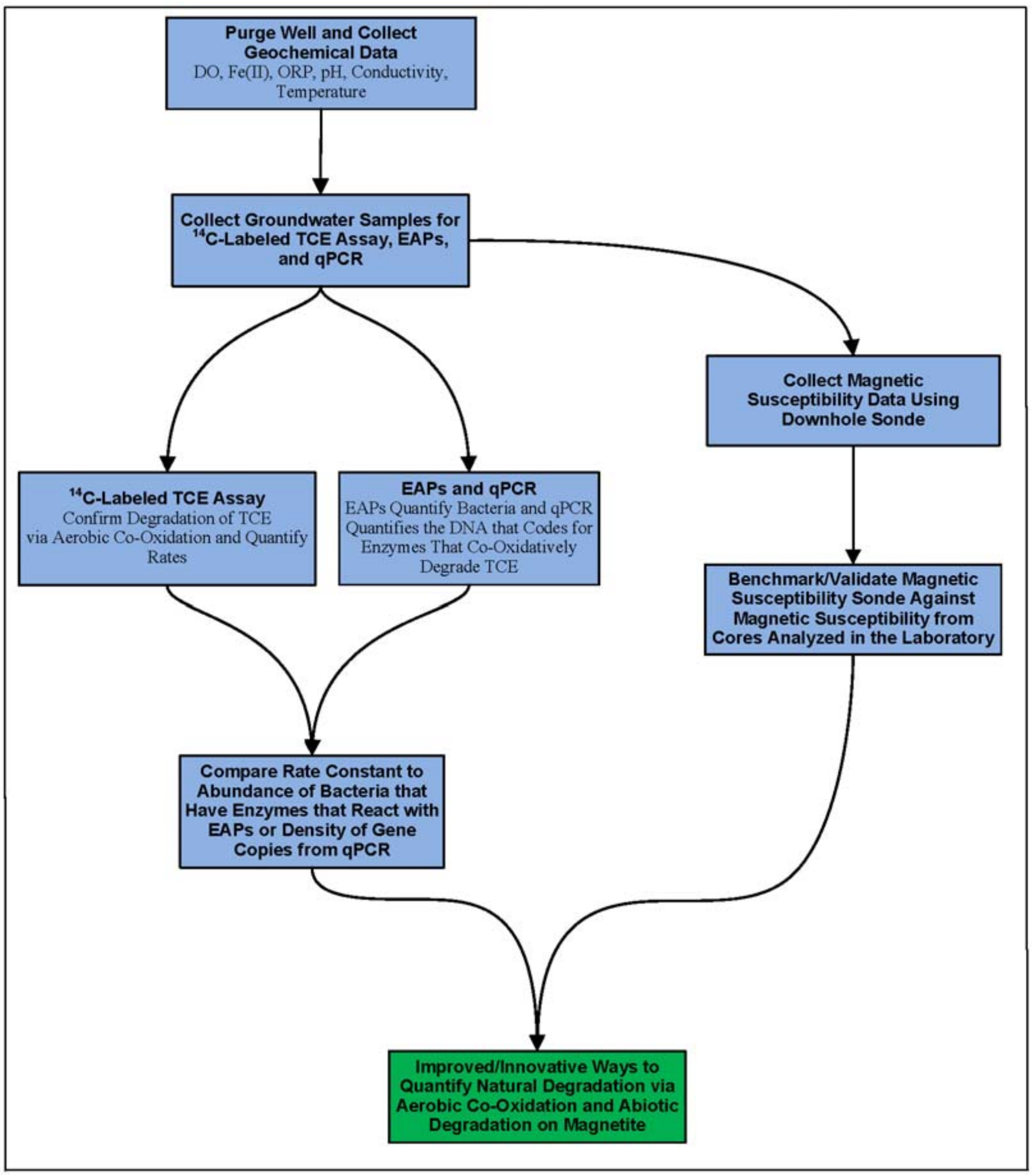

Figure 2.1.1. Process Schematic Showing Integration of Key Technology Components.

2.2 TECHNOLOGY DEVELOPMENT

This Section provides a detailed description of the technology development.

2.2.1 Quantifying Abiotic Degradation by Magnetite Using a Magnetic Susceptibility Sonde

Borehole sondes and laboratory magnetic susceptibility meters measure the volume magnetic susceptibility of the aquifer material. Volume magnetic susceptibility is a property of space. The volume magnetic susceptibility is the ratio of the magnetization (the magnetic dipole moment per unit volume) measured in amperes per meter divided by the magnetic field strength, measured in amperes per meter. The units for volume magnetic susceptibility cancel out. The mass magnetic susceptibility of the subsurface material is calculated by dividing the volume magnetic susceptibility as measured by the sonde by the bulk density of the material being analyzed (kg/m^3).

Magnetite is a natural component of many aquifers. Abiotic degradation of chlorinated ethylenes in aquifer materials containing magnetite can be an important mechanism for natural attenuation (Lee and Batchelor, 2002; Ferrey et al., 2004; Darlington, et al., 2008; He et al., 2009; Darlington, et al., 2013; He et al. 2015). In contrast to anaerobic biodegradation, abiotic degradation by magnetite does not go through a sequential reductive dechlorination (Lee and Batchelor, 2002; Darlington et al., 2013). That is, tetrachloroethylene (PCE) is not degraded to produce trichloroethylene (TCE), TCE is not degraded to *c*DCE, and *c*DCE is not degraded to produce vinyl chloride (VC). As a consequence, degradation of chlorinated ethylenes by magnetite does not produce compounds that are on the list of USEPA MCLs.

The measurement of the magnetic properties of the earth for geological mapping and for the direct detection of iron-rich ores has been used for many years. It is one of the most common geophysical survey techniques. Variations in the magnetic field reading are caused by variations in the local magnetic susceptibility and/or variations in the local remnant magnetism of geological materials.

Borehole logging of magnetic susceptibility has been used for mineral exploration for decades, being first developed for use in petroleum exploration (Broding et al., 1952). Because borehole magnetic susceptibility measurements are made using an alternating current induction technique, the downhole sonde used for this project is an instrument which responds only to very local variations in magnetic susceptibility. Such a device operates by generating a small alternating magnetic field, usually at an audio frequency, and measuring changes in the amplitude of this magnetic field caused by the presence of nearby magnetically-susceptible material (McNeill et al., 1996).

Relatively few magnetic minerals have geological significance, with magnetite (Fe_30_4) being by far the most important (McNeill et al., 1996). Other magnetic minerals that may occasionally be significant include pyrrhotite (Fe_7S_8), ilmenite (Fe_2Ti0_3), and a form of hematite known as maghemite (γFe_20_3) (Grant and West, 1965). Under ordinary circumstances the magnetic susceptibility of soil and sediment is dominated by magnetite (Dearing, 1999, page 39; He et al., 2009, pages 77-78). There is an important exception. Greigite (Fe_3S_4) can form in sediments with adequate sources of sulfide and iron (Roberts, 2015). The magnetic susceptibility of greigite can be as high 2.0E-04 m^3/kg (Decker et al., 2000), which brings it in the same range as magnetite.

In sulfate-reducing aquifers (i.e., strongly reducing/anoxic), it is possible that greigite will produce magnetic susceptibility that can be confused for magnetite. However, in such aquifer systems, anaerobic biological reductive dechlorination will likely be the predominant degradation mechanism.

Magnetite is extremely resistant to weathering, which makes it useful for environmental engineering applications. Most rocks contain magnetite, in an amount which varies from very small fractions of a percent to several percent, and even tens of percent in some iron ore deposits (McNeill et al., 1996). Rocks containing magnetite weather to form detrital magnetite which is found in sediments such as those that make up the shallow subsurface in which solute plumes of chlorinated ethylenes are found.

The magnetic susceptibility of aquifer sediment can be characterized with good sensitivity and at low cost. There is a direct correlation between the quantity of magnetic materials in aquifer sediments and their magnetic susceptibility (Figure 2.2.1; Lindsley et al., 1966; Balsley and Buddington, 1958; Werner, 1945; Canfield and Berner, 1987; Horneman et al., 2004). The relationship is linear over a range in values of two orders magnitude. However, there is significant variation from one sample to the next. The 95% prediction interval on the quantity of magnetic materials varies by a factor of 3.4 from the regression line.

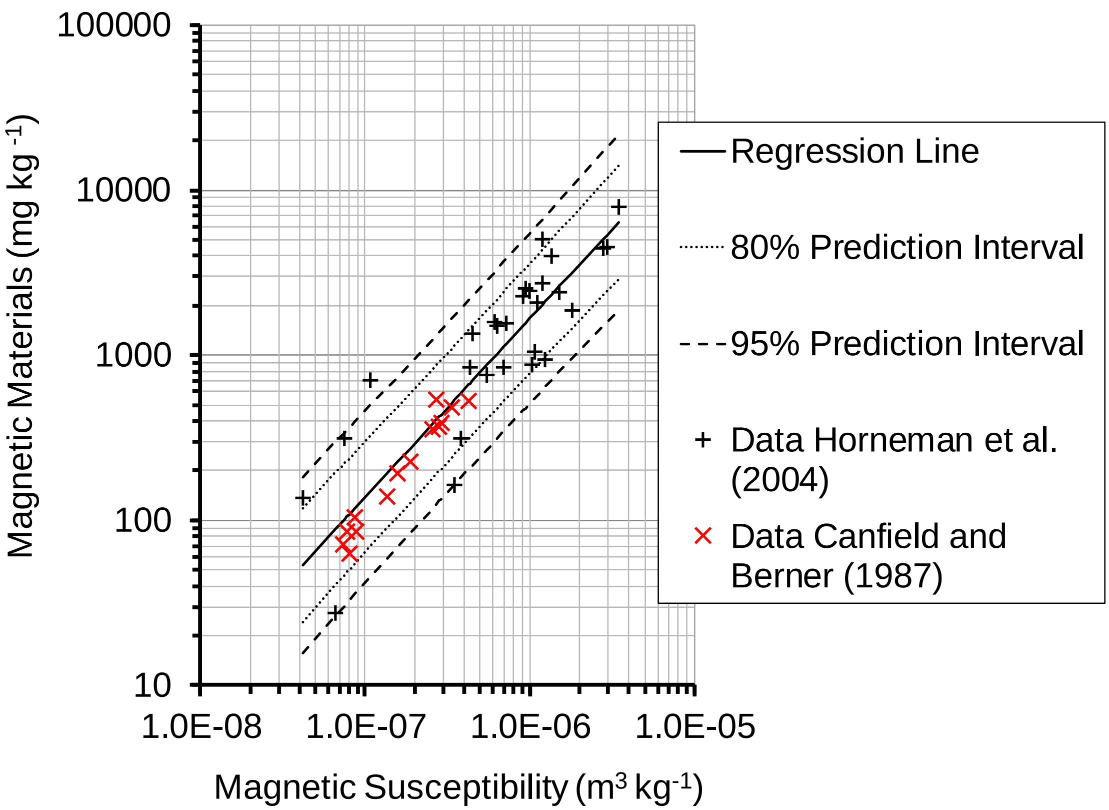

Figure 2.2.1. Relationship between the Mass Magnetic Susceptibility of a Sediment and the Content of Magnetic Minerals.

Redrawn for Figure 6.5 of He et al. (2009).

Mass magnetic susceptibility is a useful surrogate for the quantity of magnetite in aquifer material. This is particularly true because it is not possible to directly measure magnetite at concentrations less than 10000 mg kg^{-1} and most aquifer materials contain less than 10000 mg kg^{-1} of magnetic materials (He et al., 2009).

Using mass magnetic susceptibility to predict abiotic degradation of chlorinated alkenes by magnetite in the aquifer matrix has been shown to be viable, but before the work presented in this report, such evaluation required that a borehole core sample be submitted for laboratory analysis. Unfortunately, obtaining core samples at many sites is problematic because the majority of DOD and other hazardous waste sites have largely been characterized and no additional boreholes/groundwater monitoring wells are planned. Because the abiotic degradation by magnetite has only recently been discovered (Lee and Batchelor, 2002; Ferrey et al., 2004; Darlington, et al., 2008; Darlington, et al., 2013; He et al., 2009; He et al. 2015), most previous site characterization efforts did not include collection of borehole core samples for magnetic susceptibility analysis. Thus, the ability to quantify abiotic degradation by magnetite was limited before this project. In this report, an affordable technique is developed and validated that measures magnetic susceptibility with a sonde (probe) that can be easily deployed into existing two- or four-inch non-metallic groundwater monitoring wells. This project determined that there is a relationship between magnetic susceptibility determined using a relatively inexpensive downhole magnetic susceptibility sonde and the magnetic susceptibility of an aquifer determined through laboratory analyses of aquifer matrix samples collected from borehole core samples. If properly utilized, the downhole magnetic susceptibility sonde has the ability to save the DOD significant amounts of money in unnecessary drilling costs while still allowing abiotic degradation mechanisms facilitating MNA to be quantified.

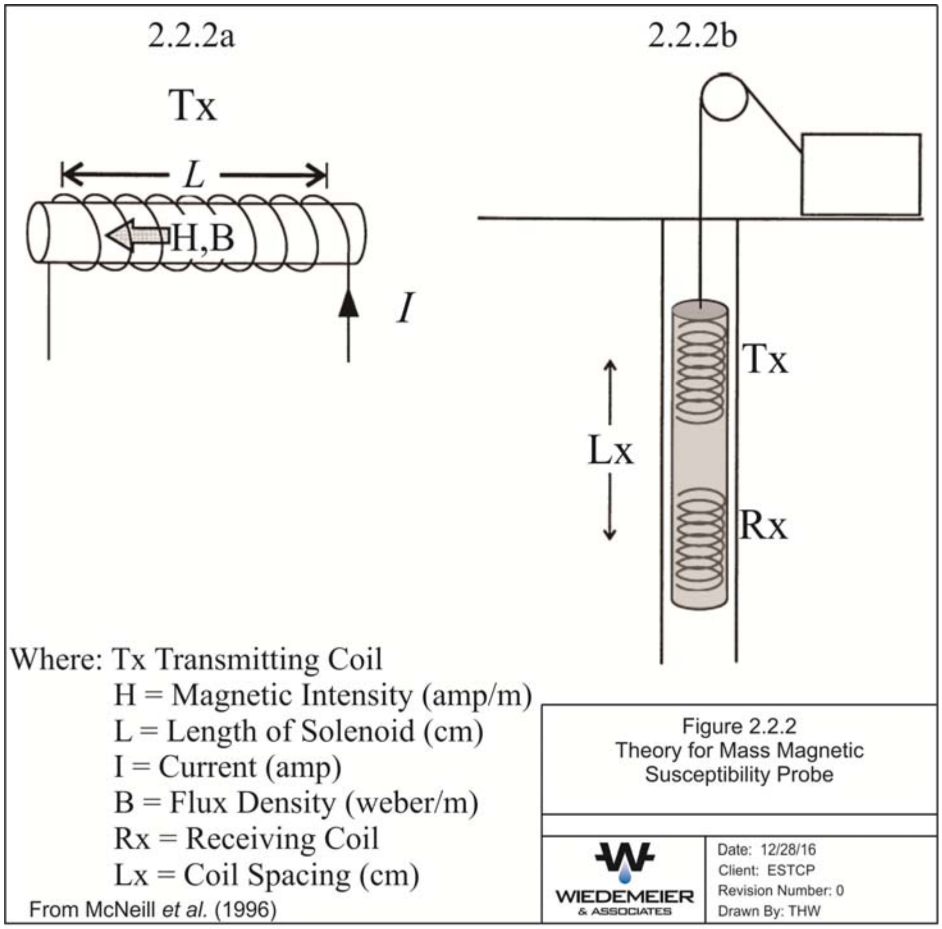

Figure 2.2.2. Theory for Mass Magnetic Susceptibility Probe

Borehole sondes such as those used for magnetic susceptibility are based on electromagnetic induction. This principle is illustrated in Figure 2.2.2. A small transmitter coil (Tx) is energized with an alternating current at an audio frequency. Figure 2.2.2a shows a long (with respect to its diameter) solenoidal coil through which flows a current. Inside the coil, at a large distance from the ends, the magnetic field is uniform, with magnetic intensity *H.*

$$H=NI/L \qquad (2.1)$$

where H = Magnetic Intensity (amp/m); N = Number of Turns; I = Current (amp); and L = Length of Solenoid (m).

This coil (Tx; Figure 2.2a) generates an alternating magnetic field which is sensed by a nearby receiver coil (Rx; Figure 2.2b). The receiver coil together with a capacitor bank and oscillator circuit produce an alternating magnetic field in the vicinity of the coil (McNeill et al., 1996). Any magnetic material which is bought within the influence of this field will bring about a reduction in the natural resonant frequency of the oscillator circuit (McNeill et al., 1996). The magnetic susceptibility of the materials immediately around the borehole is proportional to the reduction in the natural resonant frequency. This is measured by a meter/data logger attached to the sonde.

In the general case where the ground exhibits finite magnetic susceptibility and electrical conductivity, the measured magnetic field is a complicated function of the ground permeability, electrical conductivity, the operating frequency of the instrument and the intercoil spacing (McNeill et al., 1996). However, at sufficiently low frequencies, such that the low induction number approximation is fulfilled (McNeill, 1980), the response simplifies substantially. In this case, the response from the ground electrical conductivity appears essentially in the quadrature phase component of the received magnetic field while the response from the magnetic susceptibility appears in the in-phase component. Two caveats must be considered in connection with this statement (McNeill et al., 1996). The first is that, where the particles of magnetite are small enough so that they are essentially single domain, it can be shown (Mullins and Tite, 1973) that the contribution from magnetic susceptibility also has a small quadrature phase component, which, since only the in-phase component will be measured to obtain the magnetic susceptibility, is not of concern here. The second caveat is that, for moderate to large electrical conductivities, such as those associated with oil deposits and the deep subsurface, the conductivity response also contains a small in-phase response (Doll, 1949). Since it is this component that is measured, electrical conductivity must also be measured in areas with large electrical conductivities in order to correct the in-phase reading, particularly when measuring small magnetic susceptibilities (McNeill et al., 1996). Thus, unless the medium is known to be characterized by low electrical conductivities, which is the case for most shallow hydrogeologic systems, it is necessary to use a conductivity sonde to obtain conductivity data with which to correct the susceptibility data. This correction is generally small (McNeill et al., 1996) and because of the relatively low conductivities associated with shallow groundwater, was neglected. As shown by the results presented herein, this appears to be a valid assumption.

The inductive magnetic susceptibility borehole sonde that was used for this demonstration employs the general configuration shown in Figure 2.2.2. Figure 2.2.3 shows the general implementation of the theory described in the schematic diagram presented in Figure 2.2.2.

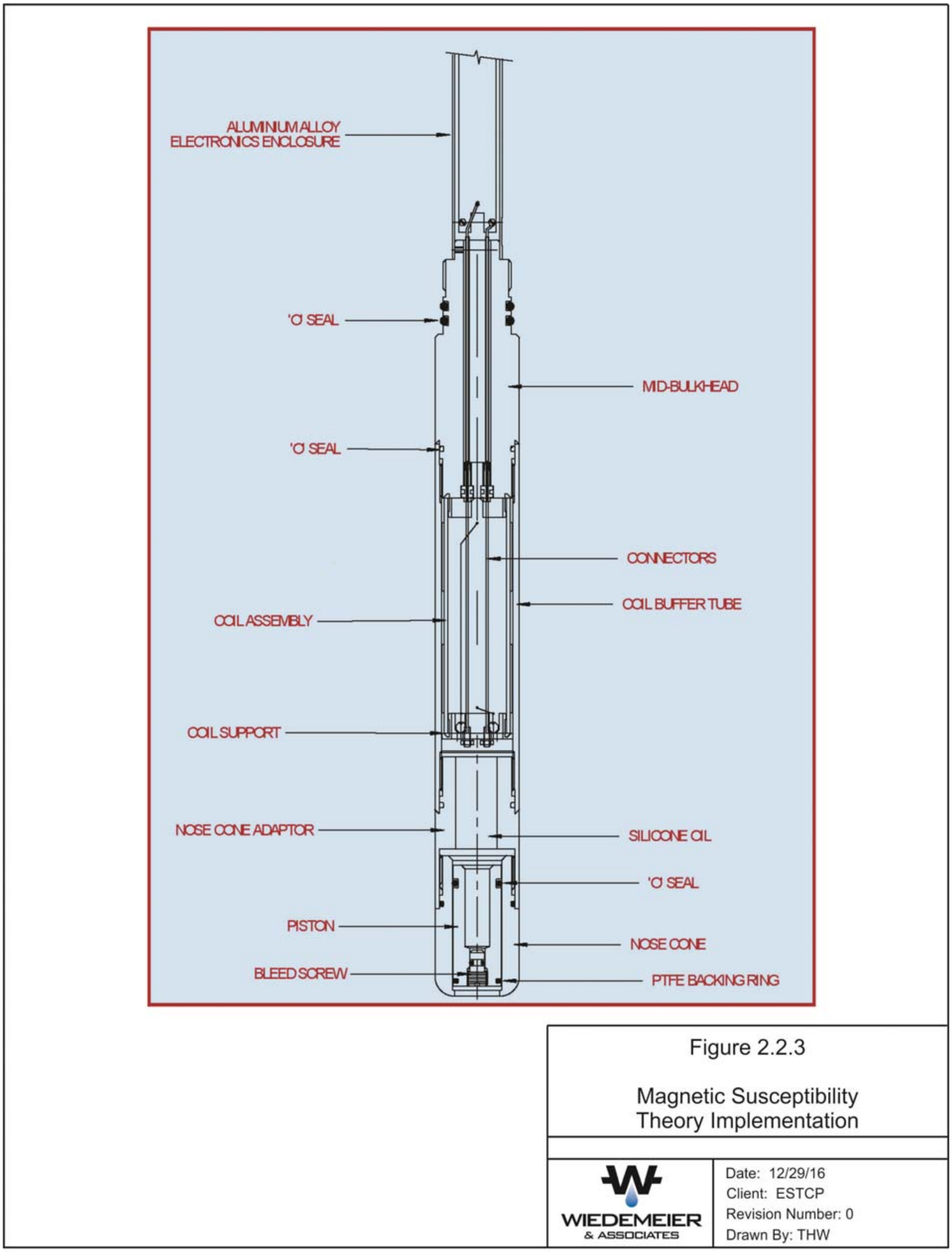

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Figure 2.2.3. Magnetic Susceptibility Theory Implementation

2.2.2 Quantifying Aerobic Co-Oxidation of Trichloroetyhlene

Bacteria that degrade natural organic matter in groundwater contain enzymes (oxygenases) that can aerobically degrade TCE through a process of co-oxidation. This degradation mechanism is promising for large dilute plumes, but its application has been limited because the numbers of bacteria in groundwater that have the oxygenase enzymes has not been directly correlated to field-scale rates of degradation. Because determining field scale rates for co-oxidation of TCE using concentration data is problematic, a ^{14}C labelled TCE assay was developed to help quantify degradation rates. To allow the use of this assay at other sites, a protocol for collecting and analyzing samples using the ^{14}C labelled TCE assay is provided in Appendix F.

The utility of enzyme activity probes (EAPs) and the quantitative real-time polymerase chain reaction (qPCR) assays was evaluated by comparing the rate constant for aerobic biodegradation to the abundance of cells that react with EAPs or the abundance of gene copies for oxygenase enzymes. To allow the use of EAPs at other sites, an abbreviated protocol for collecting and analyzing EAP samples is provided in Appendix E.

2.2.2.1 ^{14}C-TCE Assay

Co-oxidation of TCE in the environment is difficult to quantify by simply measuring changes in the concentration of TCE in the field. The monitoring approach used for this study included an assay employing ^{14}C-labeled TCE. Groundwater samples collected in the field were shipped on ice via an overnight carrier to Clemson University. Upon receipt, the groundwater was warmed to room temperature, and highly purified ^{14}C-labeled TCE was added to the collection bottles. At regular intervals (ranging from a few hours to several days), the fate of the ^{14}C-labeled TCE was ascertained by quantifying the disappearance of ^{14}C-labeled TCE and the accumulation of ^{14}C-labeled products, including $^{14}CO_2$ and soluble ^{14}C-labeled compounds such as formate, glycolate, and oxalate. The high precision of these measurements due to the strong signal emanating from ^{14}C made it possible to estimate pseudo-first order rate coefficients for TCE degradation over a relatively short time frame.

The use of ^{14}C-labeled compounds to determine the fate of a parent compound, the rate of degradation, and the identity of the products formed has been in practice for decades. This includes the fate of ^{14}C-labeled TCE and other chlorinated organic contaminants. The Freedman laboratory has extensive experience in the use of ^{14}C-labeled compounds (e.g., Darlington et al., 2008, 2013; Fullerton et al., 2013; Shan et al. 2010). One complication with using ^{14}C-labeled TCE is the presence of impurities. Typically, vendors provide ^{14}C-labeled TCE that is 95-98% radio-chemically pure. The presence of impurities presents a problem when trying to quantify TCE degradation, especially over relatively short time intervals. One way to avoid this problem is to further purify the ^{14}C-labeled TCE before adding it to microcosms. The Freedman laboratory has accomplished this in previous studies by passing a stock solution of ^{14}C-labeled TCE through a gas chromatographic column and then injecting the eluent from the column into a microcosm when TCE elutes. This has achieved an appreciable improvement in purity of the solution. For the current project, additional purification was evaluated by placing a second gas chromatograph (GC) column in series with the first. However, two columns in series turned out not to provide any additional improvement in purity, so a single column was used. Results for the comparison between one and two columns in series is presented in section 3.1.2.

The ^{14}C assay is one of three types of measurements that were used in this study to document the occurrence of in situ co-oxidation of TCE. The first order rate coefficients from the ^{14}C assays were correlated with EAP and qPCR data. As shown in this report, these three types of measurements provide a more complete picture of in situ transformation than any one of the measurements by itself.

2.2.2.2 Enzyme Activity Probes

Several methods are available to assess the in-situ activity of microbes in the subsurface. However, these methods can be time consuming and frequently provide overestimates of the actual rates of activity (Phelps et al., 1994). The recent design of a suite of EAPs has permitted the determination of specific aerobic cometabolism of chlorinated ethylenes, most notably TCE. EAPs that serve as alternate substrates for TCE cometabolizing enzymes have been developed for four separate aromatic oxygenases (Keener et al., 1998; 2001; Miller et al., 2002; Clingenpeel et al., 2005), and for the soluble methane monooxygenase (SMMO; Miller et al., 2002) (Figure 2.2.4).

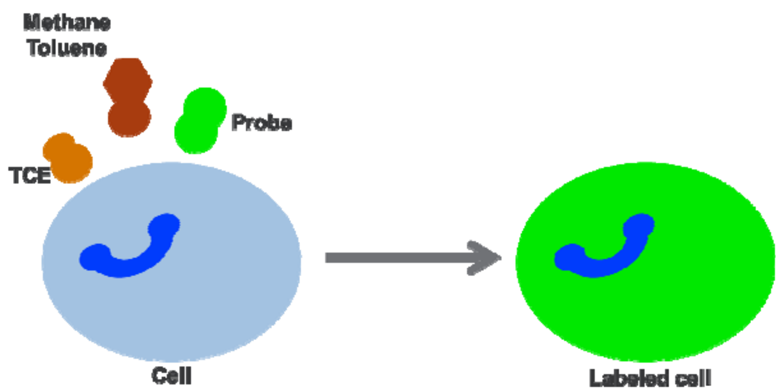

Figure 2.2.4. Schematic of Enzyme Activity Probes Showing Primary Substrates (methane/toluene), Co-metabolic Substrate (TCE) and EAP (Probe).

Once EAP is oxidized by co-metabolic enzyme, a fluorescent byproduct is generated, producing fluorescent cells. Other substrates that support TCE oxidation include: benzene; ammonia; phenol; naphthalene and propane.

These non-fluorescent probes are transformed by the enzymes into a quantifiable fluorescent signal upon transformation, thus providing direct evidence of cometabolic enzyme activity. Enzyme probes have been evaluated at a number of DOE and DOD sites over the last eight years (Lee et al., 2005; Lee et al., 2008; Wymore et al., 2007). Based on these analyses of contaminated groundwater, with TCE concentrations ranging from less than 100 µg/L to over 10,000 µg/L, it appears that enzyme probes provide a direct estimate of aerobic cometabolic enzyme activity for subsurface populations. As shown by this work, EAPs can provide valuable information regarding the presence and activity of in situ microbial enzyme systems important for aerobic cometabolism for plume-wide assessment of intrinsic assessment of degradation. Total bacteria present were determined by staining with DAPI (4,6-Diamidino-2-phenylindole), and these numbers are compared to bacteria fluorescing upon addition of EAP (Figure 2.2.5).

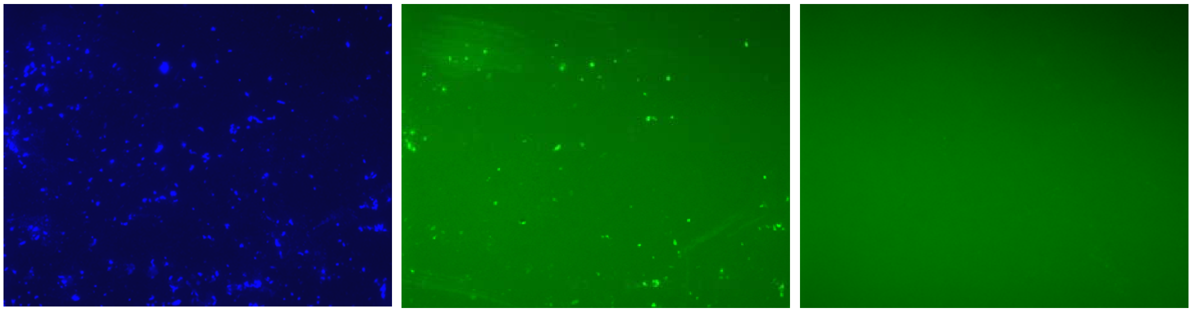

Figure 2.2.5. The Micrograph on the Left Represents the Total Number of Microbial Cells (DAPI-stained); the Center Micrograph Represents the Cells that Transformed the Probe into a Fluorescent Product.

The right micrograph shows a negative response with the probe.

2.2.3 Quantitative PCR (qPCR) for Oxygenase and Dioxygenase Genes

In general, qPCR provides an opportunity to identify specific microorganisms or even specific genes in a microbial community in order to assess the potential for that community to carry out a desired biotransformation process. Aerobic cometabolism of TCE is a fortuitous reaction catalyzed by diverse monooxygenases and dioxygenases with somewhat broad substrate ranges (Frascari et al., 2015). Because of the phylogenetic diversity of these enzymes (and the genes that code for them), it is impossible to develop a single nucleic acid-based biomarker for TCE-cometabolizing microorganisms. However, many of these enzymes do share structural similarities that are reflected in conserved stretches of their encoding DNA sequences, against which broadly-specific, degenerate PCR primers have been constructed. From environmental studies performed with these primers, it is known that there is abundant diversity in the recovered sequences (Baldwin et al., 2003; Nebe et al., 2009). Application of qPCR at contaminated sites provides quantification of a diverse range of known organisms and genes that are relevant to aerobic cometabolism. To date, qPCR is the only method that can identify the broad diversity of oxygenase genes and/or organisms known to possess those genes. In particular, qPCR allows for the assessment of genes and/or organisms relevant for aerobic cometabolism of chlorinated solvents. The qPCR results can be related back to the EAP results to provide a comprehensive assessment of changes in number and activity of genes along the midline of a contaminant plume or over spatial and/or temporal scales.

2.2.4 Relationship between EAP and qPCR Targets

The enzyme probe data relates to the qPCR data as shown in the table below (Table 2.2.1). Some of the targets for the qPCR analyses do not directly correspond to EAP analyses and are completed in order to target other oxygenase enzymes which are known to also cometabolize contaminants such as chlorinated solvents. While there are dozens of known enzymes, some are more commonly found in environmental systems and/or are potential targets for remediation strategies such as bioaugmentation or biostimulation (propane, methane, benzene etc.). Table 2.2.1 provides a list of all of the qPCR targets considered for the current demonstration and completed herein.

Table 2.2.1. Relationship between the EAP, the Oxygenase(s)/ Pathway and the qPCR Methods Completed Within.

Probe	Pathway	qPCR
3-hydroxyphenylacetylene	toluene-2-monooxygenase toluene-3-monooxygenase	RMO, PHE
	toluene-2,3-dioxygenase	TOD
	toluene-2,3-dioxygenase	TOD
phenylacetylene	toluene-3-monooxygenase toluene-2-monooxygenase	RMO, PHE
3-ethyylbenzoate	toluene-side-chain-monooxygenase	TOL
trans-cinnamonitrile	toluene-2,3-dioxygenase	TOD
coumarin, naphthalene	Soluble methane monooxygenase	mmoX, pmoA

2.3 ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY

The advantages and limitations of the technology described in this report are described below. The authors are not aware of any alternative technologies.

Advantages:

The advantages of the methods described in this report include:

- The results presented in this report allow elucidation and quantification of degradation mechanisms that in the past could not be readily quantified using only existing monitoring wells. For example, in the past, soil samples were required to quantify magnetic susceptibility in an aquifer matrix. The use of a downhole magnetic susceptibility sonde circumvents this limitation. Also, as opposed to collecting discrete soil/sediment samples which are discontinuous along the length of the borehole, the use of a downhole sonde allows continuous readings along the length of the entire borehole in which a PVC monitoring well has been installed. This increases the level of detail for magnetic susceptibility measurements across the contaminated aquifer, thus allowing better characterization. The use of a downhole sonde also significantly reduces costs at those sites where exploratory site characterization has largely been completed and there are no plans for a drilling rig to be mobilized to the site in the future.
- Outside of the ^{14}C assay described in Appendix F, there is no technically viable approach to directly measure a rate constant for the natural biological cooxidation of TCE in groundwater. Aerobic co-oxidation of TCE by oxygenase enzymes yields products such as CO_2, CO, formate, glycolate, and oxalate. These products are also formed during biodegradation of non-chlorinated and naturally occurring organic matter, and therefore prior to the work presented in this report, it was not possible to distinguish their source.

Furthermore, when the concentration of TCE in the environment is low relative to background organic matter, the concentration of biodegradation products formed from TCE co-oxidation may be very low by comparison. Use of ^{14}C-labeled TCE overcomes this problem, since all of the carbon-based products formed will also be labeled. Even trace levels of products are measurable, because of the extremely strong "signal" from ^{14}C.

- Use of ^{14}C-labeled TCE makes it possible to quantify the rate of TCE transformation with significantly greater precision than simply measuring the disappearance of TCE.
- The assay used for this project only utilized groundwater. It is shown in this report that rates of TCE co-oxidation are quantifiable without having to employ core samples in the assay. The sensitivity of the assay permits determination of transformation rates without the presence of core material.
- Although use of ^{14}C material can only be performed in laboratories permitted to use radioactive material, ^{14}C poses much lower hazards in comparison to other radioisotopes that are commonly used, e.g., for medical applications.
- EAP is a direct measurement of bacteria with active oxygenase enzymes, so few biases are associated with application of the technology. EAP is currently the only technology available to probe activity of oxygenases responsible for co-metabolism of TCE.
- qPCR is a proven and commercially available technology for determining the presence of bacteria carrying copies of oxygenase genes responsible for co-metabolism of TCE.

Possible Limitations:

The possible limitations of the work presented herein are:

- The magnetic susceptibility sonde cannot be used in stainless steel wells. Wells larger than 4 inches in diameter may be problematic for collecting accurate magnetic susceptibility data because of the size of the borehole required for such wells. However, larger sondes, with a larger radius of influence, are available.
- As mentioned above, ^{14}C assays can only be performed in laboratories that are permitted to use radioactive material. Furthermore, the cost for ^{14}C-labeled TCE is considerable (~$11,000 per mCi), mainly because it is no longer available as a stock compound and must therefore be custom synthesized. If the assay is adopted for more frequent use, suppliers may opt to once again provide ^{14}C-labeled TCE as a stock item, which will decrease the cost.
- The ^{14}C assay is not yet commercialized. It is hypothesized that the successful demonstration of the protocol presented in this report will provide considerable motivation for private companies to offer the service. An analogous situation was the use of compound specific isotope analyses (CSIA). At one time, use of this technology for groundwater samples was limited to a select few academic laboratories. As the value of the approach became apparent, commercial laboratories stepped in to meet the growing demand. We anticipate that a similar outcome will develop for the ^{14}C assay proposed in this study.

- EAP at the current level of development are only a qualitative predictor of aerobic bioremediation, since probe response was never adequately calibrated to the actual rate of contaminant biodegradation in groundwater at field sites. EAP analytical services are currently only available through PNNL.
- qPCR can be affected by biases associated with DNA extraction, as well as issues associated with efficiency of DNA amplification.

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3.0 PERFORMANCE OBJECTIVES

Tables 3.1.1 and 3.2.1 summarize the performance objectives, success criteria and data requirements for the demonstration. Subsequent sub-sections provide additional details regarding each performance objective. All performance objectives were met for this project.

3.1 QUALITATIVE PERFORMANCE OBJECTIVES

This section discusses the qualitative performance objectives for this project, which are summarized in Table 3.1.1.

3.1.1 Easy to Use Procedure for Collecting Magnetic Susceptibility Data

For magnetic susceptibility data to be useful there must be an inexpensive way to collect these data from existing monitoring wells. This is because most sites are past the borehole core data collection phase.

3.1.1.1 Data Requirements

The primary data requirement for this performance objective was field implementation of the magnetic susceptibility sonde at various depths and in various conditions. Specifically, the field testing of existing, readily-available technology to quantify magnetic susceptibility in existing PVC monitoring wells using a magnetic susceptibility sonde to determine ease of use.

3.1.1.2 Success Criteria

This qualitative performance objective is considered to be met because users are now able to easily obtain accurate magnetic susceptibility data in existing PVC monitoring wells using a commercially-available downhole magnetic susceptibility sonde.

3.1.2 Develop an Assay Based on ^{14}C-TCE That Will Allow Determination of TCE Co-Oxidation Rates in Groundwater Samples

3.1.2.1 Data Requirements

Development of the ^{14}C assay included an evaluation of a new method for purifying ^{14}C-TCE. The intent was to reach a higher level of purity than has previously been accomplished and thereby minimize interference from background contamination. The original method involved purification of the ^{14}C-TCE stock solution by an aliquot (50 µL) through a GC column and injecting the gas flow into a serum bottle as the ^{14}C-TCE eluted, presumptively separated from any contaminants. A second method was evaluated that involved placing the first column in series with a second column. The details of each arrangement are described below.

The 160 mL glass serum bottles to which the purified TCE was added contained 100 mL of groundwater, filter sterilized groundwater (FSGW), or distilled deionized (DDI) water. The bottles were sealed with Teflon-faced grey butyl rubber septa and crimp caps. Before injecting the ^{14}C-TCE, approximately 50 mL of headspace was withdrawn from each bottle using a 100-mL gas-tight syringe (SGE Analytical Science, removable Luer Lock) to ensure the bottles were not over-pressurized. After the headspace withdrawal, the bottles were immediately inverted to reduce gas diffusion through the punctured Teflon-faced septa.

Table 3.1.1. Qualitative Performance Objectives.

Objective(s)	Data Requirements	Success Criteria	Results
Develop an approach for measuring magnetic susceptibility in non-metallic groundwater monitoring wells that provides data of useful quality.	Data on magnetic susceptibility from sondes in monitoring wells that can be compared to measurements of magnetic susceptibility on core samples from the site.	Objective is met if users are able to obtain accurate magnetic susceptibility data using a commercially-available downhole sonde.	This performance metric was met. Users have access to a commercially-available downhole sonde that has been validated to provide data of useful quality.
Develop an assay based on ^{14}C-TCE that will allow for determination of TCE co-oxidation rates in groundwater samples.	Measurements of the rate of accumulation of ^{14}C label in transformation products of TCE in groundwater samples compared to accumulation in filter-sterilized controls. Accumulation of ^{14}C label in products measured with a scintillation counter.	Objectives are met if the rate of accumulation of transformation products in groundwater samples are statistically significant in comparison to controls constructed with filter sterilized groundwater.	This performance metric was met for 8 out 19 groundwater samples that were evaluated. Out of the 19 groundwater samples evaluated, statistically significant rates of TCE co-oxidation were observed in 8 samples.
Combined application of qPCR and EAP will show the presence of bacteria with active enzymes in groundwater.	Data on the abundance of bacteria in groundwater reacting to the EAP or that contain DNA that is amplified by the qPCR primers for oxygenase enzymes.	EAP and qPCR can be configured and implemented to provide sufficient sensitivity for application to diverse aerobic aquifers.	EAP and qPCR analyses were applied to 19 groundwater samples, meeting performance metrics by showing presence and activity of TCE cometabolizing bacteria at numerous sites.
Compare consumption rates of ^{14}C-TCE to number of bacteria with active enzymes	Rate constants for cooxidation of TCE in water samples as determined by the ^{14}C-TCE assay and data on the abundance of bacteria reacting to the EAP or that contain DNA that is amplified by the qPCR primers.	In every well tested, a statistically significant rate constant and an abundance above the quantitation limit of bacteria reacting to one or more EAP or DNA that is amplified by one or more qPCR primer.	Cooxidation of TCE was only detected in 8 water samples where the rate constants for cooxidation were > 0.01 per year. The abundance of bacteria with active enzymes can only be used to evaluate sites where the rate constants are > 0.01 per year.

The original method employed a stainless-steel column packed with 1% SP-1000 on 60/80 Carbopack-B (8 ft x 1/8 in x 2.1 mm, Supelco, Inc.) (Darlington et al., 2008). The end of the column was connected to a four-port valve in the GC oven. The valve was positioned so that the flow exited the oven through stainless-steel tubing (1.59 mm) rather than going to a detector. The end of the tubing from the GC oven had a threaded Luer Lock fitting for attachment of a sterile needle, through which serum bottles were injected at a predetermined residence time to trap TCE as it eluted from the column. The carrier gas in the column was high purity N_2 (Airgas®) at a flow rate of 33.5 ± 0.5 mL/min. The temperature program was 60 °C for 2 min, increase at 20°C per min to 150°C, increase at 10°C to 200°C and hold for 28.5 min.

Under these conditions, the elution time for TCE was 9.6 to 11.1 min. The GC program was continued after TCE eluted to minimize any possibility that contaminants in the stock solution might accumulate on the column.

For the second method, another stainless-steel column packed with 10% SP-1000 on 80/100 SUPELCOPORT (Supelco) was connected to the 4-port valve after the first column and before the stainless-steel tubing (1.59 mm). Addition of a second column significantly decreased the flow rate of the entire system. Thus, an isothermal temperature program at 200°C with a 20-min hold time was used to decrease the time interval that TCE eluted through both columns. At a carrier gas flow rate of 10.3±0.2 mL/min, the time interval for TCE to elute was 9.9 to 11.5 min.

Two sets of triplicate serum bottles containing 100 mL of DDI water were used to compare the two methods for adding ^{14}C-TCE. After adding the ^{14}C-TCE, a 3-mL aqueous sample was removed and processed as follows: it was added to a 20-mL glass vial; the pH was raised above 10 added by adding a drop of 8 M NaOH; it was sparged with N_2 for 30 min (550±50 mL/min); 15 mL of liquid scintillation cocktail was added; and the ^{14}C activity was quantified using a liquid scintillation counter. The average disintegrations per minute (dpm) in the 3 mL samples was 23.7±3.8 for the single column and 26.6±2.7 for the dual column approach; the difference is not statistically significantly ($p = 0.35$) (Appendix D). Consequently, the singly column method of purification was used for the ^{14}C assay. As noted in subsequent sections, this level of purification was adequate to permit detection of a half-life as long as 105 years.

3.1.2.2 Success Criteria

The success of the purification step is based on the level of impurities remaining at the start of the assay. The success of the assay is based on whether or not rates of ^{14}C-TCE transformation in samples from the field are discernable from rates in controls containing sterile DDI water.

The ^{14}C assay provides a tool to determine if TCE is undergoing transformation and if so, at what rate. Because of the specialized nature of the assay, it must be performed in a laboratory that is licensed to use ^{14}C labeled material. Nevertheless, the outcome of the assay is easily understandable to most end users, in the form of pseudo-first order rate coefficients. Based on the authors' experience teaching many university classes and giving professional training courses, the default metric to describe rates of biodegradation in groundwater are pseudo first-order rate constants. Scientists come to the courses and training familiar with first-order rate constants. Site managers are well acquainted with use of models to predict the rate of contaminant degradation based on first order transformation processes. The ^{14}C assay provides information in a familiar format that is needed to assess natural rates of attenuation.

3.1.3 Methods for Identifying Presence and Activity of Co-Metabolic Bacteria for TCE Oxidation

Aerobic co-metabolism of chlorinated ethylenes such as TCE requires the presence of bacteria with oxygenases implicated in co-metabolism. Combined application of qPCR and EAP shows the presence of active enzymes in groundwater from the site.

3.1.3.1 Data Requirements

Data on the abundance of bacteria in groundwater reacting to the EAP or that contain DNA that is amplified by the qPCR primers for oxygenase enzymes. Groundwater samples were collected and analyzed by qPCR and EAP to determine if microbial populations were detectable in site groundwater, thus demonstrating the potential for biodegradation.

3.1.3.2 Success Criteria

EAP and qPCR can be configured and implemented to provide sufficient sensitivity for application to diverse aerobic aquifers. EAP and qPCR analyses were applied to 19 groundwater samples, meeting performance metrics by showing presence and activity of TCE cometabolizing bacteria at numerous sites.

3.1.4 Demonstrate Baseline Method for Linking TCE Transformation Rates to Numbers of Bacteria with Co-oxidation Enzymes

The baseline method uses data on the abundance of bacteria that react to an EAP or the amount of DNA that is amplified by a primer for an oxygenase enzyme to estimate or predict a plausible rate constant for TCE cooxidation. The method is calibrated by a comparsion to the data provided from the wells that are sampled in the survey. Under ideal conditions, it will be possible to extract a statistically significant rate constant from the data from each well, and it should be possible to measure the abundance of one or more EAPs and one or more primers in water from each well.

3.1.4.1 Data Requirements

The data requirements are rate constants for ^{14}C-TCE cooxidation by bacteria in the groundwater samples and data on the abundance of bacteria that react to the EAPs and data on the abundance qPCR primers for oxygenase enzymes associated with bacteria that are known to cooxidize TCE.

3.1.4.2 Success Criteria

The criteria for success in the survey of wells used to calibrate the baseline method are as follows. A rate constant for TCE cooxidation will be determined that is greater than zero at 95% confidence. In each particular water sample, the abundance of bacteria responding to at least one of the EAP assays is above the quantitation limit and the abundance of DNA amplified by at least one qPCR assay is above the quantitation limit.

3.2 QUANTITATIVE PERFORMANCE OBJECTIVES

This section discusses the qualitative performance objectives for this project, which are summarized in Table 3.2.1.

Table 3.2.1. Quantitative Performance Objectives

Objective(s)	Data Requirement(s)	Success Criteria *	Results
Quantify relationship between magnetic susceptibility from a direct-reading downhole sonde and that from laboratory analyses on samples from boreholes into which PVC monitoring wells were installed.	Magnetic susceptibility data from laboratory analyses of core samples from boreholes into which PVC wells were installed. A readily available magnetic susceptibility sonde (probe) was lowered into these same wells (Section 4), and real-time magnetic susceptibility data were collected.	The correlation between magnetic susceptibility determined using the sonde and that from laboratory analyses of core samples were determined. The Pearson's correlation coefficient, r, was be calculated. If r is greater than 0.75, then the criteria for this performance objective has been met.	The plot of mass magnetic susceptibility from the sonde versus that determined from lab analyses of core samples yields r = 0.94 and R^2 = 0.88. Thus, this performance objective is met and the downhole sonde is considered to be a good tool for collecting representative magnetic susceptibility data from existing PVC wells.
Determine first order rate constants of TCE co-oxidation using a ^{14}C-TCE assay. Rate constants were determined by measuring the rate of accumulation of ^{14}C label in transformation products in water samples.	Data on the rate of accumulation of ^{14}C label in TCE transformation products as provided by the ^{14}C-TCE assay. Rate constants were determined in groundwater samples taken from 19 wells at five sites. There were four wells at each of four sites and three wells at one site.	Objective is met if the rates of ^{14}C product accumulation from ^{14}C-TCE in groundwater samples are statistically significant in comparison to controls containing filter sterilized groundwater at 95% confidence.	This performance metric was met in 8 of 19 water samples. Out of the 19 groundwater samples evaluated, statistically significant rates of TCE co-oxidation were observed in 8, with first order rates ranging from 0.00658 to 2.65 yr^{-1}.
Quantify numbers of oxygenase genes present in groundwater community with qPCR analysis, and numbers of bacteria with active oxygenase enzymes can be quantified using EAP analysis.	Quantify activity of oxygenase genes based on EAP and surrogate qPCR measurements. Quantify activity measured for positive control organisms, negative controls, matrix spikes and blanks to determine specificity of EAP and qPCR. Quantify activity in replicate samples from same well.	EAP and qPCR techniques provide reproducible data when comparing groundwater replicates (<30% RPD). Blanks have no background fluorescence. Positive controls show active enzymes. Matrix spikes provide 70 to 130% recovery of positive control organism. Control assays perform as expected.	This performance metric was achieved. EAP and qPCR provided reproducible data between replicates. Controls such as blanks, matrix spikes, and positive controls demonstrated expected results that fell within established criteria. In general, qPCR results corresponded to the EAP results for the PHE and RMO primer sets, but not for the TOD and TOL primer sets. Gene targets for sMMO were only detected significant levels (>103 cells/ml) at three of the 19 wells tested.
Demonstrate ability to determine TCE transformation rates by numbers of bacteria with active co-oxidation enzymes determined by EAP and qPCR	Rate constants for cooxidation of TCE in water samples as determined by the ^{14}C-TCE assay and data on the abundance of bacteria reacting to the EAP or that contain DNA that is amplified by the qPCR primers	The slope of a regression of the common logarithm of the rate constant for TCE cooxidaiton on the common logarithm of the abundance of EAP or qPCR markers will be greater than zero at 95% confidence.	The slope was greater than zero at 95% confidence for the CINN EAP and for the PHE, RMO, and MMO qPCR markers. The the prediction interval of the regression was used to develop a screening approach to evaluate whether TCE cooxidation might be useful for MNA at a site.

3.2.1 Evaluate the Accuracy of Data for Mass Magnetic Susceptibility

3.2.1.1 Data Requirements

To verify the validity of the data collected using the magnetic susceptibility sonde, a commercially-available sonde was deployed in wells where soil samples were collected from soil borings prior to well installation and analyzed for mass magnetic susceptibility in an analytical laboratory. The data collected using the downhole sonde were then compared to these previously-collected soil data and the relationship between the magnetic susceptibility data from the laboratory and the magnetic susceptibility measurements made using the sonde were determined.

3.2.1.2 Success Criteria

The correlation between mass magnetic susceptibility determined using the sonde and mass magnetic susceptibility data collected using laboratory analysis of soil/sediment data was determined. Specifically, the Pearson's correlation coefficient, r, was calculated from a plot of mass magnetic susceptibility obtained from the sonde versus that obtained from laboratory analyses of core samples. The success criteria for this quantitative performance objective is a Pearson's correlation coefficient, r, between the core means and the sonde means of greater than 0.75. As discussed in Section 5.7, for the work presented in this report, r = 0.94, and the coefficient of determination, $R^2 = 0.88$. Thus, the magnetic susceptibility sonde provides a good tool for collecting representative data from existing non-metallic (PVC) monitoring wells.

3.2.2 Determine First-Order Rates of TCE Co-Oxidation Using a ^{14}C-TCE Assay

3.2.2.1 Data Requirements

Development of the ^{14}C assay included evaluation of a new method for purifying ^{14}C-TCE. The intent was to reach a higher level of purity than has previously been accomplished and thereby minimize interference from background contamination.

The ^{14}C assay was tested with a sample of surface water that was locally sourced, from theTwin Lakes Recreation Area on Lake Hartwell near Pendleton, SC. The site is ~10 min driving distance from the Freedman laboratory, in order to minimize changes during transport. Measurements of ^{14}C degradation products began immediately after adding ^{14}C-TCE to microcosms containing water from a seep discharges into an area with a high level of organic debris. The rate of accumulation of ^{14}C products was used to determine the pseudo-first order rate of TCE transformation, by fitting the data to a mass balance model for ^{14}C in the microcosms.

Additional tests to evaluate the efficacy of the ^{14}C assay were performed with a propanotrophic enrichment culture. This culture served as a positive control, since propanotrophs are known to be capably of biodegrading TCE via cometabolism.

Groundwater samples were immediately placed on ice after collection. The intent of doing so was to slow the rate of microbial activity until ^{14}C-TCE could be added in the laboratory. The effect of storage conditions on the outcome of the ^{14}C assay was evaluated using the propanotrophic culture. A 0.25% dilution was selected based on the results from the experimental described below. Three conditions were used to test the effects of temperature, each in triplicate: 1) ambient room temperature; 2) storage on ice for 24 h, then warmed for 2.5 h; and 3) storage on ice for 24 h, then warmed for 24 h; the latter most closely resembles how the groundwater samples were handled.

^{14}C-TCE was added using the single column method, following the respective temperature treatments. The bottles were monitored for accumulation of ^{14}C products for 40 days.

3.2.2.2 Success Criteria

Impurities in the ^{14}C-TCE Stock Solution

The initial goal for demonstrating the success of the purification step was to reduce the presence of ^{14}C impurities (i.e., ^{14}C not attributable to TCE) to less than 0.01% of the total ^{14}C activity. As indicated in section 2.2.2.1, the intent was to achieve this goal using two GC columns in series to purify the ^{14}C-TCE stock solution prior to adding it to the serum bottles. However, preliminary testing indicated that a single column was just as effective, so that approach was used when testing the DDI water and groundwater samples.

The level of impurities added to serum bottles was determined by comparing the dpm present in water samples after sparging, with and without ^{14}C-TCE added. For DDI water, the average dpm in 3 mL samples was 25.6±2.4, compared to 11.8±1.2 in samples of DDI water that did not receive ^{14}C-TCE. For groundwater samples, the average dpm in 3 mL was 29.5±6.4, compared to 12.0±0.9 in samples of DDI water that did not receive ^{14}C-TCE. The differences in dpm between the 3 mL samples with and without ^{14}C-TCE added (17.5 and 13.9, respectively) were presumably due to contaminants. For the groundwater samples, this amounted to 0.07% of the total dpm added to the serum bottles. For the DDI water, the residual level of dpm present amounted to 0.05% of the total dpm added to the serum bottles. From this perspective, the purification goal was not met. However, the goal was predicated on a shorter incubation time (~2 days) than what was ultimately adopted (up to 46 days). The longer incubation time affords a greater opportunity to detect a statistically significant rate of product accumulation above the controls, even with a background of impurities that is above 0.01%. As the results show, the lowest net rate quantified (0.00658 yr^{-1}) translates to a half-life of 105 years, which indicates the assay is sufficiently sensitive. On this basis, the level of purification achieved is considered successful.

It should also be noted that the level of impurities reported above may not actually be impurities. The assessment of impurities involved adding the ^{14}C-TCE to the DDI water controls and then waiting approximately one hour before removing the 3 mL samples. It is quite possible that the higher level of ^{14}C products in these bottles was actually a consequence of decay, rather than impurities. Regardless, even if the activity reported was decay, the assay was still sensitive enough to detect low rates of TCE co-oxidation.

One of the concerns with the residual level of ^{14}C remaining after sparging was the possibility that 30 min of sparging was not sufficient to completely remove all of the TCE. This was evaluated by comparing residual levels of ^{14}C in samples that were sparged for 30 min versus 60 min. Triplicate serum bottles were prepared with DDI water and ^{14}C-TCE was added to each. After allowing the TCE to equilibrate between the headspace and liquid phases, duplicate 3 mL samples were removed from each bottle; one was sparged for 30 min and the other for 60 min. There was no statistically significant difference in the residual level of ^{14}C ($p = 0.58$) (Appendix D), indicating that TCE was not likely responsible for the residual levels reported above.

Preliminary Evaluation of the ^{14}C Assay Using Locally Sourced Water

As indicated above, a preliminary evaluation of the assay was performed with locally sourced water. Samples from a seep area were added to serum bottles and immediately capped in the field. Upon arrival at Clemson University, ^{14}C-TCE was added. Triplicate DDI water controls were prepared at the same time. There was a statistically significant rate of ^{14}C product accumulation in the bottles with surface water and in the DDI water controls (Appendix D). The first order rates were $5.00\times10^{-2}\pm3.56\times10^{-2}$ yr^{-1} for the surface water samples and $2.63\times10^{-2}\pm1.29\times10^{-2}$ yr^{-1} for the DDI water controls. Accumulation of ^{14}C products in the DDI water controls was likely a consequence of autoradiolysis of the ^{14}C-TCE. A Student's *t*-test indicated the first order rates are statistically different; consequently, a net rate of $2.37\times10^{-2}\pm 1.67\times10^{-2}$ yr^{-1} was calculated, which gives a half-life of 29 yr (95% confidence interval = 17-99 yr). These results confirm that the assay is capable of detecting co-oxidation rates that are useful for evaluating natural attenuation.

Experimental Controls

To determine rate constants for co-oxidation of TCE, it was necessary to demonstrate that the accumulation of ^{14}C products from ^{14}C-TCE was due to biotic activity and not a background level of reaction with the water. Intitialy, DDI water served as the negative control. For each of the five sites, triplicate DDI water controls were prepared and monitored alongside the serum bottles containing groundwater. Subsequently, filter-sterilized groundwater (FSGW) was used for this purpose. When enough groundwater was available, FSGW controls were prepared for each well. A 47-mm nylon membrane filter disk with 2 µm pores (Whatman™) was used for this purpose. When not enough groundwater was available for a particular well to prepare FSGW controls, a control from the closest well was used. Use of the FSGW controls made it possible to improve the sensitivity of the assay, allowing for detection of TCE co-oxidation at rates even lower than those measured in the preliminary samples from Twin Lakes. Apparently, FSGW contains compounds that mitigate autoradiolysis of ^{14}C-TCE and therefore FSGW serves as a more representative control for the assay. Overall, the rate of ^{14}C-product accumulation in FSGW controls was 38% lower than in DDI water controls.

A mixed propanotrophic culture (ENV487), known to co-metabolize TCE, was used as a positive control for validating the assay. The mixed culture was obtained courtesy of Dr. Robert Stefan at Chicago Bridge and Iron, Inc. It was grown on propane gas and pure oxygen in basal salt medium (BSM) to a density of ~ 5.3×10^{10} cell/mL, as previously described (Rodríguez, 2016). Following consumption of repeated additions of propane and oxygen, dilutions (25%, 2.5%, 0.25%, and 0.025%) were prepared with BSM in 160 mL serum bottles and ^{14}C-TCE was added. Accumulation of ^{14}C products is shown in Figure 3.2.1. Even in the most dilute treatment, the rate of product accumulation was significantly greater than in the BSM control with no cells present, in which there was no significant accumulation of products. The pseudo first-order rate constant and associated 95% confidence interval (CI) for the 0.01% dilution was $1.71\times10^{-1}\pm5.60\times10^{-2}$ yr^{-1}, which gives a half-life of 4.1 years (95% CI = 3.1 to 6.0 yr). As shown below, this rate is similar to the rates determined for several of the groundwater samples. Additional testing is needed to determine how low a rate of TCE co-oxidation can be detected with the propanotrophic culture.

It is noteworthy that there was no statistically significant increase in ^{14}C products in the BSM control. This suggests that the BSM contains compounds that reduce the effects of radical production from autoradiolysis of ^{14}C-TCE. The compounds responsible may include the bicarbonate buffer and the nitroloacetic acid used to chelate the trace metals. In contrast, all of the DDI water controls and FSGW controls exhibited statistically significant rates of ^{14}C product accumulation; this made it necessary to check if the first order rate in the groundwater samples was statistically greater than in the controls. In eight of the wells tested, this was observed, so a net rate was calculated by subtracting out the rate of product accumulation in the FSGW controls. In the remaining well samples, the rate of product accumulation was not statistically greater than in the FSGW controls; for those, a rate constant for co-oxidation is not reported.

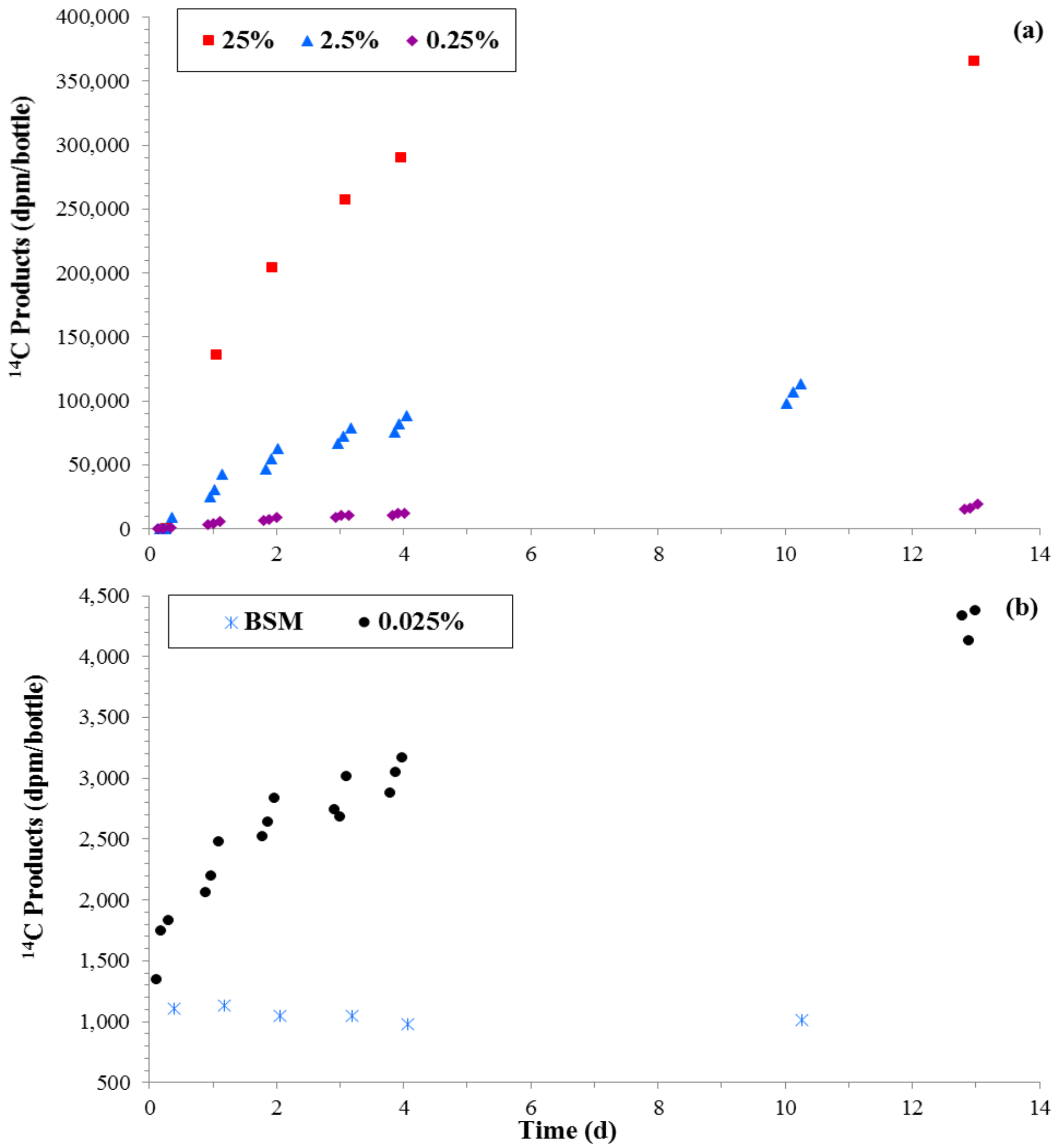

Figure 3.2.1. Accumulation of ^{14}C Products from ^{14}C-TCE Added to Various Dilutions of a Propanotrophic Enrichment Culture¶(a) 25%, 2.5%, 0.25%; and (b) 0.025% and the BSM Control with No Cells.

The data shown were fit to a mass balance model to determine first order rates of TCE co-oxidation.

Effect of Storage Conditions

The effect of storage conditions on the rate of ^{14}C product accumulation are shown in Figure 3.2.2. Rates were very similar for the control treatment that was never cooled down to 4 °C (blue circles) and the treatment that was held at 4 °C for 2.5 h before being warmed to room temperature (red squares). The treatment that was held at 4 °C for 24 h before being warmed to room temperature (black triangles) behaved differently; this was most pronounced after day 4, as the accumulation rate slowed noticeably. However, when only the first 5 days of data were considered, there were no statistically significant differences among the first order rate coefficients. These results suggest that the conditions under which the groundwater samples were handled (i.e., shipment and storage on ice overnight, followed by warming to room temperature overnight) may have decreased the reaction rate. Consequently, the rates reported in this study are likely conservative. It is difficult to envision a different approach to handling the samples, since they need to be shipped to a laboratory to perform the ^{14}C-TCE assay. Additional studies on the effect of storage conditions using groundwater samples is warranted.

Based on the results presented in this report, the ^{14}C assay provides a tool to determine if TCE is undergoing transformation and, at what rate. Because of the specialized nature of the assay, it must be performed in a laboratory that is licensed to use ^{14}C labeled material. Nevertheless, the outcome of the assay is easily understandable to most end users, in the form of first order rate coefficients. Site managers are well acquainted with use of models to predict the rate of contaminant degradation based on first order transformation processes. The ^{14}C assay provides information in a familiar format that is needed to assess natural rates of attenuation.

3.2.3 Quantification of Bacteria with Active Enzymes Associated with TCE Co-Metabolism

Numbers of oxygenase gene copies present in the groundwater community can be quantified with qPCR analysis, and numbers of bacteria with active oxygenase enzymes can be quantified using EAP analysis.

3.2.3.1 Data Requirements

Collect and analyze groundwater samples to quantify activity of oxygenase genes based on EAP and surrogate qPCR measurements. Quantify activity measured for positive control organisms, negative controls, matrix spikes and blanks to determine specificity of EAP and qPCR. Quantify activity in replicate samples from the same groundwater monitoring well.

3.2.3.2 Success Criteria

EAP and qPCR techniques provide reproducible data when comparing groundwater replicates (<30% RPD). Blanks have no background fluorescence. Positive controls show active enzymes. Matrix spikes provide 70 to 130% recovery of positive control organism. Control assays perform as expected demonstrating specificity and activity of qPCR primers and EAP probes.

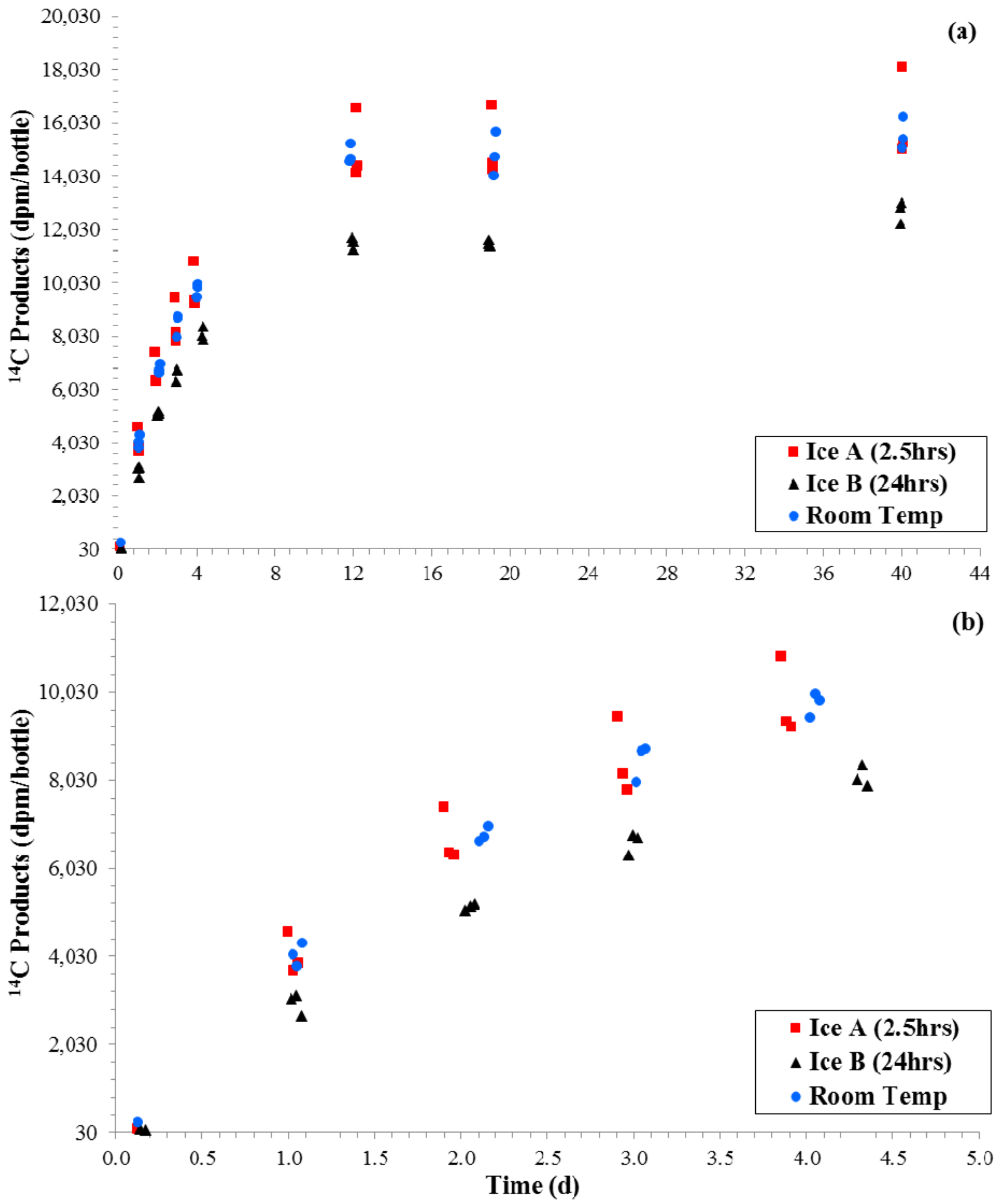

Figure 3.2.2. ^{14}C Product Accumulation in a 0.25% Propanotrophic Enrichment Culture Subjected to Different Storage and Warming Conditions Followed by Incubation with ^{14}C-TCE for (a) 40 Days and (b) the Same Bottles Showing Only the First 4 days.

Ice A represents storing bottles on at 4 °C for 24 hrs, then warming to room temperature for 2.5 hrs. Ice B represents storage on ice for 24 hrs, then warming for 24 hrs. ^{14}C-TCE was added immediately to the room temperature bottles.

3.2.4 Demonstrate Ability to Predict TCE Co-Oxidation Rates by Quantifying Number of Bacteria With Active Co-oxidation Enzymes

Linear regression will be used to evaluate the relationship between the rate constant for TCE cooxidation and abundance of bacteria that react with individual EAP or the abundance of DNA that is amplified by qPCR primers for selected oxygenase enzymes. The rate constants and the abundance data vary over several orders of magnitude. Linear regression assumes that the variance of the y data follows a normal distribution. To make the variance in the rate constants fit a normal distribution, the regression was performed usisng the logarithm of the rate constant and the logarithm of the abundance of the reactive cells or abundance of the DNA amplified by the primer.

3.2.4.1 Data Requirements

The data requirements are rate constants for ^{14}C-TCE cooxidation by bacteria in the groundwater samples and data on the abundance of bacteria that react to the EAPs and data on the abundance of qPCR primers for oxygenase enzymes associated with bacteria that are known to cooxidize TCE.

3.2.4.2 Success Criteria

For the purposes of the baseline method, a particular EAP or qPCR primer will be usedful to predict the rate constant for TCE cooxidation in the groundwater plume when the slope of the regression of the common logarithm of the rate constant on the common logarithm of the abundance of the EAP or qPCR marker is greater than zero at 95% confidence. If an EAP or qPCR primer is useful, the prediction interval on the rate constant will be used to evaluate whether the rate constant is might be useful for MNA at a particular site.

4.0 SITE DESCRIPTIONS

This section provides a concise summary of the demonstration site(s) and includes site information that is relevant to the technology. In addition, it summarizes the work done at each site during the field effort.

4.1 OVERVIEW

The following five (5) sites were selected for analysis under this program because there is an existing database for either the magnetic susceptibility of core samples from the site, or because there are existing data on the numbers of bacteria in groundwater that have enzymes that might degrade TCE, or both. In addition to the sites listed here, one other site was used for the magnetic susceptibility analysis, but no samples were collected for the ^{14}C assay or the EAP/qPCR analyses. Specifically, monitoring well U2-043 at OU-2 at Hill AFB was analyzed for mass magnetic susceptibility by collecting borehole core samples on December 7th and 8th 2015. Because the sampling team was so close to this Operable Unit during sampling at Hill AFB, OU-10, groundwater monitoring well U2-043 was sampled with the downhole sonde upon completion of sampling at OU-10. The sonde and borehole core laboratory analytical data from monitoring well U2-043 are included in the statistical analyses completed in this report.

Table 4.1.1 contains the well completion information for those wells sampled during this effort. Table 4.1.2 presents the laboratory magnetic susceptibility results for borehole core samples and grab samples for 10-20 silica sand.

Table 4.1.1. Well Completion Information for Those Wells Sampled During this Effort.

ESTCP Project Number ER-201584

Well I.D.	Date	Easting	Northing	Ground Surface Elevation (feet msl)	Well Diameter (Inches)	Borehole Diameter (Inches)	Well Material	Stick Up (feet)	Riser/Top of Casing Elevation (feet msl)	Depth to Top of Screen (feet bgs)	Depth to Base of Screen (feet bgs)	Elevation at Top of Screen (feet bgs)	Elevation at Base of Screen (feet bgs)	Depth to Water (feet btoc)	Ground-water Elevation (feet msl)	Magnetic Susceptibility	Groundwater Sample for ^{14}C TCE Assay, EAP, and qPCR
Former Plattsburgh AFB																	
MW-02-006	6/6/2016	722275.88	1700372.52	245.80	2.00	8.40	PVC	3.22	249.02	27.00	37.00	218.80	208.80	33.45	215.57	1	1
MW-02-019	6/6/2016	722797.86	1700168.45	228.20	2.00	9.60	PVC	0.00	228.20	9.00	24.00	219.20	204.20	16.74	211.46	1	1
32PLTW12	6/7/2016	724106.10	1699268.69	204.72	0.75	NA	NA	NA	204.62	15.00	18.00	189.72	186.72	13.70	190.92	--	1
35PLT13	6/7/2016	724336.46	1698809.87	194.76	0.75	NA	NA	NA	194.58	22.00	25.00	172.76	169.76	10.35	NA	--	1
TCAAP																	
01U-119	1/26/1987	486563.00	4994616.00	898.00	4.00	6.63	PVC	2.00	898.00	9.50	19.50	888.50	878.50	7.10	890.90	1	1
01U-108	8/2/1985	486497.00	4994667.00	904.00	2.00	6.63	PVC[a/]	2.00	904.00	20.00	30.00	884.00	874.00	14.00	890.00	1	1
01U-117	1/21/1987	486423.00	4994693.00	903.00	4.00	6.63	PVC	1.80	903.00	18.00	33.00	885.00	870.00	10.70	892.30	1	1
01U-115	1/19/1987	486355.00	4994726.00	901.00	4.00	6.63	PVC	1.90	901.00	17.90	32.90	883.10	868.10	12.26	888.75	1	1
Hill AFB OU-10																	
OU10-019	11/14/2002	NA	NA	NA	2.00	8.00	PVC	2.50	NA	81.00	91.00	NA	NA	??	NA	1	1
OU10-025[b/]	7/7/2004	1853352.83	287410.33	4493.80	2.00	8.00	PVC	Flush	4492.96	27.00	37.00	4466.80	4456.80	13.56	4479.40	1	1
OU10-043	NA	1854700.27	288430.06	4546.11	2.00	8.00	PVC	Flush	4545.29	20.00	30.00	4526.11	4516.11	10.70	4534.59	1	1
OU10-051	11/21/2004	1855416.44	289048.53	4565.74	4.00	9.63	PVC	2.04	4576.78	171.20	211.20	4394.54	4354.54	133.90	NA	1	--
Hopewell Precision Site																	
EPA-8S	12/22/2006	688671.47	1012878.00	303.40	2.00	6.25	PVC	Flush	303.40	20.00	30.00	283.40	273.40	15.50	287.90	1	--
EPA-10S	12/11/2006	687576.84	1011997.62	296.10	4.00	6.25	PVC	Flush	296.10	25.00	35.00	271.10	261.10	9.02	287.08	1	1
EPA-10D	12/11/2006	687576.86	1011990.02	296.43	4.00	6.25	PVC	Flush	296.43	45.00	55.00	251.43	241.43	8.85	287.58	1	--
EPA-12S	12/14/2006	685654.24	1010697.40	289.36	4.00	6.25	PVC	Flush	289.36	20.00	30.00	269.36	259.36	10.40	278.96	1	1
EPA-12D	12/14/2006	685659.42	1010701.16	289.43	4.00	6.25	PVC	Flush	289.43	35.00	45.00	254.43	244.43	10.00	279.43	1	--
EPA-15D	1/18/2007	684810.35	1010325.08	292.50	4.00	6.25	PVC	Flush	292.50	30.00	40.00	262.50	252.50	19.90	272.60	1	1
EPA-16S	1/3/2006	685807.51	1010189.44	292.86	4.00	6.25	PVC	Flush	292.86	20.00	29.92	272.86	262.94	13.40	279.46	1	1
EPA-16D	12/21/2006	685801.23	1010190.34	293.00	4.00	6.25	PVC	Flush	293.00	40.00	50.00	253.00	243.00	13.03	279.97	1	--
EPA-19S	1/23/2007	684228.48	1008563.96	282.76	2.00	6.25	PVC	Flush	282.76	15.00	25.00	267.76	257.76	23.31	259.45	1	--
EPA-19D	1/22/2007	684224.29	1008560.62	282.91	2.00	6.25	PVC	Flush	282.91	40.00	50.00	242.91	232.91	23.42	259.49	1	--
EPA-21S	1/23/2007	683399.18	1006836.10	267.91	2.00	6.25	PVC	Flush	267.91	15.00	25.00	252.91	242.91	16.82	251.09	1	--
EPA-21D	1/24/2007	683404.55	1006841.60	267.81	2.00	6.25	PVC	Flush	267.81	33.00	38.00	234.81	229.81	17.05	250.76	1	--
Tooele Army Depot																	
D-19	7/15/2005	NA	NA	4494.99	4.00	10.00	PVC	2.76	4497.75	148.00	168.00	4346.99	4326.99	140.71	4357.04	1	1
D-20	9/27/2009	1405453.07	7385352.16	NA	4.00	8.00	PVC	NA	4398.57	68.50	88.50	NA	NA	62.09	4336.48	1	1
D-23	10/5/2011	NA	NA	4395.70	4.00	8.00	PVC	2.65	4398.35	190.00	210.00	4205.70	4185.70	58.18	4340.17	1	1
D-25	12/19/2011	NA	NA	4384.89	4.00	8.00	PVC	2.85	4387.74	175.50	195.50	4209.39	4189.39	79.75	4307.99	1	1
															Totals	**26**	**19**

Notes:

NA = Not Available at this Time

a/ 7 feet of 4" steel protective casing, 2" PVC screen, Slide five in TCAAP Well logs. pptx

b/ Well Completion Log Says U10-026 but Todd Isackson says it's for U10-025

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Table 4.1.2. Laboratory Magnetic Susceptibility Results for Borehole Core Samples and Grab Samples for 10-20 Silica Sand

ESTCP Project Number ER-201584

Sample Identification	Date	Depth (ft bgs)	Elevation (ft amsl)	Mass Magnetic Susceptibility (m^3/kg)	Flag[b/]	Error Range (m^3/kg)
Well U2-043 Hill AFB, UTAH, Operable Unit 2[a/]						
U2043-SB-A	12/7-8/2015	72.7	--	2.03E-07	--	± 1.28E-08
U2043-SB-A	12/7-8/2015	73.5	--	8.63E-08	--	± 4.72E-09
U2043-SB-A	12/7-8/2015	74.3	--	8.33E-08	--	± 3.78E-09
U2043-SB-A	12/7-8/2015	75.1	--	1.79E-07	--	± 2.49E-09
U2043-SB-A	12/7-8/2015	75.9	--	2.03E-07	--	± 6.21E-09
U2043-SB-B	12/7-8/2015	76.2	--	2.58E-07	--	± 1.47E-08
U2043-SB-B	12/7-8/2015	77.0	--	9.94E-08	--	± 5.93E-09
U2043-SB-B	12/7-8/2015	77.8	--	9.90E-08	--	± 6.38E-09
U2043-SB-B	12/7-8/2015	78.6	--	9.77E-08	--	± 1.78E-09
U2043-SB-B	12/7-8/2015	79.4	--	9.58E-08	--	± 2.79E-09
Average of Borehole Core Laboratory Analyses For Sonde Inteval =				1.40E-07		
Confidence Level (95.0%) =				4.56E-08		
Tooele Army Depot						
Wells D23[c/]	9/27/2011-10/05/2011	63.5	--	1.48E-07	--	-- N/A
Wells D23[c/]	9/27/2011-10/05/2011	67.5	--	1.04E-07	--	-- N/A
Wells D23[c/]	9/27/2011-10/05/2011	69.5	--	2.41E-07	--	-- N/A
Well D23[c/]	9/27/2011-10/05/2011	73.5	--	3.31E-07	--	-- N/A
Well D23[c/]	9/27/2011-10/05/2011	78.5	--	4.72E-07	--	-- N/A
Well D20[c/]	9/25/2009-9/27/2009	75.5	--	2.25E-07	--	-- N/A
Well D20[c/]	9/25/2009-9/27/2009	85.5	--	9.37E-07	--	-- N/A
Well D20[c/]	9/25/2009-9/27/2009	89.5	--	1.47E-07	--	-- N/A
Average of Borehole Core Laboratory Analyses For Sonde Inteval =				3.26E-07		
Confidence Level (95.0%) =				2.29E-07		
TCAAP						
01U-108	7/14/2005	19	885	7.76E-07	--	-- N/A
01U-108	7/14/2005	19	885	6.88E-07	--	-- N/A
01U-108	7/14/2005	19	885	7.42E-07	--	-- N/A
01U-108	7/14/2005	25	879	5.97E-07	--	-- N/A
01U-108	7/14/2005	25	879	5.69E-07	--	-- N/A
01U-108	7/14/2005	25	879	5.76E-07	--	-- N/A
01U-108	7/14/2005	28.5	875.5	7.94E-07	--	-- N/A
01U-108	7/14/2005	28.5	875.5	8.21E-07	--	-- N/A
01U-108	7/14/2005	28.5	875.5	9.72E-07	--	-- N/A

D:\TW\WA\ESTCP ER-201584\Report - Technical\Tables\Table 4.1.2 Summary of Borehole Magnetic Susceptibility Data Used for Analysis.xlsx

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Table 4.1.2
Laboratory Magnetic Susceptibility Results for Borehole Core Samples and Grab Samples for 10-20 Silica Sand

ESTCP Project Number ER-201584

Sample Identification	Date	Depth (ft bgs)	Elevation (ft amsl)	Mass Magnetic Susceptibility (m^3/kg)	Flag[b/]	Error Range (m^3/kg)
01U-108	7/14/2005	31.5	872.5	1.33E-06	--	-- N/A
01U-108	7/14/2005	31.5	872.5	1.36E-06	--	-- N/A
01U-108	7/14/2005	31.5	872.5	1.39E-06	--	-- N/A
Average of Borehole Core Laboratory Analyses For Sonde Inteval =				7.35E-07		
Confidence Level (95.0%) =				1.10E-07		
Former Plattsburgh AFB,						
46 PLTW 8 2A	Jul-13	--	220	9.55E-07	--	-- N/A
46 PLTW 8 2B	Jul-13	--	220	1.13E-06	--	-- N/A
46 PLTW 8 2C	Jul-13	--	220	1.21E-06	--	-- N/A
46 PLTW 8 3A	Jul-13	--	218	8.71E-07	--	-- N/A
46 PLTW 8 3B	Jul-13	--	218	1.26E-06	--	-- N/A
46 PLTW 8 3C	Jul-13	--	218	1.52E-06	--	-- N/A
32 PLTW 12 2A	Jul-13	--	205	1.68E-06	--	-- N/A
32 PLTW 12 2B	Jul-13	--	205	1.65E-06	--	-- N/A
32 PLTW 12 2C	Jul-13	--	205	1.56E-06	--	-- N/A
32 PLTW 12 3A	Jul-13	--	202	5.55E-07	--	-- N/A
32 PLTW 12 3B	Jul-13	--	202	5.75E-07	--	-- N/A
32 PLTW 12 3C	Jul-13	--	202	5.20E-07	--	-- N/A
35 PLTW 13 2A	Jul-13	--	195	1.23E-06	--	-- N/A
35 PLTW 13 2B	Jul-13	--	195	1.50E-06	--	-- N/A
35 PLTW 13 2C	Jul-13	--	195	1.32E-06	--	-- N/A
35 PLTW 13 3A	Jul-13	--	193	1.80E-06	--	-- N/A
35 PLTW 13 3B	Jul-13	--	193	1.59E-06	--	-- N/A
35 PLTW 13 3C	Jul-13	--	193	1.54E-06	--	-- N/A
Average of Borehole Core Laboratory Analyses For Sonde Inteval =				1.25E-06		
Confidence Level (95.0%) =				1.10E-07		
Hopewell Precision Site, Hopewell Junction, New York - Wells 10S and 10D						
EPA-10S	Aug-13	25.3	--	1.05E-07	--	-- N/A
EPA-10S	Aug-13	26.3	--	1.29E-07	--	-- N/A
EPA-10S	Aug-13	28.0	--	1.36E-07	--	-- N/A
EPA-10S	Aug-13	28.0	--	1.09E-07	--	-- N/A
EPA-10S	Aug-13	30.0	--	3.92E-07	--	-- N/A
EPA-10S	Aug-13	30.3	--	1.87E-07	--	-- N/A
EPA-10S	Aug-13	31.0	--	1.37E-07	--	-- N/A
EPA-10S	Aug-13	31.6	--	1.32E-07	--	-- N/A
EPA-10S	Aug-13	32.3	--	1.69E-07	--	-- N/A
EPA-10S	Aug-13	32.9	--	1.63E-07	--	-- N/A
EPA-10D	Aug-13	45.5	--	2.28E-07	--	-- N/A
EPA-10D	Aug-13	46.4	--	2.09E-07	--	-- N/A
EPA-10D	Aug-13	47.2	--	2.19E-07	--	-- N/A
EPA-10D	Aug-13	47.9	--	2.07E-07	--	-- N/A
EPA-10D	Aug-13	50.5	--	2.34E-07	--	-- N/A
EPA-10D	Aug-13	51.0	--	2.26E-07	--	-- N/A
Average of Borehole Core Laboratory Analyses For Sonde Inteval =				1.87E-07		
Confidence Level (95.0%) =				3.76E-08		

D:\TRW\WA\ESTCP ER-201584\Report - Technical\Tables\Table 4.1.2 Summary of Borehole Magnetic Susceptibility Data Used for Analysis.xlsx

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Table 4.1.2
Laboratory Magnetic Susceptibility Results for Borehole Core Samples and Grab Samples for 10-20 Silica Sand

ESTCP Project Number ER-201584

Sample Identification	Date	Depth (ft bgs)	Elevation (ft amsl)	Mass Magnetic Susceptibility (m^3/kg)	Flag[b/]		Error Range (m^3/kg)
Hopewell Precision Site, Hopewell Junction, New York - Wells 12S and 12D							
EPA-12S	Aug-13	20.5	--	1.4E-07	--	--	N/A
EPA-12S	Aug-13	21.4	--	1.1E-07	--	--	N/A
EPA-12S	Aug-13	22.3	--	1.3E-07	--	--	N/A
EPA-12S	Aug-13	25.3	--	1.2E-07	--	--	N/A
EPA-12S	Aug-13	26.1	--	8.5E-08	--	--	N/A
EPA-12S	Aug-13	27.1	--	1.5E-07	--	--	N/A
EPA-12S	Aug-13	27.1	--	1.7E-07	--	--	N/A
EPA-12D	Aug-13	35.5	--	1.8E-07	--	--	N/A
EPA-12D	Aug-13	36.2	--	1.9E-07	--	--	N/A
EPA-12D	Aug-13	36.7	--	1.8E-07	--	--	N/A
EPA-12D	Aug-13	40.5	--	1.4E-07	--	--	N/A
EPA-12D	Aug-13	41.1	--	1.7E-07	--	--	N/A
EPA-12D	Aug-13	41.7	--	2.3E-07	--	--	N/A
EPA-12D	Aug-13	42.6	--	2.2E-07	--	--	N/A
EPA-12D	Aug-13	43.4	--	2.1E-07	--	--	N/A
EPA-12D	Aug-13	42.3	--	2.2E-07	--	--	N/A
Average of Borehole Core Laboratory Analyses For Sonde Inteval =				1.65E-07			
Confidence Level (95.0%) =				2.30E-08			
Hopewell Precision Site, Hopewell Junction, New York - Wells 15D							
EPA-15D	Aug-13	27.4	--	1.98E-07	--	--	N/A
EPA-15D	Aug-13	28.2	--	1.93E-07	--	--	N/A
EPA-15D	Aug-13	29.0	--	1.89E-07	--	--	N/A
EPA-15D	Aug-13	30.5	--	1.70E-07	--	--	N/A
EPA-15D	Aug-13	31.5	--	1.97E-07	--	--	N/A
EPA-15D	Aug-13	32.5	--	2.35E-07	--	--	N/A
EPA-15D	Aug-13	33.4	--	2.63E-07	--	--	N/A
EPA-15D	Aug-13	35.5	--	2.32E-07	--	--	N/A
Average of Borehole Core Laboratory Analyses For Sonde Inteval =				2.10E-07			
Confidence Level (95.0%) =				2.56E-08			
Hopewell Precision Site, Hopewell Junction, New York - Wells 16S and 16D							
EPA-16S	Aug-13	20.6	--	9.71E-08	--	--	N/A
EPA-16S	Aug-13	21.6	--	1.10E-07	--	--	N/A
EPA-16S	Aug-13	25.5	--	1.41E-07	--	--	N/A
EPA-16S	Aug-13	26.3	--	1.00E-07	--	--	N/A
EPA-16S	Aug-13	40.5	--	1.68E-07	--	--	N/A
EPA-16D	Aug-13	45.7	--	1.84E-07	--	--	N/A
EPA-16D	Aug-13	46.8	--	1.83E-07	--	--	N/A
EPA-16D	Aug-13	47.8	--	1.76E-07	--	--	N/A
Average of Borehole Core Laboratory Analyses For Sonde Inteval =				1.45E-07			
Confidence Level (95.0%) =				3.16E-08			
Hopewell Precision Site, Hopewell Junction, New York - Wells 19S							
EPA-19S	Aug-13	15.7	--	1.34E-07	--	--	N/A
EPA-19S	Aug-13	17.0	--	1.36E-07	--	--	N/A
EPA-19S	Aug-13	17.9	--	1.12E-07	--	--	N/A

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Table 4.1.2
Laboratory Magnetic Susceptibility Results for Borehole Core Samples and Grab Samples for 10-20 Silica Sand
ESTCP Project Number ER-201584

Sample Identification	Date	Depth (ft bgs)	Elevation (ft amsl)	Mass Magnetic Susceptibility (m^3/kg)	Flag[b/]	Error Range (m^3/kg)
EPA-19S	Aug-13	20.6	--	9.63E-08	--	-- N/A
EPA-19S	Aug-13	21.7	--	1.51E-07	--	-- N/A
EPA-19S	Aug-13	22.6	--	1.02E-07	--	-- N/A
Average of Borehole Core Laboratory Analyses For Sonde Inteval =				1.22E-07		
Confidence Level (95.0%) =				2.25E-08		
Hopewell Precision Site, Hopewell Junction, New York - Wells 16S and 16D						
EPA-21S	Aug-13	15.4	--	5.7E-07	--	-- N/A
EPA-21S	Aug-13	16.0	--	5.9E-07	--	-- N/A
EPA-21S	Aug-13	16.7	--	1.4E-07	--	-- N/A
EPA-21S	Aug-13	20.6	--	1.2E-07	--	-- N/A
EPA-21S	Aug-13	21.8	--	1.2E-07	--	-- N/A
EPA-21S	Aug-13	22.9	--	1.1E-07	--	-- N/A
EPA-21D	Aug-13	33.3	--	1.1E-07	--	-- N/A
EPA-21D	Aug-13	33.8	--	3.0E-07	--	-- N/A
EPA-21D	Aug-13	34.3	--	1.6E-07	--	-- N/A
EPA-21D	Aug-13	34.9	--	1.5E-07	--	-- N/A
EPA-21D	Aug-13	35.7	--	1.1E-07	--	-- N/A
Average of Borehole Core Laboratory Analyses For Sonde Inteval =				2.24E-07		
Confidence Level (95.0%) =				1.24E-07		
Magnetic Susceptibility Results for 10-20 Silica Sand Used to Build Monitoring Wells[a/]						
Premier Silica - Corner 1	6/18/2016	--	--	6.47E-09	J	± 2.21E-09
Premier Silica - Corner 2	6/18/2016	--	--	6.69E-09	J	± 3.86E-09
Premier Silica - Corner 3	6/18/2016	--	--	6.30E-09	J	± 1.03E-09
Premier Silica - Corner 4	6/18/2016	--	--	4.45E-09	J	± 2.58E-09
Premier Silica - Bottom Center	6/18/2016	--	--	6.50E-09	J	± 3.34E-09

Notes:
N/A = Not Available
a/ Analyses completed by Microbial Insights
b/ J= estimated concentration between between the quantitation and minimum detection limits.
c/ Samples collected between nested wells D20 (shallow) and D23 (deep) which are located about 20 feet apart.

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4.2 FORMER PLATTSBURGH AIR FORCE BASE, NEW YORK

This Site had existing data on magnetic susceptibility from core samples. Any potential contribution of aerobic biodegradation of the chlorinated solvents was not understood at the time the remedy was selected. An evaluation of the further contribution of aerobic co-oxidative biodegradation was not included in the last five-year review, but is completed under this investigation. In this study, the potential for abiotic TCE degradation was evaluated by measuring the magnetic susceptibility of aquifer sediment in two wells. The potential for cooxidation of TCE was evaluated in water samples from four wells.

4.2.1 Site Location and History

The study site is the FT-002 site on the former Plattsburgh AFB, which is currently the Plattsburgh International Airport, Plattsburgh, New York. The Site is located in Clinton County along the western shore of Lake Champlain in northeastern New York. The base was closed on September 30, 1995 as part of the third round of base closures mandated by the Defense Base Closure and Realignment Act of 1993.

The FT-002 Site is located approximately 500 feet west of the runway and 500 feet east of the base's western boundary (Figure 4.2.1). From the mid- to late-1950s through 1989, the Site was used to meet the training requirements of the base fire department. During training exercises, fires were ignited in fire training pits on site. As a result of releases of combustible liquids (e.g., off-specification fuel and waste solvents) into the pits, the soil and groundwater were contaminated chlorinated hydrocarbons. The fuel-related compounds are naturally biodegradable in groundwater and, at the time of the remedial investigation, concentrations had attenuated below detection limits within 4,000 feet downgradient of the source. The chlorinated hydrocarbons, which are considerably less biodegradable under the conditions present at the Site, have been detected over 6,750 feet downgradient of the source.

The site has been extensively investigated and interim removal actions have been implemented, including the installation and operation of free product recovery, soil vapor extraction, and bioventing systems. A Final Record of Decision for the source was signed in September 2014 to address sources of contamination. The remedy involved a combination of soil vapor extraction and bioventing of the contaminated soil, free product recovery, water table depression enabling remediation of residual product adhering to soil below the water table, hydraulic containment of the remaining source, institutional controls, progress monitoring and sampling, and five-year site reviews.

4.2.2 Site Geology/Hydrogeology

Four stratigraphic units underlie the Site: glaciomarine and glaciolacustrine sand (sand unit); glaciomarine and glaciolacustrine silt and clay (clay unit); glacial till (till unit); and bedrock (Figure 4.2.2). This stratigraphic sequence is consistent basewide, although the thicknesses of the individual units vary. Hydrogeologically, the stratigraphic sequence can be divided into the following units: an unsaturated zone and a water table aquifer present in the sand unit; a clay confining layer; a confined till water-bearing zone; and a confined bedrock aquifer. Thus far, groundwater contamination at the Site appears to be limited to the water table aquifer.

Groundwater flow which closely mimics surface topography, is predominantly from west to east across the Site, toward Lake Champlain.

4.2.3 Contaminant Distribution

The current distribution of contamination in groundwater from chlorinated solvents is presented in Figure 4.2.1.

4.2.4 Previous Sampling Relevant to the Current Project

Sediment samples were acquired from three locations in July 2013. See Figure 4.2.3 for the locations. Samples were acquired from 1 foot below land surface and 3 feet below land surface at each location. The samples were analyzed for mass magnetic susceptibility by staff of the R.S. Kerr Environmental Research Laboratory. These mass magnetic susceptibility data are presented in Table 4.1.2. Samples from location 46PLTW8 were acquired from elevations of 220 and 219 feet above mean sea level (amsl). Samples from location 32PLTW12 were acquired from elevations of 205 and 202 feet amsl. Samples from location 35PLTW13 were acquired from elevations of 195 and 193 feet amsl.

Figure 4.2.1. Location of the Former Fire Training Area (FT-002) on the Former Plattsburgh AFB, NY and Current Distribution of Groundwater Contaminated with Chlorinated Organic Compounds (URS 2009).

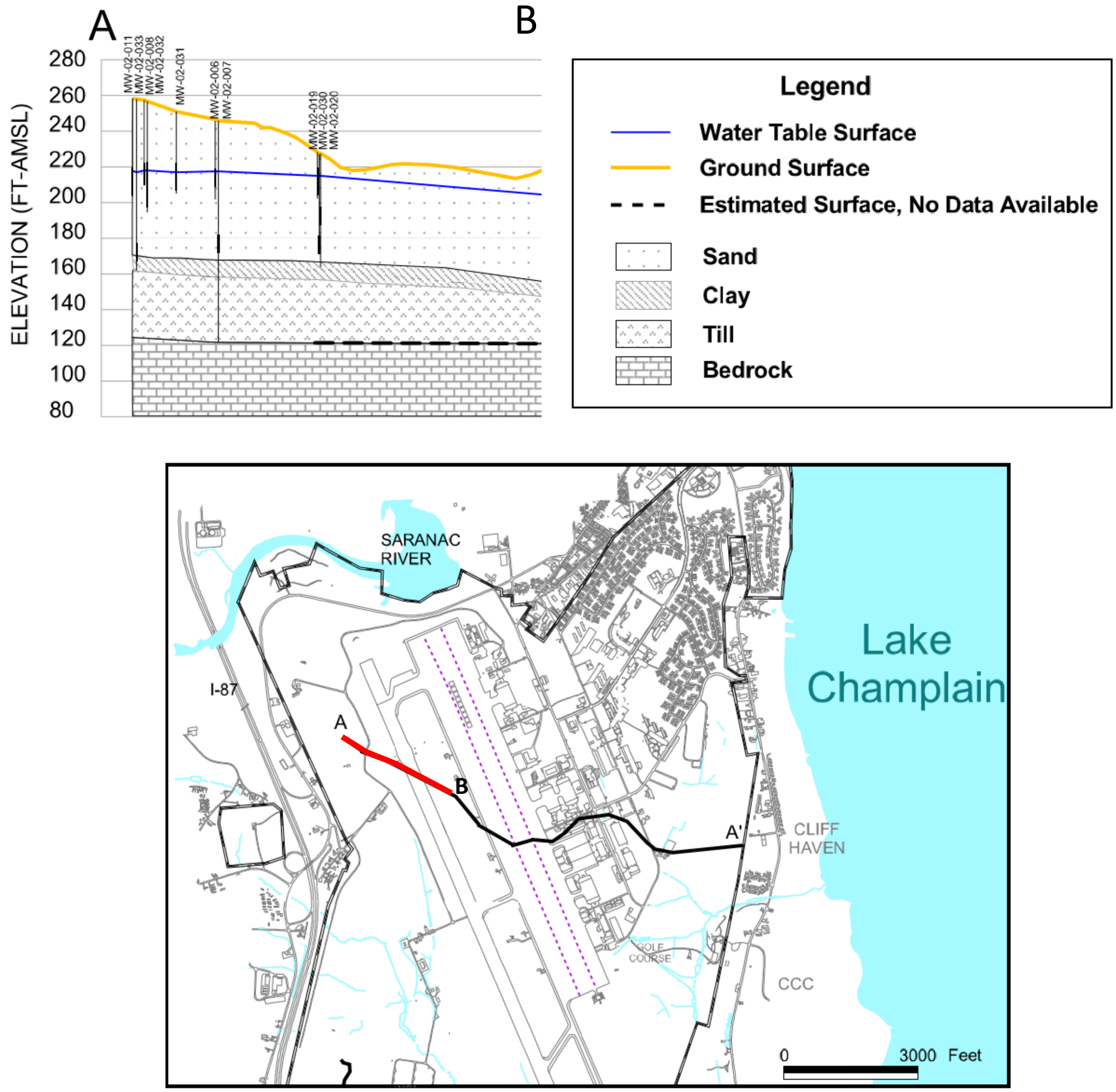


Figure 4.2.2. Geological Cross Section along the Flow Path in the Plume of Contamination from the FT-002 Site.

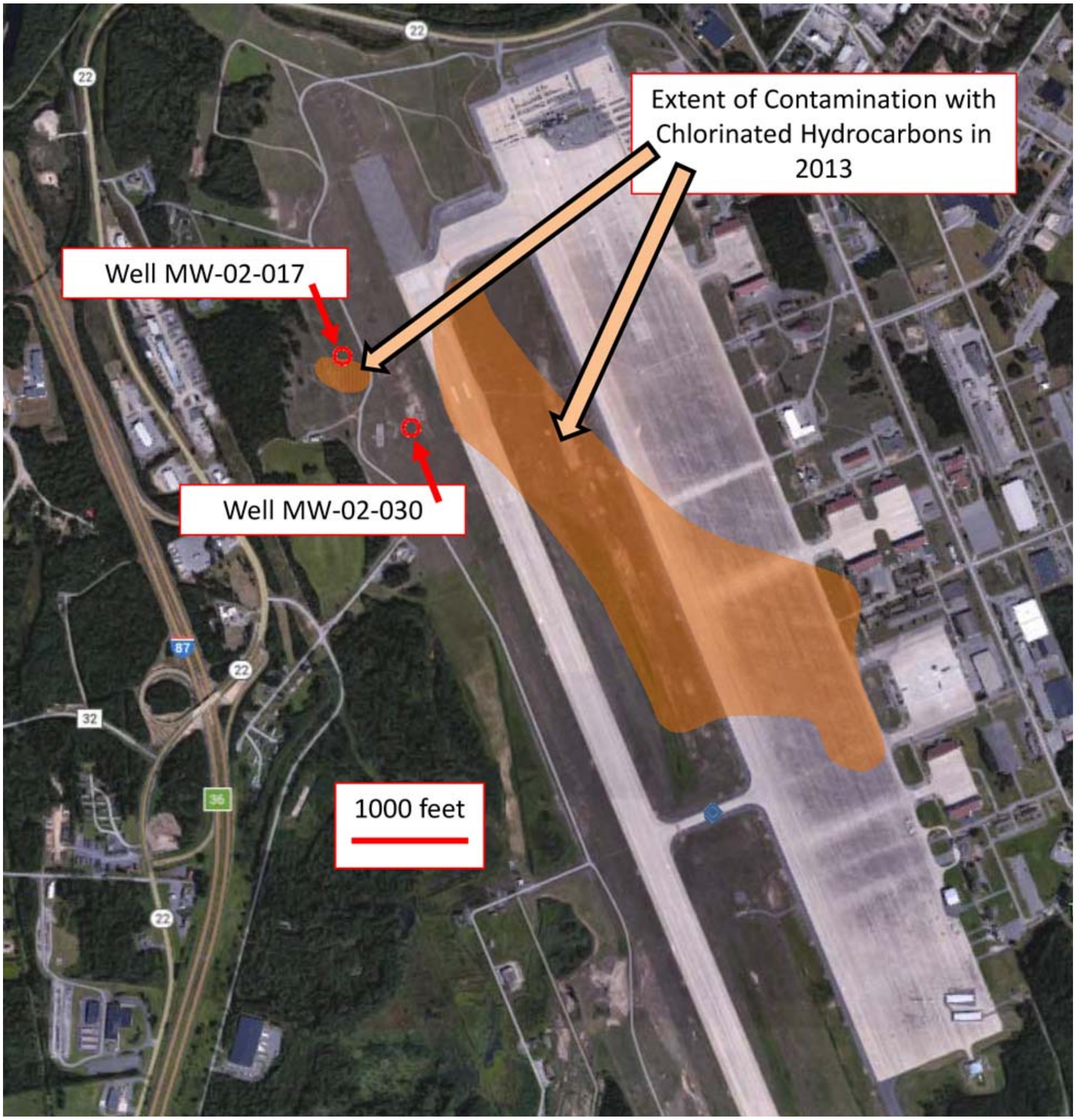


Figure 4.2.3. Locations of Wells where the Magnetic Susceptibility Sonde was Deployed, June 2016.

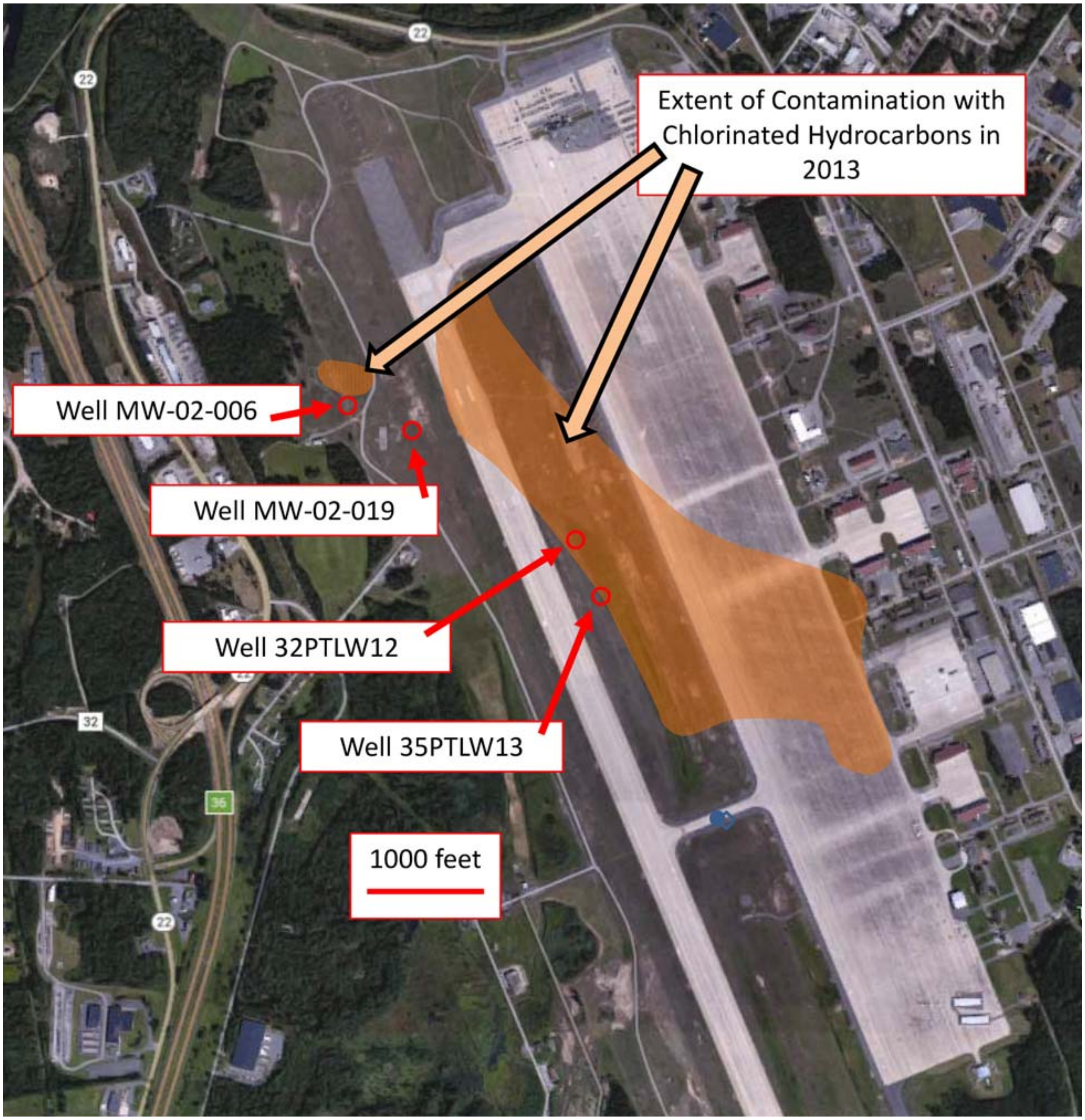


Figure 4.2.4. Sampling Locations for EAPs, qPCR, and ^{14}C-labeled TCE Assay were Well MW-02-006, Well MW-2-019, Well 32PLTW12 and Well 35PLT13.

4.2.5 Sampling Locations Used for the Current Project

The locations for this project are presented in Figure 4.2.4. Water was sampled from monitoring wells MW-02-006, well MW-2-019, well 32PLTW12 and well 35PLT13 for analysis of enzyme activity probes, qPCR assays for DNA of oxygenase enzymes, and for determination of the rate of TCE co-oxidation. Magnetic susceptibility using the sonde was ultimately determined only from monitoring wells MW-20-107 and-MW-02-030 because wells MW-02-006 and MW-02-019, the wells originally proposed for magnetic susceptibility sampling were found to be compromised such that a sonde could not be lowered into them. Per the Site-specific sampling and analysis plan, purge water from the monitoring wells was disposed to the land surface near each well. Available borehole and well completion logs are included in Appendix C of the Demonstration Plan (ESTCP, 2016).

4.3 NEW BRIGHTON/ARDEN HILLS SUPERFUND SITE (TCAAP)

This Site had existing data on magnetic susceptibility from core samples. These data are summarized in Table 4.1.2. Any potential contribution of aerobic biodegradation of the chlorinated solvents was not understood at the time that the remedy was selected. An evaluation of the further contribution of aerobic co-oxidative biodegradation was not included in the last five-year review, but was completed under this investigation.

In this study, the potential for abiotic TCE degradation was evaluated by measuring the magnetic susceptibility of aquifer sediment in three wells. The potential for cooxidation of TCE was evaluated in water samples from four wells.

4.3.1 Site Location and History

The site is located on the north end of the former Twin Cities Army Ammunition Plant (TCAAP), in the city of Shoreview, Minnesota (Figure 4.3.1). The source of contamination is south of County Highway 3, near Shamrock Park. Two residential wells that are potential receptors of groundwater contamination are located west of Schutta Road and North of County Highway 3.

Figure 4.3.2 shows the locations of the residential wells, some of the early monitoring wells, and the extraction wells for a pump and treat remedy that was installed at the site.

Aerial photographs suggest that trenches and pits were used at the site for waste in the early 1940s. The area near well 01U108 is considered the primary source of contaminants to the aquifer (Ferrey and Wilson, 2002). In 1988, extraction well 350 was installed near monitoring well 01U108 as part of an interim response action intended to remove and treat the high concentrations of contaminants found at this location. Well 350 operated at 4 gallons per minute (gpm). Pumping at this well was stopped in 1994 based on an evaluation of its effectiveness. In 1994, eight additional extraction wells were installed downgradient of the source area to prevent the groundwater plume from reaching the off-site residential wells (Figure 4.3.2). The containment wells had a combined pumping rate of approximately 30 gpm.

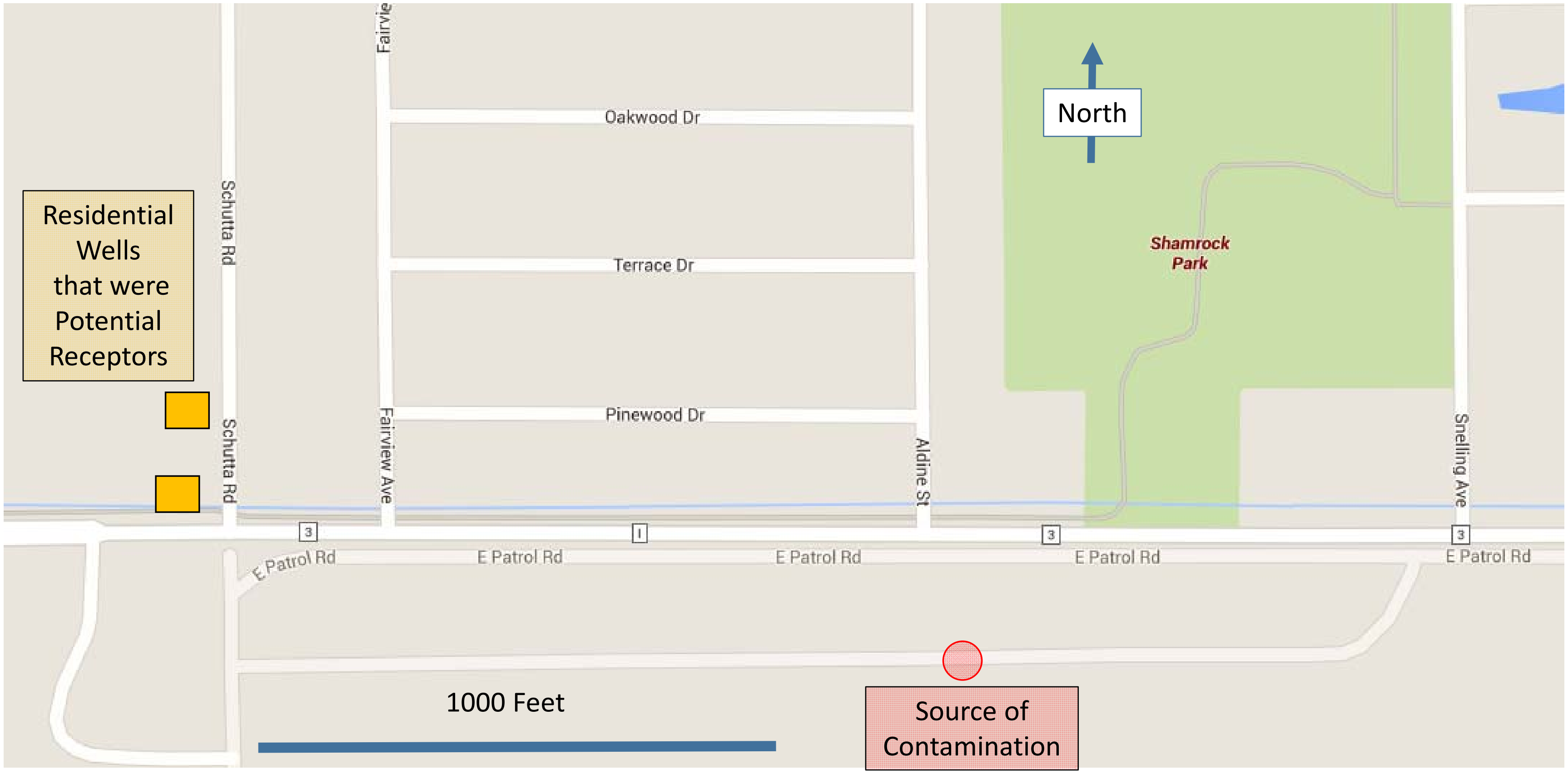
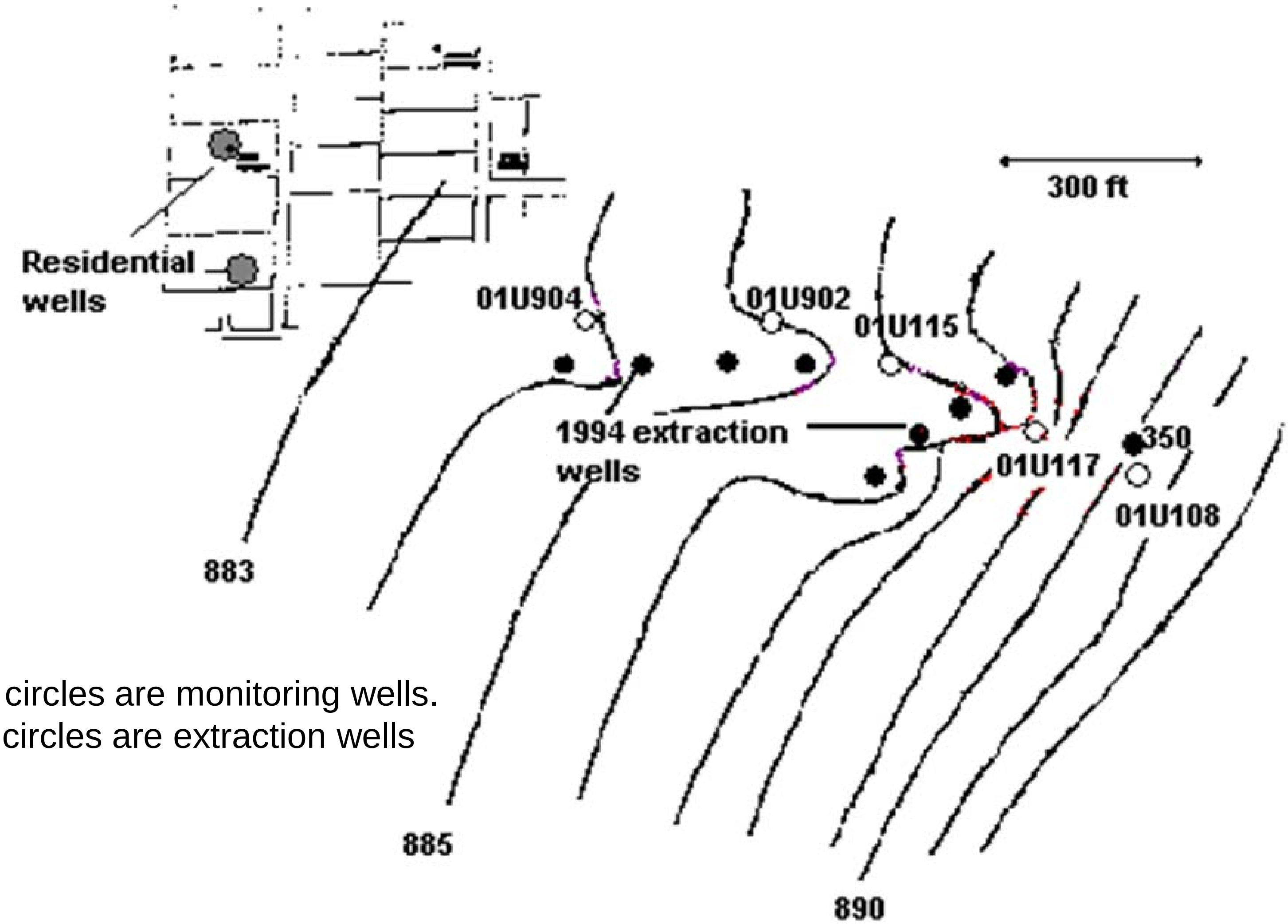


Figure 4.3.1. Location of the Source of Contamination for Site A on the Former Twin Cites Army Ammunition Plant (TCAAP) in Minnesota.



Open circles are monitoring wells.
Filled circles are extraction wells

Figure 4.3.2. Locations of Monitoring Wells and Extraction Wells at Site A.

4.3.2 Site Geology/Hydrogeology

There are two aquifer units at the site. Aquifer sediments in Unit 1 are composed of lacustrine silt and fine or medium sands. The water table is in Unit 1. Unit 1 is underlain by the Twin Cities Till (Unit 2) which, due to its high clay content, is an effective aquitard. The water table is 15 to 19 feet below ground surface. The Unit 1 aquifer ranges in thickness from 15 feet near the source area to 28 feet to the west (Figure 4.3.2). Unit 2 is approximately 12 to 88 feet thick.

Groundwater flows to the northwest (Figure 4.3.3) along a horizontal hydraulic gradient ranging from 0.0025 to 0.005 ft/ft. The hydraulic conductivity for Unit 1 was 8.3×10^{-3} cm sec^{-1}. Using a gradient of 0.005 and a porosity of 0.2, groundwater velocity was estimated at 200 feet per year at Site A.

4.3.3 Contaminant Distribution

The concentrations of PCE and its degradation products have declined over time at the site, due to a combination of active pump-and-treat and natural attenuation. Figure 4.3.4 provides the time course of attenuation in well 01U108, which was the originally the most contaminated well at the site, and the only well with laboratory analyses of borehole core samples.

The current distribution (2015) of contamination is depicted in Figures 4.3.5, 4.3.6 and 4.3.7. Only three wells at the site had concentrations of PCE above 1 µg/L (Figure 4.3.5). The maximum concentration was 2.6 µg/L. Only one well had a concentration of TCE above 1 µg/L (Figure 4.3.6). That concentration was 1.8 µg/L. Fourteen wells had concentrations of *c*DCE above 1 µg/L (Figure 4.3.7). The maximum concentration was 310 µg/L.

Apparently PCE was transformed to TCE and TCE was transformed to *c*DCE by sequential biological reductive dechlorination. However, vinyl chloride was never detected at Site A. The important mechanism for removal of *c*DCE was degradation by magnetite that was naturally occurring in the aquifer sediment.

4.3.4 Previous Sampling Relevant to the Current Project

Core samples were acquired from a location just downgradient of the source area and well 01U108 on January 5, 2005. The samples were used to construct the microcosms described in He et al. (2009). The sediment was characterized by staff of the R.S. Kerr Environmental Research Center for mass magnetic susceptibility (Table 4.1.2). All these samples were acquired from aquifer Unit 1, the glaciofluvial sand.

4.3.5 Sampling Locations for the Current Project

The locations of the four wells where groundwater was sampled for EAPS, qPCR, and the ^{14}C-TCE assay, are provided in Figure 4.3.8. These wells are not in the current "hot spot" for *c*DCE. These wells were chosen because they were the best wells available at Site A that were constructed with PVC instead of steel, and were therefore appropriate for the down-well magnetic susceptibility sonde.

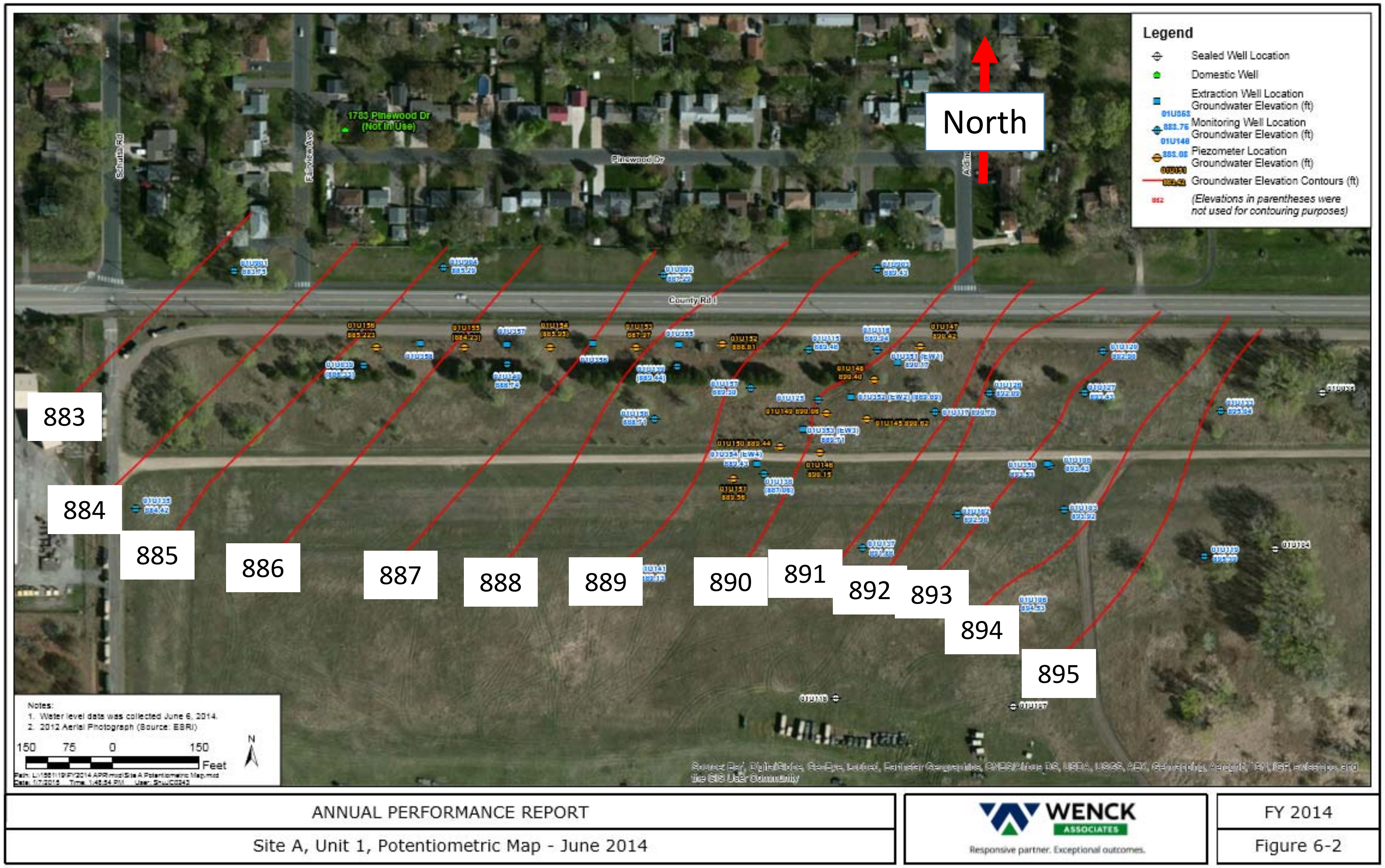


Figure 4.3.3. Water Table Elevations across Site A.

Values are feet above mean sea level.

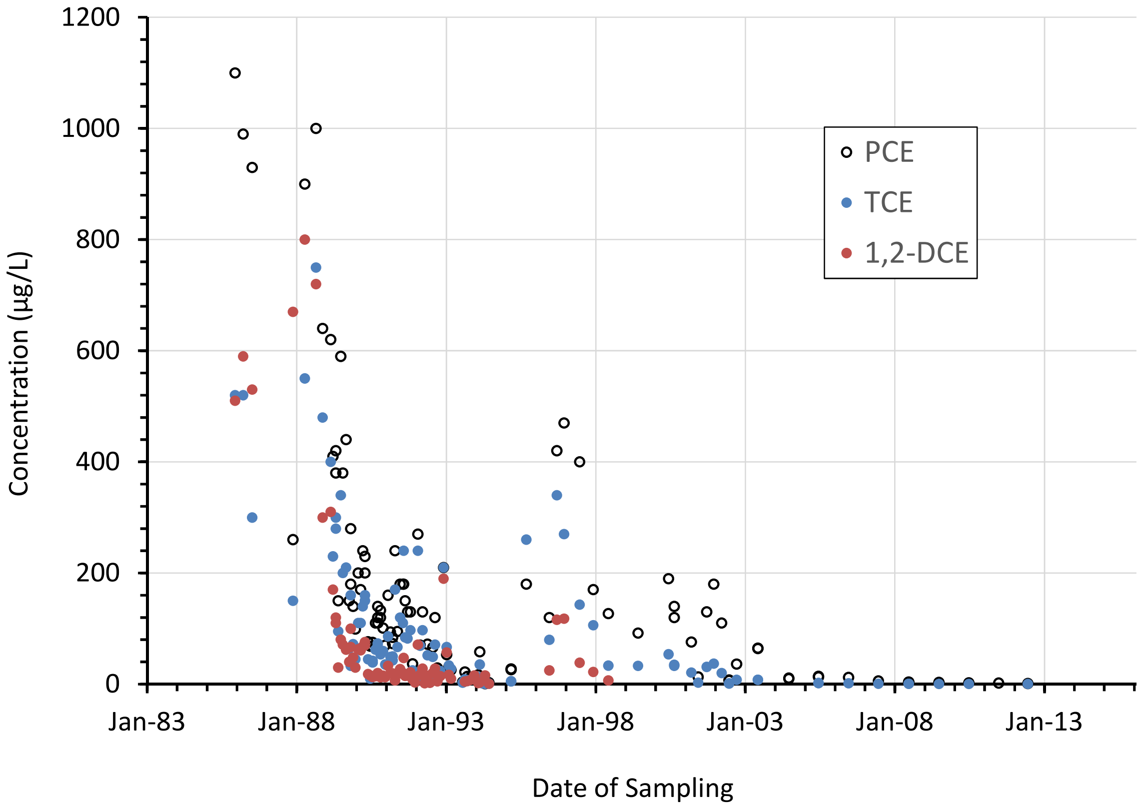


Figure 4.3.4. Decline in Concentrations of PCE, TCE, and *c*DCE + *t*-DCE Over Time in Well 01U108.

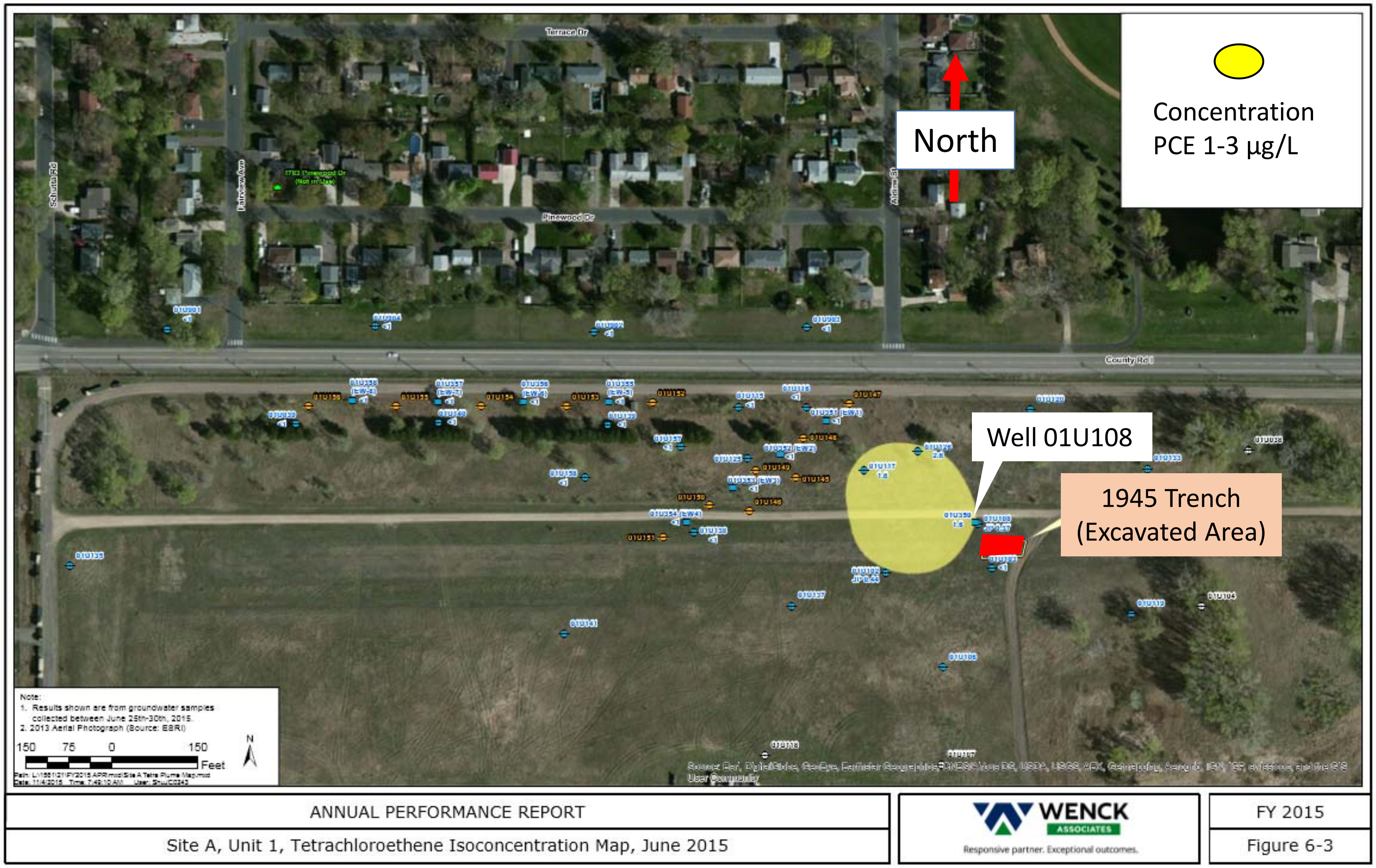


Figure 4.3.5. Distribution of PCE in Monitoring Wells at Site A in June 2015.

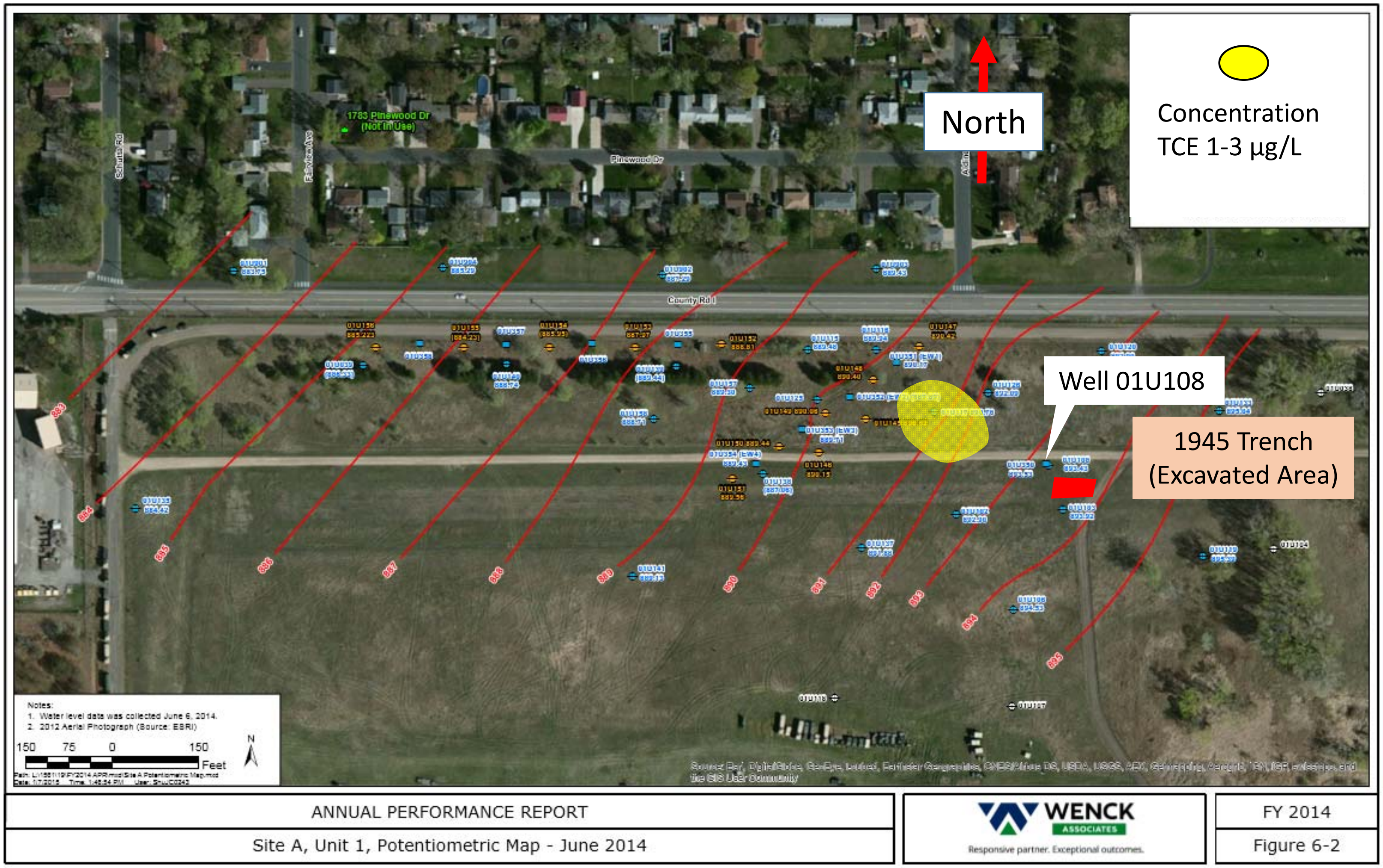


Figure 4.3.6. Distribution of TCE in Monitoring Wells at Site A in June 2015.

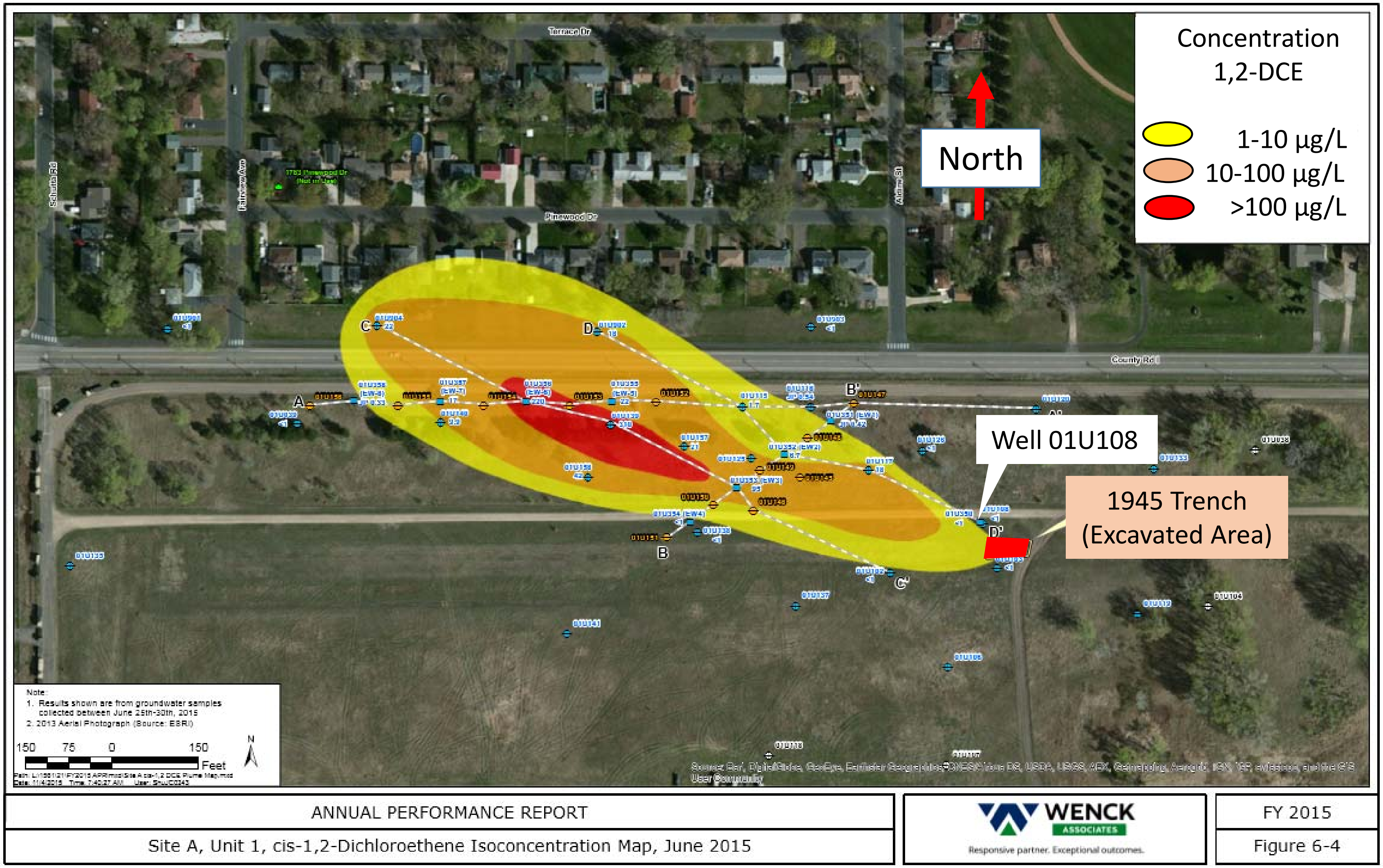


Figure 4.3.7. Distribution of *c*DCE in Monitoring Wells at Site A in June 2015.

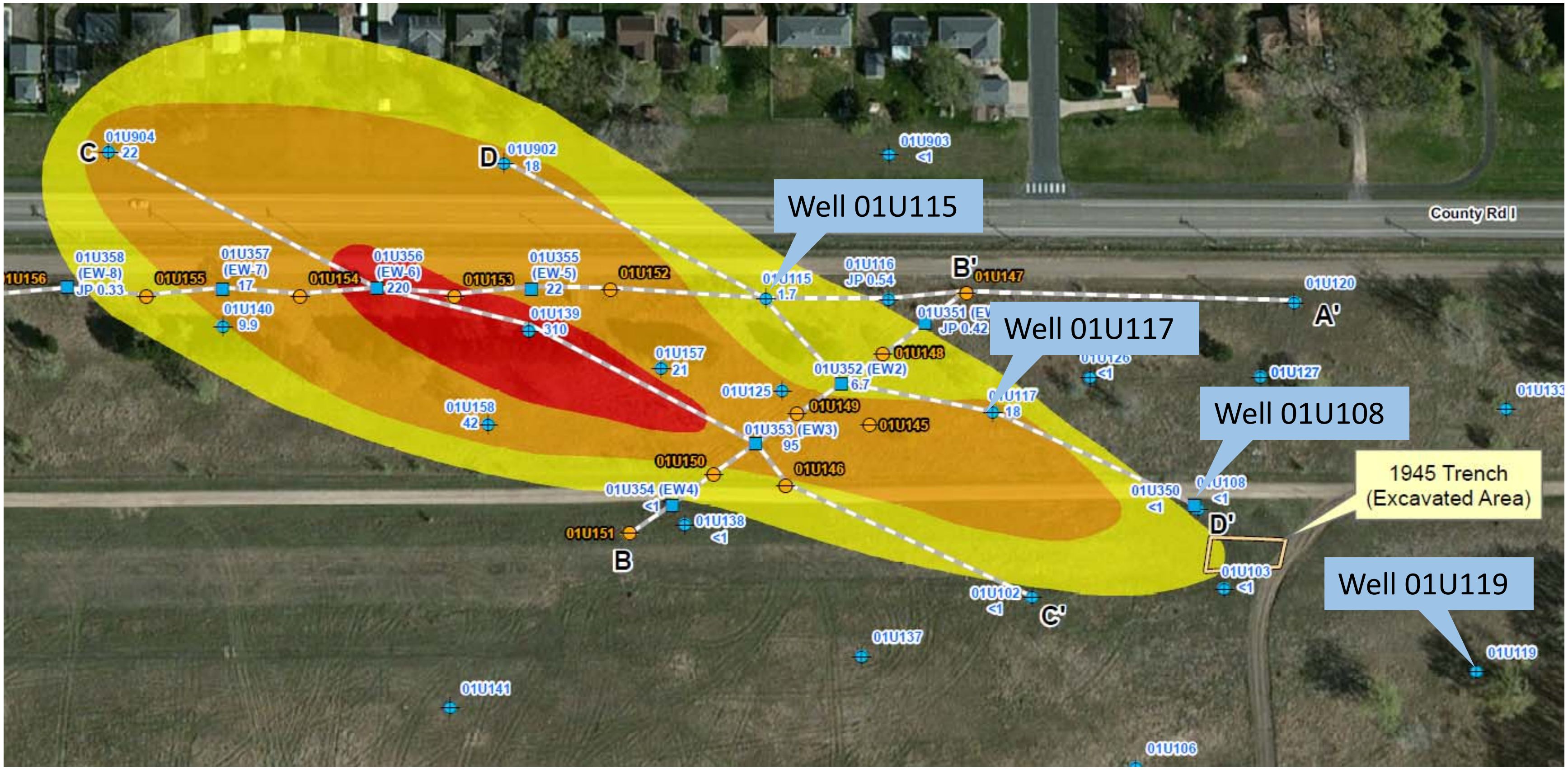


Figure 4.3.8. Location of the Four Wells at Site A to be Sampled.

Well 01U119 is an upgradient well. It provided a comparison to see if the exposure to PCE has mobilized native organic matter that would enrich aerobic microorganisms that would express a soluble monooxygenase and increase the rate of co-oxidation of TCE.

Well 01U108 is the well with the highest historical concentrations of chlorinated alkenes. Wells 01U117 and 01U115 are immediately down-gradient of well 01U108.

The concentrations of PCE, TCE, *c*DCE and vinyl chloride were each below 2 µg/L when the four wells were sampled in 2015 (Wenck, 2015). Per the site-specific sampling and analysis plan, purge water from the monitoring wells was disposed to the land surface near the well.

Borehole and well construction logs for the wells selected for the study at TCAAP are presented in Appendix D of the Demonstration Plan (ESTCP, 2016). The wells are screened within Aquifer Unit 1, the glaciofluvial sand. Table 4.3.1 compares the screened intervals of the wells to the distribution of Aquifer Unit 1, Aquifer Unit 2, and the water table.

Table 4.3.1. Relationships between the Depth to the Water Table, the Screened Interval, and the Distribution of Aquifer Unit 1 (glaciofluvial sand) and Aquifer Unit 2 (glacial till) for the Four Wells Selected at Site A.

Well	Water Table (feet bgs)	Screened Interval (feet bgs)	Top Aquifer Unit 1 (feet bgs)	Top Aquifer Unit 2 (feet bgs)
01U119	10.5	9.5 to 19.5	1.5	23.5
01U108	11.5	20 to 30	5.6	32
01U117	10.7	18.0 to 33.0	9.5	33.5
01U115	12.6	17.9 to 32.9	2.0	39.5

bgs = below ground surface

4.4 HILL AIR FORCE BASE OPERABLE UNIT 10

Most of the discussion about OU-10 is taken directly from the Remedial Investigation Report (CH2MHill, 2009). In this study, the potential for abiotic TCE degradation was evaluated by measuring the magnetic susceptibility of aquifer sediment in three wells. The potential for cooxidation of TCE was evaluated in water samples from three wells.

4.4.1 Site Location and History

Hill Air Force is a major U.S. Air Force base located in northern Utah, just south of the city of Ogden, near the towns of Clearfield, Riverdale, Roy, Sunset, and Layton. It is located about 30 miles north of Salt Lake City. Operable Unit 10 encompasses the Building 1200 Area along the western boundary of Hill AFB and extends off-base into the cities of Clearfield, Sunset, and Clinton.

Industrial activities at the 1200 Area of OU 10 began in the early 1940s. A variety of chemicals, including chlorinated solvents such as PCE and TCE, were used in those activities.

Most industrial activity in the 1200 Area ceased in 1959, and the majority of 1200 Area buildings were remodeled for administrative functions. Currently, the majority of buildings in the 1200 Area are still being used for administration purposes.

4.4.2 Site Geology/Hydrogeology

Hill AFB is located on a terrace that is a remnant of the Paleo-Weber River Delta, formed where the Weber River deposited sediments into ancient Lake Bonneville. The sediments of the Paleo-Weber River Delta are composed primarily of fine-grained delta-front sheet sands interbedded with lacustrine deposits. Fluctuations in Lake Bonneville water levels exposed the Weber River Delta to waves and currents that reworked the deltaic sediments into heterogeneous, laterally discontinuous mixtures.

The complex depositional environment is responsible for the heterogeneous geology underlying OU 10. The sediments underlying the project area have been divided into three fundamental units: (1) sand, (2) silt and clay, and (3) interbedded sand, silt, and clay. In general, the subsurface geology consists of sand deposits separated by discontinuous silt and clay lenses that vary in thickness and lateral extent.

Three principal aquifers underlie the project area. From the surface, the aquifers are (1) a shallow aquifer system, (2) the Sunset Aquifer, and (3) the Delta Aquifer. Figure 4.4.1 illustrates the relationship between the aquifers. The Delta Aquifer is the primary source of drinking water in the area, and the Sunset Aquifer is a secondary aquifer. The shallow aquifer is not a source of drinking water in the area. Groundwater contamination at OU 10 is located within the shallow aquifer system. Current site data indicate the contamination has not migrated to the Sunset or Delta Aquifers.

The shallow aquifer underlying OU 10 consists of two semi-independent water-bearing units, referred to as the Upper and Lower Zones (see Figure 4.4.2). The zones are separated by an aquitard composed of silt and clay and are characterized by distinct groundwater flow directions.

The Upper Zone consists of two hydrostratigraphic units: an aquifer and an underlying aquitard. The aquifer unit is primarily composed of fine to medium sand deposited by fluvial processes as a stream cut into lacustrine clay deposits during the regression of Lake Bonneville. The aquitard is composed of low permeability silt and clay with some interbedded sand.

The paleo-stream channel responsible for depositing the aquifer sand is an important geologic feature underlying OU 10. First, the orientation of the channel drives the groundwater flow direction in the Upper Zone. Second, the channel has substantially thinned or completely eroded the aquitard in some areas, creating localized hydraulic connections between the Upper and Lower Zones.

The depth to groundwater within the aquifer unit of the Upper Zone ranges from 3 to 33 feet below ground surface (bgs). Groundwater flows toward the southwest with an estimated average velocity of 0.5 foot per day (ft/day). In the southwestern portion of the site, in a location where the aquitard separating the Upper and Lower Zones has been completely eroded by the paleo-channel, the Upper and Lower Zones are hydraulically connected.

The Lower Zone is also composed of an aquifer unit and an aquitard. The aquifer consists of layers of sand and discontinuous lenses of silt, clay, and interbedded sand, silt, and clay that vary in thickness and lateral extent. The aquitard is a low permeability, laterally extensive, organic-rich, laminated silt and clay sequence that separates the entire OU 10 shallow aquifer system from the underlying Sunset Aquifer and deeper Delta Aquifer, the primary source of drinking water in the area.

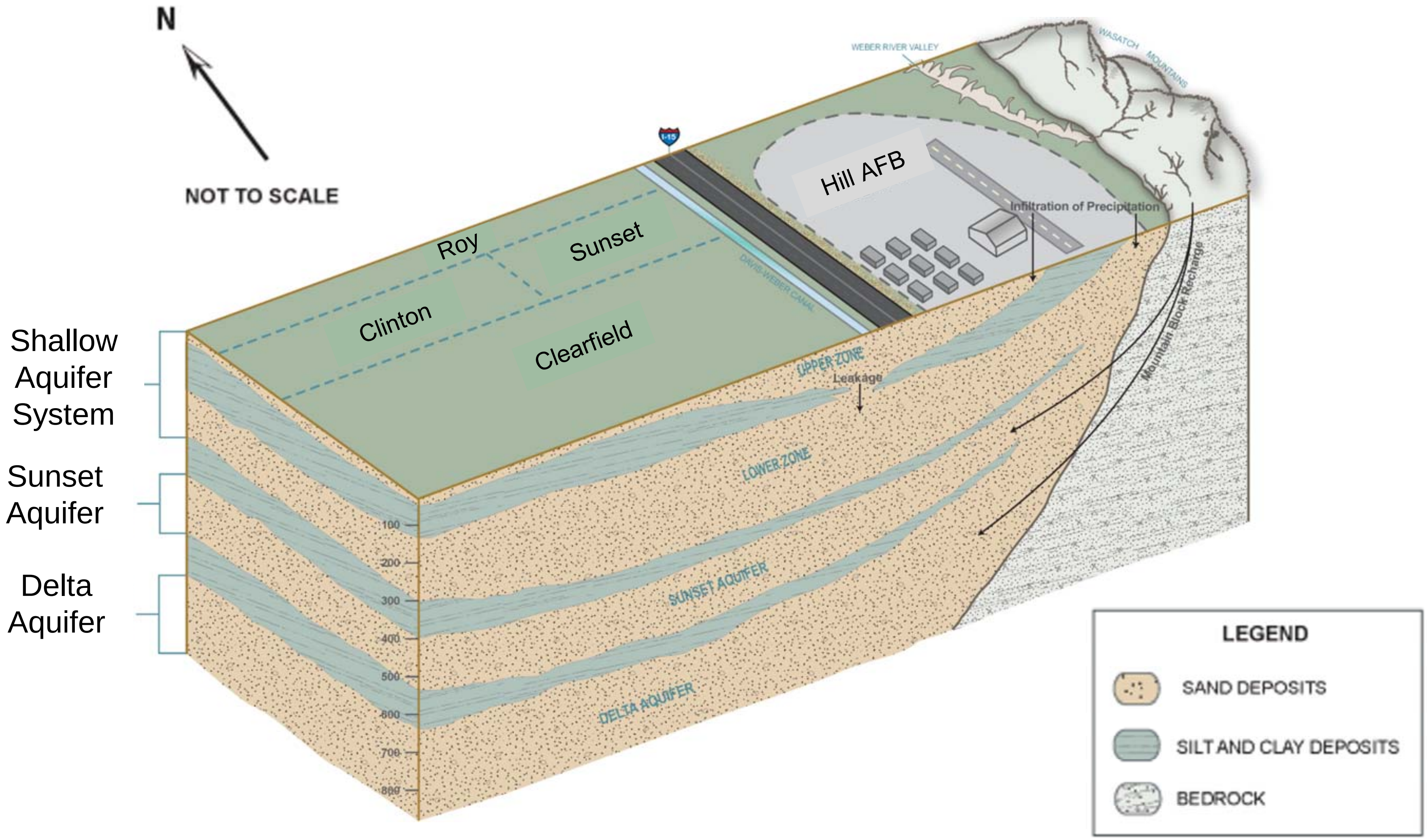


Figure 4.4.1. Major Aquifer Systems.

Zone 1 = Predominately aerobic sands **(A)**; more silty, clayey sand environments may be anaerobic.
Zone 2 = Predominately anaerobic sand, silt and clay interbeds **(C)**; sandy units have moderate potential to be aerobic.
Zone 3 = Mixing zone (**A, B and C**); potential for both aerobic and anaerobic pathways.
Zone 4 = Predominately anaerobic sand, silt and clay interbeds **(C)**; sandy units have some potential to be aerobic.

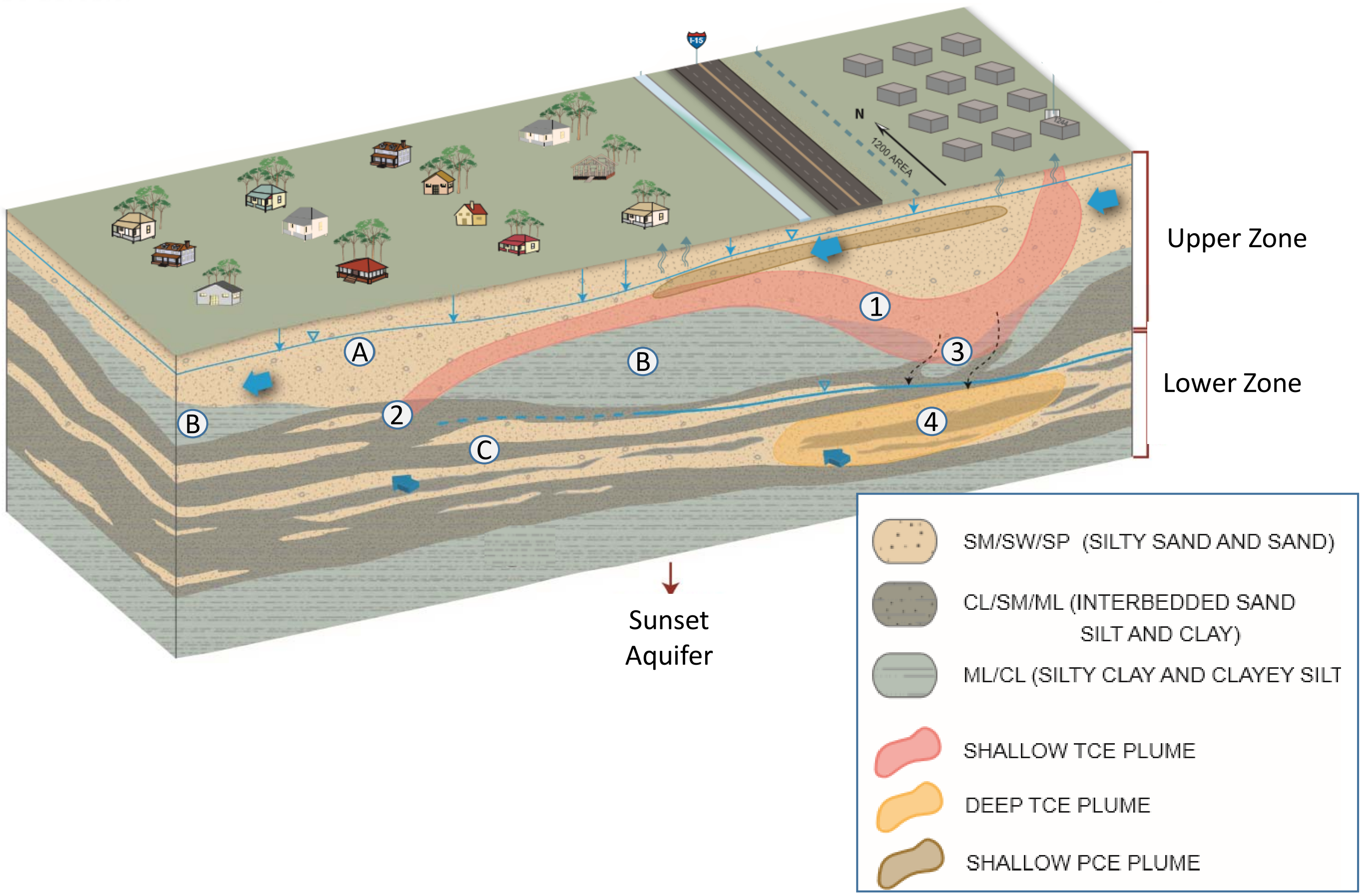


Figure 4.4.2. Relationships in the Upper and Lower Zone of the Shallow Aquifer System.

Depth to groundwater within the Lower Zone ranges between approximately 50 and 185 feet bgs. The Lower Zone is confined in the southeastern corner of the site and in the western portions of the site but is only partially saturated (unconfined) in the northeastern and central portions of the site. Groundwater within the Lower Zone flows toward the northwest. The hydraulic gradient is relatively steep in the eastern portion of the site and becomes shallower in the western portion of the site. Groundwater velocity estimates reflect the differences in hydraulic gradients, with median estimated velocities of 1.9 ft/day in the eastern portion of OU 10 and 0.6 ft/day in the west.

4.4.3 Contaminant Distribution

Figure 4.4.3 compares the distribution of PCE and TCE contamination in the upper zone of the shallow aquifer system to the sources of contamination and to the current extent of groundwater restrictions associated with OU-10. Figure 4.4.4 presents the same information for the deeper zone of the shallow aquifer system.

Groundwater flow in the upper zone is generally to the southwest. Flow in the lower zone is to the north and west. The contamination in the upper zone enters the low zone through a "window" in the silty clay that separates the upper and lower zone. See location ③ in Figure 4.4.2 and the location of well U10-051 in Figure 4.4.4.

4.4.4 Previous Sampling Relevant to the Current Project

As part of the Feasibility study, North Wind applied enzyme activity probes to samples of groundwater from OU-10 that were acquired in 2007 (North Wind, 2007). The results of their probing are summarized in Table 4.4.1.

4.4.5 Sampling Locations for the Current Project

The upper zone is generally aerobic and may support aerobic co-oxidation of TCE. Three wells in the upper zone were sampled for enzyme activity probes, qPCR assays of genes for oxygenase enzymes, and to determine the rate of TCE co-oxidation with carbon-14 labelled TCE. The three wells sampled are U10-019, U10-025, and U10-043 (Figure 4.4.3). Unfortunately, well U10-100 was scheduled to be sampled per the Demonstration Plan (Figure 4.4.3), but the sampling team was unable to find this well, and because of difficulties involved in sampling well U10-019, did not have sufficient time to sample the well and still make it to Federal Express for the requisite overnight shipping before the week ended. The magnetic susceptibility in wells U10-025, U10-043, and U10-051 also was determined.

The lower zone is anaerobic and is not expected to co oxidize TCE. None of the wells in the lower zone will be sampled for enzyme activity probes, qPCR assays of genes for oxygenase enzymes, or to determine the rate of TCE co-oxidation with ^{14}C labelled TCE. However, magnetic susceptibility was determined in the sediments around well U10-051, which is completed in the lower zone (Figure 4.4.4).

Purge water was containerized and disposed of in the Hill AFB wastewater treatment plant per the approved Waste Management Plan.

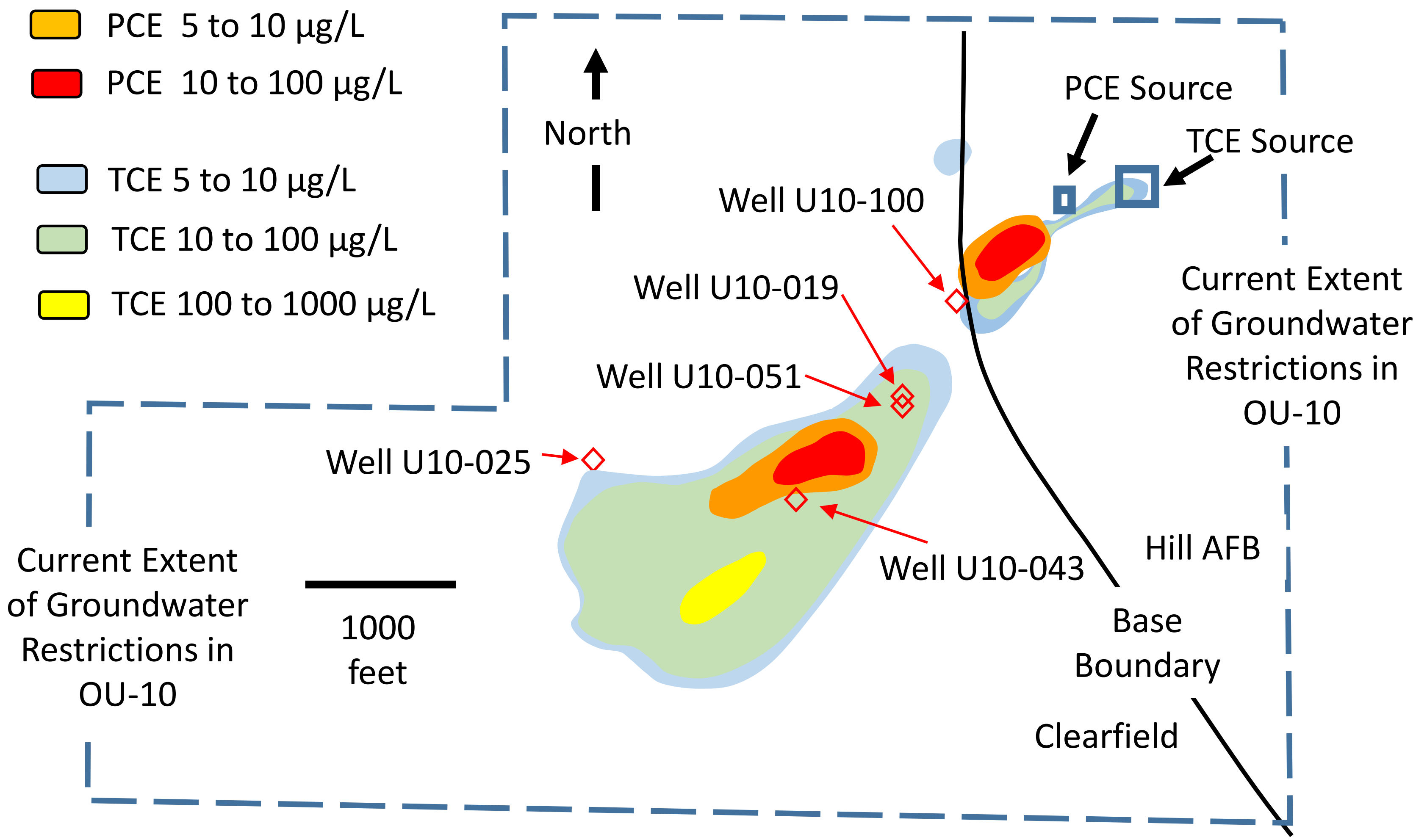


Figure 4.4.3. Comparison of the Contamination in Groundwater in the Upper Zone of the Shallow Aquifer System in 2013 to the Wells in the Upper Zone that are Selected for Sampling.

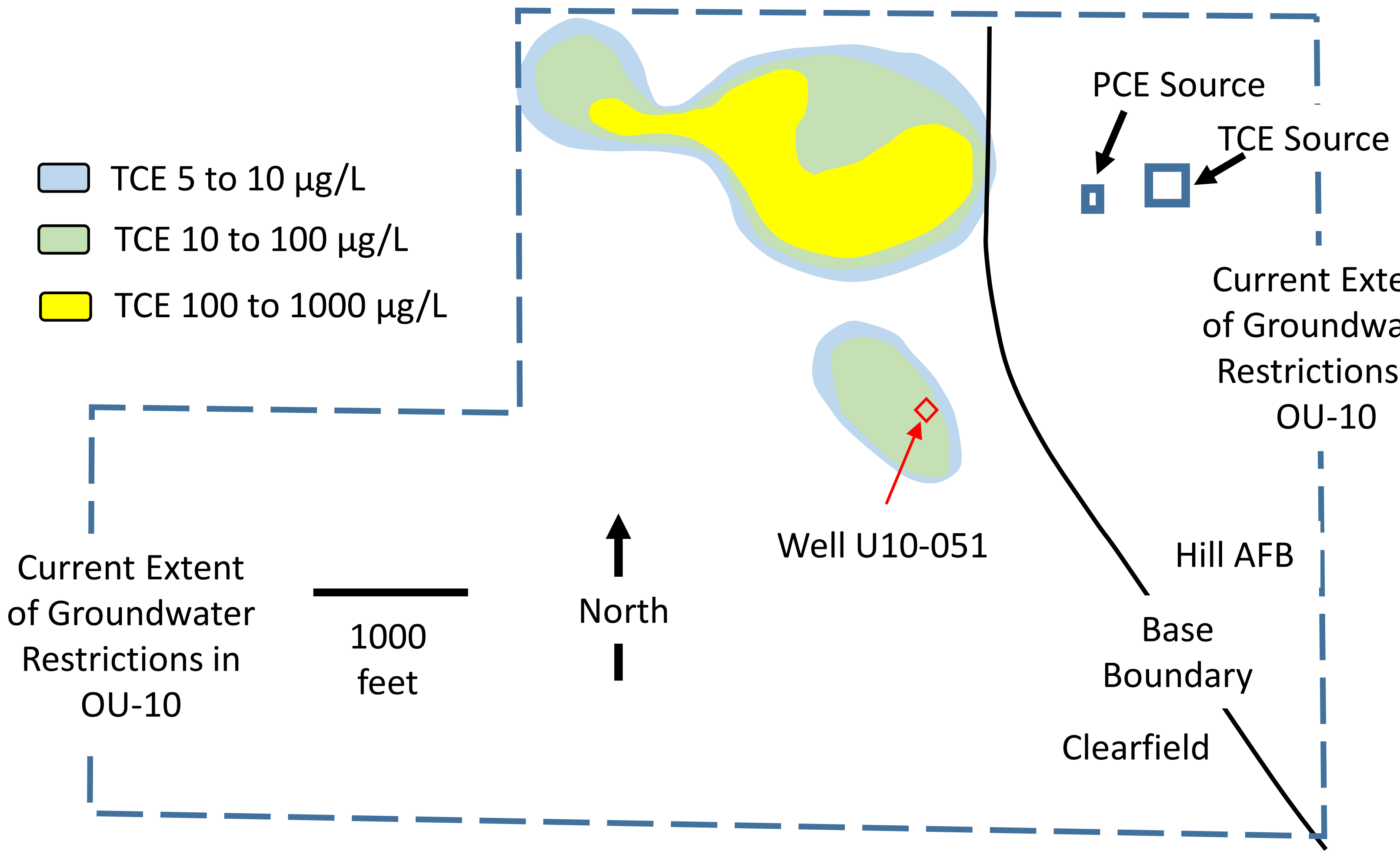


Figure 4.4.4. Comparison of the Contamination in Groundwater in the Lower Zone of the Shallow Aquifer System in 2013 to the Well in the Lower Zone that are Selected for Sampling.

Table 4.4.1. Expression of Toluene Oxygenase Enzymes in Groundwater from OU-1 at Hill AFB.

Well	Enzyme Activity			
	Toluene-3-monooxygenase	Toluene-2-monooxygenase	Toluene-2,3-dioxygenase	Total Cells
	Probe			
	3-Hydroxyphenylacetylene	Phenylacetylene	*trans*-cinnamonitrile	DAPI
	Cells per mL			
Reported July 18, 2007				
OU10-019	Not Detected	Not Detected	3.73E+04	5.32E+05
OU10-025	8.60E+03	3.00E+04	1.47E+03	5.44E+05
OU10-043	2.61E+04	8.58E+02	3.57E+04	3.73E+05

4.5 HOPEWELL JUNCTION

This site is not a DOD site. It was included in this project because it has a unique database that allowed evaluation of the downhole magnetic susceptibility sonde. Borehole core samples were acquired that corresponded to the screened interval of 11 EPA monitoring wells and analyzed in the laboratory. A total of 68 subcores were analyzed for magnetic susceptibility using laboratory methods.

The site also was evaluated using enzyme activity probes. However, it was not originally assayed using qPCR for DNA associated with oxygenase enzymes. In addition, before this project, aerobic biodegradation had not been incorporated in the site conceptual model at a quantitative level. This project includes EAPS, qPCR analyses, and a ^{14}C-TCE assay for this site, as discussed in Section 5.

In this study, the potential for abiotic TCE degradation was evaluated by measuring the magnetic susceptibility of aquifer sediment in six wells. The potential for cooxidation of TCE was evaluated in water samples from four wells.

4.5.1 Site Location and History

This section is a summary of material in CDM Federal Programs Corporation (2008, 2012).

The source of contamination of groundwater with chlorinated solvents was the former Hopewell Precision facility, at 19 Ryan Drive, Hopewell Junction, NY. U.S. EPA was made aware of the potential for contamination in 1979. In February 2003, EPA sampled 75 residential wells near the Hopewell Precision facility. Analysis of these samples revealed that five residential wells were contaminated with TCE ranging from 1.2 µg/L to 250 µg/L. At that time, the New York State Department of Environmental Conservation (NYSDEC), on behalf of New York State Department of Health (NYSDOH), requested EPA to conduct a removal action at the site, including installation of carbon filter systems on the residential wells.

From February to November 2003, EPA collected groundwater samples from hundreds of private drinking water wells in the vicinity of Hopewell Precision. TCE and 1,1,1-TCA were both detected in numerous private well samples, at individual concentrations up to 250 µg/L for TCE and 11.7 µg/L for 1,1,1-TCA. In addition, 1,1-dichloroethene (1,1-DCE), a breakdown product of 1,1,1-TCA, was detected in two samples. Several instances of TCE detection exceeded the compound's Maximum Contaminant Level (MCL) of 5 µg/L. At that time, EPA installed point-of-entry-treatment (POET) systems to remove volatile organic compounds (VOCs) at 37 homes where TCE approached or exceeded the MCL.

Since 2003, EPA's Removal Action Branch has conducted residential well sampling and collected groundwater samples from homes with POET system three times per year. As of May 2009, EPA has installed POET systems at 41 homes. In addition, NYSDEC has installed POET systems at 14 homes with 1,1,1-TCA concentrations that exceed the NYSDEC groundwater standard and NYSDOH drinking water standard.

Figure 4.5.1 compares the distribution of TCE in groundwater in 2006 and 2007. The TCE contamination extended 8,000 feet downgradient of the former Hopewell Precision facility. Figure 4.5.2 compares the distribution of TCE contamination in 2010 to the locations of POET systems and EPA monitoring wells at the site.

4.5.2 Site Geology/Hydrogeology

The site is situated in a glaciated valley underlain by the Hudson River Formation in the northern portion of the site and the Stockbridge Limestone in the southern portion of the site. The bedrock is overlain by unconsolidated sediments deposited by glaciers and glacial meltwater. The glacial outwash deposits are a complex mixture of boulders, gravel, sand, silt, and clay which form discontinuous beds or lenses. Due to multiple glaciation events, subsurface units are heterogeneous and highly localized. Till is also present in the overburden underlying the site. The till forms a mound in the shape of a tear drop with the long axis oriented north-south. The plume of contaminated groundwater is bifurcated by the till (Figure 4.5.1).

The unconsolidated deposits at the site have been grouped into three hydrostratigraphic units: a) sand and gravel unit (including silty sand, silty gravel, and mixtures of sand, silt, and gravel), b) silt and clay (including silty clay), and c) the till mound. The sand and gravel units have higher hydraulic conductivity than the silt and clay units, as indicated by the slug test results discussed below. The sand and gravel units are expected to be preferential flow paths for groundwater contamination. These units are localized and discontinuous, likely creating multiple complex flow paths through the overburden.

Figure 4.5.3 presents the potentiometric surface in the shallow wells and Figure 4.5.4 presents the potentiometric surface in the deep wells. In general, groundwater flow is towards the valley from the upland areas on the east and west sides of the valley. In the valley, groundwater flow is generally towards the southwest along the valley axis. The till mound impedes groundwater flow within the valley, as evidenced by horizontal gradient data. Groundwater flows preferentially in higher conductivity silty sand and gravel units. During the RI, the horizontal gradients were estimated in the following areas:

- Between monitoring wells EPA-8S and EPA-12S the horizontal gradient is 4.09×10^{-3}.
- Between monitoring wells EPA-16S in the north and EPA-19S south of the till unit, the gradient is 8.7×10^{-3}.
- The topography flattens and the horizontal gradient decreases to 2.53×10^{-3} between monitoring well EPA-21S and piezometer PZ-02.

The vertical gradient in most monitoring wells is upwards, indicating groundwater discharge into the valley and Whortlekill Creek which runs along the axis of the valley and also flows to the southwest. The gradient ranged from 0.06 foot at EPA-10S/EPA-10D to 6.22 feet at EPA-12S/EPA-12D. Overall, the vertical gradient at 10 of 15 well pairs was less than 1 foot.

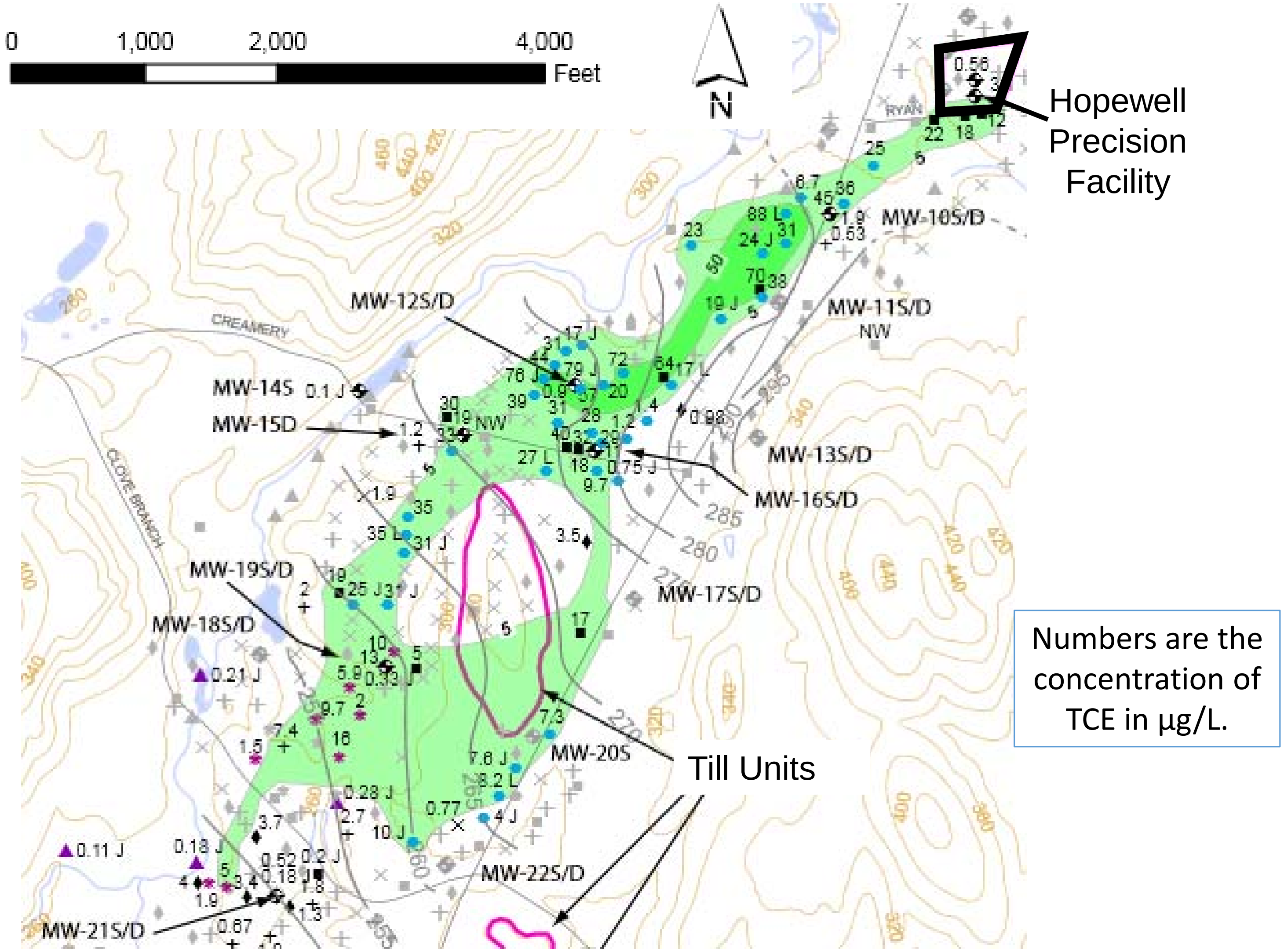


Figure 4.5.1. Distribution of TCE in Groundwater 2006 and 2007.

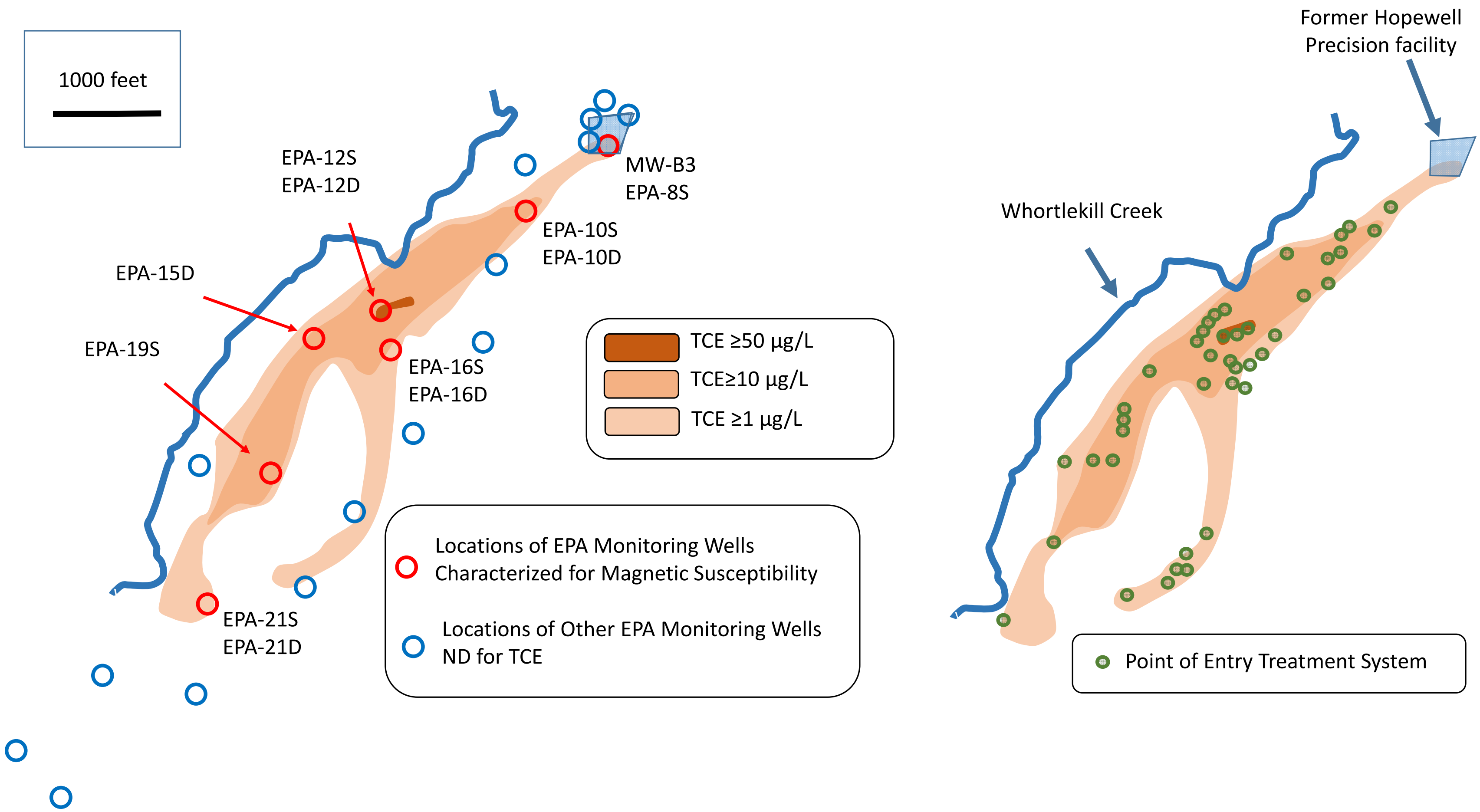


Figure 4.5.2. A Comparison of the Distribution of TCE Contamination in Groundwater in 2013 and the Location of Private Wells with Point-of-entry-treatment Systems, and the Location of EPA Monitoring Wells.

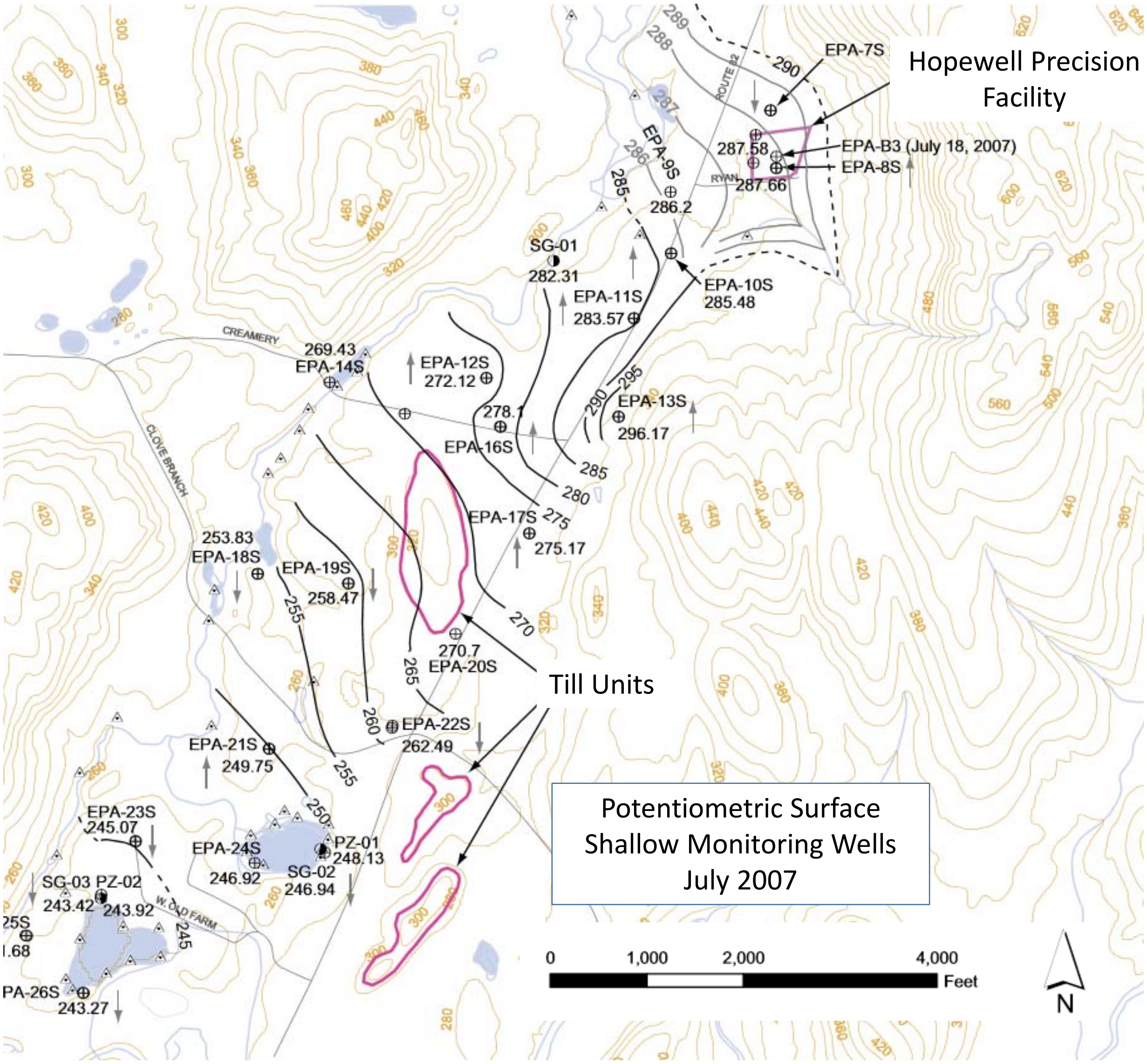


Figure 4.5.3. Potentiometric Surface in the Shallow Monitoring Wells at the Hopewell Precision Site in 2007.

From Figure 1-3 in CDM (2012).

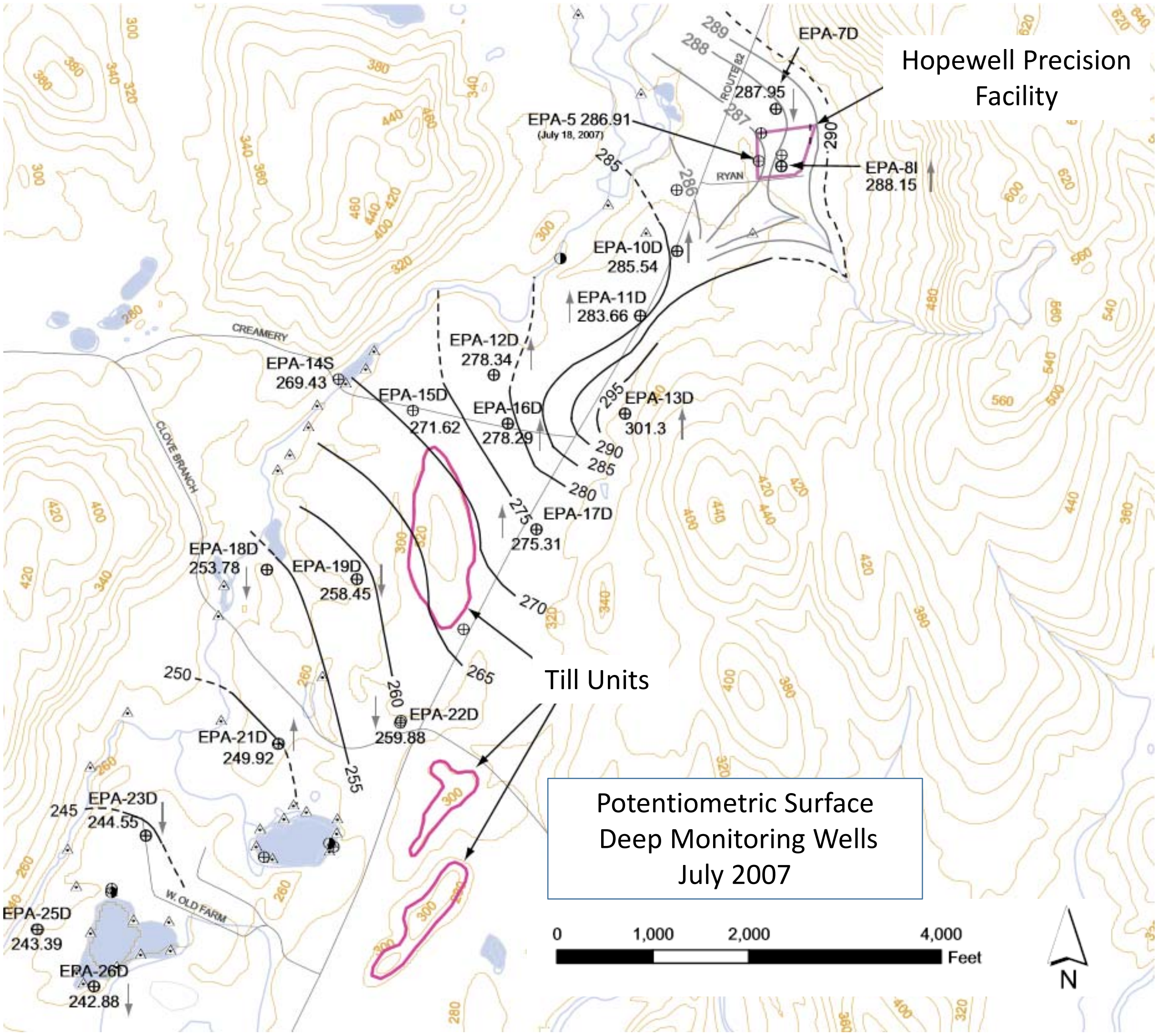


Figure 4.5.4. Potentiometric Surface in the Deep Monitoring Wells at the Hopewell Precision Site in 2007.

From Figure 1-4 in CDM (2012).

The groundwater flow velocity at the site was estimated using hydraulic conductivity values from slug tests and by evaluating movement of the TCE groundwater contaminant plume. The estimate developed by evaluating the TCE plume resulted in a hydraulic conductivity of 36 feet/day. The average hydraulic conductivity (geometric mean of the arithmetic means of results of slug tests run at each well) from slug testing was 2.53 feet/day. The average hydraulic conductivity of 2.53 feet/day represents the bulk hydraulic conductivity of unconsolidated deposits at the site and indicates that most of these deposits are fine-grained silts, silty sands, and silty clay. However, slug test results from specific wells are consistent with the higher hydraulic conductivity implied by the movement of the plume. At monitoring well EPA-18D the arithmetic mean of the nine tests conducted was 28 feet/day, while at monitoring well EPA-23S the arithmetic mean of the two tests conducted was 40 feet/day.

Based on an effective porosity of 25 percent (preferential flow paths consist of silty sand and gravel), an arithmetic mean hydraulic conductivity of 34 feet/day from slug tests at monitoring well EPA-18D and EPA-23S, groundwater flow velocities were calculated as follows:

- North portion of the flow path (EPA-8S to EPA-12S) approximately 203 feet/year
- Central portion (EPA-16S to EPA-19S) approximately 432 feet/year.
- South portion (EPA-21S to further downgradient) approximately 126 feet/year.

4.5.3 Contaminant Distribution

Figure 4.5.5 presents the distribution of TCE in the EPA monitoring wells at the most recent sampling date. Figure 4.5.6 compares the distribution of TCE in the private wells with a point-of-entry-treatment (POET) system 2015. The highest concentrations of TCE are less than 40 µg/L.

4.5.4 Previous Sampling Relevant to the Current Project

In August 2013, core samples were acquired adjacent to eleven EPA monitoring wells that were selected for this study. The cores were acquired across the vertical interval represented by the screened interval of the EPA wells. The core samples were analyzed for mass magnetic susceptibility at the R.S. Kerr Center in Ada, OK, following their in-house SOP. Table 4.1.2 summarizes the laboratory mass magnetic susceptibility data collected from this Site in August 2013.

Enzyme activity probes (EAP) were applied to groundwater samples from the Hopewell Precision site. Results were presented in Lee (2013). Results are summarized in Table 4.5.1 and Figure 4.5.7. Lee (2013) applied probes for toluene-3-monooxygenase, toluene-2-monooxygenase, toluene-2,3-dioxygenase and soluble methane monooxygenase. For this project, these probes plus a probe for the toluene side chain monooxygenase were utilized.

4.5.5 Sampling Locations for the Current Project

Of the eleven EPA monitoring well locations specified in the Demonstration Plan (ESTCP, 2016; Figure 4.5.8) ten locations were probed for magnetic susceptibility. The 8S/B3 location was not sampled because the wells were not accessible and the sonde could not be lowered into the well. Figure 4.5.9 identifies the four wells that were sampled for EAPs, DNA assays and determination of the rate of aerobic TCE cometabolism using the ^{14}C-TCE Assay.

Appendix D of the Demonstration Plan (ESTCP, 2016) provides construction logs and borehole lithologic logs prepared for the monitoring wells sampled during this investigation.

As is the State-approved practice, purge water was handled according to NYSDEC's DER-10. This allows discharge of purge water to the ground if the purged well has historical VOC concentrations below drinking water standards. For those monitoring wells where the VCOC concentrations are exceeded by more than 10 times, the purge water was containerized. Based on these criteria, purge water was discharged to the ground from all monitoring wells to be used for this investigation except 10S and 12S. Water from these wells was containerized and disposed of in accordance with the approved Waste Management Plan.

Table 4.5.1. Expression of Toluene Oxygenase Enzymes in Groundwater from the Hopewell Precision Site, as Reported in Lee (2013).

Well	Enzyme Activity			
	Toluene-3-monooxygenase	Toluene-2-monooxygenase	Toluene-2,3-dioxygenase	Total Cells
	Probe			
	3-Hydroxyphenylacetylene	Phenylacetylene	*trans*-cinnamonitrile	DAPI
	Cell per mL			
EPA-10S	3.0×10^4	1.7×10^4	9.3×10^3	7.3×10^4
EPA-10D	2.3×10^4	2.2×10^4	4.4×10^3	6.2×10^4
EPA-12S	6.7×10^4	6.7×10^3	6.4×10^3	1.6×10^5
EPA-12D	3.2×10^2	8.0×10^1	1.6×10^2	1.6×10^5
EPA-16S	1.4×10^4	1.1×10^4	4.9×10^3	1.2×10^5
EPA-16D	9.7×10^4	1.1×10^4	1.4×10^4	2.2×10^5
EPA-21D	3.1×10^3	4.2×10^3	1.1×10^4	2.3×10^5

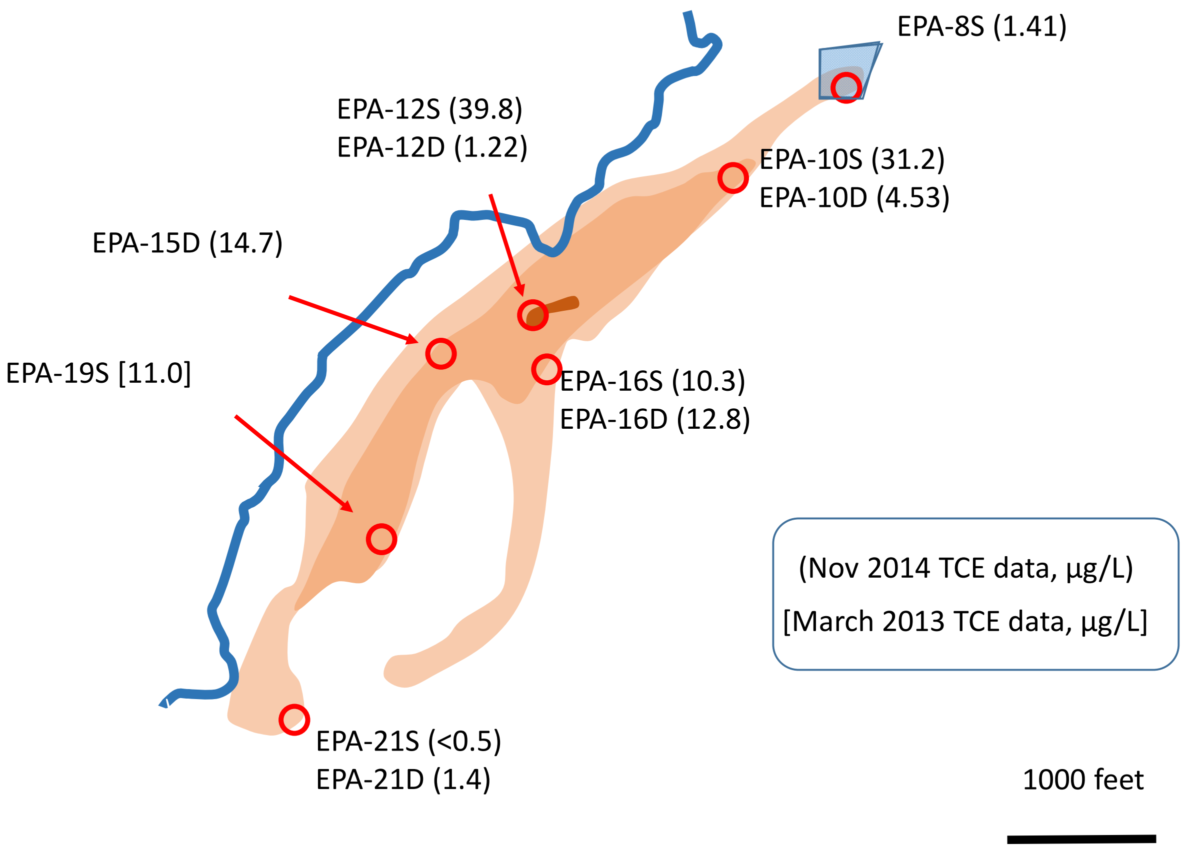


Figure 4.5.5. Concentrations of TCE in the Wells To Be Probed for Magnetic Susceptibility.

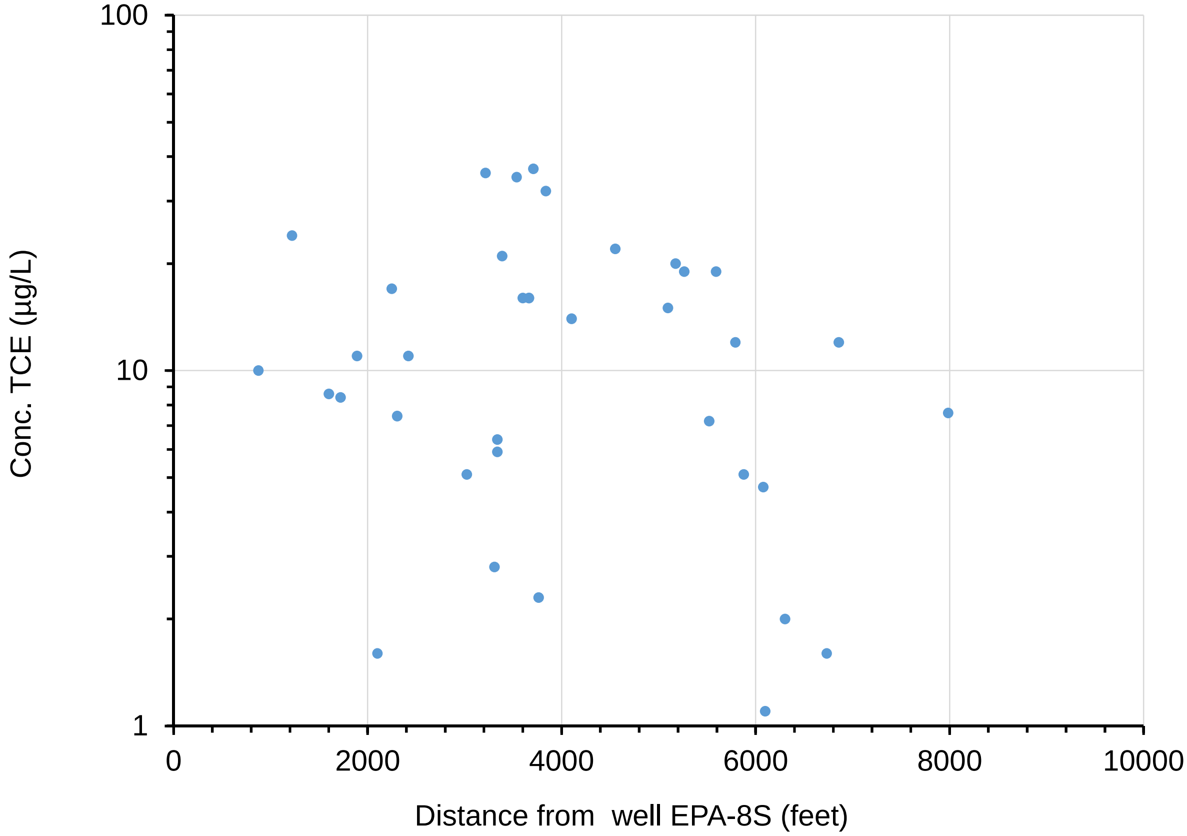


Figure 4.5.6. Concentration of TCE in the Private Wells with Point-of-entry-treatment Systems in 2015.

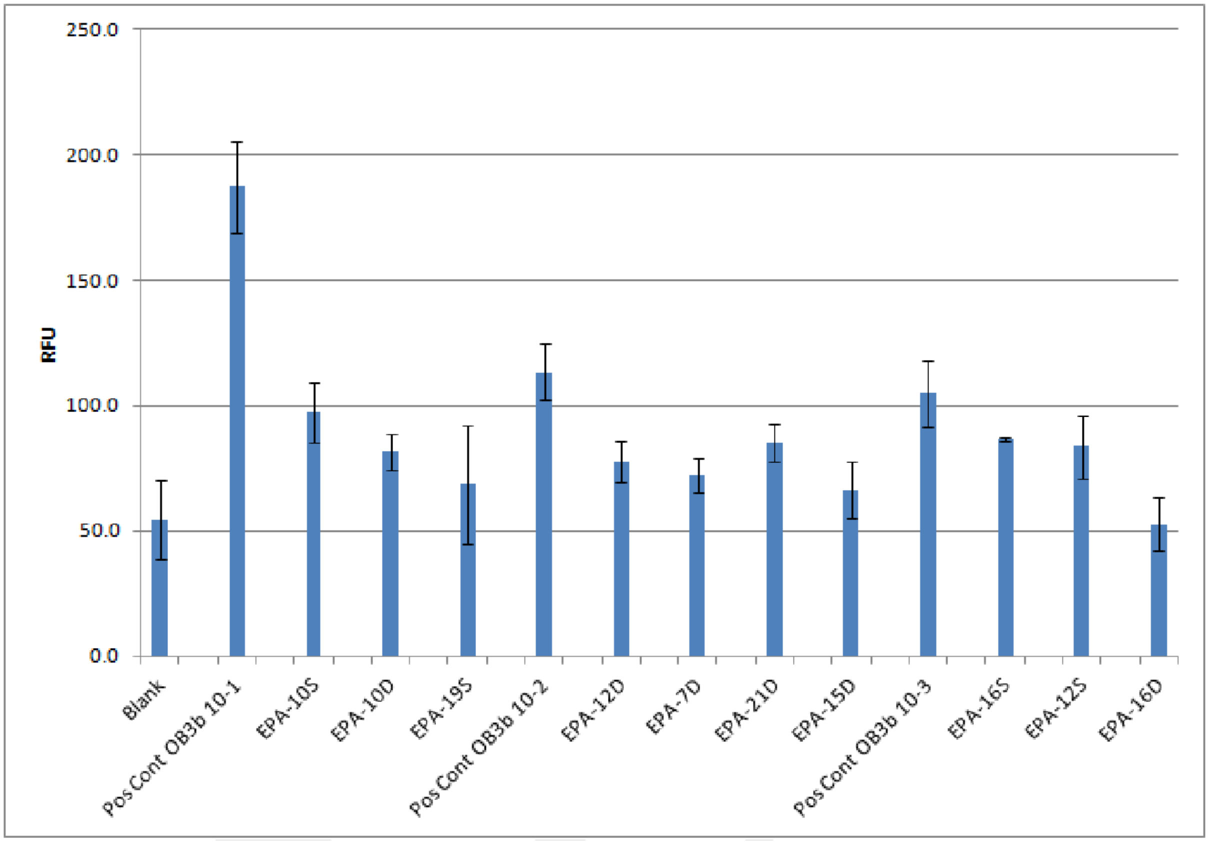


Figure 4.5.7. Screenshot of Text in Lee (2013) Discussing the Expression of Soluble Methane Monooxygenase in Water Samples from the Hopewell Precision Site.

RFU is the response in Relative Fluorescene Units that developed after exposure to coumarin in phosphate buffer. The Blank is water filtered through a 0.2 μm filter and then assayed.

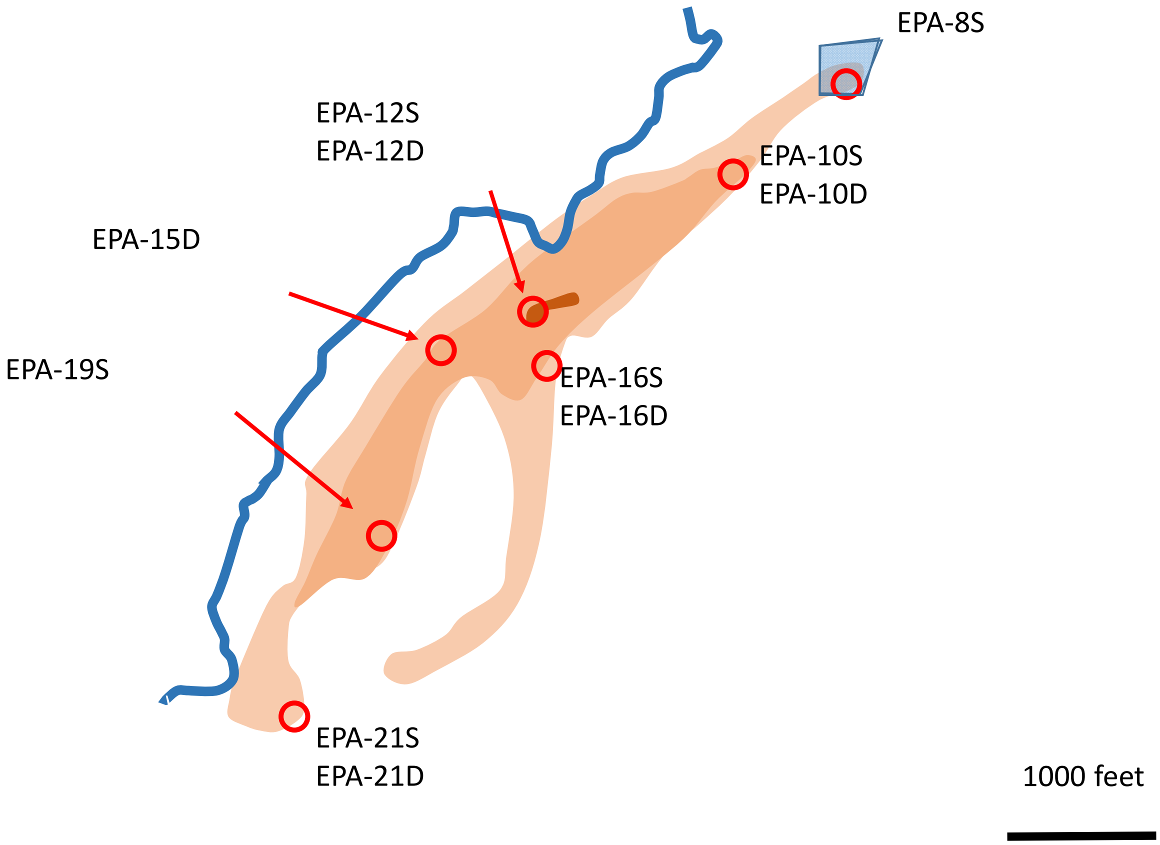


Figure 4.5.8. The Eleven Wells Proposed for Magnetic Susceptibility Sonding.

Note that well EPA-8S was not sampled because the well was compromised and the sonde could not be lowered into the well.

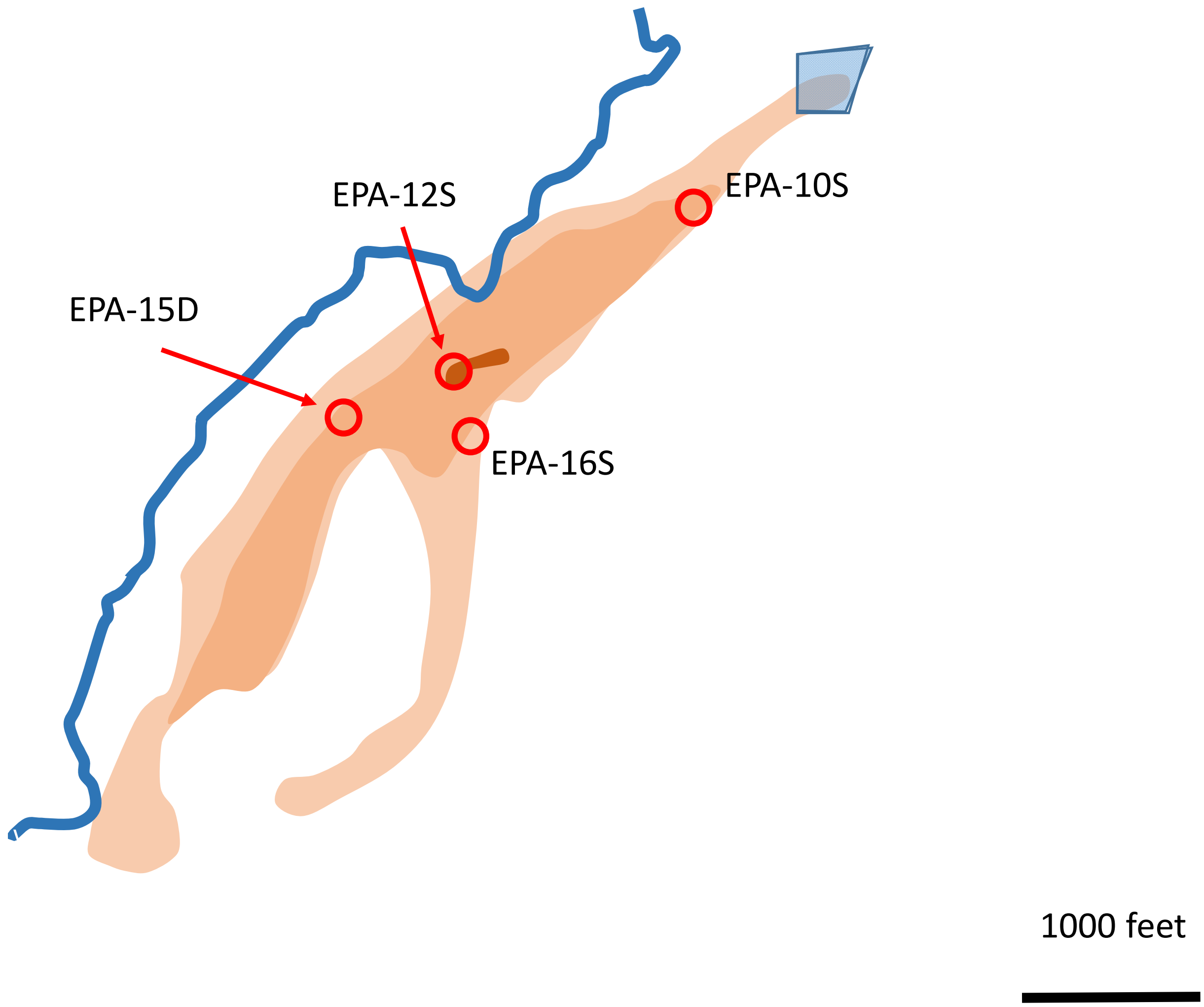


Figure 4.5.9. The Four Wells Sampled for Enzyme Activity Probes, DNA Assays and Rate of Co-oxidation of TCE.

4.6 TOOELE ARMY DEPOT

Magnetic susceptibility data was collected in numerous core samples during the installation of monitoring wells at the Site. Under this effort, the project team conducted downhole magnetic susceptibility analyses and compared the results to the laboratory-based analyses that are already available. Furthermore, in their 2013 Evaluation of MNA (Parsons, 2013), Parsons recommended using EAPs to evaluate aerobic co-oxidation of TCE. Under this effort, the project team will complete EAP analysefss in the wells that were installed in the borings from which magnetic susceptibility analyses were completed. The team will also determine the rate constant for aerobic biodegradation of TCE in the groundwater.

In this study, the potential for abiotic TCE degradation was evaluated by measuring the magnetic susceptibility of aquifer sediment in one well. Three other wells were logged for the convenience of the Army Corps of Engineers. The potential for cooxidation of TCE was evaluated in water samples from four wells.

4.6.1 Site Location and History

Unless otherwise specified, information in this report was taken from Army Corps of Engineers (ACE; 2013). In many cases, text is copied from ACE (2013) and pasted without modification.

The Tooele Army Depot (TEAD) is a United States Army post located in Tooele County, Utah. It is located south of the city of Grantsville, southeast of the city of Erda and southwest of the city of Tooele (Figure 4.6.1). The boundary of the model domain for a transport and fate model constructed by the U.S. Army Corps of Engineers and its contractors (ACE, 2013) was used to orient detailed maps in figures subsequent to Figure 4.6.1.

From 1942 to 1966, a large quantity of hazardous wastes was generated as a result of the maintenance and storage of military vehicles and equipment. The waste chemicals were piped through the industrial complex into a set of four unlined drainage ditches. These ditches ended at land-spreading areas and gravel pits that were used as evaporation/infiltration areas. These gravel pits collectively have been called the old industrial wastewater lagoon (OIWL). In 1966, a collector ditch was constructed to intercept the four existing ditches. This interceptor ditch ran north for 1.5 miles to an abandoned gravel quarry. This pit, the IWL, was used as an evaporation/infiltration pond until its closure in 1988. At that time, an industrial wastewater treatment plant was brought on-line. These hazardous waste disposal practices at TEAD led to groundwater contamination in the industrial area and northward. The primary contaminant of concern is the solvent TCE, which was used in the service and repair of military vehicles and equipment. The location of the OIWL and IWL are presented in Figure 4.6.2.

4.6.2 Site Geology/Hydrogeology

The majority of the southern and central portions of the study area are underlain by shallow bedrock. Groundwater levels indicate that the bedrock should be divided into two distinct units – the bedrock basement and an “encased,” uplifted bedrock block located in the center of the study area (Figure 4.6.3).

The conceptualization of fault zones in AEC (2013) was predicated upon evidence of abrupt water level changes typical of faults in both bedrock and alluvium. The faults are labelled in Figure 4.6.2. The water elevations are presented in Figure 4.6.3. Figure 4.6.4 presents a conceptual model of the vertical distribution of the bedrock, the alluvium, faults in the bedrock and alluvium, and the water table.

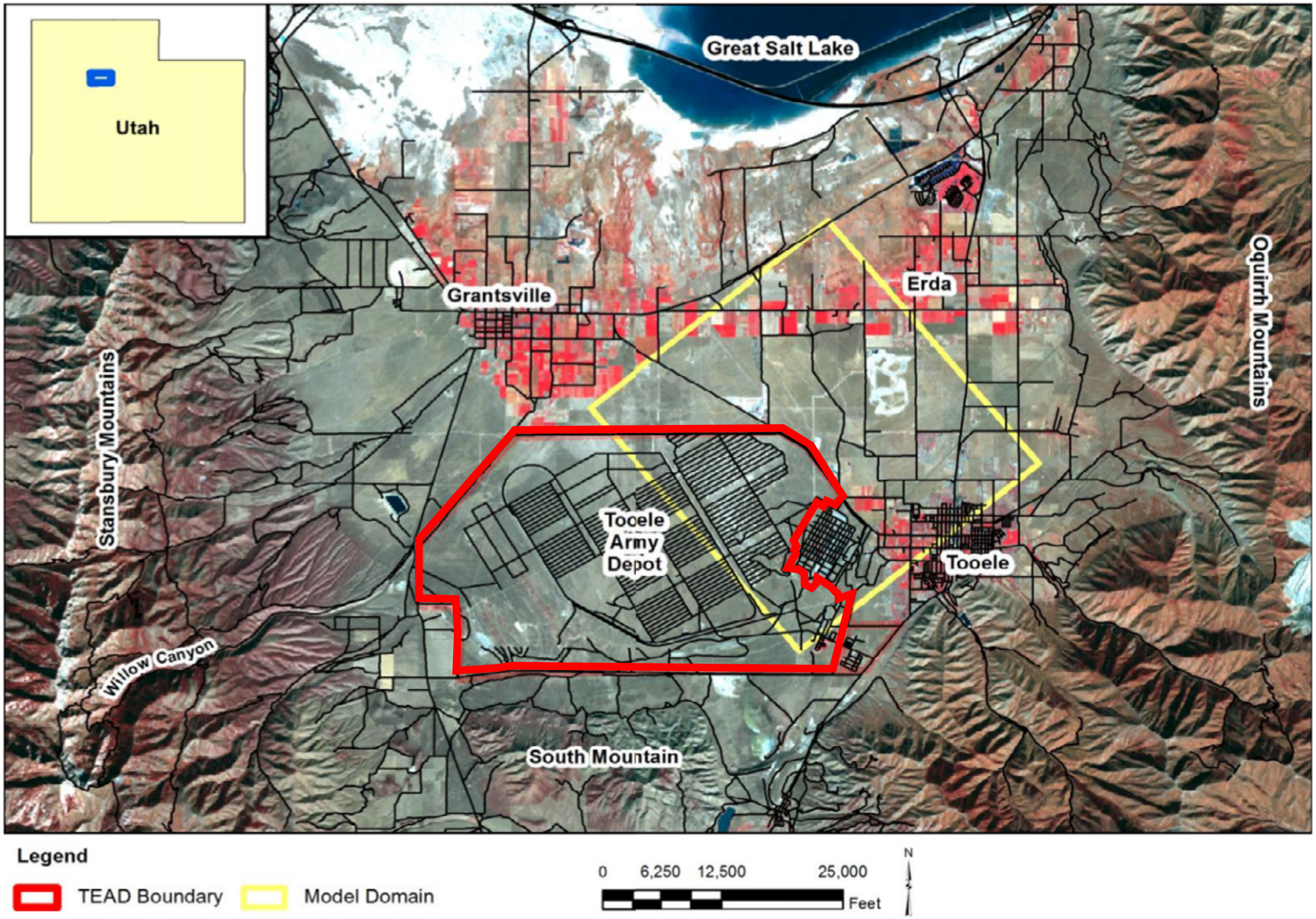


Figure 4.6.1. Location of the Tooele Army Depot (TEAD).

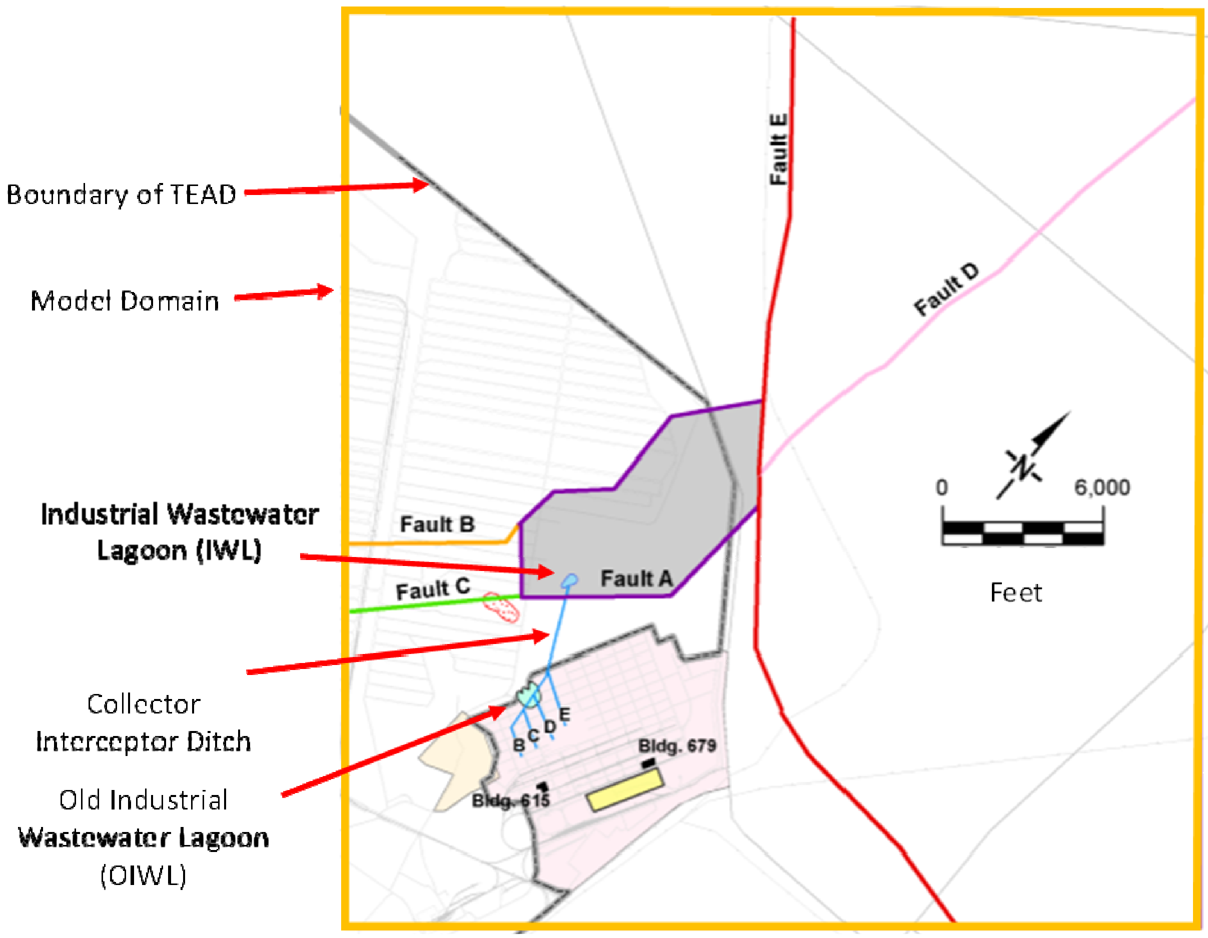


Figure 4.6.2. Location of the Industrial Wastewater Lagoons.

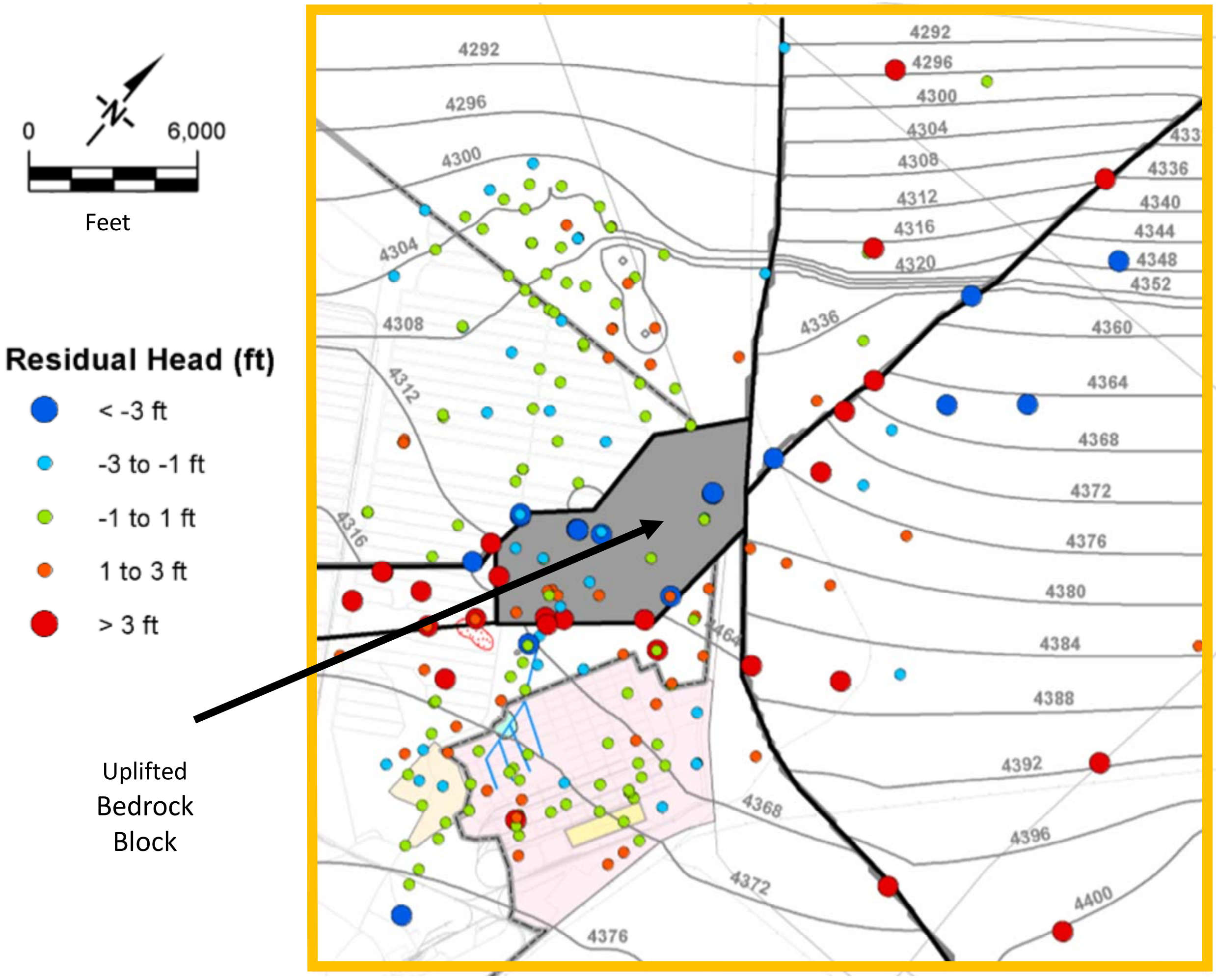


Figure 4.6.3. Elevation of the Water Table (feet above mean sea level).

The isopleths are the calibrated water levels in the groundwater flow model (ACE, 2013). The colored dots are the residuals of actual measured water table elevations from the model.

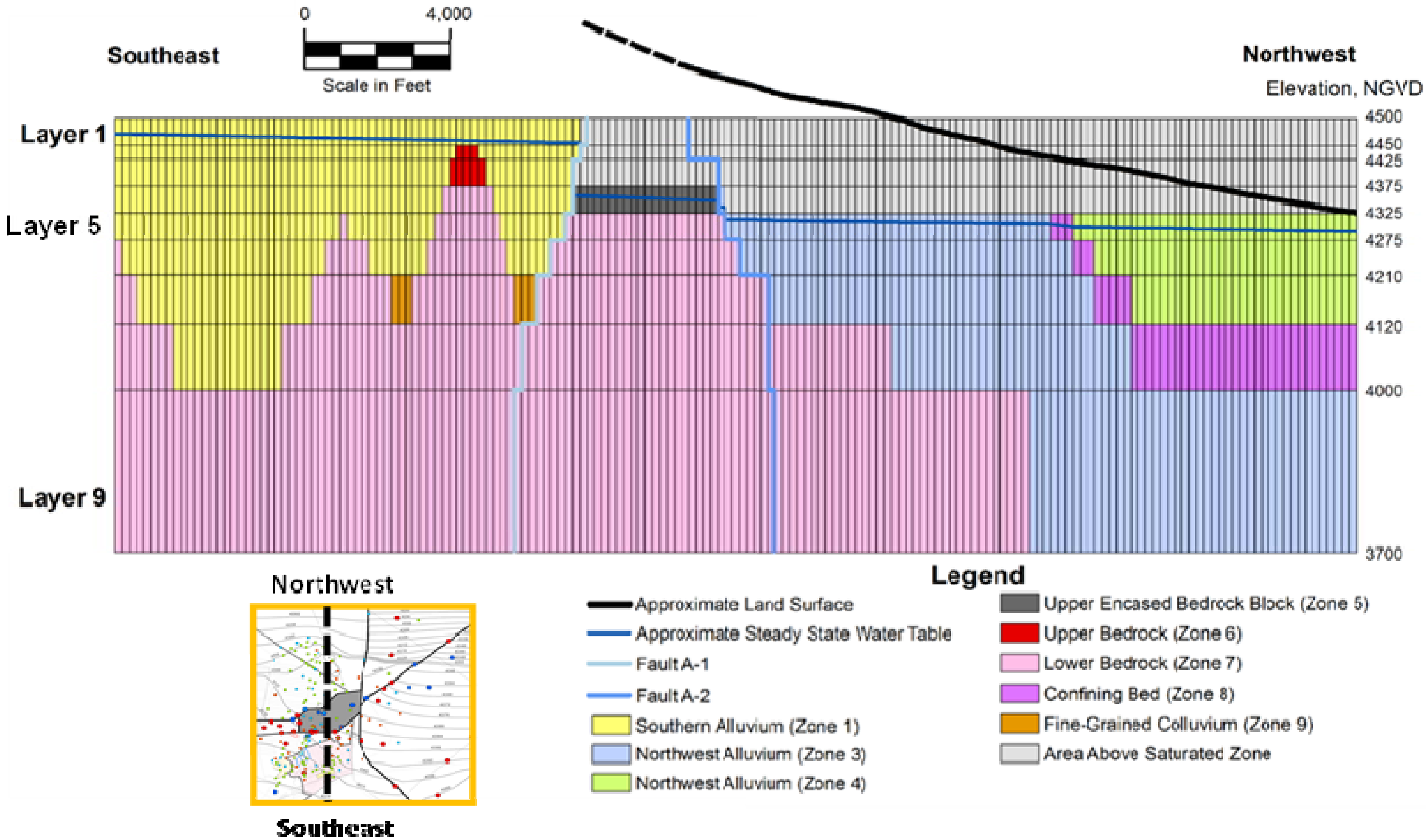


Figure 4.6.4. Conceptual Model of the Distribution of Bedrock, Alluvium, Faults in the Bedrock and Alluvium, and the Water Table in a Transect from the Southeast to the Northwest Boundaries of the Model Zone.

(See dotted black line in the insert)

ACE (2013) hypothesized that the cause of the sharp gradients across bedrock faults in bedrock was the formation of low permeability fault gouge and weathered clay products. The unconsolidated sediments, which underlie most of the study site, are heterogeneous at the scale of the computer model (ACE, 2013) and generally consist of coarser grained sand/gravel deposits with some cemented areas and inter-fingered layers of clay and silt typical of alluvial and lacustrine deposits. The alluvium on the site is conceptualized as four separate units: 1) the southeastern alluvium, located to the southeast of the uplifted bedrock block; 2) the northwestern alluvium located to the north and northwest of the uplifted bedrock block; 3) fine-grained material located at depth to the southeast of the uplifted bedrock block; and 4) the northward-dipping lacustrine confining bed located in the northern and northwestern quadrants of the study area. The depth of this latter lacustrine deposit increases downgradient, splitting the northwestern alluvial deposits into unconfined (shallow) and confined (deep) aquifers.

The shallow upgradient alluvium at the southeastern end of the site has a very flat gradient most likely resulting from a damming effect produced by the low conductivity fault/bedrock system downgradient. Additionally, a high percentage of permeable gravels and sands were noted in borings in the southern alluvium, relative to the northern alluvium. One hypothesis for this is that the southern alluvium is closer to the mountain front where coarser material would be deposited from alluvial outwash. At the southern end of the model area, the alluvium is very shallow with approximately 50 ft of saturated thickness between the bedrock basement, and the water table.

The northwestern alluvium, located downgradient from the bedrock block and adjacent faults, is composed of several interconnected aquifers. There are two prominent hydraulic features associated with the northwestern alluvium: 1) an abrupt drop in measured groundwater levels that occurs along a line that roughly parallels the southern extent of the Great Salt Lake; 2) vertical gradients that increase with depth towards the downgradient model boundary.

Results from a pumping test in estimated the horizontal hydraulic conductivity in the northwestern alluvium to be 200 ft/d. The estimated hydraulic conductivity of the bed rock varies from 50 to 70 ft/d. In the elevated bedrock block, the average hydraulic conductivity is approximately 30 ft/d.

4.6.3 Contaminant Distribution

Figure 4.6.5 compares the distribution of TCE in wells in the domain of the solute transport model to a summary evaluation of the distribution of TCE contamination based on the transport and fate model and on kriging of the data. Figure 4.6.6 presents the distribution of TCE in the local area.

4.6.4 Previous Sampling Relevant to the Current Project

Core samples that had been archived from the installation of monitoring wells were provided to staff of the R.S. Kerr Environmental Research Center for analysis of mass magnetic susceptibility. Data are available from two adjacent wells, one screened across the water table (monitoring well D-20) and one deeper into the alluvial sediments (monitoring well D-23). The borehole core mass magnetic susceptibility data for these wells is summarized in Table 4.1.2.

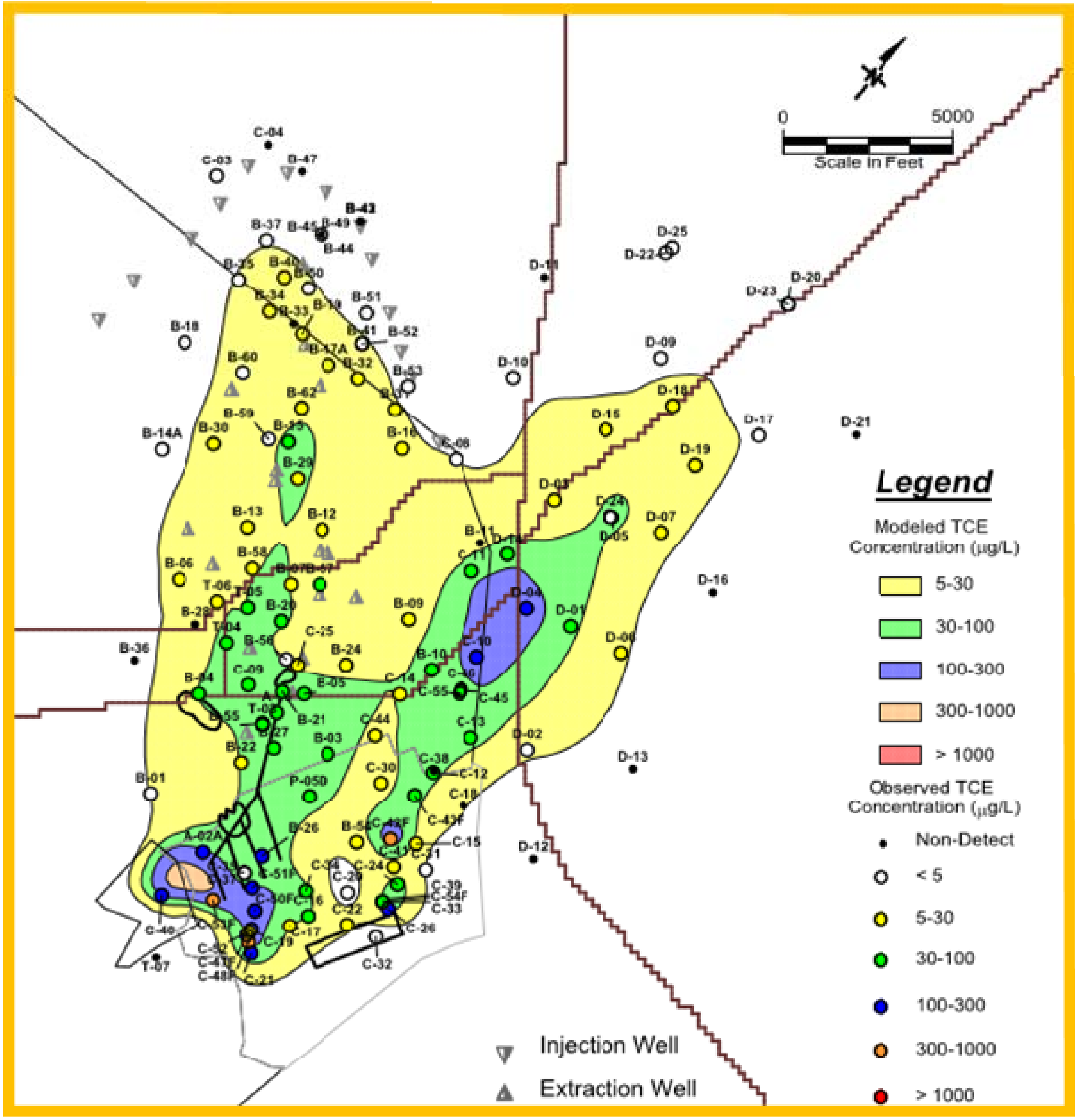


Figure 4.6.5. Distribution of TCE Contamination in Groundwater in the Model Domain.

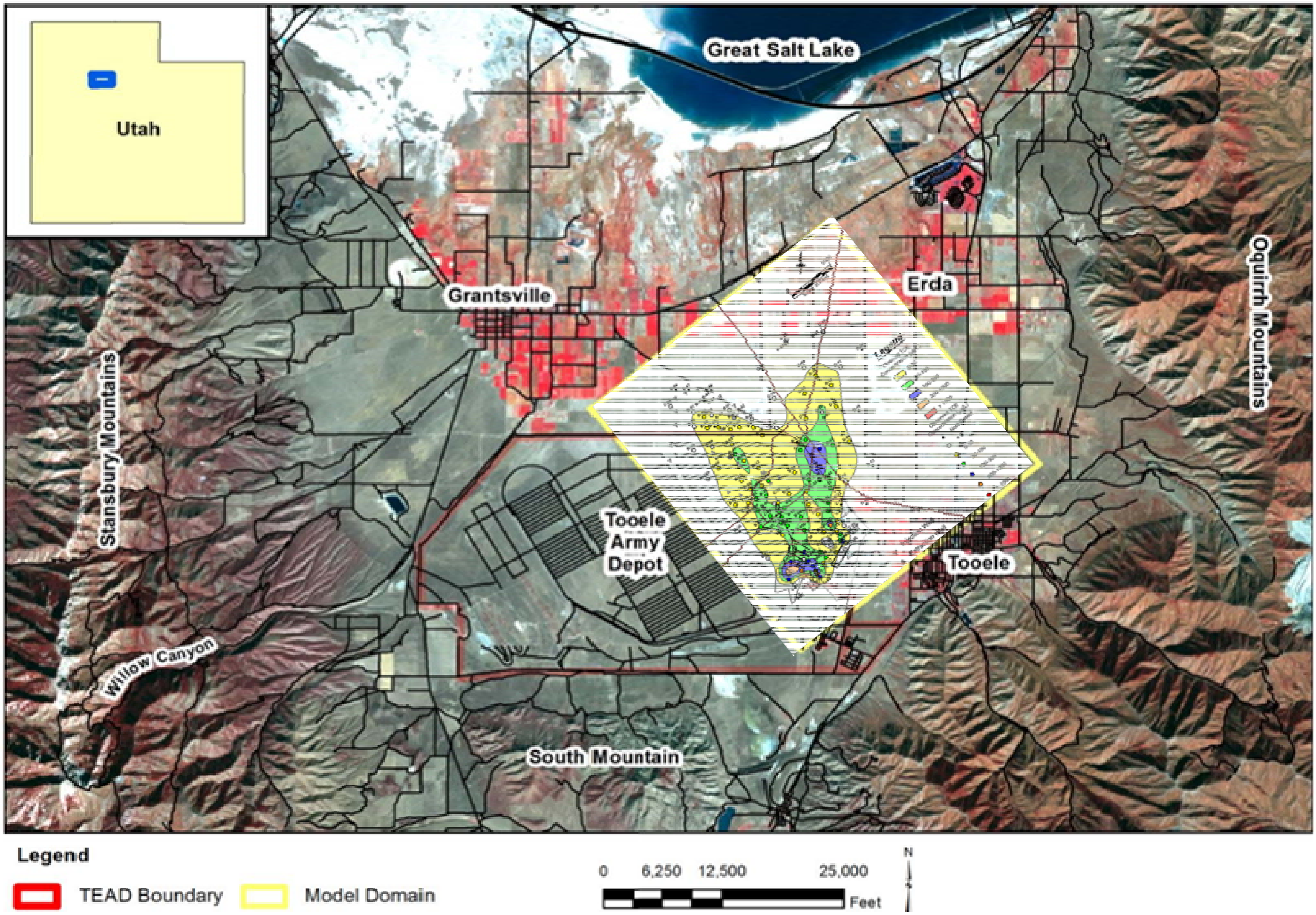


Figure 4.6.6. Distribution of TCE contamination in groundwater in the model domain.

4.6.5 Locations Sampled for the Current Project

The wells circled in red in Figure 4.6.7 were sampled for Enzyme Activity Probes, determination of the rate of aerobic co-oxidation of TCE, and a sonde was inserted in the wells to determine mass magnetic susceptibility of the sediments. They are wells D-19, D-20, D-23 and D-25. Although wells D-23 and D-25 had a sonde lowered into them, they either do not have mass magnetic susceptibility data obtained from laboratory analysis of core data, or have these data from beneath the total depth of the completed well.

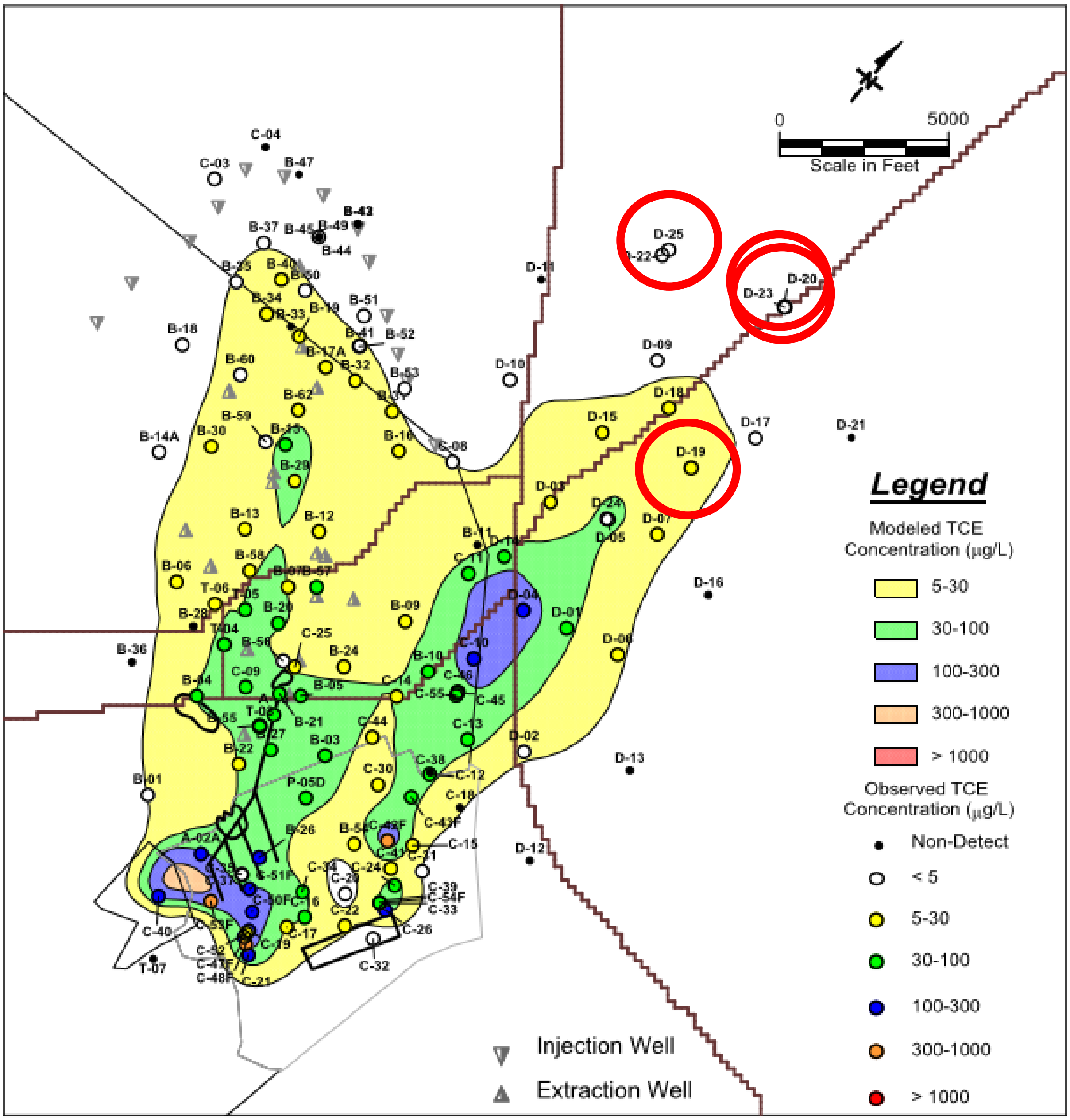


Figure 4.6.7. Locations Sampled for this Effort.

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5.0 TEST DESIGN

This section provides a detailed description of the system design and testing conducted during the demonstration.

5.1 CONCEPTUAL EXPERIMENTAL DESIGN

In order to complete the objectives outlined in the Demonstration Plan, seven (7) tasks were completed:

- Task 1 – Development of Demonstration Plan/Field Sampling Plan.
- Task 2 – Field Work - Deployment of Magnetic Susceptibility Sonde and Field Sampling for Enzyme Activity Probes, qPCR Assays of Co-Oxidation Enzymes, and Direct Assay of Rate of Aerobic Biodegradation.
- Task 3 – Develop a Carbon 14 Tracer Procedure to Directly Assay the Rate of TCE Aerobic Biodegradation.
- Task 4 – Laboratory Work to Conduct Carbon 14 Tracer Direct Assay of the Rate of TCE Aerobic Biodegradation.
- Task 5 – Laboratory Work to Implement Enzyme Activity Probes and the qPCR Assays for Oxygenase Enzymes that can Co-Oxidize TCE.
- Task 6 – Final Report.
- Task 7 –Project Management.

Each task is discussed in the following subsections.

5.1.1 Task 1 - Development of Demonstration Plan/Field Sampling Plan

Under this task, a Demonstration Plan that met all ESTCP requirements and guidelines was prepared and approved by ESTCP. This document included the objectives of the demonstration, qualitative and quantitative criteria for success, the methodologies to be employed, and the measurements that were required to determine success. The Demonstration Plan was approved in April 2016.

5.1.2 Task 2 – Field Work - Deployment of Magnetic Susceptibility Sonde (Probe) and Field Sampling for Enzyme Activity Probes, qPCR Assays of Co-Oxidation Enzymes, and Direct Assay of Rate of Aerobic Biodegradation

Task 2 consisted of:

1. Mobilization;
2. Collecting magnetic susceptibility data using a downhole sonde;
3. Collecting groundwater samples for submission to Clemson University and PNNL, and;
4. Demobilization.

Task 2.1 - Coordination and Mobilization

This task was used to coordinate field work and obtain the materials necessary for field work. The following people supported T.H. Wiedemeier & Associates, Inc. (THWA) and Scissortail Environmental Solutions, LLC (SES) to coordinate access to the sites and/or provide field assistance for the sites. Mr. Mark Ferrey with the Minnesota Environmental Pollution Control Agency, coordinated work at the TCAAP in MN. Ms. Diana Cutt with the USEPA Region 2 coordinated work at the former Plattsburgh AFB and the Hopewell Precision site in NY. Ms. Sharon Stone, AFCEC/CZO, Peterson AFB, Colorado and Mr. Todd Isakson, CH2M Hill, Taylorsville, Utah helped coordinate work at OU-10 at Hill AFB. Mr. Marc Sydow and Mr. Nicholas Montgomery with U.S. Army JMC, provided support for the effort at Tooele Army Depot, Utah. David Farnsworth with U.S. Air Force, Bryan Gamache with AECOM, Lorenzo Thantu U.S. EPA Region 2, Matt Ivers with Parsons, Travis McGuire with GSI Environmental Inc., and W. Zachary Dickson with Dickson & Associates assisted in gaining access to wells and core samples or collecting other data.

Task 2.2 - Field Work

For this task Todd Wiedemeier and Dr. John Wilson traveled to the five sites described in Section 4 to deploy the magnetic susceptibility sonde and collect the data necessary to compare these data to those previously collected from soil cores at the sites. The task also was used to collect the water samples that were assayed using enzyme activity probes, qPCR for oxygenase enzymes, and for the rate of aerobic biodegradation of TCE using the ^{14}C-labeled TCE assay.

Appendix B presents the daily field and sampling reports collected during Field Work. Appendix C contains the data collected using the downhole magnetic susceptibility sonde.

5.1.3 Task 3 - Develop a Carbon 14 Tracer Procedure to Directly Assay the Rate of TCE Aerobic Biodegradation

Task 3 was used to refine a method for purifying ^{14}C-TCE beyond what was achieved in previous studies. As indicated in sections 2.2.2 and 3.1.2, use of two GC columns in series was evaluated. It was determined that a single column provided an adequate level of purification. Although the target level for impurities was not met (i.e., less than 0.01% of the total ^{14}C added to the serum bottles), the level of impurities was sufficiently low to permit detection of first order co-oxidation rates as low as 0.00658 yr^{-1}. This necessitated increasing the incubation time of the assay to 40-46 days, to allow for sufficient accumulation of products. A potential concern with an incubation time longer than a few days is changes in the microbial community. However, as results for the groundwater samples indicate, the rates of ^{14}C product accumulation tended to diminish with time. If changes in the microbial community did occur, it resulted in a more conservative estimate of the rates of TCE degradation. Details regarding the approach that was used to accomplish Task 3 are provided in Section 5.3.

5.1.4 Task 4 - Laboratory Work to Conduct Carbon 14 Tracer Direct Assay of the Rate of TCE Aerobic Biodegradation

The goal of Task 4 was to determine pseudo-first order rate constants for TCE co-oxidation in groundwater samples from five sites, with samples taken from four wells per site. The assay was performed in 160 mL clear, borosilicate glass serum bottles (Wheaton®; Boston round, 125 mL) that were cleaned, dried, and autoclaved along with Teflon-faced gray butyl rubber septa and aluminum crimp caps (20 min, 121 °C). The bottles were labeled and massed (balance precision, ± 0.01 g) and then shipped to Wiedemeier & Asccociates for use in sample collection. In the field, triplicate 100 mL groundwater samples were collected from each monitoring well. The serum bottles were immediately capped with their respective Teflon-faced gray butyl rubber septum and crimped with an aluminum cap. The bottles were stored on ice and shipped overnight to Clemson University. Upon arrival, the bottles were removed from the packaging and warmed to room temperature (22 ± 2ºC), quiescently in the dark, for approximately 24 hours before addition of the ^{14}C-TCE stock solution.

For a given site, triplicate serum bottles were received from two wells on the first day, and a second set of triplicates was received from two additional wells on the following day. When the first set of triplicates groundwater samples was prepared, a set of triplicate DDI water controls was prepared at the same time

An overview of how the assay was performed is provided in Section 5.1.4.1. The following sections provide the details.

5.1.4.1 ^{14}C addition and time zero monitoring, sparging, direct counts, and O_2 monitoring

The ^{14}C-TCE stock solution was added to groundwater samples and control bottles using the single column method described in section 3.1.2. Prior to addition of the ^{14}C-TCE, the mass of bottles was recorded (balance precision, ± 0.01 g), in order to keep track of the amount of water in the bottles. Before adding the ^{14}C-TCE stock solution, approximately 50 mL of headspace was withdrawn from each bottle using a 100-mL gas-tight syringe (SGE Analytical Science, removable Luer Lock) to ensure the bottles were not over-pressurized. After withdrawing air from the headspace, the bottles were immediately inverted to reduce gas diffusion through the punctured Teflon-faced septa. The single column method for purifying the ^{14}C-TCE stock solution was used. During the predetermined interval when TCE eluted from the column (9.6-11.1 min), the GC gas was injected into a serum bottle. Following injection of the ^{14}C-TCE, the bottles were inverted and placed on an orbital shaker table (98 ± 2 RPM) for approximately 1 h. Agitating the liquid phase facilitated establishment of equilibrium between TCE in the headspace and liquid phases.

The total amount of TCE present in the bottles was determined by injection of a headspace sample (0.5 mL, taken with a 1.0 mL gas-tight syringe, Valco® Series A-2) onto a GC (HP 5890 Series II) equipped with a a stainless-steel column packed with 1 % SP-1000 on 60/80 Carbopack B (Supelco) and a flame ionization detector (FID). The temperature program was 60 °C for 2 min, increase at 20 °C per min to 150 °C, increase at 10 °C to 200 °C and hold for 28.5 min. GC/FID analysis also permitted detection of other VOCs in the groundwater samples.

Time zero monitoring for ^{14}C products was conducted after each bottle was injected with ^{14}C-TCE using the single column GC method and headspace checks for VOCs were completed using the GC/FID. The bottles were processed at the same time following addition of ^{14}C-TCE. The sampling procedure is outlined in Figure 5.1.1 and details are provided below. The sampling schedule and monitoring included the following sequence of events: 1) direct headspace and liquid counts; 2) sparging test; and/or 3) O_2 headspace monitoring (groundwater bottles only). After each sampling event, the bottles were incubated quiescently in the dark at ambient room temperature (22 ± 2 °C).

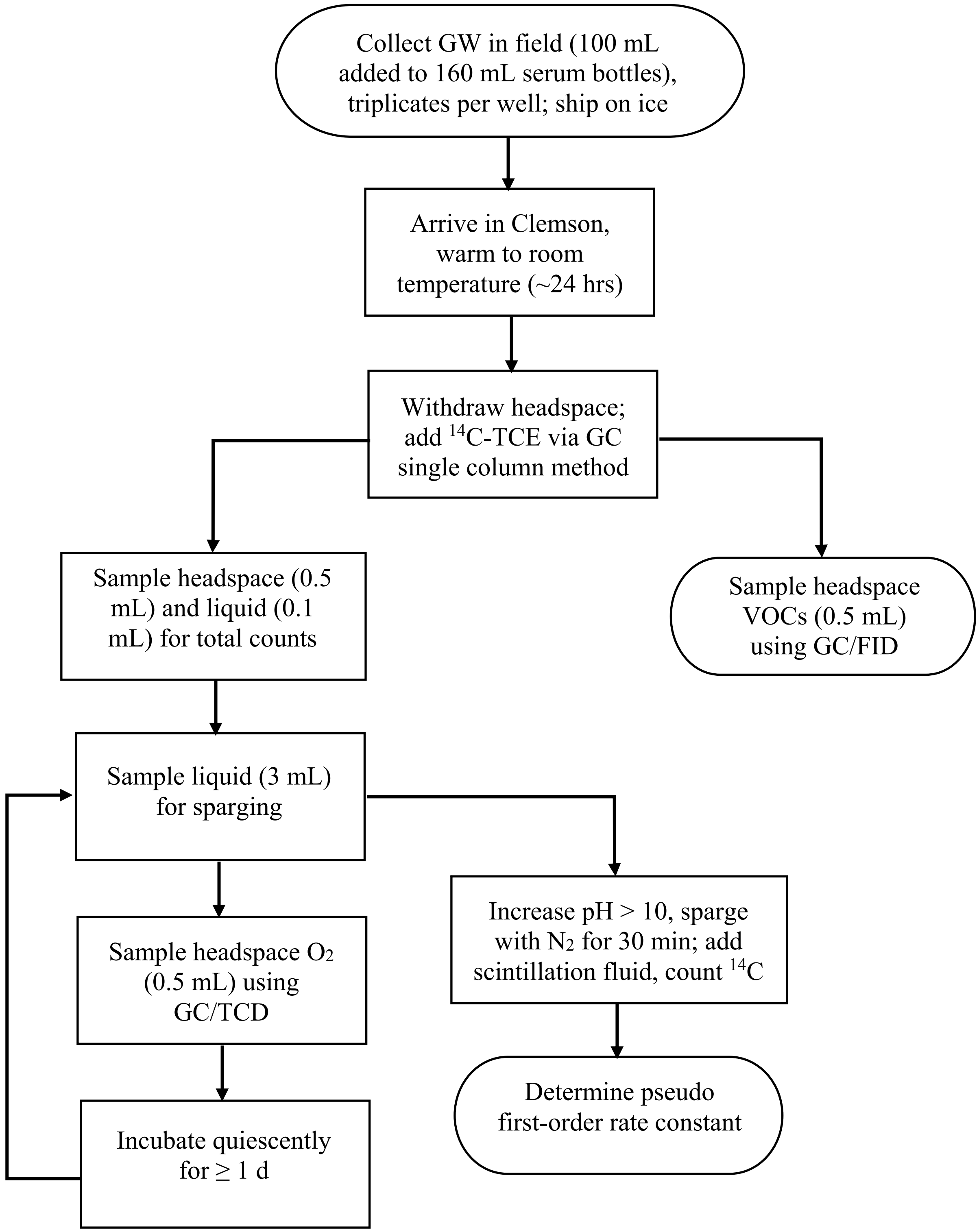

Figure 5.1.1. Overview of the Methodology Used for Experimental Wells, Including from TCAAP, Plattsburgh, Hopewell, Tooele, and Hill.

Deviations from the steps listed were made for different experiments or treatments.

Direct counts were made to quantify the total amount of radioactive material in each bottle. The headspace sample (0.5 mL gas) was removed using a gas-tight syringe (Valco® Series A-2). The liquid sample (0.1 mL) was removed using a 1.0 mL liquid syringe (Valco® Series C). The samples were injected immediately into a 20 mL borosilicate glass scintillation vial (Fisherbrand™) containing 15 mL of liquid scintillation cocktail (LSC). A hole (2.38 mm) was drilled in the polypropylene cap and a Teflon-faced gray butyl rubber septa was placed inside the cap. Inecting the samples through the septum minimized any losses of ^{14}C due to volatilization. The following equation was used to determine the total amount of ^{14}C present per bottle:

$$C_{tot,i,m} = \frac{S_{h,i}}{V_{h,s}} \cdot V_{h,b} + \frac{S_{l,i}}{V_{l,s}} \cdot V_{l,b} \tag{5.1}$$

where $C_{tot,i,m}$ = total measured dpm in a serum bottle; $S_{h,i}$ = dpm in a headspace sample; $V_{h,s}$ = volume of headspace sample (0.5 mL); $V_{l,b}$ = volume of headspace in a serum bottle (60 mL); $S_{l,i}$ = dpm in liquid sample; $V_{l,s}$ = volume of liquid sample (0.1 mL); and $V_{l,b}$ = volume of liquid in a serum bottle (100 mL).

The sparging test was conducted to determine the accumulation of ^{14}C products. Prior to removing liquid, 3 mL of room air was injected into the serum bottle using a 5 mL syringe (Valco® Series C). The liquid sample was immediately withdrawn and injected into a 20 mL borosilicate glass scintillation vial. Approximately 12 µL of 8 M NaOH was added to the 3 mL liquid sample using a 100 µL liquid syringe (Valco® Series C) to raise the pH above 10.5. The pH of the sample was confirmed qualitatively using a pH strip (BDH® VWR Analytical, pH 7.0-14.0, gradation of 0.5 units). The purpose of raising the pH above 10.5 was to ensure the retention of $^{14}CO_2$ in the aqueous phase as carbonate. The alkaline sample was sparged with N_2 gas (Airgas®) at a flow rate of 550±50 mL/min for approximately 30 min. The flow rate was controlled using air flow meters (Cole-Parmer, 1.4 LPM) connected to latex rubber tubing that terminated in a sterile, disposable needle (BD PrecisionGlide™, 22 G x 1 ½ in.). The vials were tilted on a 30-degree angle to facilitate better contact between the N_2 and liquid. The purpose of sparging was to remove VOCs, principally ^{14}C-TCE, so that any radioactivity remaining in the vial would be attributable to product formation and not residual ^{14}C-TCE. Following the sparging, 15 mL of LSC was added to the vials, which were then incubated quiescently in the dark for approximately 24 h before counting the beta radiation.

In order to prevent oxygen from becoming a limiting factor for co-oxidation of TCE, the concentration was measured in 0.5 mL samples using a GC equipped with a thermal conductivity detector (TCD) and a stainless-steel column packed with 100/120 Carbosieve S-II support (Supelco). The flow rate was approximately 50.5 ± 0.2 mL/min with N_2 gas as the carrier and reference gas. An isothermal temperature program (105 °C, 4 min) was used. O_2 eluted at 3.3 min. Room air (21% O_2) was used for calibration. After 40 to 46 days of incubation, the average O_2 level in the groundwater bottles was 12.0±0.28%; the lowest level observed was 7.50 %. This was considered adequate to avoid any limitation on co-oxidation, so that none of the experimental groundwater bottles received additional O_2.

5.1.4.2 Monitoring and ^{14}C product distribution

The groundwater samples and control bottles were monitored for a period of 40 to 46 d using the sequence of sampling events described in Figure 5.1.1, including direct headspace and liquid counts for total ^{14}C activity, sparging samples at alkaline pH to determine ^{14}C product accumulation, and O_2 headspace monitoring. Samples were analyzed most frequently over the first week of incubation.

On the last day that bottles were incubated, they were evaluated for routine parameters, along with a final analysis of VOCs in the headspace using the GC/FID method. Following the alkaline sparging test, an acidic sparging test (pH < 4) was used to determine the percentage of $^{14}CO_2$ in the ^{14}C products. The difference between the radioactivity remaining after alkaline sparging and acidic sparging tests was presumptively $^{14}CO_2$. The acidic sparging test was also performed with a 3 mL liquid sample that was added to a 20 mL glass scintillation vial; 12 µL of 6 M HCl was added decrease the pH below 4. The pH was confirmed using pH strips (BDH® VWR Analytical, pH 0-6.0, gradation of 0.5 units). The acidified sample was sparged with N_2 (550 ± 50 mL/min) for approximately 30 min using the same sparging apparatus described above. After sparging, 15 mL of LSC was added, the vials were incubated quiescently in the dark for approximately 24 h, followed by counting of the beta radiation.

For groundwater samples that exhibited a statistically signicant rate of ^{14}C product accumulation, additional confirmation of $^{14}CO_2$ was obtained by precipitation of the alkaline sparge water with barium. To do so, a larger liquid sample was used (10 mL). The sample was added into a 15 mL sterile, polypropylene centrifuge tube (VWR®). Approximately 50 µL of 8 M NaOH was injected to raise the pH above 10.5; the pH was checked using a pH strip. The samples were sparged with N_2 (550±50 mL/min) for approximately 30 min using the sparging apparatus described above. After 30 min, 3 mL of the alkaline solution was withdrawn from the 15 mL centrifuge tube and added to a 15 mL of LSC; this replicated the analysis performed with only a 3 mL liquid sample. Next, approximately 1.35 g of $Ba(OH)_2 \cdot 8H_2O$ (Alfa Aesar, CAS: 12230-71-6) was added to the remaining 7 mL of the sparged, alkaline liquid in the centrifuge tubes and vigorously mixed using a constant speed vortex mixer. The tubes were then centrifuged for 20 min (2,700 rpm). An aliquot of the centrate (2 mL) was withdrawn from the alkaline samples and added to 15 mL of LSC. The LSC vials were incubated quiescently in the dark for approximately 24 h before counting beta radiation. The centrate remaining in the centrifuge tubes was presumed to contain ^{14}C products other than $^{14}CO_2$, since $^{14}CO_2$ formed a barium carbonate precipitate. The soluble products are hereafter referred to as nonstrippable residue (NSR); the composition of the NSR was not investigated any further.

5.1.4.3 Determination of pseudo first-order decay constants (k)

^{14}C Measured Data

It was necessary to relate the ^{14}C products measured in the 3 mL sparged samples (Ss,i) to the total amount of ^{14}C products accumulated in a serum bottle (Ssb,i). This was accomplished by finding the product of the 3 mL liquid sparge counts (Ss,i) and the volume per sparge sample ($V_{s,r}$ or 3.0 mL) over the total liquid volume in the bottle ($V_{l,i}$) for that time interval:

$$S_{sb,t} = (S_{s,t})\left(\frac{V_{s,r}}{V_{l,t}}\right) \tag{5.2}$$

$V_{l,i}$ was determined by using the initial, measured volume of the liquid (i.e., through gravitmetric analysis) and subtracting 3.1 mL for each time interval.

Introduction to the Model:

Pseudo first-order rate constants (k) were determined by fitting measured ^{14}C product accumulation data (equation 2) to the summation of the following equation:

$$\Delta_i = C_{l,i-1,a} - C_{l,i-1,a}(e^{-k\Delta t}) \tag{5.3}$$

where Δ_i = the increase in ^{14}C products over the i^{th} interval between sampling events (i = 0 to 8 or 9, representing the number of sampling events); $C_{l,i,a}$ = concentration of ^{14}C products in the aqueous phase after removing the liquid and headspace samples, i.e., the beginning of the i^{th} interval; and Δt is the time between sampling events. It was assumed that Δ_i was zero at i=0 (i.e., there was no accumulation of ^{14}C products at time zero). Therefore, equation 5.3 only applies to the time intervals greater than $i = 0$.

The value for k was determined using MATLAB by minimizing the sum of squared errors between the prediction and the ^{14}C product data over time. Triplicate bottles were fit simultaneously to obtain a single value for k (i.e., as opposed to determining a k for each bottle and then taking the average).

Calculations were performed in two stages, with the first stage corresponding to the initial conditions and the second stage to all subsequent data points. Figure 5.1.2 provides an overview of the procedure used for several time intervals. The following sections describe the different stages of the model and the corresponding equations for each stage.

^{14}C Calculations for Time Zero

Prior to determining Δ_i, the initial conditions for the model were established using measured data. The initial liquid concentration of ^{14}C-TCE in the bottles before sampling ($C_{l,i,b}$) was calculated based on the total ^{14}C-TCE present and Henry's Law constant:

$$C_{l,i,b} = C_{tot,i,m}\left(\frac{V_{l,i}}{V_{l,i} + V_{g,i}H_c}\right) \tag{5.4}$$

where $C_{tot,i,m}$ = total dpm in the bottle (determined using equation 5.1); $V_{l,i}$ = the initial volume of liquid in the bottle (~100 mL at $i = 0$); $V_{g,i}$ is initial gas volume (~60 mL at $i = 0$); and H_c is the dimensionless Henry's Law constant for TCE (0.349 at 23 °C; Gossett, 1987). Equation 5.4 corresponds to point 1 on Figure 5.1.2.

The amount of ^{14}C removed due to withdrawal of the liquid at time zero ($S_{l,r}$) was calculated as follows:

$$S_{l,r} = C_{l,t,b}\left(\frac{V_{l,r}}{V_{l,t}}\right) \tag{5.5}$$

where $V_{l,r}$ = volume of liquid sample removed (3.1 mL = 3.0 mL for the sparging test + 0.1 mL for direct addition to LSC).

^{14}C was also removed during gas sampling. For the groundwater bottles, gas samples were removed to determine the total ^{14}C in the headspace and to measure O_2. The amount of ^{14}C removed in these samples ($S_{g,r}$) was calculated as follows:

$$S_{g,r} = \left(C_{tot,t,m} - C_{l,t,b}\right)\left(\frac{V_{g,r}(0.5)}{V_{g,t}} + \frac{V_{g,r}(0.5)}{V_{g,t} + V_{l,r}}\right) \tag{5.6}$$

where $V_{g,r}$ = total volume of gas removed at a sampling event (1.0 mL); and $V_{g,i}$ = total volume of gas in the bottle at the time step.

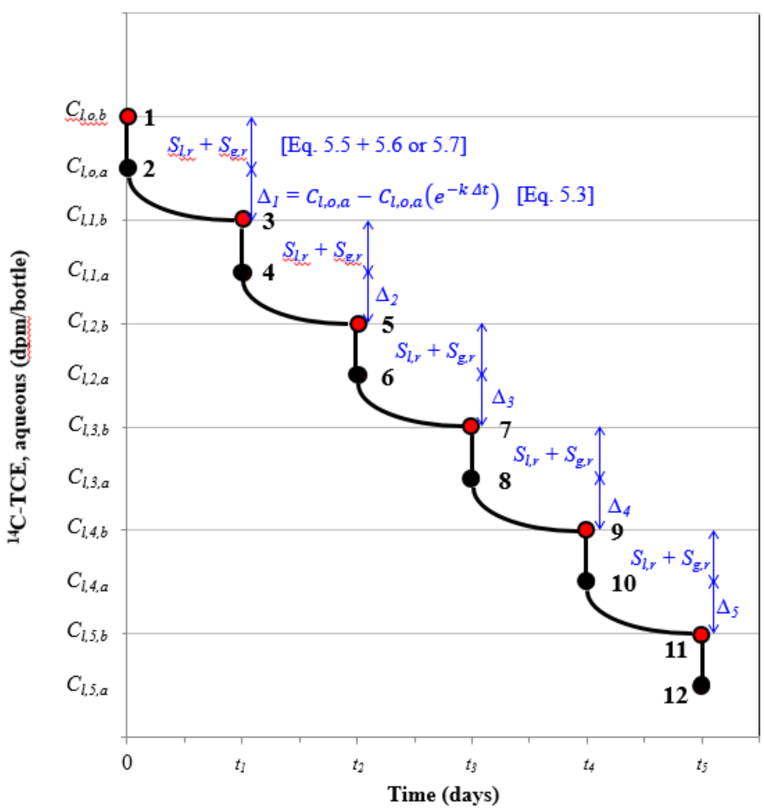

Figure 5.1.2. General Overview of Sampling Events and Respective Equations Used to Generate First-order Rate Constants with the MATLAB Model.

The red cirlces indicate the ^{14}C in the aqueous before sampling and the black circles indicate the ^{14}C in the aqueous phase after sampling.

For the DDI water controls and FSGW controls, only one headspace sample was removed per sampling event, to determine the total ^{14}C in the headspace; it was not necessary to measure O_2 in these bottles. Consequently, the amount of ^{14}C removed in the gas phase of the controls simplified to:

$$S_{g,r} = \left(C_{tot,i,m} - C_{l,i,b}\right)\left(\frac{V_{g,r}(0.5)}{V_{g,t}}\right) \tag{5.7}$$

The total ^{14}C removed during each sampling event ($S_{tot,r}$) was:

$$S_{tot,r} = S_{l,r} + S_{g,r} \tag{5.8}$$

Equation 5.8 was used to determine the vertical line from point 1 to 2 in Figure 5.1.2.

The calculated ^{14}C-TCE concentration in the bottle after the initial sampling event ($C_{tot,i}$) was:

$$C_{tot,i} = \left(C_{tot,i,m}\right) \cdot \left(S_{tot,r}\right) \tag{5.9}$$

Therefore, the ^{14}C-TCE liquid concentration in the bottle after the initial sampling event ($C_{l,i,a}$) was the product of $C_{tot,i}$ and the percent of TCE in the aqueous phase:

$$C_{l,i,a} = C_{tot,i}\left(\frac{V_{l,t} - V_{l,r}}{\left(V_{l,t} - V_{l,r}\right) + \left(V_{tot} - \left(V_{l,t} - V_{l,r}\right)\right) \times H_C}\right) \tag{5.10}$$

where V_{tot} = total volume of the serum bottles (160 mL). Equation 5.10 corresponds to point 2 in Figure 5.1.2.

For the initial conditions, it was assumed that no ^{14}C degradation products had formed. Therefore, Δ_i was set to zero for the time zero measurements because the initial point was not dependent on k, rather it was determined from the measured direct liquid and headspace counts.

<u>^{14}C Calculations for Conditions Following Time Zero</u>

For all samples taken after time zero, the quantity of ^{14}C products that accumulated was measured based on processing of the 3 mL aqueous samples. The amount of ^{14}C removed from a bottle as a consequence of sampling was calculated. The increase in ^{14}C products formed during incubation between sampling points (Δ_i) was calculated by evaluating first-order degradation reaction kinetics using the value for the previous ^{14}C-TCE concentration in the aqueous phase ($C_{l,i-1,a}$) and the pseudo first-order rate constant (k):

$$\Delta_i = C_{l,i-1,a}\left(1 - e^{-k(t_i - t_{i-1})}\right) \tag{5.11}$$

where $i \geq 1$. Equation 5.11 represents the curved path from points 2 to 3, 4 to 5, 6 to 7, 8 to 9, and 10 to 11 in Figure 5.1.2. The accumulated ^{14}C products in the bottle was calculated as the sum of the products formed during incubation between sampling events (Δ_i) and the previous summation of the products ($\sum\Delta_{i-1}$):

$$\Sigma\Delta_i = \Delta_i + \Sigma\Delta_{i-1} \tag{5.12}$$

The resulting accumulated ^{14}C products in the bottle determined from the model was compared to the experimental data using squared differences. In addition, Δ_i (equation 5.11) was used to determine the concentration of ^{14}C-TCE in the liquid phase ($C_{l,i,b}$):

$$C_{l,i,b} = C_{l,i-1,a} - \Delta_{i,p} \tag{5.13}$$

Equation 5.13 corresponds to points 3, 5, 7, 9 and 11 in Figure 5.1.2.

The result from equation 5.13 was used to determine the amount of dpm removed from the liquid and gas during sampling events. The dpm removed in the liquid is the same as equation 5.5 for time zero. The dpm removed from the gas in the experimental bottles was a modified version of equation 5.6:

$$S_{g,r} = (C_{tot,i-1} - C_{l,i,b})\left(\frac{V_{g,r}(0.5)}{V_{g,i}} + \frac{V_{g,r}(0.5)}{V_{g,i} + V_{l,r}}\right) \tag{5.14}$$

Additionally, the dpm removed from the gas in the DDI and FSGW control bottles was a modified version of equation 5.7:

$$S_{g,r} = (C_{tot,i-1} - C_{l,i,b})\left(\frac{V_{g,r}(0.5)}{V_{g,i}}\right) \tag{5.15}$$

The total dpm removed was the same as shown in equation 5.8. The removal of the total dpm corresponds to the vertical lines between points 3 to 4, 5 to 6, 7 to 8, 9 to 10, and 11 to 12 in Figure 5.1.2.

Once the total dpm removed was known, the final, total calculated ^{14}C-TCE liquid concentration in a bottle after sampling ($C_{tot,i}$) was determined:

$$C_{tot,i} = C_{tot,i-1} - S_{tot,r} - \Delta_i \tag{5.16}$$

$C_{tot,i}$ combines the headspace and liquid TCE concentrations, so it must be appropriately distributed between the headspace and liquid to find $C_{l,i,a}$ using the percent in the aqueous phase, similar to equation 5.10:

$$C_{l,i,a} = C_{tot,i}\left(\frac{V_{l,i} - V_{l,r}}{(V_{l,i} - V_{l,r}) + \left(V_{tot} - (V_{l,i} - V_{l,r})\right) \times H_C}\right) \tag{5.17}$$

Equation 5.17 was used to determine points 4, 6, 8, 10, and 12 in Figure 5.1.2.

Model Fitting

In the MATLAB script, the valve of k was iterated using equation 5.11 to 5.17 until a minimum valve was obtained for the sums of squares of error determined as the squared difference between the experimental ($S_{sb.i}$) and estimated ^{14}C product ($\sum\Delta_{i-1}$) values.

The MATLAB function used for the iterative approach was *lsqcurvefit*, which is a nonlinear curve-fitting solver function that uses the trust-region-reflective algorithm. The 95% confidence intervals were determined using the *nlparci* MATLAB function with the Jacobian matrix and residual vector determined from *lsqcurvefit.* The full MATLAB script can be found in Appendix D.

5.1.4.4 Liquid scintillation counter

Beta radiation was quantified using a Wallac 1220 Quantulus (PerkinElmer, Inc.) liquid scintillation counter. The counter was connected to a desktop computer equipped with proprietary WinQ software (PerkinElmer, Inc.). The *^{14}C (high energy beta)* configuration was used in the WinQ program to count the ^{14}C samples, with modifications. Windows 1 and 2 (used to detect beta radiation) in the program were modified and expanded from the default sizes of 50-650 and 70-500 to 5-700 and 1-700, respectively, to capture the entire range of beta radiation emission. The samples were counted for 15 min and the external standard quench parameter (SQP) was used for quench correction. The quench efficiency curve for the counting protocol was determined using prepared ^{14}C standards (Beckman Instruments Inc., quenched carbon-14 standards set) with a counting time of 15 min. The quenching curve data (Appendix D) follows the following parabolic equation:

$$-4.25 \times 10^{-4}x^2 + 8.06 \times 10^{-1}x - 2.92 \times 10^2 \tag{5.18}$$

where x is the measured SQP value. The efficiency values were determined using the measured counts per min ($cpm_{measured}$) from the ^{14}C standards over the known dpm (dpm_{known}) values of the standards:

$$Efficiency = \left(\frac{cpm_{measured}}{dpm_{known}}\right) \times 100\% \tag{5.19}$$

^{14}C samples were incubated for different time periods prior to counting. Direct headspace and liquid samples were counted within 3 h of the sampling event. The sparged samples were incubated, quiescently in the dark for approximately 24 h before counting. The long incubation time for the sparged samples reduced chemilumenscence arising from the high pH of the 3 mL of groundwater mixed with the LSC.

5.1.5 Task 5 - Laboratory Work to Implement Enzyme Activity Probes and the qPCR Assays for Oxygenase Enzymes that can Co-Oxidize TCE

PNNL assayed water samples for the density of bacteria that react to one of three Enzyme Activity Probes. The probes determine if the bacteria express an oxygenase enzyme that can carry out aerobic co-oxidation of PCE or TCE. PNNL also used qPCR to assay water samples for the abundance of gene copies for selected oxygenase enzymes. PNNL assayed water from the same wells that were sampled for Task 4. This allowed a statistical comparison of the abundance of cells that respond to an enzyme activity probe, or gene copies of oxygenase enzymes, to the directly measured rate of aerobic biodegradation.

<u>*Aromatic Oxygenase Activity*</u>

Groundwater was vacuum filtered onto 0.22 μm, 25 mm diameter, black, polycarbonate filters.

Samples were then exposed to 5 mM of an enzyme activity-dependent probe (phenylacetylene, *trans*-cinnamonitrile, 3-hydroxyphenylacetylene) for 10 minutes. Table 2.2.1 presents the list of the enzymes targeted by individual EAPs. Filters were mounted on a glass microscope slide with non-fluorescent immersion oil and a cover slip, and examined for fluorescent cells by epifluorescent microscopy. Triplicate slides, and a minimum of 20 random fields on each slide were counted for each sample and each EAP. A suite of aromatic oxygenase-containing bacteria, including *Pseudomonas putida* F1, were used as a positive control to verify EAP signal.

SMMO Enzyme Activity

To monitor for the presence of soluble methane monooxygenase, whole water (unaltered) groundwater samples were filtered onto 25mm Supor filters, and placed into separate glass Petri plates. One-mL of 5mM coumarin solution in phosphate buffer was pipetted onto each filter, and incubated for 10 minutes at room temperature. Following the incubation, phosphate buffer was used to wash the product from each filter. Solution fluorescence was determined (excitation wavelength 338 nm, emission wavelength 450 nm) using a fluorescence spectrophotometer, with a quartz cuvette of 1 cm path length. Fluorescent scans were performed in triplicate for each of the samples. *Methylosinus trichosporium* OB3b was used as a positive control to verify the signal from coumarin.

DNA Extraction and PCR amplification

Approximately one liter of groundwater was filtered and then DNA was isolated from cells trapped on filters. DNA extraction was performed using both FastDNA and the MoBio Soil DNA kit as described by the manufacturers; two kits were used to ensure that biases associated with one kit or another did not provide a false positive for the presence of the gene of interest. DNA yield from the experiments was determined using a Bioanalyzer and quantification using Picogreen assays.

PCR amplification reactions were performed in 50 μL (total volume) reaction mixtures in 0.2 mL thin-walled tubes using a DNA thermocycler. All qPCR assays were performed using a Bio-Rad CFX96 Real-Time PCR Detection System (Bio-Rad Laboratories, Hercules, CA). A SsoAdvanced SYBR Green supermix kit (Bio-Rad Laboratories, Hercules, CA) was used for amplification and real-time fluorescence measurement. Following amplification, qPCR product size was confirmed using a DNA 1000 Chip Kit, which was run on a 2100 Bioanalyzer. The PCR conditions for the toluene oxygenase primers was modified from Baldwin et al. (2003), using a large number of target organisms. The PCR primers that were used during a first round of testing are designated: RMO-F/R, which amplify the toluene-3 and -4-monooxygenase genes, TOD-F/R which amplifies the toluene 2,3-dioxygenase gene, and PHE-F/R which amplifies the toluene-2, -3, -4-monooxygenase genes (Baldwin et al., 2003). The sMMO enzyme was targeted using the mmoX primer pair (McDonald et al., 1995). Depending on results from the first round, other enzymes such as catechol 2,3-dioxygenase, alkane monooxygenase, and particulate methane monooxygenase were also targeted.

Comparison of EAP and qPCR Targets

The relationship between the EAPs and the qPCR analyses are shown in Table 2.2.1. Some of the targets for the qPCR analyses do not directly correspond to EAP analyses and were completed in order to target other oxygenase enzymes which are also known to cometabolize contaminants such as chlorinated solvents. While there are dozens of known enzymes, some are more commonly found in environmental systems and/or are potential targets for remediation strategies such as bioaugmentation or biostimulation (propane, methane, benzene etc.). Table 2.2.1 provides a list of all of the qPCR targets that were used for the current Sites.

5.1.6 Task 6 – Analyze Data, Validate Cost and Performance Data, and Prepare Final Report

This task represents what is presented in this report, which details the findings of the work described in the Demonstration Plan (ESTCP, 2016). The contribution of abiotic degradation and aerobic biodegradation at each site is evaluated herein. This is accomplished by comparing the rate constant for attenuation associated with abiotic degradation by magnetite in the aquifer matrix and the rate constant associated with aerobic co-oxidation to the bulk rate constant for natural attenuation at the site. If the rates of abiotic degradation by magnetite or the rates of aerobic biodegradation can meet the goals for MNA, this has the potential to save the DOD significant amounts of money in unnecessary remediation costs.

Project ER-201129 showed the relationship between magnetic susceptibility and degradation rate using magnetic susceptibility data from soil core samples. The material presented in this report shows that a relatively inexpensive downhole probe can be used for measurement of magnetic susceptibility in lieu of using soil core samples, the acquisition of which can be quite expensive at sites where intrusive site characterization activities have already been completed. This has the potential to save the DOD significant amounts of money in unnecessary drilling costs.

This report also evaluates the utility of Enzyme Activity Probes and qPCR assays by comparing the rate constant for aerobic co-oxidation to the abundance of cells that react with EAPs or the abundance of genes copies for oxygenase enzymes. To allow extrapolation of this approach to other sites, this report provides protocols for collecting and analyzing magnetic susceptibility data, how to perform the ^{14}C-TCE assay and the Enzyme Activity Probe assay, and the procedures to submit samples for qPCR evaluation.

Cost and performance data are provided for down-hole determination of magnetic susceptibility, for the Enzyme Activity Probes, for the qPCR assays, and for the direct assay of the rate constant for aerobic biodegradation. Cost and performance data are validated to determine if the performance objectives established in Section 3 have been met.

5.1.7 Task 7 – Project Management

This task was used for project management and project communication, and is a fairly common task.

BASELINE CHARACTERIZATION

Section 4 provides an in-depth discussion for the majority of baseline characterization activities. Baseline characterization was conducted for magnetic susceptibility using borehole core samples and fixed-base laboratory analyses at all of the sites discussed in Section 4 except Hill AFB OU-10. The results of baseline sampling for magnetic susceptibility using core samples and fixed-base laboratory analyses are summarized in Table 4.1.2, and discussed in Section 4.

Previous baseline characterization for EAP was completed for Hill AFB OU-10 and for the Hopewell Precision Site prior to the field work conducted under this effort, as described in Section 4. For Hill AFB, qPCR analyses were also performed. For the other sites, baseline for EAP and qPCR was established during this demonstration. No direct correlation between quantification of oxygenase enzymes to TCE transformation rates was performed prior to this work, so a baseline for this comparison is provided in this report.

The only additional baseline characterization that was required for this demonstration was development of the ^{14}C-TCE assay. Since the ^{14}C-TCE assay had not previously been deployed for the purposes proposed in this study, it was not possible to precisely define baseline activities. However, as described in Section 3.2.2.2, a preliminary evaluation was performed with locally sourced water from a seep that presumptively contained a high level of dissolved organic matter. It was anticipated that the naturally occurring organics included aromatic compounds that would support the induction of oxygenases. A net rate coefficient of $2.37\times10^{-2}\pm$ 1.67×10^{-2} yr^{-1} was determined, which gives a half-life of 29 yr (95% confidence interval = 17-99 yr). This result suggested that the ^{14}C assay is adequately sensitive to detect TCE co-oxidation in groundwater samples at rates that are meaningful for evaluating natural attenuation.

The waste generated from this part of the project is mixed waste due to the presence of TCE and ^{14}C. However, the level of ^{14}C activity is sufficiently low that disposal as a hazard waste is acceptable. All procedures required by Clemson University for disposal of liquid hazardous waste were followed.

5.2 TREATABILITY OR LABORATORY STUDY RESULTS

5.2.1 Treatability or Laboratory Studies Performed by Clemson

The use of ^{14}C-labeled compounds to determine the rate at which a parent compound degrades, as well as the identity of the products formed, has been in practice for decades. This includes the fate of ^{14}C-TCE and other chlorinated organic contaminants. The Freedman laboratory has extensive experience in the use of ^{14}C-labeled compounds. For example, Darlington et al. (2008, 2013) evaluated biotic and abiotic degradation of ^{14}C-TCE and ^{14}C-*c*DCE in groundwater plus crushed sandstone from a site in California. Shan et al. (2010) used ^{14}C-labeled carbon tetrachloride and chloroform to evaluate biostimulation and bioaugmentation for in situ treatment of groundwater at a different site in California. Fullerton et al. (2013) synthesized ^{14}C-labeled ethene by supplying ^{14}C-*c*DCE to a halorespiring culture enriched in *Dehalococcoides*. The ^{14}C-ethene was then used to evaluate anaerobic oxidation of ethene under sulfate reducing conditions.

Although there is an extensive collection of literature on experiments with ^{14}C-labeled environmental contaminants, it is noteworthy that the frequency of using ^{14}C has diminished over the last decade or so. As a consequence, many ^{14}C-labeled compounds such as TCE are no longer commercially available as a stock item. Custom sysnthesis is required to obtain the compound, including the ^{14}C-TCE used for this project.

The most common way for vendors to deliver ^{14}C-labeled compounds is dissolved in a solvent. For this project, the ^{14}C-TCE was purchased from Moravek Biochemicals dissolved in acetonitrile. This necessitated separating the TCE from the solvent. The same GC approach described in previous research (Darlington et al., 2008, 2013) was used; this also resulted in an increase in the purity of the ^{14}C-TCE added to groundwater samples.

An important feature of the assay developed for this project in comparison to past work is that water samples were repeatedly removed from the same serum bottles over time, in order to measure the accumulation of ^{14}C-products. The size of the aqueous samples (3.1 mL) was large enough so that it became necessary to take into account the ^{14}C activity removed with each sample. Consequently, a mass balance model was needed in order to account for both the ^{14}C products that accumulated and the ^{14}C removed during sampling. Fitting of the ^{14}C product data to the mass balance model permitted determination of the pseudo first order rate coefficient. In the previous studies, the distribution of ^{14}C was determined using the entire contents of a serum bottle. As such, in order to determine a rate, it was necessary to sacrifice replicate bottles over time. This was not feasible for the current project, due to the large number of bottles that would have needed to be prepared. This led to development of an assay that allowed for repeat sampling from the same bottle.

5.2.2 Treatability or Laboratory Studies Performed by PNNL

A suite of EAPs was designed that permitted the determination of specific aerobic cometabolism of chlorinated ethylenes, most notably TCE. EAPs that serve as alternate substrates for TCE cometabolizing enzymes have been developed for four separate aromatic oxygenases (Keener et al., 1998; 2001; Miller et al., 2001; Clingenpeel et al., 2005), and for the soluble methane monooxygenase (SMMO; Miller et al., 2001). Specific EAP and the targeted co-metabolic enzymes are shown in Table 5.3.1. These non-fluorescent probes are transformed by the enzymes into a quantifiable fluorescent signal upon transformation, thus providing direct evidence of cometabolic enzyme activity. Enzyme probes have been evaluated at a number of DOE (9), DOD (16), EPA (5) and industrial sites (9) over the last ten years (Lee et al., 2005; Lee et al., 2007; Wymore et al., 2007). Based on these analyses of groundwater with TCE concentrations ranging from <100 μg/L to >10,000 μg/L, it appears that enzyme probes provide a direct estimate of aerobic cometabolic enzyme activity for subsurface populations.

Application of EAP's at contaminated sites has provided valuable information regarding the presence and activity of in situ microbial enzyme systems important for aerobic cometabolism for plume-wide assessment of intrinsic assessment of degradation.

Table 5.2.1. EAP and Targeted Oxygenase(s)/Pathway

Probe	Pathway
3-hydroxyphenylacetylene (3HPA)	toluene-2-monooxygenase toluene-3-monooxygenase toluene-2,3-dioxygenase
Phenylacetylene (PA)	toluene-2,3-dioxygenase toluene-3-monooxygenase toluene-2-monooxygenase
trans-cinnamonitrile (CINN)	toluene-2,3-dioxygenase
Coumarin, naphthalene	Soluble methane monooxygenase

Two recent examples where EAP, and combined EAP/qPCR for one, was applied, led to an additional line of evidence for natural attenuation that was accepted by regulators and include in the final records of decision (ROD) for the sites (Lee and Lee 2012). At Travis Air Force Base, wells within TCE plumes and control wells outside of these locations were analyzed using EAP and qPCR.

Results from these analyses indicated that there were communities with oxygenase enzymes that were active and when coupled with receding contaminant plumes, indicated an additional line of evidence for natural attenuation.
At an industrial site, groundwater samples (14) from the Wichita Northern Industrial Corridor (NIC) were assayed using enzyme activity probes (Lee et al. 2016). Samples were filtered and EAP for aromatic oxygenase enzymes (phenylacetylene, 3-hydroxyphenylacetylene and cinnamonitrile) and one for soluble methane monooxygenase (coumarin) were applied.

Eight of the groundwater samples assayed showed the presence of enzymes that oxidized all three probes to a fluorescent product, while only three showed no significant fluorescence. The remaining three samples showed fluorescence with only one or two aromatic oxygenases. All samples showed some fluorescence when treated with coumarin, but only four showed moderate to high levels of fluorescence. Based on the EAP data, there is evidence that there is potential for significant intrinsic aerobic biodegradation at most locations tested; with eight of the sampling sites showing activities for all three aromatic EAPs under in situ conditions. All samples showed some SMMO activity, while three showed moderate activity and one groundwater sample showed high SMMO activity.

5.3 DESIGN AND LAYOUT OF TECHNOLOGY COMPONENTS

This section provides a description of all technology components. Provided is a subsection for each significant technology component describing its design and locations where it was implemented. Sampling locations are presented in Section 4.

5.3.1 Magnetic Susceptibility Sonde

Figure 5.4.1 shows the exterior of the magnetic susceptibility sonde. This figure also includes probe dimensions and operating parameters. As can be seen from this figure, the magnetic susceptibility sonde has a diameter of 45 mm (1.77 inches).

For the HM-453S used in this study, the Tx-Rx spacing (Section 2.2.1) is 25 cm (9.84 inches). This equates to optimal readings being made at roughly 20 cm (~8 inches) from the sonde, with the accuracy of the magnetic susceptibility measurements dropping off beyond this distance. Based on this, boreholes less than about 40 cm (~16 inches) in diameter are optimal for the HM-453S. Magnetic susceptibility readings made in boreholes larger than this will not be as accurate as those made in smaller boreholes.

In addition to borehole diameter, and well construction materials, the magnetic susceptibility sonde is particularly sensitive to temperature. Because of this, the sonde must be lowered into the formation water and allowed to equilibrate for at least 15 minutes prior to calibration and subsequent use.

The sonde reports volume magnetic susceptibility in S.I. units (International System of Units or Système International d'unités). The volume magnetic susceptibility values were converted to mass magnetic susceptibility by dividing by an assumed bulk density for aquifer material. The porosity of the aquifer material was assumed to be 0.35, and the particle density was assumed to be 2,650 kg/m^3, resulting in an assumed bulk density of 1,700 kg/m^3. Following these assumptions, the working range of the HM-453S sonde extends from 4.12E-9 m^3/kg to 4.12E-5 m^3/kg.

The sonde was recalibrated immediately prior to use in each monitoring well. The sonde was first calibrated against air, which was taken to have a value of 0, and then against a standard that was equivalent to a magnetic susceptibility of 2.94E-6 m^3/kg. The standard was contained in a holder that positioned the standard at a fixed location alongside the sonde. The response of the sonde was adjusted to match the value of the standard. The holder containing the standard was removed and the sonde was introduced into either 5.1 cm (2 inch) and 10.2 cm (4 inch) inner diameter polyvinyl chloride (PVC) groundwater monitoring wells using a Mount Sopris Instruments R-4200-1000-200 Mini Winch (Figure 5.4.2). Data from the sonde were recorded using the Mount Sopris Instruments R-5MXA-1000 Matrix Console (Figure 5.4.2). The sonde is capable of taking measurements when it is being lowered into, or raised from, a monitoring well. The sonde was lowered into, or raised from, monitoring wells at a rate of about 9 feet per minute, and magnetic susceptibility measurements were collected about every 1.3 seconds. This equates to about 8.7 readings being taken for every foot the sonde travels down or up the borehole. The sonde was not centered in the well or intentionally forced against the sidewall as it was introduced into the well. The magnetic susceptibility sonde was found to fit down both 2-inch (50.8 mm) and 4-inch (101.6 mm) PVC monitoring wells. However, if a 2-inch PVC monitoring well was compromised, such as with uneven joints or casing that was not sufficiently straight, then it was problematic to get this sonde into the well.

The sonde will interact with steel or iron used in the construction of the well and cause erroneous readings. Magnetic susceptibility measurements using a sonde can be successfully made in uncased wells or in cased wells constructed entirely of PVC or other materials containing no steel or iron. Steel centralizers used to center the well in the borehole can cause local interference with magnetic susceptibility measurements. In addition, any dedicated sampling equipment such as sampling pumps and piping, or Hydrasleeve® samplers must be removed prior to magnetic susceptibility sampling.

The components required to collect downhole data using a magnetic susceptibility sonde such as that shown in Figure 5.4.1 include (Figures 5.4.2 and 5.4.3):

1) Sonde with coaxial cable.
2) Tripod with pulley to guide the wireline cable with the sonde attached down the well.
3) Winch.
4) Data recorder to record and reduce data.
5) WellCAD or similar to analyze and display data.

Probe Parameters

Diameter	45 mm
Length	125 cm
Weight	4.5 kg
Max. Working Temperature/Pressure	75°C/20 MPa
Min. No. of Cable Conductors	2
Supply Voltage Range	30 – 45 V_{DC}
Max./Nominal Current Consumption	100/40 mA_{DC}
Supply Voltage Polarity	+ on central cond.
	– on probe casing

Measuring Parameters

Sensor	four coil system
Intercoil Spacing 1. channel	25 cm
Intercoil Spacing 2. channel	30 cm
Operating Frequency	≈2 kHz
Communication (negative pulse)	0 – 20 000 cps
Measuring range	10^{-5} – 0.5 SI units
	10^{-4} – 2 SI units
Accuracy	< 3% F.S.
Zero Drift	< 2 10^{-5} SI units/10°C

Figure 5.4.1

W&R Instruments HMM-453-S Borehole Magnetic Susceptibility Sonde With Dimensions

WIEDEMEIER & ASSOCIATES

Date: 10/15/16
Client: ESTCP
Revision Number: 0
Drawn By: THW

Figure 5.4.1. W&R Instrument HMM-453-S Borehole Magnetic Susceptibility Sonde With Dimensions

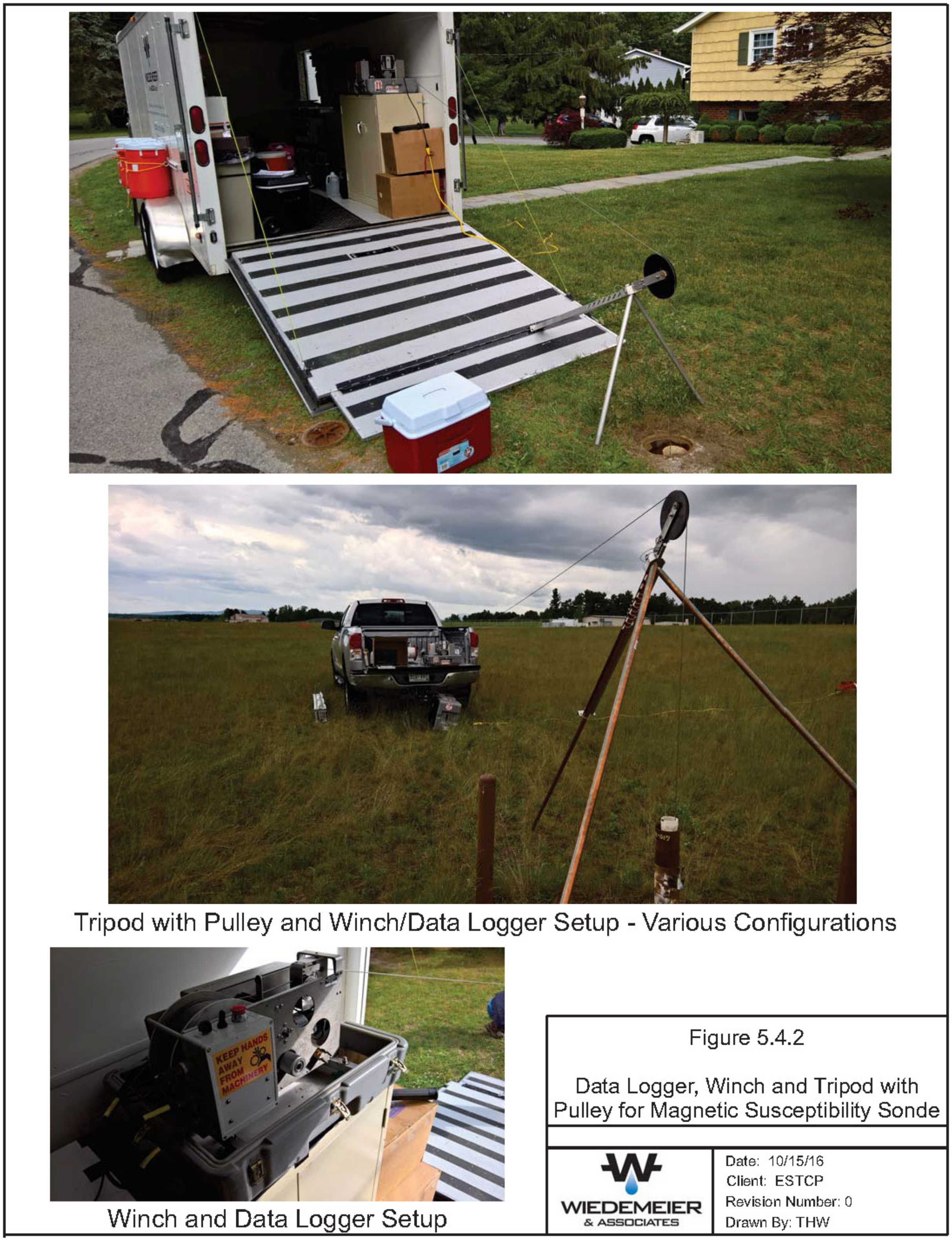

Figure 5.4.2. Data Logger, Winch and Tripod with Pulley for Magnetic Susceptibility Sonde

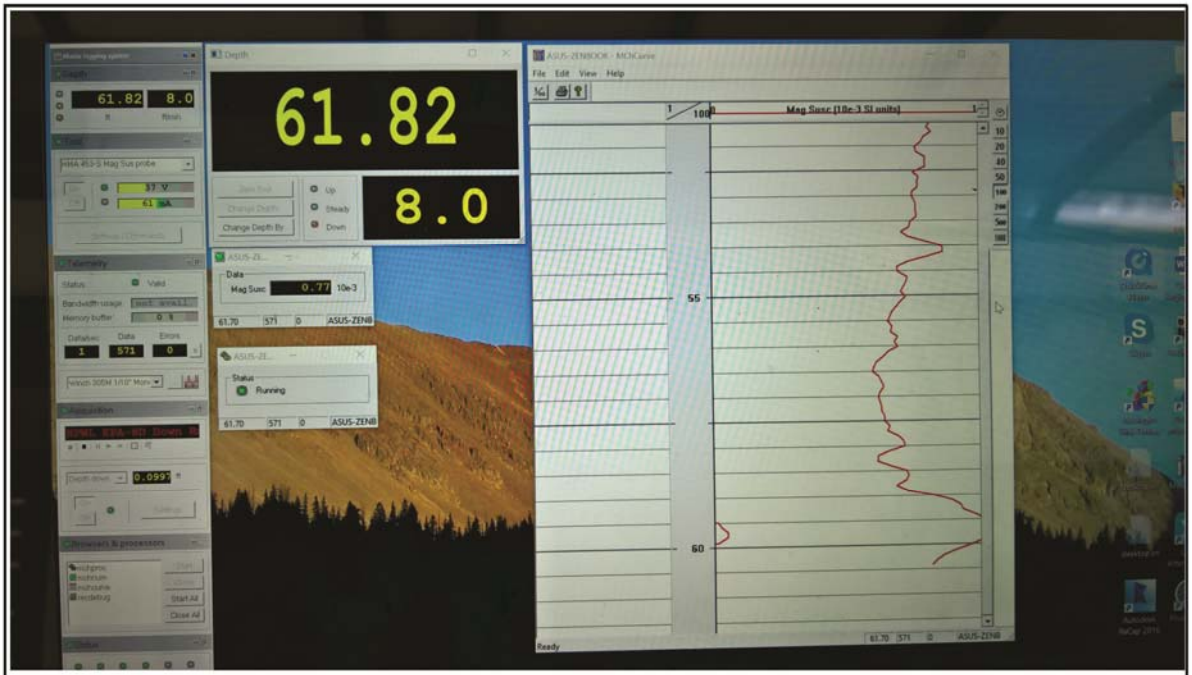

Figure 5.4.3

Real-Time Data Readout During Logging with a Magnetic Susceptibility Sonde

WIEDEMEIER & ASSOCIATES

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Client: ESTCP
Revision Number: 0
Drawn By: THW

Figure 5.4.3. Real-Time Data Readout During Logging with a Magnetic Susceptibility Sonde

Figure 5.4.2 shows the data logger, winch, and tripod (various configurations) used to lower the magnetic susceptibility sonde into a monitoring well to collect magnetic susceptibility data. The data logger is attached directly to the winch and is then connected to a computer. The tripod and attached pulley are situated over the well and the sonde is slowly lowered, at a rate on the order of 10 feet per minute, into a 2-inch or 4-inch PVC monitoring well using the winch. A 1000- or 2000-watt invertor generator was used to power the winch and data logger assembly. After testing, a 1000-watt invertor generator was found to be sufficient for this configuration, with the sonde being lowered to depths as great as 450 feet below ground surface (bgs). As with any downhole equipment, the magnetic susceptibility sonde was thoroughly decontaminated between each well, as described in Section 5.6.6.

The data from the data logger was reduced using WellCAD, a PC-based composite log package, which combines comprehensive graphic editing mechanisms and data processing tools. It combines display, editing and analysis capabilities for well data, and is used in a wide range of applications. The basic module incorporates all features and tools necessary to import, edit, process, and display monitoring well data acquired using a magnetic susceptibility sonde. After processing with WellCAD, data were exported to Microsoft Excel for final data analysis.

5.3.2 Develop a ^{14}C-Labeled Tracer Procedure to Directly Assay the Rate of TCE Aerobic Biodegradation

Details on development of the ^{14}C-TCE assay are presented in sections 2.2.2.1; 3.1.2; 3.2.2; 5.1.3; and 5.1.4. The first task was to evaluate an improved method for purifying the ^{14}C-TCE stock solution, with the goal of minimizing the amount of ^{14}C impurities added to the serum bottles that accompany the ^{14}C-TCE. The lower the initial level of impurities, the easier it becomes to detect a statistically significant increase in ^{14}C products over a relatively short timeframe (e.g., several days). In previous studies (e.g., Darlington et al., 2008, 2013), a single GC column was used for purification. In this study, two columns in series were also evaluated. It turned out that the dual column approach did not yield a statistically significant lower level of impurities. With the single and dual column methods, the target of 0.01% impurities was not met; the initial level of impurities was closer to 0.05% of the total ^{14}C added to the serum bottles. However, this was compensated for by increasing the duration of the assay, allowing for detection of an increase in ^{14}C products above the initial level impurities in the bottles. Using this approach, the lowest rate constant measured was 0.00658 yr^{-1}, which translates to a half-life of 105 yr. While it may be possible to lower the detection limit of the assay, lower rates would not likely have any practical value from the standpoint of assessing MNA.

The assay involved addition of ~100 mL of groundwater, DDI water, or FSGW to 160 mL serum bottles. Following addition of purified ^{14}C-TCE, accumulation of ^{14}C products was measured in 3 mL samples removed eight or nine times, over 40 to 46 days of incubation. The pH of the 3 mL samples was raised above 10 to retain $^{14}CO_2$, and then the water was sparged for 30 min to remove the residual ^{14}C-TCE, leaving behind only the ^{14}C products. An experiment was performed to determine if 30 min of sparging was adequate to remove all of the unreacted TCE. Sparging for 60 min was tested and shown not to further lower the ^{14}C products left after sparging. Consequently, a 30 min sparging time was used.

In order to determine a first order rate constant, the rate of ^{14}C product accumulation in groundwater must be greater than the rate of accumulation in sterile controls. Initially, DDI water was used as the negative control. It was subsequently determined that FSGW controls are a better representation of the background level of product formation; these were used to calculate net first order rate constants for eight of the 19 wells evaluated.

Section 5.1.4 specifics how the first order decay rate constant was calculated. A mass balance model that included the first order decay coefficient was fit to the measured amounts of ^{14}C products formed. The optimum value for the rate coefficient was found by minimizing the sums of squares of error between the measured and predicted amount of ^{14}C products over time. Details on the methods for counting ^{14}C activity are provided, as are the methods to quantify and/or detect VOCs by GC/FID and the amount of oxygen present in the headspace by GC/TCD.

When the incubation period was complete (40-46 days), samples were evaluated using both alkaline and acidic sparging. The difference between the two allowed for calculation of the percentage of product in the form of $^{14}CO_2$. $^{14}CO_2$ was further confirmed by precipitation with barium.

The ^{14}C assay was validated using locally sourced water from a seep with a high content of organic debris. A statistically significant rate of TCE co-oxidation was observed, confirming the viability of the assay. Additional evidence for the efficacy of the assay was obtained using a propanotrophic enrichment culture that is known to co-oxidize TCE.

The propanotrophic culture was used to evaluate the potential impact of sample storage conditions on the rate of ^{14}C product accumulation. Storage at 4 °C overnight, followed by warming to room temperature overnight, did moderately reduce the first order reaction rate coefficient when considering the full incubation period (40 d). This suggested that results for the groundwater samples are conservative with respect to in situ conditions. Nevertheless, shipment of groundwater sample to a laboratory that is licensed to handle ^{14}C is a requirement for the assay, and shipment on ice is recommended to avoid even more significant decreases in co-oxidation activity that may occur if the samples are left at ambient temperature.

5.3.3 Application of EAP and qPCR

Processing of samples using EAP and qPCR was accomplished using the parallel work-flow outlined in Figure 5.4.4. Replicate samples, positive/negative controls, matrix spikes and blanks are processed and then results are compared.

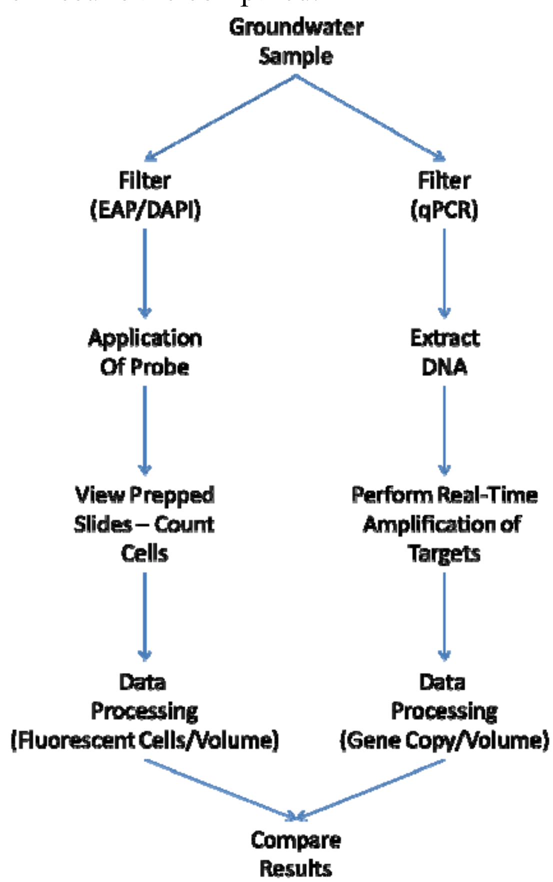

Figure 5.4.4. Schematic of Process for Application of Molecular Biological Tools (EAP and qPCR).

5.4 FIELD TESTING

Field testing consisted of collection of groundwater samples from the wells discussed in Section 4 for the analyses listed in Section 5.6. In addition, a magnetic susceptibility sonde as described in Section 5.4.1 was lowered into the wells identified in Section 4. Magnetic susceptibility versus depth data were collected using the downhole sonde in monitoring wells that were installed in boreholes from which magnetic susceptibility data were collected from soil borehole core data and analyzed in a fixed-base analytical laboratory.

An additional site not described in Section 4 was used for the magnetic susceptibility analysis. Specifically, monitoring well U2-043 at OU-2 at Hill AFB was analyzed for mass magnetic susceptibility. This is because borehole core samples were collected from the borehole in which this well was installed on December 7th and 8th 2015. Because the sampling team was so close to this Operable Unit during sampling at Hill AFB, OU-10, groundwater monitoring well U2-043 was sampled with the downhole sonde upon completion of sampling at OU-10.

5.5 SAMPLING METHODS

This section describes the procedures that were used for the collection of groundwater samples for laboratory analysis and, as appropriate, the procedures for using the downhole sonde. Groundwater samples and sonde measurements were collected from existing monitoring wells, as described in Section 4. In order to maintain a high degree of quality control (QC) during this sampling event, the procedures described in the following sections were followed.

5.5.1 Preparation for Sampling

All equipment to be used for sampling was assembled and properly cleaned and calibrated (if required) prior to the beginning of the sampling event. In addition, all record keeping materials were immediately available at the sampling site. A brief organizational meeting was held prior to field mobilization to ensure proper communication between the project management staff and field personnel. Field personnel consisted of Dr. John T. Wilson and Todd H. Wiedemeier.

Prior to starting sampling procedures, the area around the monitoring well or sampling location was cleared of foreign materials, such as brush, rocks, and debris. These procedures prevented sampling equipment from inadvertently contacting debris around the monitoring well.

5.5.1.1 Equipment Calibration

As required, field analytical equipment was calibrated according to the manufacturer's specifications prior to field use. This applies to equipment used for onsite chemical measurements such as pH, electrical conductivity, temperature, dissolved oxygen, oxidation reduction potential (ORP), Fe(II), and volume magnetic susceptibility.

5.5.1.1.1 Calibration of YSI-556

The YSI-556 multi-parameter meter was used to temperature, pH, dissolved oxygen, oxidation-reduction potential, and specific conductance. The meter was calibrated daily using the procedures detailed in the YSI-556 manual, which is available from YSI (https://www.ysi.com/).

pH was calibrated using standards of 4, 7, and 10 standard pH units. ORP was calibrated using a 220 mV standard. Dissolved oxygen was calibrated using atmospheric oxygen content adjusted automatically for altitude. Specific conductance was calibrated using a 1,413 µS/cm standard.

5.5.1.1.2 Calibration of Hach DR-890 Colorimeter

The HACH DR-890, which was used only for Fe(II) concentrations was calibrated by zeroing with DDI water, per the user's manual.

5.5.1.1.3 Calibration of Magnetic Susceptibility Sonde

The magnetic susceptibility sonde was calibrated using the following procedures:

1) The sonde was lowered below the water table in the well for a minimum of 15 minutes so that the sonde could equilibrate to the environment in which magnetic susceptibility measurements would be made. It was found that the magnetic susceptibility sonde is very sensitive to variations in temperature.
2) The sonde was then raised to the surface and placed it at least 20 feet from any metallic object and not near any power lines.
3) The sonde was then calibrated to various calibration standards by running the included computer program. For this work the sonde was calibrated to ambient conditions (zero) and 5E-3 SI units.

5.5.1.1.4 Calibration of Equipment at Clemson

Counts per minute from the liquid scientillation counter were corrected for quench using the quench curve described in section 5.1.4.4.

The amount of TCE in serum bottles was determined using a calibration curve (known amount of TCE per bottle versus GC peak area response from a 0.5 mL headspace injection). For O_2, a single point calibration was used based on the GC response to a sample of room air containing 21% O_2.

Determination of rate coefficients with MATLAB were confirmed using the solver function in EXCEL.

5.5.1.1.5 Calibration of Equipment at PNNL

Enzyme activity probe staining and qPCR were calibrated using the following procedures:

1) Fluorescence of each EAP was verified using positive control organisms known to contain the enzyme being tested.
2) Response of the fluorometer for SMMO was calibrated using the positive control microorganisms *Methylosinus trichosporium* OB3b.
3) For qPCR, known masses of positive control DNA for each primer pair were serially diluted to make a standard curve for analysis. Cycle threshold values for each unknown was compared to the standard curve and copy numbers of genes determined.

5.5.2 Sampling Procedures

Special care was taken to prevent contamination of groundwater samples. The two primary ways in which sample contamination can occur are through contact with improperly cleaned equipment and by cross-contamination through insufficient decontamination of equipment between wells. To prevent such contamination, the pump and water level probe and cable used to determine static water levels were thoroughly cleaned before and after field use and between uses at different sampling locations according to the procedures presented in this Section. In addition to the use of properly cleaned equipment, a clean pair of new, disposable nitrile gloves was worn each time a different well was sampled. Dedicated polyethylene, and in many cases, silicone tubing was used for the pumps used for this effort. This tubing was disposed of between each well. This tubing was always stored away from any substances that could cause contamination. Wells were sampled sequentially from areas suspected to be least contaminated to areas suspected to be more contaminated.

The following paragraphs present the procedures used for groundwater sample acquisition from groundwater sampling locations. These activities were performed in the same order as presented below.

5.5.2.1 Water Level and Total Depth Measurements

Prior to removing any water from monitoring wells, the static water level was measured. An electrical water level probe was used to measure the depth to groundwater below the datum to the nearest 0.01 foot. None of the wells sampled had nonaqueous-phase liquid.

5.5.2.2 Purging

Prior to sample collection, groundwater was withdrawn from the well using a peristaltic pump, a Grundfos Redi-Flo II® pump, a weighted disposable bailer, or a Hydrasleeve™. The Hydrasleeve™ was used only to collect samples at Tooele Army Ammunition Depot because of groundwater disposal requirements and because of the depth to groundwater. The Grundfos pump was used only for sampling in OU10-019. Purging and sample collection was performed at the monitoring wells listed in Table 4.1.1. Where possible, field measurements for dissolved oxygen, ORP, pH, temperature, specific conductance were collected during well purging using a flow through cell. In addition, field measurements for Fe(II) concentration were made immediately after well purging using a Hach DR 890 Colorimeter (Wiedemeier et al., 1999). Laboratory samples for the analytes listed in Tables 5.6.1 and 5.6.2 were collected immediately following well purging. Analytes collected during well purging are summarized in Table 5.6.3. Completed groundwater purge and sampling forms are included in Appendix B.

Because the pH, temperature, and specific conductance of a groundwater sample can change significantly within a short time following sample acquisition, these parameters were measured in the field in unfiltered, unpreserved, “fresh” water collected using the same technique as the samples taken for laboratory analyses. The measurements were made in a flow-through cell.

Table 5.6.1. Total Number and Types of Samples Collected and Types of Analyses Performed

Component	Matrix	Number of Samples	Analyte	Location
Pre-demonstration sampling	Solids	NA	NA	NA
	Distilled deionized water	24	Accumulation of ^{14}C products from purified ^{14}C-TCE, added to glass serum bottles prepared in lab	Clemson University
	Seep Water, Twin Lakes	3 samples of seep water	Accumulation of ^{14}C products from purified ^{14}C-TCE added to glass serum bottles preped in field	Twin Lakes Recreation Area, Pendleton, SC
	ENV487 Propanotrophic Enrichment Culture	27	Accumulation of ^{14}C products from purified ^{14}C-TCE, added to glass serum bottles prepared in the lab	Clemson University
Technology performance sampling	Aquifer Sediment	23	Magnetic Susceptibility Using a Sonde	Monitoring wells as described in Section 4 and MW U2-043 at OU-2, Hill AFB.
	Groundwater	19	Dissolved Oxygen	All monitoring wells sampled
	Groundwater	19	Fe(II)	All monitoring wells sampled
	Groundwater	19	Oxidation-Reduction Potential	All monitoring wells sampled
	Groundwater	19	pH	All monitoring wells sampled
	Groundwater	19	Temperature	All monitoring wells sampled
	Groundwater	19	Specific Conductance	All monitoring wells sampled
	Groundwater	5 sites, 4 samples per site for 4 sites, 3 samples for 1 site, 3 bottles per well: total = 57	Accumulation of ^{14}C products from purified ^{14}C-TCE, added to glass serum bottles prepared at the well head	All monitoring wells sampled
	Filter Sterilized Groundwater	5 sites, total 11 wells	Accumulation of ^{14}C products from purified ^{14}C-TCE, added to glass serum bottles prepared in lab	Subset of the monitoring wells
	Groundwater	5 sites, 4 samples for 4 sites, 3 samples for 1 site, 4 analytes = 16 samples for 4 sites and 12 samples for one site, total=76	Enzyme Activity Probes	All monitoring wells sampled – Ship to PNNL
Post-demonstration sampling[a/]	NA	NA	NA	NA

Notes: NA = Not Applicable
a/ Post-demonstration sampling not conducted under this program

Table 5.6.2. Analytical Methods for Sample Analysis

Matrix	Analyte	Method	Container(s)	Preservative /Chilled?	Analytical Laboratory	Holding Time
Soil	NA	NA	NA	NA	NA	NA
Ground -water	Magnetic Susceptibility	Magnetic Susceptibility Sonde	NA	NA	Field	NA
	Dissolved Oxygen	Direct Reading Probe in a Flow-Through-Cell per USEPA (1998)	NA	NA	Field	NA
	Fe(II)	Hach Colorimetric Technique Done Immediately After Well Purging	NA	NA	Field	NA
	Oxidation-Reduction Potential	Direct Reading Probe in a Flow-Through-Cell per USEPA (1998)	NA	NA	Field	NA
	pH	Direct Reading Probe in a Flow-Through-Cell per USEPA (1998)	NA	NA	Field	NA
	Temperature	Direct Reading Probe in a Flow-Through-Cell per USEPA (1998)	NA	NA	Field	NA
	Specific Conductance	Direct Reading Probe in a Flow-Through-Cell per USEPA (1998)	NA	NA	Field	NA
	VOCs, O_2	GC/FID for VOCs, TCD for O_2, using headspace samples	160 mL serum bottles with Teflon-faced butyl rubber septa	Store at ~4ºC until use	Clemson University	Overnigh t
	^{14}C	Various, described in journal articles	160 mL serum bottles	NA	Clemson University	NA
	EAP	EAP	1 1L HDPE Narrow-mouth	Ship at 4°C	PNNL	24 hours
	qPCR	qPCR	1 1L HDPE Narrow-mouth	Ship at 4°C	PNNL	24 hours

Notes:
NA = Not Applicable
Preservatives are not required for these samples; however, all samples will be stored and shipped at 4ºC.
FID = Flame Ionization DetectorTCD = Thermal Conductivity Detector

Table 5.6.3. Summary of Groundwater Geochemical Data

ESTCP Project Number ER-201584

Well I.D.	Date	Field Measurements: Temperature (degrees Celsius)	Temperature (degrees Fahrenheit)	pH	Conductivity (μS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	Ferrous Iron (mg/L)
TCAAP O1U108								
Conventional Purge Data Using Peristaltic Pump	6/1/2016	11.42	52.56	5.20	502	0.61	153.7[a/]	<0.03
	6/3/2016	10.64	51.15	6.97	468	0.86	242.6	--
TCAAP O1U115								
Conventional Purge Data Using Peristaltic Pump	6/1/2016	10.97	51.75	--	391	0.54	--	0.01
	6/3/2016	10.03	50.05	7.35	412	0.58	225.6	--
TCAAP O1U117								
Conventional Purge Data Using Peristaltic Pump	6/2/2016	10.67	51.21	6.98	462	4.71	243.8	<0.03
TCAAP O1U119								
Conventional Purge Data Using Peristaltic Pump	6/2/2016	8.84	47.91	6.77	865	0.96	223.2	0.10
Plattsburgh MW-02-006[/b]								
Data Collected Using Disposable Bailer	6/6/2016	10.10	50.18	6.65	824	0.42	-110.3	1.25
Plattsburgh MW-02-019								
Conventional Purge Data Using Peristaltic Pump	6/6/2016	10.95	51.71	6.94	412	0.40	-106.9	1.12
Plattsburgh 32PLTW12								
Conventional Purge Data Using Peristaltic Pump	6/7/2016	11.39	52.50	5.60	227	8.89	264.3	<0.03
Plattsburgh 35PLT13								
Conventional Purge Data Using Peristaltic Pump	6/7/2016	12.31	54.16	7.11	540	1.58	45.4	<0.03
Hopewell EPA-16S								
Conventional Purge Data Using Peristaltic Pump	6/8/2016	10.83	51.49	6.09	672	5.75	222.6	<0.03
Hopewell EPA-15D								
Conventional Purge Data Using Peristaltic Pump	6/8/2016	11.04	51.87	6.95	743	4.14	163.0	<0.03
Hopewell EPA-12S								
Conventional Purge Data Using Peristaltic Pump	6/9/2016	10.53	50.95	6.61	1004	6.72	270.9	<0.03
Hopewell EPA-10S								
Conventional Purge Data Using Peristaltic Pump	6/9/2016	9.82	49.68	6.31	771	5.86	172.8	--
Tooele D-20[/b]								
Hydrasleeve™/Peristaltic Pump	7/25/2016	17.38	63.28	6.90	1417	7.00	190	<0.03
Tooele D-23[/b]								
Hydrasleeve™/Peristaltic Pump	7/25/2016	--	--	7.05	19290	1.88	211	<0.03
Tooele D-25[/b]								
Hydrasleeve™/Peristaltic Pump	7/26/2016	--	--	7.14	4772	5.41	200	<0.03
Tooele D-19[/b]								
Hydrasleeve™/Peristaltic Pump	7/26/2016	18.34	65.01	6.47	1010	6.9	189.6	<0.03

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Table 5.6.3
Summary of Groundwater Geochemical Data

ESTCP Project Number ER-201584

Well I.D.	Date	Field Measurements: Temperature (degrees Celsius)	Temperature (degrees Fahrenheit)	pH	Conductivity (μS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	Ferrous Iron (mg/L)
Hill AFB U10-043 Conventional Purge Data Using Peristaltic Pump	7/27/2016	15.27	59.49	7.00	1145	0.75	168.2	<0.03
Hill AFB U10-025 Conventional Purge Data Using Peristaltic Pump	7/27/2016	18.87	65.97	7.17	1453	0.29	-51.5	<0.03
Hill AFB U10-019[/b] Conventional Purge Data Grundfos Pump, Well went dry multiple times	7/28/2016	23.08	73.54	8.12	1325	7.45	-51.7	0.69

Notes:

mg/L	Milligrams per liter
uS/cm	Microsiemens per centimeter
ORP (mV)	Oxidation Reduction Potential (Millivolts)
--	Variously applied to indicate: Not Applicable, Not Available, Not Measured, or Not Reported, as appropriate.
/a	PH/ORP probe not working properly during this sampling
/b	Results suspect because insufficient volume of water was removed during purging

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Well purging, where possible, continued until those parameters measured using a flow-through cell, including dissolved oxygen, pH, temperature, ORP, and specific conductance stabilized. This includes less than 0.2 standard pH units or a 10% change for the other parameters over a 5-minute period. Because of constraints on purge water disposal, this was not possible for the wells sampled at Tooele Army Depot. In addition, this was not possible for monitoring well MW-02-006 at the former Plattsburgh AFB because groundwater was too deep for the peristaltic pump, and well OU10-019 at Hill AFB OU-10, because the well went dry using the Grundfos pump and had to be allowed to recharge before samples could be collected. All purge waters were disposed of in accordance with the specifications identified in this document.

5.5.2.3 Sample Extraction

Water from sampling devices was directly discharged into the sample container. The water was carefully poured down the inner walls of the sample bottle to minimize aeration of the sample. Four sample acquisition techniques were used to collect groundwater samples, including:

1) Use of a peristaltic pump with tubing placed directly into the well (majority of wells);
2) Use of a Grundfos submersible pump (one well, U10-019);
3) Use of a bailer and draining the groundwater out of the base of the bailer (well MW-02-006 at the former Plattsburgh AFB), and;
4) Use of a Hyrdasleeve^{TM} in conjunction with a peristaltic pump. The Hydrasleeve^{TM} was lowered into the well to collect the water sample, raised to the surface and temporarily hung from the lip of the well. A peristaltic pump was then used to remove water from the Hydrasleeve^{TM}. This technique was used for all of the wells sampled at Tooele Army Ammunition Depot because no purge water could be generated.

Sample containers were filled as follows:

1) For samples sent to PNNL for EAP analyses, the sample containers were filled so that no air space (headspace) remained in the container, and;
2) For samples sent to Dr. Freedman's lab at Clemson, 160 mL serum bottles were filled with approximately 100mL of groundwater and sealed with a crimp cap with a Teflon septum.

Excess water collected during sampling was handled according to the specifications identified in the Demonstration Plan (ESTCP, 2016).

5.5.3 Handling of Samples for Laboratory Analysis

This section describes the handling of samples to be analyzed by the PNNL and Clemson University from the time of sampling until the samples arrive at the laboratory. A summary of details regarding requirements for containers, preservation techniques, sample volumes, and holding time is provided in Table 5.6.2.

5.5.3.1 Sample Container and Labels

Sample containers and appropriate container lids and labels were provided by the analytical laboratories at Clemson University and PNNL. The sample containers were filled as described in Section 5.6.2.3, and the container lids were tightly closed or crimped. Container lids were not removed at any time prior to sample collection. Sample labels were firmly attached to the container side, and the following information was legibly and indelibly written on the label:

- Facility name;
- Sample identification;
- Sample type (groundwater, surface water, etc.);
- Sampling date;
- Sampling time;
- Preservatives added (none for this effort); and
- Sample collector's initials.

5.5.3.2 Sample Preservation

No chemical preservatives were added to the sample containers for this effort. Samples were properly prepared for transportation to the laboratory by placing the samples in a cooler containing ice to maintain a shipping temperature of 4°C

5.5.3.3 Sample Shipment

After the samples were sealed and labeled, they were packaged for transport to the analytical laboratory. Samples were shipped priority overnight via Federal Express®. The following packaging and labeling procedures were followed:

- The sample was packaged so that it would not leak, spill, or vaporize from its container;
- The shipping container was labeled with:
  - Sample collector's name, address, and telephone number;
  - Laboratory's name, address, and telephone number;
  - Description of sample;
  - Quantity of sample; and
  - Date of shipment.

The packaged samples were delivered to the laboratory the day after sample acquisition to ensure testing within method-specific holding times.

5.5.3.4 Chain-of-Custody Procedures

After the samples were collected, chain-of-custody procedures were followed to establish a written record of sample handling and movement between the sampling site and the laboratory. Each shipping container had a chain-of-custody form completed in triplicate by the sampling personnel. One copy of this form was kept by the sampling team and the other two copies were sent to the laboratory. The chain-of-custody contains the following information:

- Sample identification number;
- Sample collector's printed name and signature;
- Date and time of collection;
- Place and address of collection;

- Sample matrix;
- Analyses requested;
- Signatures of individuals involved in the chain of possession; and
- Inclusive dates of possession.

The chain-of-custody documentation was placed inside the shipping container so that it was immediately apparent to the laboratory personnel receiving the container, but was not damaged or lost during transport. The shipping container was sealed with custody seals so that it would have been obvious if the seal had been tampered with or broken. Appendix B contains chain-of custody records.

5.5.3.5 Sampling Records

In order to provide complete documentation of the sampling event, detailed records were maintained by field personnel. At a minimum, these records include the following information:

- Sample location (facility name);
- Sample identification;
- Date and time of sampling;
- Sampling method;
- Field observations of
  - Sample appearance,
  - Sample odor;
- Weather conditions;
- Water level prior to purging;
- Total well depth;
- Approximate Purge volume;
- Well condition;
- Sampler's identification;
- Field measurements of pH, temperature, and specific conductivity; and
- Any other relevant information.

Groundwater sampling activities were recorded on the Groundwater Purge and Sampling Form found in the Demonstration Plan (ESTCP, 2016). These completed forms are found in Appendix B.

5.5.4 Laboratory Analyses

All samples collected for laboratory analysis were shipped to Clemson University and PNNL. Prior to sampling, arrangements were made with the laboratory to provide a sufficient number of appropriate sample containers for the samples to be collected. All containers, preservatives, and shipping requirements were consistent with laboratory protocols. Quality Control samples were prepared and acquired as described Section 5.6.6. For EAP and qPCR analyses, trip blanks sterile distilled water) were shipped with each cooler and analyzed with samples from each site.

Shipping containers with adequate padding and cooling media were sent by the laboratory to the site. Sampling personnel filled the sample containers and returned the samples to the laboratory.

5.5.4.1 Assay of Rate of TCE Co-Oxidation Using ^{14}C-Labeled TCE

Details on development of the ^{14}C-TCE assay are presented in sections 2.2.2.1; 3.1.2; 3.2.2; 5.1.3; and 5.1.4. The first task was to evaluate an improved method for purifying the ^{14}C-TCE stock solution, with the goal of minimizing the amount of ^{14}C impurities added to the serum bottles that accompany the ^{14}C-TCE. The lower the initial level of impurities, the easier it becomes to detect a statistically significant increase in ^{14}C products over a relatively short timeframe (e.g., several days). In previous studies (e.g., Darlington et al., 2008, 2013), a single GC column was used for purification. In this study, two columns in series was also evaluated. It turned out that the dual column approach did not yield a statistically significant lower level of impurities. With the single and dual column methods, the target of 0.01% impurities was not met; the initial level of impurities was closer to 0.05% of the total ^{14}C added to the serum bottles. However, this was compensated for by increasing the duration of the assay, allowing for detection of an increase in ^{14}C products above the initial level impurities in the bottles. Using this approach, the lowest rate constant measured was 0.00658 yr^{-1}, which translates to a half-life of 105 yr. While it may be possible to lower the detection limit of the assay, lower rates would not likely have any practical value from the standpoint of assessing MNA.

The assay involved addition of ~100 mL of groundwater, DDI water, or FSGW to 160 mL serum bottles. Following addition of purified ^{14}C-TCE, accumulation of ^{14}C products was measured in 3 mL samples removed eight or nine times, over 40 to 46 days of incubation. The pH of the 3 mL samples was raised above 10 to retain $^{14}CO_2$, and then the water was sparged for 30 min to remove the residual ^{14}C-TCE, leaving behind only the ^{14}C products. An experiment was performed to determine if 30 min of sparging was adequate to remove all of the unreacted TCE. Sparging for 60 min was tested and shown not to further lower the ^{14}C products left after sparging. Consequently, a 30 min sparging time was used.

In order to determine a first order rate constant, the rate of ^{14}C product accumulation in groundwater must be greater than the rate of accumulation in sterile controls. Initially, DDI water was used as the negative control. It was subsequently determined that FSGW controls are a better representation of the background level of product formation; these were used to calculate net first order rate constants for eight of the 19 wells evaluated.

Section 5.1.4 specifics how the first order decay rate constant was calculated. A mass balance model that included the first order decay coefficient was fit to the measured amounts of ^{14}C products formed. The optimum value fopr the rate coefficient was found by minimizing the sums of squares of error between the measured and predicted amount of ^{14}C products over time. Details on the methods for counting ^{14}C activity are provided, as are the methods to quantify and/or detect the VOCs by GC/FID and the amount of oxygen present in the headspace by GC/TCD.

When the incubation period was complete (40-46 days), samples were evaluated using both alkaline and acidic sparging. The difference between the two allowed for calculation of the percentage of product in the form of $^{14}CO_2$. $^{14}CO_2$ was further confirmed by precipitation with barium.

The ^{14}C assay was validated using locally sourced water from a seep with a high content of organic debris. A statistically significant rate of TCE co-oxidation was observed, confirming the viability of the assay. Additional evidence for the efficacy of the assay was obtained using a propanotrophic enrichment culture that is known to co-oxidize TCE.

The propanotrophic culture was used to evaluate the potential impact of sample storage conditions on the rate of ^{14}C product accumulation. Storage at 4 °C overnight, followed by warming to room temperature overnight, did moderately reduce the first order reaction rate coefficient when considering the full incubation period (40 d). This suggested that results for the groundwater samples are conservative with respect to in situ conditions. Nevertheless, shipment of groundwater sample to a laboratory that is licensed to handle ^{14}C is a requirement for the assay, and shipment on ice is recommended to avoid even more significant decreases in co-oxidation activity that may occur if the samples are left at ambient temperature.

5.5.4.2 Enzyme Activity Probes and qPCR Assays

Enzyme Activity Determination

Samples were received in the laboratory and inspected to ensure there was very little headspace in bottles containing groundwater. Observations were recorded and photos taken to go along with the description. For EAP analysis, samples were processed individually. Groundwater sample bottles were inverted for mixing. Once the sample was mixed, bottles were opened and an aliquot immediately pipetted (3-10 mL) onto a sterile manifold set up with GF/F (backing filter) and 0.22 µm, 25-mm diameter, black, polycarbonate filter. A vacuum was used to pull the sample through the filter, trapping the microorganisms on the surface. The vacuum was released to facilitate staining and 0.25 ml of the appropriate EAP in 40 mM phosphate buffer was filtered onto the polycarbonate filter. The manifold system was covered with aluminum foil or placed in the dark for 15 minutes of exposure time with the probe; after 15 minutes, the vacuum was reapplied to remove the probe solution. Cells on filter were counterstained with DAPI (4,6-diamidino-phenylindole), a total cell, DNA stain, by adding 60 µl of DAPI to the filter and incubated, in the dark for < 5 minutes. The filter was washed with 1 mL of nanopure water or phosphate buffer to remove any unbound EAP and DAPI. The filter was then placed onto a glass microscope slide, cell side up, and mounted with non-fluorescent citifluor solution and a cover slip.

The filters were examined and visualized for fluorescent cells on a Nikon Eclipse E600 fluorescence microscope equipped with a PLAN Fluor 100x 1.30 oil objective. A UV2E/C filter (excitation 340-380 nm, dichromatic mirror 400 nm, emission 435-485 nm) was used to count DAPI stained cells, while a B-2E/C filter (excitation 465-495 nm, dichromatic mirror 505 nm, emission 515-555 nm) was used to visualize probe positive cells.

DNA extraction and PCR amplification

Groundwater samples were filtered (typically 250ml, up to 1L) onto 0.22µm, 47mm diameter, Supor filters to capture bacteria. If DNA from the samples are not to be extracted immediately, the filters are placed into eppendorf tubes, whirlpack bags, or 50mL falcon tubes depending on the size of the Supor filters used. Samples are stored at -80 °C.

When ready to extract, samples are removed the -80 °C and the DNA from the cells trapped on filters is extracted using both Bio 101 and the MoBio UltraClean Soil DNA kits, as described by the manufacturers. Two kits were used to ensure that biases associated with one kit or another did not provide a false positive or negative for the presence of the gene of interest. DNA concentrations were quantified using a Nanodrop instrument; quality and quantity of DNA were determined and recorded.

Polymerase chain reaction (PCR) and qPCR amplification reactions were performed in 50 mL and 25 mL reaction mixtures, respectively. PCR/qPCR conditions for the primers, are as stated in (Baldwin et al., 2003; 2008 or Hendrickx et al., 2006; 2008). For those primers that were either developed or modified for use in qPCR reaction mixtures, procedures for the amplification are similar to those in the published literature. Standards for qPCR were used to determine the concentration of cells in each reaction. Positive control organisms served as standards for these analyses. Concentrations of DNA were standardized for all reactions; PCR reactions were carried out with a 50 ng starting concentration, while qPCR is initialized with 10 ng. Thus products/positive amplifications of products are comparable.

PCR and qPCR products were separated and visualized using an Agilent 2100 Bioanalyzer and DNA 1000 LabChips. Each LabChip has 16 wells, twelve of which are used for experimental samples, one well was used for a molecular weight DNA ladder, and three were used for loading the gel-dye mix. DNA 1000 LabChips were prepared and loaded with samples as recommended by the manufacturer with minor modifications. Microchannels were filled by pipetting 9 µl of gel-dye mix (consisting of a linear polymer and a fluorescent, intercalating dye of a proprietary nature) into the appropriate well and then forcing the mix into the microchannels by applying pressure to the well via a 1-ml syringe. Five microliters of marker mix was loaded into each sample well, followed by 1 µl of molecular weight ladder into the ladder well or samples into the sample well. The contents of each well on the chip was mixed using an IKEA vortexer supplied with the instrument. After being vortexed, chips were immediately inserted into the bioanalyzer and processed. All experiments were performed using Agilent Biosizing software.

5.5.5 Equipment Decontamination Procedures

5.5.5.1 Portable Sampling Equipment

All portions of non-disposable sampling and test equipment that contacted groundwater from which a sample was collected were thoroughly cleaned before each use. This equipment included the water-level probe, the Grundfos pump, and the downhole mass magnetic susceptibility sonde. The following decontamination protocol was used:

- Clean with potable water and phosphate-free laboratory detergent (Liquinox® or equivalent);
- Rinse with potable water;
- Rinse with distilled or deionized water;
- Rinse with isopropanol; and
- Air-dry the equipment prior to use.

The Grundfos pump used for purging or sampling was decontaminated by placing the pump and discharge hose into a DDI water/laboratory detergent (e.g., Liquinox) solution, washing the pump and discharge hose exterior, and pumping the solution through the pump and hose. The pump and hose exterior was then rinsed with potable water, and potable water was pumped through the pump and hose until all of the detergent solution was removed.

If pre-cleaned, dedicated sampling equipment is used, the decontamination protocol specified above will not be required. Laboratory-supplied sample containers will be cleaned and sealed by the laboratory and therefore will not need to be cleaned in the field.

5.5.6 Quality Assurance/Quality Control Samples

5.5.6.1 Field Quality Assurance/Quality Control Samples

For magnetic susceptibility measurements using the sonde, a minimum of two runs was made in each well where previously-collected magnetic susceptibility data from borehole core samples were available.

5.5.6.2 Quality Assurance/Quality Control Samples Used by Clemson

Calibration curves for TCE and O_2 were included on control charts to ensure that response factors were within one standard deviation of historical means.

For each site, the ^{14}C assay was performed with one set of DDI water controls along with the groundwater samples. The DDI water served as a negative control, to assess the rate of ^{14}C product accumulation in the absence of microbes. For 10 of the wells, FSGW controls were also prepared, also serving as negative controls. FSGW controls exhibited lower rates of product accumulation versus DDI water, likely due to the presence of quenching compounds in the groundwater that reduced the magnitude of ^{14}C-TCE autoradiolysis.

The quench efficiency curve for the ^{14}C counting protocol was determined using prepared ^{14}C standards (Beckman Instruments Inc., quenched carbon-14 standards set).

5.5.6.3 Quality Assurance/Quality Control Samples Used by PNNL

Multiple laboratory blank samples were prepared and analyzed. One blank will be prepared and analyzed each calendar day a sample is received for analyses in the laboratory. Water will be filtered onto black polycarbonate filters and viewed with epifluorescent microscopy. The purpose of these blanks is to establish that there is no background fluorescence that could potentially influence the results of the assay. If background fluorescence is detected, solutions will be filter-sterilized or replaced. Pre-sterilized filters will also be analyzed as laboratory blanks. Each lot of filters used in the laboratory will be analyzed for clarity and background or other fluorescent interference. If any of the blank sample analyses are positive, actions will be taken to correct and/or eliminate all possible contamination issues.

Laboratory standards involve the application of EAPs to positive control microorganisms kept in culture in the laboratory. Positive control organisms are actively grown under enzyme induction conditions and subsequently exposed to EAP. If the standards do not provide positive results with the EAP analysis, the analysis will be considered inaccurate and void.

One matrix spike sample will be analyzed per batch of shipment. A known number of organisms with active oxygenases will be added to a given site sample and analyzed with EAP. If the spike recovery is not within the 70-130% range, the sample will be reanalyzed. If subsequent analyses are not within range, the sample will be considered void.

5.5.7 Handling of Investigation-Derived Waste (IDW)

Purge and decontamination water (IDW) was disposed of for each site as discussed in Section 4 of the Demonstration Plan (ESTCP, 2016). For the majority of wells, purge water was discharged to the ground. Exceptions to this included:

- Any purge water collected at OU-10 was containerized in a Department of Transportation-(DOT) rated and approved 125 gallon container and disposed of at the base waste water treatment plant.
- No excess purge water was collected from Tooele.
- Purge water from monitoring wells 10S and 12S at Hopewell was containerized in Department of Transportation-(DOT) rated and approved containers. A total of 5 gallons of excess purge water was generated from these wells.

5.6 SAMPLING RESULTS AND DATA ANALYSIS

This section provides a detailed summary of sampling results in terms of both temporal and spatial dependence, as appropriate.

5.6.1 Sampling Results and Data Analysis for Magnetic Susceptibility

5.6.1.1 Introduction

The quantity of magnetite in aquifer sediment can be characterized with good sensitivity and at low cost by measuring the magnetic susceptibility of the aquifer matrix (Section 2). To date, this has been accomplished by collecting borehole core data and submitting it to an analytical laboratory. Unfortunately, the cost of acquiring core samples at many sites is too high to make an evaluation of abiotic degradation by magnetite economically feasible. This is especially true if no additional drilling activities are anticipated.

The purpose of this work was to determine if downhole sondes report a magnetic susceptibility that is equivalent to that determined by borehole core samples evaluated in the laboratory. To accomplish this, values of magnetic susceptibility provided by the downhole sonde were compared to borehole core samples.

5.6.1.2 Results – Correspondence Between Sonde and Core Samples

Appendix C contains the data collected using the sonde. Figure 5.7.1 compares the data from core samples to the data from the sonde for four of the sites. The panels in the figure are identified by the site and by the monitoring well that was investigated by the sonde. At each of the sites, there was significant variation in the values from the core samples and from the in-well sonde. At a vertical scale of meters, there was significant variation between different depth intervals and within the same depth intervals in both the core data and the sonde data.

Variation in sediment properties, which is caused by variations in depositional environments, is often a function of the vertical scale over which a sample is collected. Samples collected over larger vertical intervals may have less variation because they tend to average out the vertical variation that occurs in samples collected at a smaller vertical scale. Samples collected using boreholes also have recoverability issues. This is not the case with the magnetic susceptibility sonde. At the TCAAP, Plattsburgh and Hill AFB Sites, the scatter in the core data and the sonde data at a particular depth were roughly equivalent (Panels a, b, c in Figure 5.7.1). At the Tooele Site there was less scatter in the sonde data at a particular depth (Panel d in Figure 5.7.1).

The sonde data for wells at Plattsburgh, Hill AFB and Tooele represent the entire length of the screen and riser for these wells (Panels b, c, d in Figure 5.7.1). There is no data below an elevation of 268.5 m from the well at the TCAAP because the sonde bound up against the sides of the well casing and could not be lowered further into the well (Panel a in Figure 5.7.1). The well casing had a diameter of 5.1 cm (2.0 inch). There was no problem with binding in a well at Plattsburgh which had a diameter of 5.1 cm (2.0 inch) or in the wells at Hill AFB or Tooele that had a diameter of 10.2 cm (4.0 inch).

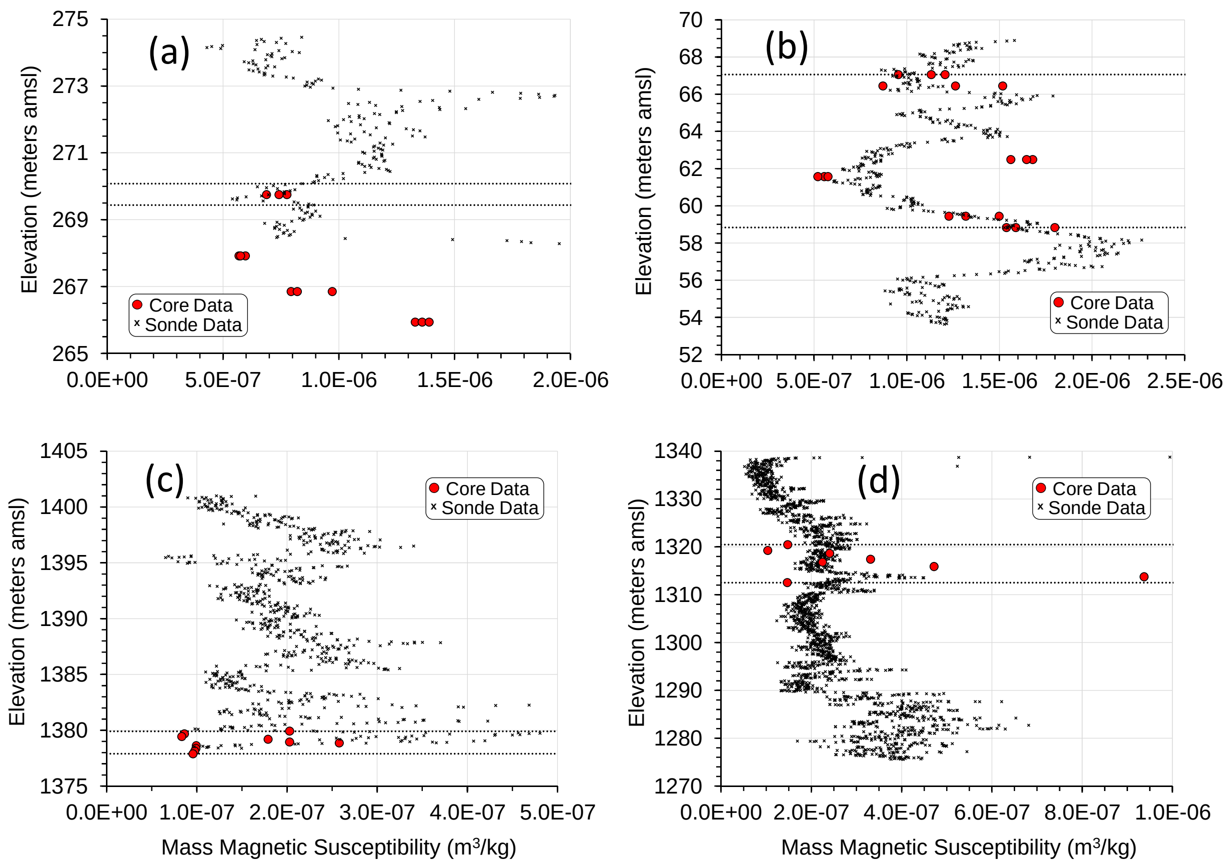


Figure 5.7.1. Comparison of Mass Magnetic Susceptibility from Core Samples to the Mass Magnetic Susceptibility from a Sonde in a Monitoring Well for Wells at the TCAAP, Plattsburgh, Hill AFB and Tooele Sites.

The dashed horizontal lines enclose the interval over which the core data were compared to the sonde data. Panel (a) is well TCAAP 01U108, Panel (b) is Plattsburgh MW-02-030, Panel (c) is Hill AFB OU2-043, Panel (d) is Toole D-23.

Figure 5.7.2 compares the data from core samples to the data from the sonde for six wells at the Hopewell site. This site was selected to provide information on the variation in magnetic susceptibility from well to well across a single site. The flow path of groundwater extends from Well EPA-10D to Wells EPA-12D and EPA-16D and EPA-15D, then to Well EPA-19S and finally to Well EPA- 21D. Well EPA-12S is 440 m downgradient of Well EPA-10D, Well EPA-19S is 570 m further downgradient of Well EPA-12S, and Well EPA-21D is 430 m even further downgradient of Well EPA-19S. At this site, the distribution of magnetic susceptibility varied widely both laterally and vertically. At some depth intervals, the data from the sonde tracked the data from the core samples. At other depth intervals, the sonde systematically overestimated the magnetic susceptibility compared to ex-situ measurements of core samples.

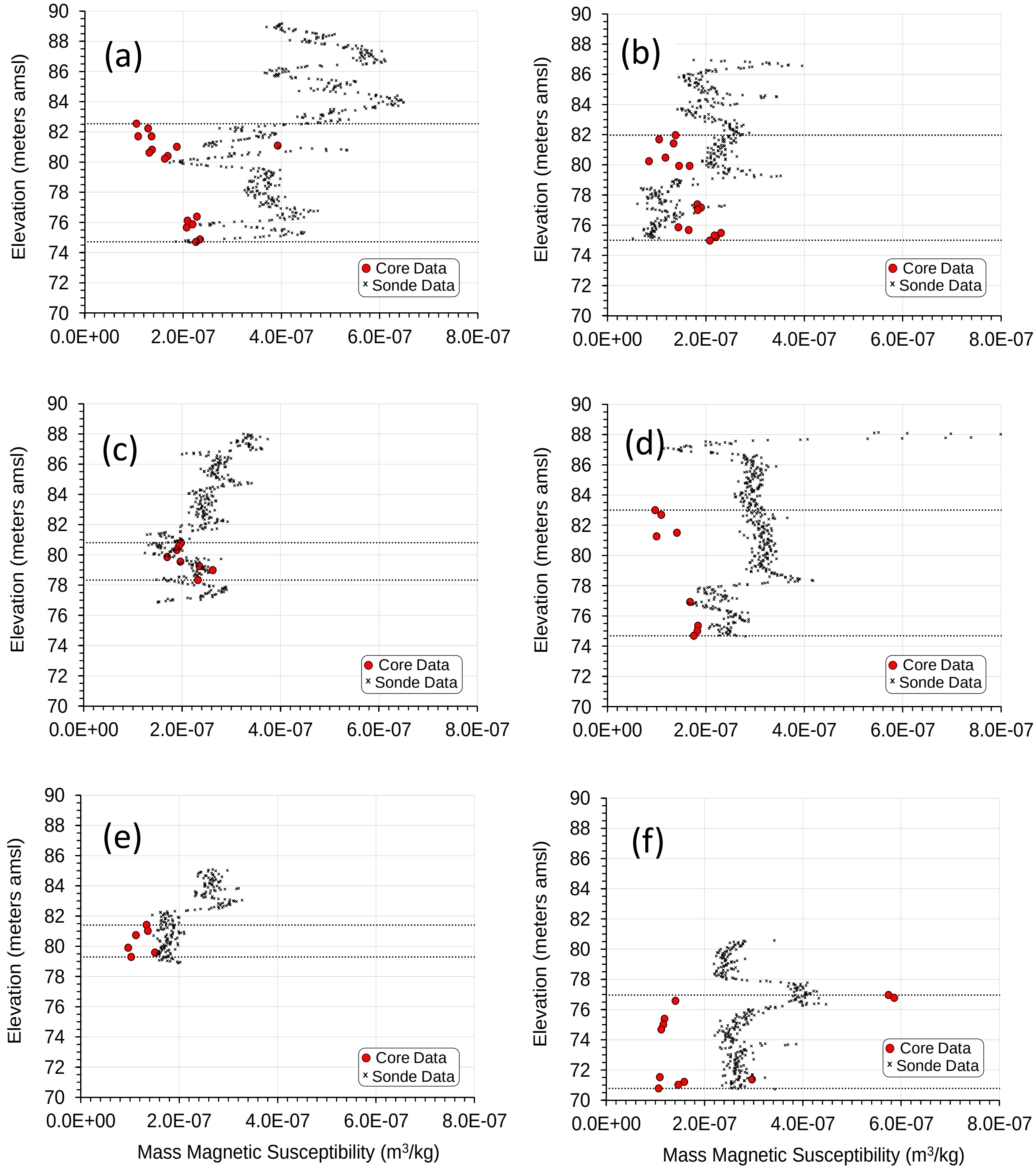


Figure 5.7.2. Comparison of Mass Magnetic Susceptibility from Core Samples to Mass Magnetic Susceptibility from a Sonde in a Monitoring Well for Wells at the Hopewell Site.

The dashed horizontal lines enclose the interval over which the core data were compared to the sonde data. Panel (a) is well EPA 10D, Panel (b) is EPA 12D, Panel (c) is EPA 15D, Panel (d) is EPA 16D, Panel (e) is EPA 19S and Panel (f) is EPA 21D.

For each of the ten wells, Figure 5.7.3 compares the mean of the mass magnetic susceptibility obtained from the HM-453S sonde to the mean that was obtained from core samples. At each well location, the mean for the sonde data and the mean for the core samples were calculated from data collected over the same depth interval. The interval that contains the data that was included in the means is bounded by the horizontal longitudinal dotted lines in each Panel of Figure 5.7.1 and Figure 5.7.2. The error bars in Figure 5.7.3 are the 95% confidence interval on the means. The Pearson Correlation Coefficient between the core means and the sonde means was R= 0.936.

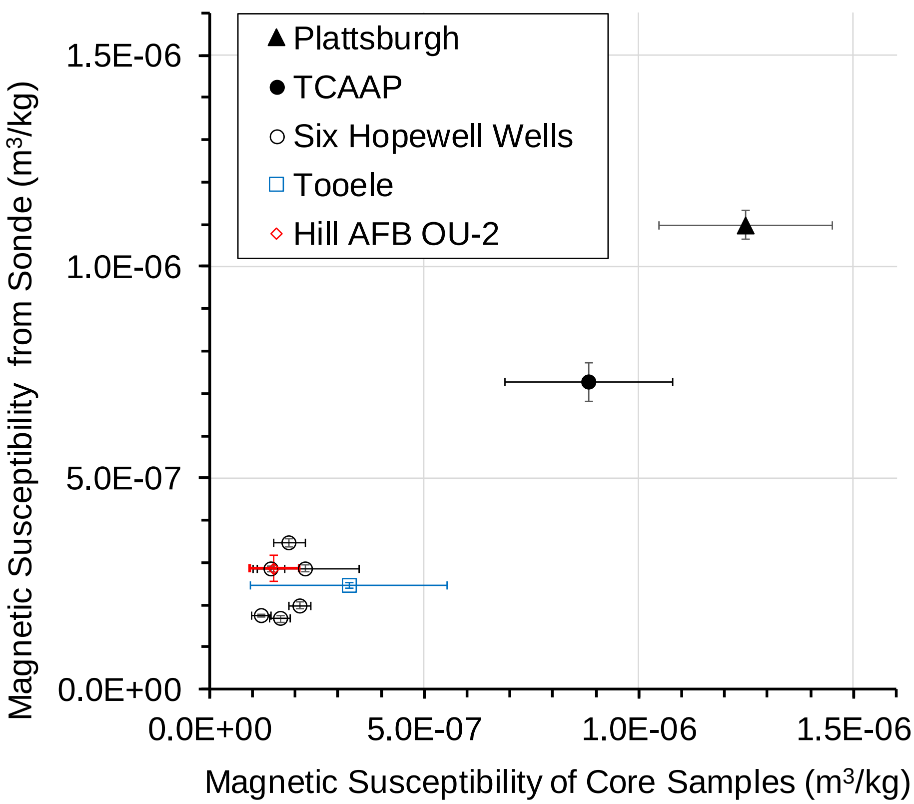


Figure 5.7.3. Relationship between Magnetic Susceptibility from Core Data and the Downhole Sonde.

Each data point is the mean of data from an individual well. The error bars are the 95% confidence interval on the mean.

Notice that the error bars are much narrower on the means of the sonde data (Figure 5.7.3), even though the apparent scatter in the data is about the same (Figures 5.7.1 and 5.7.2). The confidence intervals are calculated from the standard error of the mean, which is the standard deviation of the samples divided by the square root of the number of samples. The sonde provided many more data points to contribute to the average. However, it is important to distinguish precision from accuracy. We had no independent standard to evaluate the accuracy of the sonde compared to the accuracy of the laboratory analyses.

In general, the means of the data from the sonde were in good agreement with the means of the data from the core samples. Table 5.7.1 compares the mean of the sonde analyses for each monitoring well to the mean of the core sample analyses. The means were compared with a *t*-test for the difference of means with unequal variance. For six of the ten wells, the test failed to reject the null hypothesis that there was no difference in the means at 95% confidence ($P > 0.05$). At four of the wells the means were different at 95% confidence. However, the mean of the sonde analyses varied from the mean of the core sample analyses by less than a factor of two (Table 5.7.1). The variation between data reported by the sonde and the laboratory analysis of core samples is acceptable for the purpose of evaluating a site for abiotic degradation of TCE.

The wells at the Hopewell site, OU-2 at Hill AFB, and at Tooele were 4-inch ID. The wells at TCAAP and Plattsburgh were 2-inch ID. The larger wells would have more air in the annular space, and would be more likely to have a greater radius of engineered sand pack between the wall of the bore and the screen or casing. This should tend to reduce the response in the sonde. Despite this expectation, the ratio of the response of the sonde to the core samples was generally higher in the 4-inch wells compared to the 2-inch wells (Table 5.7.1). The well at Tooele was the only exception. In the wells in the survey, there was no indication of a systematic bias in the magnetic susceptibility reported by the sonde in 4-inch ID wells.

Table 5.7.1. Comparison of Estimates of Mass Magnetic Susceptibility from a Downhole Sonde to Estimates from Laboratory Analysis of Core Samples

Location	Well	Mean of Magnetic Susceptibility		Ratio of Means	Number of Values in Mean		*p**
		m^3kg^{-1}		Sonde/Cores			
		Sonde	Cores		Sonde	Cores	
Hopewell	EPA 19	1.8E-07	1.2E-07	1.44	71	6	1.8E-03
Hill OU-2	OU2-043	2.7E-07	1.4E-07	1.91	58	10	4.7E-05
Hopewell	EPA 16	2.8E-07	1.4E-07	1.96	273	8	7.4E-06
Hopewell	EPA 12D	1.7E-07	1.6E-07	1.03	223	15	0.65
Hopewell	EPA 10D	3.5E-07	1.9E-07	1.86	258	16	9.3E-08
Hopewell	EPA 15D	2.0E-07	2.1E-07	0.95	82	8	0.38
Hopewell	EPA 21	2.9E-07	2.2E-07	1.28	204	11	0.29
Tooele	D-23	2.2E-07	2.6E-07	0.76	261	8	0.44
TCAAP	O1U108	7.3E-07	8.8E-07	0.82	22	12	0.11
Plattsburgh	MW-02-030	1.2E-06	1.2E-06	0.95	302	18	0.51

*Probability of error, two tailed.

5.6.1.3 Summary

If appropriate monitoring wells are available, downhole magnetic susceptibility sondes in groundwater monitoring wells can provide a less expensive alternative to the collection and analysis of borehole core data, and can provide data that can be used to evaluate field-scale rate constants for abiotic degradation of PCE, TCE, and *c*DCE by magnetite.

Wells or segments of wells are appropriate for use with a magnetic susceptibility sonde when (1) they are constructed with PVC screens and risers, (2) they do not contain iron or steel, and (3) they have an internal diameter of 5.1 cm (2 inches) or 10.2 cm (4 inches).

If a well with a casing diameter of 5.1 cm (2 inches) is not straight, there is a possibility that the sonde will bind against the sides of the casing or screen. In this survey, there was no indication of a problem with wells with a casing diameter of 10.2 cm (4 inches).

Because there were many more data points provided from the sonde compared to core samples, the sonde data provided more precision in the estimate of average value for magnetic susceptibility.

At the five sites that were investigated, the downhole sonde reported values of magnetic susceptibility that were similar to values reported on borehole core samples analyzed in the laboratory. In most cases, the means of the two measurements could not be distinguished at 95% confidence. When the means could be distinguished, they still agreed within a factor of two.

If possible, the magnetic susceptibility data should be collected in the same wells that provided the concentration data used to extract the field-scale rate constant. In the *BioPIC Tool*, the purpose of surveying a site for magnetic susceptibility is to evaluate a field-scale rate constant for abiotic degradation. The rate constant is extracted by analyzing monitoring data from several wells that lie along a transect in the direction of groundwater flow. The rate constant represents that segment of the aquifer. The value for magnetic susceptibility used to evaluate the rate constant should also represent that same segment of the aquifer.

If information is available on the vertical distribution of hydraulic conductivity, or on the texture of unconsolidated porous media, use that information to filter the data on magnetic susceptibility, and take the mean of the data points that are associated with the regions that carry the major portion of groundwater flow.

Use magnetic susceptibility to provide a second line of evidence as defined by USEPA (1999). Use magnetic susceptibility to evaluate whether abiotic degradation by magnetite is a plausible explanation for a rate constant that is extracted from the monitoring data and the geological and hydrological properties of the site. Do not use magnetic susceptibility to estimate or predict a rate constant for degradation.

If the groundwater in the aquifer is sulfate reducing, do not use magnetic susceptibility as a line of evidence for abiotic degradation by magnetite, unless it can be shown that the magnetic susceptibility is associated with magnetite and not greigite. Greigite can be distinguished from magnetite by comparing total Sulfur and total Iron(II) in the sediment.

Review the data provided by the sonde. Exclude from interpretation any data where there is a sharp transition to a very high magnetic susceptibility. These data may be associated with steel or iron in centralizers in the well, or with tools that might have been dropped into the borehole.

Figure 5.7.4 shows the relationship between first order rate constant for abiotic degradation and the magnetic susceptibility of aquifer materials. This figure is modified from ESTCP (2015) and He (2009) with additional data collected during this work. Figure 5.7.4 compares the first-order rate constant for degradation of chlorinated ethenes in unconsolidated aquifer sediments to the mass magnetic susceptibility of the sediment. Panel (a) of Figure 5.7.4 compares field-scale rate constants for removal of PCE, TCE, DCE, or VC. The rate constants were extracted from monitoring data at seven sites. Depending on the site, each data point may represent a rate constant for an individual chlorinated alkene, or it may represent a composite rate constant for PCE, TCE and DCE.

The dashed lines in Panel (a) of Figure 5.7.4 are prediction intervals on a new observation. The 95% prediction interval is an order of magnitude wide. This may reflect error and uncertainty in the estimates of the rate constants; however, this may also reflect true variation in the rate constants from one site to another. Lee and Batchelor (2002) noted in their laboratory experiments that adding 42.6 mM Fe(II) to a suspension of magnetite increased the rate constant for degradation of *c*DCE and VC by an order of magnitude. Iron(II) was present in groundwater at some of the sites depicted in Panel (a) of Figure 5.7.4, but not in others.

The rate constants in Panel (a) of Figure 5.7.4 are bulk rate constants and may include aerobic biodegradation of DCE in addition to abiotic degradation by magnetite. Panel (b) of Figure 5.7.4 summarizes a series of microcosm studies that are reported in He et al. (2009). The sediment used to construct the microcosms was autoclaved to kill any microorganisms. The rate constants for removal of the chlorinated alkenes in the microcosms can be safely attributed to degradation by magnetite. Only one of the sites used to extract field-scale rate constants was used for microcosm studies (TCAAP). Nevertheless, the range of field-scale rate constants and the range of rate constants in the microcosm studies were similar. There is no evidence that the field-scale rate constants are substantially faster than the rate constants from the microcosms studies.

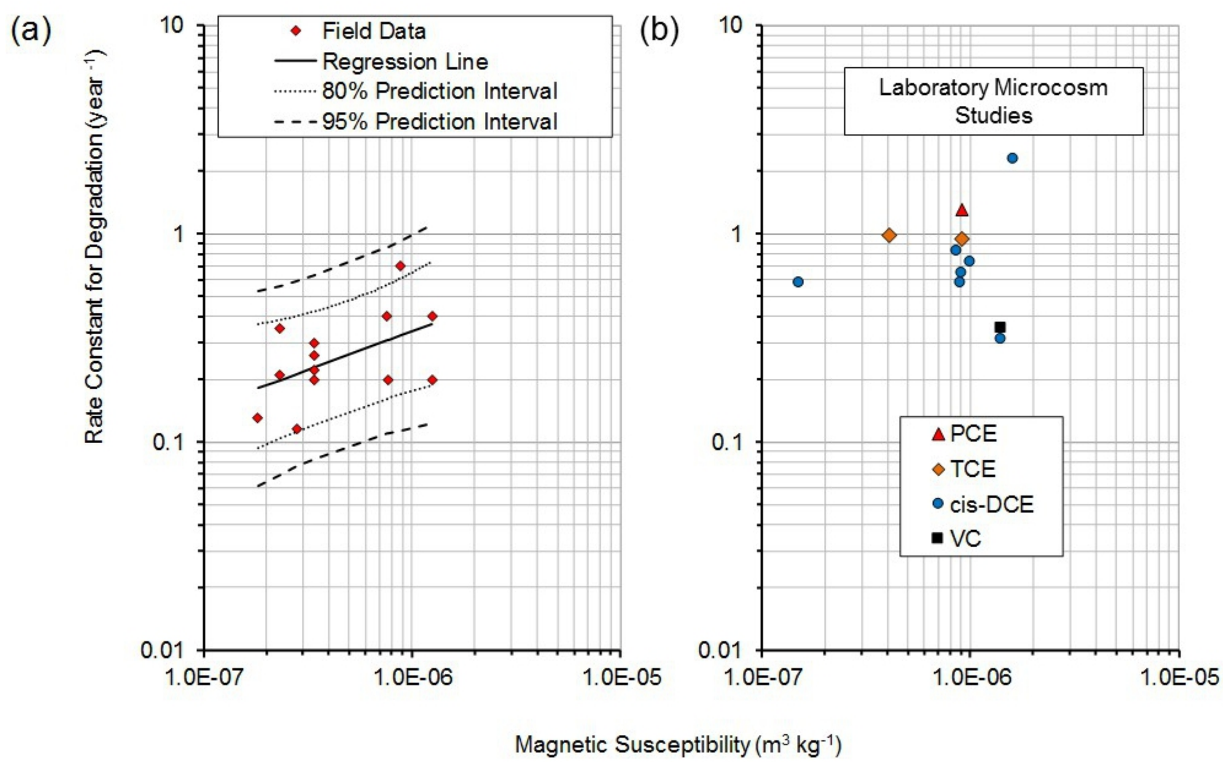


Figure 5.7.4. Relationship between First Order Rate Constant for Abiotic Degradation and the Magnetic Susceptibility of Aquifer Materials (Modified from ESTCP [2015] and He [2009]).

5.6.2 Sampling Results for Data Generated by ^{14}C-Labeled TCE Assay

Pseudo-first order rate coefficients (Table 5.7.2) were determined as described in Section 5.1.4, based on a mass balance that incorporated a decay rate for ^{14}C-TCE in the serum bottles.

Table 5.7.2. Pseudo First-order Rate Constants Based on the Difference between Experimental Rate Constants and Respective FSGW Rate Constants.

Net rates were only determined for wells that were statistically significant compared to the respective FSGW controls.

Site Location	FSGW Controls		Experimental		
	Well	*k* (yr^{-1})	Well	Net *k* (yr^{-1})	*Half Life* (yr)
TCAAP	01U115	0.032 ± 0.007	01U108	0	-
TCAAP	01U115	0.032 ± 0.007	01U115	0	-
TCAAP	01U115	0.032 ± 0.007	01U117	0	-
TCAAP	01U115	0.032 ± 0.007	01U119	0	-
Plattsburgh	MW-02-019	0.029 ± 0.009	MW-02-006	0.511 ± 0.042	1.4 ± (1.3, 1.5)
Plattsburgh	MW-02-019	0.029 ± 0.009	MW-02-019	0.129 ± 0.014	5.4 ± (4.8, 6.1)
Plattsburgh	32PTLW12	0.084 ± 0.017	32PTLW12	0	-
Plattsburgh	35PTLW13	0.014 ± 0.004	35PTLW13	0	-
Hopewell	EPA-16S	0.021 ± 0.006	EPA-16S	0	-
Hopewell	EPA-15D	0.020 ± 0.004	EPA-15D	0	-
Hopewell	EPA-12S	0.011 ± 0.003	EPA-12S	0	-
Hopewell	EPA-10S	0.031 ± 0.016	EPA-10S	0	-
Tooele	D-20	0.011 ± 0.003	D-20	0.085 ± 0.013	8.1 ± (7.0, 9.6)
Tooele	D-20	0.011 ± 0.003	D-23	0.024 ± 0.004	29 ± (25, 35)
Tooele	D-20	0.011 ± 0.003	D-25	0.058 ± 0.005	12 ± (11, 13)
Tooele	D-20	0.011 ± 0.003	D-19	0	-
Hill	U10-043	0.013 ± 0.004	U10-043	0.006 ± 0.005	107 ± (62, 395)
Hill	U10-025	0.015 ± 0.004	U10-025	0.011 ± 0.004	63 ± (45, 106)
Hill	U10-025	0.015 ± 0.004	U10-019	2.652 ± 0.138	0.3 ± (0.2, 0.3)

5.6.2.1 Results for Rate Constants

The net pseudo first-order rate constant for the degradation of ^{14}C-TCE was determined for experimental bottles that were statistically significant compared to DDI water or FSGW controls, as shown in Table 5.7.2. The net rate constant represents the difference between the degradation of the radioactive material from biotic and/or abiotic factors in the experimental bottles and the auto-degradation of the 14C-TCE stock solution in the control bottles. The likely reason for degradation of the radioactive material in the DDI water controls and consequently, the positive pseudo first-order rate constants (Table 5.7.3) was due to the radiolysis phenomenon.

Briefly, the radiolysis phenomenon occurs when the energy emitted from the radioactive material auto-degrades the radioactive material itself. Therefore, degradation of ^{14}C-TCE to ^{14}C products in the DDI water controls would be detectable with the assay developed for this project. Bottles with groundwater that exhibited less accumulation of ^{14}C products compared to the DDI or FSGW controls may be attributable to constituents in the unfiltered groundwater that quenched the radicals generated from radiolysis of the ^{14}C-TCE. The quenching of radicals by constituents in unfiltered groundwater could contribute to lower dpm values in the groundwater bottles compared to control bottles.

Table 5.7.3. Pseudo First-order Rate Constants for DDI Water Controls Prepared with Each Respective Group of Groundwater Samples.

Site Location	Identification	*k* (yr^{-1})
TCAAP	IA	0.032 ± 0.004
Plattsburgh	IIA	0.040 ± 0.004
Hopewell	IIIA	0.027 ± 0.007
Tooele	IVA	0.034 ± 0.005
Hill	VA	0.026 ± 0.003

In general, the DDI water controls monitored concurrently with the groundwater bottles from a particular site had higher rates of ^{14}C product accumulation compared to the FSGW controls from wells at that site. There are some exceptions, including the FSGW bottles from 32PTLW12 and EPA-10S, as shown in Figure 5.7.5, which have higher average pseudo first-order rate constants compared to the DDI water controls. It should be noted that not all the experimental wells had accompanying FSGW controls because the FSGW samples were tested as a forethought following evaluation of the groundwater samples. Therefore, there was insufficient additional groundwater to run FSGW controls for each well. When the 11 FSGW controls (M = 2.56×10^{-2} yr^{-1}, SD = 4.40×10^{-4} yr^{-1}) were compared to the five DDI water controls (M = 3.18×10^{-2} yr^{-1}, SD = 3.08×10^{-5} yr^{-1}), there was no significant difference (Student's *t*-test, p = 0.53). However, the 32PTLW12 control has a pseudo first-order rate constant that is an extreme outlier (i.e. > [upper quartile + (3 × interquartile range)]) compared to the other 10 FSGW bottles, as depicted in Figure 5.7.6. The outer fence of Figure 5.7.6 was determined to be 8.2×10^{-2} yr^{-1} and the rate constant for 32PTLW12 was 8.4×10^{-2} yr^{-1}. When this FSGW outlier is excluded (M = 1.97×10^{-2} yr^{-1}, SD = 6.68×10^{-5} yr^{-1}), a Student's *t*-test indicates that the ^{14}C product accumulation rate coefficient for DDI water was higher (p = 0.01). Consequently, net rates for calculated by substracting out the rate for the corresponding FSGW sample, not the DDI water control.

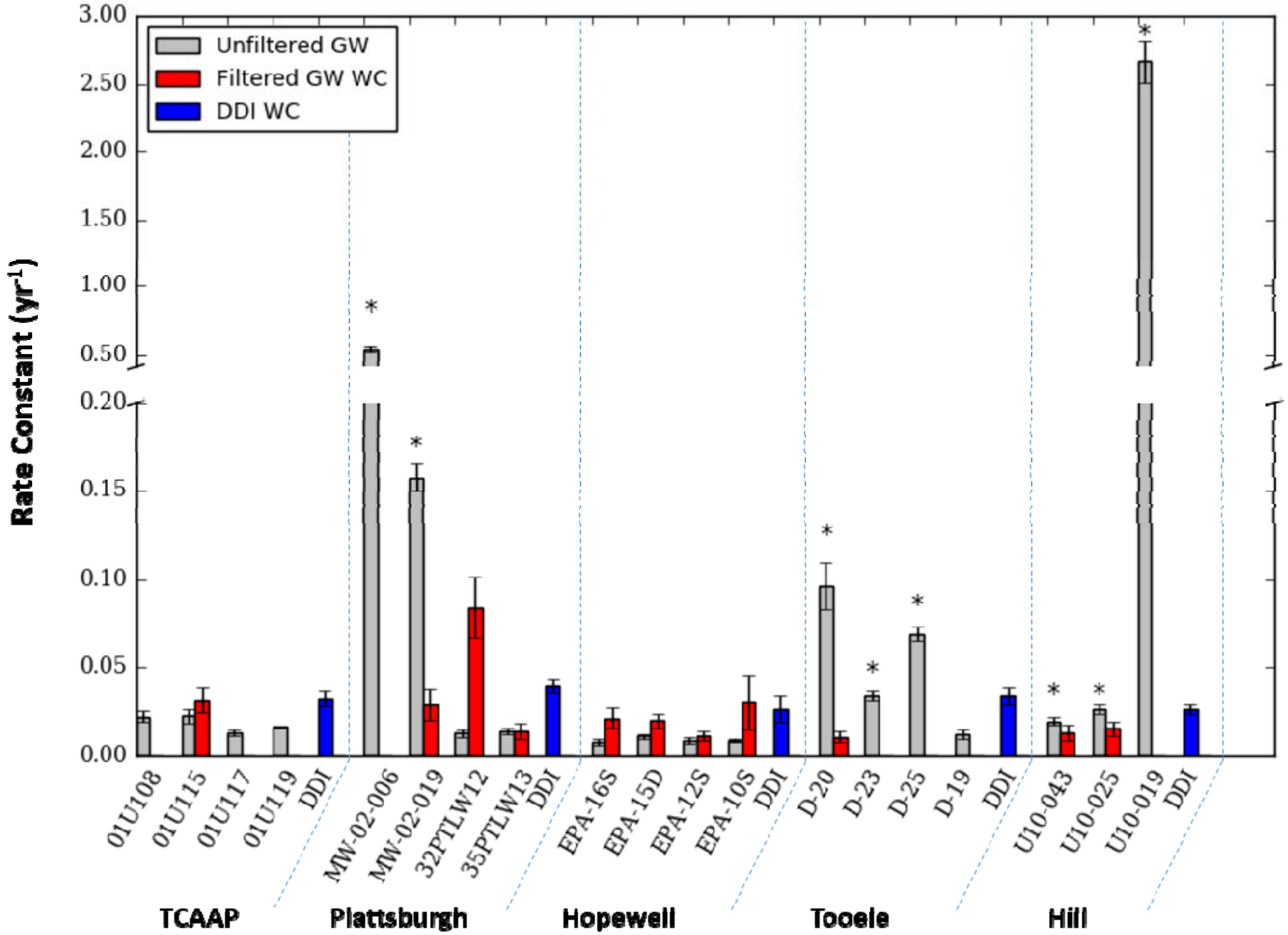


Figure 5.7.5. Average Pseudo First-order Rate Constants for Experimental Wells (gray), FSGW Controls (red), and DDI Water Controls (blue).

Error bars represent the 95% CI. Asterisks indicate the groundwater samples that were statistically significant compared to their respective FSGW controls.

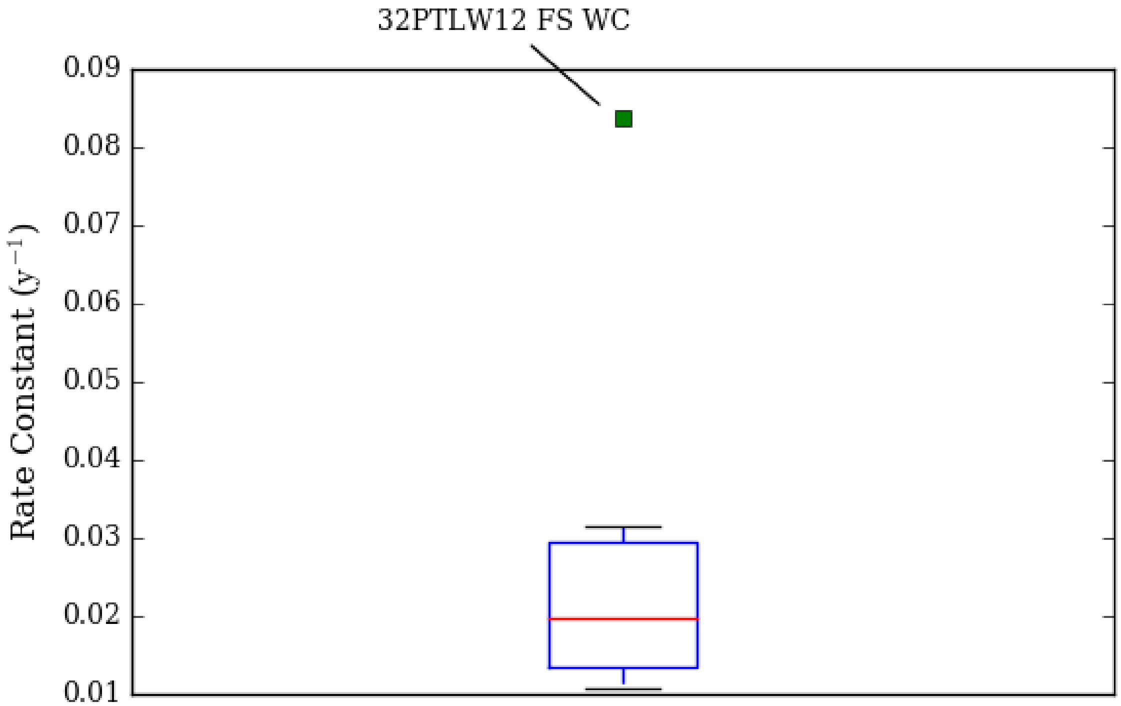


Figure 5.7.6. Boxplot Showing an Extreme Outlier for the Average Pseudo First-order Rate Constant for the FSGW Control from 32PTLW12 at Plattsburgh, Denoted by the Green Square.

The lower whisker represents the smallest first-order rate constant in the lower inner fence (Q_1 – 1.5×IQR), whereas the upper whisker represents the highest first-order rate constant in the upper inner fence (Q_3 + 1.5×IQR). The red line indicates the median value for the rate constants. The upper line of the blue box represents the third quartile (Q_3) and the lower line represents the first quartile (Q_1).

Use of FSGW controls instead of DDI water controls was important for several of the well samples. Figure 5.7.5 shows that the average pseudo first-order rate constants for the experimental bottles from U10-043 and U10-025 at Hill and D-23 at Tooele are lower or approximately equal to the DDI water control. Paired *t*-tests comparing U10-043, U10-025, and D-23 to their respective DDI water controls indicates that the differences are not statistically significant. However, comparing the rate constants for the same groundwater samples to their respective FSGW controls indicates that the groundwater pseudo first order rate constants are statistically higher. Therefore, a net rate for U10-043, U10-025, and D-23 can be determined only using the FSGW controls, not the DDI water controls. In general, using the FSGW controls results in a higher net rate for the groundwater, which translates to a shorter half-life. It appears that constituents in the FSGW dampen autoradiolysis of the ^{14}C-TCE, which would explain the lower rate of ^{14}C product accumulation compared to DDI water. Therefore, FSGW controls provide a more representative degradation rate constant by accounting for groundwater constituents from a particular site compared to the DDI water controls.

Accumulation of ^{14}C products in groundwater samples is shown in Figures 5.7.7 – 5.7.11 for sites at which at least one of the wells had a statistically significant pseudo first order rate constant.

Several of the groundwater samples were actually lower than the FSGW and/or DDI water controls (Figure 5.7.5). In particular, the average rate constants for all of the groundwater samples from TCAAP and Hopewell were not statistically different from the respective FSGW controls. The average rate constant value for 32PTLW12 at Plattsburgh was lower than its respective FSGW control. Additionally, the average rate constants for the all experimental wells at TCAAP and Hopewell, as well as 32PTLW12 and 35PTLW13 for Plattsburgh, D-19 for Tooele, and U10-043 from Hill were lower than the DDI water controls.

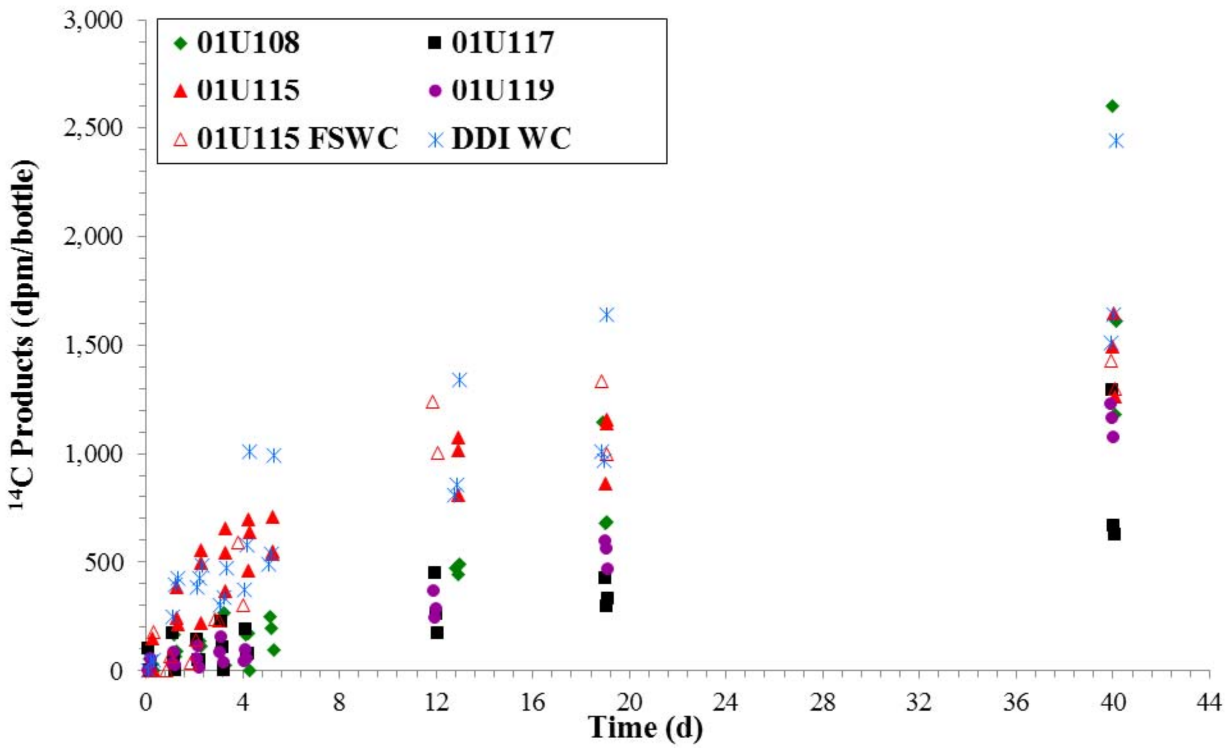


Figure 5.7.7. ^{14}C Product Accumulation in Samples from TCAAP (color-filled symbols), FSGW Controls (open symbols) and DDI Water Controls (asterisks).

Triplicate bottles were analyzed for each treatment.

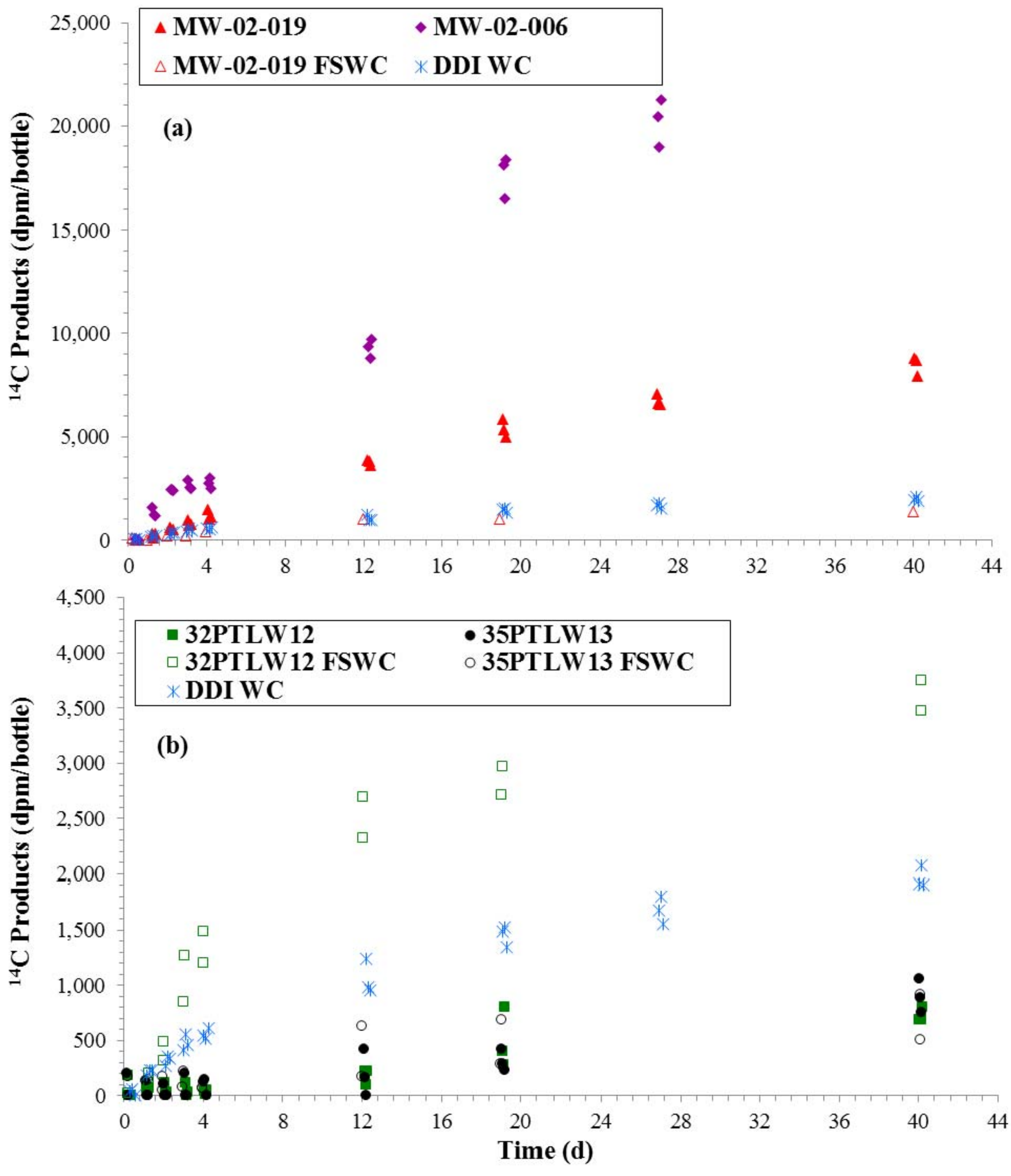


Figure 5.7.8. ^{14}C Product Accumulation in Samples from Plattsburgh (color-filled symbols), FSGW Controls (open symbols) and DDI Water Controls (asterisks), for Treatments (a) with a Statistically Significant Rate of Co-oxidation and (b) Without.

Triplicate bottles were analyzed for each treatment.

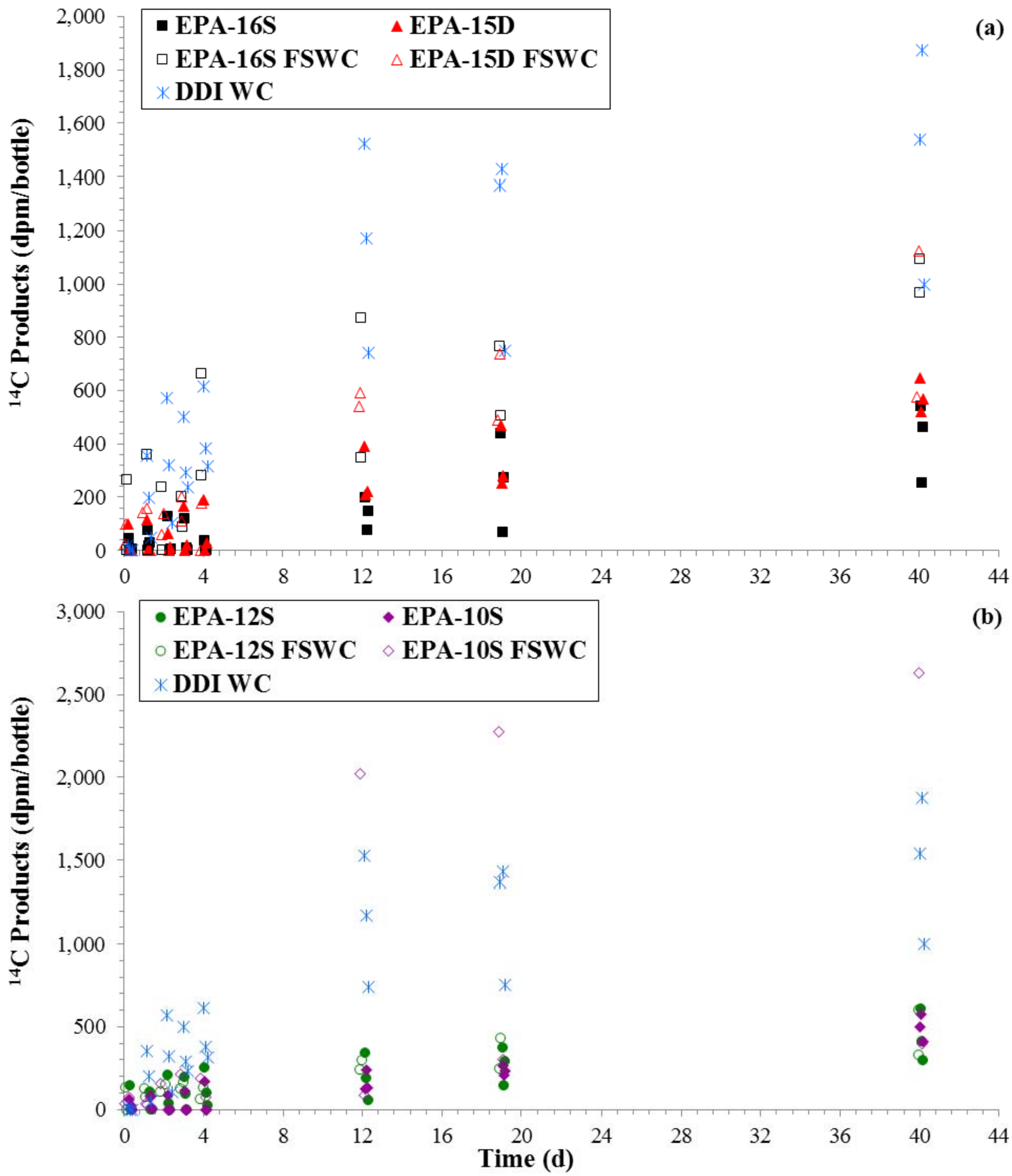


Figure 5.7.9. ^{14}C Product Accumulation in Samples from Hopewell (color-filled symbols), FSGW Controls (open symbols) and DDI Water Controls (asterisks), for Treatments (a) with a Statistically Significant Rate of Co-oxidation and (b) Without.

Triplicate bottles were analyzed for each treatment.

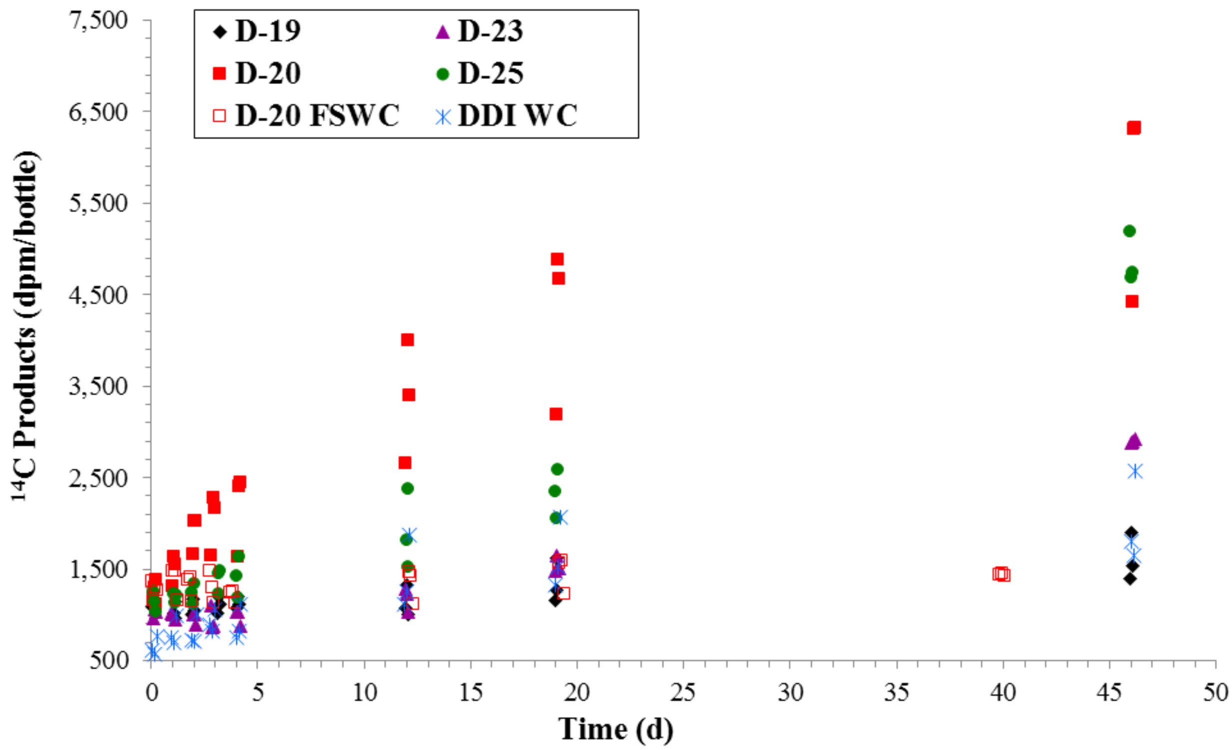


Figure 5.7.10. ^{14}C Product Accumulation in Samples from Tooele (color-filled symbols), FSGW Controls (open symbols) and DDI Water Controls (asterisks).

Triplicate bottles were analyzed for each treatment.

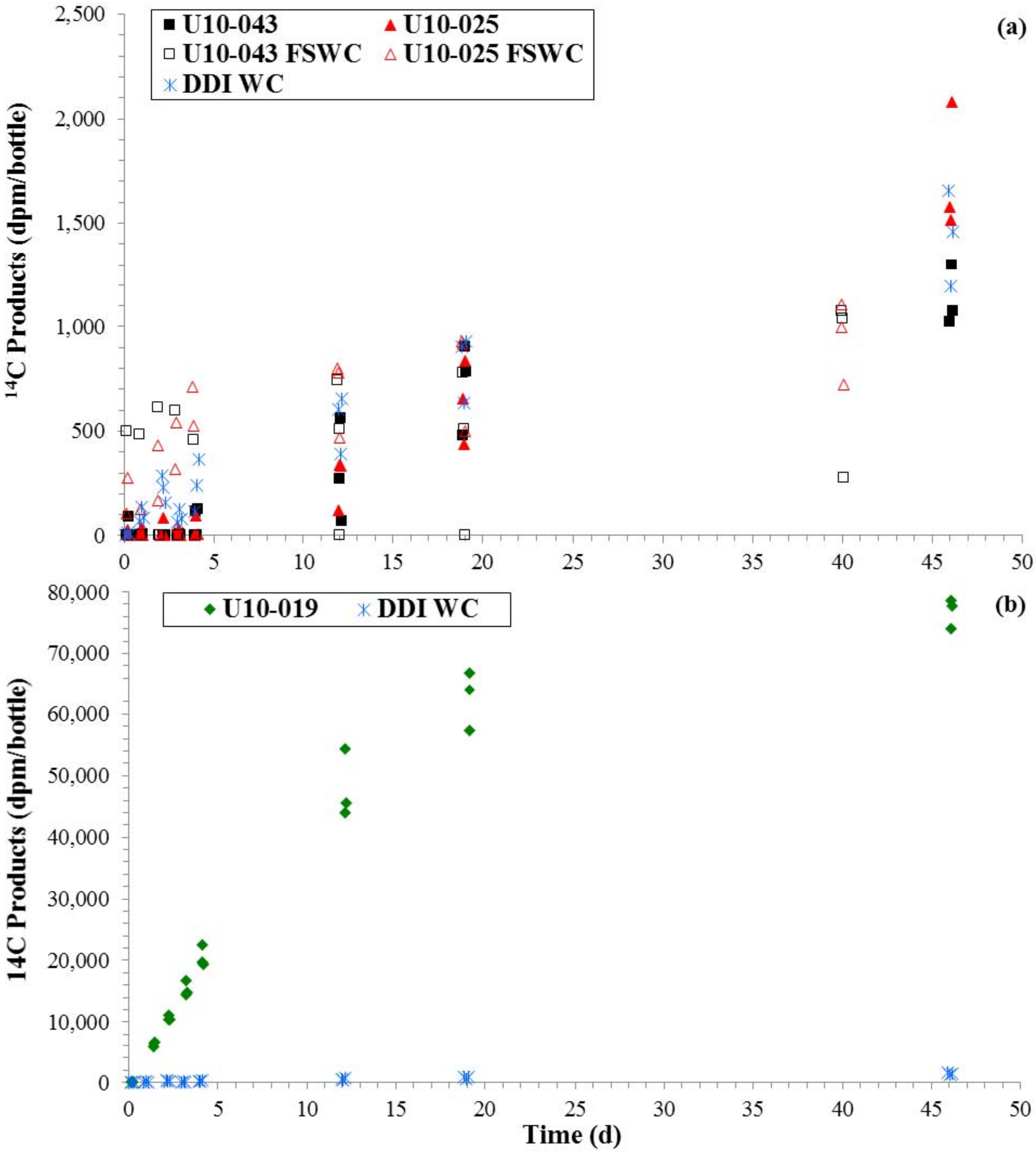


Figure 5.7.11. ^{14}C product Accumulation in Samples from Hill Air Force Base (color-filled symbols), FSGW Controls (open symbols) and DDI Water Controls (asterisks), for Treatments (a) with a Statistically Significant Rate of Co-oxidation and (b) Without.

Triplicate bottles were analyzed for each treatment.

There were eight groundwater samples that had average pseudo first-order rate constants statistically greater than respective FSGW control bottles, as denoted with asterisks in Figure 5.7.5. Additionally, five of those eight wells (MW-02-006, MW-02-019, D-20, D-25, and U10-019) had rate constants that were statistically significant compared to the respective DDI water control for that site. The rate constants from these five wells indicates that biotic activity accounted for the majority of byproduct formation in the groundwater samples.

The pseudo first-order rate constants were determined by fitting a mass balance model for the microcosms to the measured data for ^{14}C product accumulation. Comparisons of the model fit to the data for each serum bottle with groundwater are shown in Figure 5.7.12 to Figure 5.7.19. Symbols in these figures represent experimental data points collected from triplicate bottles over the monitoring period and lines represent the nonlinear model fit used to determine the average pseudo first-order rate constant. For a number of the bottles, the model overpredicted at the final data point (~day 40). This may have been a consequence of the microbes running out of the resources (e.g., reducing power) needed to sustain the oxygenases, and/or a cumulative toxicity effect caused by reactive byproducts from TCE co-oxidation. In other bottles, the model overpredicted early on; the lag in product accumulation may have had something to do with the microbial population readjusting the temperature shock.

5.6.2.2 End-of-Incubation Results

GC headspace measurements were conducted for groundwater and control bottles at time zero and at the end of the monitoring period using the methodology described previously. The purpose was to confirm the presence of TCE remaining in the bottles after the monitoring period, and to track the fate of other VOCs present in the groundwater samples. The GC chromatographs from Day 0 for several samples indicated the presence of VOCs in addition to TCE. These compounds may have served as primary substrates to induce expression of oxygenase enzymes that are responsible for co-oxidation of ^{14}C-TCE. Not all groundwater samples had additional VOCs on Day 0 (e.g. D-20 and D-23, Appendix D, Figure D.22). Other wells had significant VOCs in the groundwater at Day 0. GC chromatographs for groundwater samples that had additional VOCs are shown in Appendix D (Figures D.6-D.11). The GC chromatographs for other wells without additional VOCs are not shown. I n the two wells from Plattsburgh that had statistically significant rates of TCE co-oxidation (MW-02-006 and MW-02-019), the non-TCE VOCs were consumed over the monitoring period (Appendix D, Figures D.6-D.11). In the wells from Tooele that had statistically significant rates of TCE co-oxidation (D-20, D-23, and D-25), there were no apparent VOCs present other than TCE; a chromatogram for well D-25 is provided in Appendix D (Figure D.24). In the wells at Hill that exhibited statistically significant rates of TCE co-oxidation (U10-043, U10-025, and U10-019), there was some change in VOC levels over the monitoring period (Appendix D, Figures D.26-D.32). The identity of the peaks was not established. Based on elution the elution times for authenic material, it was possible to rule out vinyl chloride, 1,1-dichloroethene, *c*DCE, tetrachloroethene, benzene, toluene, ethylbenzene, *o*-xylene, and *p*-xylene. Additional effort to identify the non-TCE VOCs is warrented but was beyond the scope of this project.

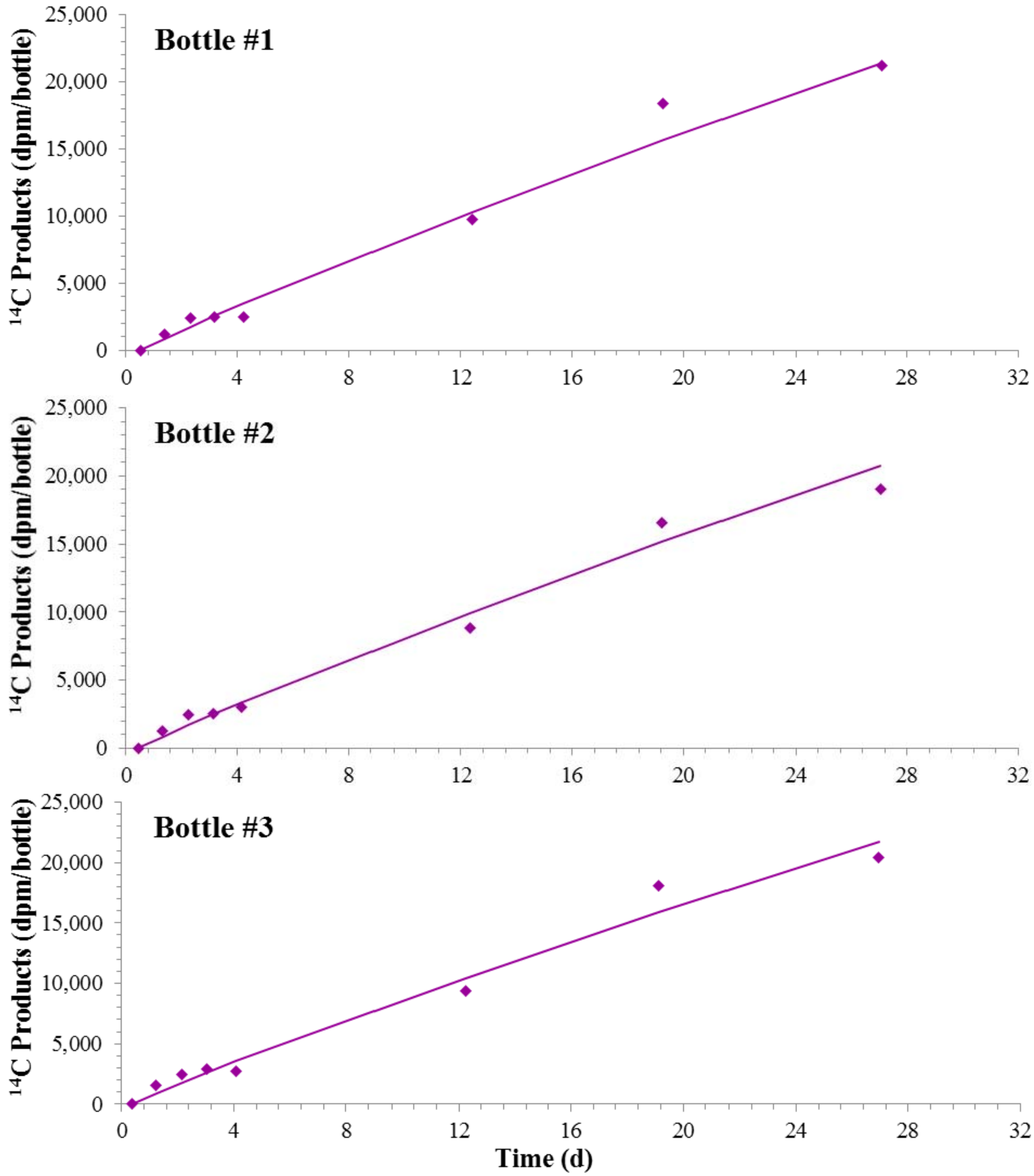


Figure 5.7.12. Comparison of the Measured Accumulation of ^{14}C Products in Triplicate Serum Bottles of Groundwater from Monitoring Well MW-02-006 at Plattsburgh to the Model Used to Determine k.

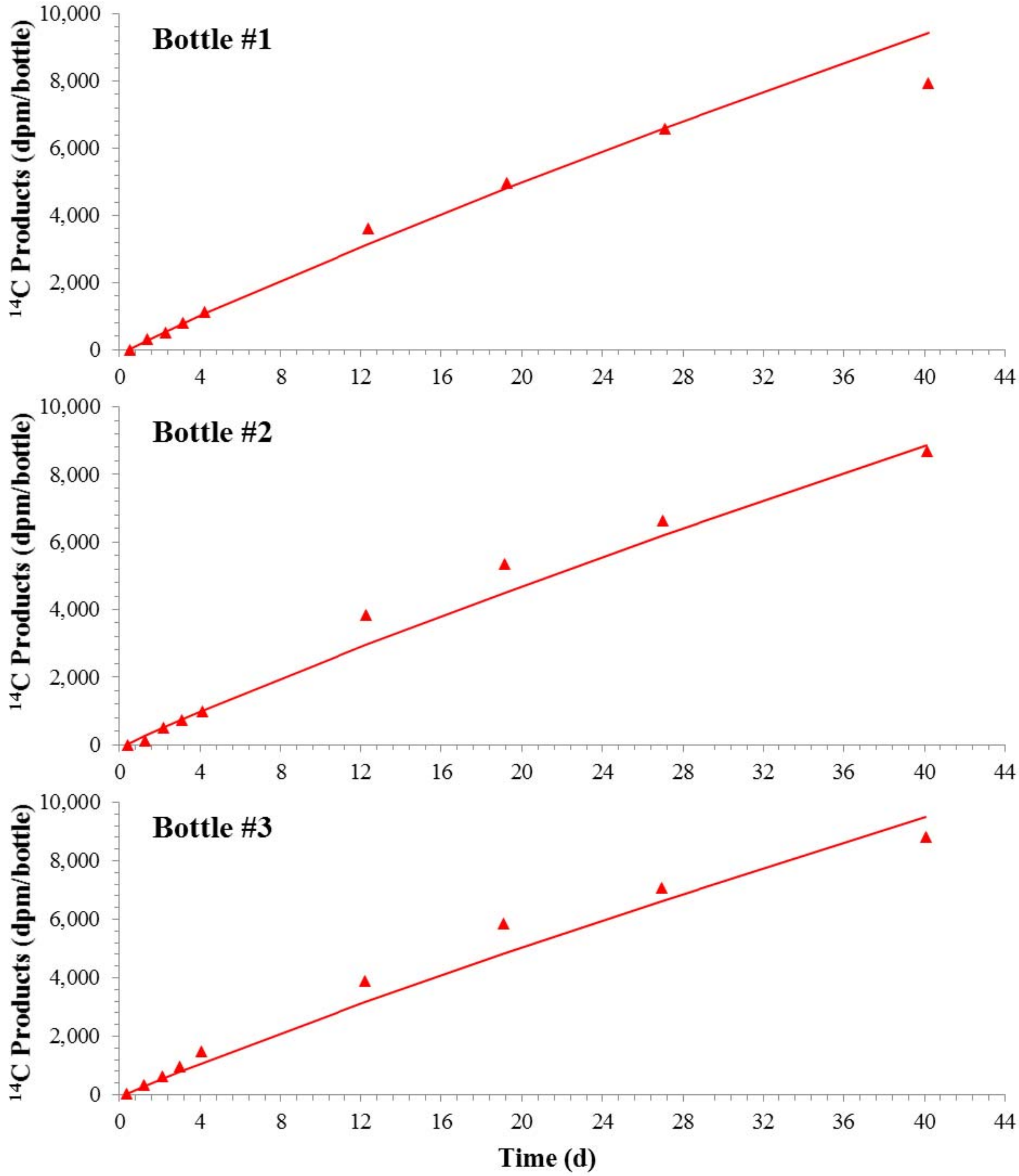


Figure 5.7.13. Comparison of the Measured Accumulation of ^{14}C Products in Triplicate Serum Bottles of Groundwater from Monitoring Well MW-02-019 at Plattsburgh to the Model Used to Determine k.

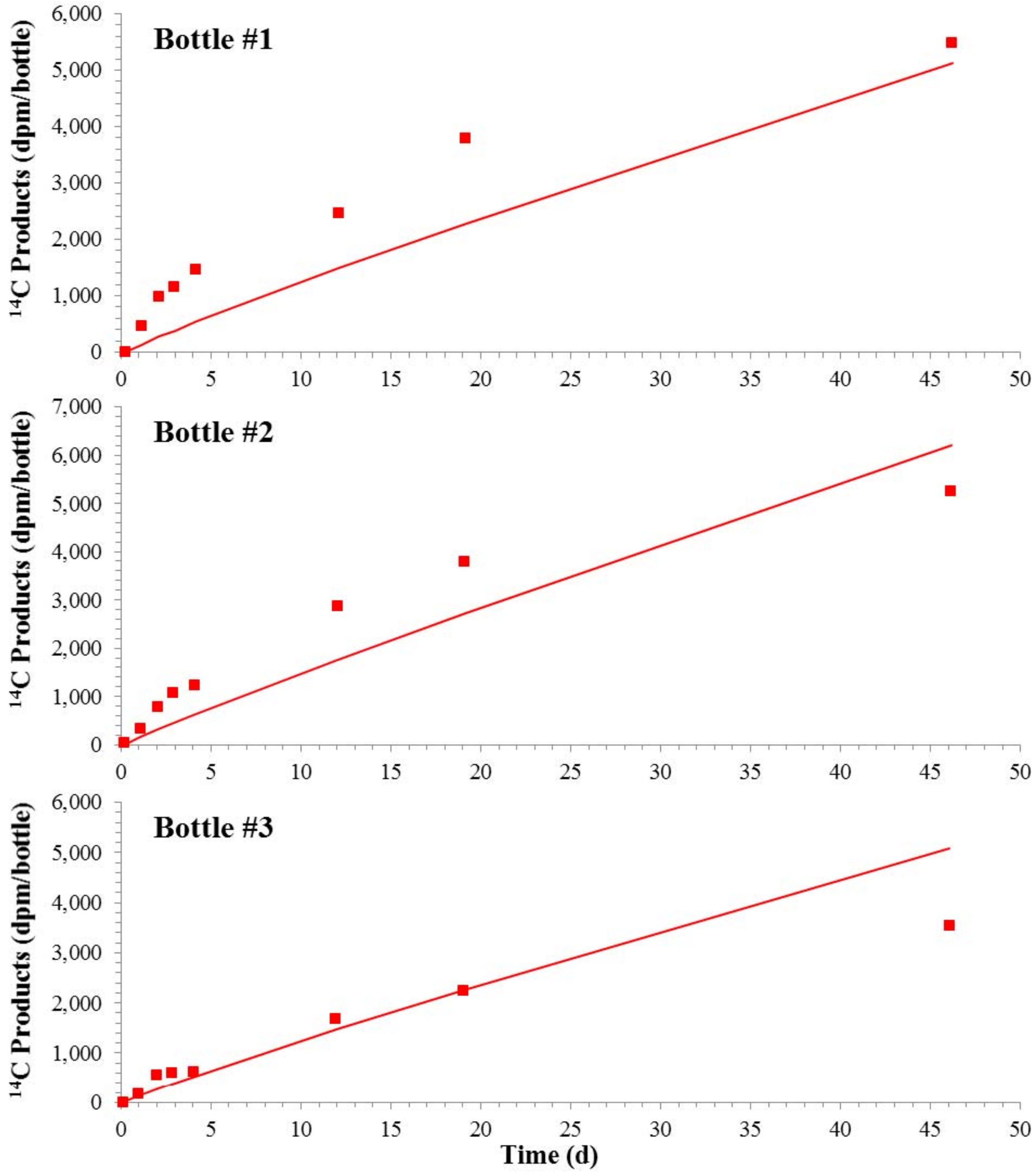


Figure 5.7.14. Comparison of the Measured Accumulation of ^{14}C Products in Triplicate Serum Bottles of Groundwater from Monitoring Well D-20 at Tooele to the Model Used to Determine k.

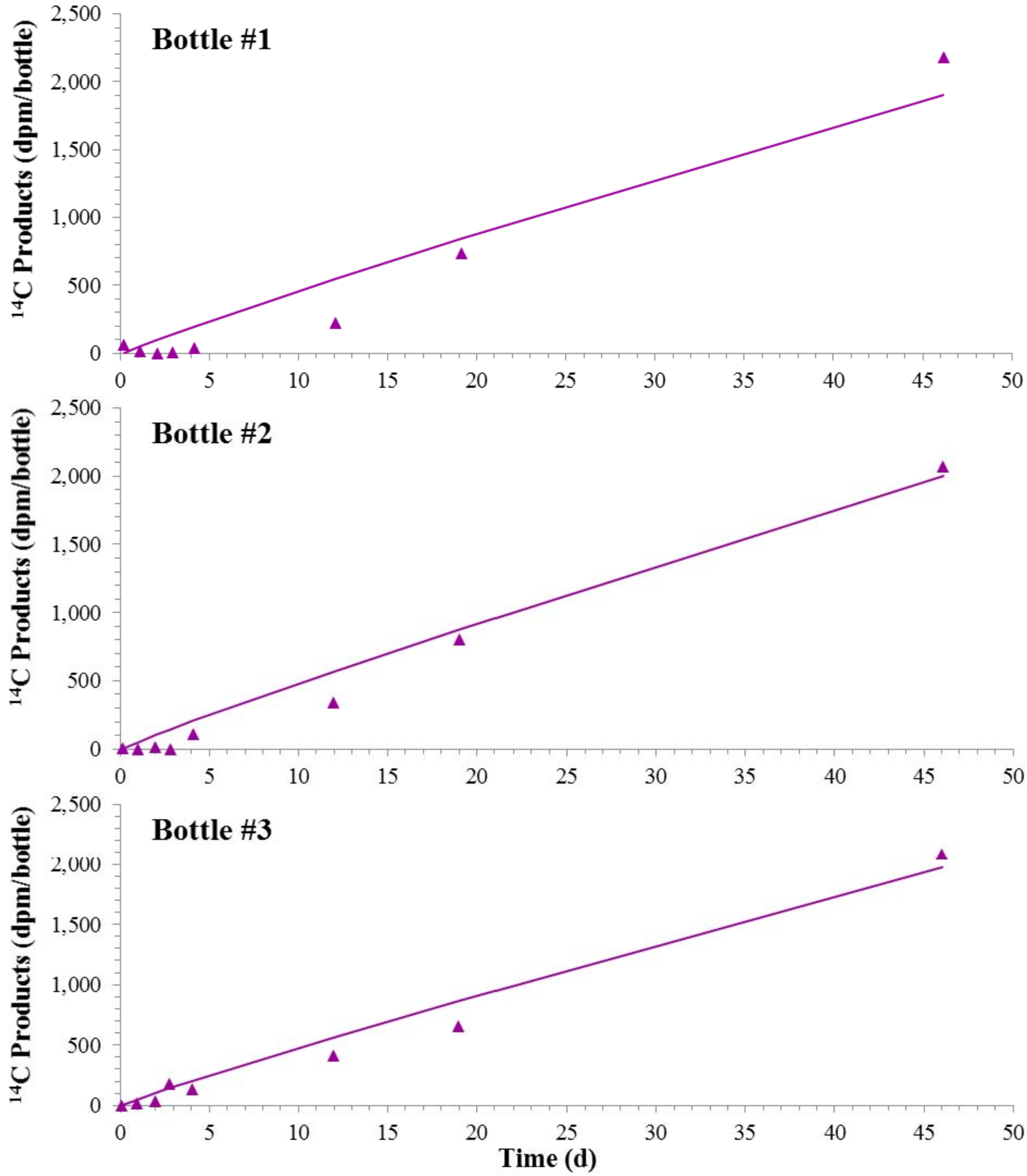


Figure 5.7.15. Comparison of the Measured Accumulation of ^{14}C Products in Triplicate Serum Bottles of Groundwater from Monitoring Well D-23 at Tooele to the Model Used to Determine k.

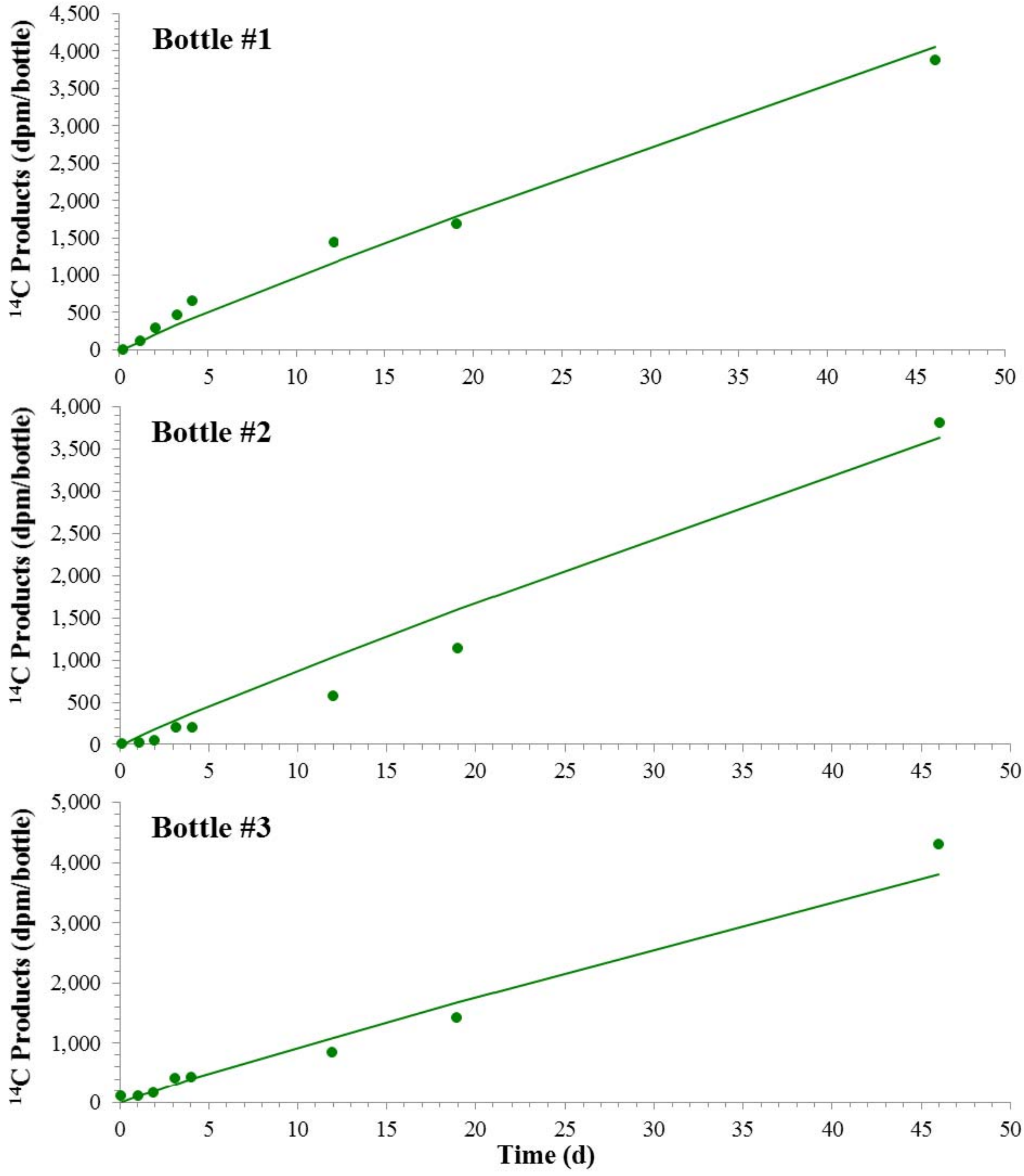


Figure 5.7.16. Comparison of the Measured Accumulation of ^{14}C Products in Triplicate Serum Bottles of Groundwater from Monitoring Well D-25 at Tooele to the Model Used to Determine k.

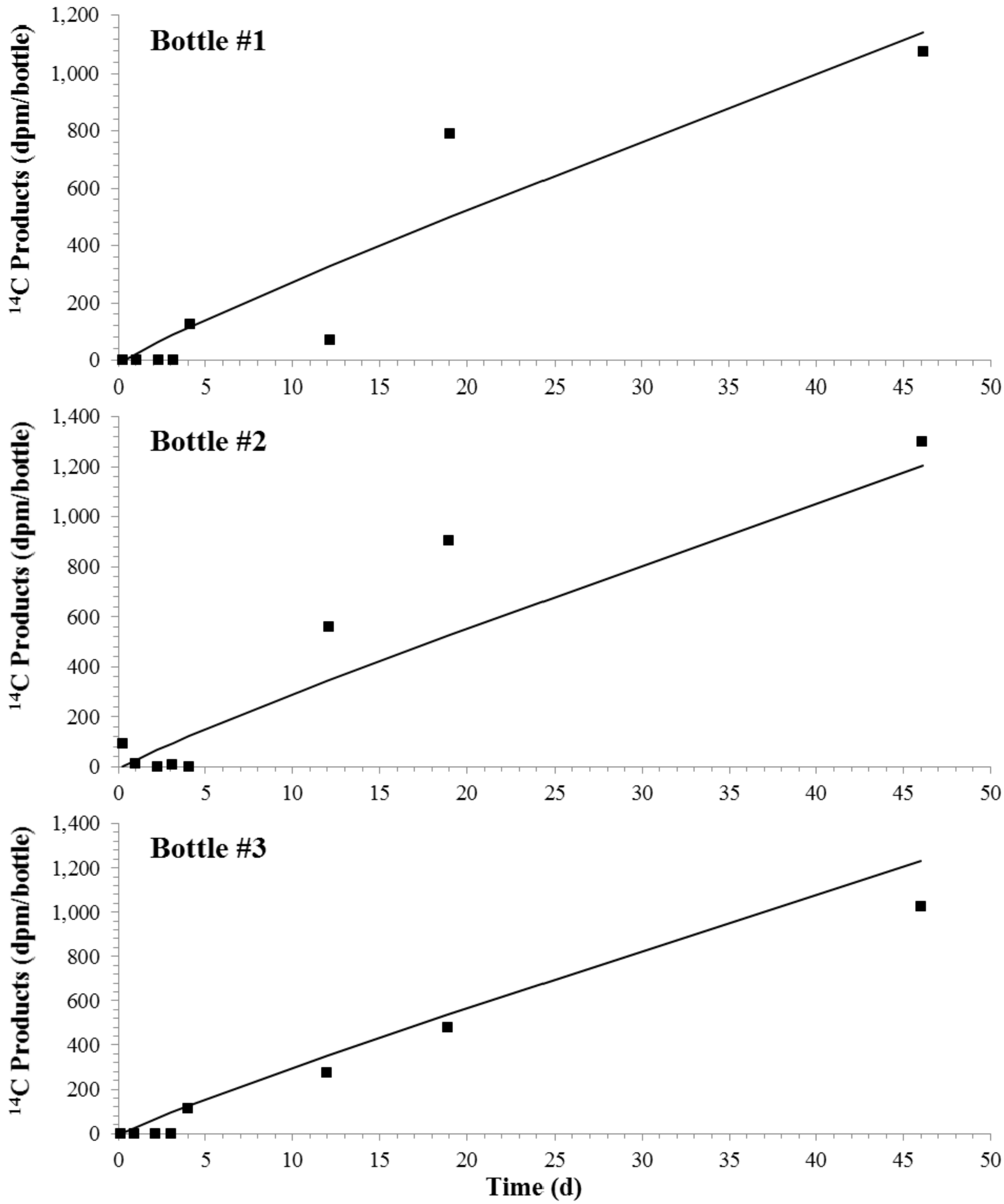


Figure 5.7.17. Comparison of the Measured Accumulation of ^{14}C Products in Triplicate Serum Bottles of Groundwater from Monitoring U10-043 at Hill AFB to the Model Used to Determine *k*.

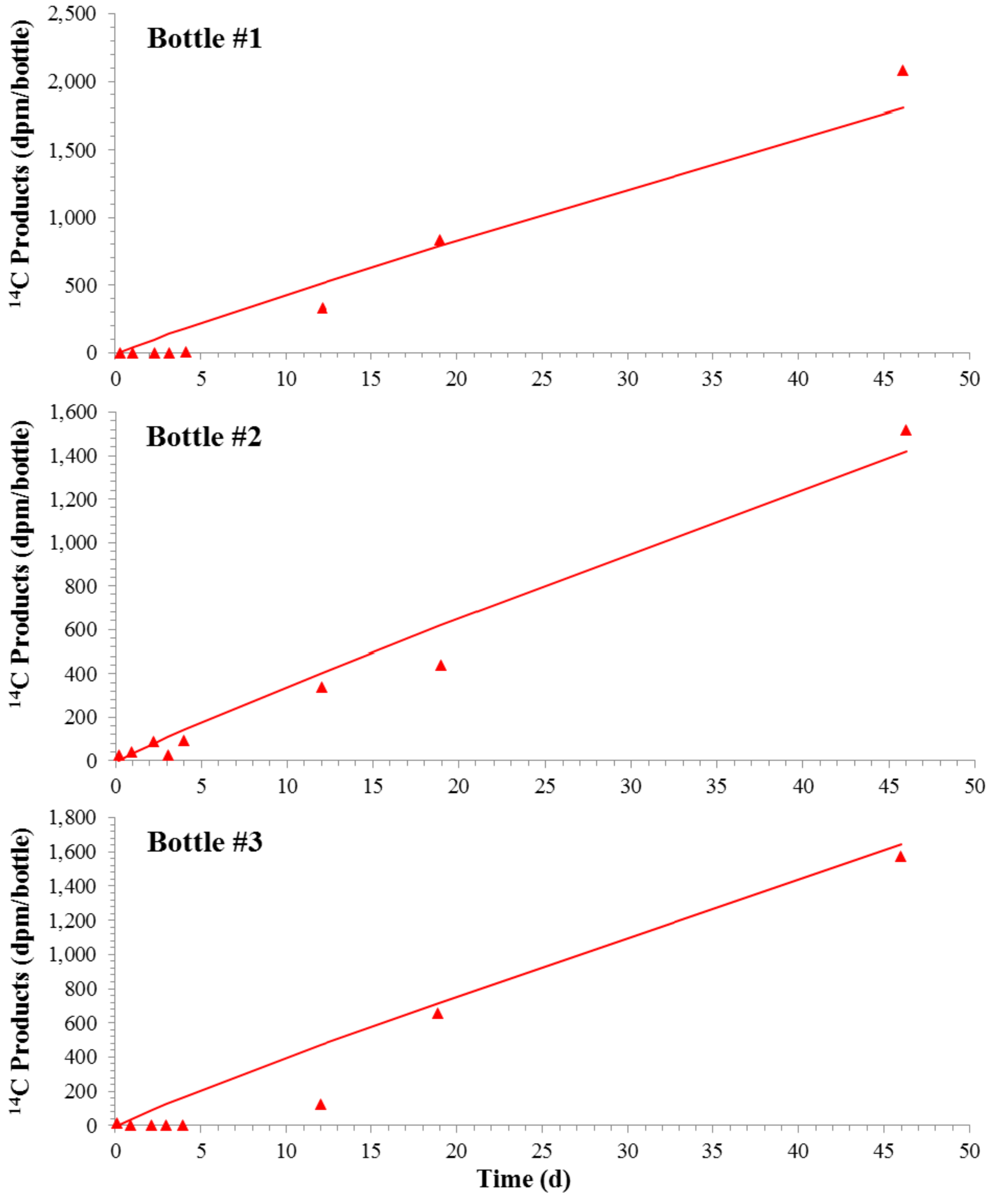


Figure 5.7.18. Comparison of the Measured Accumulation of ^{14}C Products in Triplicate Serum Bottles of Groundwater from Monitoring U10-025 at Hill AFB to the Model Used to Determine *k*.

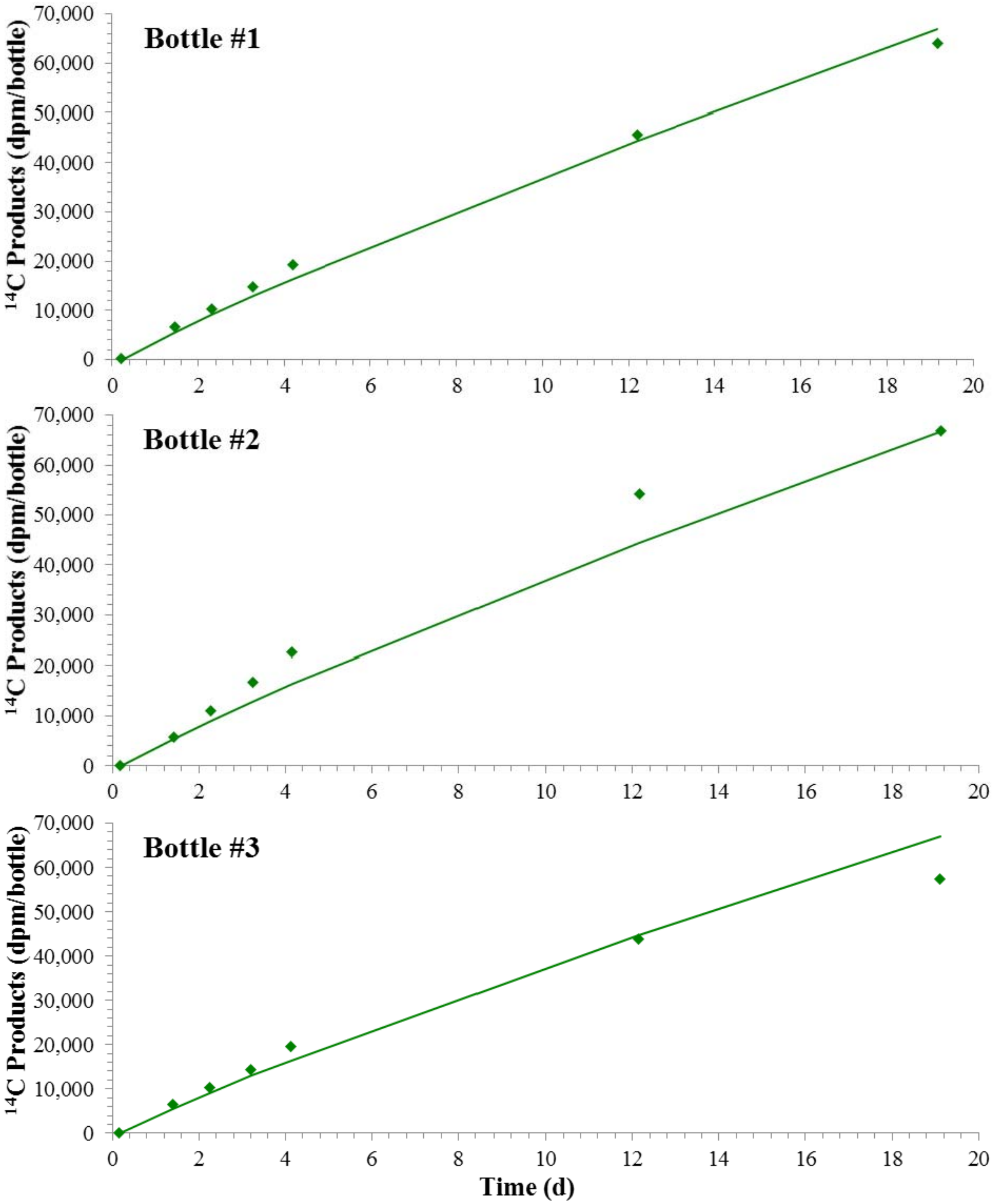


Figure 5.7.19. Comparison of the Measured Accumulation of ^{14}C Products in Triplicate Serum Bottles of Groundwater from Monitoring U10-019 at Hill AFB to the Model Used to Determine k.

For groundwater bottles that exhibited statistically significant accumulation of ^{14}C products, additional testing was performed at the end of the monitoring period to determine the percentage of $^{14}CO_2$ and ^{14}C-NSR that formed. One method utilized barium hydroxide to precipitate the ^{14}C-carbonate byproducts from alkaline sparged groundwater. The difference between the alkaline sparged sample and centrate following barium hydroxide precipitation was assumed to be the amount of $^{14}CO_2$ in solution. Results based on this method are found in Figure 5.7.20a and Table 5.7.4. The other method involved acidic sparging of the groundwater, which removed ^{14}C-TCE and $^{14}CO_2$, leaving only ^{14}C-NSR. $^{14}CO_2$ was calculated based on the difference between the alkaline and acidic sparged samples. Results are presented in Figure 5.7.20b and Table 5.7.4. There was no statistically significant difference in the percentage of $^{14}CO_2$ determined by both methods (Student's *t*-test, p=0.39).

$^{14}CO_2$ was more prevalent as a product than ^{14}C-NSR in the groundwater samples (Figure 5.7.20), indicating that the groundwater contained a sufficient diversity of microbes to accomplish minerlization of the products from the initial oxygenase attack on TCE. In contrast, the propanotrophic treatments had increasing levels of ^{14}C-NSR as the dilution increased. This is likely a consequence of propanotrophs lacking the ability to achieve mineralization, plus the low density of non-propanotrophs in the enrichment that possess this capability.

5.6.2.3 Summary

The ^{14}C-TCE assay allowed for quantification of pseudo first order rate constants in groundwater samples from eight of the 19 wells evaluated, at rates ranging from ranging from 0.00658 to 2.65 yr^{-1}. This translates to half-lives of 0.26 to 105 yr. In groundwater from the other 11 wells, the rate of ^{14}C product accumulation was not statistically different from the FSGW controls, so that no rate is reported. Although only a single GC column was used for purification of the ^{14}C-TCE, the level of impurities delievered to the serum bottles was sufficiently low to allow for detection of a half-life as long as 105 yr. This was due in part to extension of the incubation period from a few days to as long as 46 days, which permitted accumulation of a sufficient level of ^{14}C products to be distinguishable from the controls.

The initial plan was to use DDI water as the negative control. It was determined, however, that FSGW is more appropriate for this purpose. The rate of ^{14}C product accumulation in FSGW controls was statistically lower than in DDI water, likely due to the presence of constitutes that quench the autoradiolysis associated with decay of ^{14}C-TCE.

$^{14}CO_2$ constituted the majority of the ^{14}C product quantified, followed by ^{14}C-NSR. This indicated that the groundwater samples that exhibited co-oxidation of TCE contained microbes with the ability to mineralize the products formed from the initial oxygenase attack on the compound.

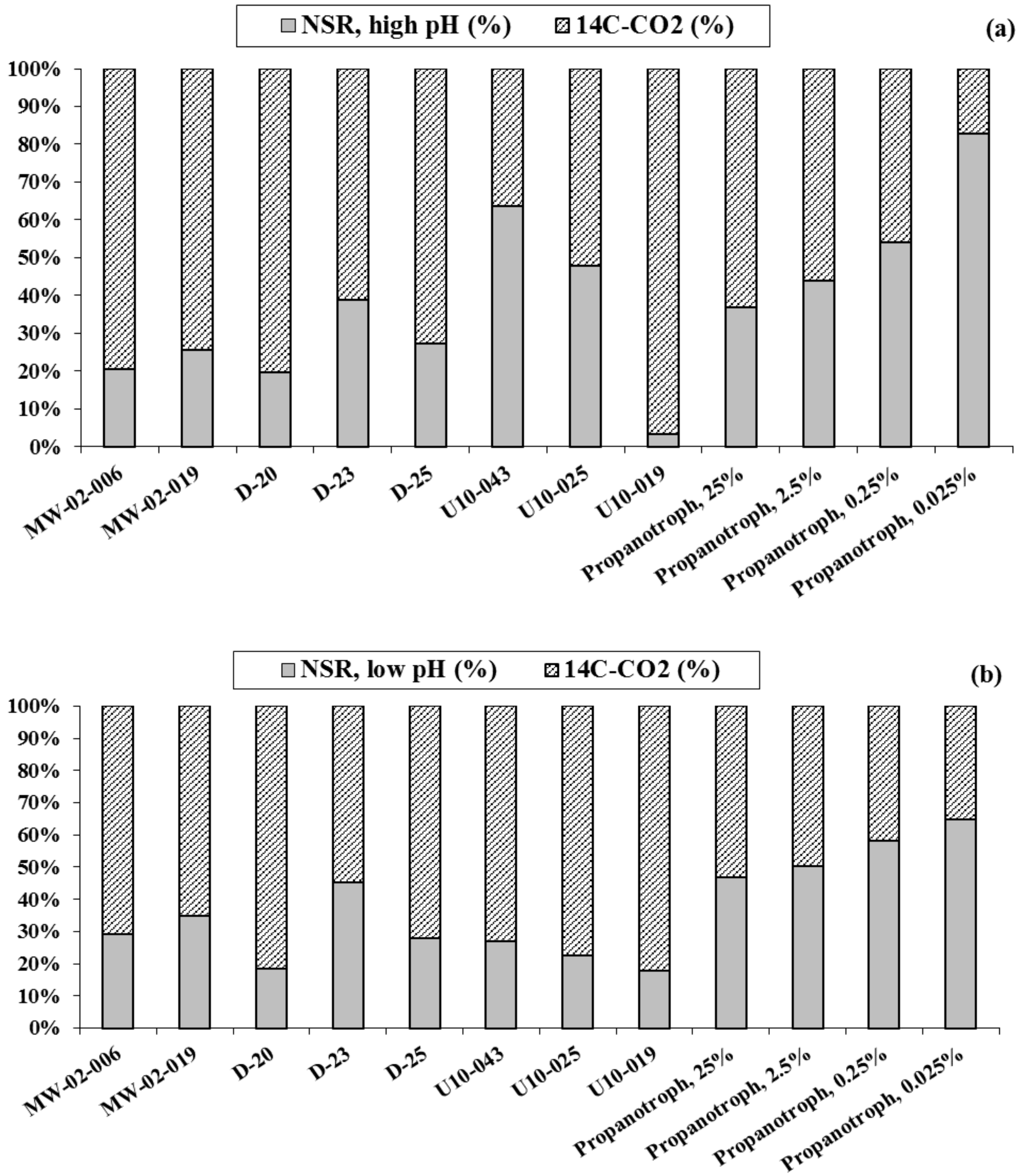


Figure 5.7.20. $^{14}CO_2$ and ^{14}C-NSR Present at the End of Incubation for Groundwater Samples that Were Statistically Significant Compared to their Respective Controls and the Propanotrophic Dilution Bottles.

Two methods were used: (a) alkaline sparging followed by barium hydroxide precipitation and (b) acidic sparging method.

Table 5.7.4. Comparison of Methods Used to Determine the Amount of $^{14}CO2$ and ^{14}C-NSR in the Groundwater Samples with a Statistically Significant k and the Propanotrophic Cultures.

Site Location	Well	Barium Hydroxide		Acidic Sparging	
		$^{14}CO_2$ (dpm/mL)	NSR, high pH (dpm/mL)	$^{14}CO_2$ (dpm/mL)	NSR, low pH (dpm/mL)
Plattsburgh	MW-02-006	296	76	211	87
Plattsburgh	MW-02-019	113	39	80	43
Tooele	D-20	83	20	65	15
Tooele	D-23	36	23	22	18
Tooele	D-25	59	22	50	19
Hill	U10-043	11	19	20	7
Hill	U10-025	20	18	26	8
Hill	U10-019	1107	37	783	171
-	Propanotroph, 25%	3927	2293	3301	2919
-	Propanotroph, 2.5%	1101	858	744	750
-	Propanotroph, 0.25%	111	130	101	140
-	Propanotroph, 0.025%	9	43	18	33

5.6.3 Sampling Results for EAPs and qPCR

5.6.3.1 Introduction

Microbial metabolism is the means by which a microbe obtains the energy and carbon it needs to live and reproduce. Microbes use many different types of metabolic strategies and species can often be differentiated from each other based on metabolic characteristics. The specific metabolic characteristics of a microbe are the major factors in determining that microbe's ecological niche, and often allow for that microbe to be useful in industrial processes, breaking down anthropogenic compounds, or responsible for biogeochemical cycles. All microbial metabolisms can be arranged according to three groups based on the primary carbon metabolized: (1) autotrophic organisms obtain carbon from carbon dioxide (CO_2), (2) heterotrophic organisms obtain carbon from organic compounds, and (3) mixotrophic organisms obtain carbon from both organic compounds and by fixing carbon dioxide. Most microbes, particularly environmentally relevant microbes, are heterotrophic, using organic compounds as both carbon and energy sources. These microbes are extremely abundant in nature and are responsible for the breakdown of large organic polymers such as cellulose, chitin or lignin which are generally indigestible to larger organisms. Some heterotrophic organisms are even able to degrade more recalcitrant compounds such as petroleum compounds or pesticides, making them useful in bioremediation.

There is a diversity of compounds that can serve as carbon for microbial metabolism. One subgroup of organisms is those that biodegrade one organic substance to obtain carbon and energy for growth, simultaneously transforming other compounds that cannot be used for growth (Thomas and Ward, 1989). This process is known as cometabolism and it describes the ability of microorganisms to fortuitously transform non-growth-supporting substrates, such as pollutants.

Cometabolic transformations are catalyzed by existing microbial enzymes and yield no carbon or energy benefits to the transforming cells (Horvath, 1972), thus a growth substrate must be available at least periodically to grow new cells, provide an energy source, and induce production of the cometabolic enzymes. Although some studies have found that naturally occurring humic substances (an organic residue of decaying organic matter; Wymore et al., 2007; Lee et al., 2008) and the chlorinated solvents themselves can act as inducers of the cometabolic enzymes, the extent of and time for activation, as well as the mechanism for cell energy and growth in these instances, are poorly understood (Shingleton et al., 1998; Park et al., 2002; Yeager et al., 2004).

Cometabolic processes were first studied in the 1950s and 60s and focused on the microbial degradation of important classes of industrial chemicals including aromatics (Dagley and Pate, 1957), chlorinated organics (Jensen, 1957, 1963), pesticides (Alexander, 1967) and petroleum hydrocarbons (Foster, 1962). Decades of research have concluded that the following compounds are among those that are readily cometabolized: trichloroethene (TCE), dichloroethene (DCE), vinyl chloride (VC), trichloroethane (TCA), dichloroethane (DCA), chloromethane (CM), dichloromethane (DCM), and chloroform (CF) (Vandenwijngaard, 1992; Hartmans, 1985; Hartmans and Debont, 1992; Munakata-Marr, 1997; Vannelli, 1998; McCarty et al., 1998; Braus-Stromeyer, 1993; Gisi, 1998; Edwards and Cox, 1997; McCarty, 1997a; Bradley and Chapelle, 1998; Travis and Rosenberg, 1997). Collectively, these studies established that microorganisms could transform many compounds/contaminants without concurrent microbial growth on those compounds, and the enzymes responsible for these transformations are mono- and dioxygenases.

Oxygenase enzymes in general are a subset of the enzymes classified as oxidoreductases, one of the six major classes of enzymes. Oxygenases serve a myriad of functions in cells including biosynthesis, detoxification, and catabolism (metabolic breakdown of complex compounds). Oxygenases catalyze the reduction of O2 with incorporation of one (monooxygenases) or two (dioxygenases) of the oxygen atoms into the substrate that is being oxidized. In the context of contaminant degradation, the oxygenase reaction generates chlorinated solvent oxidation products that may react with cellular macromolecules or may be hydrolyzed spontaneously into carbon dioxide, chloride, or other non-volatile products that are easily mineralized by microorganisms (Little et al., 1988; Tsien et al., 1989; Oldenhuis et al., 1989; Fox et al., 1990; Nelson et al., 1986, 1987; Rasche et al., 1991). Unlike anaerobic biological reductive dechlorination, aerobic cometabolism does not proceed through sequential dechlorination steps producing daughter products such as DCE, VC, and ethene; thus, signature aerobic degradation products, such as Cl- and CO2, are difficult to attribute to aerobic degradation in situ using geochemistry alone. The end result is that the only evidence for aerobic cometabolism is the disappearance of the contaminants themselves.

Chlorinated solvents and other contaminants can be oxidized by a wide range of oxygenase-expressing microorganisms including those that utilize methane (Wilson & Wilson, 1985; Strand & Shippert, 1986; Fogel et al., 1986; Little et al., 1988; Tsien et al., 1989; Oldenhuis et al., 1989), propane (Fliermans et al., 1988; Wackett et al., 1989; Phelps et al., 1990; Malachowsky et al., 1994), propene (Ensign et al., 1992; Saeki et al., 1999), isoprene (Ewers et al., 1990), isopropylbenzene (Pflugmacher et al., 1996; Dabrock et al., 1992; Kesseler et al., 1996), toluene (Nelson et al., 1986;Wackett et al., 1988; Zylstra et al., 1989; Shields et al., 1989), phenol (Folsom et al., 1990; Harker & Kim, 1990; Segar, 1995), butane (Kim et al., 1997; 2000), ethene and ethane (Freedman & Herz, 1996; Koziollek et al., 1999), and ammonia (Arciero et al, 1989; Vannelli et al., 1990; Rasche et al., 1991; Hyman et al., 1995) as energy and/or carbon sources.

Representative cultured organisms, their primary growth substrates, and kinetic data with regards to TCE are included in Table 5.7.5 (modified from Arp review 2001). The enzyme responsible for TCE oxidation in these organisms is also listed. The majority of these organisms are capable of growth on many substrates, several of which may stimulate expression of the TCE-degrading oxygenase enzymes. While some oxygenase enzymes are very specific for particular substrates, others oxygenase enzymes have remarkably broad substrate ranges. It is important to note that the TCE oxidation rates presented in Table 5.7.5 are based on cultured organisms maintained and evaluated under controlled laboratory settings, and as such may not reflect the true potential for degradation under field conditions.

In order to monitor aerobic cometabolism given the challenge of monitoring the process through groundwater chemistry, subsurface microbial communities have been interrogated using validated biomarkers including enzyme activity probes (EAP) and quantitative polymerase chain reaction (qPCR). EAPs have been applied at almost 20 contaminated sites that are oxic for their reliability, reproducibility and sensitivity in evaluating aerobic cometabolic enzymes, while qPCR has been evaluated for at least a subset of the potential aerobic oxygenase genes (McDonald et al., 1995; Baldwin et al., 2003; 2005; 2008; 2009; Bowman et al., 1993; Hendricks et al., 2006a; 2006b; Domiguez et al., 2008). These approaches provide information about both the presence of the genes of interest, which is important if evaluating the potential for enhanced attenuation of the contaminant in situ, and the activity of the oxygenases, which is important in evaluating degradation capacity and long-term sustainability. When these technologies are simultaneously evaluated and compared with more traditional approaches such as geochemical analyses, they provide a comprehensive assessment that can potentially quantitatively relate the qPCR and EAP results to contaminant biotransformation.

Several methods assess the in-situ activity of microbes in the subsurface (Keift and Phelps, 1997); however, these methods can be time consuming and frequently provide overestimates of the actual rates of activity (Phelps et al., 1994). The recent design of a suite of EAPs has permitted the determination of specific aerobic cometabolism of chlorinated ethenes, most notably TCE. EAPs that serve as alternate substrates for TCE cometabolizing enzymes have been developed for four separate aromatic oxygenases (Keener et al., 1998; 2001; Miller et al., 2001; Clingenpeel et al., 2005), and for the soluble methane monooxygenase (SMMO; Miller et al., 2001). Specific EAP and the targeted co-metabolic enzymes are shown in Table 5.7.6. These non-fluorescent probes are transformed by the enzymes into a quantifiable fluorescent signal upon transformation, thus providing direct evidence of cometabolic enzyme activity. Enzyme probes have been evaluated at a number of DOE and DOD sites over the last five years (Lee et al., 2005; Lee et al., 2007; Wymore et al., 2007). Based on these analyses of contaminated groundwater, ranging in TCE concentrations from <100 µg/L to over 10,000 µg/L, it appears that enzyme probes provide a direct estimate of aerobic cometabolic enzyme activity for subsurface populations. Application of EAP's at contaminated sites can provide valuable information regarding the presence and activity of in situ microbial enzyme systems important for aerobic cometabolism for plume-wide assessment of intrinsic assessment of degradation.

Table 5.7.5. Cometabolic Enzyme Systems with Respective Organisms and TCE Oxidation Rates.

Growth Substrate	Organism	Enzyme	TCE oxidation rate (nmol min-1 mg of protein -1)	Reference
Ethene/ propene	*Xanthobacter Py2*	Alkene monooxygenase	8.6 16-95	Ensign, 1992; Reij, 1995
Propene	*Rhodococcus corallimus*	Alkene monooxygenase	2.4	Saeki, 1999
Isopropylbenzene	*Pseudomonas sp strain JP1* *Rhodococcus erythropolis BD2*	Isopropylbenzene dioxygenase; Toluene dioxygenase	0.5-2	Pflugmacher et al., 1996; Dabrock et al., 1992; Kesseler et al., 1996
Ammonia	*Nitrosomonas europaea*	Ammonia monooxygenase	10.9	Bedard, 1989; Ely, 1995b; Hyman, 1995; Rasche, 1991
Phenol	*JMP 134*	Phenol monooxygenase	0.2	Harker , 1990
Butane	*Pseudomonas butanavora*	Butane monooxygenase	.06	Hamamura, 1997
Propane	*Mycobacterium vaccae JOB5*	Propane monooxygenase		Wackett, 1989
Methane	*Methylosinus trichosporium OB3b*	Particulate methane monooxygenase	4.1	DiSpirito, 1992; Lontoh, 1998
Methane	*Methylosinus trichosporium OB3b*	Soluble methane monooxygenase	16.6 37.5	Koh, 1993; Oldenhuis, 1989; 1991; Tsien, 1989
Methane	*Methylosinus methanica*	Soluble methane monooxygenase	38.8	Koh, 1993
Toluene	*Pseuodomonas putida F1*	Toluene dioxygenase	8 1.8 0.5	Heald, 1994; Leahy, 1996; Wackett, 1988; Zylstra, 1989
Toluene	*Burkholderia cepacia G4*	Toluene-2-monooxygenase	8 10 9 3	Folsom, 1990; Landa, 1994; Leahy, 1996; Shields, 1991
Toluene	*Pseuodomonas mendocina KR1*	Toluene-4-monooxygenase	20 2.4	Leahy, 1996; Winter 1989
Toluene	*Ralstonia pickettii PK01*	Toluene-3-monooxygenase	2.4	Leahy, 1996

Table 5.7.6. EAP and Targeted Oxygenases/ Pathways

Probe	Pathway
3-hydroxyphenylacetylene (3HPA)	toluene-2-monooxygenase toluene-3-monooxygenase toluene-2,3-dioxygenase
Phenylacetylene (PA)	toluene-2,3-dioxygenase toluene-3-monooxygenase toluene-2-monooxygenase
3-ethynylbenzoate	toluene-side-chain-monooxygenase
trans-cinnamonitrile (CINN)	toluene-2,3-dioxygenase
Coumarin, naphthalene	Soluble methane monooxygenase

5.6.3.2 Results

5.6.3.2.1 Enzyme Activity Probes:

Enzyme activity probes (EAP) have been developed for four separate toluene oxygenases (Keener et al. 1998; Keener et al. 2001; Kauffman et al. 2003) and for the soluble methane monooxygenase (SMMO) (Miller et al. 2002) all five of which can be fluorescently monitored. The probes consist of non-fluorescent compounds ("substrates") that are transformed by specific oxygenases into strongly fluorescent products. A clear, quantifiable signal (i.e., fluorescence) can be detected only when the targeted enzyme is actively functioning. As TCE can be cometabolically degraded by these aforementioned oxygenases, quantifying bacterial enzyme activity provides insight into the microbial capacity of a given samples to break down TCE as has been previously described (Lee et al. 2008).

The quantitative processing of samples for probe activity includes collecting 20 random fields (or appropriate number of fields to count a minimum 200 total cells) with a microscope-attached digital camera. Labeled (fluorescent) cells are counted to estimate the activity in the original sample in standard reporting units (cells/mL). The resulting mean and standard deviations for all of the data generated was recorded using three different enzyme probes, this data is reflected in Table 5.7.7.

5.6.3.2.2 Quantitative Polymerase Chain Reaction:

qPCR is a means to quantify the abundance of DNA in a given sample. For this work we quantified the abundance of bacteria that encoded one of five oxygenase genes. In total 200 ml of groundwater from the 76 samples representing 19 wells were vacuum filtrated onto 0.22 micron filters. For each filter 1/8 of the total surface area was processed using the Mo Bio Powersoil DNA extraction kit. DNA was subsequently analyzed after purification using a nanodrop spectrophotometer. From a 100 uL final DNA elution volume, 1 uL was analyzed by SYBR Green qPCR (see below).

Table 5.7.7. EAP Counting Data.

DAPI- total cell counts. PA (T2-mono)- phenylacetylene and 3HPA (T3-mono)- 3-hydroxyphenylacetylene target toluene-2-monooxygenase and toluene-3-monoxygenase, respectively. CINN (T23-di)-trans-cinnamonitrile targets toluene-2,3-dioxygenase

Sample ID	DAPI (total) cells/ml	Standard Error	PA (T2-mono) cells/ml	Standard Error	Cinn (T23-di) Cells/ml	Standard Error	3HPA (T3-mono) cells/ml	Standard Error
01U119	7.11E+05	4.29E+04	1.38E+03	8.37E+02	1.55E+03	1.06E+03	5.31E+03	2.80E+03
01U108	6.91E+05	4.64E+04	2.03E+03	1.21E+03	5.46E+02	4.89E+02	2.36E+03	1.67E+03
01U117	4.07E+05	2.36E+04	4.06E+02	4.06E+02	4.55E+02	3.42E+02	5.91E+02	4.85E+02
01U115	5.85E+05	2.90E+04	1.41E+05	1.49E+04	1.52E+05	1.66E+04	1.91E+05	1.51E+04
MW-02-006	1.12E+06	7.19E+04	**4.01E+04**	8.49E+03	**1.43E+04**	4.53E+03	**2.47E+04**	6.28E+03
MW-02-019	1.39E+05	7.82E+03	**1.50E+03**	8.72E+02	**7.13E+02**	4.71E+02	**2.02E+03**	9.37E+02
32PTLW12	1.69E+05	1.03E+04	2.27E+03	1.06E+03	1.76E+03	1.04E+03	1.46E+03	8.88E+02
35PTLW13	3.94E+05	2.91E+04	8.39E+02	6.81E+02	9.25E+02	7.88E+02	9.84E+02	6.40E+02
EPA-10S	1.15E+05	5.67E+03	6.82E+02	5.20E+02	2.91E+02	2.62E+02	1.11E+03	6.33E+02
EPA-12S	1.25E+05	6.35E+03	3.05E+03	1.12E+03	1.74E+03	8.30E+02	2.29E+03	8.97E+02
EPA-15D	3.22E+05	1.95E+04	9.68E+03	2.85E+03	5.51E+03	2.12E+03	1.00E+04	3.01E+03
EPA-16S	1.81E+05	9.16E+03	8.63E+03	2.58E+03	7.09E+03	2.16E+03	1.31E+04	2.83E+03
D-20	4.18E+05	2.50E+04	**2.84E+03**	1.57E+03	**1.00E+03**	8.88E+02	**2.62E+03**	1.11E+03
D-23	6.28E+05	4.50E+04	6.61E+03	2.91E+03	4.05E+03	2.01E+03	5.58E+03	2.29E+03
D-25	6.01E+05	4.20E+04	**1.46E+03**	1.12E+03	**6.37E+02**	5.24E+02	**2.53E+03**	1.35E+03
D-19	6.46E+05	3.80E+04	3.17E+03	1.71E+03	2.82E+03	1.20E+03	1.60E+03	1.14E+03
U10-043	1.97E+05	1.18E+04	8.80E+02	6.25E+02	3.03E+02	2.28E+02	7.87E+02	4.11E+02
U10-025	2.66E+05	1.15E+04	3.79E+02	3.19E+02	7.58E+01	7.58E+01	6.05E+02	4.35E+02
U10-019	1.21E+06	5.60E+04	**5.73E+03**	2.67E+03	**5.40E+03**	2.84E+03	**3.12E+03**	2.04E+03

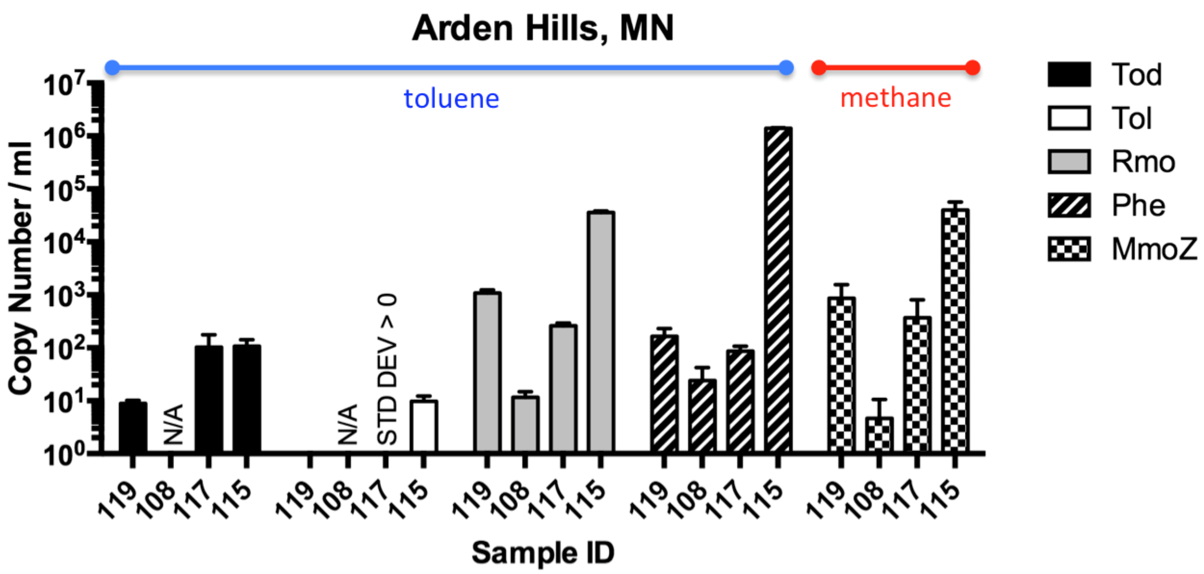
Four qPCR primer pairs specific to four types of toluene monoxygenases and one primer pair specific to methane monooxygenase were assessed (Table 5.7.8). Reference organisms within our laboratory inventory known to encode these enzymes served as positive controls and were also incorporated into our assays to accurately quantify enzyme copy numbers for our groundwater samples. Based on previous literature (McDonald et al. 1995; Baldwin et al. 2003) these primer pairs were predicted to have target gene specificity, however the published mmoX primer sequence gave robust positive readings in our negative control samples (C_t values ~24). Further analysis revealed that the mmoX primer reverse sequence was self-dimerizing and was the likely reasons for qPCR false positives. Additional analysis using a different sequence from the enzyme DNA expression cassette (*mmoZ* gene) gave little background and high specificity and is therefore used in subsequent data results.

Table 5.7.8. qPCR Primer Pairs and Reference Organisms

Organism	Oxygenase of interest	qPCR or PCR primers
Pseudomonas putida F1	Toluene 2,3 dioxygenase	TOD
Ralstonia pickettii PKO1	Toluene 3-monooxygenase	RMO, PHE
Burkholderia cepacia G4	Toluene 2-monooxygenase	PHE
Pseudomonas putida mt-2	Toluene side chain monooxygenase	TOL
Methylosinus trichosporium OB3b	Soluble methane monooxygenase	mmoX, mmoZ*

* denotes mmoZ primer pairs were later used after failure of mmoX.

Outlined in Figures 5.7.21 through 5.7.25 are the results for the five oxygenase primer sets based on sample location. Values that contain "#DIV/0!" represent one or multiple samples in which DNA was below detection limits giving zero values in our calculations.



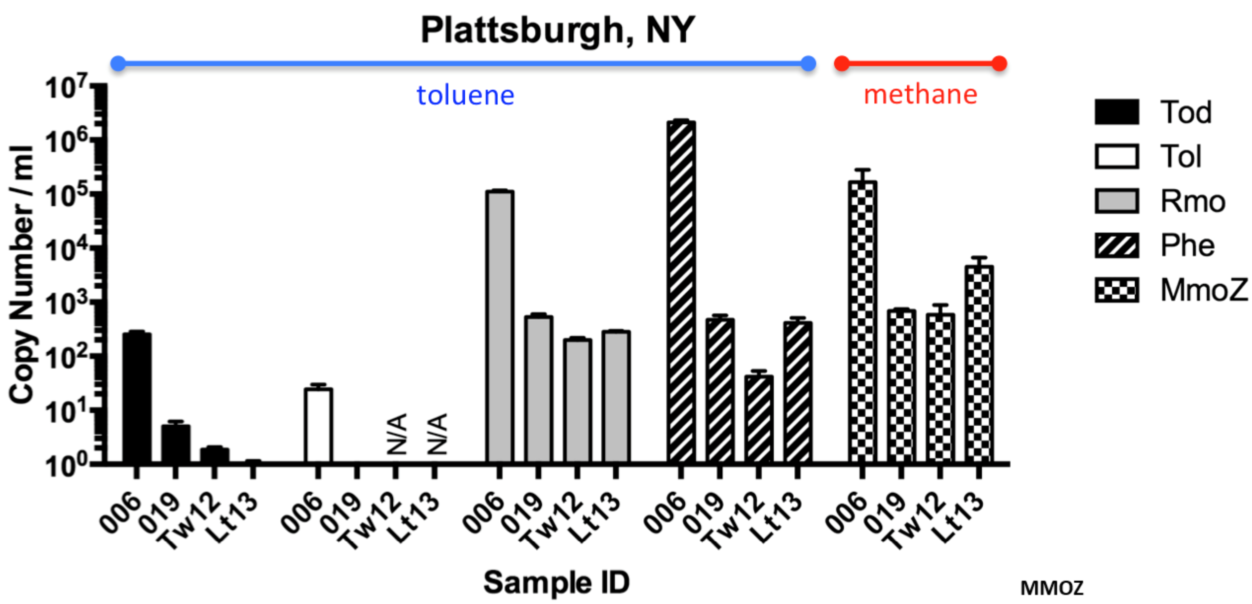
MMOZ

TCAAP. Arden Hills, MN

	TOD		TOL		RMO		PHE		MMOX	
119	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.
ct	28.78083	0.550215	32.75833	0.99157	32.98704	0.915216	35.15547	0.566374	27.46093	1.087864
copy#	277.16	80.47251	15.58417	6.731982	37544.53	28220	5160.849	3007.86	26949.22	21620.17
copy/ml	8.86912	1.265244	0.498693	0.205111	1080.683	154.8156	165.1472	66.42593	862.375	231.0607
108	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.
ct	37.85574	1.251909	#DIV/0!	#DIV/0!	36.44373	1.43153	#DIV/0!	#DIV/0!	33.67816	1.562886
copy#	3.63682	2.885939	#DIV/0!	#DIV/0!	325.6767	326.6991	#DIV/0!	#DIV/0!	146.1872	184.2423
copy/ml	0.105145	0.065208	0.002254	0.003904	11.60041	3.233517	24.0571	18.50351	4.677991	1.053188
117	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.
ct	31.19583	2.660393	#DIV/0!	#DIV/0!	35.76026	1.730097	36.31097	1.649629	29.70262	2.96933
copy#	103.6	72.87877	#DIV/0!	#DIV/0!	7164.231	4840.589	2819.166	3229.5	11535.55	13761.28
copy/ml	3.3152	0.240643	0.182187	0.101044	261.9489	34.25674	85.91484	20.66139	369.1377	264.6146
115	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.
ct	100.3933	1.000905	27.59917	0.39329	112.5157	0.396526	102.6034	0.37305	93.84917	2.107037
copy#	3333.445	1511.084	305.6975	82.09956	1150534	336286.1	43415537	14245761	1245537	523190.4
copy/ml	106.6702	35.74999	9.78232	2.513584	35764.82	2383.071	1389297	48633.98	39857.18	28599.65

Figure 5.7.21. qPCR Results for the Arden Hills, MN Site for Samples Wells TCAAP01U119 (119), TCAAP01U108 (108), TCAAP01U117 (117), TCAAP01U115 (115).

Standard deviations reflect the average Ct values of qPCR run in triplicate for each of the four samples for a given well. Values that contain "#DIV/0!" represent one or multiple samples in which DNA was below detection limits giving zero values in our calculations.



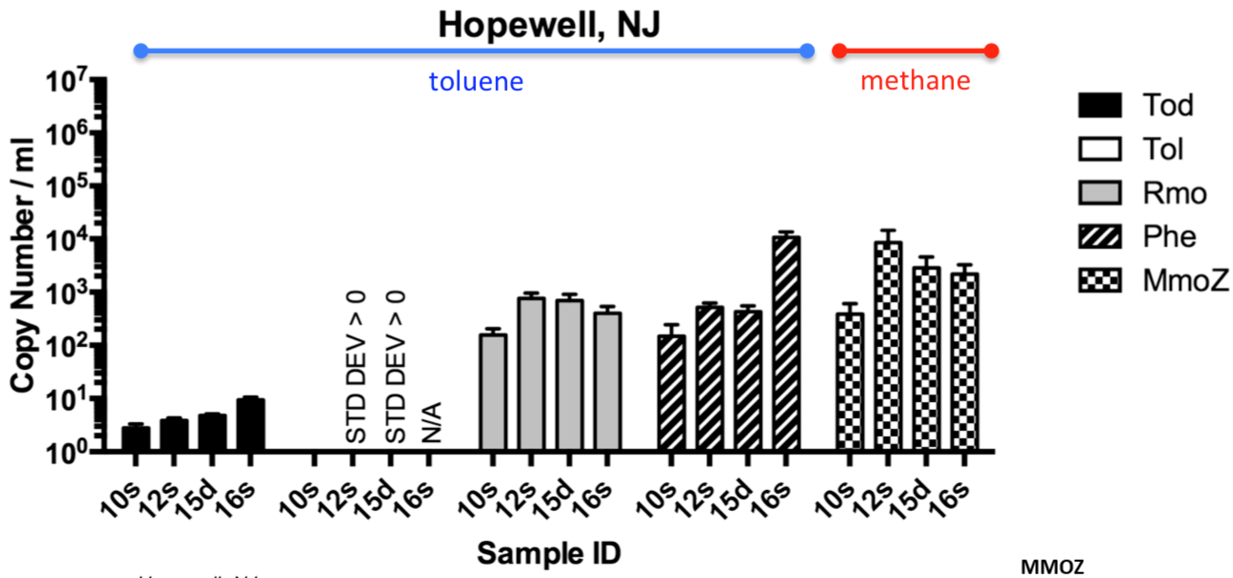
MMOZ

006 *Plattsburgh, NY*

	TOD		TOL		RMO		PHE		MMOX	
6	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.
ct	23.38	0.156938	26.1175	0.550289	26.59376	0.206747	25.20252	0.248537	21.12927	1.129303
copy# **019**	7947.361	775.0145	765.235	277.3869	3497453	537623.3	65598305	16112024	5183376	3797915
copy/ml	254.3155	30.38398	24.48752	5.19398	110729.6	6274.373	2099146	202337.4	165868	115246.5
19	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.
ct	28.78083	0.550215	35.91574	0.633813	30.58153	0.749889	32.30337	1.103835	26.86205	0.675732
copy#	277.16	80.47251	3.116309	0.994408	16863.81	7416.26	14593.35	6841.976	21482.35	10349.64
copy/ml	5.035203	1.136058	0.099722	0.027108	533.1847	69.45968	466.9872	91.65664	687.4352	54.75261
Tw12	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.
ct	33.61486	0.52023	#DIV/0!	#DIV/0!	32.3995	0.568977	33.88479	0.770465	28.56436	1.23458
copy#	58.07901	17.33085	#DIV/0!	#DIV/0!	6273.203	2401.343	1296.418	876.1578	18369.98	13680.26
copy/ml	1.858528	0.235679	0	0	200.0252	18.02503	41.48537	11.08633	587.8395	297.622
Lt13	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.
ct	35.19955	0.645093	#DIV/0!	#DIV/0!	34.70721	1.081514	31.46857	0.674037	25.79684	0.948439
copy#	25.74101	16.56177	#DIV/0!	#DIV/0!	8815.607	1517.182	10470.79	9868.359	141086.8	190948.4
copy/ml	0.823712	0.327437	0	0	280.8562	13.70945	405.6586	100.8292	4514.777	2128.825

Figure 5.7.22. qPCR Results for the Plattsburgh, NY Site for Samples Wells Plattsburgh MW-02-006 (006), Plattsburgh MW-02-019 (019), Plattsburgh 32PLTW12 (Tw12), Plattsburgh 35PTL13 (Lt13).

Standard deviations reflect the average Ct values of qPCR run in triplicate for each of the four samples for a given well. Values that contain "#DIV/0!" represent one or multiple samples in which DNA was below detection limits giving zero values in our calculations.

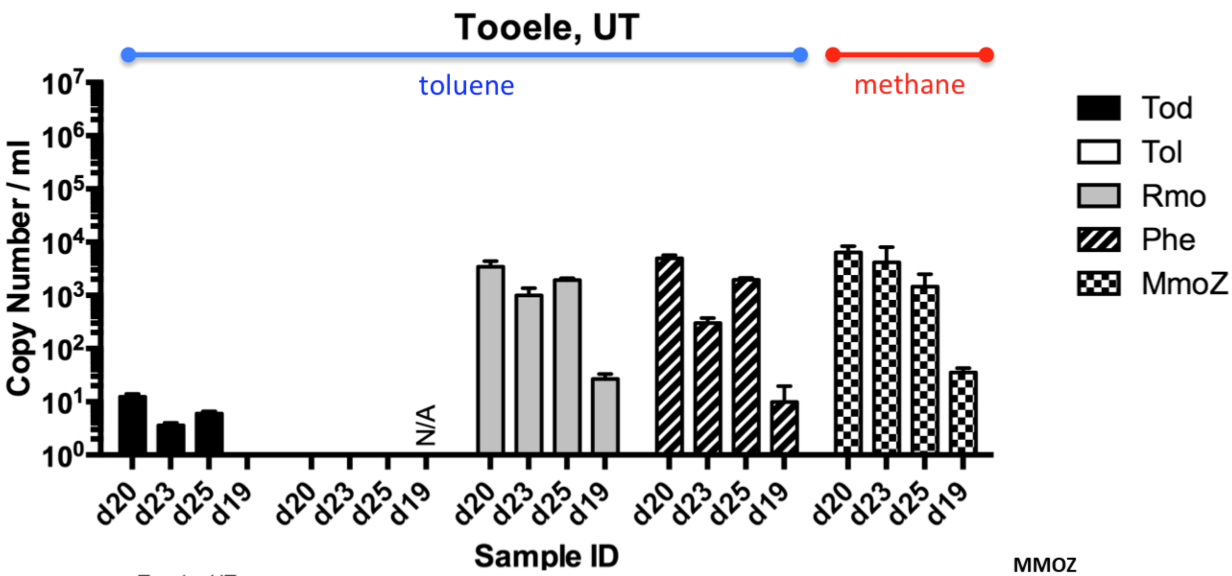


Hopewell, NJ

	TOD		TOL		RMO		PHE		MMOZ MMOX	
10s	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.
ct	30.61833	0.381707	32.92083	0.29417	35.6925532	1.41763863	35.26884	0.29867	28.32732	0.377757
copy#	87.4825	15.55768	10.79417	1.324377	6232.86402	4064.04656	4655.007	1423.272	12049.07	4540.589
copy/ml	2.79944	0.54935	0.345413	0.05737	156.994275	48.32319	148.9602	96.39824	385.5703	222.8248
12s	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.
ct	32.49087	50.459	#DIV/0!	6.13893	30.48652	17987.97	31.09466	11031.48	25.38709	202555.4
copy#	121.005	0.923031	#DIV/0!	#DIV/0!	27775.66	0.769551	16156.36	0.730466	264123.2	0.745543
copy/ml	3.872159	0.413436	0.002895	0.002962	769.3971	186.1532	517.0036	104.5726	8451.944	6182.847
15d	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.
ct	31.96289	0.242629	#DIV/0!	#DIV/0!	30.64096	0.60902	31.15198	0.105139	26.3675	0.448164
copy#	150.2662	21.73254	#DIV/0!	#DIV/0!	25087.66	15090.43	13333.62	1292.945	89470.96	34837.16
copy/ml	4.808519	0.308767	0.001417	0.00159	698.2084	209.875	426.6759	126.1369	2863.071	1715.316
16s	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.
ct	28.6775	0.519604	32.30833	0.875618	34.64477	0.436566	30.72944	0.630511	26.34575	0.921978
copy#	295.3717	101.9298	18.89	8.384427	11650.44	1345.309	357296.2	250374.9	68657.86	55053.51
copy/ml	9.451893	1.132213	0.60448	0.136929	399.5595	136.5232	10618.09	2913.407	2197.051	1087.39

Figure 5.7.23. qPCR Results for the Hopewell, NJ Site for Samples Wells Hopewell EPA-10S (10s), Hopewell EPA-12S (12s), Hopewell EPA-15D (15d), and Hopewell EPA-16S (16s).

Standard deviations reflect the average Ct values of qPCR run in triplicate for each of the four samples for a given well. Values that contain "#DIV/0!" represent one or multiple samples in which DNA was below detection limits giving zero values in our calculations.



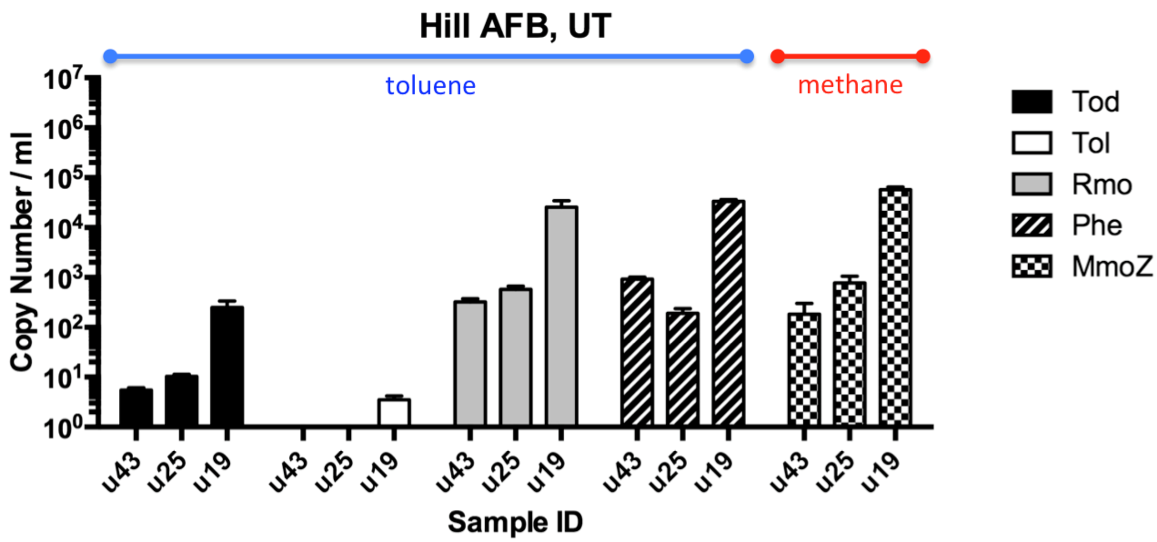
MMOZ

Tooele, UT

	TOD		TOL		RMO		PHE		MMOX	
d20	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.
ct	30.40724	0.552975	33.14922	1.540786	28.5057747	0.76032577	28.566	0.579705	25.52751	0.958596
copy#	391.8677	116.3174	6.334878	6.543617	122621.634	87115.501	155168.6	71583.81	201286.7	116474.7
copy/ml	12.53977	1.510947	0.202716	0.086373	3445.16044	932.886759	4965.394	732.3671	6441.175	1906.39
d23	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.
ct	30.61833	0.381707	37.84222	1.436119	30.40778	0.930041	31.81042	1.137524	26.27764	0.79366
copy#	87.4825	15.55768	0.309307	0.241919	32271.27	17552.76	9477.252	5445.738	129823.5	79165.85
copy/ml	3.618091	0.388963	0.009359	0.00715	1003.184	363.6166	303.2721	70.12447	4154.353	3937.055
d25	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.
ct	31.16208	1.137736	34.74963	1.663734	29.19296	1.487946	29.68954	1.739124	26.78323	2.019146
copy#	189.3468	92.62261	7.904225	4.632666	59641.06	42772.7	60910.25	38590.76	45860.55	41937.06
copy/ml	6.059098	0.601808	0.252935	0.0793	1940.062	160.8178	1949.128	168.5921	1467.538	1025.168
d19	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.
ct	37.14733	134.306	#DIV/0!	#DIV/0!	35.255	44028.16	36.32374	45992.58	31.26626	47561.59
copy#	7.368468	0.435852	#DIV/0!	#DIV/0!	988.6392	1.019748	309.5382	1.305181	1113.986	0.862406
copy/ml	0.235791	0.078295	0	0	26.74687	6.569683	9.905221	9.791578	35.64755	7.534916

Figure 5.7.24. qPCR Results for the Tooele, UT Site for Samples Wells Tooele D-20 (d20), Tooele D-23 (d23), Tooele D25 (d25) and Tooele D19 (d19).

Standard deviations reflect the average Ct values of qPCR run in triplicate for each of the four samples for a given well. Values that contain "#DIV/0!" represent one or multiple samples in which DNA was below detection limits giving zero values in our calculations.



Hill AFB, UT

	TOD		TOL		RMO		PHE		MMOZ	
u43	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.
ct	31.25127	124.7014	#DIV/0!	#DIV/0!	31.39462	8315.664	30.85639	20222.2	28.95193	2839.266
copy#	170.9093	0.797938	35.5958	0.960458	10167.71	0.96741	28994.05	0.866544	5764.076	1.191087
copy/ml	5.469097	0.670209	0.128947	0.031709	320.6098	48.21906	927.8097	80.43886	184.4504	116.48
u25	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.
ct	30.18423	0.689665	34.00435	0.794182	30.49891	0.638596	33.90958	0.48675	26.7543	0.663146
copy#	321.1182	127.8076	10.06908	4.107126	17967.68	9305.519	5992.222	1382.129	24354.36	12702.99
copy/ml	10.27578	1.11704	0.322211	0.051938	568.0785	91.41734	191.7511	44.01172	779.3396	275.5273
u19	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.	mean	std. dev.
ct	25.07441	0.387346	29.95867	0.328928	25.49838	0.930662	24.57054	2.13927	21.42576	0.499826
copy#	7806.346	2106.771	109.7636	22.61876	982476.5	788514.2	1047335	1287399	1795742	687352
copy/ml	249.8031	87.10931	3.512435	0.703915	25285.84	8710.786	33514.73	2912.627	57463.73	7601.408

Figure 5.7.25. qPCR Results for the Hill Air Force Base, UT Site for Samples Wells HillAFB U10-043 (u43), HillAFB U10-025 (u25), HillAFB U10-019 (u19).

Standard deviations reflect the average Ct values of qPCR run in triplicate for each of the four samples for a given well. Values that contain "#DIV/0!" represent one or multiple samples in which DNA was below detection limits giving zero values in our calculations.

5.6.3.2.3 Comparison of qPCR and EAP Results:

When comparing qPCR data with fluorescent EAP data, similarities emerged for the most abundant samples (Fig. 5.7.26 – 5.7.29). This indicates that the qPCR primer sets amplified DNA that was associated with enzymes in the cells that could cooxidize TCE. For example, sample Plattsburgh MW-02-006 from the Plattsburgh, NY site had the most abundant oxygenase counts when cumulatively adding the results from all five primer sets (Fig. 5.7.26, left). The PHE primer set specific to Toluene 3-monooxygenase and Toluene 2-monooxygenase contributed the most qPCR signal to the overall counts (Fig. 5.7.26, middle). In comparison to DAPI fluorescent staining which measures the abundance of bacteria, MW-02-006 gave the second highest counts of the samples. These results show good agreement between samples for MW-02-006. Additionally, sample HillAFB U10-019 from Hill Air Force Base, UT was third highest through qPCR assays versus but the most abundant bacteria in DAPI fluorescent staining.

	qPCR	copy # all 5		qPCR	PHE primer		EAP	DAPI (total)	
	Sample ID		rank	Sample ID		rank	Sample ID	cells/ml	rank
Arden Hills, MN	01U119	2118		01U119	165		01U119	7.11E+05	3
	01U108	40		01U108	24		01U108	6.91E+05	
	01U117	720		01U117	86		01U117	4.07E+05	
	01U115	1465036	2	01U115	1389297	2	01U115	5.85E+05	
Plattsburgh, NY	MW-02-006	2376022	1	MW-02-006	2099146	1	MW-02-006	1.12E+06	2
	MW-02-019	1693		MW-02-019	467		MW-02-019	1.39E+05	
	32PTLW12	831		32PTLW12	41		32PTLW12	1.69E+05	
	35PTLW13	5202		35PTLW13	406		35PTLW13	3.94E+05	
Hopewell, NJ	EPA-10S	695		EPA-10S	149		EPA-10S	1.15E+05	
	EPA-12S	9742		EPA-12S	517		EPA-12S	1.25E+05	
	EPA-15D	3993		EPA-15D	427		EPA-15D	3.22E+05	
	EPA-16S	13225		EPA-16S	10618		EPA-16S	1.81E+05	
Tooele, UT	D-20	14864		D-20	4965		D-20	4.18E+05	
	D-23	5464		D-23	303		D-23	6.28E+05	
	D-25	5363		D-25	1949		D-25	6.01E+05	
	D-19	73		D-19	10		D-19	6.46E+05	
Hill AFB, UT	U10-043	1438		U10-043	928		U10-043	1.97E+05	
	U10-025	1550		U10-025	192		U10-025	2.66E+05	
	U10-019	116518	3	U10-019	33515	3	U10-019	1.21E+06	1

Figure 5.7.26. qPCR Copy Number Counts (left, middle) versus DAPI Nuclear Staining Counts (right).

The top 3 highest samples are ranked.

When analyzing qPCR primers specific to toluene-2-monooxygenase (PHE primers) (Fig. 5.7.27, left) versus enzyme fluorescent activity (Fig. 5.7.27, right), there was good agreement with the top 3 sample wells.

Toluene-2-monooxygenase

qPCR	Josh P.	PHE pr	EAP	Joe M.	PA (T2-mono)	
	Sample ID		rank	Sample ID	cells/ml	rank
Arden Hills, MN	01U119	1081		01U119	1.38E+03	
	01U108	12		01U108	2.03E+03	
	01U117	262		01U117	4.06E+02	
	01U115	35765	2	01U115	1.41E+05	1
Plattsburgh, NY	MW-02-006	110730	1	MW-02-006	**4.01E+04**	2
	MW-02-019	533		MW-02-019	**1.50E+03**	
	32PTLW12	200		32PTLW12	2.27E+03	
	35PTLW13	281		35PTLW13	8.39E+02	
Hopewell, NJ	EPA-10S	157		EPA-10S	6.82E+02	
	EPA-12S	769		EPA-12S	3.05E+03	
	EPA-15D	698		EPA-15D	9.68E+03	
	EPA-16S	400		EPA-16S	8.63E+03	
Tooele, UT	D-20	3445		D-20	**2.84E+03**	
	D-23	1003		D-23	6.61E+03	
	D-25	1940		D-25	**1.46E+03**	
	D-19	27		D-19	3.17E+03	
Hill AFB, UT	U10-043	321		U10-043	8.80E+02	
	U10-025	568		U10-025	3.79E+02	
	U10-019	25286	3	U10-019	**5.73E+03**	3

Figure 5.7.27. qPCR Copy Number Counts (left) Versus PA Fluorescent Activity Assay (right).

The top 3 highest samples are ranked.

When analyzing qPCR primers specific to toluene-3-monooxygenase (both PHE primers and RMO primers) (Fig. 5.7.28, left, middle) versus 3HPA enzyme fluorescent activity (Fig. 5.7.28, right), there was good agreement for 3 of the top 4 sample wells.

Toluene-3-monooxygenase

	qPCR	PHE primer		qPCR	RMO primer		EAP	3HPA (T3-mono)	
	Sample ID		rank	Sample ID		rank	Sample ID	cells/ml	rank
Arden Hills, MN	01U119	1081		01U119	165		01U119	5.31E+03	
	01U108	12		01U108	24		01U108	2.36E+03	
	01U117	262		01U117	86		01U117	5.91E+02	
	01U115	35765	2	01U115	1389297	2	01U115	1.91E+05	1
Plattsburgh, NY	MW-02-006	110730	1	MW-02-006	2099146	1	MW-02-006	2.47E+04	2
	MW-02-019	533		MW-02-019	467		MW-02-019	2.02E+03	
	32PTLW12	200		32PTLW12	41		32PTLW12	1.46E+03	
	35PTLW13	281		35PTLW13	406		35PTLW13	9.84E+02	
Hopewell, NJ	EPA-10S	157		EPA-10S	149		EPA-10S	1.11E+03	
	EPA-12S	769		EPA-12S	517		EPA-12S	2.29E+03	
	EPA-15D	698		EPA-15D	427		EPA-15D	1.00E+04	4
	EPA-16S	400		EPA-16S	10618	4	EPA-16S	1.31E+04	3
Tooele, UT	D-20	3445	4	D-20	4965		D-20	2.62E+03	
	D-23	1003		D-23	303		D-23	5.58E+03	
	D-25	1940		D-25	1949		D-25	2.53E+03	
	D-19	27		D-19	10		D-19	1.60E+03	
Hill AFB, UT	U10-043	321		U10-043	928		U10-043	7.87E+02	
	U10-025	568		U10-025	192		U10-025	6.05E+02	
	U10-019	25286	3	U10-019	33515	3	U10-019	3.12E+03	

Figure 5.7.28. qPCR Copy Number Counts (left, middle) Versus 3HPA T3-mono Fluorescent Activity Assay (right).

The top 4 highest samples are ranked.

When analyzing qPCR primers specific to toluene-2,3-monooxygenase (TOD primers) (Fig. 5.7.29, left) versus 3HPA enzyme fluorescent activity (Fig. 5.7.29, right), there was good agreement for 3 of the top 4 sample wells.

Toluene-2,3-monooxygenase

	qPCR	TOD primer		EAP	Cinn (T23-di) Cells/ml	
	Sample ID		rank	Sample ID		rank
Arden Hills, MN	01U119	8.87		01U119	1.55E+03	
	01U108	0.11		01U108	5.46E+02	
	01U117	3.32		01U117	4.55E+02	
	01U115	106.67	3	01U115	1.52E+05	1
Plattsburgh, NY	MW-02-006	254.32	1	MW-02-006	1.43E+04	2
	MW-02-019	5.04		MW-02-019	7.13E+02	
	32PTLW12	1.86		32PTLW12	1.76E+03	
	35PTLW13	0.82		35PTLW13	9.25E+02	
Hopewell, NJ	EPA-10S	2.80		EPA-10S	2.91E+02	
	EPA-12S	3.87		EPA-12S	1.74E+03	
	EPA-15D	4.81		EPA-15D	5.51E+03	
	EPA-16S	9.45		EPA-16S	7.09E+03	3
Tooele, UT	D-20	12.54	4	D-20	1.00E+03	
	D-23	3.62		D-23	4.05E+03	
	D-25	6.06		D-25	6.37E+02	
	D-19	0.24		D-19	2.82E+03	
Hill AFB, UT	U10-043	5.47		U10-043	3.03E+02	
	U10-025	10.28		U10-025	7.58E+01	
	U10-019	249.80	2	U10-019	5.40E+03	4

Figure 5.7.29. qPCR Copy Number Counts (left) versus CINN (T2,3-di) Fluorescent Activity Assay (right).

The top 4 highest samples are ranked.

5.6.3.3 Summary

Quantitative polymerase chain reaction provides evidence for the presence of cometabolism genes in groundwater samples, while EAP provided lines of evidence that there are active cometabolic enzymes in a groundwater sample. Groundwater from five sites across the U.S. were analyzed using qPCR and EAP, and surprisingly few of the samples showed the presence and activity of the cometabolic oxygenase enzymes probed for during the project. Four of the 19 wells analyzed using the phenylacetylene and 3-hydroxyphenylacetylene EAP, showed activity considered to be statistically significant (>8×10^3 cells/ml). Cinnamonitrile only showed positive results for two of the nineteen wells tested.

In general, qPCR results corresponded to the EAP results for the PHE and RMO primer sets, but not for the TOD and TOL primer sets. Gene targets for SMMO were only detected significant levels (>10^3 cells/ml) at three of the 19 wells tested.

5.6.4 Analysis of Relationship Between TCE Assay, EAP, and qPCR Data

5.6.4.1 Introduction

In Section 5.7.2, first order rate constants for TCE co-oxidation were determined on water samples from four wells at each of four sites and three wells from one site for a total of nineteen water samples. One set of rate constants was determined on groundwater samples as acquired from the well. The rate constant for degradation included the rate constant for biological cooxidation and the rate constant for abiotic radiolysis of the ^{14}C- labelled TCE. A *t*-test was used to determine if the rate constant was different from zero at 95% confidence. In all nineteen wells, the rate constant was different from zero.

A second set of samples was filtered to remove the bacteria, before the water was incubated with ^{14}C-labelled TCE. In these samples, the rate constant for degradation of TCE is the rate constant for radiolysis of the ^{14}C-labelled TCE.

To estimate the rate constant for biodegradation of TCE by cooxidation, the rate constant for TCE degradation in the filtered samples was subtracted from the rate constant for TCE degradation in the samples that were not filtered. For eight of the nineteen water samples, the rate constant for cooxidation minus the 95% confidence interval on the rate constant for cooxidation was greater than zero. For these eight wells, data on TCE degradation are reported as the rate of cooxidation. For the other eleven wells, data on TCE degradation are reported as the overall rate of degradation. Because the overall rate included the rate of TCE radiolysis, the overall rate is an upper boundary on the rate of cooxidation.

As reported in Section 5.7.3, the abundance of bacteria that respond to each of the EAP probes, and the abundance of gene copies for each of the qPCR targets were determined in the same nineteen water samples. The abundance of the EAP probe or qPCR target was determined in three separate subsamples from each of four samples of groundwater from each well. This provided a total of twelve estimates of the abundance of each EAP probe or qPCR target in each groundwater from each well. The standard error of the mean was calculated by dividing the standard deviation of the samples by the square root of 12. The 95% confidence interval on the mean was calculated using the standard error of the mean and the critical value of the *t* distribution.

A second set of samples were provided to Microbial Insights, Inc. (Knoxville, TN). Water samples were filtered in the field onto Sterivex-GS filter units. Filter units for analysis of mRNA were preserved with RNAprotect Cell Reagent (QIAGEN Inc., Valencia, CA). One filter unit for DNA and one filter unit for mRNA was analyzed from each well sampled. The reporting limit for DNA and mRNA samples varied between 5 and 8.3 cells per mL.

The abundance of cells that react with each EAP and the abundance of DNA or mRNA gene copies that was amplified by each qPCR primer was compared to the first order rate constants for TCE co-oxidation. The relationship was evaluated by a linear regression of the common logarithm of the rate constant on the common logarithm of the abundance of the marker.

Under ideal conditions, the rate constant for TCE cooxidation should be directly proportional to the abundance of the genetic marker that predicts biological activity. The slope of a regression of the rate constant on abundance should have a value of 1.0. The figures are scaled so that when the slope is 1.0, the line has an angle of 45^{o} above the x-axis.

5.6.4.2 Results

5.6.4.2.1 Enzyme Activity Probes

Panel (a) of Figure 5.7.30 compares the distribution of the rate constant to the abundance of cells that react to the Phenylacetylene (PA) probe. Panel (b) of Figure 5.7.30 is a regression of the rate constants on the abundance of reactive cells.

In the eight wells where cooxidation of TCE was detected, the density of bacteria that reacted with the PA probe varied from 4E+02 to 4E+04 per mL. The density of total bacteria in the eight wells varied from 1E+05 to 1E+06 per mL. The bacteria that reacted with the PA probe were less than 10% of the total bacterial population. In the eleven wells where the rate constant for TCE degradation in the water sample was not different from the rate in the filtered controls, the rate constants were ≤ 0.02 per year. However, the abundance of cells that were reactive to PA varied from 4E+02 to 1E+05 per mL. This range is greater than the range in abundance of reactive cells in the water samples where TCE cooxidation was detected.

The same general pattern applied for the distribution of the rate constant to the abundance of cells that react to the 3-Hydroxyphenylacetylene (3HPA) Probe [Panel (a) of Figure 5.7.31] and to the *trans*-Cinnamonitrile (CINN) Probe [Panel (a) of Figure 5.7.32].

When the abundance of cells that reacted with the PA or 3-HPA probe was low (on the order of 1E+03 cells per mL) the rate constants were low (near or less than 0.02 per year). If the abundance of cells that reacted with the CINN probe was low (on the order of 3E+02 cells per mL) the rate constants were low (near or less than 0.002 per year). However, when the abundance of reactive cells was higher (on the order of (1E+04 cells per mL), the rate constants varied from <0.02 per year to 2.7 per year. Based on this behavior, the abundance of the cells that react to the Enzyme Activity Probes cannot be used as the sole criterion to associate a rate constant for TCE cooxidation to a plume.

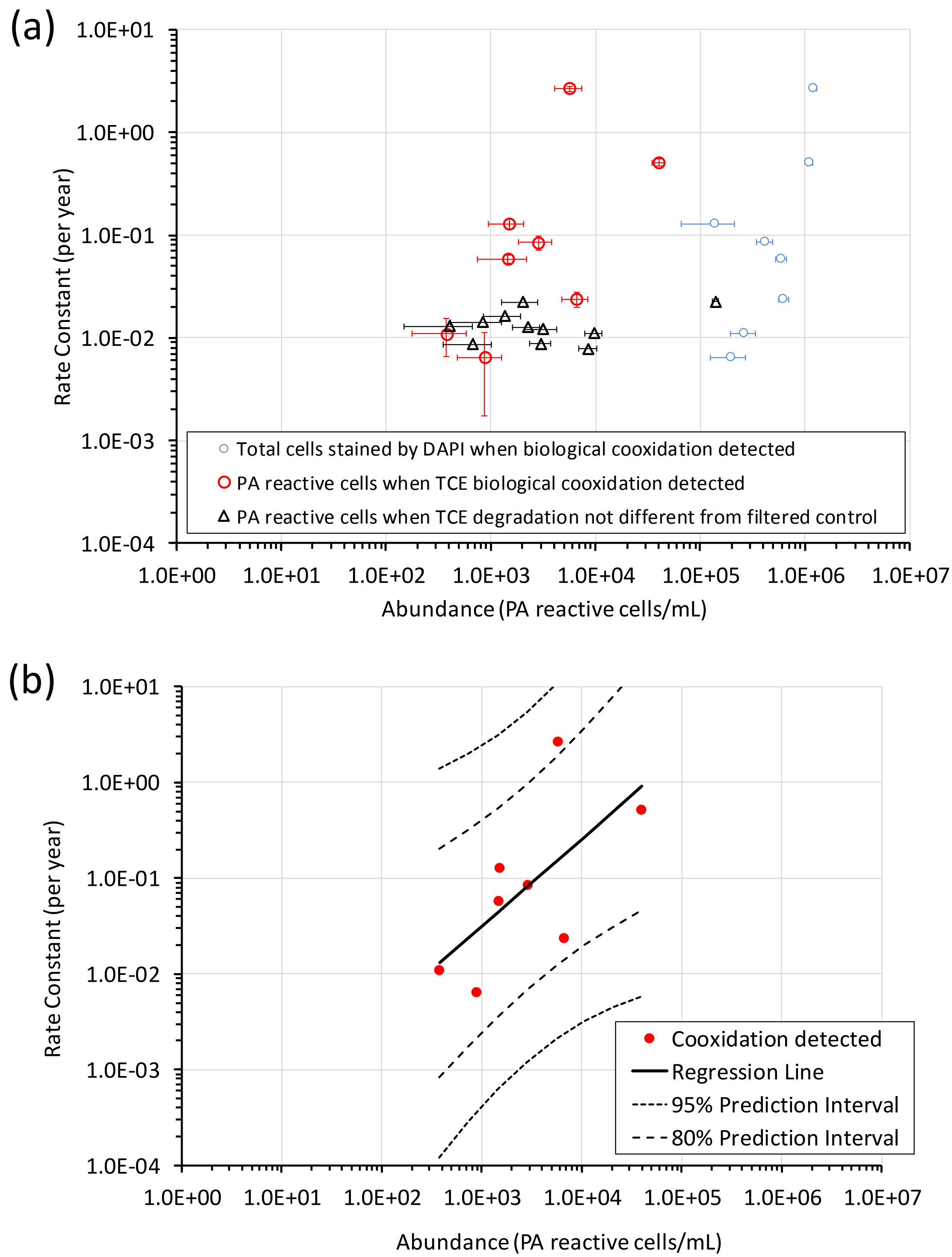


Figure 5.7.30. Relationship between the Rate Constant for Co-oxidation of TCE and the Abundance of Cells that React with the Phenylacetylene (PA) Enzyme Activity Probe.
Error bars in Panel (a) are 95% confidence intervals on the estimate of the parameter.

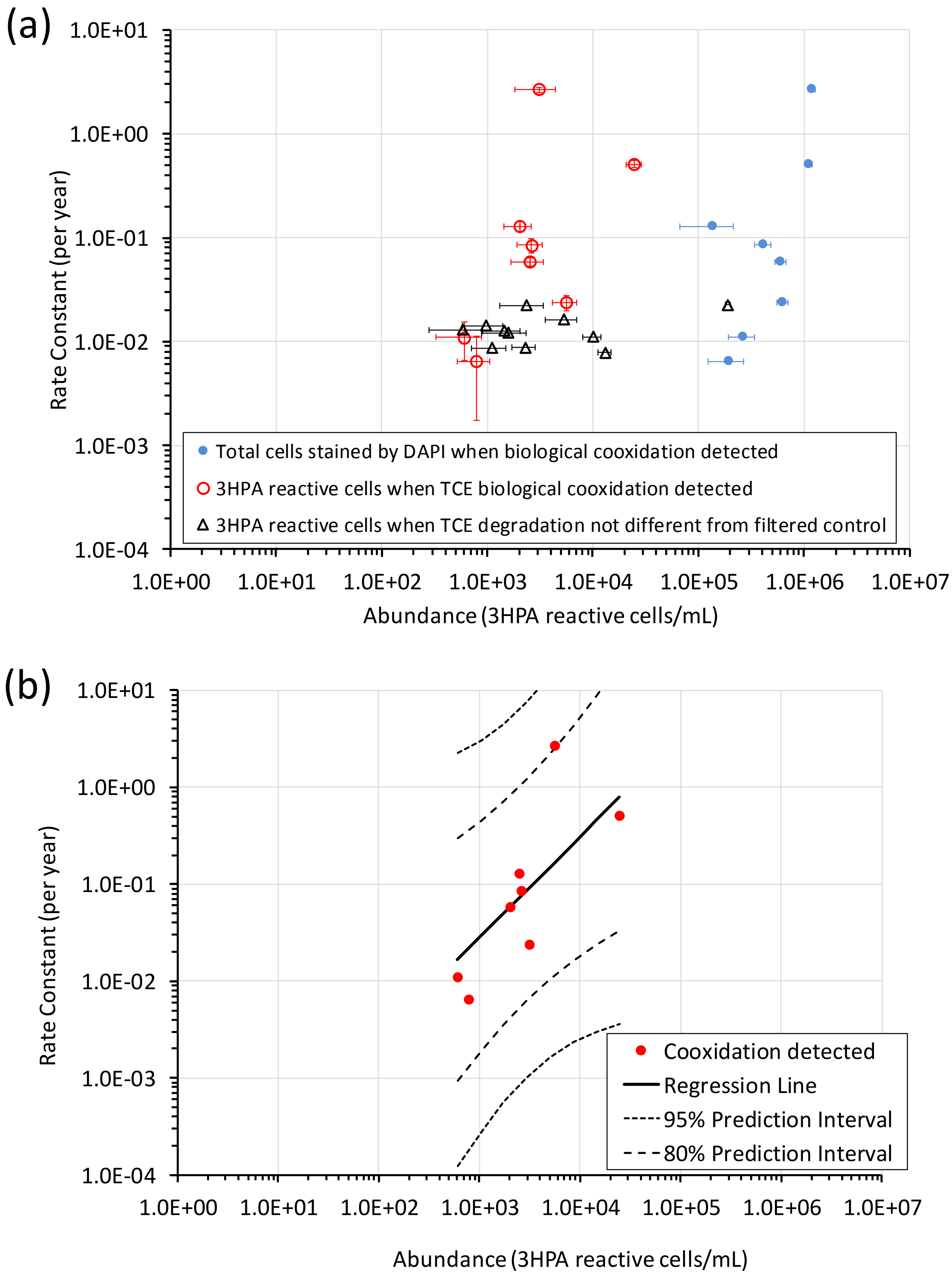


Figure 5.7.31. Relationship between the Rate Constant for Co-oxidation of TCE and the Abundance of Cells that React with the 3-Hydroxyphenylacetylene (3HPA) Enzyme Activity Probe.

Error bars in Panel (a) are 95% confidence intervals on the estimate of the parameter.

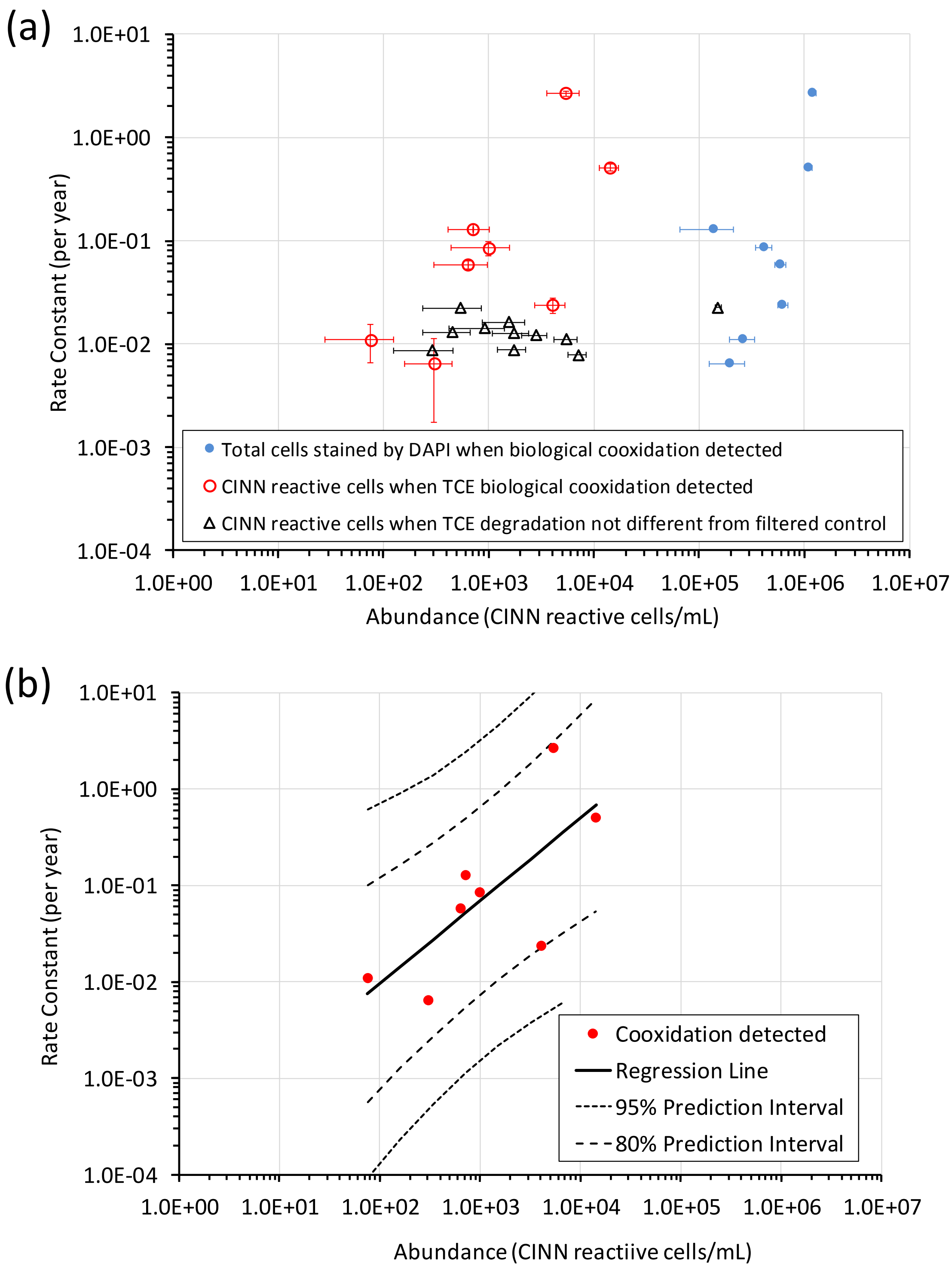


Figure 5.7.32. Relationship between the Rate Constant for Co-oxidation of TCE and the Abundance of Cells that React with the *trans*-Cinnamonitrile (CINN) Enzyme Activity Probe.

Error bars in Panel (a) are 95% confidence intervals on the estimate of the parameter.

5.6.4.2.2 The PHE Primer for Phenol Monooxygenase Enzyme

Panel (a) of Figure 5.7.33 compares the distribution of the rate constants to the abundance of DNA gene copies amplified by the PHE primer in the samples that were analyzed by PNNL. Panel (b) of Figure 5.7.33 is a regression of the rate constants on the abundance of gene copies.

In the eight wells where cooxidation of TCE was detected, the density of DNA gene copies that were amplified by the PHE primer varied from 2E+02 to 2E+06 per mL. The density of total bacteria in the eight wells varied from 1E+05 to 1E+06 per mL. With one exception, abundance of PHE gene copies was less than 10% of the total bacterial population. In one well, the abundance of PHE gene copies exceeded the number of cells that were stained by DAPI. This has not been explained.

In eleven wells where the rate constant for TCE degradation in the water sample was not different from the rate in the filtered controls, the rate constants were ≤ 0.02 per year. However, the abundance of PHE gene copies varied from 1E+01 to 1E+06 per mL. This range is equivalent to the range in abundance of PHE gene copies in the water samples where TCE cooxidation was detected.

Panel (a) of Figure 5.7.34 compares the distribution of the rate constants to the abundance of gene copies amplified by the PHE primer in the samples that were analyzed by Microbial Insights. The pattern was similar to the pattern for PNNL.

See Panel (a) of Figure 5.7.33 and Figure 5.7.34. If the abundance of PHE gene copies was low (on the order of 1E+02 cells per mL) the rate constants were low (near or less than 0.02 per year). However, when the abundance of PHE gene copies was higher (on the order of (1E+04 cells per mL), the rate constants varied from <0.02 per year to 2.7 per year. Based on this behavior, the abundance of DNA gene copies amplified by the PHE primer cannot be used as the sole criterion to associate a rate constant for TCE cooxidation in a plume.

Figure 5.7.35 compare the distribution of the rate constants to the abundance of gene copies amplified by the PHE DNA primer and the PHE mRNA primer in the samples that were analyzed by Microbial Insights. PHE mRNA copies were detected in three of the eight wells where TCE cooxidation was detected, and three of the eleven wells where the rate of TCE degradation was not different in the filtered controls. In contrast, PHE DNA copies were detected in all eight wells where TCE cooxidation was detected, and seven of eleven wells where the rate of TCE degradation was not different in the filtered controls. At lower abundance, the distribution of DNA gene copies and mRNA genes copies were similar. At higher abundance, there were many more DNA gene copies than mRNA genes copies. The mRNA data showed that the PHE genes were being transcribed in some of the wells, but the mRNA data did not have a closer and more direct association to the rate constants than the DNA data.

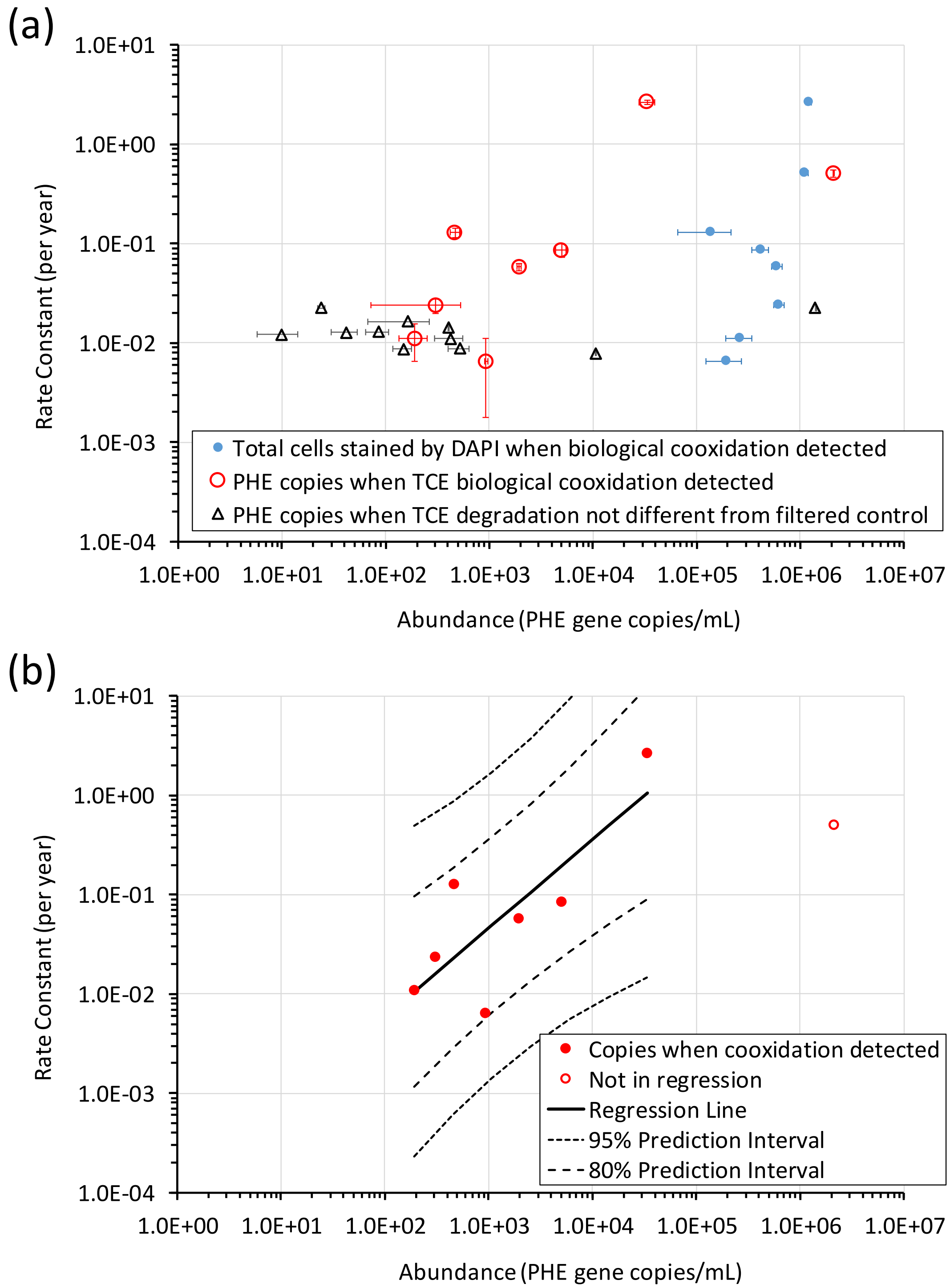


Figure 5.7.33. Relationship between the Rate Constant for Co-oxidation of TCE and the Abundance of DNA that is Amplified by the PHE Primer.

The qPCR and total cell data are from PNNL. Error bars in Panel (a) are 95% confidence intervals on the estimate of the parameter.

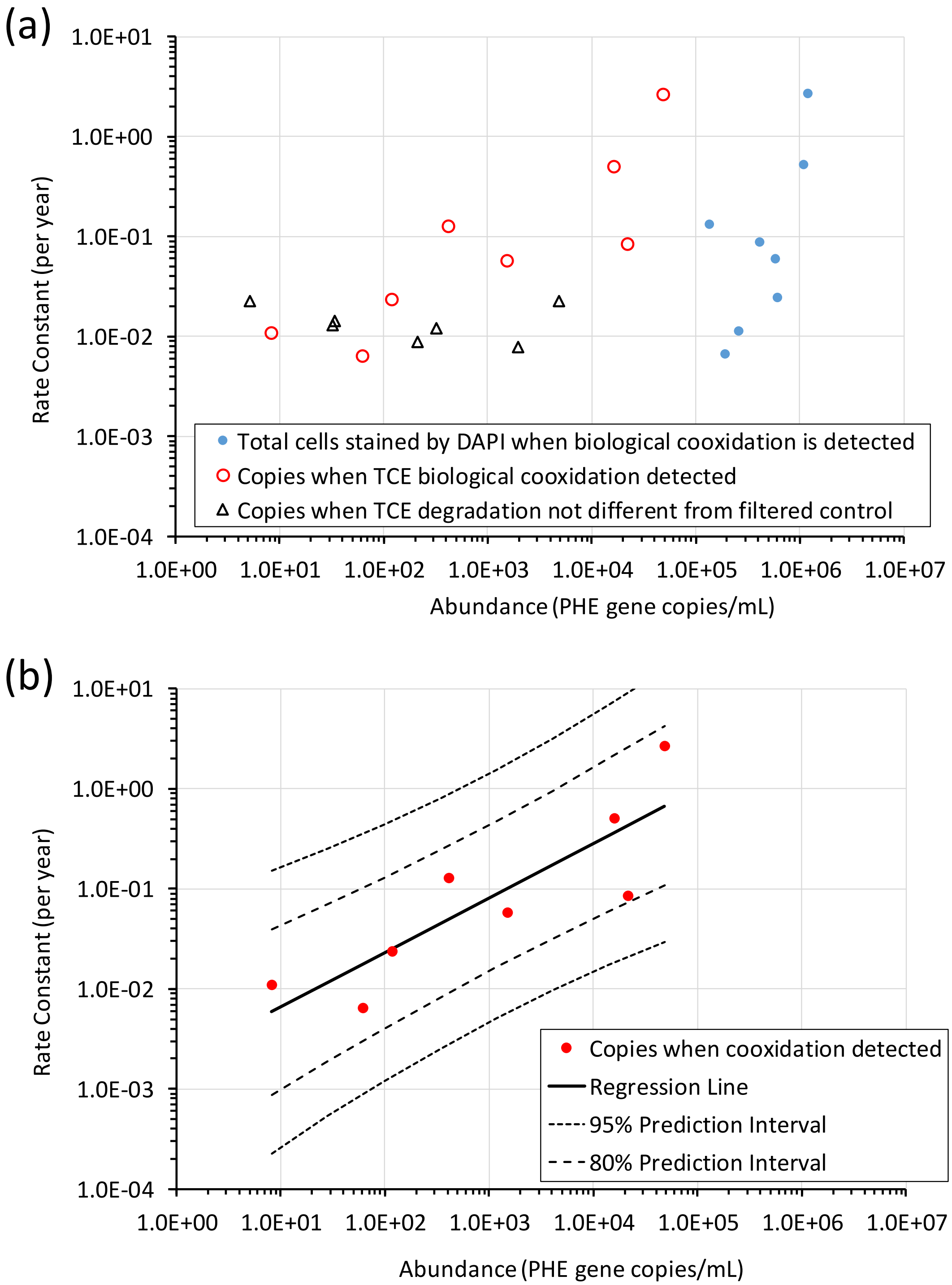


Figure 5.7.34. Relationship between the Rate Constant for Co-oxidation of TCE and the Abundance of DNA that is Amplified by the PHE Primer.

The qPCR data are from Microbial Insights. The total cell data are from PNNL.

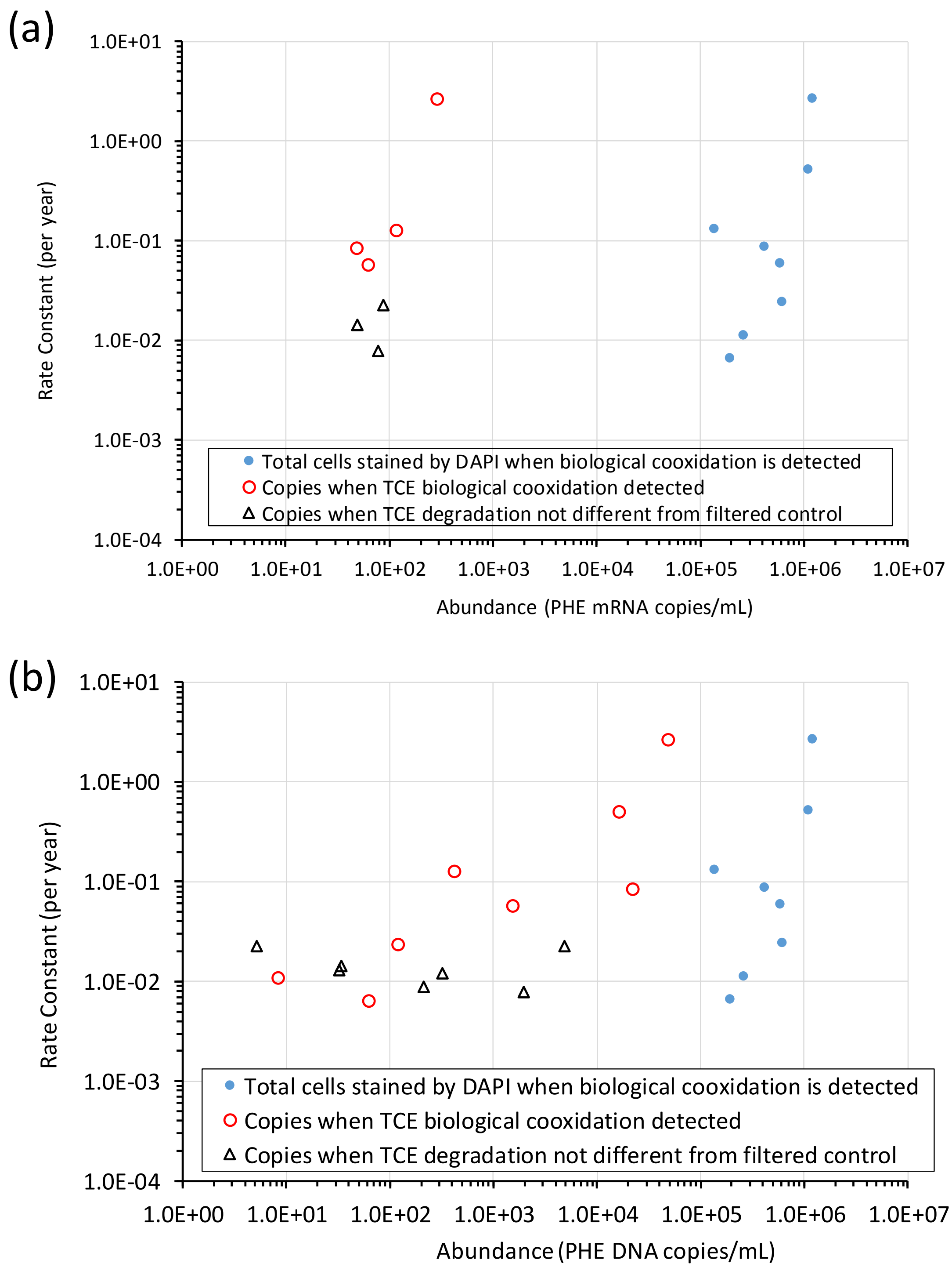


Figure 5.7.35. Comparison of the Relationship between the Rate Constant for Co-oxidation of TCE and the Abundance of DNA or mRNA that is Amplified by the PHE Primer.

The qPCR data are from Microbial Insights. The total cell data are from PNNL.

5.6.4.2.3 The RMO Primer for Ring-Hydroxylating Toluene Monooxygenease Enzyme

Panel (a) of Figure 5.7.36 compares the distribution of the rate constants to the abundance of DNA gene copies amplified by the RMO primer in the samples that were analyzed by PNNL. Panel (b) of Figure 5.7.36 is a regression of the rate constants on the abundance of gene copies. In the eight wells where cooxidation of TCE was detected, the density of DNA gene copies that were amplified by the RMO primer varied from 3E+02 to 1E+05 per mL. The density of total bacteria in the eight wells varied from 1E+05 to 1E+06 per mL. The abundance of RMO gene copies were less than 10% of the total bacterial population. In eleven wells where the rate constant for TCE degradation in the water sample was not different from the rate in the filtered controls, the rate constants were ≤ 0.02 per year. However, the abundance of RMO gene copies varied from 1E+01 to 4E+04 per mL. This range is significantly overlaps the range in abundance of RMO gene copies in the water samples where TCE cooxidation was detected.

Panel (a) of Figure 5.7.37 compares the distribution of the rate constants to the abundance of gene copies amplified by the RMO primer in the samples that were analyzed by Microbial Insights. The pattern was similar to the pattern for PNNL. However, the reporting limit from the Microbial Insights samples was higher, in general 5E+00 gene copies/mL. DNA amplified by the RMO primer was not detected in four of the eight wells where TCE cooxidation was detected, and nine of the eleven wells where TCE was not different in the filtered controls.

See Panel (a) of Figure 5.7.36 and Figure 5.7.37. If the abundance of RMO gene copies was low (on the order of 3E+02 cells per mL) the rate constants were low (near or less than 0.02 per year). However, when the abundance of RMO gene copies was higher (on the order of 1E+04 cells per mL), the rate constants varied from 0.02 per year to 2.7 per year. Based on this behavior, the abundance of DNA gene copies amplified by the RMO primer cannot be used as the sole criterion to associate a rate constant for TCE cooxidation in a plume.

Figure 5.7.38 compares the distribution of rate constants to the abundance of gene copies amplified by the RMO DNA primer and RMO mRNA primer in the samples that were analyzed by Microbial Insights. RMO mRNA copies were not detected in any of the 19 wells sampled.

5.6.4.2.4 The RDEG Primer for Ring-Hydroxylating Toluene Monooxygenease Enzyme

DNA gene copies amplified by the RDEG primer were not analyzed by PNNL. Panel (a) of Figure 5.7.39 compares the distribution of the rate constants to the abundance of gene copies amplified by the RDEG primer in the samples that were analyzed by Microbial Insights. Figure 5.7.39, Panel (b) is a regression of rate constants on the abundance of gene copies. The pattern was similar to the pattern for the RMO primer (Figure 5.7.37) and particularly for PHE primer (Figure 5.7.34). See Panel (a) of Figure 5.7.39. If the abundance of RDRG gene copies was low (less than 1E+02 cells per mL) the rate constants were low (near or less than 0.02 per year). However, when the abundance of RDEG gene copies was higher (on the order of (1E+04 cells per mL), the rate constants varied from <0.02 per year to 2.7 per year. Based on this behavior, the abundance of DNA gene copies amplified by the RDEG primer cannot be used as the sole criterion to associate a rate constant for TCE cooxidation in a plume.

Figure 5.7.40 compares the distribution of the rate constants to the abundance of gene copies amplified by the RDEG DNA primer and the RDEG mRNA primer in the samples that were analyzed by Microbial Insights. RDEG mRNA copies were detected in only two of the 19 wells that were sampled, and there is no logical relationship between the rate constants and the abundance of RDEG mRNA.

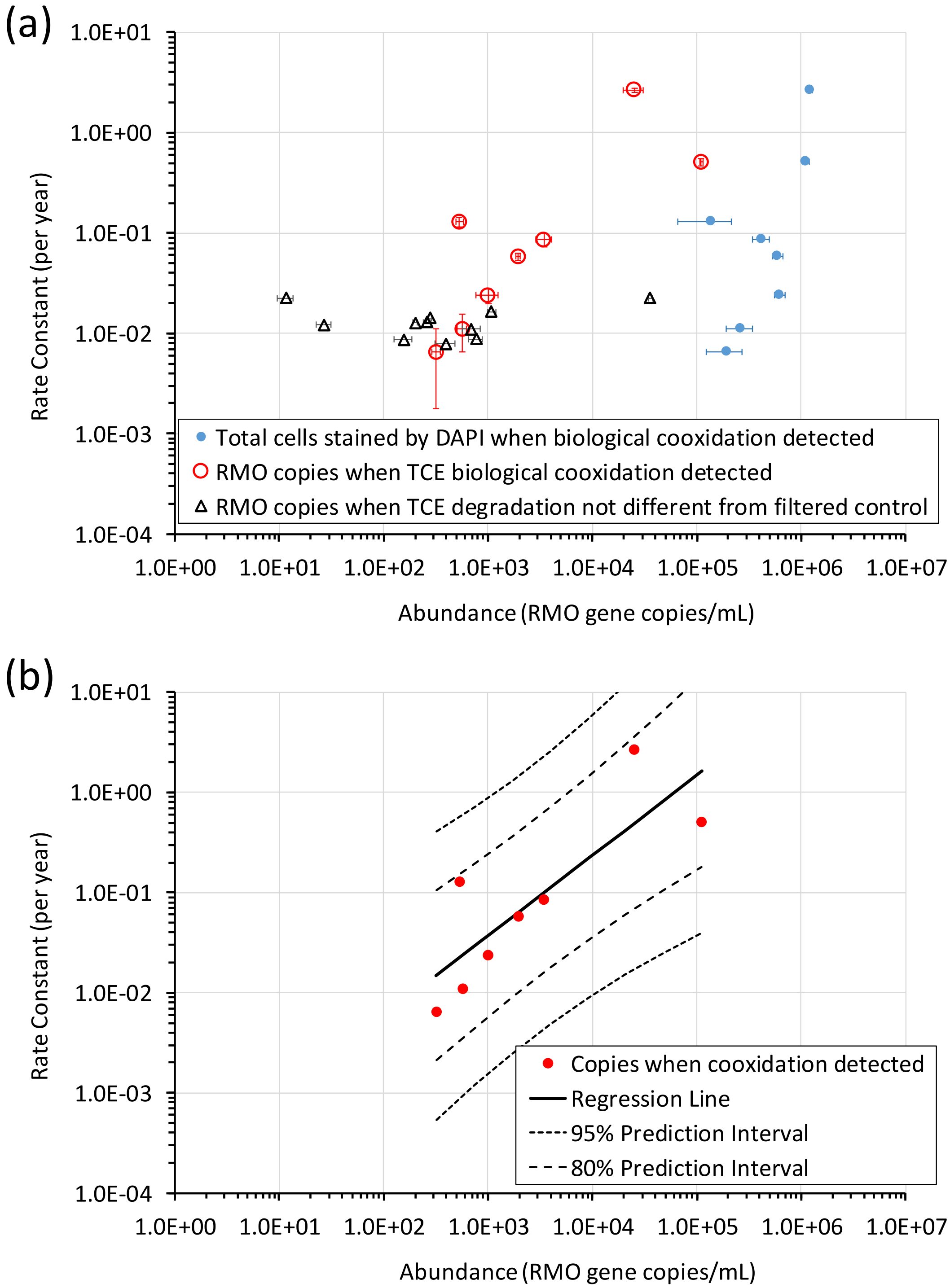


Figure 5.7.36. Relationship between the Rate Constant for Co-oxidation of TCE and the Abundance of DNA that is Amplified by the RMO Primer.

The qPCR and total cell data are from PNNL. Error bars in Panel (a) are 95% confidence intervals on the estimate of the parameter.

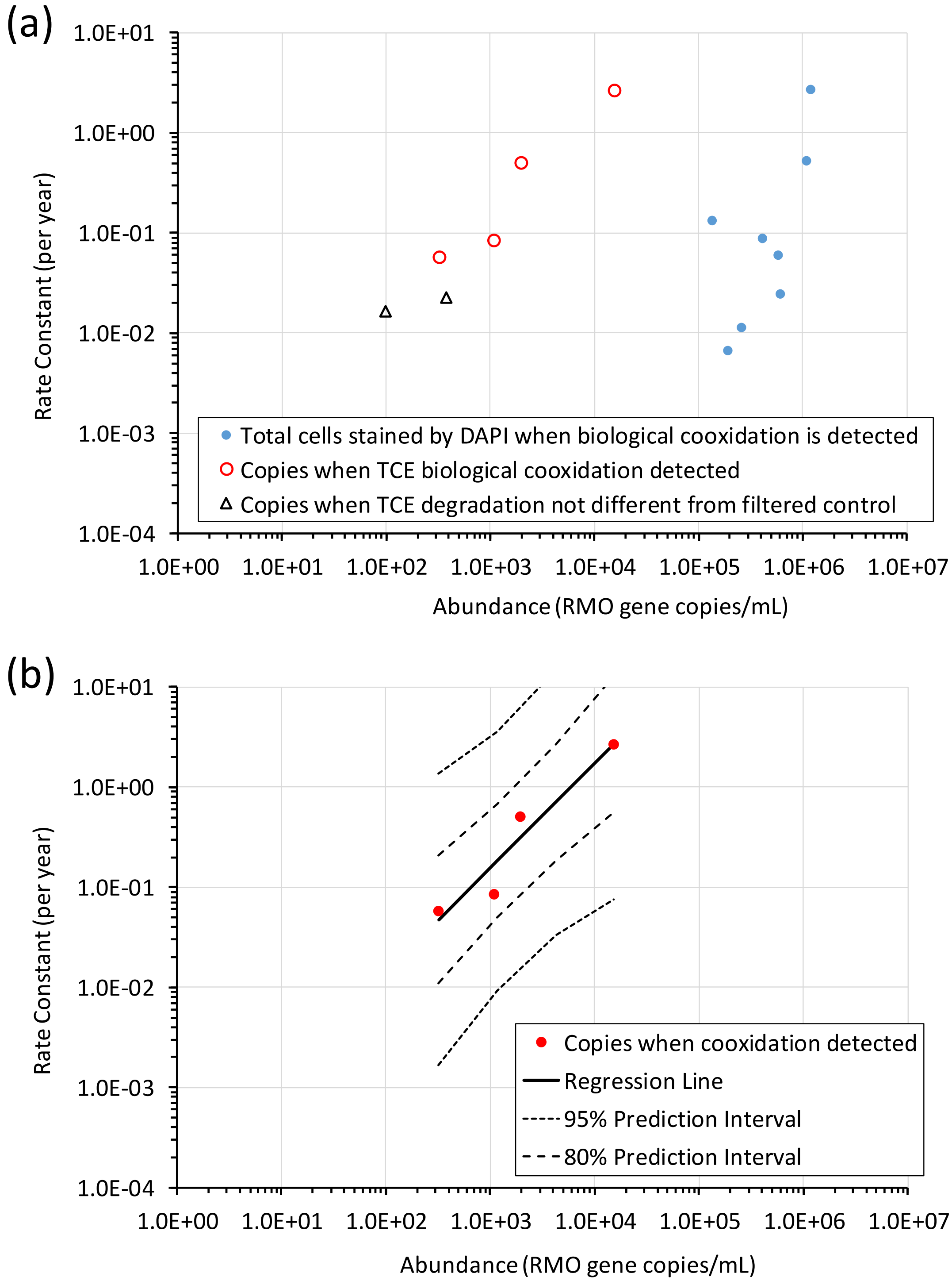


Figure 5.7.37. Relationship between the Rate Constant for Co-oxidation of TCE and the Abundance of DNA that is Amplified by the RMO Primer.

The qPCR data are from Microbial Insights. The total cell data are PNNL.

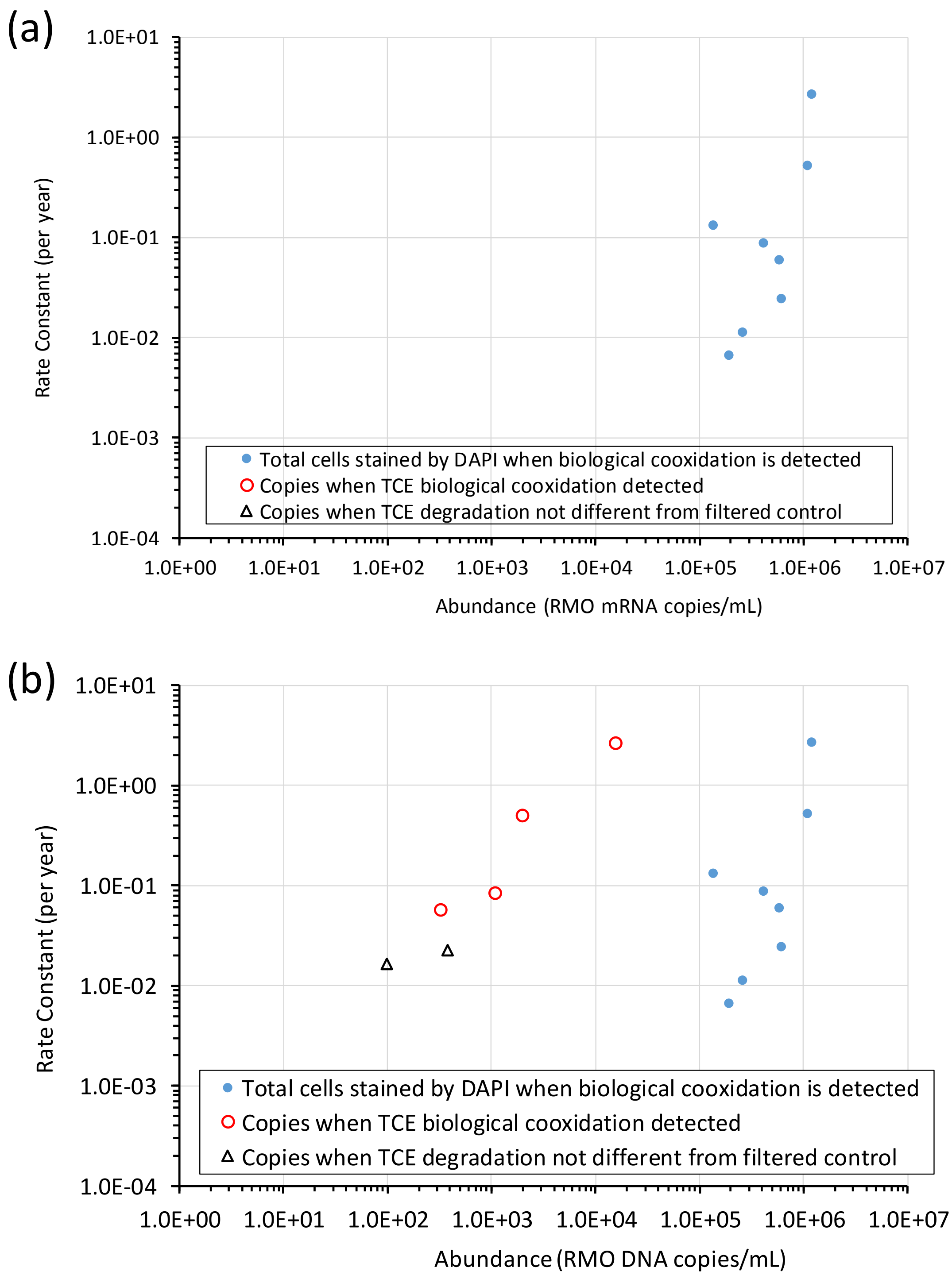


Figure 5.7.38. Comparison of the Relationship between the Rate Constant for Co-oxidation of TCE and the Abundance of DNA or mRNA that is Amplified by the RMO Primer.

The qPCR data are from Microbial Insights. The total cell data are from PNNL.

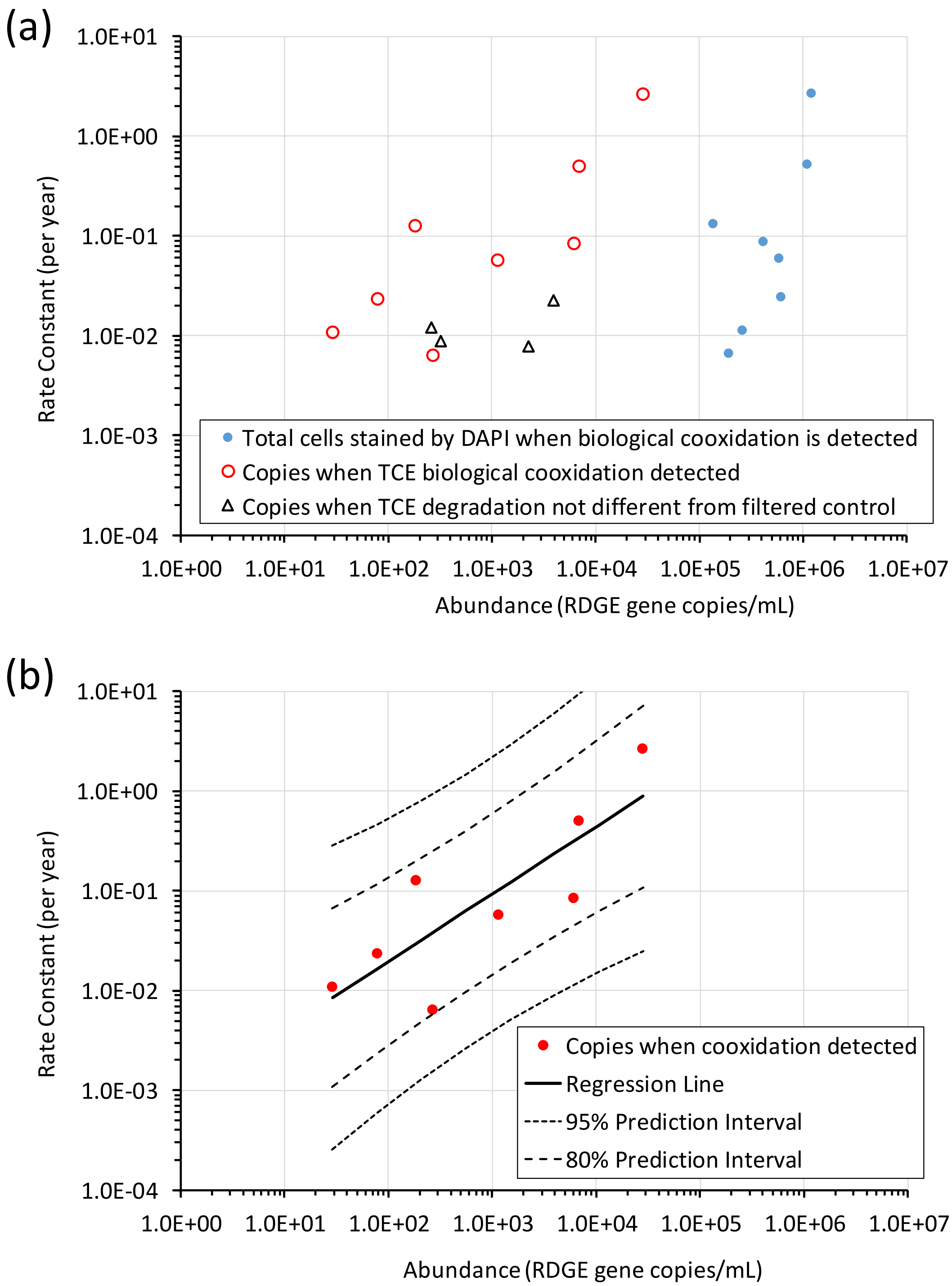


Figure 5.7.39. Relationship between the Rate Constant for Co-oxidation of TCE and the Abundance of DNA that is Amplified by the RDEG Primer.

The qPCR data are from Microbial Insights. The total cell data are PNNL.

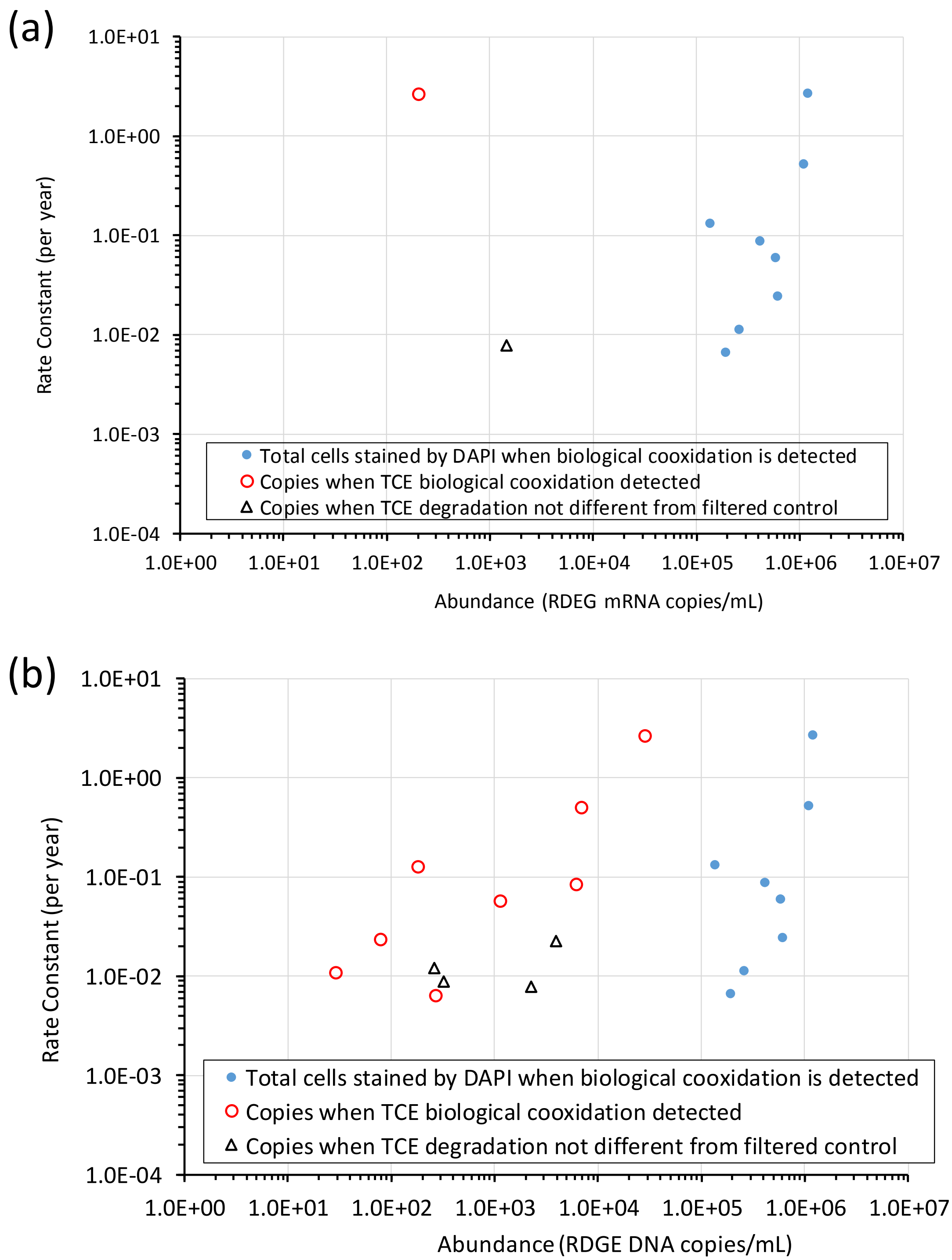


Figure 5.7.40. Comparison of the Relationship between the Rate Constant for Co-oxidation of TCE and the Abundance of DNA or mRNA that is Amplified by the RDEG Primer.

The qPCR data are from Microbial Insights. The total cell data are from PNNL.

5.6.4.2.5 The SMMO or mmoZ Primers for Methane Monooxygenease Enzyme

Panel (a) of Figure 5.7.41 compares the distribution of the rate constants to the abundance of DNA gene copies amplified by the mmoZ primer in the samples that were analyzed by PNNL. Panel (b) of Figure 5.7.41 is a regression of the rate constants on the abundance of gene copies.

In the eight wells where cooxidation of TCE was detected, the density of DNA gene copies that were amplified by the mmoZ primer varied from 2E+02 to 2E+05 per mL. The density of total bacteria in the eight wells varied from 1E+05 to 1E+06 per mL. The abundance of mmoZ gene copies were equal to or less than 10% of the total bacterial population.

In eleven wells where the rate constant for TCE degradation in the water sample was not different from the rate in the filtered controls, the rate constants were ≤ 0.02 per year. However, the abundance of mmoZ gene copies varied from 5E+00 to 4E+04 per mL. This range is significantly overlaps the range in abundance of mmoZ gene copies in the water samples where TCE cooxidation was detected.

Panel (a) of Figure 5.7.42 compares the distribution of the rate constants to the abundance of gene copies amplified by the SMMO primer in the samples that were analyzed by Microbial Insights. The pattern was roughly similar to the pattern for PNNL. However, the geometric mean of the MI samples was 10 SMMO gene copies per mL while the mean of the PNNL analyses was 36 mmoX gene copies per mL. DNA amplified by the SMMO primer was detected in all nineteen wells.

See Pane (a) of Figure 5.7.41 and Figure 5.7.42. If the abundance of mmoZ gene copies was low (on the order of 3E+02 cells per mL) the rate constants were low (near or less than 0.02 per year. However, when the abundance of mmoZ gene copies was higher (on the order of (1E+03 cells per mL), the rate constants varied from 0.02 per year to 2.7 per year. If the abundance of SMMO gene copies was low (on the order of 1E+02 cells per mL) the rate constants were low (near or less than 0.002 per year. However, when the abundance of SMMO gene copies was higher (on the order of (1E+03 cells per mL), the rate constants varied from 0.02 per year to 2.7 per year. Based on this behavior, the abundance of DNA gene copies amplified by the mmoZ primer or the sMMO primer cannot be used as the sole criterion to associate a rate constant for TCE cooxidation in a plume.

Figure 5.7.43 compare the distribution of the rate constants to the abundance of gene copies amplified by the SMMO DNA primer and the SMMO mRNA primer in the samples that were analyzed by Microbial Insights. SMMO mRNA copies were detected in two of the eight wells where cooxidation of TCE was detected and six of the eleven wells where the rate constant for TCE degradation was not different in the filtered control. However, there was no logical relationship between the value of the rate constants and the abundance of the gene copies.

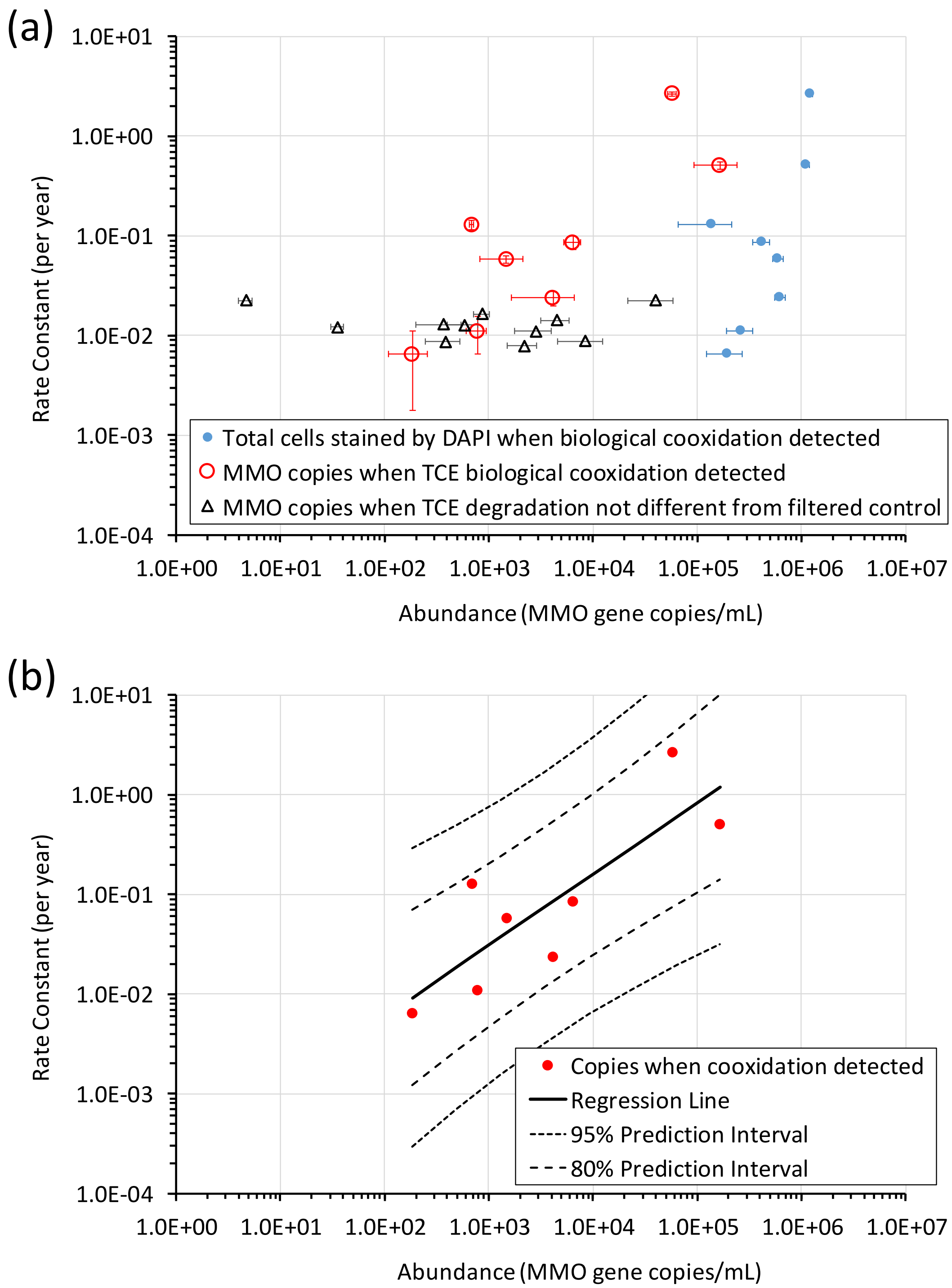


Figure 5.7.41. Relationship between the Rate Constant for Co-oxidation of TCE and the Abundance of DNA that is Amplified by the mmoZ Primer.

The qPCR and total cell data are from PNNL. Error bars in Panel (a) are 95% confidence intervals on the estimate of the parameter.

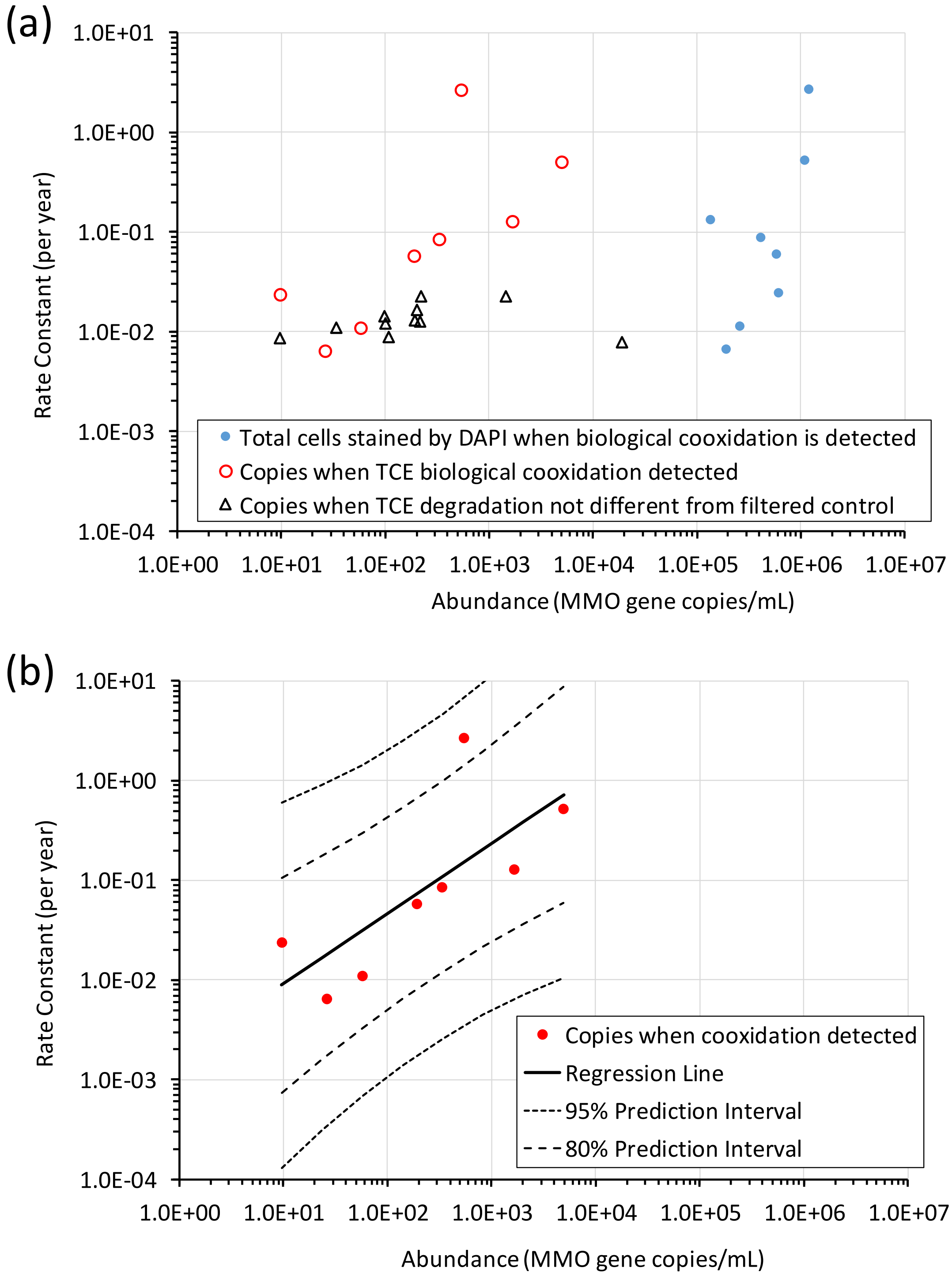


Figure 5.7.42. Relationship between the Rate Constant for Co-oxidation of TCE and the Abundance of DNA that is Amplified by the SMMO Primer.

The qPCR data are from Microbial Insights. The total cell data are PNNL.

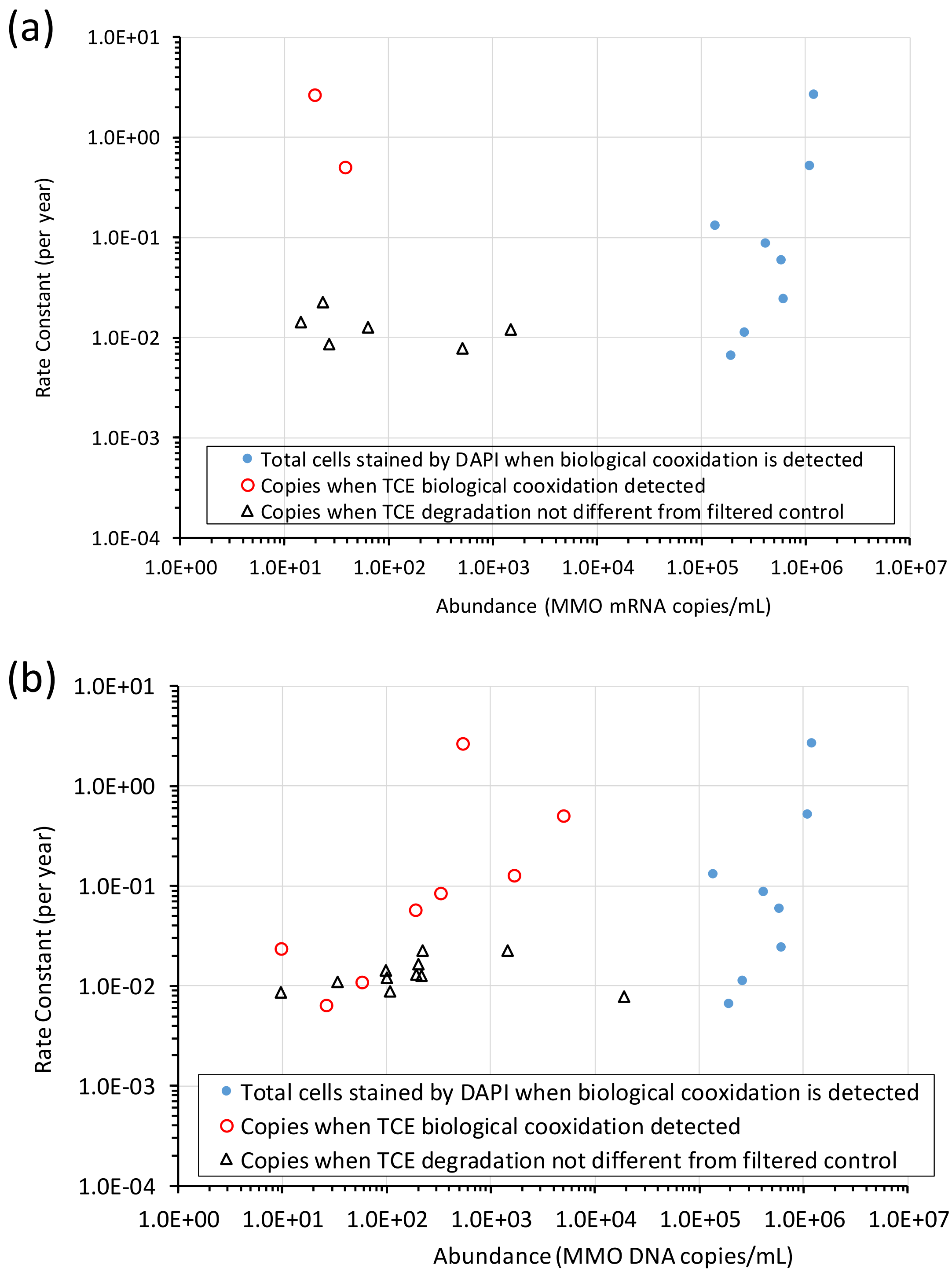


Figure 5.7.43. Comparison of the Relationship between the Rate Constant for Co-oxidation of TCE and the Abundance of DNA or mRNA that is Amplified by the SMMO Primer.

The qPCR data are from Microbial Insights. The total cell data are from PNNL.

5.6.4.2.6 The TOD Primer for Toluene Dioxygenase Enzyme

Panel (a) of Figure 5.7.44 compares the distribution of the rate constants to the abundance of DNA gene copies amplified by the TOD primer in the samples that were analyzed by PNNL. Panel (b) of Figure 5.7.44 is a regression of the rate constants on the abundance of gene copies.

In the eight wells where cooxidation of TCE was detected, the density of DNA gene copies that were amplified by the RMO primer varied from 4E+00 to 3E+02 per mL. The density of total bacteria in the eight wells varied from 1E+05 to 1E+06 per mL. The abundance of RMO gene copies were less than 0.1% of the total bacterial population.

In eight of eleven wells where the rate constant for TCE degradation in the water sample was not different from the rate in the filtered controls, the rate constants were ≤ 0.02 per year. However, the abundance of TOD gene copies varied from 2E+00 to 1E+02 per mL. This range significantly overlaps the range in abundance of TOD gene copies in the water samples where TCE cooxidation was detected.

Panel (a) of Figure 5.7.45 compares the distribution of the rate constants to the abundance of gene copies amplified by the TOD primer in the samples that were analyzed by Microbial Insights. The pattern was similar to the pattern for PNNL. However, the reporting limit from the Microbial Insights samples was higher, in general 5E+00 gene copies/mL. DNA amplified by the TOD primer was not detected in four of the eight wells where TCE cooxidation was detected, and three of the eleven wells where TCE was not different in the filtered controls.

See Panel (a) of Figure 5.7.44 and Figure 5.7.45. If the abundance of TOD gene copies was low (on the order of 3E+00 cells per mL) the rate constants were low (near or less than 0.03 per year (Figure 5.7.44). However, when the abundance of TOD gene copies was higher (on the order of (1E+02 cells per mL), the rate constants varied from 0.02 per year to 2.7 per year. Based on this behavior, the abundance of DNA gene copies amplified by the TOD primer cannot be used as the sole criterion to associate a rate constant for TCE cooxidation in a plume.

Figure 5.7.46 compare the distribution of the rate constants to the abundance of gene copies amplified by the TOD DNA primer and the TOD mRNA primer in the samples that were analyzed by Microbial Insights. TOD mRNA copies were detected in one of the eight wells where cooxidation of TCE was detected and three of the eleven wells where the rate constant for TCE degradation was not different in the filtered control.

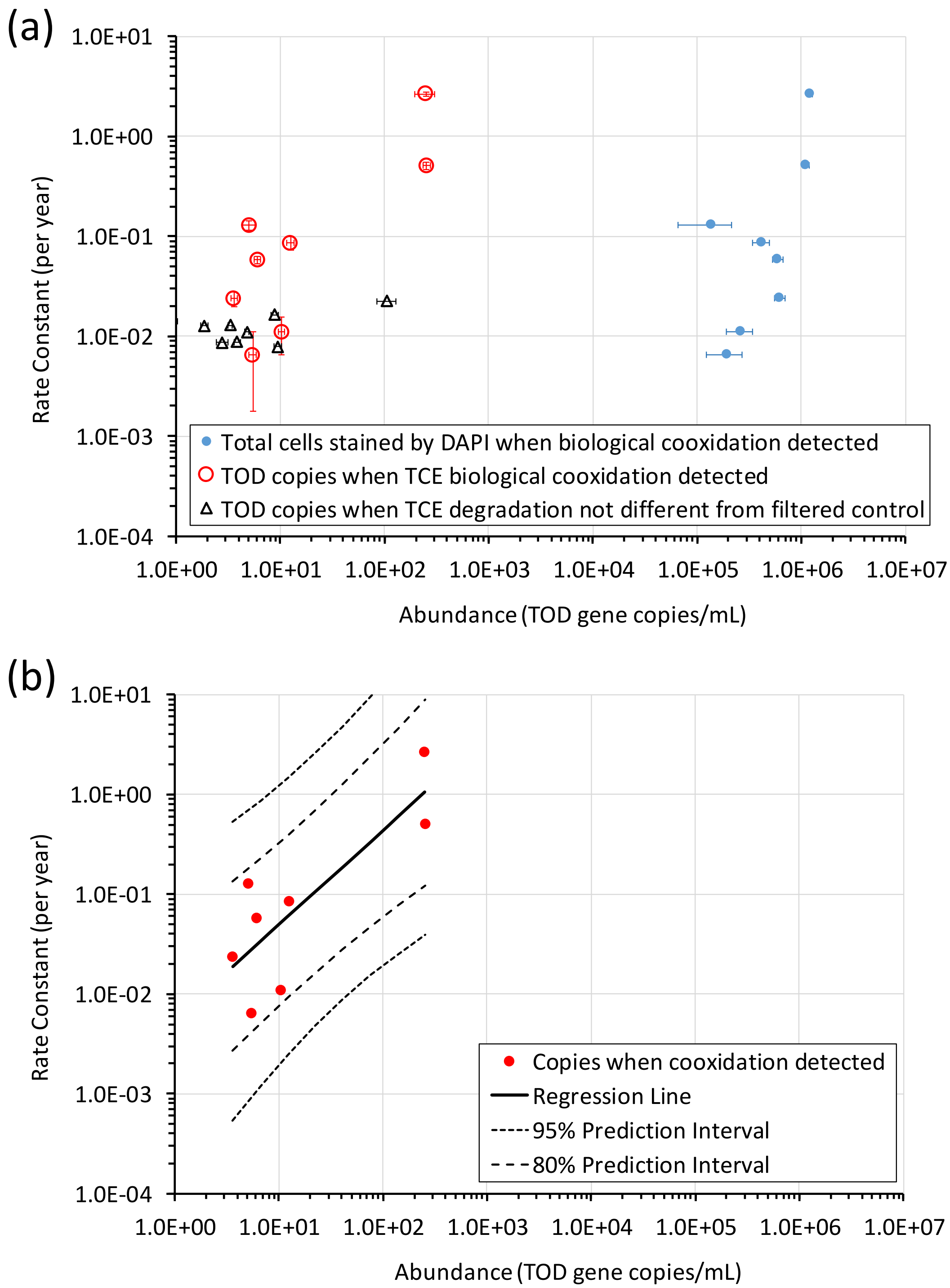


Figure 5.7.44. Relationship between the Rate Constant for Co-oxidation of TCE and the Abundance of DNA that is Amplified by the TOD Primer.

The qPCR and total cell data are from PNNL. Error bars in Panel (a) are 95% confidence intervals on the means.

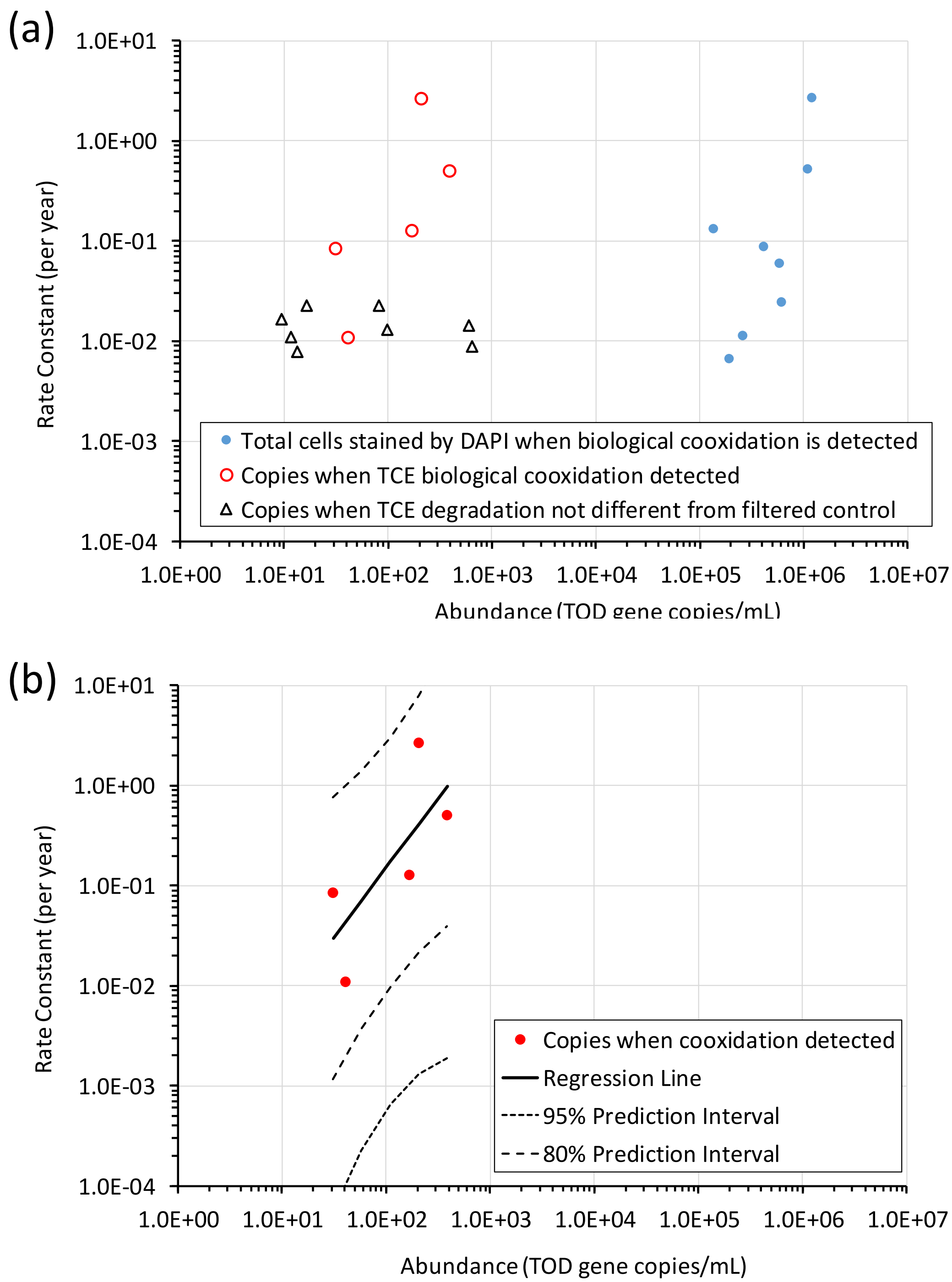
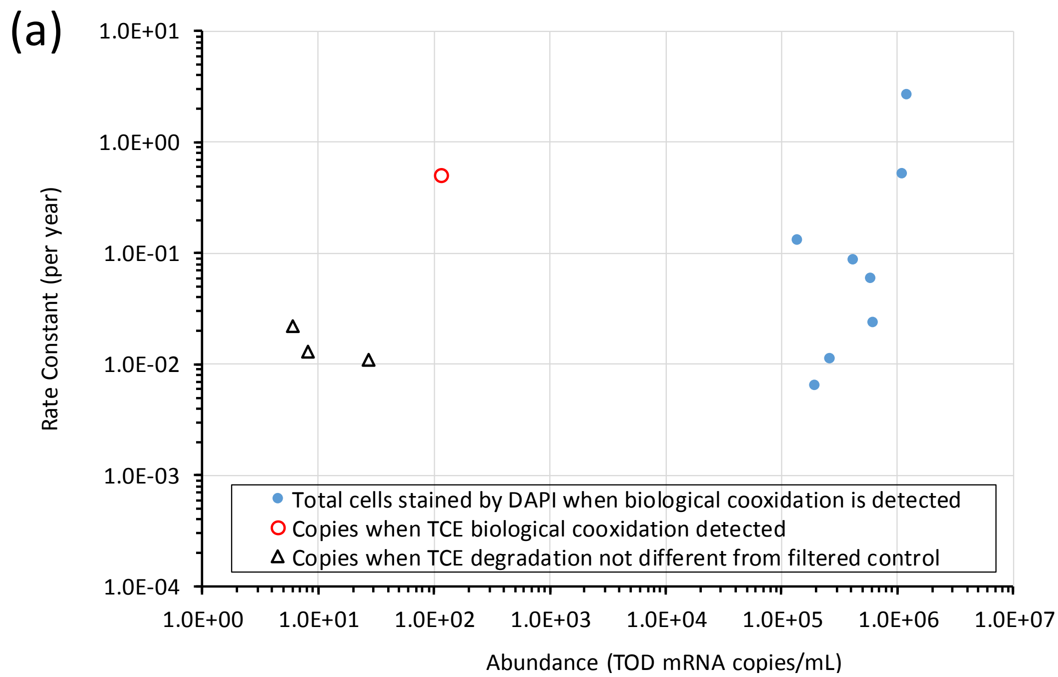


Figure 5.7.45. Relationship between the Rate Constant for Co-oxidation of TCE and the Abundance of DNA that is Amplified by the TOD Primer.

The qPCR data are from Microbial Insights. The total cell data are PNNL.



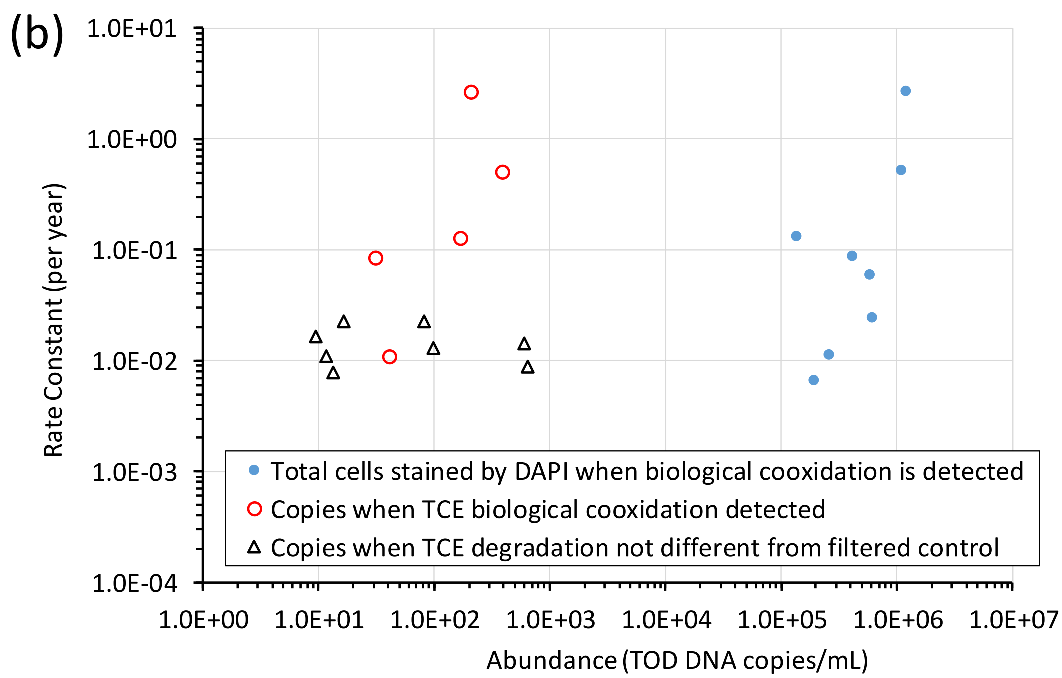


Figure 5.7.46. Comparison of the Relationship between the Rate Constant for Co-oxidation of TCE and the Abundance of DNA or mRNA that is Amplified by the TOD Primer.

The qPCR data are from Microbial Insights. The total cell data are from PNNL.

5.6.4.2.7 The TOL Primer for Toluene Monooxygenase Enzyme

Panel (a) of Figure 5.7.47 compares the distribution of the rate constants to the abundance of DNA gene copies amplified by the TOL primer in the samples that were analyzed by PNNL. Panel (b) of Figure 5.7.47 is a regression of the rate constants on the abundance of gene copies.

In the eight wells where cooxidation of TCE was detected, the density of DNA gene copies that were amplified by the TOL primer varied from 1E-02 to 2E+01 per mL. The density of total bacteria in the eight wells varied from 1E+05 to 1E+06 per mL. The abundance of RMO gene copies were less than 0.01% of the total bacterial population.

In nine wells where the rate constant for TCE degradation in the water sample was not different from the rate in the filtered controls, the rate constants were ≤ 0.02 per year. However, the abundance of TOL gene copies varied from 1E-03 to 1E+01 per mL. This range significantly overlaps the range in abundance of TOL gene copies in the water samples where TCE cooxidation was detected.

See Panel (a) of Figure 5.7.47 and Figure 5.7.48. If the abundance of TOL gene copies was low (on the order of 1E-02 cells per mL) the rate constants were low (near or less than 0.04 per year (Figure 5.7.47). However, when the abundance of TOL gene copies was higher (on the order of (1E+01 cells per mL), the rate constants varied from 0.02 per year to 2.7 per year. Based on this behavior, the abundance of DNA gene copies amplified by the TOL primer cannot be used as the sole criterion to associate a rate constant for TCE cooxidation in a plume.

Panel (a) of Figure 5.7.48 compares the distribution of the rate constants to the abundance of gene copies amplified by the TOL primer in the samples that were analyzed by Microbial Insights. The pattern was similar to the pattern for PNNL. However, the reporting limit from the Microbial Insights samples was higher, in general 5E+00 gene copies/mL. DNA amplified by the TOD primer was not detected in five of the eight wells where TCE cooxidation was detected, and ten of the eleven wells where TCE was not different in the filtered controls.

Figure 5.7.49 compares the distribution of the rate constants to the abundance of gene copies amplified by the TOL DNA primer and the TOL mRNA primer in the samples that were analyzed by Microbial Insights. TOD mRNA copies were not detected in any of the nineteen wells that were sampled.

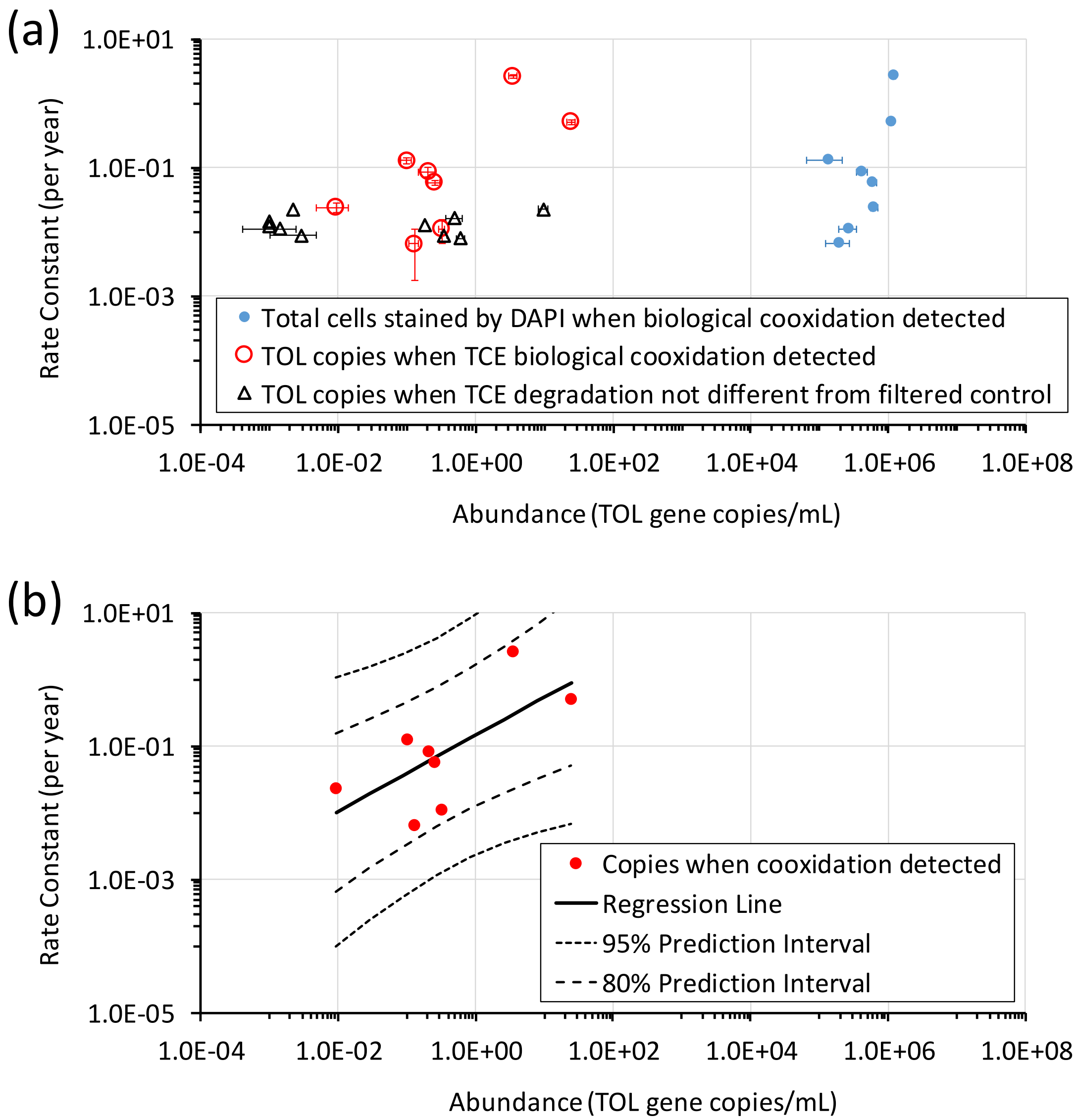


Figure 5.7.47. Relationship between the Rate Constant for Co-oxidation of TCE and the Abundance of DNA that is Amplified by the TOL Primer.

The qPCR and total cell data are from PNNL. Error bars in Panel (a) are 95% confidence intervals on the estimate of the parameter.

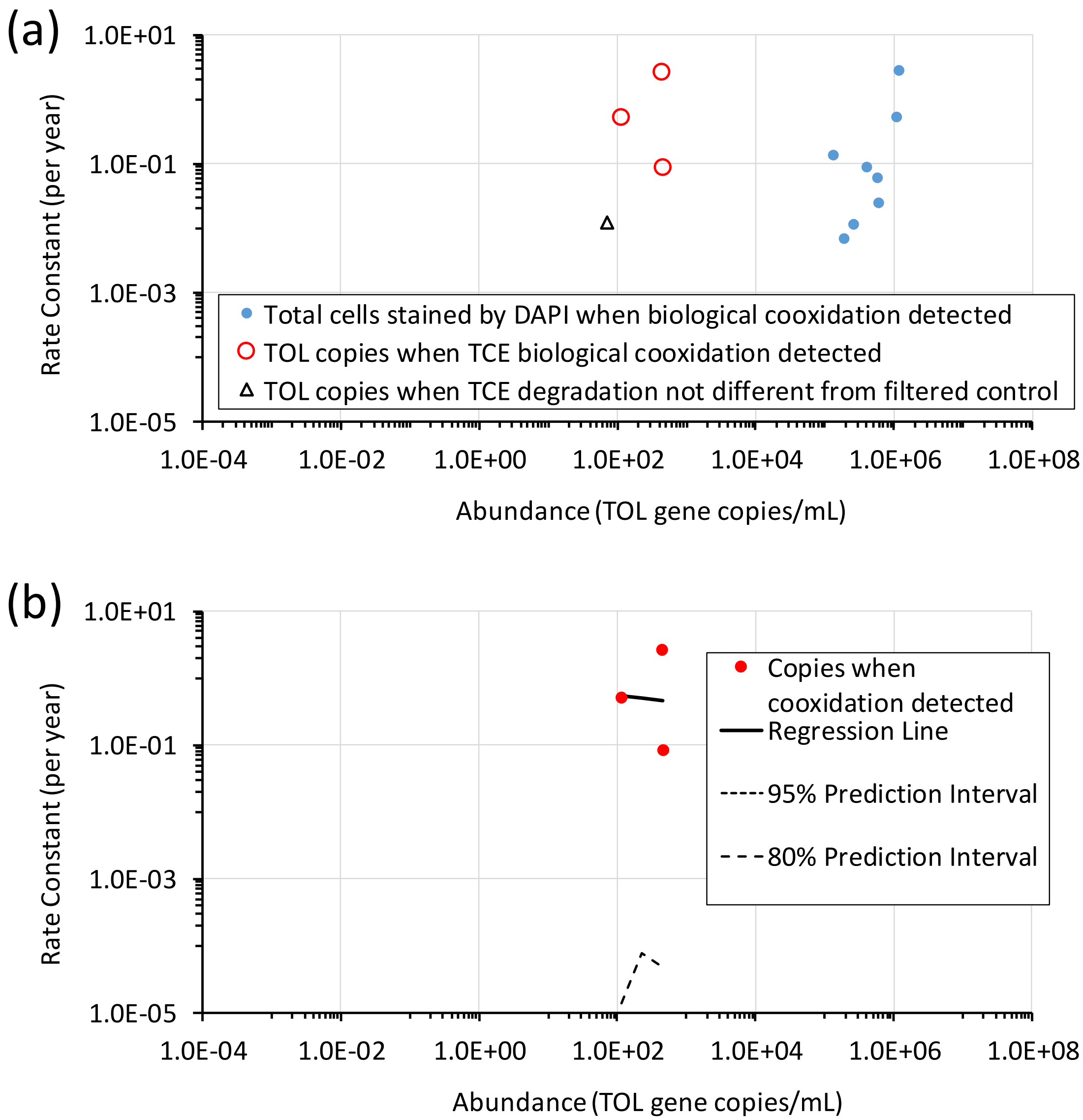


Figure 5.7.48. Relationship between the Rate Constant for Co-oxidation of TCE and the Abundance of DNA that is Amplified by the TOL Primer.

The qPCR data are from Microbial Insights. The total cell data are PNNL.

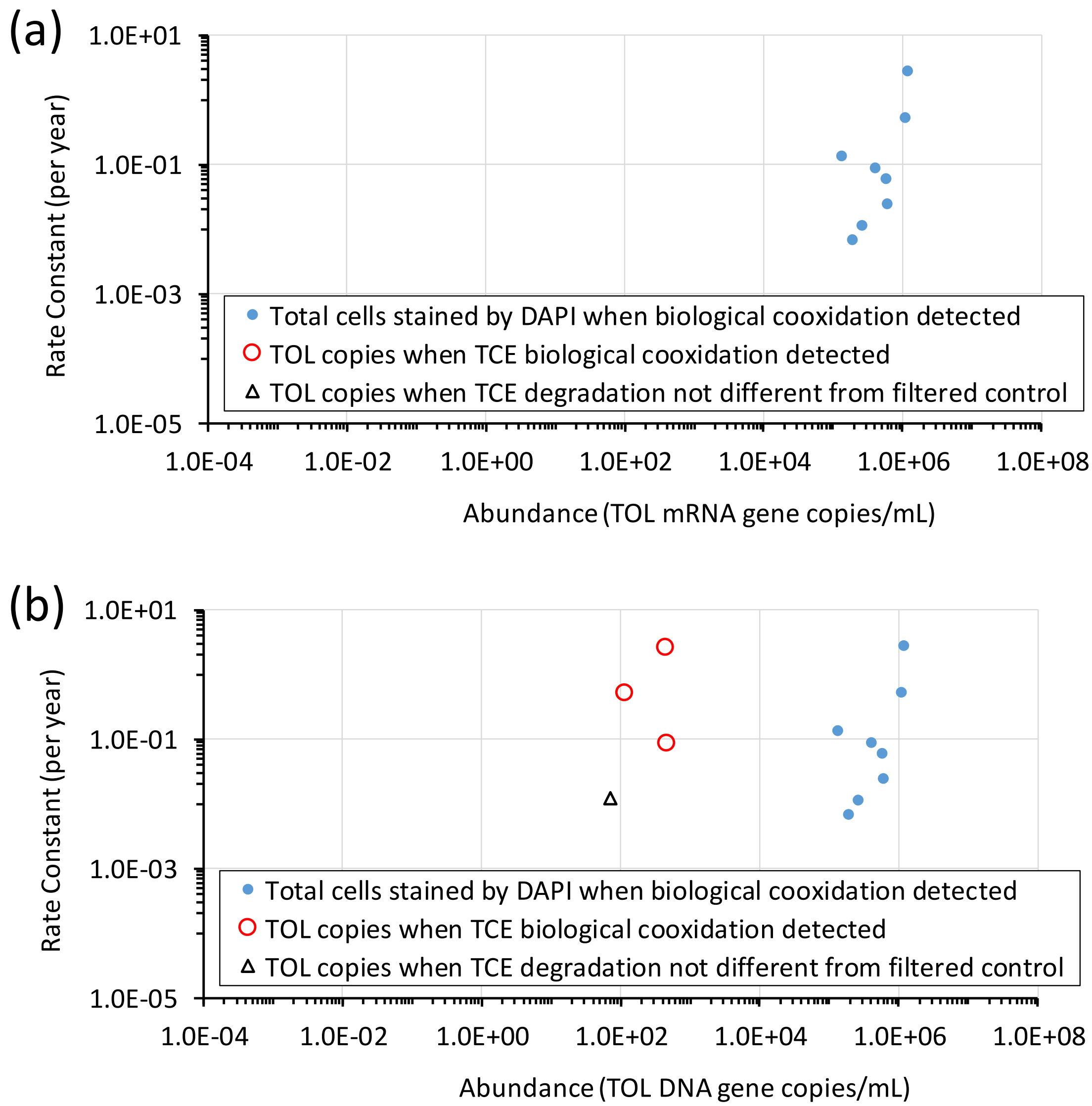


Figure 5.7.49. Comparison of the Relationship between the Rate Constant for Co-oxidation of TCE and the Abundance of DNA or mRNA that is Amplified by the TOL Primer.

The qPCR data are from Microbial Insights. The total cell data are from PNNL.

5.6.4.3 Discussion and Summary

Table 5.7.9 compares the geometric mean of the abundance of cells reacting to the three Enzyme Activity Probes and the abundance of DNA amplified by the seven qPCR primers in the eight wells where cooxidation of TCE was detected. The abundance of cells that reacted with the PA and 3-HPA probes was essentially identical. The abundance of cells that reacted to the CINN probe may have been less, but any difference was not significant at 95% confidence.

Table 5.7.9. Relative Abundance of Markers in the Eight Wells Where TCE Cooxidation Was Detected

Marker	Analyzed by	Geometric Mean	Lower 95% Confidence Interval	Upper 95% Confidence Interval	Number Wells where DNA Detected	Number Wells where mRNA Detected
		Gene Copy per mL	Gene Copy per mL	Gene Copy per mL		
PA	PNNL	2,700	820	9,100		
3-HPA	PNNL	2,700	1,000	7,000		
CINN	PNNL	1,200	280	4,800		
PHE	MI	950	69	1,300	8	3
PHE	PNNL	1,400	300	6000	8	
RMO	MI	1,800	140	24,000	4	0
RMO	PNNL	2,600	500	14,000	8	
RDEG	MI	790	103	6,000	8	1
SMMO	MI	210	37	1,200	8	2
mmoZ	PNNL	3,700	540	26,000	8	
TOD	MI	110	29	430	5	1
TOD	PNNL	16	3.8	67	8	
TOL	MI	280	40	2,000	3	0
TOL	PNNL	0.34	0.05	2.5	8	

No differences between the abundance of DNA amplified by the PHE primer, the RMO primer, the RDEG primer and the mmoZ primer could be distinguished that were significant at 95% confidence, and no differences between the abundance of DNA amplified by these primers and the abundance of cells that reacted with the Enzyme Activity Probes could be distinguished at 95% confidence. It is likely that the Probes and the primers were interacting with the same population of cells. If this is true, then much of the DNA amplified by the primers is associated with living cells that are capable of supporting the activity of an oxygenase enzyme.

There is no explanation for the behavior of the bacteria in the eleven wells where the cells reacted with the Enzyme Activity Probes, but did not cooxidize TCE at detectable rates. If the cells would react with the Probe, then why did they not react with TCE? It is possible that the cells were in a dormant state in the groundwater, and the presence of the Probe, or some other factor in the performance of the assay, restored the cells to an active state. This phenomenon will require further study before the behavior can be explained.

The abundance of DNA that was amplified by the TOD and TOL primers was orders of magnitude lower than the abundance of DNA amplified by the PHE primer, the RMO primer, the RDEG primer and the mmoZ primer. It is unlikely that enzymes coded by DNA amplified by the TOD and TOL primers are responsible for a significant fraction of TCE cooxidation.

Assays for DNA amplified by PHE primer, the RMO primer, the RDEG primer are commercially available. The PHE primer may be the best primer to describe TCE cooxidation. In addition to a high abundance of DNA amplified by this primer, there was a reasonably high abundance of mRNA that was amplified by this primer.

Table 5.7.9 compares the slope of the regession line for the three EAP markers and the qPCR markers. According to the criterion in Table 3.2.1 and Section 3.2.4.2, a marker will be useful to predict the value of the rate constant when the slope of the regression of the logarithm of the rate constant on the logarithm of the abundance of the marker is greater than zero at 95% confidence. The CINN EAP marker met this criterion, though just barely, but the PH and 3-HPA EAP markers did not. The PHE, RMO, and MMO primers analyzed by both PNNL and MI met the criterion. The TOD marker as analyzed by PNNL met the criterion, but the TOD marker as analyzed by MI did not. This difference is due to the greater sensitivity of the analyses performed by PNNL.

The TOL marker as analyzed by either PNNL or MI did not meet the criterion.

Table 5.7.10. Relative Abundance of Markers in the Eight Wells Where TCE Cooxidation Was Detected

Marker	Analyzed by	Slope of Regression Line	Lower 95% Confidence Interval	Upper 95% Confidence Interval	Number of Wells in Regression
PA	PNNL	0.91	-0.13	1.95	8
3-HPA	PNNL	1.04	-0.34	2.42	8
CINN	PNNL	0.86	**0.06**	**1.66**	8
PHE	MI	0.55	**0.22**	**0.87**	8
PHE	PNNL	0.90	**0.18**	**1.61**	8
RMO	MI	1.05	**0.10**	**1.98**	4
RMO	PNNL	0.81	**0.26**	**1.35**	8
RDEG	MI	0.68	**0.21**	**1.14**	8
SMMO	MI	0.70	**0.07**	**1.34**	8
mmoZ	PNNL	0.71	**0.23**	**1.20**	8
TOD	MI	1.40	-0.94	3.72	5
TOD	PNNL	0.94	**0.29**	**1.60**	8
TOL	MI	-0.10	-27.59	27.39	3
TOL	PNNL	0.57	-0.04	1.18	8

5.6.4.4 Appropriate Use of EAP and qPCR Data

As described previously, the number of cells that reacted to the Enzyme Activity Probes or the abundance of DNA gene copies amplified by the qPCR primers should not be used as the sole criterion to associate a rate constant for TCE cooxidation in a plume. However, there are two useful applications for these data. The data can be used to screen a site to determine whether cooxidation of TCE is a possible mechanism for a natural attenuation remedy. The data can also be used to provide a second line of evidence to evaluate a rate constant that is extracted from other information.

To use the biological markers to determine whether TCE cooxidation might provide a remedy, it is necessary to know the value of the rate constant that is required to provide the desired environment outcome. The value is site specific. It may depend on the travel time of groundwater from a source to a property boundary, sentry well, or a vulnerable receptor. If further contamination of the groundwater is prevented, it may depend on the time available before the cleanup goal is to be attained. For the sake of illustration, assume that a rate constant ≥0.03 per year can lead to a desirable outcome. This is equivalent to a half-life of 23 years.

The next step is to compare the required site-specific value of the rate constant to the rate constant that might plausibly be expected from the abundance of the biomarkers. The best candidates are the PHE primer and the RMO primer.

The process will be illustrated by data for the PHE primer. Figure 5.7.50 repeats information provided in Panel (b) of Figure 5.7.34. The lower 80% two-tailed prediction interval in Panel (b) of Figure 5.7.34 also corresponds to the 90% one-tailed prediction interval in Figure 5.7.50. If the measured abundance of DNA that is amplified by the PHE primer is 1E+04 gene copies per mL, there is a 50% chance the rate constant is greater than 0.2 per year, and a 90% confidence that the rate constant is greater than 0.05 per year. In this example, both exceed the rate constant that would produce the desired outcome. This would justify collecting the information necessary to provide a valid rate constant

Valid rate constants could be obtained using the ^{14}C assay for TCE cooxidation. Valid rate constants can also be extracted from long term monitoring data and the geohydrological properties of the site using the method described in Lebrón et al. (2015). If rate constants for TCE degradation are already available at a site, the qPCR data could be used to provide a line of evidence that aerobic TCE cooxidation is a plausible mechanism to explain the degradation rate.

After the PHE primer, the RMO primer is the most useful qPCR marker. Figure 5.7.51 provides the regression line and the lower one-tailed 90% prediction interval for the RMO primer. The CINN marker was the only EAP that met the criterion that the slope of the regession line will be greater than zero at 95% confidence. Figure 5.7.52 provides the regression line and lower one-tailed 90% prediction interval for the CINN EAP.

Use caution when extraplating rate contants for groundwater with Fe(II). The ^{13}C-TCE assay provides adequate dissolved oxygen to support aerobic biological cooxidation. Oxygen reacts readiy with Fe(II). If there is measureable Fe(II) in groundwater, that water is devoid of oxygen. If both oxygen and Fe(II) are present in a sample of well water, some portion of the flowlines to the well have oxygen and no Fe(II), and other portions have Fe(II) and no oxygen.

Three of the wells in the survey had measurable concentrations of Fe(II), and the same three wells had the highest rate constants for TCE cooxidation (Table 5.6.3 and Table 5.7.2). The well with the highest rate constant (U10-019 at Hill AFB) had 0.69 mg/L Fe(II). The well with the next highest rate constant (MW-01-006 at Plattsburgh AFB) had 1.25 mg/L Fe(II). The well with the third highest rate constant (MW-02-019 at Plattsburgh AFB) had 1.12 mg/L Fe(II). The concentration of Fe(II) was <0.03 mg/L in the other wells. Data points from these wells are enclosed within a ▢ shape in Figure 5.7.50, Figure 5.7.51 and Figure 5.7.52.

If Fe(II) is present in the well water, some portion of the aquifer sampled by the well does not have oxygen to support cooxidation of TCE. As a result, the rate constant determined using the ^{13}C-TCE assay will overestimate the true rate constant in the aquifer. If the well water has measurable Fe(II), supplement and validate the rate constant provided from the assaywith a rate constant extracted from the long-term monitoring data and the geohydrological properties of the aquifer.

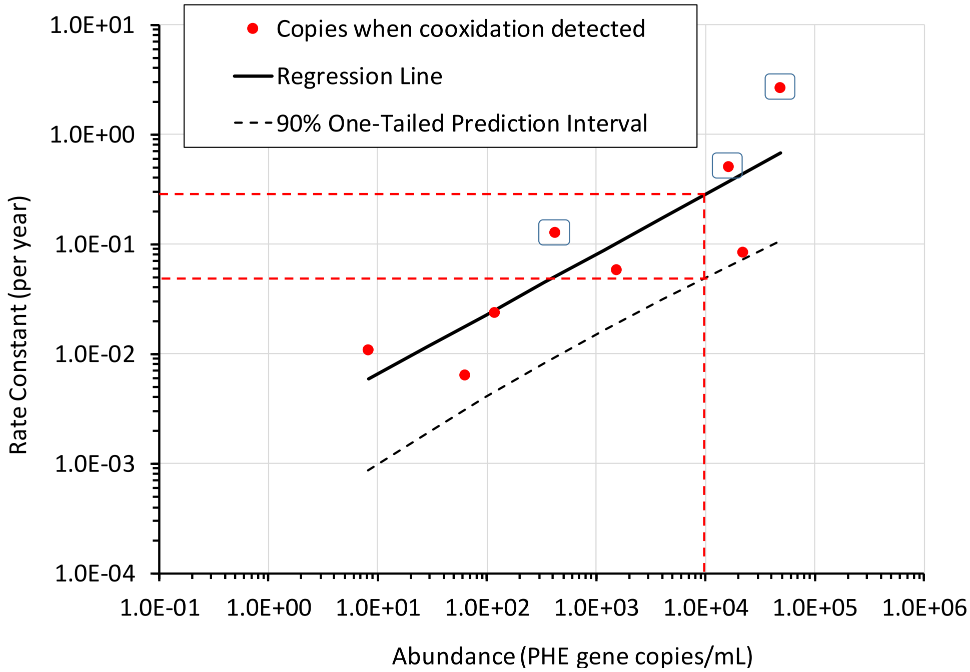


Figure 5.7.50. Predicting Provisional Rate Constants for TCE Co-oxidation from the Abundance of DNA Amplified by the PHE Primer.

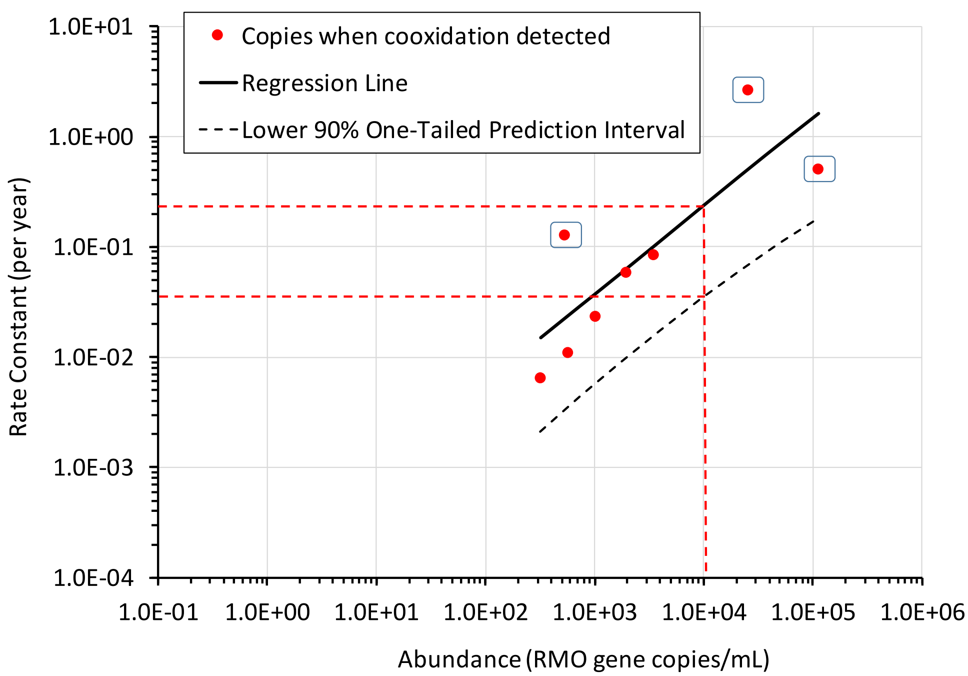


Figure 5.7.51. Predicting Provisional Rate Constants for TCE Co-oxidation from the Abundance of DNA Amplified by the RMO Primer.

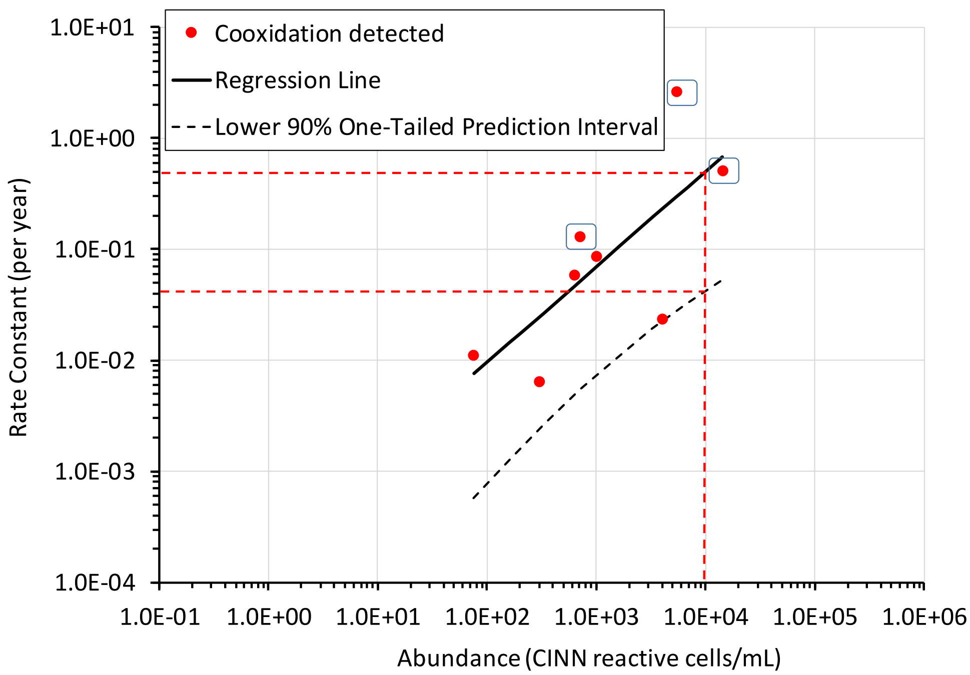


Figure 5.7.52. Predicting Provisional Rate Constants for TCE Co-oxidation from the Abundance of Cells that React with the CINN EAP.

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6.0 PERFORMANCE ASSESSMENT

Qualitative and quantitative performance metrics were initially established and performance assessed through project execution. Performance was assessed using the performance objectives listed in Section 3 as a benchmark. The following subsections relate to the results that pertain to these metrics and goals.

6.1 QUALITATIVE PERFORMANCE OBJECTIVES

This section discusses the qualitative performance objectives for this project, which are summarized in Table 3.1.1.

6.1.1 Develop an Easy to Use Procedure for Collecting Magnetic Susceptibility Data

To be able to readily assess abiotic degradation by magnetite, reliable, yet relatively inexpensive magnetic susceptibility data for the aquifer matrix along the solute flowpath must be available. In order to achieve this performance objective, the implementation of a magnetic susceptibility sonde at various depths and in various conditions was tested. Specifically, the field testing of existing, readily-available technology to quantify magnetic susceptibility in existing PVC monitoring wells using a commercially-available magnetic susceptibility sonde was conducted to determine ease of use and accuracy. This performance objective was met for the following reasons:

1) Based on the experience of the field crew (i.e., Mr. Wiedemeier and Dr. Wilson), the sonde was very easy to use. After the initial learning curve, which will be much reduced for people reading this document, the field crew was able to set up and have the sonde down-hole and ready to obtain measurements within 0.5 hour of arriving at a given sampling location. Of course, this assumes that the field crew has no problems gaining access to the sampling point.

2) Based on the data and discussion presented in Section 5.7.1.2, the sonde used for this project produces accurate magnetic susceptibility data.

6.1.2 Develop an Assay Based on ^{14}C-TCE That Will Allow TCE Co-Oxidation Rates in Groundwater Samples

The ^{14}C-TCE assay allowed for quantification of pseudo first order rate constants in groundwater samples from eight of the 19 wells evaluated, at rates ranging from ranging from 0.00658 to 2.65 yr^{-1}. This translates to half-lives of 0.26 to 105 yr. In groundwater from the other 11 wells, the rate of ^{14}C product accumulation was not statistically different from the FSGW controls, so that no rate is reported. Although only a single GC column was used for purification of the ^{14}C-TCE, the level of impurities delivered to the serum bottles was sufficiently low to allow for detection of a half-life as long as 105 yr. This was due in part to extension of the incubation period from a few days to as long as 46 days, which permitted accumulation of a sufficient level of ^{14}C products to be distinguishable from the controls.

In several of the groundwater samples, VOCs were detected in addition to TCE. These decreased in amount during the incubation period, often at a faster rate than the TCE. It is not yet known if these co-contaminants contributed to co-oxidation of TCE. The fact that co-oxidation occurred in some of the groundwater samples that did not contain VOCs other than TCE indicates their presence is not a requirement. Demonstration of co-oxidation in a surface water sample obtained from a seep with no prior exposure to chlorinated contaminants indicated that naturally occurring processes can support TCE co-oxidation at a meaningful rate.

The initial plan was to use DDI water as the negative control for the ^{14}C-TCE assay. It was determined, however, that FSGW is more appropriate for this purpose. The rate of ^{14}C product accumulation in FSGW controls was statistically lower than in DDI water, likely due to the presence of constitutes that quench the autoradiolysis associated with decay of ^{14}C-TCE.

A propanotrophic culture that co-oxidized TCE was used as a positive control to evaluate the ^{14}C-TCE assay. ENV485 was used to assess the effect of storage conditions on the co-oxidation rate. It was determined that handling the culture in the same manner as the groundwater samples (i.e., 24 h at 4 °C to mimic shipping on ice, followed warming overnight to room temperature) caused a modest decrease in the first order rate coefficient. This suggests that the co-oxidation rates for the groundwater are conservative with respect to in situ conditions.

6.1.3 Methods for Identifying Presence and Activity of Co-Metabolic Bacteria for TCE Oxidation

Results from the experiments demonstrated that both qPCR and EAP performed as expected for analysis of cometabolism genes in groundwater samples. While responses from most wells was considered low, the qPCR primer sets and EAP provided lines of evidence that there are active cometabolic enzymes in a groundwater sample.

In general, qPCR results corresponded to the EAP results for the PHE and RMO primer sets, but not for the TOD and TOL primer sets.

6.1.4 Demonstrate Baseline Method for Linking TCE Transformation Rates to Numbers of Bacteria with Co-oxidation Enzymes

The ^{13}C-TCE assay was an effective tool to determine rate constants for TCE cooxidation at some sites, but not at others. At 95% confidence, the ^{14}C-TCE assay could extract a rate constant for TCE cooxidation from 8 of 19 water samples. The rate rate constant for total degradation of TCE is an upper boundary on the rate constant for biological cooxidation. The highest rate constant in any well where biological cooxidation could not be distinguished from radiolysis was 0.084 per year. This corresponds to a half-life of 8.3 years. At many sites, a rate constant of 0.084 per year would be make biological cooxidation a plausible mechanism for a MNA remedy. The ^{13}C-TCE assay will provide a rate constant for TCE cooxidation at may many sites where cooxidation is a plausible remedy, but not all of them.

In every well sampled, whether the TCE cooxidation was detected or not detected, the abundance of cells reacting to each of the EAPs was above the quantitation limit. In every well sampled, the abundance of DNA that was amplified by the PHE, RMO, and MMO primers was above the quantition limit.

6.2 QUANTITATIVE PERFORMANCE OBJECTIVES

This section discusses the qualitative performance objectives for this project, which are summarized in Table 3.2.1.

6.2.1 Evaluate the Accuracy of Data for Magnetic Susceptibility

To verify the validity of the data collected using the magnetic susceptibility sonde, the sonde was deployed in wells where soil samples were previously collected from soil borings prior to well installation and analyzed for mass magnetic susceptibility in an analytical laboratory. The data collected using the downhole sonde were then compared to the previously-collected borehole soil data.

The correlation between magnetic susceptibility determined using the sonde and magnetic susceptibility data collected using laboratory analysis of soil/sediment data was determined (Figure 5.7.3). The Pearson's correlation coefficient, r, was calculated and determined to be $r = 0.94$ ($R^2 = 0.88$). Based on the quantitative performance objective for this task of a Pearson's correlation coefficient greater than 0.75 ($r > 0.75$), this performance objective is considered met. Thus, the magnetic susceptibility sonde provides a good tool for collecting representative magnetic susceptibility data from existing non-metallic (e.g., PVC) monitoring wells.

Based on this, if appropriate monitoring wells are available, downhole magnetic susceptibility sondes in groundwater monitoring wells can provide a less expensive alternative to the collection and analysis of borehole core data, and can provide data that can be used to evaluate field-scale rate constants for abiotic degradation of PCE, TCE, and *c*DCE by magnetite.

6.2.2 Determine First-Order Rates of TCE Co-Oxidation Using a ^{14}C-TCE Assay

The ^{14}C-TCE assay allowed for quantification of pseudo first order rate constants in groundwater samples from eight of the 19 wells evaluated, at rates ranging from ranging from 0.00658 to 2.65 yr^{-1}. This translates to half-lives of 0.26 to 105 yr. In groundwater from the other 11 wells, the rate of ^{14}C product accumulation was not statistically different from the FSGW controls, so that no rate is reported. Although only a single GC column was used for purification of the ^{14}C-TCE, the level of impurities delievered to the serum bottles was sufficiently low to allow for detection of a half-life as long as 105 yr. This was due in part to extension of the incubation period from a few days to as long as 46 days, which permitted accumulation of a sufficient level of ^{14}C products to be distinguishable from the controls.

In several of the groundwater samples, VOCs were detected in addition to TCE. These decreased in amount during the incubation period, often at a faster rate than the TCE. It is not yet known if these co-contamiants contributed to co-oxidation of TCE. The fact that co-oxidation occurred in some of the groundwater samples that did not contain VOCs other than TCE indicates their presence is not a requirement. Demonstration of co-oxidation in a surface water sample obtained from a seep with no prior exposure to chlorinated contaminants indicated that naturally occurring processes can support TCE co-oxidation at a meaningful rate.

The initial plan was to use DDI water as the negative control for the ^{14}C-TCE assay. It was determined, however, that FSGW is more appropriate for this purpose. The rate of ^{14}C product accumulation in FSGW controls was statistically lower than in DDI water, likely due to the presence of constitutes that quench the autoradiolysis associated with decay of ^{14}C-TCE.

A propanotrophic culture that co-oxidized TCE was used as a positive control to evaluate the ^{14}C-TCE assay. ENV485 was used to assess the effect of storage conditions on the co-oxidation rate. It was determined that handling the culture in the same manner as the groundwater samples (i.e., 24 h at 4 °C to mimic shipping on ice, followed warmining overnight to room temperature) caused a modest decrease in the first order rate coefficient. This suggests that the co-oxidation rates for the groundwater are conservative with respect to in situ conditions.

6.2.3 Quantification of Bacteria with Active Enzymes Associated with TCE Co-Metabolism

Quantitative polymerase chain reaction provides evidence for the presence of cometabolism genes in groundwater samples, while EAP provided lines of evidence that there are active cometabolic enzymes in a groundwater sample. Groundwater from five sites across the U.S. were analyzed using qPCR and EAP, and surprisingly few of the samples showed the presence and activity of the cometabolic oxygenase enzymes probed for during the project. Four of the 19 wells analyzed using the phenylacetylene and 3-hydroxyphenylacetylene EAP, showed activity considered to be statistically significant (>8x10^3 cells/ml). Cinnamonitrile only showed positive results for two of the nineteen wells tested.

In general, qPCR results corresponded to the EAP results for the PHE and RMO primer sets, but not for the TOD and TOL primer sets. Gene targets for SMMO were only detected significant levels (>10^3 cells/ml) at three of the 19 wells tested.

6.2.4 Demonstrate Ability to Predict TCE Co-Oxidation Rates by Quantifying Number of Bacteria With Active Co-oxidation enzymes

In the eight wells where biological cooxidation could be distinguished from radiolysis, the CINN EAP assay and the PHE and RMO qPCR determination provided a useful prediction of the rate constant for TCE cooxidation, although the prediction intervals in the regression are broad. However, in many of the wells where cooxidation was not detected, the abundance of cells reacting with the CINN EAP and the abundance of DNA that is amplified by the PHE and RMO primer was high. The EAP and qPCR data do not provide an unequivocal prediction of the rate constant for TCE cooxidation.

Because the CINN EAP marker or the PHE and RMO qPCR markers do not provide an unequivocal prediction of the rate constant, the CINN EAP marker or the PHE and RMO qPCR markers can only be used to identify groundwater where the predicted rate constants are possible. To use cooxidation of TCE as part of a MNA remedy, it will be necessary to validate the predictions from the CINN EAP marker or the PHE and RMO qPCR markers by obtaining rate constants using the ^{13}C-TCE assay or by extracting rate constants from the long-term monitoring data and the geohydrologial properties of the aquifer.

If the groundwater used to perform the ^{13}C-TCE assay has measureable concentrations of Fe(II), it would be good practice to supplement and validate the rate constant produced by the assay with a rate constant that is extracted from the long-term monitoring data and the geohydrological properties of the aquifer.

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7.0 COST ASSESSMENT

This section provides information on the costs for implementing the various technology elements described in this report at a given site. In addition, this section provides a discussion of the cost benefit of the technology.

7.1 COST MODEL

A simple cost model for the technology is presented so that a remediation professional can understand costing implications. The cost model reflects all cost elements required for implementing the technology at a real site. For each cost element, the cost data that was tracked during the demonstration and the associated cost as incurred during the demonstration are presented.

Each cost element includes the following information:

- A description to briefly explain the cost element and the need for it in the implementation of the technology.
- A description and, if appropriate, supporting analysis as to what data supports the listed cost estimate or range.
- A description of how issues of scale are addressed is included by providing per-well costs.

7.2 COST DRIVERS

Anticipated cost drivers in selecting the technology for future implementation are discussed in this cost assessment. The only site-specific characteristic that would significantly impact cost/implementibility is if only 2inch wells that have been compromised are available for a given site. Wells that are considered compromised include those wells that are insufficiently straight to allow insertion and lowering of the downhole magnetic susceptibility sonde. In addition, compromised wells could have joints that are not flush, and the sonde cannot move past the joint. In such cases the sonde cannot be used and a drilling rig will have to be mobilized if the interested party wants to collect magnetic susceptibility data.

7.3 COST ANALYSIS

This section provides estimates for the costs of the technology when implemented. The basic site description for which costs were developed includes a site contaminated with chlorinated ethylenes that contains 2- or 4-inch monitoring wells installed to 100 feet in unconsolidated sediment or fractured rock. In order for the technology elements described in this document to be the most useful, monitoring wells used for sample collection should be located as near as possible to the plume centerline, parallel to the direction of solute flow.

This section describes and quantifies the operational costs for the various components of the technologies being developed and/or refined under this demonstration. For the purposes of developing the cost model presented herein, the technology has been broken down into cost elements, which are discussed and quantified in the following sections.

7.3.1 COST ELEMENT 1 – DOWNHOLE MAGNETIC SUSCEPTIBILITY MEASUREMENTS

This cost element includes mobilization of a two-person field crew to the field for three days to collect continuous downhole magnetic susceptibility measurements. Mobilization includes making all arrangements for equipment rental and site access. It is assumed that the wells to be analyzed have already been selected. Included in the costs for magnetic susceptibility measurements using a magnetic susceptibility sonde are the continuous sampling of up to eight wells to a depth of 100 feet below ground surface over a period of three days. These costs include the rental of all necessary equipment as well as labor hours. Table 7.1 summarizes the costs for this cost element. These costs can be scaled up and down by taking the mobilization cost, which includes the costs for renting and obtaining the equipment, of $1,200 and adding it to the per-well cost of $800 times the number of wells to be sampled. Thus, sonding one well would cost roughly $2,000, two wells would cost $2,800, and so on.

These costs are considerably cheaper than mobilizing a drilling rig specifically for the collection of soil/sediment cores for the analysis of magnetic susceptibility. This is the primary advantage of using the in-well sonde. If a drilling rig is already on site, samples can be obtained from the proper location, and continuous coring is already occurring, then using soil borehole samples analyzed in a fixed-based laboratory is probably the more economical way to go. As shown in this report, both the downhole sonde and soil borehole data analyzed in a fixed-base laboratory give similar results, so the choice of which methodology to utilize will depend primarily upon where the site characterization effort for the site stands. Because rental costs are fixed and well sampling must be completed at a specific rate, economies of scale are not likely to be significant with downhole sonde measurements.

7.3.2 COST ELEMENT 2 – GOUNDWATER SAMPLE COLLECTION FOR ^{14}C-LABELED TCE ASSAY, EAPS, AND qPCR ANALYSES

This cost element includes mobilization of a two-person field crew to the field for three days to collect eight (8) groundwater samples for the ^{14}C-Labeled TCE assay as well as EAPs and qPCR analyses. Mobilization includes making all arrangements for equipment rental and site access. It is assumed that the wells to be analyzed have already been selected. Included in the costs are purging of up to three (3) casing volumes for wells up to 100 feet deep and the collection of DO, ORP, pH, temperature, and specific conductance data using a flow-through cell during well purging. It is assumed that sampling of these eight (8), 100 foot-deep wells will take three (3) days. These costs include the rental of all necessary equipment as well as labor hours. Table 7.1 summarizes the costs for this cost element. These costs can be scaled up and down by taking the mobilization cost of $1,400, which includes the costs for renting and obtaining the equipment, and adding it to the per-well cost of $1,220 times the number of wells to be sampled. Thus, sampling one well would cost roughly $2,620, two wells would cost $3,840, and so on. This cost element is required for implementation of cost elements 3, 4, and 5.

7.3.3 COST ELEMENT 3 – ^{14}C-TCE ASSAY

The cost estimate is based on custom-synthesized ^{14}C-TCE and associated supplies, including liquid scintillation cocktail, liquid scintillation vials, supplies for the gas chromatograph (gases, septa, syringes), serum bottles, and reagents. The cost of the custom synthesized ^{14}C-TCE is based on 1 mCi ($11,000) and a total of 500 bottles. Assuming triplicate bottles per groundwater sample, the sample cost of $66. Other material and supply costs are estimated at ~$150 per sample, for a total supply cost of ~$216 per sample.

Staff labor to perform the assay was estimated at four hours per sample (from preparation through clean-up, plus data reduction). At $50/hr, the staff labor is estimated at $200 per sample. Time for supervisory labor is estimated at 10% of the staff and $150/hr, or $60 per sample. This brings the total cost to $476 per sample.

As the assay matures, there will no doubt be opportuties to bring the costs down. This has certainly been the experience with application of molecular tools to groundwater contamination. Regardless, the pay-off from using the ^{14}C-assay may be considerable. An assay based on ^{14}C product accumulation from ^{14}C-TCE affords an opportuntity to determine realistic decay rates that can be used in groundwater models to predict if MNA will be successful. Absent this type of information, there is considerable uncertainty in what constitutes an appropriate rate to use in modeling.

7.3.4 COST ELEMENT 4 – ENZYME ACTIVITY PROBES

EAP and qPCR will be applied to groundwater samples taken from monitoring wells. This cost element includes sample bottles and material for sample processing for shipment to lab, EAP probes, filters, microscope slides, other reagents required for sample preparation. This cost analysis assumes that equipment such as vacuum pumps or house vacuum supply, fluorometer (coumarin) and a microscope with epifluorescence capability is available for use. Total supplies costs for eight samples will be approximately $200.

Staff labor is estimated at five hours per probe per sample. For eight groundwater samples and triplicate analysis per sample, a total of 20 hours will be required for the analysis, which includes sample filtration and manual enumeration using epifluorescence microscopy. Blanks, positive controls and matrix spikes are included in per unit cost for the analyses, so these analyses will require an additional 20 hours per sample. The time for the project Principal Investigator is approximately 10% of the staff time, or 4 hours. Staff time for data reduction is estimated to require 10% of the analysis time, or 4 hours. The time for the project Principal is estimated to be 5% of the analysis time, or 2 hours. Table 7.1 summarizes the costs for this cost element. These costs are for the demonstration and include PNNL cost schedule and burden rates. For analysis of eight samples with four EAP (3-hydroxyphenylacetylene, phenylacetylene, cinnamonitrile and coumarin), and counterstaining with 4′,6-Diamidino-2-phenylindole dihydrochloride (DAPI) by a commercial laboratory or university core facility is estimated to be approximately $400 per EAP per sample. Eight samples could be analyzed for $13,000 which includes the supplies estimate from above. Adding the costs for analyzing the data (data reduction and reporting), the per-sample cost for this analysis is about $1,900. Table 7.1 summarizes the costs for this cost element. These costs are for this demonstration. It is anticipated that unit costs will decrease significantly if this process is commercialized.

Because the CINN EAP marker does not provide an unequivocal prediction of the rate constant, the CINN EAP marker can only be used to identify groundwater where the predicted rate constants are possible.

7.3.5 COST ELEMENT 5 – qPCR ANALYSES

This cost element includes sample bottles and material for sample processing for shipment to lab, DNA extraction kits, filters, oligonucleotide primers, DNA polymerase core kits, 96-well PCR plates and other reagents required for sample preparation and preservation.

Due to the nature of the analyses, blanks, standards, and positive controls can be processed in parallel in the same PCR plate. Blanks, and positive controls are included in per unit cost for the analyses and do not require additional time. Staff time for data reduction and reporting is estimated to require 8 hours. The time for the project Principal Investigator is estimated to be 3 hours.

Table 7.1 summarizes the costs for this cost element, not including sample collection costs. These costs include CENSUS-DNA data and are based on a cost estimate from Microbial Insights in Knoxville, TN. CENSUS-DNA data included in the costs presented in Table 7.1 include costs for:

- Toluene Monooxygenase--RMO
- Toluene Monooxygenase 2--RDEG
- Phenol Hydroxylase--PHE
- Toluene Dioxygenase--TOD
- Xylene Monooxygenase--TOL
- Soluble Methane Monooxygenase--SMMO

The per-sample cost for these analyses is roughly $835 per sample, including data analysis and reporting costs. The benefit of the *q*PCR analyses is that they allow the user to determine if aerobic cometabolism is possible. Because the PHE and RMO qPCR markers do not provide an unequivocal prediction of the rate constant, the PHE and RMO qPCR markers can only be used to identify groundwater where the predicted rate constants are possible. The markers should to be used as a primary line of evidence to predict a rate constant.

Table 7.3.1. Cost Model

Eight samples each for magnetic susceptibility, ^{14}C-labeled TCE assay, EAPs, and qPCR

Cost Element	Administration/ Secretarial $60 (per hour)	Drafting $90 (per hour)	Staff Environmental Professional $100 (per hour)	Senior Environmental Professional $135 (per hour)	Principal $200 (per hour)	Other Direct Cost[a/]	Number of Samples or Days of Rental (total)		Other Direct Costs Subtotal	Subtotal - Labor Plus ODCs
1 - Downhole Magnetic Susceptibility Measurements[b/]										
Mobilization			10		1					$ 1,200
Two Person Field Crew for Two (2) Days			32							$ 3,200
Sonde, Tripod, Winch, Data Logger (including shipping time)			2		1	$400	3	daily	$1,200	$ 1,600
Data Reduction and Reporting			8		4					$ 1,600
								TASK SUBTOTAL		**$ 7,600**
2 - Groundwater Sample Collection for ^{14}C-Labeled Assay, EAPs, and qPCR Analyses[c/]										
Mobilization			10		2					$ 1,400
Two Person Field Crew for Three Days			60		2					$ 6,400
Grundfos Pump, Generator, Meter for DO, pH, Temp, spec. cond., ORP, and Fe(II), Health and Safety Equipment, etc.			2			$500	3	daily	$1,500	$ 1,700
Data Reduction and Reporting	4		8		3					$ 1,640
								TASK SUBTOTAL		**$ 11,140**
3 - ^{14}C-Labeled TCE Assay[d/]										
^{14}C-TCE + associated supplies; triplicates for each sample from a monitoring well. Includes all labor costs.						$476	8	each	$3,808	$ 3,808
Data Reduction and Reporting	1		8		3			each		$ 1,460
								TASK SUBTOTAL		**$ 5,268**
4 - Enzyme Activity Probes[d/]										
Four Probes Per Sample, Eight (8) samples					4	$1,625	8	each	$13,000	$ 13,800
Data Reduction and Reporting	1		8		3			each		$ 1,460
								TASK SUBTOTAL		**$ 15,260**
5 - *p* PCR Analyses[d/]										
CENSUS-DNA (Toluene Monooxygenase--RMO)						$275	8	each	$2,200	$ 2,200
CENSUS-DNA (Toluene Monooxygenase 2--RDEG)						$75	8	each	$600	$ 600
CENSUS-DNA (Phenol Hydroxylase--PHE)						$75	8	each	$600	$ 600
CENSUS-DNA (Toluene Dioxygenase--TOD)						$75	8	each	$600	$ 600
CENSUS-DNA (Xylene Monooxygenase--TOL)						$75	8	each	$600	$ 600
CENSUS-DNA (Soluble Methane Monooxygenase--SMMO)						$75	8	each	$600	$ 600
Data Reduction and Reporting	1		8		3			each		$ 1,460
								TASK SUBTOTAL		**$ 6,660**
Totals	**7**		**156**		**26**			**Total Labor Costs**		**$ 21,220**
								Total ODCs		**$ 24,708**
								Total Estimated Cost =		**$ 45,928**

Notes and Assumptions

a/ Other direct cost in the form of laboratory analyses, field analyses, or equipment rental

b/ Assumes sonding of 8 boreholes to depths of 100 feet below ground surface.

c/ Assumes purging 3 casing volumes from 8 groundwater monitoring wells that are completed to a depth of 100 feet below ground surface and collecting groundwater samples for submission to the analytical laboratory.

d/ Does not include the cost of obtaining the sample, the costs for which are included under Item 2, Groundwater Sample Collection.

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8.0 IMPLEMENTATION ISSUES

This section provides information that will aid in the future implementation of the technology. A brief description and references for other documents such as guidance or protocols are provided. The technology elements described in this document were developed or refined because of shortcomings identified in ESTCP (2015). Specifically, the lack of a way to quantify the degradation of the chlorinated ethylenes by magnetite after intrusive site characterization activities (i.e., drilling) had been completed, and the lack of a method to conclusively show and quantify aerobic cometabolism of TCE. The technologies presented in this report represent an improvement over that presented in ESTCP (2015).

Lessons learned during the demonstration are as follows:

- The only regulations that apply to the use of the technologies presented in this report are the permits required to use of the ^{14}C assay. The analytical laboratory must obtain certification in order to handle ^{14}C.
- The magnetic susceptibility sonde provides a readily-accessible and accurate alternative to intrusive soil borehole data collection for magnetic susceptibility.
- The magnetic susceptibility sonde cannot be used in stainless steel wells. Wells larger than 4 inches in diameter may be problematic for collecting accurate magnetic susceptibility data using the sonde identified in this report because of the size of the borehole required for such wells. However, larger sondes, with a larger radius of influence, are available.
- Metallic tools dropped into boreholes in which monitoring wells are subsequently installed will interfere with the magnetic susceptibility sonde, but are readily identifiable.
- As mentioned above, ^{14}C assays can only be performed in laboratories that are permitted to use radioactive material. Furthermore, the cost for ^{14}C-labeled TCE is considerable (~$11,000 per mCi), mainly because it is no longer available as a stock compound and must therefore be custom synthesized. If the assay is adopted for more frequent use, suppliers may opt to once again provide ^{14}C-labeled TCE as a stock item, which will decrease the cost.
- The ^{14}C assay is not yet commercialized. It is hypothesized that the successful demonstration of the protocol presented in this report will provide considerable motivation for private companies to offer the service. An analogous situation was the use of compound specific isotope analyses (CSIA). At one time, use of this technology for groundwater samples was limited to a select few academic laboratories. As the value of the approach became apparent, commercial laboratories stepped in to meet the growing demand. We anticipate that a similar outcome will develop for the ^{14}C assay proposed in this study.
- EAP at the current level of development are only a qualitative predictor of aerobic bioremediation, since probe response was never adequately calibrated to the actual rate of contaminant biodegradation in groundwater at field sites. EAP analytical services are currently only available through PNNL.

- *q*PCR can be affected by biases associated with DNA extraction, as well as issues associated with efficiency of DNA amplification.

Overall, implementation issues are negligible, and the technologies presented herein should allow the decision framework (and BioPIC) presented in ESTCP (2015) to be updated so that additional degradation pathways can be readily elucidated and quantified.

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APPENDIX A POINTS OF CONTACT

Point of Contact Name	Organization Name	Phone Email	Role in Project
Todd Wiedemeier (deceased)	T.H. Wiedemeier & Associates, Inc.	(303) 670-7999 todd@thwa.com	Principal Investigator
Dr. John T. Wilson	Scissortail Environmental, LLC	(580) 421-3551 john@scissortailenv.com	Senior technical advisor to the team on MNA and abiotic processes, participation in field work, and report development.
Dr. David L. Freedman	Clemson University	864-656-5566 dfreedm@clemson.edu	Senior technical advisor on aerobic microbial aspects. Lead on ^{14}C-labeled TCE assay for degradation rates.
Dr. Brady Lee	Pacific Northwest National Laboratory (Federal Partner)	509-375-4593 brady.lee@pnnl.gov	Senior technical advisor for enzyme activity probes and qPCR assays.

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APPENDIX B DAILY FIELD AND SAMPLING REPORTS

5-31-16

Page 1 of ___

DAILY FIELD ACTIVITY REPORT

Client Name: ______________________
Project Name: ESTCP -201584- TCAAP SITE A
Contractor: ______________________
Weather: ______________________

Project Number: ______________________
Date: May 31, 2016
Arrival Time: TCAAP 9:30 AM

Time Breakdown: Drive: ________ Work: ________ Standby: ________

Location and Description of Activities:
Onsite 10:20 AM

Equipment Used on Project:

Activity Summary and General Remarks:

Well 01U108

13.87 dept to water

Well protector to top of casing = 2 inches
Ground level to top of casing = 30 inches
Gr level to top of well protector = 32 inches

- Pink Tape Flag on Sonde at 30 inches
- Probe 4.79 ft. Long?
- When lowering feel for slack in line - in case hangup
- Marks on ... to know if moved

20 ft - submerged to equalabrate
then calibrate

1700 to change to S I

Equilibrated
Remove from well - walk 6 ft from metal. Took ___ ? Sonde

Technician Signature: ______________________ Date: ______________

Sonde down to base black tape
In well
TCAAP 01U108

WIEDEMEIER & ASSOCIATES

5-31-16

DAILY FIELD ACTIVITY REPORT

Client Name:
Project Name: ESTCP201584 TCAAP
Contractor:
Weather:

Project Number:
Date:
Arrival Time:

Time Breakdown: Drive: Work: Standby:

Location and Description of Activities:

Equipment Used on Project:

Calib
Close tom
GO
?

Activity Summary and General Remarks:

5×10^{-3}

12:11

HM453S Magnetic Suscep Probe

2:00-2:30 Lunch

2:32PM Second Probe

5-31-16 5.68ft length Probe 2

29.15 ft Depth Bottom Well - Went deeper than large probe HM453S

well log 30 ft bottom of well

Calibration tool - put one end in then the other

Coil

Calibrated high / low Back in well 2:58pm

RMP PROBE

Offsite 3:30pm

Technician Signature: Date:

WIEDEMEIER & ASSOCIATES

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP-201584 - TCAAP Site A COC Number:
Well ID: 01U108
Date of Collection: 5/31/16

Sample Collected by:

EQUIPMENT

Purging Equipment:
Sampling Equipment:
Filtering Equipment:
Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
YSI 556 Multi Parameter Meter	05C1520 AA	
HACH DR 890 Colorimeter		N/A

FIELD PARAMETERS

Ambient Air Temperature (°F):
Sampling Depth (ft): Pump Inlet@
Weather Conditions:
Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate ___/min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments

PURGE INFORMATION

Starting Flow meter Reading:________ Ending Flow meter Reading:________ Flow Rate:__________

Total Volume Purged:________ Purged Dry (Y/N):_____ Micro purged (Y/N):_____Minimal purged (Y/N):____

Casing Inner Diameter (inches) 2" Initial Depth to Water (feet) 13.87 Depth to bottom of well (feet)____
Tubing inner diameter_______(in) Tubing & Pump Volume_______(ml)
Controller settings: Pressure___(psi) Discharge (sec.) Recharge__________(sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

	Rev	By	Date	Ck	Date	Title:
WIEDEMEIER & ASSOCIATES						
						Job:
						Author: Sheet Of

OW108

Distance between Steel Protective Casing & top of PVC = 2"

Steel is 32" Tall from Ground

∴

TOC (PVC) = 30" above ground Surface

For the 453 the depth Correction is 4.76 ft

~~1.700~~

~~For the EMP Probe the~~

Depth Correction is 5.68 feet

2-Point Calibration Left 24.1 to Right 1.4

DAILY FIELD ACTIVITY REPORT

Client Name: ESTCP 201584 TCAAP
Project Name:
Contractor:
Weather:

Project Number:
Date: 6-1-2016
Arrival Time: 8:30

Time Breakdown: Drive: Work: Standby:

Location and Description of Activities:
TCAAP Well 01U108

Equipment Used on Project:

Activity Summary and General Remarks:
01U108 TCAAP
8:40 AM Depth to water 13.92 ft
Depth of well 31.47 } 31.75 ft depth well
Length Probe .28 }

Well Volume 2 gallons = 1 purge volume
Mark on top of tube 25 ft from top of casing
Set tubing at ~~15~~ 20 ft below TOC

Started Pumping 10:37 AM

12:19 PM Pump 1 gallon

12:30 PM Collected 4 samples for Brady
3 Samples for David Freedman
Put both on ice to cool
1:14 PM Samples for Microbial Insights
2 500 mL samples filtered 3 mL preservative added, capped
1:32 PM 2-500 mL Samples filtered

Technician Signature: Date:

WIEDEMEIER & ASSOCIATES

Figure 5.5.1

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP 201584 TCAAP
COC Number:
Well ID: TCAAP01U108
Sample Collected by: Barbara Wilson
Date of Collection: 6-1-16

EQUIPMENT

Purging Equipment:
Sampling Equipment:
Filtering Equipment:
Equipment Decontamination:

Equipment Calibration		
Equipment Model	Serial Number	Date Calibrated

FIELD PARAMETERS

Ambient Air Temperature (°F):
Weather Conditions:
Sampling Depth (ft): Pump Inlet@
Reference Point: Top of inner PVC casing

Flow rate	Depth to water	Time	Vol. Purged	Temp	Sp.Cond.	DO	pH	ORP	Water Description
		10:37Am	1gal	12.16	0.575	4.28	5.24	162.7	[redacted] - Brown
		10:44	2gal	11.3	0.57	3.5	4.9	197	[redacted]-Brown
		10:51	3 gal	11.1	0.547	1.55	5.17	139	Less Brown
		10:56	4gal	11.2	0.530	1.17	5.23	141.1	
		11:03	5	11.54	0.514	0.88	5.22	150.4	Almost colorless
		11:07	6	11.42	0.502	0.67	5.20	153.7	
≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

No Bubbles →

Bubbles in tube

Reduced flow rate

	Filtered Fe2+ mg/l Hach	Non Filtered Fe2+ mg/l Hach	Comments
	~~0.00 mg/l~~	0.00 mg/L	

Total Volume Purged: Purged Dry (Y/N): Micro purged (Y/N): Minimal purged (Y/N):

PURGE INFORMATION

Casing ID (in.) Initial Depth to Water (ft.) Depth to well bottom (ft.)
Tubing inner diameter (in) Tubing & Pump Volume (ml)
Controller settings: Pressure (psi) Discharge (sec.) Recharge (sec.)

Set bottom of 1/4" tubing above top of screen

Pumped 6 gallons = 3 casing volumes.

DAILY FIELD ACTIVITY REPORT

Client Name:
Project Name: ESTCP 201584
Contractor:
Weather:

Project Number:
Date: 6-1-16
Arrival Time:

Time Breakdown: Drive: Work: Standby:
2:00Pm onsite

Location and Description of Activities:
TCAAP 01U115

Equipment Used on Project:

Activity Summary and General Remarks:

12.255 ~~[illegible]~~ft Depth to water TOC
34.7ft Depth of well Soft bottom
-8 TOC
20+35 = 15ft Screen
Set purge well 23 ft from TOC
2:17pm Purge Started
0.01mg/L Ferrous Iron 3:10pm
3:15Pm 4samples Brady Lee 1 liter
3:21 Pm 3 100 ml+
3:26 Pm 2 Dora 1000mL,

Technician Signature:

Date:

WIEDEMEIER & ASSOCIATES

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP 201584 COC Number:

Sample Collected by: JTW/BW Well ID: TCAAP 01U115

Date of Collection: 6/1/16

EQUIPMENT

Purging Equipment: Geotech Peristaltic pump

Sampling Equipment: " " " & HDPE Tubing

Filtering Equipment:

Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
YSI 556 Multi Parameter Meter	05C1520 AA	
HACH DR 890 Colorimeter		N/A

FIELD PARAMETERS

Ambient Air Temperature (°F): Weather Conditions:

Sampling Depth (ft): Pump Inlet@ Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate __/min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
		12.255	14:17	0						
			14:23:30	1						
	Stopped									
			14:26:30	0						
			14:29:30	1	10.18	.371	0.7	—	—	Clear, no odor
			14:32:30	2	9.91	0.372	0.55	—	—	
			14:35:30	3	10.02	0.372	0.58	—	—	
			14:38:30	4	10.25	0.372	0.56	—	—	
			14:41:30	5	10.43	0.372	0.50	—	—	
			14:44:15	6	10.47	0.373	0.54	—	—	
			14:47:00	7	10.39	0.378	0.51	—	—	
			14:49:50	8	10.40	0.371	0.53	—	—	
			14:52:50	9	10.56	0.372	0.53	—	—	
				See	Next	Page				
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments

PURGE INFORMATION

Starting Flow meter Reading:________ Ending Flow meter Reading:________ Flow Rate:__________

Total Volume Purged:________ Purged Dry (Y/N)_____ Micro purged (Y/N):_____ Minimal purged (Y/N)____

Casing Inner Diameter (inches) 4 Initial Depth to Water (feet) 12.255 Depth to bottom of well (feet) 34.7

Tubing inner diameter_______(in) Tubing & Pump Volume_______(ml)

Controller settings: Pressure___(psi) Discharge (sec.) Recharge___________(sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

1/3/15 ,33

GROUNDWATER PURGE AND SAMPLING FORM - Continued

Project Name: ESTCP 2015,84 Well ID: TCAAP 01U115

Sample Collected by: TTW/BHW Date of Collection: 6/1/16

Flow Meter (gallons)	Flow rate __/min	Depth to water	Time	Volume Purged (Gallons)	Temp (°F)	Sp.Cond µS/cm	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
			14:55:30	10	10.62	0.380	0.51	—	—	clear, No odor
			14:58:30	11	10.72	0.382	0.56	—	—	" "
			15:01:00	12	10.79	0.385	0.55	—	—	" "
			15:04:00	13	10.87	0.388	0.53	—	—	" "
			15:07:00	14	10.97	0.391	0.54	—	—	" "
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

Start Sampling @ 15:07:00

D:\THWA\Admin\Forms - Field\Groundwater Purge and Sampling Form.doc

WIEDEMEIER & ASSOCIATES

Chain of Custody Record

SEVERN TRENT **STL**
Severn Trent Laboratories, Inc.

STL Denver
4955 Yarrow Street
Arvada, CO 80002

STL-4124 (0901)

Client	Project Manager	Date	Chain of Custody Number
TCP - Todd Wiedemeier	Todd Wiedemeier	6-1-16	345881

Address	Telephone Number (Area Code)/Fax Number	Lab Number	Page
309 Coronado [illegible]	3036707999	PNNL	Page 1 of 1

City	State	Zip Code	Site Contact	Lab Contact
[illegible]		80135	Todd W.	Brady Lee

Project Name and Location (State)	Carrier/Waybill Number
TCAAP Arden Hills, MN	

Contract/Purchase Order/Quote No.: N/A

Analysis (Attach list if more space is needed)

Special Instructions/ Conditions of Receipt

Sample I.D. No. and Description (Containers for each sample may be combined on one line)	Date	Time	Matrix: Air	Aqueous	Sed.	Soil	Containers & Preservatives: Unpres.	H2SO4	HNO3	HCl	NaOH	ZnAc/ NaOH	EAP	qPCR
TCAAP 01U108 #1	6-1-16	13:00		✓									✓	✓
TCAAP 01U108 #2	6-1-16	↓		✓									✓	✓
TCAAP 01U108 #3	6-1-16	↓		✓									✓	✓
TCAAP 01U108 #4	6-1-16	↓		✓									✓	✓
TCAAP 01U115 #1	6-1-16	15:10		✓									✓	✓
TCAAP 01U115 #2	6-1-16	↓		✓									✓	✓
TCAAP 01U115 #3	6-1-16	↓		✓									✓	✓
TCAAP 01U115 #4	6-1-16	↓		✓									✓	✓
Trip Blank	6-1-16			✓									✓	✓

Possible Hazard Identification
☑ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal
☐ Return To Client ☑ Disposal By Lab ☐ Archive For ______ Months (A fee may be assessed if samples are retained longer than 1 month)

Turn Around Time Required
☑ 24 Hours ☐ 48 Hours ☐ 7 Days ☐ 14 Days ☐ 21 Days ☐ Other______

QC Requirements (Specify)

1. Relinquished By	Date	Time	1. Received By	Date	Time
[illegible]	6-1-16	16:48			
2. Relinquished By	**Date**	**Time**	**2. Received By**	**Date**	**Time**
3. Relinquished By	**Date**	**Time**	**3. Received By**	**Date**	**Time**

Comments

DISTRIBUTION: WHITE - Returned to Client with Report; CANARY - Stays with the Sample; PINK - Field Copy

Chain of Custody Record

SEVERN TRENT **STL**
Severn Trent Laboratories, Inc.

STL Denver
4955 Yarrow Street
Arvada, CO 80002

STL-4124 (0901)

Field	Entry
Client	ESTCP - Todd Wiedemeier
Project Manager	Todd Wiedemeier
Date	6-1-16
Chain of Custody Number	345882
Address	309 Coronado Dr
Telephone Number (Area Code)/Fax Number	303-670-7999
Lab Number	Clemson
Page	1 of 1
City	Golden
State	CO
Zip Code	80035
Site Contact	Todd W
Lab Contact	Brady Lee
Project Name and Location (State)	TCAAP Arden Hills MN
Carrier/Waybill Number	
Contract/Purchase Order/Quote No.	N/A

Analysis (Attach list if more space is needed): Alks, TCE Degradation

Special Instructions/ Conditions of Receipt

Sample I.D. No. and Description (Containers for each sample may be combined on one line)	Date	Time	Air	Aqueous	Sed.	Soil	Unpres.	H2SO4	HNO3	HCl	NaOH	ZnAc/ NaOH
TCAAP 01U108 1	6-1-16	12:15		✓								
TCAAP 01U108 2	6-1-16	↓		✓								
TCAAP 01U108 3	6-1-16	↓		✓								
TCAAP 01U115 1	6-1-16	15:20		✓								
TCAAP 01U115 2	↓			✓								
TCAAP 01U115 3	↓			✓								

Possible Hazard Identification
☑ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal
☐ Return To Client ☐ Disposal By Lab ☐ Archive For ____ Months (A fee may be assessed if samples are retained longer than 1 month)

Turn Around Time Required
☑ 24 Hours ☐ 48 Hours ☐ 7 Days ☐ 14 Days ☐ 21 Days ☐ Other____

QC Requirements (Specify)

Relinquished By	Date	Time	Received By	Date	Time
1. Barbara Wilson	6-1-16	16:50	1.		
2.			2.		
3.			3.		

Comments

DISTRIBUTION: WHITE - Returned to Client with Report; CANARY - Stays with the Sample; PINK - Field Copy

DAILY FIELD ACTIVITY REPORT

Client Name:
Project Name: TCAAP ESTCP201584
Contractor:
Weather: Cloudy

Project Number:
Date: 6-2-16
Arrival Time: 8:35

Time Breakdown: Drive: Work: Standby:
Onsite 8:35Am

Location and Description of Activities:
01U117

Equipment Used on Project:

Activity Summary and General Remarks:

13.89ft depth to water TOC
(1) 34.81ft Bottom of well TOC soft bottom
(2) 34.95ft Bottom of well TOC Soft bottom
~~2~~28.5ft TOC to middle well screen
14gal = 1 pore volume 21ft water

Purple - DNA } preservatives
Blue - RNA }

~~10~~ Clemson Samples IA2 = 01U117 6-2-16
10:27 4 Samples PNNL (each 1 Liter)
TCAAP 01U117 Samples 1-4
10:30 3 Samples Clemson ~~IA2 #1, IA2#2, IA2#3~~
(~100mL each) IB1 #1 IB1#2, IB1# 3

Technician Signature: Date:

1000 mL 10:34 DNA 2 Samples Microbial Insights TCAAP10U117 DNA 1000mL
1000mL 10:49 RNA TCAAP10U117 RNA preserved
Black flecks in water samples from well

WIEDEMEIER & ASSOCIATES

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP 201584 TCAAP COC Number:

Well ID: 01U117

Sample Collected by: John Wilson/Barbara Wilson Date of Collection: 6-2-16

EQUIPMENT

Purging Equipment:

Sampling Equipment:

Filtering Equipment:

Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
YSI 556 Multi Parameter Meter	05C1520 AA	
HACH DR 890 Colorimeter		N/A

FIELD PARAMETERS

Ambient Air Temperature (°F): 60°

Weather Conditions:

Sampling Depth (ft): Pump Inlet@

Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate __/min	Depth to water ft	Time 9:27 Time 0	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
		13.89	0	0						
			1:44	1						
			4:47	2						
			8:01	3						
			10:46	4						
			13:30	5						
			16:24	6						
			19:11	7	10.33	.456	6.44	7.16	233.7	colorless, no turb
			22:11	8	10.29	.453	6.31	6.01	289.5	
			25:04	9	10.18	.454	6.07	6.18	280.4	
			28:02	10	10.39	.455	5.94	6.48	262.8	
			30:55	11	10.53	.458	5.51	6.76	248.4	
			33:50	12	10.63	.460	5.22	6.87	243.5	
			36:52	13	10.65	.460	5.12	6.93	245.6	
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments
					0.00				

PURGE INFORMATION

Starting Flow meter Reading: ________ Ending Flow meter Reading: ________ Flow Rate: ________

Total Volume Purged: 14 gal Purged Dry (Y/N): N Micro purged (Y/N): N Minimal purged (Y/N): ____

Casing Inner Diameter (inches) 4 Initial Depth to Water (feet) 13.89 Depth to bottom of well (feet) 34.95

Tubing inner diameter 1/4 OD (in) Tubing & Pump Volume ______ (ml)

Controller settings: Pressure ___ (psi) Discharge (sec.) Recharge ________ (sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

WIEDEMEIER & ASSOCIATES

GROUNDWATER PURGE AND SAMPLING FORM - Continued

Project Name: ESTCP 201584 TCAAP Well ID: 01U117
Sample Collected by: JOhN Wilson / Barbera Wilson Date of Collection: 6-2-16

Flow Meter (gallons)	Flow rate ___/min	Depth to water	Time	Volume Purged (Gallons)	Temp (°F)	Sp.Cond µS/cm	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
			39:51	14	10.67	.462	4.71	6.98	243.8	
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

WIEDEMEIER & ASSOCIATES

DAILY FIELD ACTIVITY REPORT

Client Name:
Project Name: TCAAP ESTCP 201584
Contractor:
Weather: Partly Sunny

Project Number:
Date: 6-2-16
Arrival Time: 11:10

Time Breakdown: Drive: Work: Standby:
11:10 onsite

Location and Description of Activities:
01U 119

Equipment Used on Project:

Activity Summary and General Remarks:
6.12 ft Depth to water TOC
21.35 bottom of well TOC

Purge Volume = 10 gal
Set Tubing at 16 ft below TOC

1B2#1,2,3 Clemson TCAAP 01U119

12:45 4 Samples PNNL TCAAP 01U119 Samples 1-4 (1L each)
13:02 3 Samples Clemson TCAAP 01U119 1B2#1,2,3 (~100 mL each)
13:12 DNA 2 Samples Microbial Insights TCAAP 01U119 1-DNA 1000 mL; 1-RNA preserved 1000 mL
13:21 RNA

finished purging 12:35

12:40 Fe^{2+} 0.10 mg/L

Technician Signature:
Date:

WIEDEMEIER & ASSOCIATES

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP 201584 TCAAP COC Number: ____

Well ID: 01U119

Sample Collected by: John Wilson/Barbara Wilson Date of Collection: 6-2-16

EQUIPMENT

Purging Equipment: ____

Sampling Equipment: ____

Filtering Equipment: ____

Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
YSI 556 Multi Parameter Meter	05C1520 AA	
HACH DR 890 Colorimeter		N/A

FIELD PARAMETERS

Ambient Air Temperature (°F): 63° Weather Conditions: ____

Sampling Depth (ft): Pump Inlet@ Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate /min	Depth to water	Time 12:10	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
		6.12	0:0	0						
			3:17	1	9.31	.599	1.89	6.71	222.3	light color
			4:53	2	8.88	.657	1.39	6.67	224.1	light color
			6:54	3	8.64	.750	1.16	6.65	224.7	light color
			8:56	4	8.57	.818	.90	6.68	227.3	light color
			11:09	5	8.50	.841	.81	6.69	236.5	no color
			13:10	6	8.55	.856	.73	6.71	227.3	no color
			15:13	7	8.49	.882	.71	6.72	233.9	
			17:16	8	8.47	.864	.82	6.73	232.1	
			19:23	9	8.58	.864	.88	6.74	230.1	
			21:28	10	8.59	.862	.97	6.76	226.3	
			22:41	10.5	[illegible]	.865	.96	6.77	223.2	
				Tubing at 16 ft below TOC						
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments
					0.10				

PURGE INFORMATION

Starting Flow meter Reading: ____ Ending Flow meter Reading: ____ Flow Rate: ____

Total Volume Purged: 10.6 gal Purged Dry (Y/N): N Micro purged (Y/N): N Minimal purged (Y/N): ____

Casing Inner Diameter (inches) 4 Initial Depth to Water (feet) 6.12 Depth to bottom of well (feet) 21.35

Tubing inner diameter 1/4 OD (in) Tubing & Pump Volume ____ (ml)

Controller settings: Pressure ___ (psi) Discharge ___ (sec.) Recharge ____ (sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

1 casing volume = 10 gal

WIEDEMEIER & ASSOCIATES

Chain of Custody Record

SEVERN TRENT **STL**
Severn Trent Laboratories, Inc.

STL Denver
4955 Yarrow Street
Arvada, CO 80002

STL-4124 (0901)

Client: ESTCP-Todd Wiedemeier	Project Manager: Todd Wiedemeier	Date: 6-2-16	Chain of Custody Number: 345885
Address: 309 Coronado Dr	Telephone Number (Area Code)/Fax Number: 303-670-7999	Lab Number: PNNL	Page 1 of 1
City: Sedalia · State: CO · Zip Code: 80135	Site Contact: Todd W. · Lab Contact: Brady Lee		
Project Name and Location (State): TCAAP Arden Hills, MN	Carrier/Waybill Number:		
Contract/Purchase Order/Quote No.: N/A			

Analysis (Attach list if more space is needed)

Special Instructions/ Conditions of Receipt

Sample I.D. No. and Description (Containers for each sample may be combined on one line)	Date	Time	Matrix: Air	Matrix: Aqueous	Matrix: Sed.	Matrix: Soil	Containers & Preservatives: Unpres.	H2SO4	HNO3	HCl	NaOH	ZnAc/NaOH	CHP	qPCR
TCAAP 01U117 Sample 1	6-2	10:27		✓									✓	✓
TCAAP 01U117 Sample 2	6-2	↓		✓									✓	✓
TCAAP 01U117 Sample 3	6-2	↓		✓									✓	✓
TCAAP 01U117 Sample 4	6-2	↓		✓									✓	✓
TCAAP 01U119 Sample 1	6-2	12:15		✓									✓	✓
TCAAP 01U119 Sample 2	6-2	↓		✓									✓	✓
TCAAP 01U119 Sample 3	6-2	↓		✓									✓	✓
TCAAP 01U119 Sample 4	6-2	↓		✓									✓	✓

Possible Hazard Identification
☑ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal
☐ Return To Client ☐ Disposal By Lab ☐ Archive For ____ Months (A fee may be assessed if samples are retained longer than 1 month)

Turn Around Time Required
☑ 24 Hours ☐ 48 Hours ☐ 7 Days ☐ 14 Days ☐ 21 Days ☐ Other ____

QC Requirements (Specify)

1. Relinquished By: Barbara Wilson	Date: 6-1-16	Time: 14:53	1. Received By	Date	Time
2. Relinquished By	Date	Time	2. Received By	Date	Time
3. Relinquished By	Date	Time	3. Received By	Date	Time

Comments

DISTRIBUTION: WHITE - Returned to Client with Report; CANARY - Stays with the Sample; PINK - Field Copy

Chain of Custody Record

SEVERN TRENT **STL**
Severn Trent Laboratories, Inc.

STL Denver
4955 Yarrow Street
Arvada, CO 80002

STL-4124 (0901)

Client	Project Manager	Date	Chain of Custody Number
ESTCP - Todd Wiedemeier	Todd Wiedemeier	6-2-16	345883
Address	**Telephone Number (Area Code)/Fax Number**	**Lab Number**	
309 Coronado Dr.	303-670-7999	Clemson N	**Page** 1 **of** 1

City	State	Zip Code	Site Contact	Lab Contact	Analysis (Attach list if more space is needed)
Cedalia	CO	80135	Todd W	David Freedman	Assay TCE ; Degradation

Project Name and Location (State): TCHAP Arden Hills, MN

Carrier/Waybill Number:

Contract/Purchase Order/Quote No.: N/A

Special Instructions/Conditions of Receipt

Sample I.D. No. and Description (Containers for each sample may be combined on one line)	Date	Time	Air	Aqueous	Sed.	Soil	Unpres.	H2SO4	HNO3	HCl	NaOH	ZnAc/NaOH	Assay TCE
TCHAP 011417 IB1 #1	6-2	10:30		✓									✓
TCHAP 011417 IB1 #2	6-2	↓		✓									✓
TCHAP 011417 ~~IBI~~ #3 IB1	6-2	↓		✓									✓
TCHAP 011417 IB2 #1	6-2	13:02		✓									✓
TCHAP 011417 IB2 #2	6-2	↓		✓									✓
TCHAP 011417 IB2 #3	6-2	↓		✓									✓

Possible Hazard Identification
☑ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal
☐ Return To Client ☐ Disposal By Lab ☐ Archive For ______ Months (A fee may be assessed if samples are retained longer than 1 month)

Turn Around Time Required
☑ 24 Hours ☐ 48 Hours ☐ 7 Days ☐ 14 Days ☐ 21 Days ☐ Other______

QC Requirements (Specify)

Relinquished By	Date	Time	Received By	Date	Time
1. Relinquished By: [illegible signature]	6-2-16	14:55	1. Received By		
2. Relinquished By			2. Received By		
3. Relinquished By			3. Received By		

Comments

DISTRIBUTION: WHITE - Returned to Client with Report; CANARY - Stays with the Sample; PINK - Field Copy

REPORT TO:

Name: ~~John Wilson~~
Company: ~~Scissortail Environmental~~
Address: ~~PO Box 1206~~
~~Ada, OK 745[illegible]~~

email: ~~john@scissortailenv.com~~
Phone: ~~580-421-3551~~
Fax:

Project Manager:
Project Name: ~~ESTCP 201584 TCAAP~~
Project No.:

INVOICE TO: (For Invoices paid by a third party it is imperative that all information be provided)

Name:
Company:
Address:

email:
Phone:
Fax:

Purchase Order No.
Subcontract No.
MI Quote No.

microbialinsights

10515 Research Dr
Knoxville, TN 37932
865-573-8188

www.microbe.com

Please Check One:
☐ More samples to follow
☐ No Additional Samples

Report Type: ☐ Standard (default) ☐ Microbial Insights Level III raw data(15% surcharge) ☐ Microbial Insights Level IV (25% surcharge) ☐ Comprehensive Interpretive(15%) ☐ Historical Interpretive (35%)

EDD type: ☐ Microbial Insights Standard (default) ☐ All other available EDDs (5% surcharge) Specify EDD Type: ____________

Please contact us with any questions about the analyses or filling out the COC at (865) 573-8188 (9:00 am to 5:00 pm EST, M-F). After hours email: customerservice@microbe.com

MI ID (Laboratory Use Only)	Sample Name	Date Sampled	Time Sampled	Matrix	PLFA	NGS	QuantArray Chlor	QuantArray Petro	DHC (Dehalococcoides)	DHC Functional genes (bvc, tce, vcr)	DHBt (Dehalobacter)	DHG (Dehalogenimonas)	DSM (Desulfuromonas)	DSB (Desulfitobacterium)	EBAC (Total)	SRB (Sulfate Reducing Bacteria-APS)	MGN (Methanogens)	MOB (Methanotrophs)	SMMO	DNF (Dentrifiers-nirS and nirK)	AOB (ammonia oxidizing bacteria)	PM1 (MTBE aerobic)	RMO (Toluene Monooxygenase)	RDEG (Toluene Monooxygenase)	PHE (Phenol Hydroxylase)	NAH (Napthalene-aerobic)	BSSA (Toluene/Xylene-Anaerobic)	add. qPCR:	RNA (Expression Option)*	Other:	Other:	Other:
	TCAAP10U117	6-2	10:34	Aq																												
	TCAAP10U117	6-2	10:49	Aq																												
	[illegible]																															
	TCAAP10U119	6-2	13:12	Aq																												
	TCAAP10U119	6-2	13:21	Aq																												

Relinquished by: Barbara Wilson
6/2/16
14:56

Received by:

Date

It is vital that chain of custody is filled out correctly & that all relative information is provided.
Failure to provide sufficient and/or correct information regarding reporting, invoicing & analyses requested information may result in delays for which MI will not be liable.

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP 201584 - TCAAP COC Number: ____

Well ID: OU 103 - May Susp.

Sample Collected by: FHW / Mark Ferrey Date of Collection: ____

EQUIPMENT arrived @ location @ 11:30

~~Purging~~ Equipment: ~~N/A~~ HMA 4535 May Sus Sonde

Sampling Equipment: ____

Filtering Equipment: ____

Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
~~YSI 556 Multi Parameter Meter~~	~~05C1520 AA~~	
HACH DR 890 Colorimeter		N/A

FIELD PARAMETERS

Ambient Air Temperature (°F): ____ Weather Conditions: ____

Sampling Depth (ft): Pump Inlet@ ____ Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate /min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
11:30 - Arrive										
Place tool @ 25 feet for Equilibration of H_2O Temp										
11:30-12:30										
After zeroing, Sonde/Matrix logging system										
reads 28.49' below Top of PVC casing versus										
measured value of 29.65' BTOC with water-										
level Probe										
12:30 Begin Equipment Calibration 0 and 5 X10^-3 SI										
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments

PURGE INFORMATION Tool = 5.68' Long

Starting Flow meter Reading: ____ Ending Flow meter Reading: ____ Flow Rate: ____

Total Volume Purged: N/A Purged Dry (Y/N): ____ Micro purged (Y/N): ____ Minimal purged (Y/N): ____

Casing Inner Diameter (inches) 2" Initial Depth to Water (feet) 13.8 Depth to bottom of well (feet) ~~29.6~~ 29.65

Tubing inner diameter ____ (in) Tubing & Pump Volume ____ (ml)

Controller settings: Pressure ___ (psi) Discharge (sec.) Recharge ____ (sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

Top of Steel Casing = 2.3 feet ~~above~~ ags

Total Depth = 29.65 ft BTOC

Top of PVC Casing = 2.15 ft ags

Distance from TOC to Top of Steel Casing = .15 ft

zeroed Tool @ this Depth

GROUNDWATER PURGE AND SAMPLING FORM 6/2/16

Project Name: ESTCP – TCAAP COC Number:
Well ID: 01U103
Sample Collected by: THW – Mark Ferrey Date of Collection:

EQUIPMENT
~~Purging~~ Equipment: HMA-453S
Sampling Equipment:
Filtering Equipment:
Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
YSI 556 Multi Parameter Meter	05C1520 AA	
HACH DR 890 Colorimeter		N/A

FIELD PARAMETERS
Ambient Air Temperature (°F): Weather Conditions:
Sampling Depth (ft): Pump Inlet@ Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate _/min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
										SI units
15 ft/min Run	1/calib 1	Down		15 ft/min						Calib 1 Settings
15 ft/min Run	1/calib 1	up		15 ft/min						0 = 60.586 cps 5E-3 = 1160.53 cps
7 ft/min Run	2/calib 1	up only		7 ft/min						
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments

PURGE INFORMATION

Starting Flow meter Reading:________ Ending Flow meter Reading:________ Flow Rate:__________

Total Volume Purged:________ Purged Dry (Y/N):_____ Micro purged (Y/N):_____Minimal purged (Y/N):____

Casing Inner Diameter (inches)______ Initial Depth to Water (feet)_________ Depth to bottom of well (feet)____
Tubing inner diameter_______(in) Tubing & Pump Volume_______(ml)
Controller settings: Pressure___(psi) Discharge (sec.) Recharge___________(sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

WIEDEMEIER & ASSOCIATES

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP-201584 - TCAAP COC Number:
Well ID: 01U-102
Sample Collected by: Date of Collection: 6/2/16

EQUIPMENT Magnetic Susceptibility measurement
~~Purging~~ Equipment: HMA-4535
Sampling Equipment:
Filtering Equipment:
Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
YSI 556 Multi Parameter Meter	05C1520 AA	
HACH DR 890 Colorimeter		N/A

FIELD PARAMETERS
Ambient Air Temperature (°F): 75 Weather Conditions: Sunny/Partly Cloudy
Sampling Depth (ft): Pump Inlet@ Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate __/min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
13:20 onsite Arrive @ 01U-102										
	13:43 Calibrating to 0 (zero) & 5X10^-3 SI units									
						0 SI units = 69.5 cps				
						5E-3 SI units = 1168.27 cps				
	1st Run		TCAAP 01U-102 Down - Calib 1							7 ft/min
	2nd Run		TCAAP 01U-102 Up - Calib 1							7 ft/min
	Tool could only go to 20 feet bgs									
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments

PURGE INFORMATION Tool = 4.68' Long

Starting Flow meter Reading:____ Ending Flow meter Reading:____ Flow Rate:____

Total Volume Purged:____ Purged Dry (Y/N):____ Micro purged (Y/N):____ Minimal purged (Y/N):____

Casing Inner Diameter (inches) 2" Initial Depth to Water (feet) 15.22 Depth to bottom of well (feet) 29.6
Tubing inner diameter____(in) Tubing & Pump Volume____(ml)
Controller settings: Pressure___(psi) Discharge (sec.) Recharge____(sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

~~Stick up~~ Top of Metal Casing = 2.6 feet ags
Top of PVC Casing = 1.2 inches below Top of metal casing
Top of Stickup = 2.48' ≈ 2'6"

WIEDEMEIER & ASSOCIATES

D:\THWA\Admin\Forms - Field\Groundwater Purge and Sampling Form.doc

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP 201584 COC Number:
Well ID: 01U-106
Sample Collected by: THW/Mark Ferrey Date of Collection: 6/2/16

EQUIPMENT
~~Purging~~ Equipment: HMA-453 S
Sampling Equipment:
Filtering Equipment:
Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
YSI 556 Multi Parameter Meter	05C1520 AA	
HACH DR 890 Colorimeter		N/A

FIELD PARAMETERS Got Tool to 25.22 ft bgs
Ambient Air Temperature (°F): Weather Conditions:
Sampling Depth (ft): Pump Inlet@ Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate ___/min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
Arrive @ 01U-106 @ ~ 14:22										
Zero Tool @ 14:30										
Lowering Tool – 14:32										
Tool made it to 25.22' bgs										
Letting Temp equilibrate 14:35 –										
Start Calibration @ 14:50										
0 E-3 = 56.91 CPS										
5 E-3 = 1187.23 CPS										
Run 1 = TCAAP 01U-106 Down Run 1 Calib 1 → 7 ft/min										
Run 2 = TCAAP 01U-106 UP Run 1 Calib 1 → 7 ft/min										
Run 3 = TCAAP 01U-106 Down Run 2 Calib 1 → 15 ft/min										
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

Run 4 = TCAAP 01U-106 UP Run 2 Calib 1 → 15 ft/min

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments
Done @ 15:05									

PURGE INFORMATION Tool Length 4.79'

Starting Flow meter Reading:________ Ending Flow meter Reading:________ Flow Rate:__________

Total Volume Purged:________ Purged Dry (Y/N):_____ Micro purged (Y/N):_____ Minimal purged (Y/N):____

Casing Inner Diameter (inches)______ Initial Depth to Water (feet) 7.53 Depth to bottom of well (feet) 29.05
Tubing inner diameter_______(in) Tubing & Pump Volume_______(ml)
Controller settings: Pressure___(psi) Discharge (sec.) Recharge___________(sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

Top of Metal Casing = 4.05 ft ags
Top of PVC casing = 0.18' ft below top of Stick Casing
∴ Stickup = 3.87 ft

WIEDEMEIER & ASSOCIATES

DAILY FIELD ACTIVITY REPORT

Client Name: ______________________ Project Number: ______________________

Project Name: ESTCP 2016 ___ Date: 6-3-16

Contractor: ______________________ Arrival Time: ______________________

Weather: Partly Cloudy 64°F

Time Breakdown: Drive: ________ Work: ________ Standby: ________

Location and Description of Activities:

TCAAP 01U108 depth to water 13.95 feet below TOC

Set sample tube at 27 feet below TOC

Equipment Used on Project:

Activity Summary and General Remarks:

Technician Signature: ______________________ Date: ______________________

WIEDEMEIER & ASSOCIATES

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP 201584 COC Number: ______

Well ID: 01U108

Sample Collected by: John Wilson / Barbara Wilson Date of Collection: 6-3-16

EQUIPMENT

Purging Equipment: ______

Sampling Equipment: ______

Filtering Equipment: ______

Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
YSI 556 Multi Parameter Meter	05C1520 AA	
HACH DR 890 Colorimeter		N/A

FIELD PARAMETERS

Ambient Air Temperature (°F): 64 Weather Conditions: ______

Sampling Depth (ft): Pump Inlet@ Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate /min	Depth to water	Time 9:54	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
			0.00	0						color light brown/gray
			6:35	1	10.59	.535	2.38	5.53	342.1	
			11:34	2	10.61	.520	1.79	6.58	278.0	color light gray
			16:42	3	10.62	.500	1.36	6.79	264.7	no color
			21:46	4	10.62	.485	1.15	6.50	280.3	no color
			26:50	5	10.66	.476	1.02	6.45	277.8	no color
			31:53	6	10.63	.475	.90	6.55	268.1	no color
			37:06	7	10.64	.468	.86	6.97	242.6	no color
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments

PURGE INFORMATION

Starting Flow meter Reading: ______ Ending Flow meter Reading: ______ Flow Rate: ______

Total Volume Purged: 7 Purged Dry (Y/N): N Micro purged (Y/N): N Minimal purged (Y/N): ______

Casing Inner Diameter (inches) 2 Initial Depth to Water (feet) 13.95 Depth to bottom of well (feet) ______

Tubing inner diameter 1/4 OD (in) Tubing & Pump Volume ______ (ml)

Controller settings: Pressure ___ (psi) Discharge (sec.) Recharge ______ (sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

DAILY FIELD ACTIVITY REPORT

Client Name: ______________________ Project Number: ______________
Project Name: ______________________ Date: 6-3-16
Contractor: ______________________ Arrival Time: 10:46
Weather: ______________________

Time Breakdown: Drive: _______ Work: _______ Standby: _______

Location and Description of Activities:

OW 115

Equipment Used on Project:

Activity Summary and General Remarks:

Depth to Water 12.25 ft

Tubing for purge set at 27 ft from TOC

Started purging 11:00

Technician Signature: ______________________ Date: ______________

WIEDEMEIER & ASSOCIATES

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP 201584 TCAAP
COC Number:
Well ID: 01U115
Sample Collected by: John Wilson
Date of Collection: 6-3-16

EQUIPMENT

Purging Equipment:
Sampling Equipment:
Filtering Equipment:
Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
YSI 556 Multi Parameter Meter	05C1520 AA	
HACH DR 890 Colorimeter		N/A

FIELD PARAMETERS

Ambient Air Temperature (°F): 70
Weather Conditions: Partly cloudy / light rain
Sampling Depth (ft): Pump Inlet@
Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate __/min	Depth to water	Time 11:00	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
				0	~~9.79~~	~~.395~~	~~1.56~~	~~7.42~~	~~238.6~~	no color
			3:42	1	9.79	.395	1.56	7.42	238.6	
			6:10	2	9.72	.393	1.37	7.39	236.7	no color
			8:21	3	9.82	.393	1.15	7.40	232.9	no color
			10:22	4	9.84	.394	1.03	7.41	[illegible].3	no color
			12:45	5	9.87	.394	.92	7.41	228.8	no color
			15:17	6	9.91	.396	.91	7.41	227.8	no color
			17:57	7	9.93	.399	.81	7.40	226.8	no color
			20:16	8	9.99	.402	.82	7.40	226.3	no color
			23:00	9	9.99	.402	.75	7.39	225.7	no color
			25:31	10	10.05	.405	.67	7.39	225.4	no color
			28:14	11	10.02	.403	.68	7.38	225.4	no color
			30:39	12	9.99	.405	.71	7.38	225.4	no color
			33:14	13	9.99	.411	.66	7.37	225.1	no color
	≥40 ≤200		35:44	14	~~±10%~~ 10.03	~~±10%~~ .412	~~±10%~~ .58	~~±0.2~~ 7.35	~~±10mv~~ 225.6	no color

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments

PURGE INFORMATION

Finished Purging 11:37

Starting Flow meter Reading: ________ Ending Flow meter Reading: ________ Flow Rate: ________

Total Volume Purged: ________ Purged Dry (Y/N): N Micro purged (Y/N): N Minimal purged (Y/N): ____

Casing Inner Diameter (inches) 4 Initial Depth to Water (feet) 12.25 Depth to bottom of well (feet) ____

Tubing inner diameter 1/4 OD (in) Tubing & Pump Volume ______ (ml)

Controller settings: Pressure ___ (psi) Discharge (sec.) Recharge __________ (sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT

Where WCT = Water Column Thickness (feet)

WIEDEMEIER & ASSOCIATES

Page ___ of ___

DAILY FIELD ACTIVITY REPORT

Client Name: ______________________
Project Name: ESTCP201584 Plattsburgh NY
Contractor: ______________________
Weather: ______________________

Project Number: ______________________
Date: 6-6-16
Arrival Time: 8:15

Time Breakdown: Drive: _______ Work: _______ Standby: _______

Location and Description of Activities:

~~MW-02-006~~
MW-02-006

Equipment Used on Project:
Purged 1.5 gal

Activity Summary and General Remarks:
Depth to water 33.45 ft
Depth of well 39.98 ft

9:26 II A1 #3 Clemson MW-02-006
II A1 #1
II A1 #2

9:10 Plattsburgh MW-02-006 Sample 1 PNNL
2
3
4

9:31 Plattsburgh MW-02-006 DNA I 400 mLs
II 400 mLs
III 400 mLs

Technician Signature: ______________________ Date: ______________________

9:50 Plattsburgh MW-02-006 RNA I 400 mLs Microbial Insights
II 300 mLs
III 300 mLs.
3 mL preservative added to each

WIEDEMEIER & ASSOCIATES

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP 201584 Plattsburgh COC Number:
Well ID: MW 2-006
Sample Collected by: Date of Collection: 6-6-16

EQUIPMENT
Purging Equipment:
Sampling Equipment:
Filtering Equipment:
Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
YSI 556 Multi Parameter Meter	05C1520 AA	
HACH DR 890 Colorimeter		N/A

FIELD PARAMETERS
Ambient Air Temperature (°F): 63 Weather Conditions: Partly Sunny / Windy
Sampling Depth (ft): Pump Inlet@ Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate __/min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
				2	—	—	—	—	—	
				3	~~14.5~~					
				5	10.1	.624	.42	6.65	-110.3	Clear VFA odor
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments
					.29 1/10 dil 1.25 mg/L				

PURGE INFORMATION
Starting Flow meter Reading: Ending Flow meter Reading: Flow Rate:
Total Volume Purged: 1.5 gal Purged Dry (Y/N): Micro purged (Y/N): N Minimal purged (Y/N):
Casing Inner Diameter (inches) Initial Depth to Water (feet) Depth to bottom of well (feet)
Tubing inner diameter 1/4 OD (in) Tubing & Pump Volume (ml)
Controller settings: Pressure (psi) Discharge (sec.) Recharge (sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

DAILY FIELD ACTIVITY REPORT

Client Name: ____________________ Project Number: ____________________

Project Name: ESTCP 201584 Plattsburgh Date: 6-6-16

Contractor: ____________________ Arrival Time: 11:10

Weather: ____________________

Time Breakdown: Drive: ________ Work: ________ Standby: ________

Location and Description of Activities:

MW-02-019

Equipment Used on Project:

Activity Summary and General Remarks:

Depth to water 16.74 ft TOC

Depth well 25.8 soft bottom

Screen 9-24

Set tube ~~18~~ 20 ft below TOC

Purge Vol 3.5 gal for 3 casing volumes

11:52 Plattsburgh MW-02-[redacted] 019 Sample 1, 2, 3, 4 } PNNL 1 liter

12:01 MW-02-[redacted] 019 II A2 #1, II A2 #2, II A2 #3 } Clemson ~100 mL

12:16 DNA MW-02-[redacted] 019 1000 mL } Microbial Insights

RNA MW-02-[redacted] 019 1000 mL

Technician Signature: ____________________ Date: ____________________

WIEDEMEIER & ASSOCIATES

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP – Plattsburgh COC Number: ______
Well ID: MW-02-019
Sample Collected by: JTW/BHW Date of Collection: 6-6-16

EQUIPMENT
Purging Equipment: Peristaltic Pump
Sampling Equipment: " "
Filtering Equipment: N/A except for Microbial insights samples
Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
YSI 556 Multi Parameter Meter	05C1520 AA	
HACH DR 890 Colorimeter		N/A

FIELD PARAMETERS
Ambient Air Temperature (°F): ______ Weather Conditions: ______
Sampling Depth (ft): Pump Inlet@ ______ Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate __/min	Depth to water	Time 11:26 EDT	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
				0	12.33	.425	1.33	7.08	-95.7	
			16:11	1	11.22	0.419	.54	6.57	-82.0	color rusty red
		Minutes	11:22	2	11.1	.416	.46	6.82	-97.3	browncolor turbid
			16:31	3	11.05	.415	.36	6.93	-105.4	faint brown
			21:42	4	10.95	.412	.40	6.94	-106.9	no color no turbi
			finished		11:47					
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments
					1.12				

PURGE INFORMATION
Starting Flow meter Reading: ______ Ending Flow meter Reading: ______ Flow Rate: ______
Total Volume Purged: 4.0 Purged Dry (Y/N): N Micro purged (Y/N): N Minimal purged (Y/N): N
Casing Inner Diameter (inches) 2 Initial Depth to Water (feet) 16.74 Depth to bottom of well (feet) 25
Tubing inner diameter 0.17 (in) Tubing & Pump Volume ______ (ml)
Controller settings: Pressure ___ (psi) Discharge (sec.) Recharge ______ (sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

WIEDEMEIER & ASSOCIATES

Chain of Custody Record

SEVERN TRENT **STL**
Severn Trent Laboratories, Inc.

STL Denver
4955 Yarrow Street
Arvada, CO 80002

STL-4124 (0901)

Client: Todd Wiedemeier	Project Manager: Todd Wiedemeier	Date: 6-6-16	Chain of Custody Number: 348472
Address: 309 Coronado Dr	Telephone Number (Area Code)/Fax Number: 303-670-7999	Lab Number: Microbial Ins	Page 1 of 1
City: Sedalia; State: CO; Zip Code: 80135	Site Contact: Todd W; Lab Contact: Dora Taggart		
Project Name and Location (State): ESTCP 201584 Plattsburgh NY Int Airport	Carrier/Waybill Number:		
Contract/Purchase Order/Quote No.: N/A			

Sample I.D. No. and Description (Containers for each sample may be combined on one line)	Date	Time	Matrix: Air	Aqueous	Sed.	Soil		Containers & Preservatives: Unpres.	H2SO4	HNO3	HCl	NaOH	ZnAc/NaOH		Analysis (Attach list if more space is needed)	Special Instructions/ Conditions of Receipt
Plattsburgh																
MW-02-006 DNA I 400mLs	6-6	9:31														
MW-02-006 DNA II 400mLs	6-6	↓														
MW-02-006 DNA III 400mLs	6-6	↓														
MW-02-006 RNA I 400mLs	6-6	9:50														
MW-02-006 RNA II 500mLs	6-6	↓														
MW-02-006 RNA III 500mLs	6-6	↓														
MW-02-019 DNA 1000mL	6-6	12:16														
MW-02-019 RNA 1000mL	6-6	↓														

Possible Hazard Identification
☒ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal
☐ Return To Client ☐ Disposal By Lab ☐ Archive For ______ Months (A fee may be assessed if samples are retained longer than 1 month)

Turn Around Time Required
☒ 24 Hours ☐ 48 Hours ☐ 7 Days ☐ 14 Days ☐ 21 Days ☐ Other ______

QC Requirements (Specify)

	Date	Time		Date	Time
1. Relinquished By: Barbara Wilson	6-6-16	16:00	1. Received By		
2. Relinquished By			2. Received By		
3. Relinquished By			3. Received By		

Comments

DISTRIBUTION: WHITE - Returned to Client with Report; CANARY - Stays with the Sample; PINK - Field Copy

Chain of Custody Record

4124 (0807)

SEVERN TRENT STL
Severn Trent Laboratories, Inc.

Client: ECTCP-Todd Wiedemeier	Project Manager: Todd Wiedemeier	Date: 6-6-16	Chain of Custody Number: 430986
Address: 309 Coronado Dr	Telephone Number (Area Code)/Fax Number: 303-670-7997	Lab Number: PNNL	Page 1 of 1
City: Sedalia / State: CO / Zip Code: 80135	Site Contact: Todd W. / Lab Contact: Brady Lee		
Project Name and Location (State): Plattsburg Int Airport Plattsburgh NY	Carrier/Waybill Number:		
Contract/Purchase Order/Quote No.: N/A			

Sample I.D. No. and Description (Containers for each sample may be combined on one line)	Date	Time	Matrix: Air	Aqueous	Sed.	Soil		Containers & Preservatives: Unpres.	H2SO4	HNO3	HCl	NaOH	ZnAc/ NaOH	Analysis (Attach list if more space is needed): EHP	qPCR	Special Instructions/ Conditions of Receipt
Plattsburgh MW-02-006 Sample 1	6-6-16	9:10		✓										✓	✓	
MW-02-006 Sample 2	↓	↓		✓										✓	✓	
MW-02-006 Sample 3	↓	↓		✓										✓	✓	
MW-02-006 Sample 4	↓	↓		✓										✓	✓	
Plattsburgh MW-02-019 Sample 1	6-6-16	11:52		✓										✓	✓	
MW-02-019 Sample 2	↓	↓		✓										✓	✓	
MW-02-019 Sample 3	↓	↓		✓										✓	✓	
MW-02-019 Sample 4	↓	↓		✓										✓	✓	
Trip Blank DW #6 5-16-16 SB	6-6-16	9:30														

Possible Hazard Identification
☑ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal
☐ Return To Client ☐ Disposal By Lab ☐ Archive For ______ Months (A fee may be assessed if samples are retained longer than 1 month)

Turn Around Time Required
☑ 24 Hours ☐ 48 Hours ☐ 7 Days ☐ 14 Days ☐ 21 Days ☐ Other______

QC Requirements (Specify)

	Date	Time		Date	Time
1. Relinquished By: Barbara Wilson	6-6-16	15:56	1. Received By:		
2. Relinquished By:			2. Received By:		
3. Relinquished By:			3. Received By:		

Comments

DISTRIBUTION: WHITE - Returned to Client with Report; CANARY - Stays with the Sample; PINK - Field Copy

Chain of Custody Record

SEVERN TRENT STL
Severn Trent Laboratories, Inc.

4124 (0807)

Client	Project Manager	Date	Chain of Custody Number
ESTCP- Todd Wiedemeier	Todd Wiedemeier	6-6-16	400987
Address	**Telephone Number (Area Code)/Fax Number**	**Lab Number**	**Page** 1 **of** 1
309 Coronado Dr	303-670-7999	Clemson	

City	State	Zip Code	Site Contact	Lab Contact
Sedalia	CO	80135	Todd W.	Clemson David Freedman

Project Name and Location (State): Plattsburgh Int Airport Plattsburgh NY

Carrier/Waybill Number:

Contract/Purchase Order/Quote No.: N/A

Analysis (Attach list if more space is needed)

Special Instructions/ Conditions of Receipt

Sample I.D. No. and Description (Containers for each sample may be combined on one line)	Date	Time	Matrix: Air	Aqueous	Sed.	Soil	Containers & Preservatives: Unpres.	H2SO4	HNO3	HCl	NaOH	ZnAc/ NaOH	Analysis: TCE D[illegible]
Plattsburgh MW-02-006 II A1 #1	6-6-16	9:26		✓									✓
MW-02-006 II A1 #2	6-6-16	↓		✓									✓
MW-02-006 II A1 #3	6-6-16	↓		✓									✓
Plattsburgh MW-02-019 II A2 #1	6-6-16	12:01		✓									✓
MW-02-019 II A2 #2	6-6-16	↓		✓									✓
MW-02-019 II A2 #3	6-6-16	↓		✓									✓

Possible Hazard Identification
☑ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal
☐ Return To Client ☐ Disposal By Lab ☐ Archive For ______ Months (A fee may be assessed if samples are retained longer than 1 month)

Turn Around Time Required
☑ 24 Hours ☐ 48 Hours ☐ 7 Days ☐ 14 Days ☐ 21 Days ☐ Other______

QC Requirements (Specify)

Relinquished By	Date	Time	Received By	Date	Time
1. Barbara Wilson	6-6-16	15:50	1.		
2.			2.		
3.			3.		

Comments

DISTRIBUTION: WHITE - Returned to Client with Report; CANARY - Stays with the Sample; PINK - Field Copy

REPORT TO:

Name: John Wilson
Company: [illegible] ENV
Address: [illegible] 1616
[illegible] OK 74321

email: [illegible].com
Phone: [illegible] 421 557
Fax:

Project Manager:
Project Name: [illegible] 201584 Plattsburgh NY
Project No.:

INVOICE TO: (For Invoices paid by a third party it is imperative that all information be provided)

Name:
Company:
Address:

email:
Phone:
Fax:

Purchase Order No.
Subcontract No.
MI Quote No.

microbialinsights

10515 Research Dr
Knoxville, TN 37932
865-573-8188

www.microbe.com

Please Check One:
☐ More samples to follow
☐ No Additional Samples

Report Type: ☐ Standard (default) ☐ Microbial Insights Level III raw data(15% surcharge) ☑ Microbial Insights Level IV (25% surcharge) ☐ Comprehensive Interpretive(15%) ☐ Historical Interpretive (35%)

EDD type: ☐ Microbial Insights Standard (default) ☐ All other available EDDs (5% surcharge) Specify EDD Type:

Please contact us with any questions about the analyses or filling out the COC at (865) 573-8188 (9:00 am to 5:00 pm EST, M-F). After hours email: customerservice@microbe.com

Sample Information					**Analyses**				**CENSUS: Please select the target organism/gene**																						
MI ID (Laboratory Use Only)	Plattsburgh NY 400 mL **Sample Name**	Date Sampled	Time Sampled	Matrix	**PLFA**	**NGS**	**QuantArray Chlor**	**QuantArray Petro**	**DHC (Dehalococcoides)**	DHC Functional genes (bvc, tce, vcr)	DHBt (Dehalobacter)	DHG (Dehalogenimonas)	DSM (Desulfuromonas)	DSB (Desulfitobacterium)	EBAC (Total)	SRB (Sulfate Reducing Bacteria-APS)	MGN (Methanogens)	MOB (Methanotrophs)	SMMO	DNF (Dentrifiers-nirS and nirK)	AOB (ammonia oxidizing bacteria)	PM1 (MTBE aerobic)	RMO (Toluene Monooxygenase)	RDEG (Toluene Monooxygenase)	PHE (Phenol Hydroxylase)	NAH (Napthalene-aerobic)	BSSA (Toluene/Xylene-Anaerobic)	add. qPCR:	**RNA (Expression Option)***	Other:	Other:	Other:
	MW-02-00[illegible] DNA I	6-6	9:21							[illegible] forgot																					
	400mL DNA II	6-6																													
	400mL DNA III	6-6																													
	400mL RNA I		9:50																												
	300mL RNA II																														
	300mL RNA III																														
	MW-02-019 DNA 1000mL	6-6	12:16																												
	MW-02-019	6-6																													
	RNA 1000mL																														

Relinquished by: Barbara Wilson **Received by:** **Date** 6-6-2016

It is vital that chain of custody is filled out correctly & that all relative information is provided.
Failure to provide sufficient and/or correct information regarding reporting, invoicing & analyses requested information may result in delays for which MI will not be liable.

16:01
6-6-16

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP – Plattsburgh COC Number:

Well ID: MW-02-006

Sample Collected by: JTW/BHW Date of Collection: 6/6/16

EQUIPMENT

Purging Equipment: Bailer

Sampling Equipment:

Filtering Equipment:

Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
YSI 556 Multi Parameter Meter	05C1520 AA	
HACH DR 890 Colorimeter		N/A

FIELD PARAMETERS

Ambient Air Temperature (°F): Weather Conditions:

Sampling Depth (ft): Pump Inlet@ Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate __/min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

This well was the first one that was bailed. Bailed because of Depth to water. Obstruction @ about 5' bgs means that we cannot do magnetic susceptibility in this well → can't get the sonde down the well. Bailed water & put it in a one-liter Nalgene bottle & then transferred to sampling containers with a peristaltic pump

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments

PURGE INFORMATION

Starting Flow meter Reading:________ Ending Flow meter Reading:________ Flow Rate:__________

Total Volume Purged:________ Purged Dry (Y/N):_____ Micro purged (Y/N):_____ Minimal purged (Y/N):____

Casing Inner Diameter (inches)______ Initial Depth to Water (feet) 33.45 Depth to bottom of well (feet) 39.98

Tubing inner diameter_______(in) Tubing & Pump Volume_______(ml)

Controller settings: Pressure___(psi) Discharge (sec.) Recharge___________(sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

WIEDEMEIER & ASSOCIATES

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP - Plattsburgh COC Number:
Well ID: MW-02-030
Sample Collected by: THW/JTW Date of Collection: 6/6/16

EQUIPMENT
~~Purging~~ Equipment: HMA-4535
Sampling Equipment:
Filtering Equipment:
Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
~~YSI 556 Multi Parameter Meter~~	~~05C1520~~ AA	
~~HACH DR 890 Colorimeter~~		N/A

FIELD PARAMETERS
Ambient Air Temperature (°F): Used 7ft/min Rate Down Weather Conditions: Ptly cloudy, breezy ~75°F
Sampling Depth (ft): Pump Inlet@ Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate __/min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
		Sonde makes it to 54.5 2 = TD								
	14:48	Start Equilibrating Sonde to Water Temp								
		15:05 Calibration 1								
		Zero(0) = ~~[illegible]~~ 29.94 cps								
		SE-3 = ~~[illegible]~~ 1164.64								
		Run 1 Down = MW-02-030 Run 1 Down Calib 1 6-6-16								
		Run 1 Up = " " " " " Up " " " "								
		Run 2 Down = MW-02-030 Run 2 Down Calib 2 6-6-16								
		Run 2 Up = MW-02-030 Run 2 Up Calib 2 6-6-16								
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

Bad Run

Going to Re-run

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments

PURGE INFORMATION Calibration 2 Zero = 68.82cps SE-3 = 1105.78cps

Starting Flow meter Reading:________ Ending Flow meter Reading:________ Flow Rate:__________

Total Volume Purged:________ Purged Dry (Y/N):_____ Micro purged (Y/N):_____ Minimal purged (Y/N):____

Casing Inner Diameter (inches)______ Initial Depth to Water (feet) 15.20 Depth to bottom of well (feet) 54.6
Tubing inner diameter_______(in) Tubing & Pump Volume_______(ml)
Controller settings: Pressure___(psi) Discharge (sec.) Recharge__________(sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

Below Grade Cover – Zero Sonde @ Ground Surface

WIEDEMEIER & ASSOCIATES

DAILY FIELD ACTIVITY REPORT

Client Name: ______
Project Number: ______
Project Name: ESTCP Plattsburgh
Date: 6-7-16
Contractor: 201584
Arrival Time: 8:55
Weather: Light Rain / Partly Sunny 58°F

Time Breakdown: Drive: ______ Work: ______ Standby: ______

Location and Description of Activities:
32 PLTW 12
32 PLTW 12

Equipment Used on Project:

Activity Summary and General Remarks:
Depth to water 13.7ft BTOC
Depth Well 16.8ft felt like sand (JW)
Set Tube (2ft above depth) 14.8ft.
Purge Volume 0.3gal

9:40 Plattsburgh 32PLTW12 Sample 1, 2, 3, 4 } PNNL 1 liter

9:57 Plattsburgh 32PLTW12 IIB1 #1, #2, #3 } Clemson ~100mLS

10:05 Plattsburgh 32PLTW12 DNA 1000mL } Microbial Insights
10:15 Plattsburgh 32PLTW12 RNA 1000mL

Technician Signature: ______ Date: ______

WIEDEMEIER & ASSOCIATES

C:\Admin\Forms\Daily Field Activity Report.doc

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP201584 Plattsburgh COC Number:
Well ID: 32PLTW12
Sample Collected by: JW/BW/TW Date of Collection: 6-7-16

EQUIPMENT

Purging Equipment:
Sampling Equipment:
Filtering Equipment:
Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
YSI 556 Multi Parameter Meter	05C1520 AA	
HACH DR 890 Colorimeter		N/A

FIELD PARAMETERS

Ambient Air Temperature (°F): 58°
Weather Conditions: Light Rain / Partly Sunny
Sampling Depth (ft): Pump Inlet@
Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate __/min	Depth to water	Time 9:24	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
				0	12.03	.216	9.49	6.91	144.6	
			1:58	.5	11.22	.225	9.38	5.25	255.8	
			4:59	1.0	10.85	.227	9.21	4.73	298.0	turbid brown
			7:45	1.5	11.11	.227	9.02	4.95	294.1	slight brown color
			10:35	2.0	11.39	.227	8.88	5.60	264.3	very slight brown
			Stopped 9:36							
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments
					0.00				

PURGE INFORMATION

Starting Flow meter Reading: Ending Flow meter Reading: Flow Rate:
Total Volume Purged: 2gal Purged Dry (Y/N): Micro purged (Y/N): Minimal purged (Y/N):
Casing Inner Diameter (inches) Initial Depth to Water (feet) 13.7 Depth to bottom of well (feet) 16.8
Tubing inner diameter 0.17 (in) Tubing & Pump Volume (ml)
Controller settings: Pressure (psi) Discharge (sec.) Recharge (sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

WIEDEMEIER & ASSOCIATES

Page ___ of ___

DAILY FIELD ACTIVITY REPORT

Client Name: ______________________
Project Name: ESTCP 201584 Plattsburgh
Contractor: ______________________
Weather: ______________________

Project Number: ______________________
Date: 6-7-16
Arrival Time: 10:35
Off Site 12:08

Time Breakdown: Drive: _______ Work: ________ Standby: _________

Location and Description of Activities:
64°F Mostly Cloudy 35PLT13

Equipment Used on Project:
Geotech Pump
YSI 556 MPS
HACH DR 890 Calorimeter

Activity Summary and General Remarks:
Depth to Water 10.35ft
Sand at 24.25ft BTOC (Base of well)
Set Tube at 17 ft BTOC for sampling
1gal = 3 casing volumes

11:30 Plattsburgh 35PTL13 Sample 1, 2, 3, 4 } PNNL

11:43 Plattsburgh 35PTL13 IIB2 #1, 2, 3 } Clemson

12:00 Plattsburgh 35PTL13 DNA 1000 mL
Plattsburgh 35PTL13 RNA 1000 mL } Microbial Insights

Technician Signature: ______________________ Date: ____________

WIEDEMEIER & ASSOCIATES

C:\Admin\Forms\Daily Field Activity Report.doc

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ______ COC Number: ______

Well ID: 35PLT13

Sample Collected by: JW/BW/TW Date of Collection: 6-7-16

EQUIPMENT

Purging Equipment: Geotech Pump

Sampling Equipment: ______

Filtering Equipment: ______

Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
YSI 556 Multi Parameter Meter	05C1520 AA	6-7-16
HACH DR 890 Colorimeter		N/A

FIELD PARAMETERS

Ambient Air Temperature (°F): 64 Weather Conditions: Partly Sunny/Cloudy

Sampling Depth (ft): Pump Inlet@ Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate __/min	Depth to water	Time 10:57	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
				0	14.97	.536	2.91	7.33	-71.0	
Back off too much			6:52	.5	13.66	.536	6.27	6.93	35.2	clear, faint brown
drawdown			10:08	1.0	12.17	.540	4.78	6.50	81.5	
Lower Tubing ~1 ft			16:00	1.5	12.8	.538	2.28	6.57	72.7	
			19:11	2.0	12.22	.539	1.69	6.84	58.3	clear, colorless
			24:54	2.5	12.31	.540	1.58	7.11	45.4	clear, colorless
		Stopped 11:17								
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments
					0.00				

PURGE INFORMATION

Starting Flow meter Reading: ______ Ending Flow meter Reading: ______ Flow Rate: ______

Total Volume Purged: 2.5 gal Purged Dry (Y/N): N Micro purged (Y/N): N Minimal purged (Y/N): N

Casing Inner Diameter (inches) ______ Initial Depth to Water (feet) 10.35 Depth to bottom of well (feet) 24.25

Tubing inner diameter .17 (in) Tubing & Pump Volume ______ (ml)

Controller settings: Pressure ___ (psi) Discharge (sec.) Recharge ______ (sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

WIEDEMEIER & ASSOCIATES

Chain of Custody Record

SEVERN TRENT **STL**
Severn Trent Laboratories, Inc.

STL Denver
4955 Yarrow Street
Arvada, CO 80002

STL-4124 (0901)

Client: Todd Wiedemeier - ESTCP	Project Manager: Todd Wiedemeier	Date: 6-7-16	Chain of Custody Number: 348476
Address: 309 Coronado Dr	Telephone Number (Area Code)/Fax Number: 303-670-7999	Lab Number: Clonwon	Page 1 of 1
City: Sedalia · State: CO · Zip Code: 80135	Site Contact: Todd W / Lab Contact: David Freedman		
Project Name and Location (State): Plattsburg Int Airport Plattsburgh Ny	Carrier/Waybill Number:		
Contract/Purchase Order/Quote No.: N/A			

Analysis (Attach list if more space is needed): Assay TCE Degradation

Special Instructions/ Conditions of Receipt

Sample I.D. No. and Description (Containers for each sample may be combined on one line)	Date	Time	Matrix: Air	Aqueous	Sed.	Soil	Containers & Preservatives: Unpres.	H2SO4	HNO3	HCl	NaOH	ZnAc/NaOH	Assay TCE Degradation
Plattsburgh 32 PTLW12 II B1 #1	6-7-16	9:51		✓									✓
Plattsburgh 32 PTLW12 II B1 #2	↓	↓		✓									✓
Plattsburgh 32 PTLW12 II B1 #3	↓	↓		✓									✓
Plattsburgh 35 PTL13 II B2 #1	6-7-16	11:43		✓									✓
Plattsburgh 35 PTL13 II B2 #2	↓	↓		✓									✓
Plattsburgh 35 PTL13 II B2 #3	↓	↓		✓									✓

Possible Hazard Identification: ☑ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal: ☐ Return To Client ☐ Disposal By Lab ☐ Archive For ____ Months (A fee may be assessed if samples are retained longer than 1 month)

Turn Around Time Required: ☑ 24 Hours ☐ 48 Hours ☐ 7 Days ☐ 14 Days ☐ 21 Days ☐ Other____

QC Requirements (Specify)

	Date	Time		Date	Time
1. Relinquished By: Barbara Wilson	6-7-16	15:04 EDT	1. Received By		
2. Relinquished By			2. Received By		
3. Relinquished By			3. Received By		

Comments

DISTRIBUTION: WHITE - Returned to Client with Report; CANARY - Stays with the Sample; PINK - Field Copy

Chain of Custody Record

SEVERN TRENT STL
Severn Trent Laboratories, Inc.

STL Denver
4955 Yarrow Street
Arvada, CO 80002

STL-4124 (0901)

Client: ESTCP- Todd Wiedemeier	Project Manager: Todd Wiedemeier	Date: 6-7-16	Chain of Custody Number: 348474
Address: 309 Coronado Dr	Telephone Number (Area Code)/Fax Number: 303-670-7999	Lab Number: PNNL	Page 1 of 1
City: Sedalia; State: CO; Zip Code: 80135	Site Contact: Todd W; Lab Contact: Brady Lee		
Project Name and Location (State): Plattsburgh Int Airport Plattsburgh NY	Carrier/Waybill Number:		
Contract/Purchase Order/Quote No.: N/A			

Analysis (Attach list if more space is needed)

Special Instructions/ Conditions of Receipt

Sample I.D. No. and Description (Containers for each sample may be combined on one line)	Date	Time	Matrix: Air	Aqueous	Sed.	Soil	Containers & Preservatives: Unpres.	H2SO4	HNO3	HCl	NaOH	ZnAc/ NaOH	EAP	qPCR
Plattsburgh 32PLTW12 Sample 1	6-7-16	9:40		✓									✓	✓
Plattsburgh 32PLTW12 Sample 2	↓	↓		✓									✓	✓
Plattsburgh 32PLTW12 Sample 3	↓	↓		✓									✓	✓
Plattsburgh 32PLTW12 Sample 4	↓	↓		✓									✓	✓
Plattsburgh 35PTL13 Sample 1	6-7-16	11:30		✓									✓	✓
Plattsburgh 35PTL13 Sample 2	↓	↓		✓									✓	✓
Plattsburgh 35PTL13 Sample 3	↓	↓		✓									✓	✓
Plattsburgh 35PTL13 Sample 4	↓	↓		✓									✓	✓
Trip Blank ~~DIW114~~ 5-16-16SB	6-7-16			✓									✓	✓

Possible Hazard Identification: ☑ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal: ☐ Return To Client ☐ Disposal By Lab ☐ Archive For ____ Months (A fee may be assessed if samples are retained longer than 1 month)

Turn Around Time Required: ☑ 24 Hours ☐ 48 Hours ☐ 7 Days ☐ 14 Days ☐ 21 Days ☐ Other ____

QC Requirements (Specify)

1. Relinquished By: Barbara Wilson	Date: 6-7-16	Time: 15:03 EDT	1. Received By	Date	Time
2. Relinquished By	Date	Time	2. Received By	Date	Time
3. Relinquished By	Date	Time	3. Received By	Date	Time

Comments

DISTRIBUTION: WHITE - Returned to Client with Report; CANARY - Stays with the Sample; PINK - Field Copy

Chain of Custody Record

SEVERN TRENT **STL**
Severn Trent Laboratories, Inc.

STL Denver
4955 Yarrow Street
Arvada, CO 80002

STL-4124 (0901)

Client: ESTCP - Todd Wiedemeier	Project Manager: Todd Wiedemeier	Date: 6-7-16	Chain of Custody Number: 348478
Address: 309 Coronado Dr	Telephone Number (Area Code)/Fax Number: 303-670-7999	Lab Number: Microbial Insights	Page 1 of 1
City: Sedalia / State: CO / Zip Code: 80135	Site Contact: Todd W. / Lab Contact: Dora Taggart	Analysis (Attach list if more space is needed)	
Project Name and Location (State): Plattsburgh Int Airport, Plattsburgh NY	Carrier/Waybill Number:		Special Instructions/ Conditions of Receipt
Contract/Purchase Order/Quote No.: N/A			

Sample I.D. No. and Description (Containers for each sample may be combined on one line)	Date	Time	Air	Aqueous	Sed.	Soil	Unpres.	H2SO4	HNO3	HCl	NaOH	ZnAc/NaOH
Plattsburgh32PTLW12 DNA 1000 mL	6-7-16	10:05		✓			per Dora Taggart					
Plattsburgh32PTLW12 RNA 1000 mL	6-7-16	10:15		✓								
Plattsburgh35PTL13 DNA 1000 mL	6-7-16	12:00		✓								
Plattsburgh35PTL13 RNA 1000 mL	6-7-16	12:10		✓								

Possible Hazard Identification
☒ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal
☐ Return To Client ☐ Disposal By Lab ☐ Archive For ____ Months (A fee may be assessed if samples are retained longer than 1 month)

Turn Around Time Required
☒ 24 Hours ☐ 48 Hours ☐ 7 Days ☐ 14 Days ☐ 21 Days ☐ Other ____

QC Requirements (Specify)

	Date	Time		Date	Time
1. Relinquished By: Barbara Watson	6-7-16	14:58 EDT	1. Received By		
2. Relinquished By			2. Received By		
3. Relinquished By			3. Received By		

Comments

DISTRIBUTION: WHITE - Returned to Client with Report; CANARY - Stays with the Sample; PINK - Field Copy

REPORT TO:

Name: John Wilson
Company: Scissortail ENV
Address: PO BOX 1606
ADA, OK 74821

email: john@scissortailenv.com
Phone: 580-421-3551
Fax:

Project Manager: Todd Wiedemeier
Project Name: ESTCP 201584
Project No.: Plattsburgh Int Airport Plattsburgh NY

INVOICE TO: (For Invoices paid by a third party it is imperative that all information be provided)

Name:
Company:
Address:

email:
Phone:
Fax:

Purchase Order No.
Subcontract No.
MI Quote No.

microbialinsights

10515 Research Dr
Knoxville, TN 37932
865-573-8188

www.microbe.com

Please Check One:
☐ More samples to follow
☐ No Additional Samples

Report Type: ☐ Standard (default) ☒ Microbial Insights Level III raw data(15% surcharge) ☐ Microbial Insights Level IV (25% surcharge) ☐ Comprehensive Interpretive(15%) ☐ Historical Interpretive (35%)

EDD type: ☐ Microbial Insights Standard (default) ☐ All other available EDDs (5% surcharge) Specify EDD Type:

Please contact us with any questions about the analyses or filling out the COC at (865) 573-8188 (9:00 am to 5:00 pm EST, M-F). After hours email: customerservice@microbe.com

Sample Information					**Analyses**				**CENSUS: Please select the target organism/gene**																								
MI ID (Laboratory Use Only)	Sample Name	Date Sampled	Time Sampled	Matrix	**PLFA**	**NGS**	**QuantArray Chlor**	**QuantArray Petro**	**DHC (Dehalococcoides)**	DHC Functional genes (bvc, tce, vcr)	DHBt (Dehalobacter)	DHG (Dehalogenimonas)	DSM (Desulfuromonas)	DSB (Desulfitobacterium)	EBAC (Total)	SRB (Sulfate Reducing Bacteria-APS)	MGN (Methanogens)	MOB (Methanotrophs)	SMMO	DNF (Dentrifiers-nirS and nirK)	AOB (ammonia oxidizing bacteria)	PM1 (MTBE aerobic)	RMO (Toluene Monooxygenase)	RDEG (Toluene Monooxygenase)	PHE (Phenol Hydroxylase)	NAH (Napthalene-aerobic)	BSSA (Toluene/Xylene-Anaerobic)	add. qPCR:	**RNA (Expression Option)***	Other:	Other:	Other:
	Plattsburgh												[illegible]																			
	32PTLW12 DNA	6-7-16	10:05	Aq																												
	32PTLW12 RNA	6-7-16	10:10	Aq																												
	35PTL12DNA	6-7-16	12:00	Aq																												
	35PTL12RNA	6-7-16	12:10	Aq																												

Relinquished by: [illegible signature] **Received by:** **Date**

6-7-16
14:58 EDT

It is vital that chain of custody is filled out correctly & that all relative information is provided.
Failure to provide sufficient and/or correct information regarding reporting, invoicing & analyses requested information may result in delays for which MI will not be liable.

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP ~ Plattsburgh

COC Number: ______

Well ID: MW-02-17

Sample Collected by: THW / JTW

Date of Collection: 6/7/16

EQUIPMENT

Purging Equipment: HMA - 453 S

Sampling Equipment: ______

Filtering Equipment: ______

Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
~~YSI 556 Multi Parameter Meter~~	~~05C1520 AA~~	
~~HACH DR 890 Colorimeter~~		N/A

FIELD PARAMETERS

Ambient Air Temperature (°F): ______

Weather Conditions: Cloudy ~ 68°F may Rain Breezy

Sampling Depth (ft): Pump Inlet@ ______

Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate ___/min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
13:39 Zero Tool To Surface										
13:40 tool in water Tool Stopped @ 41.82' ft BGS										
13:55 Probe out of water for calibrating										
Calibration 1 Zero = 70.56										
5E-3 = 1152.19										
1410 Run 1 ~~PLTS Run1 Calib1 Down~~										
Down @ 8.5 ft/min ⇒ PLTS Run1 Down Calib 1 MW-02-017 6-7-16 txt										
Hit bottom @ 42.02										
up @ 8.5 ft/min ⇒ PLTS Run1 Up Calib 1 MW-02-017 6-7-16										
Steel casing interfers near Surface going to Start										
Run 2 @ 10' bgs → Start with Probe @ 10' bgs										
Run-2 ⇒ PLTS Run 2 Down Calib 1 MW-02-017-6-7-17										
Run-2 ⇒ PLTS Run 2 Up Calib 1 MW-02-017 6-7-16										
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments

Stickup = 2.64' So Measure from zero up 2.64

PURGE INFORMATION

Starting Flow meter Reading: ______ Ending Flow meter Reading: ______ Flow Rate: ______

Total Volume Purged: ______ Purged Dry (Y/N): ______ Micro purged (Y/N): ______ Minimal purged (Y/N): ______

Casing Inner Diameter (inches) 2" Initial Depth to Water (feet) 33.42 Depth to bottom of well (feet) 44.62

Tubing inner diameter N/A (in) Tubing & Pump Volume N/A (ml)

Controller settings: Pressure N/A (psi) Discharge (sec.) Recharge N/A (sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

DAILY FIELD ACTIVITY REPORT

Client Name:
Project Name: ESTCP 201584
Contractor:
Weather: Cloudy & Calm

Project Number:
Date: 6-8-16
Arrival Time: 9:30 AM

Time Breakdown: Drive: ______ Work: ______ Standby: ______

Location and Description of Activities:
EPA-165 (124 Creamery Road)

Equipment Used on Project:

Activity Summary and General Remarks:

10:40
Samples collected: Hopewell EPA-165 1 } PNNL
" " " 2
" " " 3 } 1 Liter
" " " 4
" " "

10:56
Hopewell EPA-165 II A 1 #1
#2
#3

11:02
Hopewell EPA-165 DNA 1000mL
11:07 RNA 1000mL preserved

Technician Signature: ______ Date: ______

WIEDEMEIER & ASSOCIATES

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP - Hopewell COC Number: ______

Well ID: MW-16S

Sample Collected by: ______ Date of Collection: 6/8/16

EQUIPMENT

Purging Equipment: ______

Sampling Equipment: ______

Filtering Equipment: ______

Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
YSI 556 Multi Parameter Meter	05C1520 AA	
HACH DR 890 Colorimeter		N/A

FIELD PARAMETERS

Ambient Air Temperature (°F): 62°F Weather Conditions: Cloudy & Calm

Sampling Depth (ft): Pump Inlet@ Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate __/min	Depth to water	Time 10:06	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
				0						
			2:41	1	11.45	.666	6.63	6.47	224.5	Clear no color
			5:31	2	10.94	.667	5.93	5.90	247.8	↓
			8:04	3	10.85	.669	5.79	5.81	247.3	
			10:39	4	10.84	.671	5.75	5.84	242.1	
			13:19	5	10.86	.671	5.69	5.92	235.8	
			15:58	6	10.87	.673	5.72	6.01	230.1	
			18:40	7	10.86	.673	5.74	6.05	225.4	
			21:16	8	10.83	.672	5.75	6.09	222.6	
		Finished	10:22							
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments
					0.00				

PURGE INFORMATION

Starting Flow meter Reading: ______ Ending Flow meter Reading: ______ Flow Rate: ______

Total Volume Purged: ______ Purged Dry (Y/N): ____ Micro purged (Y/N): ____ Minimal purged (Y/N): ____

Casing Inner Diameter (inches) 4" Initial Depth to Water (feet) ~~3~~ 13.40' Depth to bottom of well (feet) ~~30~~ 29.92

Tubing inner diameter .17 (in) Tubing & Pump Volume ______ (ml)

Controller settings: Pressure ___ (psi) Discharge (sec.) Recharge ______ (sec.)

30.2

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

.28

D:\THWA\Admin\Forms - Field\Groundwater Purge and Sampling Form.doc

WIEDEMEIER & ASSOCIATES

Page ___ of ___

DAILY FIELD ACTIVITY REPORT

Client Name: ______________________
Project Name: ESTCP 201584
Contractor: ______________________
Weather: 58°F Light Rain

Project Number: ______________________
Date: 6-8-16
Arrival Time: 13:50

Time Breakdown: Drive: _______ Work: _______ Standby: _______

Location and Description of Activities:

EPA 15D 45-55 screen interval?
167 Creamery Rd
Hopewell Junction NY

Equipment Used on Project:

Activity Summary and General Remarks:

Depth to Water 19.9 ft
Bottom Well 49.2 ft
Screened Interval 45-55 ft ? per Dianna Cutt
flush mounted well 8.5 inches TOC to ground surface

14:50 Hopewell EPA-15D Sample 1 } PNNL
2
3
4

15:00 Hopewell EPA-15D III A2 #1 } Clemson
#2
#3

15:10 Hopewell EPA-15D DNA 1000 ml } Microbial Insights

15:16

Technician Signature: ______________________ Date: ______________

WIEDEMEIER & ASSOCIATES

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP 201584 Hopewell COC Number:

Well ID: EPA-15D 167 Creamery Rd

Sample Collected by: JW / BW / DC Date of Collection: 6-8-16

EQUIPMENT

Purging Equipment:

Sampling Equipment:

Filtering Equipment:

Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	Serial Number	Date Calibrated
YSI 556 Multi Parameter Meter	05C1520 AA	
HACH DR 890 Colorimeter		N/A

FIELD PARAMETERS

Ambient Air Temperature (°F): 58 Weather Conditions: Light Rain

Sampling Depth (ft): Pump Inlet@ Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate __/min	Depth to water	Time 14:18	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
				0	13.07	.337	13.42	7.54	89.7	Clear
			4:17	1	11.47	.646	4.99	7.21	134.4	Clear no color
			7:57	2	11.15	.678	4.33	7.15	147.9	clear no color
			11:43	3	11.06	.710	3.85	7.07	154.3	Clear no color brown
		15.28	15:28	4	11.05	.730	3.82	7.03	158.4	Clear faint color
			19:08	5	11.04	.743	4.14	6.95	163.0	Clear slight brown color
			23.07	6						
				7						
		Stopped		14:42						
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments
					0.00				

PURGE INFORMATION

Starting Flow meter Reading:________ Ending Flow meter Reading:________ Flow Rate:__________

Total Volume Purged: 6 gal Purged Dry (Y/N): Micro purged (Y/N): Minimal purged (Y/N):

Casing Inner Diameter (inches) 4 Initial Depth to Water (feet) 19.9 Depth to bottom of well (feet) 42.2

Tubing inner diameter .17 (in) Tubing & Pump Volume_______(ml)

Controller settings: Pressure___(psi) Discharge (sec.) Recharge__________(sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

WIEDEMEIER & ASSOCIATES

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP - Hopewell
COC Number:
Well ID: MW-16D
Sample Collected by:
Date of Collection: 6-8-16

EQUIPMENT

Purging Equipment:
Sampling Equipment:
Filtering Equipment:
Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
YSI 556 Multi Parameter Meter	05C1520 AA	
HACH DR 890 Colorimeter		N/A

FIELD PARAMETERS

Ambient Air Temperature (°F): 62°F
Weather Conditions: Cloudy & Calm
Sampling Depth (ft): Pump Inlet@
Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate __/min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments

PURGE INFORMATION

Starting Flow meter Reading: ________ Ending Flow meter Reading: ________ Flow Rate: __________

Total Volume Purged: ________ Purged Dry (Y/N): _____ Micro purged (Y/N): _____ Minimal purged (Y/N): ____

Casing Inner Diameter (inches) 4 Initial Depth to Water (feet) 13.44' Depth to bottom of well (feet) 48.42'

Tubing inner diameter _______ (in) Tubing & Pump Volume _______ (ml)

Controller settings: Pressure ___ (psi) Discharge (sec.) Recharge __________ (sec.)

48.7

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT

Where WCT = Water Column Thickness (feet) -.28

48.42

WIEDEMEIER & ASSOCIATES

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Chain of Custody Record

STL-4124 (0901)

SEVERN TRENT **STL**
Severn Trent Laboratories, Inc.

STL Denver
4955 Yarrow Street
Arvada, CO 80002

Client	Todd Wiedemeier - ESTCP
Address	309 Coronado Dr
City	Sedalia
State	CO
Zip Code	80135
Project Name and Location (State)	Hopewell Junction NPL Site
Contract/Purchase Order/Quote No.	Hopewell Junction NY
Project Manager	Todd Wiedemeier
Telephone Number (Area Code)/Fax Number	303-670-7999
Site Contact	Todd W/
Lab Contact	Brady Lee
Carrier/Waybill Number	
Date	6-8-16
Lab Number	PNNL
Chain of Custody Number	324052
Page	1 of 1

Sample I.D. No. and Description (Containers for each sample may be combined on one line)	Date	Time	Matrix: Air	Aqueous	Sed.	Soil	Containers & Preservatives: Unpres.	H2SO4	HNO3	HCl	NaOH	ZnAc/NaOH	Analysis (Attach list if more space is needed): EAP	qPCR	Special Instructions/ Conditions of Receipt
Hopewell EPA-16S Sample 1	6-8-16	10:40		✓									✓	✓	
Hopewell EPA-16S Sample 2	6-8-16	↓		✓									✓	✓	
Hopewell EPH-16S Sample 3	6-8-16	↓		✓									✓	✓	
Hopewell EPA-16S Sample 4	6-8-16	↓		✓									✓	✓	
Hopewell EPA-15D Sample 1	6-8-16	14:50		✓									✓	✓	
Hopewell EPH-15D Sample 2	6-8-16	↓		✓									✓	✓	
Hopewell EPH-15D Sample 3	6-8-16	↓		✓									✓	✓	
Hopewell EPA-15D Sample 4	6-8-16	↓		✓									✓	✓	
Trip Blank DIW#15 16-16 SB	6-8-16	10:40		✓									✓	✓	

Possible Hazard Identification
☒ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal
☐ Return To Client ☐ Disposal By Lab ☐ Archive For ____ Months (A fee may be assessed if samples are retained longer than 1 month)

Turn Around Time Required
☒ 24 Hours ☐ 48 Hours ☐ 7 Days ☐ 14 Days ☐ 21 Days ☐ Other____

QC Requirements (Specify)

	Date	Time		Date	Time
1. Relinquished By: Barbara Wilson	6-8-16	17:35	1. Received By		
2. Relinquished By			2. Received By		
3. Relinquished By			3. Received By		

Comments

DISTRIBUTION: WHITE - Returned to Client with Report; CANARY - Stays with the Sample; PINK - Field Copy

Chain of Custody Record

SEVERN TRENT **STL**

Severn Trent Laboratories, Inc.

STL Denver
4955 Yarrow Street
Arvada, CO 80002

STL-4124 (0901)

Client: ESTCP-Todd Wiedemeier

Project Manager: Todd Wiedemeier

Date: 6-8-16

Chain of Custody Number: 324051

Address: 309 Coronado Dr

Telephone Number (Area Code)/Fax Number: 303-670-7999

Lab Number: Clemson

Page 1 of 1

City: Sedalia | State: CO | Zip Code: 80135

Site Contact: Todd W

Lab Contact: David Freedman

Project Name and Location (State): Hopewell Junction NPL Site Hopewell Junction NY

Carrier/Waybill Number:

Contract/Purchase Order/Quote No.: N/A

Analysis (Attach list if more space is needed): Assay TCE Degradation

Special Instructions/ Conditions of Receipt

Sample I.D. No. and Description (Containers for each sample may be combined on one line)	Date	Time	Matrix: Air	Aqueous	Sed.	Soil	Containers & Preservatives: Unpres.	H2SO4	HNO3	HCl	NaOH	ZnAc/ NaOH	Assay TCE Degradation
Hopewell EPA-16S III A1 #1	6-8-16	10:56		✓									✓
Hopewell EPA-16S III A1 #2	6-8-16	↓		✓									✓
Hopewell EPA-16S III A1 #3	6-8-16	↓		✓									✓
Hopewell EPA-15D III A2 #1	6-8-16	15:00		✓									✓
Hopewell EPA-15D III A2 #2	6-8-16	↓		✓									✓
Hopewell EPA-15D III A2 #3	6-8-16	↓		✓									✓

Possible Hazard Identification: ☑ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal: ☐ Return To Client ☐ Disposal By Lab ☐ Archive For ____ Months (A fee may be assessed if samples are retained longer than 1 month)

Turn Around Time Required: ☑ 24 Hours ☐ 48 Hours ☐ 7 Days ☐ 14 Days ☐ 21 Days ☐ Other____

QC Requirements (Specify)

	Date	Time		Date	Time
1. Relinquished By: Barbara Wilson	6-8-16	16:19	1. Received By		
2. Relinquished By			2. Received By		
3. Relinquished By			3. Received By		

Comments

DISTRIBUTION: WHITE - Returned to Client with Report; CANARY - Stays with the Sample; PINK - Field Copy

Chain of Custody Record

STL-4124 (0901)

SEVERN TRENT **STL**

Severn Trent Laboratories, Inc.

STL Denver
4955 Yarrow Street
Arvada, CO 80002

Client: ESTCP-Todd Wiedemeier	Project Manager: Todd Wiedemeier	Date: 6-8-16	Chain of Custody Number: 324053
Address: 309 Coronado Dr	Telephone Number (Area Code)/Fax Number: 303-670-7999	Lab Number: Microbial Insights	Page 1 of 1
City: Sedalia; State: CO; Zip Code:	Site Contact: Todd W; Lab Contact: Dora Taggart		
Project Name and Location (State): Hopewell Junction NPL Site, Hopewell Junction NY	Carrier/Waybill Number:		
Contact/Purchase Order/Quote No.: N/A			

Sample I.D. No. and Description (Containers for each sample may be combined on one line)	Date	Time	Matrix: Air	Aqueous	Sed.	Soil	Containers & Preservatives: Unpres.	H2SO4	HNO3	HCl	NaOH	ZnAc/NaOH	Analysis (Attach list if more space is needed)	Special Instructions/ Conditions of Receipt
Hopewell EPH-16S DNA 1000 mL	6-8-16	11:02		✓			per Dora Taggart							
Hopewell EPA-16S RNA 1000 mL	6-8-16	11:07		✓										
Hopewell EPA-15D DNA 1000 mL	6-8-16	15:10		✓										
Hopewell EPA-15D RNA 1000 mL	6-8-16	15:16		✓										

Possible Hazard Identification
☑ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal
☐ Return To Client ☐ Disposal By Lab ☐ Archive For ____ Months (A fee may be assessed if samples are retained longer than 1 month)

Turn Around Time Required
☑ 24 Hours ☐ 48 Hours ☐ 7 Days ☐ 14 Days ☐ 21 Days ☐ Other____

QC Requirements (Specify)

	Date	Time		Date	Time
1. Relinquished By: Barbara Wilson	6-8-16	16:07	1. Received By		
2. Relinquished By			2. Received By		
3. Relinquished By			3. Received By		

Comments

DISTRIBUTION: WHITE - Returned to Client with Report; CANARY - Stays with the Sample; PINK - Field Copy

REPORT TO:

Name: John Wilson
Company: [illegible]
Address: PO Box 1566
[illegible]

email: [illegible]
Phone: [illegible]
Fax:

Project Manager:
Project Name: [illegible] Hopewell
Project No.:

INVOICE TO: (For Invoices paid by a third party it is imperative that all information be provided)

Name:
Company:
Address:

email:
Phone:
Fax:

Purchase Order No.
Subcontract No.
MI Quote No.

microbialinsights

10515 Research Dr
Knoxville, TN 37932
865-573-8188

www.microbe.com

Please Check One:
☐ More samples to follow
☐ No Additional Samples

Report Type: ☐ Standard (default) ☐ Microbial Insights Level III raw data(15% surcharge) ☐ Microbial Insights Level IV (25% surcharge) ☐ Comprehensive Interpretive(15%) ☐ Historical Interpretive (35%)

EDD type: ☐ Microbial Insights Standard (default) ☐ All other available EDDs (5% surcharge) Specify EDD Type:

Please contact us with any questions about the analyses or filling out the COC at (865) 573-8188 (9:00 am to 5:00 pm EST, M-F). After hours email: customerservice@microbe.com

Sample Information					**Analyses**				**CENSUS: Please select the target organism/gene**																							
MI ID (Laboratory Use Only)	Sample Name	Date Sampled	Time Sampled	Matrix	**PLFA**	**NGS**	**QuantArray Chlor**	**QuantArray Petro**	**DHC (Dehalococcoides)**	DHC Functional genes (bvc, tce, vcr)	DHBt (Dehalobacter)	DHG (Dehalogenimonas)	DSM (Desulfuromonas)	DSB (Desulfitobacterium)	EBAC (Total)	SRB (Sulfate Reducing Bacteria-APS)	MGN (Methanogens)	MOB (Methanotrophs)	SMMO	DNF (Dentrifiers-nirS and nirK)	AOB (ammonia oxidizing bacteria)	PM1 (MTBE aerobic)	RMO (Toluene Monooxygenase)	RDEG (Toluene Monooxygenase)	PHE (Phenol Hydroxylase)	NAH (Napthalene-aerobic)	BSSA (Toluene/Xylene-Anaerobic)	add. qPCR:	**RNA (Expression Option)***	Other:	Other:	Other:
	[illegible]	6-8	11:02	aq																												
	EPA 14S DNA	6-8	11:07	aq																												
	EPA 14S RNA																															
	EPA-15D DNA	6-8	15:10																													
	EPA-15D RNA	6-8	15:16																													

Relinquished by: [illegible] Wilson **Received by:** **Date**

6-8-16
11:07

It is vital that chain of custody is filled out correctly & that all relative information is provided.
Failure to provide sufficient and/or correct information regarding reporting, invoicing & analyses requested information may result in delays for which MI will not be liable.

NW

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP – Hopewell
COC Number:
Well ID: EPA-16-D
Sample Collected by: THW
Date of Collection: 6/8/16

EQUIPMENT
~~Purging~~ Equipment: HMA-453S
Sampling Equipment:
Filtering Equipment:
Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	~~Serial Number~~	Date Calibrated
~~YSI 556 Multi Parameter Meter~~	~~05C1520 AA~~	
~~HACH DR 890 Co~~lorimeter		N/A

FIELD PARAMETERS
Ambient Air Temperature (°F):
Weather Conditions:
Sampling Depth (ft): Pump Inlet@
Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate __/min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
	11:20	Zero	Tool	Depth	& lower into	well			Zeroed @	Ground Surface
	11:23	Tool	In	Water						
	11:36	Calib		1	Zero =	70.532				
					5E-3 =	1105.86				
	11:40	Run	1	HPWL	EPA16D	Down	Calib	1		Speed 8.4 Ft/min
		Run	1	HPWL	EPA16D	up	Calib	1		" "
										" "
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments

PURGE INFORMATION   Tool Reads 49.09' BGS   Stick up = 5"

Starting Flow meter Reading: ________ Ending Flow meter Reading: ________ Flow Rate: ________

Total Volume Purged: ________ Purged Dry (Y/N): _____ Micro purged (Y/N): _____ Minimal purged (Y/N): ____

Casing Inner Diameter (inches) ______ Initial Depth to Water (feet) 13.44 Depth to bottom of well (feet) 48.42 BTOC
Tubing inner diameter ______ (in) Tubing & Pump Volume ______ (ml)
Controller settings: Pressure ___ (psi) Discharge _(sec.) Recharge ________ (sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT   Where WCT = Water Column Thickness (feet)

Cloudy & Cool

WIEDEMEIER & ASSOCIATES

9/20 mm

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP – Hopewell

COC Number:

Well ID: EPA-16-S

Sample Collected by: THW

Date of Collection: 6/8/16

EQUIPMENT

~~Purging~~ Equipment: HMA 453-S

Sampling Equipment:

Filtering Equipment:

Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	Serial Number	Date Calibrated
YSI 556 Multi Parameter Meter	05C1520 AA	
HACH DR 890 Colorimeter		N/A

FIELD PARAMETERS

Ambient Air Temperature (°F):

Weather Conditions: Cloudy & Cool ~65°

Sampling Depth (ft): Pump Inlet@

Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate __/min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
	11:57		Start ⇒ ~~[illegible]~~	Zero	Tool	to	Ground	Surface		
	11:58		Run 1	HPWL	Run 1	EPA16S	Down	Calib 1 6-8-16		
	12:01		Run 1	HPWL	Run 1	EPA16S	UP	Calib 1 6-8-16		
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments

PURGE INFORMATION Stick up = 4" ⇒ Not a Stick up = Flush mount TOC = 4 inches BGS

Starting Flow meter Reading:_______ Ending Flow meter Reading:_______ Flow Rate:_______

Total Volume Purged:_______ Purged Dry (Y/N):_____ Micro purged (Y/N):_____ Minimal purged (Y/N):____

Casing Inner Diameter (inches) 4" Initial Depth to Water (feet) 13.4 Depth to bottom of well (feet) 29.92

Tubing inner diameter_______(in) Tubing & Pump Volume_______(ml)

Controller settings: Pressure___(psi) Discharge (sec.) Recharge_______(sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

2 m

WIEDEMEIER & ASSOCIATES

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP - Hopewell
COC Number:
Well ID: EPA-15D
Sample Collected by: THW
Date of Collection: 6-8-16

EQUIPMENT
~~Purging~~ Equipment: HMA-453-S
Sampling Equipment:
Filtering Equipment:
Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
YSI 556 Multi Parameter Meter	05C1520 AA	
HACH DR 890 Colorimeter		N/A

FIELD PARAMETERS
Ambient Air Temperature (°F):
Weather Conditions:
Sampling Depth (ft): Pump Inlet@
Reference Point: Top of inner PVC casing

~~Flow meter~~ (gallons)	Flow rate __/min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
Time 15:38 Zero Tool to Ground Surface										
15:39 Sonde goes down to 40.84 before										Hitting Bottom
15:52 Pulling Sonde to calibrator										
(Sonde in water from 15:39 - 15:52)										
15:55 Calibration 1 Zero = 75.065										Down Speed 8.4 ft/min
5E-3 = 1137.69										up Speed 8.7 ft/min
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments

PURGE INFORMATION

Starting Flow meter Reading: ________ Ending Flow meter Reading: ________ Flow Rate: ________

Total Volume Purged: ________ Purged Dry (Y/N): _____ Micro purged (Y/N): _____ Minimal purged (Y/N): ____

Casing Inner Diameter (inches) 4" Initial Depth to Water (feet) 19.9 Depth to bottom of well (feet) 42.2
Tubing inner diameter ______(in) Tubing & Pump Volume ______(ml)
Controller settings: Pressure ___(psi) Discharge _(sec.) Recharge ________(sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT   Where WCT = Water Column Thickness (feet)

WIEDEMEIER & ASSOCIATES

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP - Hopewell COC Number:
Well ID: EPA 21-S
Sample Collected by: THWLTTW Date of Collection: 6-8-16

EQUIPMENT
~~Purging~~ Equipment: HMA-453-S
Sampling Equipment:
Filtering Equipment:
Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
~~YSI 556 Multi Parameter Meter~~	~~05C1520 AA~~	
HACH ~~DR 890 Colorimeter~~		N/A

FIELD PARAMETERS
Ambient Air Temperature (°F): Weather Conditions:
Sampling Depth (ft): Pump Inlet@ Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate __/min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
	17:25 Zero Tool									
	17:28 tool Hits Bottom @ 26.05									
		Tool in Water Equilibrating With Temp								
	17:40		Calibration 1 Zero = 169.75							
						SE-3 = 1140.52				
	17:43			Run 1 Down HPWL EPA 21S Down Calib 1-6-8-16 Down Speed 8.5 ft/min						
				Hit Bottom @ 26.04						
	17:47			Run 1 up HPWL EPA 21S up Calib 1-6-8-16 up Speed ~8.7						
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments

PURGE INFORMATION Flush Mount TOC = 8.25" BGS

Starting Flow meter Reading: ________ Ending Flow meter Reading: ________ Flow Rate: __________

Total Volume Purged: ________ Purged Dry (Y/N): _____ Micro purged (Y/N): _____ Minimal purged (Y/N): ____

Casing Inner Diameter (inches) 4" Initial Depth to Water (feet) 16.95 Depth to bottom of well (feet) 25.7
Tubing inner diameter _______ (in) Tubing & Pump Volume _______ (ml)
Controller settings: Pressure ___ (psi) Discharge (sec.) Recharge ___________ (sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

WIEDEMEIER & ASSOCIATES

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP- Hopewell
COC Number:
Well ID: EPA 21D
Sample Collected by: THW/JTW
Date of Collection: 6-8-16

EQUIPMENT
~~Purging~~ Equipment: HMA-453-S
Sampling Equipment:
Filtering Equipment:
Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
~~YSI 556 Multi Parameter Meter~~	~~05C1520 AA~~	
HAC~~H DR 890 Colorimeter~~		N/A

FIELD PARAMETERS
Ambient Air Temperature (°F):
Weather Conditions:
Sampling Depth (ft): Pump Inlet@
Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate __/min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
		17:53 Zero Tool								
		Used Calibration from ~~21D~~ 21S								
	17:54 Start Probe Down hole for Run 1									
		Run 1 DN/HPWL EPA 21D Down Calib 1-6-8-16								Down Speed 8.5 ft/sec
17:59:20 Run 1 UP/HPWL EPA 21D UP " " " "										
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments

TOC is 1 inch BGS => Flush Mount

PURGE INFORMATION

Starting Flow meter Reading:________ Ending Flow meter Reading:________ Flow Rate:__________

Total Volume Purged:________ Purged Dry (Y/N):_____ Micro purged (Y/N):_____ Minimal purged (Y/N):____

Casing Inner Diameter (inches) 4" Initial Depth to Water (feet) 17.15 Depth to bottom of well (feet) 37.2
Tubing inner diameter_______(in) Tubing & Pump Volume_______(ml)
Controller settings: Pressure___(psi) Discharge (sec.) Recharge__________(sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

WIEDEMEIER & ASSOCIATES

DAILY FIELD ACTIVITY REPORT

Client Name:
Project Name: ESTCP 201584 Hopewell
Contractor:
Weather: 60°F mostly cloudy

Project Number:
Date: 6-9-16
Arrival Time:

Time Breakdown: Drive: Work: Standby:

Location and Description of Activities:
EPA 12 Shallow

Equipment Used on Project:

Activity Summary and General Remarks:
Depth to water 10.4ft BTOC
Depth bottom well 28.32ft BTOC (28.60 - 0.28) = 28.32ft

10:15 Hopewell EPA12S Sample 1, 2, 3, 4 } PNNL 1 Liter

10:30 Hopewell EPA12S III B1 # 1, III B1 # 2, III B1 # 3 } Clemson ~100 ml
Background Hopewell EPA12S ~150mL

10:43 Hopewell EPA 12S DNA 1000mL } Microbial Insights
10:50 Hopewell EPA 12S RNA 1000mL

nominal 500 mL = 510mL
both Nalgene 500 mL Beakers

Technician Signature:
Date:

WIEDEMEIER & ASSOCIATES

C:\Admin\Forms\Daily Field Activity Report.doc

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP 201584 Hopewell
COC Number:
Well ID: EPA - 12S
Sample Collected by: JW / BW / TW / DC
Date of Collection: 6/9/16

EQUIPMENT

Purging Equipment:
Sampling Equipment:
Filtering Equipment:
Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
YSI 556 Multi Parameter Meter	05C1520 AA	
HACH DR 890 Colorimeter		N/A

FIELD PARAMETERS

Ambient Air Temperature (°F): 60°
Weather Conditions: Mostly Cloudy
Sampling Depth (ft): Pump Inlet@
Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate ___/min	Depth to water	Time 9:58	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
				0	12.23	.970	10.89	7.19	242.6	Clear no color
			4:35	1	10.62	1.01	6.81	6.70	272.8	Clear no color
			6:17	2	10.56	1.009	6.77	6.71	269.8	clear no color
			8:10	3	10.55	1.009	6.73	6.76	264.7	clear no color
			10:30	4	10.53	1.004	6.72	6.61	270.9	clear no color
		Stopped		10:09						
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments
					0.00				

PURGE INFORMATION

Starting Flow meter Reading: ________ Ending Flow meter Reading: ________ Flow Rate: ________

Total Volume Purged: 4 Purged Dry (Y/N): _____ Micro purged (Y/N): _____ Minimal purged (Y/N): _____

Casing Inner Diameter (inches) 4 Initial Depth to Water (feet) 10.4' Depth to bottom of well (feet) 28.32'

Tubing inner diameter .17 (in) Tubing & Pump Volume ______ (ml)

Controller settings: Pressure ___ (psi) Discharge (sec.) Recharge ________ (sec.)

28.60
-.28
28.32

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

All purge water containerized in 5 gallon DOT - Approved container per work Plan & Treated

WIEDEMEIER & ASSOCIATES

DAILY FIELD ACTIVITY REPORT

Client Name:
Project Name: ESTCP 201584 Hopewell
Contractor:
Weather: 67°F Mostly clear/Sunny

Project Number:
Date: 6-9-16
Arrival Time: 13:22

Time Breakdown: Drive: Work: Standby:

Location and Description of Activities:
EPA 10S

Equipment Used on Project:
2ft off bottom for purging

Activity Summary and General Remarks:

Depth to water 20.2ft BTOC
Depth Well ~~30.4~~
34.65 ft BTOC
.28 ft correction sensor + bottom probe.
Distance TOC and ground surface 6.2 inches

51 gal

14:20 Hopewell EPA 10S Sample 1
Hopewell EPA 10S Sample 2
Hopewell EPA 10S Sample 3
Hopewell EPA 10 S Sample 4
} PNNL 1 Liter + 1 Trip Blank (1 Liter)

14:33 Hopewell EPA 10S III B2 #1
Hopewell EPA 10S III B2 #2
Hopewell EPA 10S III B2 #3
} Clemson

Background Hopewell EPA 10S ~150mL Transfer 14:50 To Background Hopewell EPA 15D Extra 6 ~150mL
Transfer Background Hopewell EPA 16S Extra 12 ~150mL
14:41 Hopewell EPA 10S DNA 1000mL
14:51 Hopewell EPA 10S ~~RNA~~ RNA 1000mL preserved

Technician Signature: Date:

WIEDEMEIER & ASSOCIATES

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP 201584 Hopewell
COC Number:
Well ID: EPA 105
Sample Collected by: JW/BW/TW/DC
Date of Collection: 6-9-16

EQUIPMENT

Purging Equipment:
Sampling Equipment:
Filtering Equipment:
Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
YSI 556 Multi Parameter Meter	05C1520 AA	
HACH DR 890 Colorimeter		N/A

FIELD PARAMETERS

Ambient Air Temperature (°F): 67
Weather Conditions: mostly clear/Sunny
Sampling Depth (ft): Pump Inlet@
Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate ___/min	Depth to water	Time 13:55	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
				0	12.19	.522	5.55	6.74	95.7	Clear no color
			3:00	1	10.68	.620	4.79	6.32	133.4	clear no color
			5:11	2	9.93	.712	5.49	6.38	150.2	clear no color
			7:31	3	9.87	.756	5.75	6.05	179.1	clear no color
			9:49	4	9.82	.771	5.86	6.31	172.8	clear no color
			Stopped		14:07					
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments

PURGE INFORMATION

Starting Flow meter Reading:________ Ending Flow meter Reading:________ Flow Rate:__________

Total Volume Purged: 4 Purged Dry (Y/N):_____ Micro purged (Y/N):_____ Minimal purged (Y/N):____

Casing Inner Diameter (inches) 4 Initial Depth to Water (feet) 9.02 Depth to bottom of well (feet) 34.65

Tubing inner diameter .17 (in) Tubing & Pump Volume_______(ml)

Controller settings: Pressure___(psi) Discharge (sec.) Recharge__________(sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

WIEDEMEIER & ASSOCIATES

Chain of Custody Record

SEVERN TRENT **STL**
Severn Trent Laboratories, Inc.

STL Denver
4955 Yarrow Street
Arvada, CO 80002

STL-4124 (0901)

Client: ESTCP-Todd Wiedemeier	Project Manager: Todd Wiedemeier	Date: 6-9-16	Chain of Custody Number: 324050
Address: 309 Coronado Dr	Telephone Number (Area Code)/Fax Number: 303-670-7999	Lab Number: Microbial Insights	Page 1 of 1
City: Sedalia; State: CO; Zip Code: 80135	Site Contact: Todd W; Lab Contact: Dora Taggart		
Project Name and Location (State): Hopewell Junction NPL Site	Carrier/Waybill Number:		
Contract/Purchase Order/Quote No.: Hopewell Junction NY			

Sample I.D. No. and Description (Containers for each sample may be combined on one line)	Date	Time	Air	Aqueous	Sed.	Soil	Unpres.	H2SO4	HNO3	HCl	NaOH	ZnAc/NaOH	Analysis (Attach list if more space is needed)	Special Instructions/ Conditions of Receipt
Hopewell EPA 12S DNA 1000mL	6-9-16	10:43		✓			per Dora Taggart							
Hopewell EPA 12S RNA 1000mL	6-9-16	10:50		✓										
Hopewell EPA 10S DNA 1000mL														
Hopewell EPA 10S RNA 1000mL														

Possible Hazard Identification
☒ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal
☐ Return To Client ☐ Disposal By Lab ☐ Archive For ______ Months (A fee may be assessed if samples are retained longer than 1 month)

Turn Around Time Required
☒ 24 Hours ☐ 48 Hours ☐ 7 Days ☐ 14 Days ☐ 21 Days ☐ Other______

QC Requirements (Specify)

	Date	Time		Date	Time
1. Relinquished By: Barbara Wilson	6-9-16	16:10	1. Received By		
2. Relinquished By			2. Received By		
3. Relinquished By			3. Received By		

Comments

DISTRIBUTION: WHITE - Returned to Client with Report; CANARY - Stays with the Sample; PINK - Field Copy

Chain of Custody Record

STL-4124 (0901)

SEVERN TRENT **STL**
Severn Trent Laboratories, Inc.

STL Denver
4955 Yarrow Street
Arvada, CO 80002

Client	ESTCP-Todd Wiedemeier
Project Manager	Todd Wiedemeier
Date	6-9-16
Chain of Custody Number	324049
Address	309 Coronado Dr
Telephone Number (Area Code)/Fax Number	303-670-7999
Lab Number	PNNL
Page	1 of 1
City	Sedalia
State	CO
Zip Code	80135
Site Contact	Todd W/
Lab Contact	Brady Lee
Project Name and Location (State)	Hopewell Junction NPL Site. Hopewell Junction NY
Carrier/Waybill Number	
Contract/Purchase Order/Quote No.	N/A

Sample I.D. No. and Description (Containers for each sample may be combined on one line)	Date	Time	Matrix: Air	Matrix: Aqueous	Matrix: Sed.	Matrix: Soil		Containers & Preservatives: Unpres.	H2SO4	HNO3	HCl	NaOH	ZnAc/NaOH		Analysis (Attach list if more space is needed): EAP	qPCR	Special Instructions/ Conditions of Receipt
Hopewell EPA 12S Sample 1	6-9-16	10:15		✓											✓	✓	
Hopewell EPA 12S Sample 2	↓	↓		✓											✓	✓	
Hopewell EPA 12S Sample 3	↓	↓		✓											✓	✓	
Hopewell EPA 12S Sample 4	↓	↓		✓											✓	✓	
Hopewell EPA 10S Sample 1	6-9-16	14:20		✓											✓	✓	
Hopewell EPA 10S Sample 2	↓	↓		✓											✓	✓	
Hopewell EPA 10S Sample 3	↓	↓		✓											✓	✓	
Hopewell EPA 10S Sample 4	↓	↓		✓											✓	✓	
Trip Blank	6-9-16	10:00		✓											✓	✓	

Possible Hazard Identification
☒ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal
☐ Return To Client ☐ Disposal By Lab ☐ Archive For ______ Months (A fee may be assessed if samples are retained longer than 1 month)

Turn Around Time Required
☒ 24 Hours ☐ 48 Hours ☐ 7 Days ☐ 14 Days ☐ 21 Days ☐ Other______

QC Requirements (Specify)

	Date	Time		Date	Time
1. Relinquished By: Barbara Wilson	6-9-16	16:18	1. Received By		
2. Relinquished By			2. Received By		
3. Relinquished By			3. Received By		

Comments

DISTRIBUTION: WHITE - Returned to Client with Report; CANARY - Stays with the Sample; PINK - Field Copy

Chain of Custody Record

STL-4124 (0901)

SEVERN TRENT **STL**

Severn Trent Laboratories, Inc.

STL Denver
4955 Yarrow Street
Arvada, CO 80002

Client: ESTCP-Todd Wiedemeier	Project Manager: Todd Wiedemeier		Date: 6-9-16	Chain of Custody Number: 342283
Address: 309 Coronado Dr	Telephone Number (Area Code)/Fax Number: 303-670-7999		Lab Number: Clemson	Page 1 of 1
City: Sedalia / State: CO / Zip Code: 80135	Site Contact: Todd W	Lab Contact: David Freedman		
Project Name and Location (State): Hopewell Junction NPL Site, Hopewell Junction NY	Carrier/Waybill Number:			
Contract/Purchase Order/Quote No.: N/A				

Analysis (Attach list if more space is needed): Away TCE degradation

Special Instructions/Conditions of Receipt

Sample I.D. No. and Description (Containers for each sample may be combined on one line)	Date	Time	Matrix: Air	Aqueous	Sed.	Soil	Containers & Preservatives: Unpres.	H2SO4	HNO3	HCl	NaOH	ZnAc/NaOH	Away TCE degradation
Hopewell EPA-12S III B1 #1	6-9-16	10:30		✓									✓
Hopewell EPA-12S III B1 #2	6-9-16	↓		✓									✓
Hopewell EPA-12S III B1 #3	6-9-16	↓		✓									✓
Hopewell EPA 10S III B2 #1	6-9-16	14:33		✓									✓
Hopewell EPA 10S III B2 #2	6-9-16	↓		✓									✓
Hopewell EPA 10S III B2 #3	6-9-16	↓		✓									✓
Background Hopewell EPA 10S	6-9-16	↓		✓		Extra 1							
Transfer background Hopewell EPA 16S		14:50		✓		Extra 12							
Transfer background Hopewell EPA 15D		14:50		✓		Extra 6							

Possible Hazard Identification: ☑ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal: ☐ Return To Client ☐ Disposal By Lab ☐ Archive For ______ Months (A fee may be assessed if samples are retained longer than 1 month)

Turn Around Time Required: ☑ 24 Hours ☐ 48 Hours ☐ 7 Days ☐ 14 Days ☐ 21 Days ☐ Other______

QC Requirements (Specify)

	Date	Time		Date	Time
1. Relinquished By: Barbara Wilson	6-9-16	16:18	1. Received By		
2. Relinquished By			2. Received By		
3. Relinquished By			3. Received By		

Comments

DISTRIBUTION: WHITE - Returned to Client with Report; CANARY - Stays with the Sample; PINK - Field Copy

REPORT TO:
Name: [illegible]
Company: [illegible]
Address: [illegible]
[illegible]
email: [illegible]
Phone: [illegible]
Fax:

Project Manager:
Project Name:
Project No.:

INVOICE TO: (For Invoices paid by a third party it is imperative that all information be provided)
Name:
Company:
Address:
email:
Phone:
Fax:

Purchase Order No.
Subcontract No.
MI Quote No.

microbialinsights
10515 Research Dr
Knoxville, TN 37932
865-573-8188

www.microbe.com

Please Check One:
☐ More samples to follow
☐ No Additional Samples

Report Type: ☐ Standard (default) ☐ Microbial Insights Level III raw data(15% surcharge) ☐ Microbial Insights Level IV (25% surcharge) ☐ Comprehensive Interpretive(15%) ☐ Historical Interpretive (35%)
EDD type: ☐ Microbial Insights Standard (default) ☐ All other available EDDs (5% surcharge) Specify EDD Type:

Please contact us with any questions about the analyses or filling out the COC at (865) 573-8188 (9:00 am to 5:00 pm EST, M-F). After hours email: customerservice@microbe.com

Sample Information					**Analyses**				**CENSUS: Please select the target organism/gene**																							
MI ID (Laboratory Use Only)	Sample Name	Date Sampled	Time Sampled	Matrix	**PLFA**	**NGS**	**QuantArray Chlor**	**QuantArray Petro**	**DHC (Dehalococcoides)**	DHC Functional genes (bvc, tce, vcr)	DHBt (Dehalobacter)	DHG (Dehalogenimonas)	DSM (Desulfuromonas)	DSB (Desulfitobacterium)	EBAC (Total)	SRB (Sulfate Reducing Bacteria-APS)	MGN (Methanogens)	MOB (Methanotrophs)	SMMO	DNF (Dentrifiers-nirS and nirK)	AOB (ammonia oxidizing bacteria)	PM1 (MTBE aerobic)	RMO (Toluene Monooxygenase)	RDEG (Toluene Monooxygenase)	PHE (Phenol Hydroxylase)	NAH (Napthalene-aerobic)	BSSA (Toluene/Xylene-Anaerobic)	add. qPCR:	**RNA (Expression Option)***	Other:	Other:	Other:
	[illegible]								[illegible]																							
	[illegible] DNA	6-9	[illegible]	aq																												
	[illegible] DNA	6-9	11:50	aq																												
	[illegible]																															
	E[illegible]	6-9	14:41	aq																												
	EM[illegible]	6-9	14:57	aq																												

Relinquished by: Barbara Wilson **Received by:** **Date**

6-9-16
16:10

It is vital that chain of custody is filled out correctly & that all relative information is provided.
Failure to provide sufficient and/or correct information regarding reporting, invoicing & analyses requested information may result in delays for which MI will not be liable.

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP - Hopewell
COC Number:
Well ID: EPA-12S
Sample Collected by: THW / DMC
Date of Collection: 6/9/16

EQUIPMENT

~~Purging~~ Equipment: HMA-453S
Sampling Equipment:
Filtering Equipment:
Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
YSI 556 Multi Parameter Meter	05C1520 AA	
HACH DR 890 Colorimeter		N/A

FIELD PARAMETERS

Ambient Air Temperature (°F): 62°
Weather Conditions: Clear & Breezy/Cool
Sampling Depth (ft): ~~Pump Inlet@~~
Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate __/min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
	11:13	Zero Tool & lower into water ⇒ Tool Reads 28.98' bgs @ bottom of hole								
	11:27	Calibrating Tool				Zero = ~~58~~ 97.466				
						5E-3 = 1148.78				
	11:36	Run 1		~~H~~PWL	EPA12S	Down	Run 1	Calib 1	6-9-16	
	11:40	Run 1		HPWL	EPA12S	Up	Run 1	Calib 1		Ran probe up & down at approx 8'/min 6-9-16
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments

PURGE INFORMATION Flush mount TOC is 6" BGS

Starting Flow meter Reading:________ Ending Flow meter Reading:________ Flow Rate:__________

Total Volume Purged:________ Purged Dry (Y/N):_____ Micro purged (Y/N):_____ Minimal purged (Y/N):____

Casing Inner Diameter (inches)______ Initial Depth to Water (feet) 10.4 Depth to bottom of well (feet) 28.32
Tubing inner diameter_______(in) Tubing & Pump Volume_______(ml)
Controller settings: Pressure___(psi) Discharge (sec.) Recharge__________(sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

WIEDEMEIER & ASSOCIATES

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP - Hopewell
COC Number:
Well ID: EPA-12D
Sample Collected by: THW / DMC
Date of Collection: 6-9-16

EQUIPMENT

~~Purging~~ Equipment: HMA-453-S
Sampling Equipment:
Filtering Equipment:
Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
~~YSI 556 Multi Parameter Meter~~	05C1520 AA	
~~HACH DR 890 Colorimeter~~		N/A

FIELD PARAMETERS

Ambient Air Temperature (°F):
Weather Conditions:
Sampling Depth (ft): Pump Inlet@
Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate __/min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
	11:50 zero Tool to ground Surface									
	11:52 Run 1 HPWL EPA 12D Down Run 1 Calib 1 6/9/16									
	11:58 Run 1 HPWL EPA 12D Up Run Calib 1 6/9/16									
										RATE APPROX 8'/min
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments

PURGE INFORMATION Flush mount TOC ~~TO~~ is 6" BGS

Starting Flow meter Reading:________ Ending Flow meter Reading:________ Flow Rate:__________

Total Volume Purged:________ Purged Dry (Y/N):_____ Micro purged (Y/N):_____ Minimal purged (Y/N):____

Casing Inner Diameter (inches) 4 Initial Depth to Water (feet) 10.15 Depth to bottom of well (feet) 43.92' BTOC

Tubing inner diameter_______(in) Tubing & Pump Volume_______(ml)

Controller settings: Pressure___(psi) Discharge (sec.) Recharge__________(sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

44.2

WIEDEMEIER & ASSOCIATES

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP ~ Hopewell
COC Number:
Well ID: EPA105
Sample Collected by: THW / DMC
Date of Collection: 6-9-16

EQUIPMENT
~~Purging~~ Equipment: HMA-453-S SN 5554
Sampling Equipment:
Filtering Equipment:
Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
~~YSI 556 Multi Parameter Meter~~	05C1520 AA	
~~HACH DR 890 Colorimeter~~		N/A

FIELD PARAMETERS
Ambient Air Temperature (°F):
Weather Conditions:
Sampling Depth (ft): Pump Inlet@
Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate ___/min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
										Speed ~ 8 ft/min
		15:40	Zero to Ground Surface							
		15:42	Run 1 Down HPWL EPA215 Down Calib 1							6-9-16
		15:46	Run 1 Up HPWL EPA215 Up Calib 1							6-9-16
		15:51	Run 2 ⇒ Down HPWL EPA215 Down Calib 1							6-9-16
			Run 2 Up → HPWL EPA215 Up Calib 1							6-9-16
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments

PURGE INFORMATION Flush Mount TOC = 6.2" BGS

Starting Flow meter Reading:________ Ending Flow meter Reading:________ Flow Rate:__________

Total Volume Purged:________ Purged Dry (Y/N):_____ Micro purged (Y/N):_____ Minimal purged (Y/N):____

Casing Inner Diameter (inches) 4 Initial Depth to Water (feet) 9.02 Depth to bottom of well (feet) 34.65

Tubing inner diameter_______(in) Tubing & Pump Volume_______(ml)

Controller settings: Pressure___(psi) Discharge (sec.) Recharge__________(sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

Power Lines Overhead

WIEDEMEIER & ASSOCIATES

54.40 31
.28

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP – Hopewell | COC Number: ___
Well ID: EPA 10D
Sample Collected by: THW/DMC | Date of Collection: 6-9-16

EQUIPMENT
Purging Equipment: HMA-453-S Serial Number 5554
Sampling Equipment: ___
Filtering Equipment: ___
Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
YSI 556 Multi Parameter Meter	05C1520 AA	
HACH DR 890 Colorimeter		N/A

FIELD PARAMETERS
Ambient Air Temperature (°F): ___ Weather Conditions: ___
Sampling Depth (ft): Pump Inlet@ ___ Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate __/min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
	14:06	Zero	Tool	to	Ground	Surface				
	14:07	Lower	Tool	into	water	to		Equilibrate		Temp
	TOOL	HITS	BOTTOM	AT	MEASURED	DEPTH	OF 53.02	ftbgs		Down Speed ~8.5 ft/min
	15:26	Calibrate			Zero –	60.86				
					5E-3 =	1151.1				
Down	15:20	Run 1		HPWL	EPA 10D	Down	Run 1	Calib 1		6-9-16
	15:27	Run 1		HPWL	EPA 10D	Up	Run 1	Calib 1		6-9-16
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments

PURGE INFORMATION TOC = 6.75" BGS => Flush mount

Starting Flow meter Reading: ___ Ending Flow meter Reading: ___ Flow Rate: ___
Total Volume Purged: ___ Purged Dry (Y/N): ___ Micro purged (Y/N): ___ Minimal purged (Y/N): ___
Casing Inner Diameter (inches) 4 Initial Depth to Water (feet) 9.20 Depth to bottom of well (feet) 54.12
Tubing inner diameter ___ (in) Tubing & Pump Volume ___ (ml)
Controller settings: Pressure ___ (psi) Discharge (sec.) Recharge ___ (sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

Power Lines overhead

WIEDEMEIER & ASSOCIATES

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP-Hopewell
COC Number:
Well ID: EPA-19D
Sample Collected by: THW/JTW
Date of Collection: 6-10-16

EQUIPMENT

~~Purging~~ Equipment: HMA-453-S
Sampling Equipment:
Filtering Equipment:
Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
~~YSI 556 Multi Parameter Meter~~	~~05C1520 AA~~	
~~HACH DR 890 Colorimeter~~		N/A

FIELD PARAMETERS

Ambient Air Temperature (°F): 63
Weather Conditions: Clear & Breezy
Sampling Depth (ft): Pump Inlet@
Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate __/min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
			09:35	Zero Tool to ground surface						
			09:37	Tool in water to equilibrate TOC						
			09:39	Tool reads 49.56' bgs when bottomed out						
			09:53	Calibration 1 Zero = 65.7						
				5E-3 = 1128.81						
			09:59	Run 1 ⇒ HPWL EPA-19D Down Run 1 Calib 1 6-10-16						
			10:06	Run 1 ⇒ HPWL EPA-19D Up Run 1 Calib 1 6-10-16						
										Speed up & down ~7.7 ft/min
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments

PURGE INFORMATION

Starting Flow meter Reading:________ Ending Flow meter Reading:________ Flow Rate:__________

Total Volume Purged:________ Purged Dry (Y/N):_____ Micro purged (Y/N):_____ Minimal purged (Y/N):____

Casing Inner Diameter (inches)______ Initial Depth to Water (feet) 23.7' BTOC Depth to bottom of well (feet) 48.87' BTOC

Tubing inner diameter 4 (in) Tubing & Pump Volume_______(ml)

Controller settings: Pressure___(psi) Discharge (sec.) Recharge__________(sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

49.56

48.85 (8 ' 01)
.28
48.87

WIEDEMEIER & ASSOCIATES

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Z4.80
,28
52

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP-Hopewell
COC Number:
Well ID: EPA-195
Sample Collected by: THW/JTW
Date of Collection: 6-10-16

EQUIPMENT
~~Purging~~ Equipment: HMA-453-S SN/5554
Sampling Equipment:
Filtering Equipment:
Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
~~YSI 556 Multi Parameter~~ Meter	~~05C1520 AA~~	
~~HACH DR 890 Colori~~meter		N/A

FIELD PARAMETERS
Ambient Air Temperature (°F): 66
Weather Conditions: Clear, Cool & Breezy
Sampling Depth (ft): Pump Inlet@
Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate __/min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
		10:16 Zero Tool & Start Run								
Run 1										
Down		Run 1	HPWL		EPA-195 Down Run 1 Calib 1					6-10-16
Up		Run 1	HPWL		EPA-195 Up Run 1 Calib 1					6-10-16
										Down & Up speed 27.9 ft/min
Run 2			Tool Reads 25.26 @ Bottom							
Down		Run 2	HPWL		EPA-195 Down Run 2 Calib 1					6-10-16
Up		Run 2	HPWL		EPA-195 Up Run 2 Calib 1					6-10-16
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments

PURGE INFORMATION TOC is 6" below Ground Surface => Flush mount

Starting Flow meter Reading:________ Ending Flow meter Reading:________ Flow Rate:__________

Total Volume Purged:________ Purged Dry (Y/N):_____ Micro purged (Y/N):_____ Minimal purged (Y/N):____

Casing Inner Diameter (inches)______ Initial Depth to Water (feet) 23.56 BTOC Depth to bottom of well (feet) 24.52 BTOC
Tubing inner diameter 4 (in) Tubing & Pump Volume_______(ml)
Controller settings: Pressure___(psi) Discharge (sec.) Recharge__________(sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP - Hopewell
COC Number:
Well ID: EPA-8D
Sample Collected by: THW/JTW
Date of Collection: 6-10-16

EQUIPMENT

~~Purging~~ Equipment: HMA-453-S
Sampling Equipment:
Filtering Equipment:
Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
~~YSI 556 Multi Parameter~~ Meter	05C1520 AA	
~~HACH DR 890 Colorimeter~~		N/A

FIELD PARAMETERS
Ambient Air Temperature (°F):
Weather Conditions:
Sampling Depth (ft): Pump Inlet@
Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate /min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
		10:59 Zero Tool To Ground Surface								
			Did not recalibrate tool from last well because surrounded by lots of steel => could not find area without large steel pieces or structure							
Down	Run 1		HPWL EPA-8D Down Run 1 Calib 1 6-10-16							
Up	Run 1		HPWL EPA-8D Up Run 1 Calib 1 6-10-16							
				Tool Reads Bottom @ 81.78' BGS						
Run 2	HPWL EPA-8D Down Run 2 Calib 1 6-10-16 Speed ~ 8ft/min									
Run 2	HPWL EPA-8D Up Run 2 Calib 1 6-10-16									
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

Out of Hole @ 11:46

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments

PURGE INFORMATION Flush Mount ~~TOC [illegible] BGS~~ TOC = 0.6' BGS

Starting Flow meter Reading: Ending Flow meter Reading: Flow Rate:
Total Volume Purged: Purged Dry (Y/N): Micro purged (Y/N): Minimal purged (Y/N):
Casing Inner Diameter (inches) Initial Depth to Water (feet) 13.00' BTOC Depth to bottom of well (feet) 82.72' BTOC
Tubing inner diameter 4 (in) Tubing & Pump Volume (ml)
Controller settings: Pressure (psi) Discharge (sec.) Recharge (sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT
Where WCT = Water Column Thickness (feet)

83.00
.28
82.72

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WIEDEMEIER & ASSOCIATES

2' 10 3/4"

1.25"

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP – Hopewell
COC Number:
Well ID: MW-R3
Sample Collected by: THW
Date of Collection: 6-10-16

EQUIPMENT

~~Purging~~ Equipment: HMA-453-S SN/5554
Sampling Equipment:
Filtering Equipment:
Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
YSI 556 Multi Parameter Meter	05C1520 AA	
HACH DR 890 Colorimeter		N/A

FIELD PARAMETERS

Ambient Air Temperature (°F):
Weather Conditions:
Sampling Depth (ft): Pump Inlet@
Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate __/min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

Could Not Log
Sonde Would not go
in Well

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments

PURGE INFORMATION

Stickup => Steel Casing = 3' Above Ground Surface
Top of PVC casing = 0.1 foot below Steel Casing

Starting Flow meter Reading: Ending Flow meter Reading: ~~Flow~~ Rate: " Top of PVC Casing = 2.9'

Total Volume Purged: Purged Dry (Y/N): Micro purged (Y/N): Minimal purged (Y/N): AGS

Casing Inner Diameter (inches) 2 Initial Depth to Water (feet) 17.4 Depth to bottom of well (feet) 39.92
Tubing inner diameter ____ (in) Tubing & Pump Volume ____ (ml)
Controller settings: Pressure ___ (psi) Discharge (sec.) Recharge ____ (sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT
Where WCT = Water Column Thickness (feet)

Two Inch well
Not Flush Mounted

WIEDEMEIER & ASSOCIATES

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP [redacted] Industrial Client IN-1 COC Number: ____________
Well ID: MW-6D
Sample Collected by: THW/WZD Date of Collection: 6-12-16

EQUIPMENT
~~Purging~~ Equipment: HMA-453-S
Sampling Equipment: ____________
Filtering Equipment: ____________
Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
~~YSI 556 Multi Parameter Meter~~	~~05C1520 AA~~	6-12-16
HACH ~~DR 890 Colori~~meter		N/A

FIELD PARAMETERS
Ambient Air Temperature (°F): ____________ Weather Conditions: ____________
Sampling Depth (ft): Pump Inlet@ ____________ Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate /min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
	1724	Zero	Tool	to	Ground		Surface			
	1725	Tool	in	Water						
17:48	Calibration			1		Zero	= 101.746			
					5E-3	=		1128.47		
17:49	Run 1			MTSU	MW-8D		Down	Run 1	Calib 1	6-12-16
18:00	Run 1			MTSU	MW-8D		UP	Run 1	Calib 1	6-12-16
		* Sonde		Went	@ the		Way	to	TD	
										Down/UP
										Speed ft/min
										~8.5
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments

PURGE INFORMATION Flush Mount => TOC = .45 ft BGS

Starting Flow meter Reading: ________ Ending Flow meter Reading: ________ Flow Rate: ________

Total Volume Purged: ________ Purged Dry (Y/N): _____ Micro purged (Y/N): _____ Minimal purged (Y/N): _____

Casing Inner Diameter (inches) 2 Initial Depth to Water (feet) 12.45 BTOC Depth to bottom of well (feet) 96.72

Tubing inner diameter _______ (in) Tubing & Pump Volume _______ (ml)

Controller settings: Pressure ___ (psi) Discharge (sec.) Recharge ________ (sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

Soft Bottom

97.00
(.28)

WIEDEMEIER & ASSOCIATES

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP [redacted] Industrial Client III COC Number:

Well ID: MW-6S

Sample Collected by: Date of Collection: 6-12-16

EQUIPMENT

Purging Equipment: GMA 453-S

Sampling Equipment:

Filtering Equipment:

Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
~~YSI 556 Multi Parameter Meter~~	~~05C1520 AA~~	6-12-16
~~HACH DR 890 Colorimeter~~		N/A

FIELD PARAMETERS

Ambient Air Temperature (°F): Weather Conditions:

Sampling Depth (ft): Pump Inlet@ Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate ___/min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
			18.14	Zero	Tool	to	Ground		Surface	
	Run 1	Down		MTSU	MW6S	Down		Run 1	Calib1 -	6-12-16
	Run 1	UP		MTSU	MW6S	UP		Run 1	Calib 1	6-12-16
							Down	& UP	Speed	~8.5 ft/min
				Tool	Reads	18.12	@	Bottom	of	Hole
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments

PURGE INFORMATION Flush Mount TOC = .57 ft BGS

Starting Flow meter Reading:________ Ending Flow meter Reading:________ Flow Rate:__________

Total Volume Purged:________ Purged Dry (Y/N):_____ Micro purged (Y/N):_____ Minimal purged (Y/N):____

Casing Inner Diameter (inches)______ Initial Depth to Water (feet) 12.425 BTOC Depth to bottom of well (feet) 17.22

Tubing inner diameter_______(in) Tubing & Pump Volume_______(ml)

Controller settings: Pressure___(psi) Discharge (sec.) Recharge___________(sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

Soft Bottom

4)
17.50
(.28)
17.22

WIEDEMEIER & ASSOCIATES

ESTCP

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: [redacted] Industrial client IV-1

COC Number: ______

Well ID: MW-6

Sample Collected by: THW WZD

Date of Collection: ~~4/4/16~~ ~~6/4/16~~ 6-12-16

EQUIPMENT

~~Purging~~ Equipment: HMA-453-S

Sampling Equipment: ______

Filtering Equipment: ______

Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
YSI 556 Multi Parameter Meter	05C1520 AA	
HACH DR 890 Colorimeter		N/A

FIELD PARAMETERS

Ambient Air Temperature (°F): ______

Weather Conditions: ______

Sampling Depth (ft): Pump Inlet@ ______

Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate __/min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
			18:27	Zero	Tool	to	Ground		Surface	
			18:28	Run 1						
Down:	Run 1		MTSU		MW-6		Down	Run 1	Calib1	6-12-16
Up	Run 1		MTSU		MW-6		Up	Run 1	Calib 1	6-12-16
							39.01			Down/Up
						Tool Bottomed @	~~34.42~~			Speed
							BGS			9.1 ft/min
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments

PURGE INFORMATION

~~St~~ Flush Mount TOC = 0.5 ft ~~BGS~~ BGS

Starting Flow meter Reading: ______ Ending Flow meter Reading: ______ Flow Rate: ______

Total Volume Purged: ______ Purged Dry (Y/N): ____ Micro purged (Y/N): ____ Minimal purged (Y/N): ____

Casing Inner Diameter (inches) ______ Initial Depth to Water (feet) 12.44 Depth to bottom of well (feet) 38.33

Tubing inner diameter ______ (in) Tubing & Pump Volume ______ (ml)

Controller settings: Pressure ___ (psi) Discharge (sec.) Recharge ______ (sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

38.61
.28
33

3/4/2

WIEDEMEIER & ASSOCIATES

ESTCA GROUNDWATER PURGE AND SAMPLING FORM

Project Name: [redacted] Industrial Client IW-1 COC Number:

Well ID: MW-6MD

Sample Collected by: THW/WZD Date of Collection: 6-12-16

EQUIPMENT

Purging Equipment: HMA-453-S

Sampling Equipment:

Filtering Equipment:

Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
YSI 556 Multi Parameter Meter	05C1520 AA	6-12-16
HACH DR 890 Colorimeter		N/A

FIELD PARAMETERS

Ambient Air Temperature (°F):

Weather Conditions:

Sampling Depth (ft): Pump Inlet@

Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate ___/min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
			18:48	Zero	Top	to Grand		Surface		
			18:49	Start	Run 1	Down				
Down		Run 1		MTSV MW-6MD Down Run 1 Calib 1 6-12-16						
Up		Run 1		MTSV MW-6MD Up Run 1 Calib 1 6-12-16						
		Reads		69.10						Down/up Speed 9 ft/min
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments

PURGE INFORMATION Flush Mount TOC = .57' ft BGS

Starting Flow meter Reading:________ Ending Flow meter Reading:________ Flow Rate:__________

Total Volume Purged:________ Purged Dry (Y/N):_____ Micro purged (Y/N):_____ Minimal purged (Y/N): 68.62'

Casing Inner Diameter (inches)______ Initial Depth to Water (feet) 12.47' BTOC Depth to bottom of well (feet) 68.62

Tubing inner diameter_______(in) Tubing & Pump Volume_______(ml)

Controller settings: Pressure___(psi) Discharge (sec.) Recharge___________(sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

Soft Bottom

68.90
(.28)
68.62

D:\THWA\Admin\Forms - Field\Groundwater Purge and Sampling Form.doc

WIEDEMEIER & ASSOCIATES

ESTCP **GROUNDWATER PURGE AND SAMPLING FORM**

Project Name: [redacted] Industrial Client IN-1 COC Number: ______
Well ID: MW-8 MD
Sample Collected by: THW/WZD Date of Collection: 6-12-16

EQUIPMENT
Purging Equipment: WMA 453-S
Sampling Equipment: ______
Filtering Equipment: ______
Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
~~YSI 556 Multi Parameter Meter~~	~~05C1520 AA~~	6-12-16
~~HACH DR 890 Colorimeter~~		N/A

FIELD PARAMETERS
Ambient Air Temperature (°F): ______ Weather Conditions: ______
Sampling Depth (ft): Pump Inlet@ ______ Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate ___/min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
		19:56		Zero	Tool					
		19:58		Tool in		Water to		equilibrate		
		20:13		Calibration 1			Zero	= 103.5		
								5E-3	= 1174.56	
Down		Run 1		MTSV		MW-8 MD	Down		Run 1	Calib 1 6-12-16
Up		Run 2		MTSV		MW-8 MD	Up		Run 1	Calib 1 6-12-16
										up/Down speed = 9 ft/min
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments

PURGE INFORMATION Flush Mount TOC = 0.4' BGS

Starting Flow meter Reading: ______ Ending Flow meter Reading: ______ Flow Rate: ______

Total Volume Purged: ______ Purged Dry (Y/N): ______ Micro purged (Y/N): ______ Minimal purged (Y/N): ______

Casing Inner Diameter (inches) 2" Initial Depth to Water (feet) 13.95' Depth to bottom of well (feet) 79.05
Tubing inner diameter ______ (in) Tubing & Pump Volume ______ (ml)
Controller settings: Pressure ___ (psi) Discharge (sec.) Recharge ______ (sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

V1
79.83
6,287

WIEDEMEIER & ASSOCIATES

ESTCP **GROUNDWATER PURGE AND SAMPLING FORM**

Project Name: [redacted] Industrial Client IV COC Number:______

Sample Collected by: THW / WZD

Well ID: ~~[illegible]~~ MW-8S

Date of Collection: 6-12-16

EQUIPMENT

Purging Equipment: HMA 453-S

Sampling Equipment:______

Filtering Equipment:______

Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
YSI 556 Multi Parameter Meter	05C1520 AA	
HACH DR 890 Colorimeter		N/A

FIELD PARAMETERS

Ambient Air Temperature (°F):______ Weather Conditions:______

Sampling Depth (ft): Pump Inlet@______ Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate /min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
		20.42		Zero Tool to Ground Surface						
Down		Run 1		MTSV		MW-8S	Down		Run 1	Calib 1 6-12-16
UP		Run 1		MTSV		MW-8S	UP		Run 1	Calib 1 6-12-16
										UP/Down
				Tool Ready		20.15				Speed
							@ Base			~9 ft/min
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments

PURGE INFORMATION Flush Mount TOC = .45' BGS

Starting Flow meter Reading:______ Ending Flow meter Reading:______ Flow Rate:______

Total Volume Purged:______ Purged Dry (Y/N):______ Micro purged (Y/N):______ Minimal purged (Y/N):______

Casing Inner Diameter (inches) 2 Initial Depth to Water (feet) 13.97 Depth to bottom of well (feet) 19.39

Tubing inner diameter______(in) Tubing & Pump Volume______(ml)

Controller settings: Pressure____(psi) Discharge (sec.) Recharge______(sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

19.87
.28
19.39

2

WIEDEMEIER & ASSOCIATES

ESTCA **GROUNDWATER PURGE AND SAMPLING FORM**

Project Name: [redacted] Industrial Client IN-1 COC Number: ____________

Well ID: MW-8

Sample Collected by: THW / WZD Date of Collection: 6-12-16

EQUIPMENT

~~Purging~~ Equipment: HMA 453-S

Sampling Equipment: ____________

Filtering Equipment: ____________

Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
~~YSI 556 Multi Parameter Meter~~	05C1520 AA	6-12-16
HACH DR 890 Colorimeter		N/A

FIELD PARAMETERS

Ambient Air Temperature (°F): ____________ Weather Conditions: ____________

Sampling Depth (ft): Pump Inlet@ ____________ Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate ___/min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
		20:51	Zero		Tool	to	Ground	Surface		
Down		Run	→	MTSU		MW-8	Down		Run	Calib 6-12-16
up		Run	→	MTSU		MW-8	Up		Run	Calib 6-12-16
				Got		Stuck				
							@ 15.45			
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments

PURGE INFORMATION Flush Mount TOC = 0.3' BGS

Starting Flow meter Reading: ______ Ending Flow meter Reading: ______ Flow Rate: ______

Total Volume Purged: ______ Purged Dry (Y/N): ______ Micro purged (Y/N): ______ Minimal purged (Y/N): ______

Casing Inner Diameter (inches) ______ Initial Depth to Water (feet) 14.29 Depth to bottom of well (feet) 49.26

Tubing inner diameter 2 (in) Tubing & Pump Volume ______ (ml)

Controller settings: Pressure ___ (psi) Discharge (sec.) Recharge ______ (sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

TD

41

49.54

-.28

49.26

WIEDEMEIER & ASSOCIATES

DAILY FIELD ACTIVITY REPORT

Client Name: ______________________ Project Number: ______________________
Project Name: ESTCP 201584 Tooele Date: 7-25-16
Contractor: ______________________ Arrival Time: 8:45 am
Weather: 81°F Clear

Time Breakdown: Drive: _______ Work: _______ Standby: _______

Location and Description of Activities:
Well ~~23B~~ D20 pulled ~~[illegible]~~ reel for Hydro Sleeve

Equipment Used on Project:

Activity Summary and General Remarks:
Slightly turbid water

PNNL Tooele D-20 Sample	1	Hydrosleeve 1 ~~Hydrosleeve~~	10:40
1 liter Samples	2	Hydrosleeve 2	10:50
without headspace	3	2	
	4	Hydrosleeve 3	11:40
100 mL Clemson Tooele D-20	IV	A1 #1 Hydrosleeve 1	10:42
100 mL	IV	A1 #2 Hydro 2	11:00
100 mL	IV	A1 #3	11:43

1 liter Bottle From Hydrosleeve 2+3

Microbial Insights Tooele D-20 ~~Hydro~~

2 filters 11:20 RNA 400 mL Hydrosleeve 2 11:44 250 mL HS3

2 filters DNA 500 + 500 mL Hydrosleeve 1 10:45

Technician Signature: ______________________ Date: ______________________

WIEDEMEIER & ASSOCIATES

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP 201584 Tooele　　COC Number:

Well ID: D-20

Sample Collected by: JTW/ RHW　　Date of Collection: 7/25/16

EQUIPMENT

Purging Equipment: Hydro Sleeve / Peristaltic Pump

Sampling Equipment:

Filtering Equipment:

Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
YSI 556 Multi Parameter Meter	05C1520 AA	
HACH DR 890 Colorimeter		N/A

FIELD PARAMETERS

Ambient Air Temperature (°F):　　Weather Conditions:

Sampling Depth (ft): Pump Inlet@　　Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate __/min	Depth to water	Time	Volume Purged (~~Gallons~~)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
				Liters						
		11:03				1,446	7.24	7.16	1838	Clear
			12:05	½ gal	17.0	1430	7.87	7.41	161	~~12:05~~
			12:07		16.52	1,423	7.60	7.04	179	
					17.38	1417	7.0	6.9	190	
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments
					0.0				

PURGE INFORMATION　Top of Screen = 68.5 ft bgs　Base of Screen 88.5 ft bgs

Starting Flow meter Reading:_____ Ending Flow meter Reading:_____ Flow Rate:_____

Total Volume Purged:_____ Purged Dry (Y/N):_____ Micro purged (Y/N):_____ Minimal purged (Y/N):_____

Casing Inner Diameter (inches) 4" Initial Depth to Water (feet) 69.68 Depth to bottom of well (feet)_____

Tubing inner diameter_____(in) Tubing & Pump Volume_____(ml)

Controller settings: Pressure___(psi) Discharge (sec.) Recharge_____(sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT　Where WCT = Water Column Thickness (feet)

Ground Surface Elevation 4396.40 ft msl

TOC Elevation 4398.57 ft msl

WIEDEMEIER & ASSOCIATES

Page ___ of ___

DAILY FIELD ACTIVITY REPORT

Client Name: ______________________ Project Number: ______________________

Project Name: ESTCP201584 Tooele Date: 7-25-16

Contractor: ______________________ Arrival Time: ~~8:45~~ 2:18pm

Weather: ~~81°~~ 96° Clear

Time Breakdown: Drive: _______ Work: _______ Standby: _______

Location and Description of Activities:

Well ~~26~~ ~~sw~~ pulled well Logger
D23
bubbles in water

Equipment Used on Project:

Depth to water @ 7.38 TOC to water

Activity Summary and General Remarks:

2:20	PNNL Tooele D23 Sample	1		HS1
		2		HS2
		3		HS2
		4		HS3
2:25	Clemson Tooele D23 IV A2	1		HS1
		2		HS2
		3		HS3
	Extra water	160mL Serum bottle		HS3
2:35	DNA	1000mL	Hydrosleeve 1	
3:00	RNA	750mL	Hydrosleeve 2	

Technician Signature: ______________________ Date: ______________________

WIEDEMEIER & ASSOCIATES

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: Tooele Army Depot COC Number: ____
Well ID: D 23
Sample Collected by: T H Wiedemeier Date of Collection: 7/25/16

EQUIPMENT
Purging Equipment: HydroSleeve & Peristaltic Pump
Sampling Equipment: ____
Filtering Equipment: ____
Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
YSI 556 Multi Parameter Meter	05C1520 AA	
HACH DR 890 Colorimeter		N/A

FIELD PARAMETERS
Ambient Air Temperature (°F): 96 Weather Conditions: Hot, Breezy & Clear
Sampling Depth (ft): Pump Inlet@ 200 ft BTOC Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate __/min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
					—	18,770	2.12	7.11	233	
						19,290	1.88	7.05	211	
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments
			ND 0.0						

PURGE INFORMATION

Starting Flow meter Reading:____ Ending Flow meter Reading:____ Flow Rate:____

Total Volume Purged:____ Purged Dry (Y/N):____ Micro purged (Y/N):____ Minimal purged (Y/N):____

Casing Inner Diameter (inches)____ Initial Depth to Water (feet)____ Depth to bottom of well (feet)____
Tubing inner diameter____(in) Tubing & Pump Volume____(ml)
Controller settings: Pressure____(psi) Discharge (sec.) Recharge____(sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

WIEDEMEIER & ASSOCIATES

REPORT TO:
Name: John Wilson
Company: Scissortail Env
Address: PO BOX 1206
Ada OK 74821
email: john@scissortailenv.com
Phone: 580 421 3551
Fax:

INVOICE TO: (For Invoices paid by a third party it is imperative that all information be provided)
Name:
Company:
Address:
email:
Phone:
Fax:

microbialinsights
10515 Research Dr
Knoxville, TN 37932
865-573-8188
www.microbe.com

Project Manager:
Project Name:
Project No.:

Purchase Order No.
Subcontract No.
MI Quote No.

Please Check One:
☐ More samples to follow
☐ No Additional Samples

Report Type: ☐ Standard (default) ☐ Microbial Insights Level III raw data(15% surcharge) ☐ Microbial Insights Level IV (25% surcharge) ☐ Comprehensive Interpretive(15%) ☐ Historical Interpretive (35%)
EDD type: ☐ Microbial Insights Standard (default) ☐ All other available EDDs (5% surcharge) Specify EDD Type:

Please contact us with any questions about the analyses or filling out the COC at (865) 573-8188 (9:00 am to 5:00 pm EST, M-F). After hours email: customerservice@microbe.com

Sample Information					Analyses				CENSUS: Please select the target organism/gene																							
MI ID (Laboratory Use Only)	Sample Name	Date Sampled	Time Sampled	Matrix	PLFA	NGS	QuantArray Chlor	QuantArray Petro	DHC (Dehalococcoides)	DHC Functional genes (bvc, tce, vcr)	DHBt (Dehalobacter)	DHG (Dehalogenimonas)	DSM (Desulfuromonas)	DSB (Desulfitobacterium)	EBAC (Total)	SRB (Sulfate Reducing Bacteria-APS)	MGN (Methanogens)	MOB (Methanotrophs)	SMMO	DNF (Dentrifiers-nirS and nirK)	AOB (ammonia oxidizing bacteria)	PM1 (MTBE aerobic)	RMO (Toluene Monooxygenase)	RDEG (Toluene Monooxygenase)	PHE (Phenol Hydroxylase)	NAH (Napthalene-aerobic)	BSSA (Toluene/Xylene-Anaerobic)	add. qPCR:	RNA (Expression Option)*	Other:	Other:	Other:
	Tooele D20DNA	7-25-16		aq								Per Dora Daggett																				
	D20 DNA	7-25-16		aq																												
	Tooele D20RNA	7-25-16		aq																												
	20RNA	7-25-16		aq																												
	Tooele D23RNA	7-25-16		aq																												
	Tooele D23DNA	7-25-16		aq																												

Relinquished by: Barbara Wilson
Received by:
Date 7-25-16

It is vital that chain of custody is filled out correctly & that all relative information is provided.
Failure to provide sufficient and/or correct information regarding reporting, invoicing & analyses requested information may result in delays for which MI will not be liable.

Chain of Custody Record

SEVERN TRENT **STL**
Severn Trent Laboratories, Inc.

STL Denver
4955 Yarrow Street
Arvada, CO 80002

STL-4124 (0901)

Client	Project Manager	Date	Chain of Custody Number
ESTCP Todd Wiedemeier	Todd Wiedemeier	4/25/16	310485

Address	Telephone Number (Area Code)/Fax Number	Lab Number	Page
509 Coronado Dr	303-670-7999	Microbial Insights	Page 1 of 1

City	State	Zip Code	Site Contact	Lab Contact
Sedalia	CO	80135	Todd W	Cora Taggart

Project Name and Location (State): Tooele Army Depot Tooele Utah

Carrier/Waybill Number:

Contract/Purchase Order/Quote No.:

Analysis (Attach list if more space is needed)

Special Instructions/ Conditions of Receipt

Sample I.D. No. and Description (Containers for each sample may be combined on one line)	Date	Time	Matrix: Air	Aqueous	Sed.	Soil	Containers & Preservatives: Unpres.	H2SO4	HNO3	HCl	NaOH	ZnAc/NaOH
Tooele D-20 DNA	4-25-16	10:15		✓			per Cora Taggart					
Tooele D-20 DNA	4-25-16	10:15		✓								
Tooele D-20 RNA	4-25-16	11:20		✓								
Tooele D-20 DNA	4-21-16	11:44		✓								
1750 mL Tooele D-23 RNA	4-25-16	3:00pm		✓								
1000 mL Tooele D-23 DNA	4-25-16	~~3:00pm~~ 3:30pm		✓								

Possible Hazard Identification: ☑ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal: ☐ Return To Client ☐ Disposal By Lab ☐ Archive For ______ Months (A fee may be assessed if samples are retained longer than 1 month)

Turn Around Time Required: ☑ 24 Hours ☐ 48 Hours ☐ 7 Days ☐ 14 Days ☐ 21 Days ☐ Other______

QC Requirements (Specify)

Relinquished By	Date	Time	Received By	Date	Time
1. Relinquished By: [illegible signature]	4-25-16	4:00pm	1. Received By		
2. Relinquished By			2. Received By		
3. Relinquished By			3. Received By		

Comments

DISTRIBUTION: WHITE - Returned to Client with Report; CANARY - Stays with the Sample; PINK - Field Copy

SEVERN TRENT **STL**

Severn Trent Laboratories, Inc.

STL Denver
4955 Yarrow Street
Arvada, CO 80002

Chain of Custody Record

STL-4124 (0901)

Client: ESTCP Todd Wiedemeier		Project Manager: Todd Wiedemeier	Date: 7-25-16	Chain of Custody Number: 310483
Address: 309 Coronado Dr		Telephone Number (Area Code)/Fax Number: 303-670-4999	Lab Number: Clemson	Page 1 of 1
City: Sedalia	State: CO	Zip Code: 80135	Site Contact: Todd W	Lab Contact: David Freedman
Project Name and Location (State): Tooele Army Depot Tooele, Utah			Carrier/Waybill Number:	
Contract/Purchase Order/Quote No.				

Sample I.D. No. and Description (Containers for each sample may be combined on one line)	Date	Time	Matrix: Air	Aqueous	Sed.	Soil	Containers & Preservatives: Unpres.	H2SO4	HNO3	HCl	NaOH	ZnAc/ NaOH	Analysis: Dissolved TCE	Special Instructions/ Conditions of Receipt
Tooele D-20 IV A1 #1	7-25-16			✓									✓	
D-20 IVA1 #2	↓			✓									✓	
D-20 IVA1 #3	↓			✓									✓	
4 ~~Tooele [illegible]~~	↓			✓									✓	
Tooele D-23 IV H2 #1	7-21-16			✓									✓	
D-23 IV H #2	↓			✓									✓	
D-23 IV A #3	↓			✓									✓	
160 ~~[illegible]~~	↓			✓										

Possible Hazard Identification: ☑ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal: ☐ Return To Client ☐ Disposal By Lab ☐ Archive For ______ Months (A fee may be assessed if samples are retained longer than 1 month)

Turn Around Time Required: ☑ 24 Hours ☐ 48 Hours ☐ 7 Days ☐ 14 Days ☐ 21 Days ☐ Other______

QC Requirements (Specify)

	Date	Time		Date	Time
1. Relinquished By: Barbara Wilson	7-25-16	4:50 pm	1. Received By		
2. Relinquished By			2. Received By		
3. Relinquished By			3. Received By		

Comments

DISTRIBUTION: WHITE - Returned to Client with Report; CANARY - Stays with the Sample; PINK - Field Copy

Chain of Custody Record

SEVERN TRENT **STL**
Severn Trent Laboratories, Inc.

STL Denver
4955 Yarrow Street
Arvada, CO 80002

STL-4124 (0901)

Client: ESTCP Todd Wiedemeier	Project Manager: Todd Wiedemeier	Date: 7/25/16	Chain of Custody Number: 310484
Address: 309 Coronado Dr	Telephone Number (Area Code)/Fax Number: 303-670-7999	Lab Number: PNNL	Page 1 of 1
City: Sedalia; State: CO; Zip Code: 80135	Site Contact: Todd W; Lab Contact: Brady Lee		
Project Name and Location (State): Tooele Army Depot Tooele Utah	Carrier/Waybill Number:		
Contract/Purchase Order/Quote No.			

Analysis (Attach list if more space is needed)

Special Instructions/Conditions of Receipt

Sample I.D. No. and Description (Containers for each sample may be combined on one line)	Date	Time	Matrix: Air	Aqueous	Sed.	Soil	Containers & Preservatives: Unpres.	H2SO4	HNO3	HCl	NaOH	ZnAc/NaOH	EAP	qPCR
Tooele D-20 Sample 1	7-25-16			✓									✓	✓
Sample 2	↓			✓									✓	✓
Sample 3				✓									✓	✓
Sample 4				✓									✓	✓
Tooele D-23 Sample 1	7-25-16			✓									✓	✓
Sample 2	↓			✓									✓	✓
Sample 3				✓									✓	✓
Sample 4				✓									✓	✓
Trip Blank DIW#9 SB 7-15-16	7-25-16			✓									✓	✓

Possible Hazard Identification
☒ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal
☐ Return To Client ☐ Disposal By Lab ☐ Archive For ____ Months (A fee may be assessed if samples are retained longer than 1 month)

Turn Around Time Required
☒ 24 Hours ☐ 48 Hours ☐ 7 Days ☐ 14 Days ☐ 21 Days ☐ Other____

QC Requirements (Specify)

	Date	Time		Date	Time
1. Relinquished By: Barbara Wilson	7-25-16	5:30 pm	1. Received By		
2. Relinquished By			2. Received By		
3. Relinquished By			3. Received By		

Comments

DISTRIBUTION: WHITE - Returned to Client with Report; CANARY - Stays with the Sample; PINK - Field Copy

2.17

MAGNETIC SUSCEPTIBILITY MEASUREMENT FORM - SONDE

PROJECT NAME: Tooele Army Depot

Well ID: D-20

Sample Collected by: THWiedemeier Date of Collection: 7/25/16

SAMPLING EQUIPMENT HMA-453-S

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
HMA-453-S	5554	7/25/16

EQUIPMENT DECONTAMINATION: Alconox Wash, Double Rinse, and Isopropyl Alcohol Spray

CALIBRATION RESULTS

Ambient Air Temperature (^{O}F)[a/]: 96 Weather Conditions: Clear

Groundwater Temperature (^{O}F)[a/]: 16°C

Time Probe Inserted into Ambient Groundwater (Minimum = 20 Minutes): 12:59

Calibration Standards (Include Units): Low: 0 High 5E-3 SI Units

Time of Calibration: 13:20

Calibration Results (Include Units): Low: 230 High 1326.4

Casing Inner Diameter (inches) 4" Borehole Diameter (Inches)

Initial Depth to Water (feet) 69.68 ft btoc Depth to bottom of well (feet) ~90' BTOC

Screened Interval, If Known (Include Datum) 68-88 ft bgs

Depth Measured by Sonde 89.17 ft bgs (Include Units)

Reference Point: Top of inner PVC casing or BGS, Specify:

Run Number	Calibration Number	Up Versus Down	Winch Speed (specify Units)	Comments
1	1	Down	9 ft/min	worked Great
1	1	up	9 ft/min	

Notes:
a/ The greater the difference between the groundwater temperature and the ambient temperature at the surface where the sonde will be calibrated, the longer the sonde should be allowed to equilibrate because the sonde is very sensitive to temperature.

WIEDEMEIER & ASSOCIATES

3433 W 2400 S
W. Valley, UT 84119

MAGNETIC SUSCEPTIBILITY MEASUREMENT FORM - SONDE

PROJECT NAME: Tooele Army Depot

Well ID: D-23

Sample Collected by: TH Wiedemeier   Date of Collection: 7/25/16

SAMPLING EQUIPMENT

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
MMA-453-S	5554	7/25/16

EQUIPMENT DECONTAMINATION: Alconox Wash, Double Rinse, and Isopropyl Alcohol Spray

CALIBRATION RESULTS

Ambient Air Temperature (^{O}F)[a/]: 98   Weather Conditions: Clear, Breezy & Hot

Groundwater Temperature (^{O}F)[a/]: ?

Time Probe Inserted into Ambient Groundwater (Minimum = 20 Minutes): ~16:20

Calibration Standards (Include Units): Low: 0   High 5E-3 SI units

Time of Calibration: 12:20

Calibration Results (Include Units): Low: 230   High 1326.4

Casing Inner Diameter (inches) 4"   Borehole Diameter (Inches)

Initial Depth to Water (feet) 67.38   Depth to bottom of well (feet)

Screened Interval, If Known (Include Datum)

Depth Measured by Sonde 212 ft bgs (Include Units)

Reference Point: Top of inner PVC casing or BGS, Specify:

Run Number	Calibration Number	Up Versus Down	Winch Speed (specify Units)	Comments
1	1	Down	9 ft/sec	
1	1	Up	9 ft/sec	

Notes:
a/ The greater the difference between the groundwater temperature and the ambient temperature at the surface where the sonde will be calibrated, the longer the sonde should be allowed to equilibrate because the sonde is very sensitive to temperature.

WIEDEMEIER & ASSOCIATES

DAILY FIELD ACTIVITY REPORT

Client Name:
Project Name: ESTCP 201584 Tooele
Contractor:
Weather: 78° F Clear

Project Number:
Date: 7-26-16
Arrival Time: 8:00

Time Breakdown: Drive: Work: Standby:

Location and Description of Activities:

D25
Set Hydrosleeve at 185
Depth to water 87.42 ft (?)

Equipment Used on Project:

Activity Summary and General Remarks:

	PNNL		
8:35	Tooele D25 Sample 1	1L	HS1
9:05	Tooele D25 Sample 2	1L	HS2
9:05	Tooele D25 Sample 3	1L	HS2
9:17	Tooele D25 Sample 4	1L	HS3
8:40	Clemson		
	Tooele IVB1 # 1	100 mL	HS1
9:07	IVB1 # 2	100 mL	HS2
9:20	IVB1 # 3	100 mL	HS3
*11:50 Am	160 mL extra collected		
8:42	Microbial Insights		#
	DNA 1000 mL		HS1
8:50	RNA 900 mL		HS1

* note added 8-2-16

Technician Signature:

Date:

WIEDEMEIER & ASSOCIATES

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: Tooele Army Depot
COC Number:
Sample Collected by: JTW/BHW/THW
Well ID: D-25
Date of Collection: 7-26-16

EQUIPMENT
Purging Equipment: Hydrasleeve
Sampling Equipment:
Filtering Equipment:
Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	Serial Number	Date Calibrated
YSI 556 Multi Parameter Meter	05C1520 AA	
HACH DR 890 Colorimeter		N/A

FIELD PARAMETERS
Ambient Air Temperature (°F):
Weather Conditions:
Sampling Depth (ft): Pump Inlet@
Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate __/min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
		87.42	9:10			4945	5.69	7.13	182.4	
			9:21			4776	5.44	7.2	194	
			9:24			4772	5.41	7.14	200	
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments
					0.0				

PURGE INFORMATION
Starting Flow meter Reading:________ Ending Flow meter Reading:________ Flow Rate:__________
Total Volume Purged:________ Purged Dry (Y/N):_____ Micro purged (Y/N):_____ Minimal purged (Y/N):____
Casing Inner Diameter (inches) 4 Initial Depth to Water (feet) 87.42 Depth to bottom of well (feet)____
Tubing inner diameter_______(in) Tubing & Pump Volume_______(ml)
Controller settings: Pressure___(psi) Discharge (sec.) Recharge__________(sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT   Where WCT = Water Column Thickness (feet)

Hydro Sleeve @ 185' BTOC

WIEDEMEIER & ASSOCIATES

DAILY FIELD ACTIVITY REPORT

Client Name: ____________

Project Name: ESTCP 201584 Tooele

Contractor: ____________

Weather: 93°F Clear

Project Number: ____________

Date: 7-26-16

Arrival Time: 12:25

Time Breakdown: Drive: _______ Work: _______ Standby: _______

Location and Description of Activities:

Well D19

Equipment Used on Project:

142.5 to TOC

Activity Summary and General Remarks:

PNNL

13:02	Tooele D19 Sample	1	HS1
		2	HS2
		3	HS2
		4	HS3

Clemson

13:05	Tooele D19	IVB2 # 1	HS1
		IVB2 # 2	HS2
		IVB2 # 3	HS3

Microbial Insights

13:06	DNA	1000 mL	HS
13:10	RNA	800 mL	HS1

Technician Signature: ____________ Date: ____________

WIEDEMEIER & ASSOCIATES

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: Tooele Army Depot
COC Number:
Well ID: D19
Sample Collected by: JW/TW/BW
Date of Collection: 7-26-16

EQUIPMENT
Purging Equipment: Hydrosleeve
Sampling Equipment:
Filtering Equipment:
Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
YSI 556 Multi Parameter Meter	05C1520 AA	
HACH DR 890 Colorimeter		N/A

FIELD PARAMETERS
Ambient Air Temperature (°F): 93
Weather Conditions: Clear
Sampling Depth (ft): Pump Inlet@
Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate ___/min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
			~~[illegible]~~			990				
			13:40		18.3	~~[illegible]~~	6.73	6.95	172.7	
			13:43		17.59	991	6.49	6.27	210	
					18.34	1,010	6.7	6.47	187.6	
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments
					0.0				

PURGE INFORMATION
Starting Flow meter Reading:________ Ending Flow meter Reading:________ Flow Rate:__________
Total Volume Purged:________ Purged Dry (Y/N):_____ Micro purged (Y/N):_____ Minimal purged (Y/N):____
Casing Inner Diameter (inches)______ Initial Depth to Water (feet) 142.5 Depth to bottom of well (feet)____
Tubing inner diameter_______(in) Tubing & Pump Volume_______(ml)
Controller settings: Pressure___(psi) Discharge (sec.) Recharge___________(sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

Chain of Custody Record

STL-4124 (0901)

SEVERN TRENT **STL** Severn Trent Laboratories, Inc.

STL Denver
4955 Yarrow Street
Arvada, CO 80002

Client: ESTCP Todd Wiedemeier	Project Manager: Todd Wiedemeier	Date: 7-26-16	Chain of Custody Number: 310487
Address: 309 Coronado Dr	Telephone Number (Area Code)/Fax Number: 303-670-7999	Lab Number: Clemson	Page 1 of 1
City: Sedalia · State: CO · Zip Code: 80135	Site Contact: Todd W · Lab Contact: David Freedman		
Project Name and Location (State): Tooele Chemical Depot Tooele Utah	Carrier/Waybill Number:		
Contract/Purchase Order/Quote No.			

Sample I.D. No. and Description (Containers for each sample may be combined on one line)	Date	Time	Matrix: Air	Aqueous	Sed.	Soil	Containers & Preservatives: Unpres.	H2SO4	HNO3	HCl	NaOH	ZnAc/NaOH	Analysis (Attach list if more space is needed): Assay TCE Degradation	Special Instructions/ Conditions of Receipt
Tooele IV B1 #1 D25	7-26-16	8:40		✓										
Tooele D25 IV B1 #2	7-26-16	9:07		✓										
Tooele D25 IV B1 #3	7-26-16	9:20		✓										
Tooele D19 IV B2 #1	7-26-16	13:05		✓										
Tooele D19 IV B2 #2	7-26-16			✓										
Tooele D19 IV B2 #3	7-26-16			✓										
Serum bottle														
Extra Water D25	7-26-16	12:00												
Serum Extra water D25	7-26-16	12:00												
bottle														
Extra water 1L D20	7-25-16													

Possible Hazard Identification
☒ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal
☐ Return To Client ☐ Disposal By Lab ☐ Archive For ______ Months (A fee may be assessed if samples are retained longer than 1 month)

Turn Around Time Required
☒ 24 Hours ☐ 48 Hours ☐ 7 Days ☐ 14 Days ☐ 21 Days ☐ Other______

QC Requirements (Specify)

1. Relinquished By: Barbara Wilson	Date: 7-26-16	Time: 15:47	1. Received By	Date	Time
2. Relinquished By	Date	Time	2. Received By	Date	Time
3. Relinquished By	Date	Time	3. Received By	Date	Time

Comments

DISTRIBUTION: WHITE - Returned to Client with Report; CANARY - Stays with the Sample; PINK - Field Copy

Chain of Custody Record

STL-4124 (0901)

SEVERN TRENT STL
Severn Trent Laboratories, Inc.

STL Denver
4955 Yarrow Street
Arvada, CO 80002

Client	Project Manager	Date	Chain of Custody Number
ESTCP Todd Windemeier	Todd Windemeier	7-26-16	310488

Address	Telephone Number (Area Code)/Fax Number	Lab Number	Page
309 Coronado Dr	303-670-7999	Microbial	Page 1 of 1

City	State	Zip Code	Site Contact	Lab Contact
Sedalia	CO	80134	Todd W.	Dora Taggart

Project Name and Location (State): Tooele Army Depot Tooele Utah

Carrier/Waybill Number:

Contract/Purchase Order/Quote No.:

Analysis (Attach list if more space is needed):

Special Instructions/ Conditions of Receipt

Sample I.D. No. and Description (Containers for each sample may be combined on one line)	Date	Time	Matrix: Air	Aqueous	Sed.	Soil	Containers & Preservatives: Unpres.	H2SO4	HNO3	HCl	NaOH	ZnAc/ NaOH
1000 mL Tooele D25 DNA	7-26-16	8:42	per Dora Taggart									
900 mL Tooele D25 RNA	7-26-16	8:50										
1000 mL Tooele D19 DNA	7-26-16	13:06										
900 mL Tooele D19 RNA	7-26-16	13:10										

Possible Hazard Identification
☒ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal
☐ Return To Client ☐ Disposal By Lab ☐ Archive For ______ Months (A fee may be assessed if samples are retained longer than 1 month)

Turn Around Time Required
☒ 24 Hours ☐ 48 Hours ☐ 7 Days ☐ 14 Days ☐ 21 Days ☐ Other______

QC Requirements (Specify)

Relinquished By	Date	Time	Received By	Date	Time
1. Barbara Wilson	7-26-16	15:38	1.		
2.			2.		
3.			3.		

Comments

DISTRIBUTION: WHITE - Returned to Client with Report; CANARY - Stays with the Sample; PINK - Field Copy

Chain of Custody Record

STL-4124 (0901)

SEVERN TRENT STL
Severn Trent Laboratories, Inc.

STL Denver
4955 Yarrow Street
Arvada, CO 80002

Client	ESTCP Todd Wiedemeier
Project Manager	Todd Wiedemeier
Date	7-26-16
Chain of Custody Number	310486
Address	309 Coronado Dr
Telephone Number (Area Code)/Fax Number	303-670-7999
Lab Number	PNNL
Page	1 of 1
City	Sedalia
State	CO
Zip Code	80135
Site Contact	Todd W
Lab Contact	Brady Lee
Project Name and Location (State)	Tooele Army Depot Tooele, Utah
Carrier/Waybill Number	
Contract/Purchase Order/Quote No.	

Sample I.D. No. and Description (Containers for each sample may be combined on one line)	Date	Time	Matrix: Air	Aqueous	Sed.	Soil		Containers & Preservatives: Unpres.	H2SO4	HNO3	HCl	NaOH	ZnAc/NaOH	Analysis (Attach list if more space is needed): EAP	90 PCR	Special Instructions/ Conditions of Receipt
Tooele D25 Sample 1	7-26-16	8:35		✓										✓	✓	
Tooele D25 Sample 2	↓	9:05		✓										✓	✓	
Tooele D25 Sample 3	↓	9:05		✓										✓	✓	
Tooele D25 Sample 4	↓	9:17		✓										✓	✓	
Tooele D19 Sample 1	7-26-16			✓										✓	✓	
Tooele D19 Sample 2	↓			✓										✓	✓	
Tooele D19 Sample 3	↓			✓										✓	✓	
Tooele D19 Sample 4	↓			✓										✓	✓	
Trip Blank DIW#10 SB 7-15-16	7-26-16			✓										✓	✓	

Possible Hazard Identification
☑ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal
☐ Return To Client ☐ Disposal By Lab ☐ Archive For ______ Months (A fee may be assessed if samples are retained longer than 1 month)

Turn Around Time Required
☑ 24 Hours ☐ 48 Hours ☐ 7 Days ☐ 14 Days ☐ 21 Days ☐ Other______

QC Requirements (Specify)

	Date	Time		Date	Time
1. Relinquished By: Barbara Wilson	7-26-16	15:33	1. Received By		
2. Relinquished By			2. Received By		
3. Relinquished By			3. Received By		

Comments

DISTRIBUTION: WHITE - Returned to Client with Report; CANARY - Stays with the Sample; PINK - Field Copy

MAGNETIC SUSCEPTIBILITY MEASUREMENT FORM - SONDE

PROJECT NAME: Tooele Army Depot

Well ID: D-25

Sample Collected by: THW/JTW Date of Collection: 7/26/17

SAMPLING EQUIPMENT

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
HMA-453-5	5554	7/26/17

EQUIPMENT DECONTAMINATION: Alconox Wash, Double Rinse, and Isopropyl Alcohol Spray

CALIBRATION RESULTS Stickup = 2.85 Zero Tool 09:46

Ambient Air Temperature (^{O}F)[a/]: 83 °F Weather Conditions: Ptly Cloudy & Breezy

Groundwater Temperature (^{O}F)[a/]:

Time Probe Inserted into Ambient Groundwater (Minimum = 20 Minutes): 09:52 Start pull out @ 10:15

Calibration Standards (Include Units): Low: High

Time of Calibration: ~10:23

Calibration Results (Include Units): Low: 236.4 High 1533

Casing Inner Diameter (inches) 4 Borehole Diameter (Inches)

Initial Depth to Water (feet) 87.42 Depth to bottom of well (feet) ~145

Screened Interval, If Known (Include Datum)

Depth Measured by Sonde (Include Units)

Reference Point: Top of inner PVC casing or BGS, Specify:

Run Number	Calibration Number	Up Versus Down	Winch Speed (specify Units)	Comments
1	1	Down	9.5 ft/min	
1	1	up		

Notes:

a/ The greater the difference between the groundwater temperature and the ambient temperature at the surface where the sonde will be calibrated, the longer the sonde should be allowed to equilibrate because the sonde is very sensitive to temperature.

MAGNETIC SUSCEPTIBILITY MEASUREMENT FORM - SONDE

PROJECT NAME: ~~TEAD~~ Tooele Army Depot
Well ID: D-19
Sample Collected by: THW/JTW Date of Collection: 7/26/16
SAMPLING EQUIPMENT HMA-553-S

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
HMA-553-S	5554	7/26/16

EQUIPMENT DECONTAMINATION: Alconox Wash, Double Rinse, and Isopropyl Alcohol Spray

CALIBRATION RESULTS Stickup 2.76 ~14:00 Probe in water

Ambient Air Temperature (^{O}F)[a/]: 93 Weather Conditions: Clear, Breezy HOT

Groundwater Temperature (^{O}F)[a/]:

Time Probe Inserted into Ambient Groundwater (Minimum = 20 Minutes): 1400 hours

Calibration Standards (Include Units): Low: 205,3 High

Time of Calibration: 14:44

Calibration Results (Include Units): Low: High

Casing Inner Diameter (inches) 4" Borehole Diameter (Inches)

Initial Depth to Water (feet) 142.5' BTOC Depth to bottom of well (feet) 167.07 TOC

Screened Interval, If Known (Include Datum)

Depth Measured by Sonde (Include Units)

Reference Point: Top of inner PVC casing or BGS, Specify:

Run Number	Calibration Number	Up Versus Down	Winch Speed (specify Units)	Comments
1	1	Down	10 ft/min	
1	1	Up	10 ft/min	

Notes:
a/ The greater the difference between the groundwater temperature and the ambient temperature at the surface where the sonde will be calibrated, the longer the sonde should be allowed to equilibrate because the sonde is very sensitive to temperature.

WIEDEMEIER & ASSOCIATES

DAILY FIELD ACTIVITY REPORT

Client Name:
Project Name: Hill AFB ESTCP 201584
Contractor: Clearfield UT
Weather: 70°F clear

Project Number:
Date: 7-27-16
Arrival Time: 8:30

Time Breakdown: Drive: ______ Work: ______ Standby: ______

Location and Description of Activities:
Well 43 Well ~~OU 2 43~~
U10-043

Equipment Used on Project:
10.55 ft depth to water
Below top casing

Activity Summary and General Remarks:
PNNL
10:05 Hill AFB Well #3 Sample 1
:07 2
:08 3
:09 4

10:12 Clemson
Hill AFB Well 43 VAI #1
10:13 2
10:14 3

10:15 Microbial Insight
DNA 1000 mL
10:20 RNA 1000 mL

Technician Signature: ______________________ Date: __________

WIEDEMEIER & ASSOCIATES

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: Hill AFB ESTCP 201584 COC Number: ______
Well ID: ~~#3~~ U10-043
Sample Collected by: JW/TW/BW Clearfield UT
Date of Collection: 7-27-16

EQUIPMENT

Purging Equipment: Geotech Peristaltic Pump
Sampling Equipment: ______
Filtering Equipment: ______
Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
YSI 556 Multi Parameter Meter	05C1520 AA	
HACH DR 890 Colorimeter		N/A

FIELD PARAMETERS

Ambient Air Temperature (°F): 70 Clearfield, UT Weather Conditions: Clear
Sampling Depth (ft): Pump Inlet@ ______ Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate ___/min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
			9:23	—	—	—	—	—		
			9:25	.750	15.73	1096	7.84	6.26	211.2	
			9.27	1	15.87	1017	4.2	6.32	207.7	
			9.29	2	15.87	938	3.1	6.5	199.9	
			9.31	3	15.9	910	1.85	6.6	195.3	
			9.34	4	15.77	966	3.10	6.64	190.8	
			9.36	4.5	15.64	1023	2.5	6.65	189.3	
			Stopped 9:36							
			9:39	—	16.71	1075	1.17	6.7	183.0	
			9.41	1	15.75	1113	1.65	6.81	179.4	
			9.44	2	15.4	1099	1.52	6.83	178.7	
			9.47	3	15.4	1104	2.45	6.86	176.9	
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments
					0.0				

PURGE INFORMATION

Starting Flow meter Reading:______ Ending Flow meter Reading:______ Flow Rate:______

Total Volume Purged:______ Purged Dry (Y/N):_____ Micro purged (Y/N):_____ Minimal purged (Y/N):____

Casing Inner Diameter (inches)______ Initial Depth to Water (feet)______ Depth to bottom of well (feet)____

Tubing inner diameter______(in) Tubing & Pump Volume______(ml)

Controller settings: Pressure___(psi) Discharge (sec.) Recharge______(sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

WIEDEMEIER & ASSOCIATES

GROUNDWATER PURGE AND SAMPLING FORM - Continued

Project Name: Hill AFB ESTCP 201584 Well ID: ~~B~~ U10-043
Sample Collected by: JW/TW/RW Date of Collection: 7-27-16

Flow Meter (gallons)	Flow rate __/min	Depth to water	Time	Volume Purged (Gallons)	Temp (°F)	Sp.Cond µS/cm	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
			9.51							
			9.54	1	15.18	1177	1.24	6.94	172.4	
			9.57	2	15.27	1135	0.85	6.92	172.6	
			10:00	3	15.31	1138	0.76	6.98	168.5	
			10:00		15.27	1145	.75	7.0	168.2	
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D:\THWA\Admin\Forms - Field\Groundwater Purge and Sampling Form.doc

WIEDEMEIER & ASSOCIATES

DAILY FIELD ACTIVITY REPORT

Client Name:
Project Name: Hill AFB ESTCP 201584
Contractor:
Weather: 90° F Clear

Project Number:
Date: 7-27-16
Arrival Time: 13:10

Time Breakdown: Drive: ______ Work: ______ Standby: ______

Location and Description of Activities:

U10-025
14.45 ft Depth to water from TOC
11.5 gal purging Set at 32 ft Screen

Equipment Used on Project:

Activity Summary and General Remarks:

PNNL
15:03 Hill AFB U10-025 Sample 1
7 2
11 3
16 4

22 1
2
3

15:27 DNA 1000 mL
RNA 1000 mL

Technician Signature: ______________________ Date: ____________

WIEDEMEIER & ASSOCIATES

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: Hill AFB ESTCP 201584 COC Number:
Well ID: U10-025
Sample Collected by: TW/JW/BW Date of Collection: 9-27-16

EQUIPMENT
Purging Equipment: GeoTech Peristaltic Pump
Sampling Equipment:
Filtering Equipment:
Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
YSI 556 Multi Parameter Meter	05C1520 AA	
HACH DR 890 Colorimeter		N/A

FIELD PARAMETERS
Ambient Air Temperature (°F): 90 Weather Conditions: Clear
Sampling Depth (ft): Pump Inlet@ Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate ___/min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
			13:46							
			13:49	1	16.67	772	7.54	6.95	-178.2	odor - Sulfur
			13:50	1.5	18.22	984	20.13	6.98	-182.0	
			13:59	2	18.61	1214	2.18	6.97	-175.2	
			14:09	2.5	19.06	1347	2.12	7.09	-169.1	
			14:15	3						
			14:25	3.5						
			14:30	4.0	20.10	1493	1.27	7.28	-32.3	
			14:38	4.5	18.98	1457	0.31	7.13	-35.5	
			14:44	5.0	19.47	1454	0.30	7.17	-61.4	
			14:53	5.5	19.04	1455	0.31	7.16	-46.9	
				~~[illegible]~~						
				6.00	18.87	1453	0.29	~~[illegible]~~	-51.5	
								7.17		
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments
					0.0				

PURGE INFORMATION
Starting Flow meter Reading:________ Ending Flow meter Reading:________ Flow Rate:__________
Total Volume Purged:________ Purged Dry (Y/N):_____ Micro purged (Y/N):_____ Minimal purged (Y/N):____
Casing Inner Diameter (inches)______ Initial Depth to Water (feet) 14.45 Depth to bottom of well (feet)____
Tubing inner diameter_______(in) Tubing & Pump Volume_______(ml)
Controller settings: Pressure___(psi) Discharge (sec.) Recharge___________(sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

Chain of Custody Record

STL-4124 (0901)

SEVERN TRENT **STL**

Severn Trent Laboratories, Inc.

STL Denver
4955 Yarrow Street
Arvada, CO 80002

Client: ESTCP Todd Wiedemeier	Project Manager: Todd Wiedemeier	Date: 7-27-16	Chain of Custody Number: 324056
Address: 309 Coronado Dr	Telephone Number (Area Code)/Fax Number: 303-670-7999	Lab Number: NI	Page 1 of 1
City: Sedalia; State: CO; Zip Code: 80135	Site Contact: Todd W; Lab Contact: Dora Taggart	Analysis (Attach list if more space is needed)	
Project Name and Location (State): Hill AFB	Carrier/Waybill Number:		Special Instructions/ Conditions of Receipt
Contract/Purchase Order/Quote No.:			

Sample I.D. No. and Description (Containers for each sample may be combined on one line)	Date	Time	Matrix: Air	Aqueous	Sed.	Soil	Containers & Preservatives: Unpres.	H2SO4	HNO3	HCl	NaOH	ZnAc/NaOH	Analysis	Special Instructions/ Conditions of Receipt
Hill AFB W10-043 DNA	7-27-16	10:15		✓			w/ Dora Taggart							
Hill AFB W10-043 RNA	7-27-16	10:20		✓										
Hill AFB W10-025 DNA	7-27-16	15:27		✓										
Hill AFB W10-025 RNA	7-27-16	15:36		✓										

Possible Hazard Identification
☑ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal
☐ Return To Client ☐ Disposal By Lab ☐ Archive For ______ Months (A fee may be assessed if samples are retained longer than 1 month)

Turn Around Time Required
☑ 24 Hours ☐ 48 Hours ☐ 7 Days ☐ 14 Days ☐ 21 Days ☐ Other______

QC Requirements (Specify)

Relinquished By	Date	Time	Received By	Date	Time
1. Relinquished By: Barbara Wilson	7-27-16	16:09	1. Received By		
2. Relinquished By			2. Received By		
3. Relinquished By			3. Received By		

Comments

DISTRIBUTION: WHITE - Returned to Client with Report; CANARY - Stays with the Sample; PINK - Field Copy

Chain of Custody Record

SEVERN TRENT STL
Severn Trent Laboratories, Inc.

STL Denver
4955 Yarrow Street
Arvada, CO 80002

STL-4124 (0901)

Client: ESTCP Todd Wiedemeier	Project Manager: Todd Wiedemeier	Date: 7-27-16	Chain of Custody Number: 324054
Address: 309 Coronado Dr	Telephone Number (Area Code)/Fax Number: 303-670-7999	Lab Number: PNNL	Page 1 of 1
City: Sedalia; State: CO; Zip Code: 80135	Site Contact: Todd W.; Lab Contact: Brady Lee	Analysis (Attach list if more space is needed)	
Project Name and Location (State): Hill AFB	Carrier/Waybill Number:		Special Instructions/ Conditions of Receipt
Contract/Purchase Order/Quote No.:			

Sample I.D. No. and Description (Containers for each sample may be combined on one line)	Date	Time	Air	Aqueous	Sed.	Soil	Unpres.	H2SO4	HNO3	HCl	NaOH	ZnAc/NaOH	EHP	qPCR
Hill AFB U10-043 Sample 1	7-27 16	10:05		✓									✓	✓
Hill AFB U10-043 Sample 2	↓	10:07		✓									✓	✓
Hill AFB U10-043 Sample 3		10:08		✓									✓	✓
Hill AFB U10-043 Sample 4	↓	10:09		✓									✓	✓
Hill AFB U10-025 Sample 1	7-27-16	15:03		✓									✓	✓
Hill AFB U10-025 Sample 2	↓	15:07		✓									✓	✓
Hill AFB U10-025 Sample 3		15:11		✓									✓	✓
Hill AFB U10-025 Sample 4	↓	15:16		✓									✓	✓
Trip Blank DIW #7	7-27-16	17:00		✓									✓	✓
TB 7-15-16														

Possible Hazard Identification
☑ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal
☐ Return To Client ☐ Disposal By Lab ☐ Archive For ______ Months (A fee may be assessed if samples are retained longer than 1 month)

Turn Around Time Required
☑ 24 Hours ☐ 48 Hours ☐ 7 Days ☐ 14 Days ☐ 21 Days ☐ Other ______

QC Requirements (Specify)

1. Relinquished By: Barbara Wilson	Date: 7-27-16	Time: 17:00	1. Received By	Date	Time
2. Relinquished By	Date	Time	2. Received By	Date	Time
3. Relinquished By	Date	Time	3. Received By	Date	Time

Comments

DISTRIBUTION: WHITE - Returned to Client with Report; CANARY - Stays with the Sample; PINK - Field Copy

Chain of Custody Record

STL-4124 (0901)

SEVERN TRENT STL
Severn Trent Laboratories, Inc.

STL Denver
4955 Yarrow Street
Arvada, CO 80002

Client	ESTCP Todd Wiedemeier
Project Manager	Todd Wiedemeier
Date	7-27-2016
Chain of Custody Number	324055
Address	309 Coronado Dr
Telephone Number (Area Code)/Fax Number	303-670-7999
Lab Number	Clemson
Page	1 of 1
City	Sedalia
State	CO
Zip Code	80135
Site Contact	Todd W
Lab Contact	Clemson
Project Name and Location (State)	Hill AFB
Carrier/Waybill Number	David Freedman
Contract/Purchase Order/Quote No.	

Analysis (Attach list if more space is needed): TCE degradation assay for

Special Instructions/ Conditions of Receipt

Sample I.D. No. and Description (Containers for each sample may be combined on one line)	Date	Time	Matrix: Air	Matrix: Aqueous	Matrix: Sed.	Matrix: Soil	Unpres.	H2SO4	HNO3	HCl	NaOH	ZnAc/NaOH	TCE degradation assay
Hill AFB U10-043 V A1 #1	7-27-16	10:12		✓									✓
Hill AFB U10-043 V A1 #2	↓	10:13		✓									✓
Hill AFB U10-043 V A1 #3	↓	10:14		✓									✓
Hill AFB U10-025 V A2 #1	7-27-16	15:22		✓									✓
Hill AFB U10-025 V A2 #2	↓	15:23		✓									✓
Hill AFB U10-025 V A2 #3	↓	15:25		✓									✓

Possible Hazard Identification
☑ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal
☐ Return To Client ☐ Disposal By Lab ☐ Archive For ____ Months (A fee may be assessed if samples are retained longer than 1 month)

Turn Around Time Required
☑ 24 Hours ☐ 48 Hours ☐ 7 Days ☐ 14 Days ☐ 21 Days ☐ Other____

QC Requirements (Specify)

	Date	Time		Date	Time
1. Relinquished By: Barbara Wilson	7-27-16	16:10	1. Received By		
2. Relinquished By			2. Received By		
3. Relinquished By			3. Received By		

Comments

DISTRIBUTION: WHITE - Returned to Client with Report; CANARY - Stays with the Sample; PINK - Field Copy

MAGNETIC SUSCEPTIBILITY MEASUREMENT FORM - SONDE

PROJECT NAME: Hill AFB

Well ID: ~~a~~ U10-043

Sample Collected by: THW

Date of Collection: 7/27/16

SAMPLING EQUIPMENT

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
HMA-~~4~~53-S	5554	7/27/16

EQUIPMENT DECONTAMINATION: Alconox Wash, Double Rinse, and Isopropyl Alcohol Spray

CALIBRATION RESULTS

Ambient Air Temperature (^{O}F)[a/]: 87°F

Weather Conditions: Clear & Hot

Groundwater Temperature (^{O}F)[a/]:

Time Probe Inserted into Ambient Groundwater (Minimum = 20 Minutes): 10:45

Calibration Standards (Include Units): Low: ~~[illegible]~~ High 5E-3

Time of Calibration: 11:10

Calibration Results (Include Units): Low: 213.33 High 1335.6

Casing Inner Diameter (inches) 2

Borehole Diameter (Inches) 8

Initial Depth to Water (feet) 10.55 ft BTOC

Depth to bottom of well (feet) 30.38 ft bgs

Screened Interval, If Known (Include Datum)

Depth Measured by Sonde (Include Units)

Reference Point: Top of inner PVC casing or BGS, Specify:

Run Number	Calibration Number	Up Versus Down	Winch Speed (specify Units)	Comments
1	1	Down	9 ft/min	
1	1	UP	9 ft/min	

Notes:

a/ The greater the difference between the groundwater temperature and the ambient temperature at the surface where the sonde will be calibrated, the longer the sonde should be allowed to equilibrate because the sonde is very sensitive to temperature.

WIEDEMEIER & ASSOCIATES

MAGNETIC SUSCEPTIBILITY MEASUREMENT FORM - SONDE

PROJECT NAME: Hill AFB - OU10

Well ID: U10 - 025

Sample Collected by: THW   Date of Collection: 7-27-16

SAMPLING EQUIPMENT

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
HMA - 453-S	5554	7/27/16

EQUIPMENT DECONTAMINATION: Alconox Wash, Double Rinse, and Isopropyl Alcohol Spray

CALIBRATION RESULTS

Ambient Air Temperature (^{O}F)[a/]: 90   Weather Conditions: Clear & Hot

Groundwater Temperature (^{O}F)[a/]:

Time Probe Inserted into Ambient Groundwater (Minimum = 20 Minutes): 16:04

Calibration Standards (Include Units): Low: 0   High 5E-3

Time of Calibration: 16:25

Calibration Results (Include Units): Low: 2 24,375 High 1 281.87

Casing Inner Diameter (inches) 2   Borehole Diameter (Inches) 8

Initial Depth to Water (feet) 14.45 Depth to bottom of well (feet) 41.87 ft bgs

Screened Interval, If Known (Include Datum)

Depth Measured by Sonde ______ (Include Units)

Reference Point: Top of inner PVC casing or BGS, Specify:

Run Number	Calibration Number	Up Versus Down	Winch Speed (specify Units)	Comments
~~1~~	~~1~~	~~Down~~	~~10 ft/min~~	Didn't Run Started w/ UP
1	1	UP	10 ft/min	
2	1	Down	10 ft/min	
2	1	Up	10 ft/min	

Notes:

a/ The greater the difference between the groundwater temperature and the ambient temperature at the surface where the sonde will be calibrated, the longer the sonde should be allowed to equilibrate because the sonde is very sensitive to temperature.

WIEDEMEIER & ASSOCIATES

MAGNETIC SUSCEPTIBILITY MEASUREMENT FORM - SONDE

PROJECT NAME: Hill AFB OU-10

Well ID: 410-051

Sample Collected by: JHW/JTW Date of Collection: 7/27/16

SAMPLING EQUIPMENT

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
HMA-453-S	5554	7/27/16

EQUIPMENT DECONTAMINATION: Alconox Wash, Double Rinse, and Isopropyl Alcohol Spray

CALIBRATION RESULTS

Ambient Air Temperature (^{O}F)[a/]: 94 Weather Conditions: Clear & Hot

Groundwater Temperature (^{O}F)[a/]: ________

Time Probe Inserted into Ambient Groundwater (Minimum = 20 Minutes): 1903 hours

Calibration Standards (Include Units): *Low: 0 High 5E-3 from calibration

Time of Calibration: Could not calibrate because of Transformer station, used previous calib from 410-025 for 410-025

Calibration Results (Include Units): Low: ________ High also checked with 10E-5 ST Rock calib was fine

Casing Inner Diameter (inches) 4" Borehole Diameter (Inches) ________

Initial Depth to Water (feet) ________ Depth to bottom of well (feet) ________

Screened Interval, If Known (Include Datum) ________

Depth Measured by Sonde ________ (Include Units)

Reference Point: Top of inner PVC casing or BGS, Specify: ________

Run Number	Calibration Number	Up Versus Down	Winch Speed (specify Units)	Comments
1	1	UP	15 ft/min	

Notes:
a/ The greater the difference between the groundwater temperature and the ambient temperature at the surface where the sonde will be calibrated, the longer the sonde should be allowed to equilibrate because the sonde is very sensitive to temperature.

WIEDEMEIER & ASSOCIATES

Page ___ of ___

DAILY FIELD ACTIVITY REPORT

Client Name: ______________________
Project Name: ESTCP 201584 Hill AFB
Contractor: ______________________
Weather: 68° F Clear

Project Number: ______________________
Date: 7-28-16
Arrival Time: 8:00

Time Breakdown: Drive: _______ Work: _______ Standby: _______

Location and Description of Activities:

72.83 ft Depth to water from TOC

Well U10-019 2 gal purge water

Equipment Used on Project:

Grundfos Pump 215 Hz for pump

Activity Summary and General Remarks:

PNNL

10:29 Hill AFB U10-019 Sample 1 aerated

2 unaerated

11:20 3 partial

10:45 4 partial collector filled 11:00

9:50 Clemson

9:52 Hill AFB U10-019 IB1 #1

9:55 #2

#3

10:09 Microbial Insights

DNA 300 + 300 10:14

10:18 RNA 300 + 300 10:22

Technician Signature: ______________________ Date: ______________________

Fe^{2+} 2.64 mg/L DI Blank

0.69 mg/L aq water blank

WIEDEMEIER & ASSOCIATES

GROUNDWATER PURGE AND SAMPLING FORM

Project Name: ESTCP 201584 Hill AFB COC Number: ____
Well ID: U10-019
Sample Collected by: TW/JW/BW Date of Collection: 7-28-16

EQUIPMENT
Purging Equipment: Grundfos Pump
Sampling Equipment: ____
Filtering Equipment: ____
Equipment Decontamination: Per Work Plan – Alconox Wash with Triple Rinse and Isopropyl Alcohol Rinse

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
YSI 556 Multi Parameter Meter	05C1520 AA	
HACH DR 890 Colorimeter		N/A

FIELD PARAMETERS
Ambient Air Temperature (°F): ____ Weather Conditions: ____
Sampling Depth (ft): Pump Inlet@ ____ Reference Point: Top of inner PVC casing

Flow meter (gallons)	Flow rate ___/min	Depth to water	Time	Volume Purged (Gallons)	Temp (°C)	Sp.Cond (µS/cm)	DO (mg/L)	pH	ORP (mV)	Water Description/Comments
			~~[illegible]~~							
		9:35	~~[illegible]~~		22.98	1325	6.10	7.42	-143.6	
		9:45			23.41		8.02	8.0	-59.8	
					23.08	.007	7.45	8.12	-51.7	
	≥40 ≤200				±10%	±10%	±10%	±0.2	±10mv	

D.O. mg/l Chemetrix (Visual)	Filtered Alk mg/l Hach	Non Filtered Alk mg/l Hach	Filtered Fe2+ mg/l Hach	Filtered Fe2+ mg/l Chemetrix (Visual)	Non Filtered Fe2+ mg/l Hach	Filtered Manganese mg/l Hach	Filtered Manganese mg/l Chemetrix (Visual)	Non Filtered Manganese mg/l Hach	Comments

PURGE INFORMATION

Starting Flow meter Reading: ____ Ending Flow meter Reading: ____ Flow Rate: ____

Total Volume Purged: ____ Purged Dry (Y/N): ____ Micro purged (Y/N): ____ Minimal purged (Y/N): ____

Casing Inner Diameter (inches) ____ Initial Depth to Water (feet) 72.83 Depth to bottom of well (feet) ____

Tubing inner diameter ____ (in) Tubing & Pump Volume ____ (ml)

Controller settings: Pressure ____ (psi) Discharge (sec.) Recharge ____ (sec.)

Casing Volume Calculation (gallons): 2" well = 0.17 x WCT 4" well = 0.66 x WCT 6" well = 1.47 x WCT Where WCT = Water Column Thickness (feet)

WIEDEMEIER & ASSOCIATES

Chain of Custody Record

SEVERN TRENT **STL**
Severn Trent Laboratories, Inc.

STL Denver
4955 Yarrow Street
Arvada, CO 80002

STL-4124 (0901)

Client: ESTCP Todd Wiedemeier	Project Manager: Todd Wiedemeier	Date: 7-28-16	Chain of Custody Number: 318291
Address: 309 Coronado Dr	Telephone Number (Area Code)/Fax Number: 303-670-7999	Lab Number: PNNL	Page 1 of 1
City: Sedalia · State: CO · Zip Code: 80135	Site Contact: Todd W · Lab Contact: Brady Lee		
Project Name and Location (State): Hill AFB Sunset, UT	Carrier/Waybill Number:		
Contract/Purchase Order/Quote No.:			

Analysis (Attach list if more space is needed)

Sample I.D. No. and Description (Containers for each sample may be combined on one line)	Date	Time	Air	Aqueous	Sed.	Soil	Unpres.	H2SO4	HNO3	HCl	NaOH	ZnAc/NaOH	FITP	qPCR	Special Instructions/ Conditions of Receipt
Hill HFB 410-019 Sample 1	7-28-16	10:29		✓									✓	✓	
Hill HFB 410-019 Sample 2	↓	10:45		✓									✓	✓	
Hill HFB 410-019 Sample 3	↓	11:20		✓									✓	✓	
Hill HFB 410-019 Sample 4	↓	10:45		✓									✓	✓	
Trip Blank DIW#8	7-28-16	12:40													
SL 7-15-16															

Possible Hazard Identification
☑ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal
☐ Return To Client ☐ Disposal By Lab ☐ Archive For ______ Months (A fee may be assessed if samples are retained longer than 1 month)

Turn Around Time Required
☑ 24 Hours ☐ 48 Hours ☐ 7 Days ☐ 14 Days ☐ 21 Days ☐ Other______

QC Requirements (Specify)

	Date	Time		Date	Time
1. Relinquished By: 1204 Dora Wilson	7-28-16	12:14	1. Received By		
2. Relinquished By			2. Received By		
3. Relinquished By			3. Received By		

Comments

DISTRIBUTION: WHITE - Returned to Client with Report; CANARY - Stays with the Sample; PINK - Field Copy

Chain of Custody Record

SEVERN TRENT **STL**
Severn Trent Laboratories, Inc.

STL Denver
4955 Yarrow Street
Arvada, CO 80002

STL-4124 (0901)

Client: ESTCP Todd Wiedemeier	Project Manager: Todd Wiedemeier	Date: 9-28-16	Chain of Custody Number: 318293
Address: 309 Coronado Dr	Telephone Number (Area Code)/Fax Number: 303-670-7999	Lab Number: MI	Page 1 of 1
City: Sedalia — State: CO — Zip Code: 80135	Site Contact: Todd W — Lab Contact: Dora Taggart	Analysis (Attach list if more space is needed)	Special Instructions/ Conditions of Receipt
Project Name and Location (State): Hill AFB Sunset, UT	Carrier/Waybill Number:		
Contract/Purchase Order/Quote No.			

Sample I.D. No. and Description (Containers for each sample may be combined on one line)	Date	Time	Air	Aqueous	Sed.	Soil	Unpres.	H2SO4	HNO3	HCl	NaOH	ZnAc/NaOH	Analysis
300 mL Hill AFB U10-019 DNA	9-28-16	10:09		✓									Ask Dora Taggart
300 mL Hill AFB U10-019 DNA	9-28-16	10:14		✓									
300 mL Hill AFB U10-019 RNA	9-28-16	10:18		✓									
Hill AFB U10-019 RNA	9-28-16	10:22		✓									

Possible Hazard Identification
☒ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal
☐ Return To Client ☐ Disposal By Lab ☐ Archive For ____ Months (A fee may be assessed if samples are retained longer than 1 month)

Turn Around Time Required
☒ 24 Hours ☐ 48 Hours ☐ 7 Days ☐ 14 Days ☐ 21 Days ☐ Other____

QC Requirements (Specify)

	Date	Time		Date	Time
1. Relinquished By: Barbara Wilson	9-28-16	12:14	1. Received By		
2. Relinquished By			2. Received By		
3. Relinquished By			3. Received By		

Comments

DISTRIBUTION: WHITE - Returned to Client with Report; CANARY - Stays with the Sample; PINK - Field Copy

SEVERN TRENT **STL**
Severn Trent Laboratories, Inc.

STL Denver
4955 Yarrow Street
Arvada, CO 80002

Chain of Custody Record

STL-4124 (0901)

Client	Project Manager	Date	Chain of Custody Number
ESTCP Todd Wiedemeier	Todd Wiedemeier	7-28-16	318292

Address	Telephone Number (Area Code)/Fax Number	Lab Number	Page
309 Coronado Dr	303-670-7999	Clemson	Page 1 of 1

City	State	Zip Code	Site Contact	Lab Contact
Sedalia	CO	80135	Todd W	David Freedman

Project Name and Location (State)	Carrier/Waybill Number
Hill AFB Sunset, UT	

Contract/Purchase Order/Quote No.

Analysis (Attach list if more space is needed): TCE Degradation

Special Instructions/ Conditions of Receipt

Sample I.D. No. and Description (Containers for each sample may be combined on one line)	Date	Time	Matrix: Air	Aqueous	Sed.	Soil	Containers & Preservatives: Unpres.	H2SO4	HNO3	HCl	NaOH	ZnAc/ NaOH	TCE Degradation
Hill AFB U10-019 VBI #1	7-28-16	9:50		✓									✓
Hill AFB U10-019 VBI #2	↓	9:52		✓									✓
Hill AFB U10-019 VBI #3	↓	9:55		✓									✓

Possible Hazard Identification
☑ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal
☐ Return To Client ☐ Disposal By Lab ☐ Archive For ______ Months (A fee may be assessed if samples are retained longer than 1 month)

Turn Around Time Required
☑ 24 Hours ☐ 48 Hours ☐ 7 Days ☐ 14 Days ☐ 21 Days ☐ Other______

QC Requirements (Specify)

Relinquished By	Date	Time	Received By	Date	Time
1. Rebecca Wilson	7-28-16	12:30	1.		
2.			2.		
3.			3.		

Comments

DISTRIBUTION: WHITE - Returned to Client with Report; CANARY - Stays with the Sample; PINK - Field Copy

MAGNETIC SUSCEPTIBILITY MEASUREMENT FORM - SONDE

PROJECT NAME: ~~U10-019~~ Hill AFB - OU-10

Well ID: U10-019

Sample Collected by: JHW Date of Collection: 7/28/16

SAMPLING EQUIPMENT

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
MMA-453-S	5554	——

EQUIPMENT DECONTAMINATION: Alconox Wash, Double Rinse, and Isopropyl Alcohol Spray

CALIBRATION RESULTS

Ambient Air Temperature (^{O}F)[a/]: 90 Weather Conditions: Hot & Sunny

Groundwater Temperature (^{O}F)[a/]: ____

Time Probe Inserted into Ambient Groundwater (Minimum = 20 Minutes): 12:00

Calibration Standards (Include Units): Low: 0 High 5E-3

Time of Calibration: ____

Calibration Results (Include Units): Low: Refusal in Well High ____

Casing Inner Diameter (inches) 2" Borehole Diameter (Inches) ____

Initial Depth to Water (feet) 73' Depth to bottom of well (feet) ____

Screened Interval, If Known (Include Datum) ____

Depth Measured by Sonde ____ (Include Units)

Reference Point: Top of inner PVC casing or BGS, Specify: ____

Run Number	Calibration Number	Up Versus Down	Winch Speed (specify Units)	Comments
	Got	refusal	@ ≈	27' BGS - Probe
	Would	Go	No	further

Notes:
a/ The greater the difference between the groundwater temperature and the ambient temperature at the surface where the sonde will be calibrated, the longer the sonde should be allowed to equilibrate because the sonde is very sensitive to temperature.

WIEDEMEIER & ASSOCIATES

GW-2

5 E-3 Calibration

MAGNETIC SUSCEPTIBILITY MEASUREMENT FORM - SONDE

PROJECT NAME: Hill AFB - 402-43

Well ID: 42-043

Sample Collected by: THW/BHW Date of Collection: 7/29/16

SAMPLING EQUIPMENT

Equipment Calibration		
Equipment/Model	**Serial Number**	**Date Calibrated**
HMA-~~4~~53-S	5554	7/29/16

EQUIPMENT DECONTAMINATION: Alconox Wash, Double Rinse, and Isopropyl Alcohol Spray

CALIBRATION RESULTS

Ambient Air Temperature (°F)[a/]: 82 Weather Conditions: Clear & Warm

Groundwater Temperature (°F)[a/]:

Time Probe Inserted into Ambient Groundwater (Minimum = 20 Minutes): 0905

Calibration Standards (Include Units): Low: 0 High 5E-3

Time of Calibration: 09:25

Calibration Results (Include Units): Low: High

Casing Inner Diameter (inches) 4" Borehole Diameter (Inches)

Initial Depth to Water (feet) 41.30 BTOC Depth to bottom of well (feet) 81.88' BTOC

Screened Interval, If Known (Include Datum)

Depth Measured by Sonde (Include Units)

Reference Point: Top of inner PVC casing or BGS, Specify:

Run Number	Calibration Number	Up Versus Down	Winch Speed (specify Units)	Comments
1	1	Down	10 ft/min	
	1	UP	10 ft/min	

Notes: Stickup = 3'

a/ The greater the difference between the groundwater temperature and the ambient temperature at the surface where the sonde will be calibrated, the longer the sonde should be allowed to equilibrate because the sonde is very sensitive to temperature.

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APPENDIX C DATA COLLECTED USING THE DOWNHOLE MAGNETIC SUSCEPTIBILITY SONDE

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FROM THE FORMER TWIN CITIES ARMY AMMUNITION PLANT

01U108-Up/Down Average Sonde Data					
Depth (ft bgs)	Elevation feet amsl	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)		
	904				
3.54	900.46	1.43	8.40E-07		
3.64	900.36	1.28	7.51E-07	Mean	7.26499E-07
3.76	900.24	1.13	6.65E-07	Standard Error	2.1558E-08
3.86	900.14	1.10	6.44E-07	Median	7.49526E-07
3.96	900.04	1.15	6.78E-07	Mode	#N/A
4.06	899.94	1.24	7.30E-07	Standard Deviation	1.01116E-07
4.16	899.84	1.31	7.71E-07	Sample Variance	1.02245E-14
4.26	899.75	1.10	6.47E-07	Kurtosis	-0.716024798
4.36	899.65	0.85	4.98E-07	Skewness	-0.352777309
4.46	899.55	0.77	4.51E-07	Range	3.50579E-07
4.56	899.45	0.73	4.30E-07	Minimum	5.40591E-07
4.66	899.35	0.83	4.90E-07	Maximum	8.91171E-07
4.76	899.25	1.08	6.38E-07	Sum	1.5983E-05
4.86	899.15	1.26	7.41E-07	Count	22
4.96	899.05	1.36	7.99E-07	Confidence Level(95.0'	4.48324E-08
5.05	898.95	1.41	8.29E-07		
5.15	898.85	1.21	7.12E-07		
5.25	898.75	1.18	6.92E-07		
5.35	898.65	1.20	7.06E-07		
5.45	898.55	1.21	7.11E-07		
5.55	898.45	1.30	7.67E-07		
5.65	898.35	1.28	7.54E-07		
5.75	898.25	1.16	6.84E-07		
5.85	898.15	1.07	6.29E-07		
5.95	898.05	1.01	5.91E-07		
6.05	897.95	1.04	6.11E-07		
6.15	897.85	1.07	6.30E-07		
6.25	897.75	1.09	6.42E-07		
6.35	897.65	1.18	6.93E-07		
6.45	897.55	1.23	7.23E-07		
6.55	897.45	1.16	6.85E-07		
6.65	897.35	1.11	6.51E-07		
6.75	897.25	1.04	6.12E-07		
6.85	897.15	1.07	6.30E-07		
6.95	897.05	1.12	6.56E-07		
7.05	896.95	1.15	6.77E-07		
7.15	896.85	1.16	6.82E-07		
7.25	896.75	1.15	6.78E-07		
7.35	896.65	1.22	7.15E-07		
7.45	896.55	1.31	7.73E-07		
7.55	896.45	1.37	8.03E-07		
7.65	896.36	1.55	9.11E-07		
7.75	896.26	1.57	9.25E-07		
7.85	896.16	1.53	8.98E-07		
7.95	896.06	1.47	8.63E-07		
8.05	895.96	1.50	8.84E-07		
8.15	895.86	1.51	8.90E-07		
8.25	895.76	1.47	8.62E-07		
8.34	895.66	1.45	8.53E-07		
8.44	895.56	1.49	8.77E-07		
8.54	895.46	1.66	9.75E-07		
8.64	895.36	1.84	1.08E-06		
8.74	895.26	2.16	1.27E-06		
8.84	895.16	2.52	1.48E-06		

01U103-Up/Down Average Sonde Data				Data not used for core data versus sonde data analysis because no core data
Depth ft bgs	Elevation feet amsl	Mag Susc 10e-3 SI un	Mag Susc m3/kg	
	904			
4.45	899.55	0.480648	2.83E-07	
4.55	899.45	0.693829	3.34E-07	
4.65	899.35	0.917049	4.62E-07	
4.75	899.25	1.08657	5.9E-07	
4.85	899.15	1.21713	6.78E-07	
4.95	899.05	1.32703	7.68E-07	
5.05	898.95	1.41533	7.93E-07	
5.15	898.85	1.30352	8.12E-07	
5.25	898.75	1.37828	8.04E-07	
5.35	898.65	1.37835	8.23E-07	
5.45	898.55	1.38036	8.06E-07	
5.55	898.45	1.46647	8.49E-07	
5.65	898.35	1.39496	8.55E-07	
5.75	898.25	1.39938	8.38E-07	
5.85	898.15	1.5664	9.06E-07	
5.95	898.05	1.47332	8.99E-07	
6.05	897.95	1.42182	8.42E-07	
6.15	897.85	1.45952	8.46E-07	
6.25	897.75	1.51648	8.57E-07	
6.35	897.65	1.57219	8.62E-07	
6.45	897.55	1.56796	9E-07	
6.54	897.46	1.41391	8.56E-07	
6.64	897.36	1.42215	8.21E-07	
6.74	897.26	1.33314	8.12E-07	
6.84	897.16	1.48011	8.21E-07	
6.94	897.06	1.52726	8.86E-07	
7.04	896.96	1.59939	9.06E-07	
7.14	896.86	1.69892	9.61E-07	
7.24	896.76	1.62543	9.41E-07	
7.34	896.66	1.64413	9.82E-07	
7.44	896.56	1.641	9.42E-07	
7.54	896.46	1.74676	9.98E-07	
7.64	896.36	1.58176	1E-06	
7.74	896.26	1.45299	8.87E-07	
7.84	896.16	1.73903	9.51E-07	
7.94	896.06	2.22164	1.17E-06	
8.04	895.96	2.66224	1.44E-06	
8.14	895.86	2.68452	1.57E-06	
8.24	895.76	1.98604	1.43E-06	
8.34	895.66	1.83247	1.15E-06	
8.44	895.56	2.21243	1.19E-06	
8.54	895.46	2.57622	1.37E-06	
8.64	895.36	2.73525	1.57E-06	
8.74	895.26	2.3239	1.47E-06	
8.84	895.16	1.61779	1.16E-06	
8.94	895.06	1.58058	9.57E-07	
9.04	894.96	1.68537	9.51E-07	
9.14	894.86	1.67791	9.99E-07	
9.24	894.76	1.71596	1.01E-06	
9.34	894.66	1.60963	9.44E-07	
9.44	894.56	1.70857	9.69E-07	
9.54	894.46	1.80175	1.03E-06	
9.64	894.36	2.00149	1.15E-06	
9.74	894.26	2.04164	1.22E-06	

01U106-Up/Down Average Sonde Data				Data not used for core data versus sonde data analysis because no core data
Depth (ft b	Elevation feet amsl	Mag Susc 10e-3 SI Ur	Mag Susc (m3/kg)	
	897			
3.59	893.41	1.207055	7.1E-07	
3.68	893.32	1.258857	7.41E-07	
3.7775	893.2225	1.23356	7.26E-07	
3.8775	893.1225	1.15295	6.78E-07	
3.9775	893.0225	1.068423	6.28E-07	
4.0775	892.9225	1.090918	6.42E-07	
4.1775	892.8225	1.242143	7.31E-07	
4.2775	892.7225	1.163678	6.85E-07	
4.3775	892.6225	1.157335	6.81E-07	
4.4775	892.5225	1.187938	6.99E-07	
4.5775	892.4225	1.259565	7.41E-07	
4.6775	892.3225	1.291185	7.6E-07	
4.7775	892.2225	1.191882	7.01E-07	
4.8775	892.1225	1.012743	5.96E-07	
4.9775	892.0225	1.049575	6.17E-07	
5.0775	891.9225	1.223816	7.2E-07	
5.1775	891.8225	1.439368	8.47E-07	
5.2775	891.7225	1.38539	8.15E-07	
5.3775	891.6225	1.342105	7.89E-07	
5.4775	891.5225	1.255335	7.38E-07	
5.5775	891.4225	1.167253	6.87E-07	
5.6775	891.3225	1.13264	6.66E-07	
5.7775	891.2225	1.076042	6.33E-07	
5.875	891.125	1.13825	6.7E-07	
5.975	891.025	1.236545	7.27E-07	
6.075	890.925	1.354895	7.97E-07	
6.17	890.83	1.305548	7.68E-07	
6.27	890.73	1.202698	7.07E-07	
6.37	890.63	1.161978	6.84E-07	
6.47	890.53	1.292398	7.6E-07	
6.57	890.43	1.402328	8.25E-07	
6.67	890.33	1.399908	8.23E-07	
6.77	890.23	1.255638	7.39E-07	
6.87	890.13	1.08594	6.39E-07	
6.9675	890.0325	1.062202	6.25E-07	
7.0675	889.9325	1.371239	8.07E-07	
7.1675	889.8325	1.675425	9.86E-07	
7.2675	889.7325	1.679138	9.88E-07	
7.3675	889.6325	1.347172	7.92E-07	
7.4675	889.5325	1.165603	6.86E-07	
7.5675	889.4325	1.14334	6.73E-07	
7.6675	889.3325	1.391038	8.18E-07	
7.7675	889.2325	1.589943	9.35E-07	
7.8675	889.1325	1.519955	8.94E-07	
7.9675	889.0325	1.349085	7.94E-07	
8.0675	888.9325	1.285403	7.56E-07	
8.1675	888.8325	1.350325	7.94E-07	
8.2675	888.7325	1.438048	8.46E-07	
8.3675	888.6325	1.514485	8.91E-07	
8.4675	888.5325	1.549288	9.11E-07	
8.5675	888.4325	1.754435	1.03E-06	
8.6675	888.3325	1.909728	1.12E-06	
8.7675	888.2325	2.315	1.36E-06	
8.8675	888.1325	2.707195	1.59E-06	

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FROM THE FORMER TWIN CITIES ARMY AMMUNITION PLANT

01U108-Up/Down Average Sonde Data

Depth (ft bgs)	Elevation feet amsl	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)
8.94	895.06	2.83	1.66E-06
9.04	894.96	3.03	1.79E-06
9.14	894.86	3.17	1.86E-06
9.24	894.76	3.29	1.93E-06
9.34	894.66	3.28	1.93E-06
9.44	894.56	3.17	1.87E-06
9.54	894.46	3.03	1.78E-06
9.64	894.36	2.73	1.60E-06
9.74	894.26	2.39	1.41E-06
9.84	894.16	2.30	1.35E-06
9.94	894.06	1.93	1.13E-06
10.04	893.96	1.77	1.04E-06
10.14	893.86	1.84	1.08E-06
10.24	893.76	1.97	1.16E-06
10.34	893.66	2.16	1.27E-06
10.44	893.56	2.44	1.43E-06
10.54	893.46	2.63	1.55E-06
10.64	893.36	2.44	1.44E-06
10.74	893.26	2.17	1.28E-06
10.84	893.16	2.12	1.25E-06
10.94	893.07	2.12	1.25E-06
11.04	892.97	1.96	1.15E-06
11.14	892.87	2.00	1.18E-06
11.24	892.77	1.85	1.09E-06
11.34	892.67	1.78	1.05E-06
11.44	892.57	1.85	1.09E-06
11.54	892.47	1.89	1.11E-06
11.63	892.37	1.73	1.02E-06
11.73	892.27	1.62	9.54E-07
11.83	892.17	1.79	1.05E-06
11.93	892.07	2.07	1.22E-06
12.03	891.97	2.07	1.22E-06
12.13	891.87	1.86	1.09E-06
12.23	891.77	1.69	9.95E-07
12.33	891.67	1.67	9.85E-07
12.43	891.57	1.98	1.16E-06
12.53	891.47	2.19	1.29E-06
12.63	891.37	2.25	1.32E-06
12.73	891.27	2.30	1.35E-06
12.83	891.17	1.89	1.11E-06
12.93	891.07	1.69	9.95E-07
13.03	890.97	1.79	1.05E-06
13.13	890.87	1.93	1.14E-06
13.23	890.77	2.24	1.32E-06
13.33	890.67	2.33	1.37E-06
13.43	890.57	2.04	1.20E-06
13.53	890.47	1.82	1.07E-06
13.63	890.37	1.71	1.01E-06
13.73	890.27	1.76	1.04E-06
13.83	890.17	1.79	1.05E-06
13.93	890.07	2.00	1.18E-06
14.03	889.97	2.10	1.23E-06
14.13	889.87	2.03	1.19E-06
14.23	889.78	1.96	1.15E-06
14.33	889.68	1.95	1.15E-06

01U103-Up/Down Average Sonde Data

Data not used for core data versus sonde data analysis because no core data

Depth ft bgs	Elevation feet amsl	Mag Susc 10e-3 SI un	Mag Susc m3/kg
9.83	894.17	2.21544	1.27E-06
9.93	894.07	2.19798	1.25E-06
10.03	893.97	2.60981	1.45E-06
10.13	893.87	2.77126	1.59E-06
10.23	893.77	2.99766	1.67E-06
10.33	893.67	3.58869	1.92E-06
10.43	893.57	4.27703	2.32E-06
10.53	893.47	4.70673	2.61E-06
10.63	893.37	4.87341	2.82E-06
10.73	893.27	4.90963	2.85E-06
10.83	893.17	5.23835	2.99E-06
10.93	893.07	5.52384	3.12E-06
11.03	892.97	5.21488	3.15E-06
11.13	892.87	4.16713	2.76E-06
11.23	892.77	3.349	2.2E-06
11.33	892.67	3.21972	1.94E-06
11.43	892.57	3.36543	1.95E-06
11.53	892.47	3.4792	1.99E-06
11.63	892.37	3.51432	2.02E-06
11.73	892.27	3.52001	2.08E-06
11.83	892.17	3.54907	2.09E-06
11.93	892.07	3.328	2.04E-06
12.03	891.97	3.14544	1.95E-06
12.13	891.87	2.74459	1.72E-06
12.23	891.77	2.84109	1.66E-06
12.33	891.67	2.67204	1.61E-06
12.43	891.57	2.37711	1.45E-06
12.53	891.47	2.26109	1.37E-06
12.63	891.37	2.19227	1.31E-06
12.73	891.27	2.24014	1.29E-06
12.83	891.17	2.28678	1.34E-06
12.93	891.07	2.35715	1.34E-06
13.03	890.97	2.3284	1.35E-06
13.12	890.88	2.65483	1.44E-06
13.22	890.78	2.67784	1.52E-06
13.32	890.68	2.56585	1.52E-06
13.42	890.58	2.45715	1.49E-06
13.52	890.48	2.69079	1.49E-06
13.62	890.38	2.96561	1.67E-06
13.72	890.28	3.02152	1.77E-06
13.82	890.18	2.985	1.81E-06
13.92	890.08	2.99111	1.78E-06
14.02	889.98	3.14266	1.83E-06
14.12	889.88	2.84281	1.77E-06
14.22	889.78	2.96113	1.79E-06
14.32	889.68	2.70255	1.66E-06
14.42	889.58	2.60823	1.59E-06
14.52	889.48	2.43819	1.5E-06
14.62	889.38	2.44788	1.39E-06
14.72	889.28	2.65017	1.53E-06
14.82	889.18	2.73359	1.59E-06
14.92	889.08	2.76265	1.62E-06
15.02	888.98	2.85017	1.65E-06
15.12	888.88	2.73957	1.63E-06
15.22	888.78	2.83898	1.67E-06

01U106-Up/Down Average Sonde Data

Data not used for core data versus sonde data analysis because no core data

Depth (ft b	Elevation feet amsl	Mag Susc 10e-3 SI Ur	Mag Susc (m3/kg)
8.9675	888.0325	2.939788	1.73E-06
9.0675	887.9325	2.97879	1.75E-06
9.165	887.835	2.963803	1.74E-06
9.265	887.735	2.918283	1.72E-06
9.365	887.635	2.847095	1.67E-06
9.4625	887.5375	2.93278	1.73E-06
9.56	887.44	3.404518	2E-06
9.66	887.34	4.22469	2.49E-06
9.76	887.24	5.098695	3E-06
9.86	887.14	5.70229	3.35E-06
9.96	887.04	6.026765	3.55E-06
10.06	886.94	6.15785	3.62E-06
10.16	886.84	6.397345	3.76E-06
10.26	886.74	6.329408	3.72E-06
10.3575	886.6425	5.848075	3.44E-06
10.4575	886.5425	5.19194	3.05E-06
10.5575	886.4425	4.63588	2.73E-06
10.6575	886.3425	4.135508	2.43E-06
10.7575	886.2425	3.741238	2.2E-06
10.8575	886.1425	3.40371	2E-06
10.9575	886.0425	3.062145	1.8E-06
11.0575	885.9425	3.032283	1.78E-06
11.1575	885.8425	2.987808	1.76E-06
11.2575	885.7425	2.970158	1.75E-06
11.3575	885.6425	2.90165	1.71E-06
11.4575	885.5425	3.02226	1.78E-06
11.5575	885.4425	3.269503	1.92E-06
11.6575	885.3425	3.294055	1.94E-06
11.7575	885.2425	3.269883	1.92E-06
11.8575	885.1425	3.171718	1.87E-06
11.9575	885.0425	3.291618	1.94E-06
12.0575	884.9425	3.425793	2.02E-06
12.1575	884.8425	3.570158	2.1E-06
12.2575	884.7425	3.48509	2.05E-06
12.3575	884.6425	3.388578	1.99E-06
12.455	884.545	3.429398	2.02E-06
12.555	884.445	3.593638	2.11E-06
12.655	884.345	3.71349	2.18E-06
12.7525	884.2475	3.78951	2.23E-06
12.85	884.15	3.848253	2.26E-06
12.95	884.05	3.77727	2.22E-06
13.05	883.95	3.84199	2.26E-06
13.15	883.85	3.605863	2.12E-06
13.25	883.75	3.34444	1.97E-06
13.35	883.65	3.237218	1.9E-06
13.45	883.55	3.286855	1.93E-06
13.55	883.45	3.45783	2.03E-06
13.6475	883.3525	3.664855	2.16E-06
13.7475	883.2525	3.492373	2.05E-06
13.8475	883.1525	3.139878	1.85E-06
13.9475	883.0525	3.051408	1.79E-06
14.0475	882.9525	3.082045	1.81E-06
14.1475	882.8525	3.337795	1.96E-06
14.2475	882.7525	3.580898	2.11E-06
14.3475	882.6525	3.952903	2.33E-06

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FROM THE FORMER TWIN CITIES ARMY AMMUNITION PLANT

01U108-Up/Down Average Sonde Data			
Depth (ft bgs)	Elevation feet amsl	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)
14.43	889.58	1.99	1.17E-06
14.53	889.48	2.01	1.18E-06
14.63	889.38	2.02	1.19E-06
14.73	889.28	1.96	1.15E-06
14.83	889.18	1.87	1.10E-06
14.93	889.08	1.89	1.11E-06
15.02	888.98	2.01	1.18E-06
15.12	888.88	2.01	1.19E-06
15.22	888.78	2.02	1.19E-06
15.32	888.68	1.96	1.15E-06
15.42	888.58	1.95	1.15E-06
15.52	888.48	1.98	1.16E-06
15.62	888.38	2.04	1.20E-06
15.72	888.28	2.03	1.19E-06
15.82	888.18	1.85	1.09E-06
15.92	888.08	1.84	1.08E-06
16.02	887.98	1.87	1.10E-06
16.12	887.88	1.93	1.13E-06
16.22	887.78	1.89	1.11E-06
16.32	887.68	1.94	1.14E-06
16.42	887.58	1.99	1.17E-06
16.52	887.48	2.05	1.21E-06
16.62	887.38	2.06	1.21E-06
16.72	887.28	2.08	1.22E-06
16.82	887.18	1.89	1.11E-06
16.92	887.08	1.73	1.02E-06
17.02	886.98	1.62	9.53E-07
17.12	886.88	1.54	9.05E-07
17.22	886.78	1.54	9.06E-07
17.32	886.68	1.60	9.39E-07
17.42	886.58	1.73	1.02E-06
17.52	886.49	1.66	9.75E-07
17.62	886.39	1.55	9.12E-07
17.72	886.29	1.52	8.95E-07
17.82	886.19	1.51	8.89E-07
17.92	886.09	1.43	8.42E-07
18.02	885.99	1.31	7.68E-07
18.12	885.89	1.22	7.18E-07
18.22	885.79	1.10	6.48E-07
18.31	885.69	1.17	6.88E-07
18.41	885.59	1.25	7.35E-07
18.51	885.49	1.38	8.10E-07
18.61	885.39	1.34	7.90E-07
18.71	885.29	1.30	7.64E-07
18.81	885.19	1.30	7.65E-07
18.91	885.09	1.30	7.65E-07
19.01	884.99	1.18	6.96E-07
19.11	884.89	1.13	6.66E-07
19.21	884.79	1.02	6.00E-07
19.31	884.69	0.96	5.62E-07
19.41	884.59	0.92	5.41E-07
19.51	884.49	0.95	5.60E-07
19.61	884.39	1.14	6.73E-07
19.71	884.29	1.37	8.07E-07
19.81	884.19	1.40	8.24E-07

01U103-Up/Down Average Sonde Data				Data not used for core data versus sonde data analysis because no core data
Depth ft bgs	Elevation feet amsl	Mag Susc 10e-3 SI un	Mag Susc m3/kg	
15.32	888.68	2.67412	1.6E-06	
15.42	888.58	2.69669	1.58E-06	
15.52	888.48	2.61423	1.55E-06	
15.62	888.38	2.62533	1.53E-06	
15.72	888.28	2.47808	1.47E-06	
15.82	888.18	2.54073	1.5E-06	
15.92	888.08	2.72835	1.59E-06	
16.02	887.98	2.64951	1.55E-06	
16.12	887.88	2.69244	1.54E-06	
16.22	887.78	2.88394	1.65E-06	
16.32	887.68	2.72287	1.58E-06	
16.42	887.58	2.49537	1.51E-06	
16.51	887.49	2.8034	1.62E-06	
16.61	887.39	2.4334	1.51E-06	
16.71	887.29	2.35158	1.42E-06	
16.81	887.19	2.64388	1.49E-06	
16.91	887.09	2.87488	1.63E-06	
17.01	886.99	3.01475	1.72E-06	
17.11	886.89	3.02873	1.76E-06	
17.21	886.79	3.09033	1.83E-06	
17.31	886.69	3.15934	1.86E-06	
17.41	886.59	3.34257	1.92E-06	
17.51	886.49	3.70966	2.08E-06	
17.61	886.39	3.7313	2.13E-06	
17.71	886.29	3.5917	2.12E-06	
17.81	886.19	4.0006	2.3E-06	
17.91	886.09	4.18296	2.42E-06	
18.01	885.99	4.08221	2.4E-06	
18.11	885.89	4.46287	2.51E-06	
18.21	885.79	4.54612	2.6E-06	
18.31	885.69	4.2944	2.52E-06	
18.41	885.59	4.39929	2.55E-06	
18.51	885.49	4.071	2.5E-06	
18.61	885.39	3.89539	2.36E-06	
18.71	885.29	3.49692	2.14E-06	
18.81	885.19	3.20787	1.96E-06	
18.91	885.09	3.30594	1.92E-06	
19.01	884.99	3.27646	1.94E-06	
19.11	884.89	3.04379	1.86E-06	
19.21	884.79	3.06401	1.79E-06	
19.31	884.69	3.19945	1.83E-06	
19.41	884.59	3.37654	1.93E-06	
19.51	884.49	3.10248	1.89E-06	
19.61	884.39	2.84117	1.77E-06	
19.71	884.29	3.04327	1.79E-06	
19.8	884.2	2.94156	1.7E-06	
19.9	884.1	2.80979	1.67E-06	
20.0	884	2.75557	1.62E-06	
20.1	883.9	2.53151	1.56E-06	
20.2	883.8	2.01103	1.33E-06	
20.3	883.7	1.75481	1.09E-06	
20.4	883.6	1.53558	9.9E-07	
20.5	883.5	1.23553	8.1E-07	
20.6	883.4	1.57533	8.02E-07	
20.7	883.3	2.23732	1.15E-06	

01U106-Up/Down Average Sonde Data				Data not used for core data versus sonde data analysis because no core data
Depth (ft b	Elevation feet amsl	Mag Susc 10e-3 SI Ur	Mag Susc (m3/kg)	
14.4475	882.5525	4.189138	2.46E-06	
14.5475	882.4525	4.402348	2.59E-06	
14.6475	882.3525	4.701538	2.77E-06	
14.7475	882.2525	4.70912	2.77E-06	
14.8475	882.1525	4.575168	2.69E-06	
14.9475	882.0525	4.401035	2.59E-06	
15.0475	881.9525	4.210525	2.48E-06	
15.1475	881.8525	3.905058	2.3E-06	
15.2475	881.7525	3.691598	2.17E-06	
15.3475	881.6525	3.596823	2.12E-06	
15.4475	881.5525	3.472525	2.04E-06	
15.5475	881.4525	3.353383	1.97E-06	
15.6475	881.3525	3.3768	1.99E-06	
15.7475	881.2525	3.569745	2.1E-06	
15.845	881.155	3.460983	2.04E-06	
15.945	881.055	3.208193	1.89E-06	
16.045	880.955	3.088508	1.82E-06	
16.14	880.86	3.210473	1.89E-06	
16.24	880.76	3.29232	1.94E-06	
16.34	880.66	3.33742	1.96E-06	
16.44	880.56	3.02443	1.78E-06	
16.54	880.46	2.517965	1.48E-06	
16.64	880.36	2.29173	1.35E-06	
16.74	880.26	2.420195	1.42E-06	
16.84	880.16	2.532918	1.49E-06	
16.9375	880.0625	2.519855	1.48E-06	
17.0375	879.9625	2.41371	1.42E-06	
17.1375	879.8625	2.29431	1.35E-06	
17.2375	879.7625	2.203953	1.3E-06	
17.3375	879.6625	2.25754	1.33E-06	
17.4375	879.5625	2.249393	1.32E-06	
17.5375	879.4625	2.06218	1.21E-06	
17.6375	879.3625	2.033548	1.2E-06	
17.7375	879.2625	2.0178	1.19E-06	
17.8375	879.1625	2.319903	1.36E-06	
17.9375	879.0625	2.53814	1.49E-06	
18.0375	878.9625	2.58663	1.52E-06	
18.1375	878.8625	2.407258	1.42E-06	
18.2375	878.7625	2.209005	1.3E-06	
18.3375	878.6625	2.102103	1.24E-06	
18.4375	878.5625	2.092245	1.23E-06	
18.5375	878.4625	2.140738	1.26E-06	
18.6375	878.3625	2.014035	1.18E-06	
18.7375	878.2625	1.920538	1.13E-06	
18.8375	878.1625	1.987418	1.17E-06	
18.9375	878.0625	1.994328	1.17E-06	
19.0375	877.9625	1.900065	1.12E-06	
19.135	877.865	1.832578	1.08E-06	
19.235	877.765	1.849745	1.09E-06	
19.335	877.665	1.726545	1.02E-06	
19.4325	877.5675	1.693728	9.96E-07	
19.53	877.47	1.746948	1.03E-06	
19.63	877.37	1.770128	1.04E-06	
19.73	877.27	1.882485	1.11E-06	
19.83	877.17	2.143335	1.26E-06	

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FROM THE FORMER TWIN CITIES ARMY AMMUNITION PLANT

01U108-Up/Down Average Sonde Data

Depth (ft bgs)	Elevation feet amsl	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)
19.91	884.09	1.48	8.70E-07
20.01	883.99	1.51	8.91E-07
20.11	883.89	1.47	8.66E-07
20.21	883.79	1.47	8.68E-07
20.31	883.69	1.41	8.32E-07
20.41	883.59	1.37	8.04E-07
20.51	883.49	1.43	8.39E-07
20.61	883.39	1.53	9.00E-07
20.71	883.29	1.47	8.65E-07
20.81	883.19	1.45	8.54E-07
20.91	883.10	1.50	8.84E-07
21.01	883.00	1.51	8.86E-07
21.11	882.90	1.56	9.19E-07
21.21	882.80	1.49	8.76E-07
21.31	882.70	1.41	8.31E-07
21.41	882.60	1.44	8.50E-07
21.51	882.50	1.44	8.45E-07
21.61	882.40	1.36	7.97E-07
21.70	882.30	1.25	7.33E-07
21.80	882.20	1.16	6.80E-07
21.90	882.10	1.27	7.45E-07
22.00	882.00	1.30	7.64E-07
22.10	881.90	1.24	7.31E-07
22.20	881.80	1.23	7.23E-07
22.30	881.70	1.23	7.23E-07
22.40	881.60	1.26	7.44E-07
22.50	881.50	1.32	7.77E-07
22.60	881.40	1.37	8.07E-07
22.70	881.30	1.30	7.64E-07
22.80	881.20	1.29	7.60E-07
22.90	881.10	1.35	7.92E-07
23.00	881.00	1.34	7.86E-07
23.10	880.90	1.25	7.36E-07
23.20	880.80	1.24	7.31E-07
23.30	880.70	1.75	1.03E-06
23.40	880.60	2.54	1.49E-06
23.50	880.50	2.93	1.73E-06
23.60	880.40	3.04	1.79E-06
23.70	880.30	3.11	1.83E-06
23.80	880.20	3.32	1.95E-06

*Note, The average of 19 feet for core samples was obtained from samples collected from 18 to 20 ft bgs

01U103-Up/Down Average Sonde Data

Data not used for core data versus sonde data analysis because no core data

Depth ft bgs	Elevation feet amsl	Mag Susc 10e-3 SI un	Mag Susc m3/kg
20.8	883.2	2.51899	1.41E-06
20.9	883.1	2.67494	1.5E-06
21	883	2.99202	1.67E-06
21.1	882.9	3.03078	1.71E-06
21.2	882.8	3.52807	1.93E-06
21.3	882.7	3.84495	2.11E-06
21.4	882.6	4.13059	2.35E-06
21.5	882.5	4.22991	2.44E-06
21.6	882.4	3.88979	2.41E-06
21.7	882.3	3.88912	2.28E-06
21.8	882.2	3.47377	2.14E-06
21.9	882.1	2.91726	1.86E-06
22	882	2.23973	1.49E-06
22.1	881.9	2.10066	1.28E-06
22.2	881.8	1.79948	1.16E-06
22.3	881.7	1.59202	9.88E-07
22.4	881.6	1.71899	9.97E-07
22.5	881.5	1.64889	9.48E-07
22.6	881.4	1.82194	9.89E-07
22.7	881.3	1.91042	1.08E-06
22.8	881.2	2.02112	1.2E-06
22.9	881.1	2.15377	1.22E-06
23	881	2.04817	1.2E-06
23.09	880.91	2.0514	1.16E-06
23.19	880.81	2.37378	1.26E-06
23.29	880.71	2.49341	1.47E-06
23.39	880.61	2.75285	1.56E-06
23.49	880.51	3.04569	1.73E-06
23.59	880.41	2.78508	1.72E-06
23.69	880.31	2.73985	1.66E-06
23.79	880.21	2.9866	1.67E-06
23.89	880.11	3.05403	1.81E-06
23.99	880.01	3.2804	1.87E-06
24.09	879.91	3.36996	1.95E-06
24.19	879.81	3.01659	1.89E-06
24.29	879.71	2.66373	1.66E-06
24.39	879.61	2.67223	1.54E-06
24.49	879.51	2.68778	1.6E-06
24.59	879.41	2.54965	1.51E-06
24.69	879.31	2.33	1.40E-06
24.79	879.21	2.23	1.32E-06
24.89	879.11	2.17	1.24E-06
24.99	879.01	2.07776	1.27E-06
25.09	878.91	2.2094	1.27E-06
25.19	878.81	2.51304	1.37E-06
25.29	878.71	2.61913	1.58E-06
25.39	878.61	2.43485	1.52E-06
25.49	878.51	2.5532	1.46E-06
25.59	878.41	3.52544	1.78E-06
25.69	878.31	4.13348	2.3E-06
25.79	878.21	3.8114	2.31E-06
25.89	878.11	3.30971	2.1E-06
25.99	878.01	2.68838	1.72E-06
26.09	877.91	2.83514	1.62E-06
26.19	877.81	2.99498	1.71E-06

01U106-Up/Down Average Sonde Data

Data not used for core data versus sonde data analysis because no core data

Depth (ft b	Elevation feet amsl	Mag Susc 10e-3 SI Ur	Mag Susc (m3/kg)
19.93	877.07	2.2667	1.33E-06
20.03	876.97	2.14875	1.26E-06
20.13	876.87	1.794165	1.06E-06
20.23	876.77	1.778	1.05E-06
20.3275	876.6725	1.938043	1.14E-06
20.4275	876.5725	2.154988	1.27E-06
20.5275	876.4725	2.198868	1.29E-06
20.6275	876.3725	2.073553	1.22E-06
20.7275	876.2725	1.861893	1.1E-06
20.8275	876.1725	1.82471	1.07E-06
20.9275	876.0725	1.872613	1.1E-06
21.0275	875.9725	1.872003	1.1E-06
21.1275	875.8725	1.782183	1.05E-06
21.2275	875.7725	1.603388	9.43E-07
21.3275	875.6725	1.454033	8.55E-07
21.4275	875.5725	1.308413	7.7E-07
21.5275	875.4725	1.209915	7.12E-07
21.6275	875.3725	1.368525	8.05E-07
21.7275	875.2725	1.587058	9.34E-07
21.8275	875.1725	1.77742	1.05E-06
21.9275	875.0725	1.84797	1.09E-06
22.0275	874.9725	1.873	1.1E-06
22.1275	874.8725	2.077095	1.22E-06
22.2275	874.7725	2.53255	1.49E-06
22.3275	874.6725	2.871793	1.69E-06
22.425	874.575	2.870698	1.69E-06
22.525	874.475	2.812058	1.65E-06
22.625	874.375	2.97499	1.75E-06
22.7225	874.2775	3.403308	2E-06
22.82	874.18	3.784135	2.23E-06
22.92	874.08	3.792553	2.23E-06
23.02	873.98	3.6507	2.15E-06
23.12	873.88	3.309258	1.95E-06
23.22	873.78	3.222525	1.9E-06
23.32	873.68	3.058803	1.8E-06
23.42	873.58	2.93435	1.73E-06
23.52	873.48	2.90729	1.71E-06
23.6175	873.3825	2.962745	1.74E-06
23.7175	873.2825	3.018993	1.78E-06
23.8175	873.1825	2.976043	1.75E-06
23.9175	873.0825	2.4902	1.46E-06
24.005	872.995	2.400035	1.41E-06

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FROM THE FORMER TWIN CITIES ARMY AMMUNITION PLANT

01U108-Up/Down Average
Sonde Data

Depth (ft bgs)	**Elevation** feet amsl	**Mag Susc** (10e-3 SI units)	**Mag Susc** (m3/kg)

01U103-Up/Down Average
Sonde Data

Data not used for core data versus sonde data analysis because no core data

Depth ft bgs	Elevation feet amsl	Mag Susc 10e-3 SI un	Mag Susc m3/kg
26.29	877.71	2.47884	1.61E-06
26.39	877.61	2.58309	1.51E-06
26.48	877.52	2.79943	1.58E-06
26.58	877.42	2.69549	1.62E-06
26.68	877.32	2.61643	1.55E-06
26.78	877.22	2.86318	1.61E-06
26.88	877.12	3.01221	1.7E-06
26.98	877.02	2.89905	1.75E-06
27.08	876.92	2.2708	1.48E-06
27.18	876.82	0.945118	9.04E-07

01U106-Up/Down Average
Sonde Data

Data not used for core data versus sonde data analysis because no core data

Depth (ft b	Elevation feet amsl	Mag Susc 10e-3 SI Ur	Mag Susc (m3/kg)

WIEDEMEIER & ASSOCIATES

PROJECT ESTCP 201584

LOCATION Former Twin Cities Army Ammunition Plant

WELL O1U108

LOGGER THW

DATE May 31, 2016

TOOL HMA-453-S

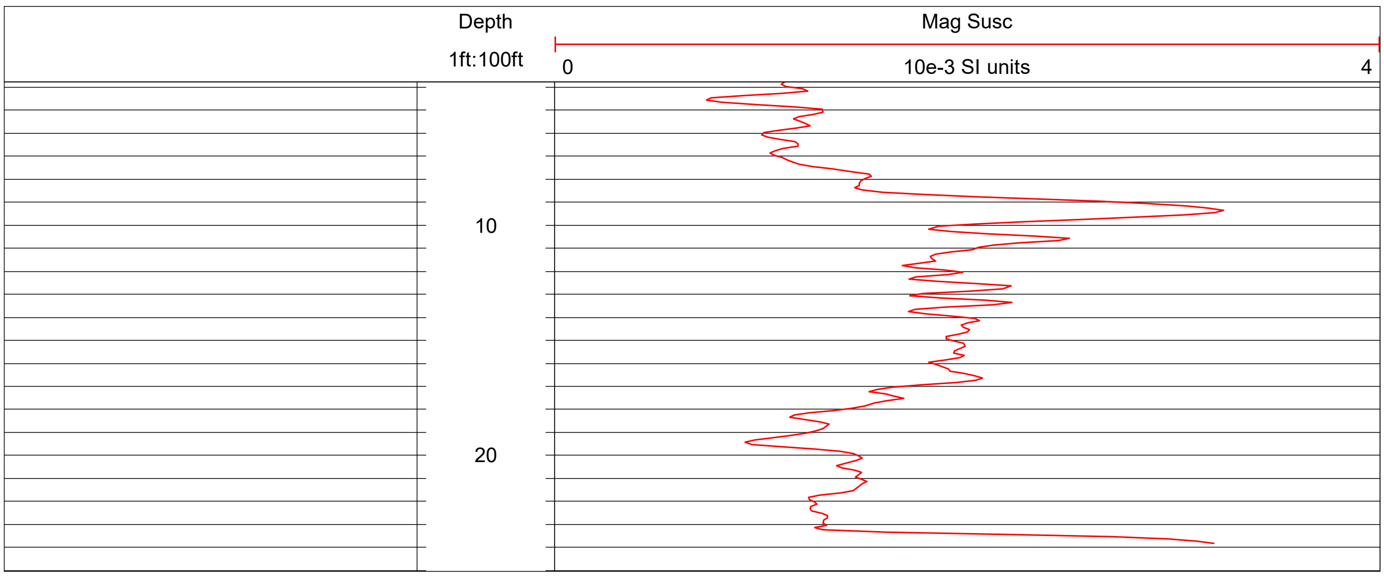
CALIBRATION DATE/TIME 5/31/16 12:15

CALIBRATION STANDARDS 0 and 5E-3 SI Units

CALIBRATION RESULTS Not Recorded

REMARKS

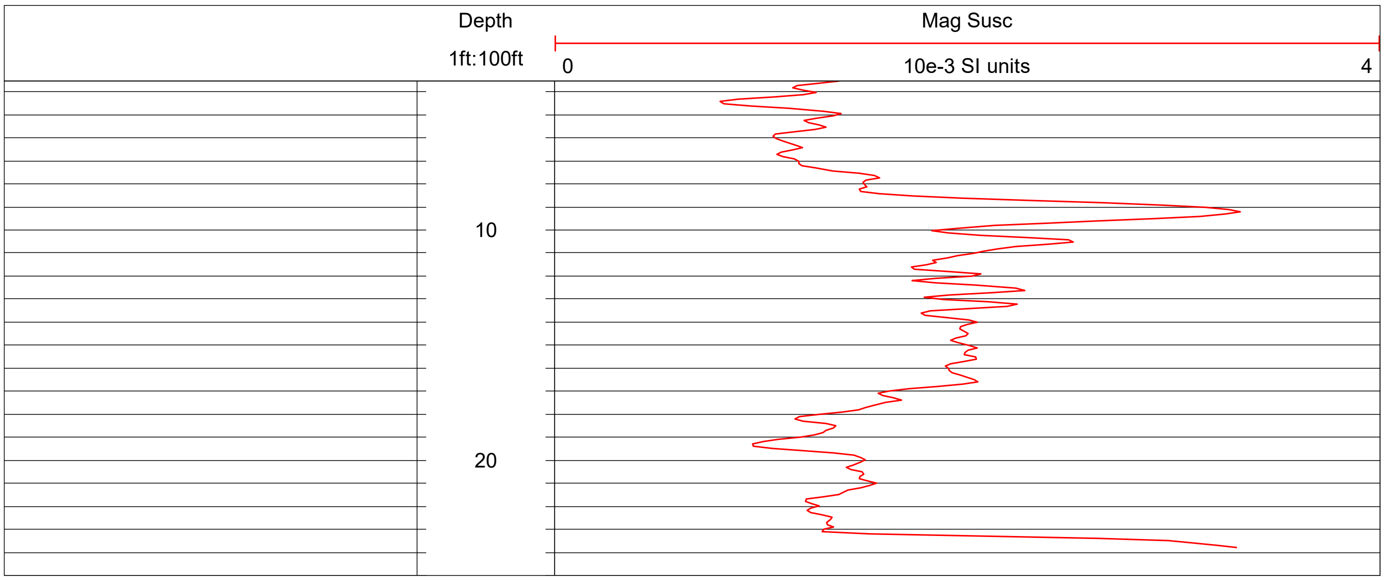
Tool bottomed out at 23.82 feet BGS.



PROJECT	ESTCP 201584
LOCATION	Former Twin Cities Army Ammunition Plant
WELL	01U108
LOGGER	THW
DATE	5/31/16

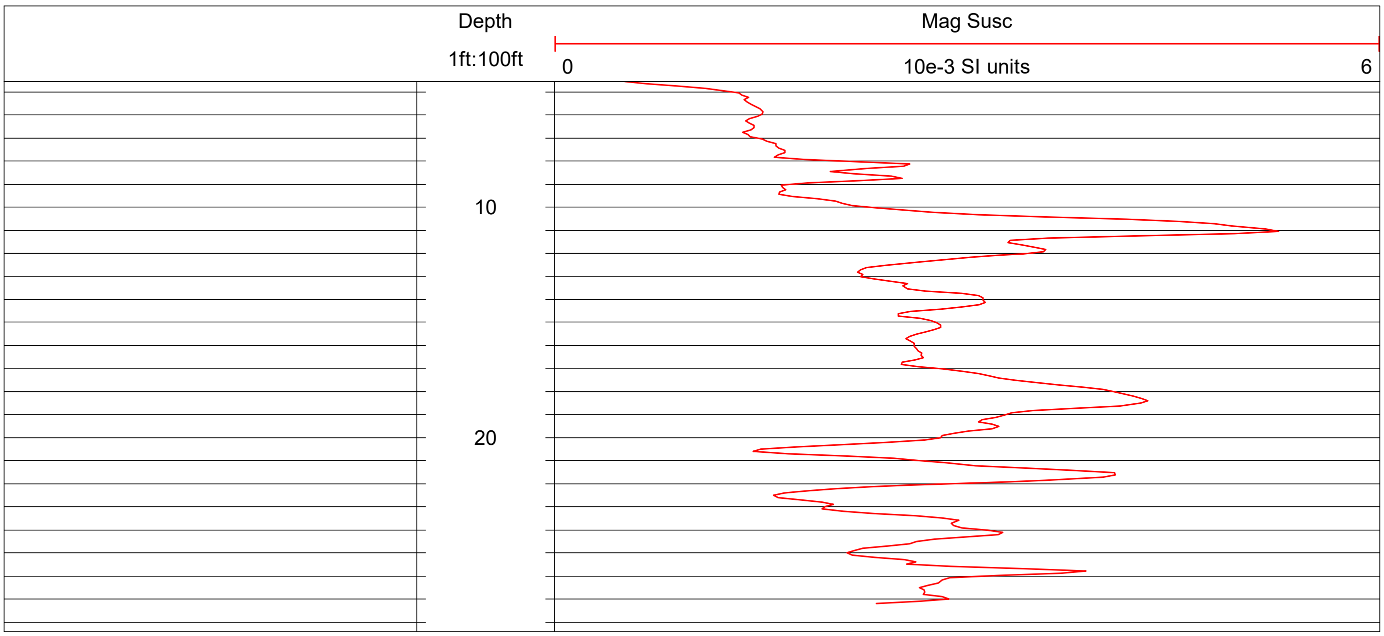
TOOL	HMA-453-S
CALIBRATION DATE/TIME	5/31/16 12:15
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	Not Recorded
REMARKS	

Tool bottomed out at 23.82 feet BGS



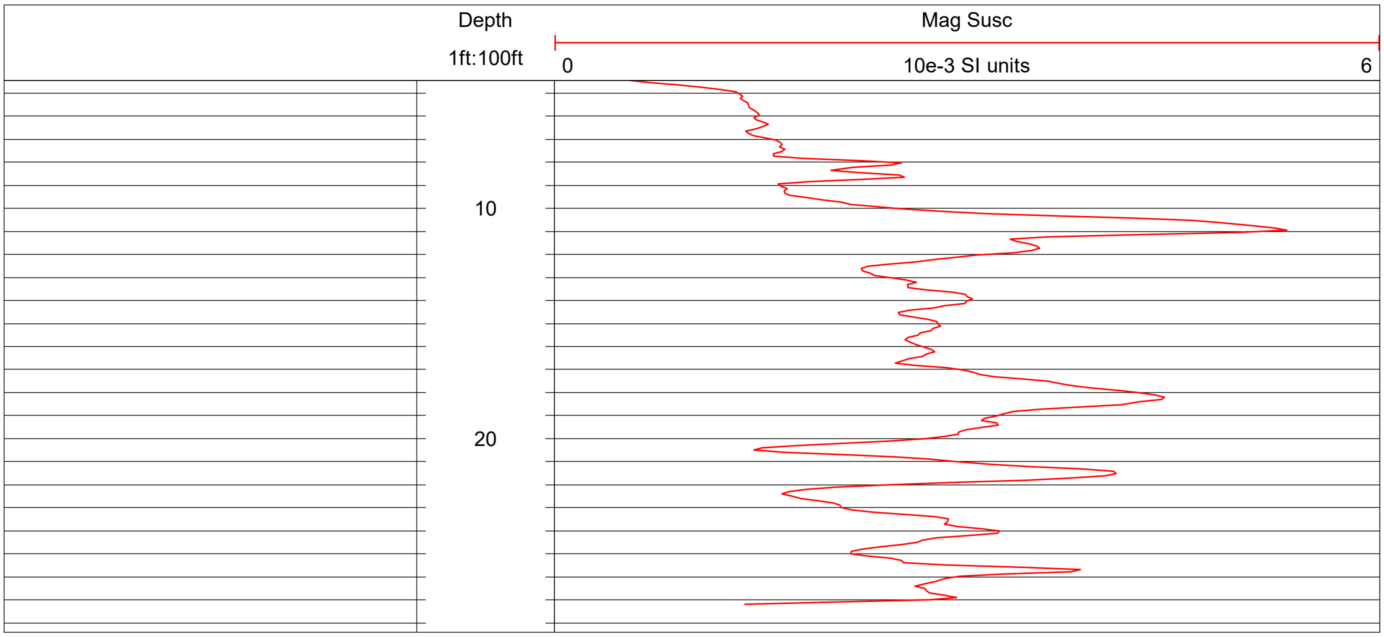
PROJECT	ESTCP ER-201584
LOCATION	TCAAP, Shoreview, MN
WELL	O1U-103 -- Down - Calib 1
LOGGER	Todd Wiedemeier
DATE	June 2, 2016

TOOL	HMA-453-S
CALIBRATION DATE/TIME	6/2/16 - 12:30
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	Zero = 60.6, 5E-3 = 1160.53 cps
REMARKS	



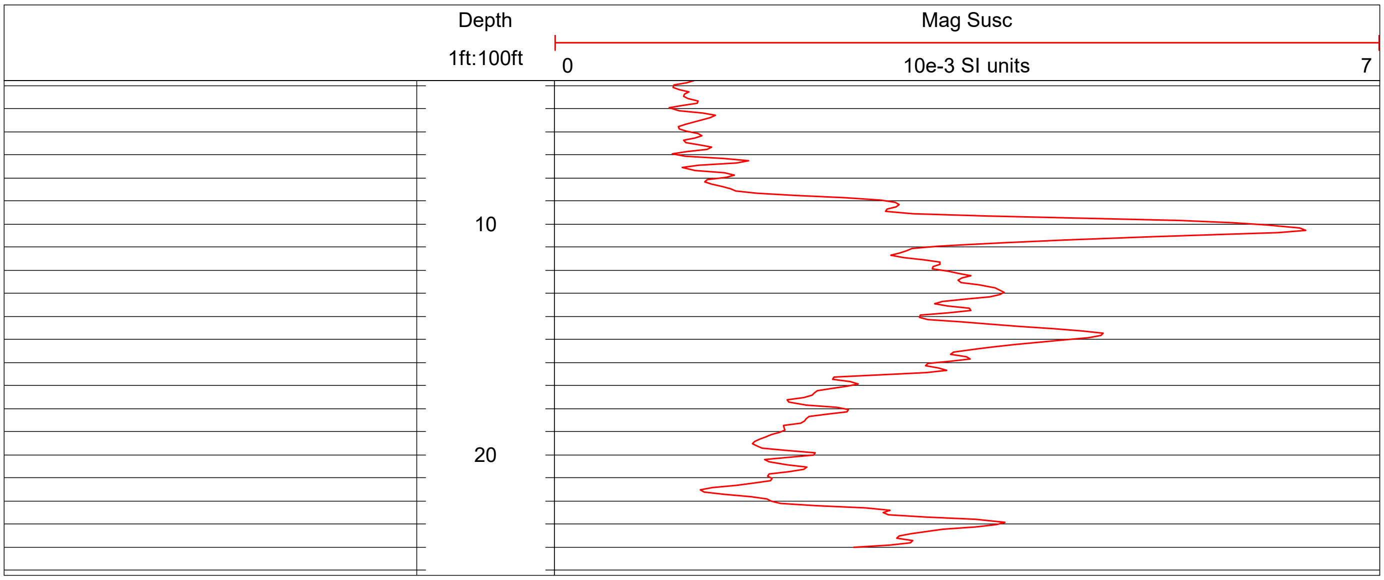
PROJECT	ESTCP ER-201584
LOCATION	TCAAP, Shoreview, MN
WELL	O1U-103 -- Up -- Calibration 1
LOGGER	Todd Wiedemeier
DATE	June

TOOL	HMA-453-S
CALIBRATION DATE/TIME	6/2/16 - 12:30
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	Zero = 60.6, 5E-3 = 1160.53 cps
REMARKS	



PROJECT	ESTCP ER-201584
LOCATION	TCAAP, Shoreview, MN
WELL	O1U-106 - Down - Run 1 - Calib 1
LOGGER	Todd Wiedemeier
DATE	June 2, 2016

TOOL	HMA-453-S
CALIBRATION DATE/TIME	6/2/16 -- 14:50
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	0 = 56.91, 5E-3 = 1187.23 cps
REMARKS	



WIEDEMEIER & ASSOCIATES

PROJECT ESTCP ER-201184

LOCATION TCAAP, Shoreview, MN

WELL O1U-106 - Down - Run 2 - Calib 1

LOGGER Todd Wiedemeier

DATE June 2, 2016

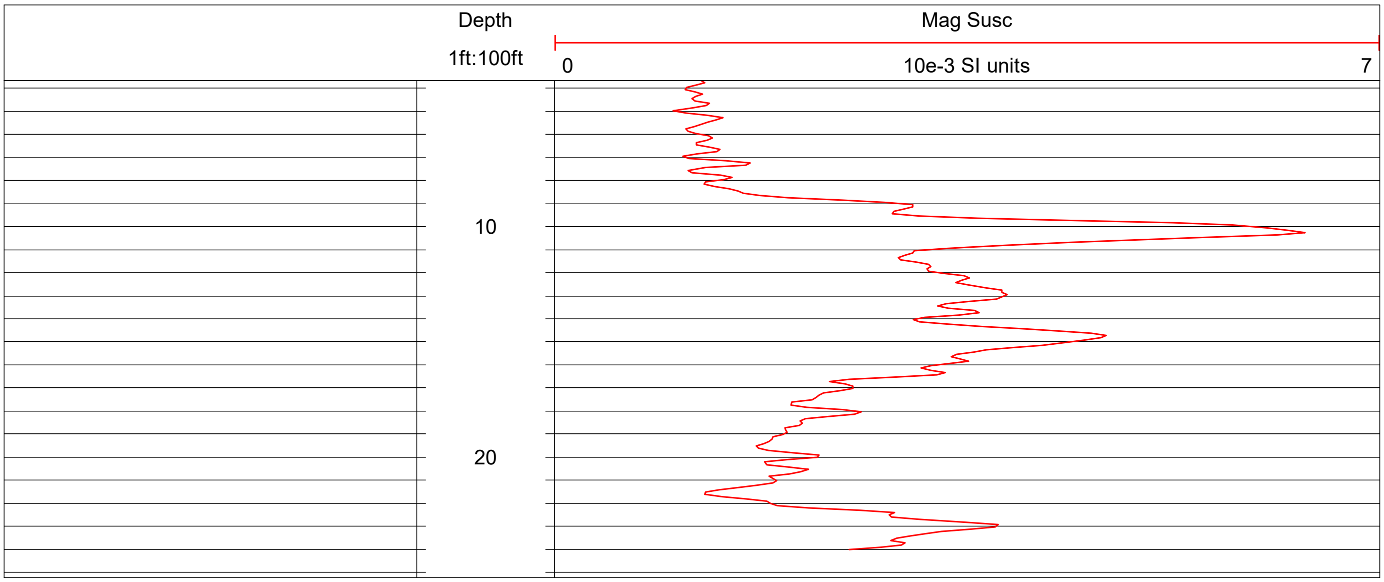
TOOL HMA-453-S

CALIBRATION DATE/TIME 6/2/16 - 14:50

CALIBRATION STANDARDS 0 and 5E-3 SI Units

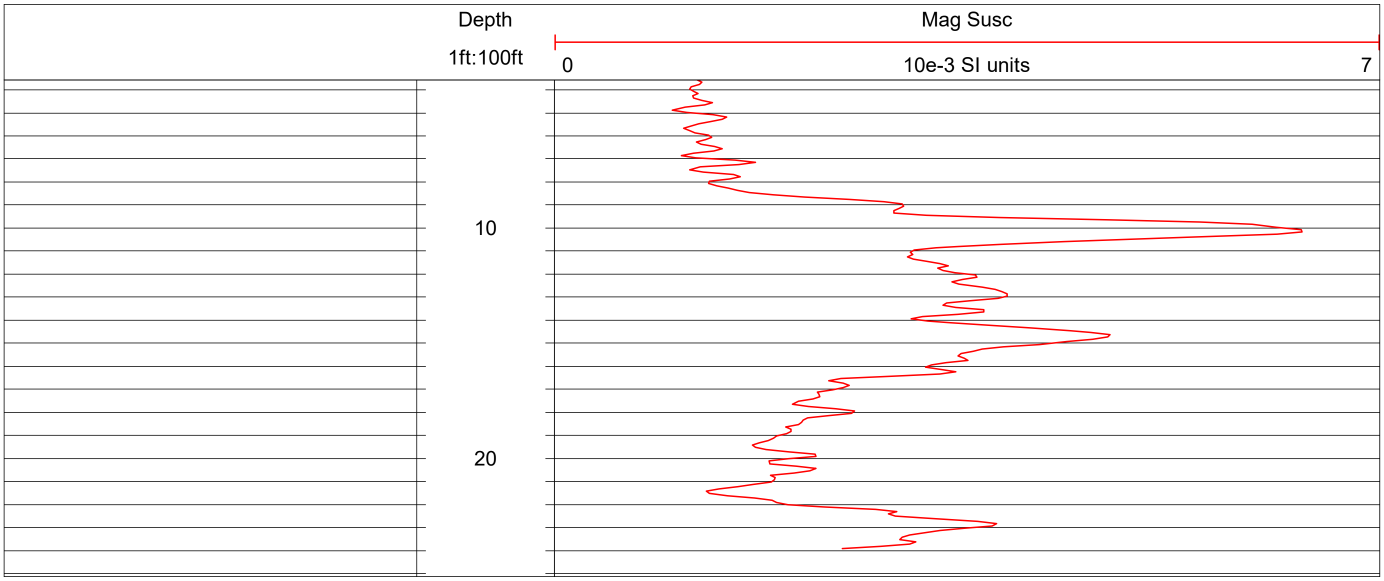
CALIBRATION RESULTS 0 = 56.91, 5E-3 = 1187.23 cps

REMARKS



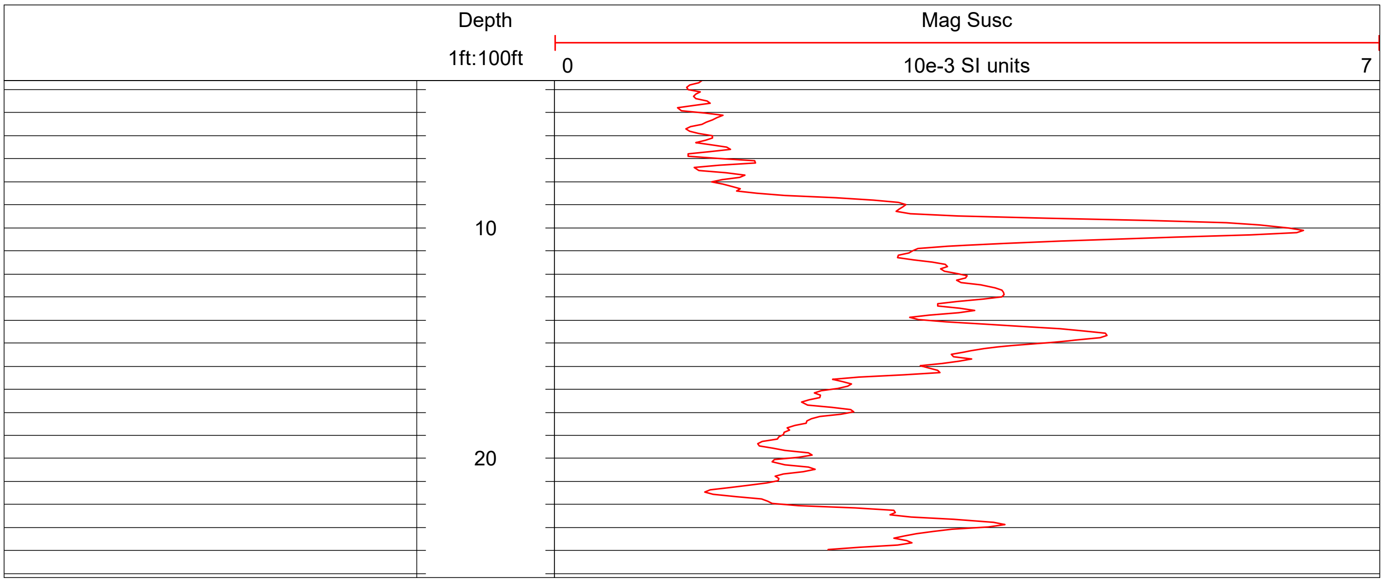
PROJECT	ESTCP ER-201584
LOCATION	TCAAP, Shoreview, MN
WELL	O1U-106 - Up - Run 1 - Calib 1
LOGGER	Todd Wiedemeier
DATE	June 2, 2016

TOOL	HMA-453-S
CALIBRATION DATE/TIME	6/2/16 -- 14:50
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	0 = 56.91, 5E-3 = 1187.23 cps
REMARKS	



PROJECT	ESTCP ER-201184
LOCATION	TCAAP, Shoreview, MN
WELL	O1U-106 - Up - Run 2 - Calib 1
LOGGER	Todd Wiedemeier
DATE	June 2, 2016

TOOL	HMA-453-S
CALIBRATION DATE/TIME	6/2/16 - 14:50
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	0 = 56.91, 5E-3 = 1187.23 cps
REMARKS	



MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR THE FORMER PLATTSBURGH AIR FORCE BASE, NEW YORK

Top of riser elevation (feet) 250.44

MW-02-017 Run 2 Up and Down - Average

Elevation feet amsl	Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
241.85	8.59	2.08	1.23E-06
241.75	8.69	2.07	1.22E-06
241.65	8.79	2.01	1.18E-06
241.55	8.89	2.11	1.24E-06
241.45	8.99	2.04	1.20E-06
241.35	9.09	2.03	1.19E-06
241.25	9.19	2.01	1.18E-06
241.15	9.29	2.07	1.22E-06
241.05	9.39	2.18	1.28E-06
240.95	9.49	2.04	1.20E-06
240.85	9.59	1.90	1.11E-06
240.75	9.69	1.88	1.11E-06
240.65	9.79	1.87	1.10E-06
240.56	9.88	1.77	1.04E-06
240.46	9.98	1.74	1.02E-06
240.355	10.085	1.94	1.14E-06
240.255	10.185	1.75	1.03E-06
240.155	10.285	1.85	1.09E-06
240.055	10.385	1.93	1.13E-06
239.955	10.485	1.98	1.17E-06
239.855	10.585	2.04	1.20E-06
239.755	10.685	2.10	1.23E-06
239.655	10.785	2.09	1.23E-06
239.555	10.885	2.10	1.24E-06
239.455	10.985	2.04	1.20E-06
239.355	11.085	1.98	1.17E-06
239.255	11.185	1.81	1.06E-06
239.155	11.285	1.64	9.64E-07
239.055	11.385	1.59	9.38E-07
238.955	11.485	1.53	9.01E-07
238.855	11.585	1.51	8.91E-07
238.755	11.685	1.60	9.39E-07
238.655	11.785	1.81	1.06E-06
238.555	11.885	2.00	1.18E-06
238.455	11.985	2.35	1.38E-06
238.355	12.085	2.57	1.51E-06
238.255	12.185	2.85	1.67E-06
238.155	12.285	2.92	1.72E-06
238.055	12.385	2.75	1.62E-06
237.955	12.485	2.45	1.44E-06
237.855	12.585	2.06	1.21E-06
237.755	12.685	1.51	8.91E-07
237.655	12.785	1.11	6.54E-07

Top of riser elevation (feet) 229.55

MW-02-030 Run 2 Up and Down Average

feet amsl	Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
226.02	3.53	2.69	1.58E-06
225.92	3.63	2.62	1.54E-06
225.81	3.74	2.51	1.48E-06
225.71	3.84	2.34	1.37E-06
225.61	3.94	2.27	1.34E-06
225.51	4.04	2.24	1.31E-06
225.415	4.135	2.18	1.29E-06
225.315	4.235	2.17	1.28E-06
225.215	4.335	2.13	1.25E-06
225.115	4.435	2.25	1.32E-06
225.015	4.535	2.17	1.28E-06
224.915	4.635	2.27	1.34E-06
224.815	4.735	2.28	1.34E-06
224.715	4.835	2.33	1.37E-06
224.615	4.935	2.39	1.40E-06
224.515	5.035	2.29	1.35E-06
224.415	5.135	2.26	1.33E-06
224.315	5.235	2.19	1.29E-06
224.215	5.335	2.05	1.21E-06
224.115	5.435	2.07	1.22E-06
224.015	5.535	2.12	1.25E-06
223.915	5.635	2.14	1.26E-06
223.815	5.735	2.09	1.23E-06
223.715	5.835	1.95	1.15E-06
223.615	5.935	1.82	1.07E-06
223.515	6.035	1.85	1.09E-06
223.415	6.135	1.86	1.09E-06
223.315	6.235	1.84	1.08E-06
223.215	6.335	1.87	1.10E-06
223.115	6.435	1.93	1.13E-06
223.015	6.535	1.95	1.15E-06
222.915	6.635	1.96	1.15E-06
222.815	6.735	2.07	1.22E-06
222.715	6.835	2.06	1.21E-06
222.62	6.93	2.27	1.33E-06
222.52	7.03	2.30	1.36E-06
222.42	7.13	2.31	1.36E-06
222.32	7.23	2.24	1.32E-06
222.22	7.33	2.13	1.25E-06
222.12	7.43	2.01	1.18E-06
222.025	7.525	1.91	1.12E-06
221.925	7.625	1.94	1.14E-06
221.825	7.725	1.90	1.12E-06

Mean 190 to 220 feet	**1.2E-06**
Sample Standard Deviation	**3.7E-07**

Mean	1.18151E-06
Standard Error	2.15102E-08
Median	1.07027E-06
Mode	#N/A
Standard Deviation	3.73807E-07
Sample Variance	1.39732E-13
Kurtosis	-0.162552451
Skewness	0.743357621
Range	1.66179E-06
Minimum	6.0655E-07
Maximum	2.26834E-06
Sum	0.000356815
Count	302
Confidence Level(95.0%)	4.23294E-08

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR THE FORMER PLATTSBURGH AIR FORCE BASE, NEW YORK

Top of riser elevation (feet) 250.44 — MW-02-017 Run 2 Up and Down - Average

Elevation feet amsl	Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
237.555	12.885	0.84	4.95E-07
237.46	12.98	0.77	4.51E-07
237.36	13.08	0.83	4.90E-07
237.26	13.18	0.86	5.06E-07
237.165	13.275	0.89	5.22E-07
237.065	13.375	0.99	5.82E-07
236.965	13.475	1.07	6.28E-07
236.865	13.575	1.28	7.54E-07
236.765	13.675	1.54	9.05E-07
236.665	13.775	1.73	1.01E-06
236.565	13.875	1.89	1.11E-06
236.465	13.975	1.99	1.17E-06
236.365	14.075	1.95	1.15E-06
236.265	14.175	1.90	1.12E-06
236.165	14.275	1.83	1.08E-06
236.065	14.375	1.75	1.03E-06
235.965	14.475	1.74	1.02E-06
235.865	14.575	1.74	1.02E-06
235.765	14.675	1.64	9.65E-07
235.665	14.775	1.69	9.96E-07
235.565	14.875	1.63	9.58E-07
235.465	14.975	1.59	9.37E-07
235.365	15.075	1.49	8.78E-07
235.265	15.175	1.39	8.20E-07
235.165	15.275	1.38	8.10E-07
235.065	15.375	1.34	7.88E-07
234.965	15.475	1.30	7.65E-07
234.865	15.575	1.32	7.78E-07
234.765	15.675	1.39	8.16E-07
234.665	15.775	1.40	8.22E-07
234.565	15.875	1.43	8.39E-07
234.465	15.975	1.38	8.14E-07
234.365	16.075	1.30	7.66E-07
234.265	16.175	1.29	7.58E-07
234.165	16.275	1.29	7.57E-07
234.07	16.37	1.27	7.49E-07
233.97	16.47	1.31	7.72E-07
233.875	16.565	1.28	7.51E-07
233.775	16.665	1.37	8.05E-07
233.675	16.765	1.53	9.02E-07
233.575	16.865	1.52	8.92E-07
233.475	16.965	1.70	1.00E-06
233.375	17.065	1.79	1.05E-06

Top of riser elevation (feet) 229.55 — MW-02-030 Run 2 Up and Down Average

feet amsl	Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
221.725	7.825	2.01	1.18E-06
221.625	7.925	2.17	1.28E-06
221.525	8.025	2.22	1.30E-06
221.425	8.125	2.12	1.25E-06
221.325	8.225	2.18	1.28E-06
221.225	8.325	2.06	1.21E-06
221.125	8.425	1.94	1.14E-06
221.025	8.525	1.68	9.88E-07
220.925	8.625	1.58	9.31E-07
220.825	8.725	1.47	8.64E-07
220.725	8.825	1.50	8.84E-07
220.625	8.925	1.60	9.42E-07
220.525	9.025	1.68	9.88E-07
220.425	9.125	1.69	9.95E-07
220.325	9.225	1.77	1.04E-06
220.225	9.325	1.75	1.03E-06
220.125	9.425	1.72	1.01E-06
220.025	9.525	1.72	1.01E-06
219.925	9.625	1.66	9.77E-07
219.825	9.725	1.61	9.47E-07
219.725	9.825	1.57	9.24E-07
219.625	9.925	1.61	9.45E-07
219.525	10.025	1.68	9.86E-07
219.425	10.125	1.72	1.01E-06
219.33	10.22	1.79	1.05E-06
219.23	10.32	1.80	1.06E-06
219.13	10.42	1.80	1.06E-06
219.03	10.52	1.74	1.02E-06
218.93	10.62	1.82	1.07E-06
218.83	10.72	1.80	1.06E-06
218.735	10.815	1.80	1.06E-06
218.635	10.915	1.72	1.01E-06
218.535	11.015	1.69	9.93E-07
218.435	11.115	1.67	9.80E-07
218.335	11.215	1.72	1.01E-06
218.235	11.315	1.73	1.02E-06
218.135	11.415	1.82	1.07E-06
218.035	11.515	1.94	1.14E-06
217.935	11.615	2.03	1.20E-06
217.835	11.715	1.99	1.17E-06
217.735	11.815	1.90	1.12E-06
217.635	11.915	1.81	1.06E-06
217.535	12.015	1.71	1.00E-06

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR THE FORMER PLATTSBURGH AIR FORCE BASE, NEW YORK

Top of riser elevation (feet)	MW-02-017 Run 2 Up and Down - Average			Top of riser elevation (feet)	MW-02-030 Run 2 Up and Down Average		
250.44				229.55			
Elevation	Depth	Mag Susc 10e-3 SI	Mag Susc		Depth	Mag Susc 10e-3 SI	Mag Susc
feet amsl	ft bgs	units	m3/kg	feet amsl	ft bgs	units	m3/kg
233.275	17.165	1.98	1.16E-06	217.42	12.13	1.62	9.54E-07
233.175	17.265	1.94	1.14E-06	217.335	12.215	1.62	9.52E-07
233.075	17.365	2.01	1.18E-06	217.235	12.315	1.55	9.11E-07
232.975	17.465	1.89	1.11E-06	217.135	12.415	1.63	9.58E-07
232.875	17.565	1.68	9.86E-07	217.035	12.515	1.74	1.03E-06
232.775	17.665	1.57	9.26E-07	216.935	12.615	2.07	1.22E-06
232.675	17.765	1.41	8.30E-07	216.835	12.715	2.27	1.34E-06
232.575	17.865	1.32	7.74E-07	216.735	12.815	2.51	1.48E-06
232.475	17.965	1.28	7.51E-07	216.635	12.915	2.56	1.51E-06
232.375	18.065	1.26	7.41E-07	216.535	13.015	2.50	1.47E-06
232.275	18.165	1.31	7.68E-07	216.435	13.115	2.71	1.59E-06
232.175	18.265	1.36	8.01E-07	216.32	13.23	2.90	1.70E-06
232.075	18.365	1.41	8.28E-07	216.235	13.315	3.04	1.79E-06
231.975	18.465	1.40	8.21E-07	216.135	13.415	2.86	1.68E-06
231.875	18.565	1.38	8.10E-07	216.04	13.51	2.50	1.47E-06
231.775	18.665	1.36	8.01E-07	215.94	13.61	2.42	1.42E-06
231.675	18.765	1.40	8.24E-07	215.84	13.71	2.56	1.50E-06
231.575	18.865	1.38	8.12E-07	215.74	13.81	2.75	1.62E-06
231.475	18.965	1.35	7.93E-07	215.64	13.91	2.84	1.67E-06
231.375	19.065	1.31	7.68E-07	215.54	14.01	2.76	1.63E-06
231.275	19.165	1.24	7.30E-07	215.445	14.105	2.64	1.56E-06
231.175	19.265	1.28	7.55E-07	215.345	14.205	2.57	1.51E-06
231.075	19.365	1.38	8.10E-07	215.245	14.305	2.54	1.49E-06
230.975	19.465	1.38	8.09E-07	215.145	14.405	2.66	1.56E-06
230.875	19.565	1.38	8.12E-07	215.045	14.505	2.64	1.55E-06
230.78	19.66	1.33	7.83E-07	214.945	14.605	2.57	1.51E-06
230.68	19.76	1.28	7.54E-07	214.845	14.705	2.70	1.59E-06
230.585	19.855	1.23	7.23E-07	214.745	14.805	2.60	1.53E-06
230.485	19.955	1.17	6.87E-07	214.645	14.905	2.62	1.54E-06
230.385	20.055	1.16	6.83E-07	214.545	15.005	2.47	1.45E-06
230.285	20.155	1.19	6.99E-07	214.445	15.105	2.47	1.45E-06
230.185	20.255	1.16	6.82E-07	214.345	15.205	2.39	1.41E-06
230.085	20.355	1.18	6.96E-07	214.245	15.305	2.39	1.40E-06
229.985	20.455	1.22	7.17E-07	214.145	15.405	2.34	1.38E-06
229.885	20.555	1.30	7.65E-07	214.045	15.505	2.23	1.31E-06
229.785	20.655	1.33	7.82E-07	213.945	15.605	2.09	1.23E-06
229.685	20.755	1.33	7.84E-07	213.845	15.705	2.01	1.18E-06
229.585	20.855	1.38	8.11E-07	213.745	15.805	1.82	1.07E-06
229.485	20.955	1.45	8.51E-07	213.645	15.905	1.81	1.07E-06
229.385	21.055	1.61	9.46E-07	213.545	16.005	1.83	1.08E-06
229.285	21.155	1.60	9.41E-07	213.445	16.105	1.86	1.10E-06
229.185	21.255	1.65	9.72E-07	213.345	16.205	1.83	1.08E-06
229.085	21.355	1.56	9.20E-07	213.245	16.305	1.75	1.03E-06

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR THE FORMER PLATTSBURGH AIR FORCE BASE, NEW YORK

Top of riser elevation (feet) 250.44 — MW-02-017 Run 2 Up and Down - Average

Elevation feet amsl	Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
228.985	21.455	1.43	8.43E-07
228.885	21.555	1.44	8.47E-07
228.785	21.655	1.38	8.12E-07
228.685	21.755	1.41	8.27E-07
228.585	21.855	1.43	8.41E-07
228.485	21.955	1.43	8.41E-07
228.385	22.055	1.50	8.80E-07
228.285	22.155	1.63	9.58E-07
228.185	22.255	1.70	1.00E-06
228.085	22.355	1.55	9.10E-07
227.985	22.455	1.29	7.57E-07
227.885	22.555	1.17	6.87E-07
227.785	22.655	1.16	6.85E-07
227.685	22.755	1.24	7.32E-07
227.585	22.855	1.28	7.53E-07
227.49	22.95	1.14	6.70E-07
227.39	23.05	0.91	5.35E-07
227.29	23.15	0.86	5.06E-07
227.195	23.245	0.88	5.21E-07
227.095	23.345	0.86	5.04E-07
226.995	23.445	0.85	5.03E-07
226.895	23.545	0.84	4.91E-07
226.795	23.645	0.75	4.42E-07
226.695	23.745	0.75	4.43E-07
226.595	23.845	0.79	4.64E-07
226.495	23.945	0.71	4.20E-07
226.395	24.045	0.70	4.14E-07
226.295	24.145	0.71	4.17E-07
226.195	24.245	0.70	4.12E-07
226.095	24.345	0.68	3.99E-07
225.995	24.445	0.61	3.57E-07
225.895	24.545	0.66	3.87E-07
225.795	24.645	0.59	3.49E-07
225.695	24.745	0.54	3.15E-07
225.595	24.845	0.54	3.20E-07
225.495	24.945	0.52	3.08E-07
225.395	25.045	0.47	2.74E-07
225.295	25.145	0.47	2.79E-07
225.195	25.245	0.47	2.74E-07
225.095	25.345	0.50	2.97E-07
224.995	25.445	0.57	3.33E-07
224.895	25.545	0.62	3.64E-07
224.795	25.645	0.74	4.36E-07

Top of riser elevation (feet) 229.55 — MW-02-030 Run 2 Up and Down Average

feet amsl	Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
213.145	16.405	1.66	9.78E-07
213.045	16.505	1.64	9.62E-07
212.945	16.605	1.61	9.45E-07
212.845	16.705	1.66	9.74E-07
212.745	16.805	1.68	9.89E-07
212.65	16.9	1.82	1.07E-06
212.55	17	1.82	1.07E-06
212.45	17.1	1.88	1.10E-06
212.35	17.2	1.92	1.13E-06
212.25	17.3	1.91	1.12E-06
212.15	17.4	1.92	1.13E-06
212.055	17.495	1.99	1.17E-06
211.955	17.595	2.07	1.22E-06
211.855	17.695	2.12	1.25E-06
211.755	17.795	2.06	1.21E-06
211.655	17.895	1.94	1.14E-06
211.555	17.995	1.94	1.14E-06
211.455	18.095	2.00	1.18E-06
211.355	18.195	2.10	1.24E-06
211.255	18.295	2.18	1.28E-06
211.155	18.395	2.23	1.31E-06
211.055	18.495	2.29	1.35E-06
210.955	18.595	2.25	1.33E-06
210.855	18.695	2.17	1.28E-06
210.755	18.795	2.17	1.28E-06
210.655	18.895	2.15	1.26E-06
210.555	18.995	2.33	1.37E-06
210.455	19.095	2.46	1.45E-06
210.355	19.195	2.53	1.49E-06
210.255	19.295	2.44	1.43E-06
210.155	19.395	2.41	1.41E-06
210.055	19.495	2.44	1.44E-06
209.955	19.595	2.52	1.48E-06
209.855	19.695	2.56	1.50E-06
209.755	19.795	2.52	1.48E-06
209.655	19.895	2.41	1.41E-06
209.555	19.995	2.43	1.43E-06
209.455	20.095	2.55	1.50E-06
209.36	20.19	2.47	1.45E-06
209.26	20.29	2.45	1.44E-06
209.16	20.39	2.55	1.50E-06
209.06	20.49	2.62	1.54E-06
208.96	20.59	2.49	1.46E-06

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR THE FORMER PLATTSBURGH AIR FORCE BASE, NEW YORK

Top of riser elevation (feet)	MW-02-017 Run 2 Up and Down - Average			Top of riser elevation (feet)	MW-02-030 Run 2 Up and Down Average		
250.44				229.55			
Elevation	Depth	Mag Susc 10e-3 SI	Mag Susc		Depth	Mag Susc 10e-3 SI	Mag Susc
feet amsl	ft bgs	units	m3/kg	feet amsl	ft bgs	units	m3/kg
224.695	25.745	0.77	4.55E-07	208.86	20.69	2.44	1.44E-06
224.595	25.845	0.81	4.76E-07	208.765	20.785	2.20	1.30E-06
224.495	25.945	0.88	5.20E-07	208.665	20.885	2.05	1.21E-06
224.395	26.045	0.87	5.10E-07	208.565	20.985	2.05	1.20E-06
224.295	26.145	0.83	4.86E-07	208.465	21.085	2.02	1.19E-06
224.195	26.245	0.84	4.96E-07	208.365	21.185	2.12	1.25E-06
224.1	26.34	0.82	4.82E-07	208.265	21.285	2.13	1.26E-06
224	26.44	0.81	4.74E-07	208.165	21.385	2.07	1.22E-06
223.905	26.535	0.85	5.02E-07	208.065	21.485	1.89	1.11E-06
223.805	26.635	0.85	4.98E-07	207.965	21.585	1.77	1.04E-06
223.705	26.735	0.95	5.57E-07	207.865	21.685	1.70	1.00E-06
223.605	26.835	0.98	5.76E-07	207.765	21.785	1.73	1.02E-06
223.505	26.935	0.98	5.76E-07	207.665	21.885	1.66	9.74E-07
223.405	27.035	0.98	5.78E-07	207.565	21.985	1.63	9.60E-07
223.305	27.135	0.98	5.74E-07	207.465	22.085	1.60	9.44E-07
223.205	27.235	0.90	5.32E-07	207.365	22.185	1.68	9.87E-07
223.105	27.335	0.85	5.03E-07	207.265	22.285	1.73	1.02E-06
223.005	27.435	0.85	4.97E-07	207.165	22.385	1.71	1.01E-06
222.905	27.535	0.81	4.77E-07	207.065	22.485	1.52	8.93E-07
222.805	27.635	0.81	4.74E-07	206.965	22.585	1.46	8.58E-07
222.705	27.735	0.84	4.95E-07	206.865	22.685	1.49	8.76E-07
222.605	27.835	0.85	4.98E-07	206.765	22.785	1.55	9.14E-07
222.505	27.935	0.85	5.00E-07	206.665	22.885	1.53	8.99E-07
222.405	28.035	0.84	4.95E-07	206.565	22.985	1.43	8.42E-07
222.305	28.135	0.84	4.91E-07	206.465	23.085	1.33	7.84E-07
222.205	28.235	0.80	4.73E-07	206.365	23.185	1.38	8.10E-07
222.105	28.335	0.80	4.68E-07	206.265	23.285	1.39	8.17E-07
222.005	28.435	0.91	5.33E-07	206.165	23.385	1.42	8.33E-07
221.905	28.535	0.93	5.46E-07	206.07	23.48	1.57	9.22E-07
221.805	28.635	0.96	5.63E-07	205.97	23.58	1.53	9.02E-07
221.705	28.735	0.98	5.77E-07	205.87	23.68	1.41	8.29E-07
221.605	28.835	0.98	5.78E-07	205.77	23.78	1.46	8.58E-07
221.505	28.935	0.98	5.76E-07	205.67	23.88	1.47	8.66E-07
221.405	29.035	0.95	5.57E-07	205.57	23.98	1.41	8.28E-07
221.305	29.135	0.90	5.29E-07	205.47	24.08	1.32	7.75E-07
221.205	29.235	0.89	5.24E-07	205.375	24.175	1.35	7.92E-07
221.105	29.335	0.79	4.63E-07	205.275	24.275	1.29	7.59E-07
221.005	29.435	0.79	4.67E-07	205.175	24.375	1.32	7.78E-07
220.905	29.535	0.79	4.64E-07	205.075	24.475	1.37	8.07E-07
220.81	29.63	0.78	4.57E-07	204.975	24.575	1.46	8.60E-07
220.71	29.73	0.70	4.09E-07	204.875	24.675	1.46	8.60E-07
220.61	29.83	0.63	3.71E-07	204.775	24.775	1.42	8.36E-07
220.515	29.925	0.66	3.87E-07	204.675	24.875	1.46	8.59E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR THE FORMER PLATTSBURGH AIR FORCE BASE, NEW YORK

Top of riser elevation (feet)	MW-02-017 Run 2 Up and Down - Average			Top of riser elevation (feet)	MW-02-030 Run 2 Up and Down Average		
250.44				229.55			
Elevation	Depth	Mag Susc 10e-3 SI units	Mag Susc		Depth	Mag Susc 10e-3 SI units	Mag Susc
feet amsl	ft bgs		m3/kg	feet amsl	ft bgs		m3/kg
220.415	30.025	0.57	3.38E-07	204.575	24.975	1.42	8.34E-07
220.315	30.125	0.53	3.12E-07	204.475	25.075	1.39	8.20E-07
220.215	30.225	0.56	3.30E-07	204.375	25.175	1.41	8.27E-07
220.115	30.325	0.52	3.07E-07	204.275	25.275	1.28	7.52E-07
220.015	30.425	0.64	3.76E-07	204.175	25.375	1.29	7.61E-07
219.915	30.525	0.67	3.96E-07	204.075	25.475	1.29	7.61E-07
219.815	30.625	0.68	3.99E-07	203.975	25.575	1.30	7.67E-07
219.715	30.725	0.75	4.39E-07	203.875	25.675	1.28	7.51E-07
219.615	30.825	0.78	4.61E-07	203.775	25.775	1.25	7.34E-07
219.515	30.925	0.98	5.76E-07	203.675	25.875	1.21	7.13E-07
219.415	31.025	1.17	6.88E-07	203.575	25.975	1.26	7.39E-07
219.315	31.125	1.34	7.91E-07	203.475	26.075	1.26	7.43E-07
219.215	31.225	1.49	8.74E-07	203.375	26.175	1.12	6.58E-07
219.115	31.325	1.58	9.32E-07	203.275	26.275	1.11	6.53E-07
219.015	31.425	1.89	1.11E-06	203.175	26.375	1.13	6.65E-07
218.915	31.525	2.20	1.29E-06	203.075	26.475	1.17	6.90E-07
218.815	31.625	2.49	1.46E-06	202.975	26.575	1.26	7.42E-07
218.715	31.725	2.49	1.47E-06	202.875	26.675	1.38	8.11E-07
218.615	31.825	2.41	1.42E-06	202.775	26.775	1.35	7.95E-07
218.515	31.925	2.27	1.34E-06	202.67	26.88	1.40	8.21E-07
218.415	32.025	2.20	1.30E-06	202.58	26.97	1.42	8.33E-07
218.315	32.125	2.14	1.26E-06	202.48	27.07	1.45	8.52E-07
218.215	32.225	2.20	1.29E-06	202.38	27.17	1.47	8.63E-07
218.115	32.325	2.09	1.23E-06	202.28	27.27	1.43	8.39E-07
218.015	32.425	1.99	1.17E-06	202.18	27.37	1.42	8.34E-07
217.915	32.525	1.78	1.05E-06	202.085	27.465	1.45	8.53E-07
217.815	32.625	1.58	9.30E-07	201.985	27.565	1.43	8.40E-07
217.715	32.725	1.55	9.14E-07	201.885	27.665	1.37	8.04E-07
217.615	32.825	1.67	9.85E-07	201.785	27.765	1.33	7.82E-07
217.52	32.92	1.66	9.75E-07	201.685	27.865	1.25	7.36E-07
217.42	33.02	1.60	9.41E-07	201.585	27.965	1.27	7.50E-07
217.32	33.12	1.65	9.70E-07	201.47	28.08	1.23	7.22E-07
217.225	33.215	1.49	8.76E-07	201.385	28.165	1.16	6.83E-07
217.125	33.315	1.49	8.77E-07	201.285	28.265	1.04	6.13E-07
217.025	33.415	1.58	9.28E-07	201.185	28.365	1.03	6.08E-07
216.925	33.515	1.66	9.77E-07	201.085	28.465	1.03	6.07E-07
216.825	33.615	1.65	9.69E-07	200.985	28.565	1.06	6.22E-07
216.725	33.715	1.85	1.09E-06	200.885	28.665	1.11	6.54E-07
216.625	33.815	1.97	1.16E-06	200.785	28.765	1.19	6.99E-07
216.525	33.915	2.19	1.29E-06	200.685	28.865	1.22	7.19E-07
216.425	34.015	2.25	1.32E-06	200.585	28.965	1.27	7.45E-07
216.325	34.115	2.57	1.51E-06	200.485	29.065	1.39	8.19E-07
216.225	34.215	2.58	1.52E-06	200.385	29.165	1.45	8.51E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR THE FORMER PLATTSBURGH AIR FORCE BASE, NEW YORK

Top of riser elevation (feet) 250.44

MW-02-017 Run 2 Up and Down - Average

Elevation feet amsl	Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
216.125	34.315	2.74	1.61E-06
216.025	34.415	2.72	1.60E-06
215.925	34.515	2.50	1.47E-06
215.825	34.615	2.36	1.39E-06
215.725	34.715	2.20	1.29E-06
215.625	34.815	2.18	1.28E-06
215.525	34.915	2.14	1.26E-06
215.425	35.015	1.98	1.16E-06
215.325	35.115	1.78	1.05E-06
215.225	35.215	1.64	9.67E-07
215.125	35.315	1.53	8.97E-07
215.025	35.415	1.47	8.67E-07
214.925	35.515	1.51	8.90E-07
214.825	35.615	1.47	8.64E-07
214.725	35.715	1.35	7.95E-07
214.625	35.815	1.39	8.15E-07
214.525	35.915	1.39	8.19E-07
214.425	36.015	1.36	8.00E-07
214.325	36.115	1.38	8.15E-07
214.225	36.215	1.37	8.08E-07
214.13	36.31	1.28	7.50E-07
214.03	36.41	1.32	7.75E-07
213.935	36.505	1.33	7.81E-07
213.835	36.605	1.28	7.52E-07
213.735	36.705	1.23	7.26E-07
213.635	36.805	1.37	8.07E-07
213.535	36.905	1.42	8.35E-07
213.435	37.005	1.49	8.74E-07
213.335	37.105	1.50	8.80E-07
213.235	37.205	1.51	8.91E-07
213.135	37.305	1.53	8.98E-07
213.035	37.405	1.54	9.03E-07
212.935	37.505	1.55	9.10E-07
212.835	37.605	1.56	9.18E-07
212.735	37.705	1.56	9.18E-07
212.635	37.805	1.62	9.54E-07
212.535	37.905	1.55	9.13E-07
212.435	38.005	1.49	8.77E-07
212.335	38.105	1.46	8.58E-07
212.235	38.205	1.42	8.35E-07
212.135	38.305	1.29	7.56E-07
212.035	38.405	1.35	7.92E-07
211.935	38.505	1.39	8.18E-07

Top of riser elevation (feet) 229.55

MW-02-030 Run 2 Up and Down Average

feet amsl	Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
200.285	29.265	1.46	8.56E-07
200.185	29.365	1.44	8.45E-07
200.085	29.465	1.44	8.47E-07
199.985	29.565	1.41	8.32E-07
199.885	29.665	1.39	8.15E-07
199.785	29.765	1.34	7.90E-07
199.685	29.865	1.33	7.83E-07
199.585	29.965	1.36	8.03E-07
199.485	30.065	1.29	7.56E-07
199.39	30.16	1.33	7.84E-07
199.29	30.26	1.34	7.89E-07
199.19	30.36	1.33	7.82E-07
199.09	30.46	1.34	7.89E-07
198.99	30.56	1.37	8.07E-07
198.89	30.66	1.30	7.65E-07
198.795	30.755	1.30	7.63E-07
198.695	30.855	1.37	8.04E-07
198.595	30.955	1.46	8.59E-07
198.495	31.055	1.57	9.26E-07
198.395	31.155	1.70	9.99E-07
198.295	31.255	1.70	1.00E-06
198.195	31.355	1.76	1.03E-06
198.095	31.455	1.74	1.02E-06
197.995	31.555	1.75	1.03E-06
197.895	31.655	1.68	9.88E-07
197.795	31.755	1.67	9.83E-07
197.695	31.855	1.74	1.02E-06
197.595	31.955	1.77	1.04E-06
197.495	32.055	1.76	1.04E-06
197.395	32.155	1.80	1.06E-06
197.295	32.255	1.74	1.03E-06
197.195	32.355	1.77	1.04E-06
197.095	32.455	1.80	1.06E-06
196.995	32.555	1.84	1.08E-06
196.895	32.655	1.75	1.03E-06
196.795	32.755	1.73	1.02E-06
196.695	32.855	1.64	9.66E-07
196.595	32.955	1.64	9.66E-07
196.495	33.055	1.64	9.63E-07
196.395	33.155	1.52	8.94E-07
196.295	33.255	1.56	9.18E-07
196.195	33.355	1.58	9.29E-07
196.095	33.455	1.75	1.03E-06

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR THE FORMER PLATTSBURGH AIR FORCE BASE, NEW YORK

Top of riser elevation (feet) 250.44

MW-02-017 Run 2 Up and Down - Average

Elevation feet amsl	Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
211.835	38.605	1.62	9.53E-07
211.735	38.705	1.82	1.07E-06
211.635	38.805	2.00	1.17E-06
211.535	38.905	2.11	1.24E-06
211.435	39.005	2.12	1.25E-06
211.335	39.105	2.16	1.27E-06
211.235	39.205	2.21	1.30E-06
211.135	39.305	2.16	1.27E-06
211.035	39.405	1.97	1.16E-06
210.935	39.505	1.88	1.11E-06
210.84	39.6	1.82	1.07E-06
210.74	39.7	1.71	1.00E-06
210.64	39.8	1.68	9.87E-07
210.545	39.895	1.71	1.01E-06
210.445	39.995	1.67	9.82E-07
210.345	40.095	1.63	9.57E-07
210.245	40.195	1.66	9.77E-07
210.145	40.295	1.63	9.60E-07
210.045	40.395	1.64	9.63E-07
209.945	40.495	1.68	9.88E-07
209.845	40.595	1.65	9.68E-07
209.74	40.7	1.67	9.82E-07

Top of riser elevation (feet) 229.55

MW-02-030 Run 2 Up and Down Average

feet amsl	Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
196	33.55	1.86	1.09E-06
195.9	33.65	1.90	1.12E-06
195.8	33.75	1.94	1.14E-06
195.7	33.85	2.05	1.20E-06
195.6	33.95	2.13	1.25E-06
195.505	34.045	2.21	1.30E-06
195.405	34.145	2.16	1.27E-06
195.305	34.245	2.19	1.29E-06
195.205	34.345	2.22	1.31E-06
195.105	34.445	2.27	1.33E-06
195.005	34.545	2.32	1.37E-06
194.905	34.645	2.28	1.34E-06
194.805	34.745	2.29	1.35E-06
194.705	34.845	2.36	1.39E-06
194.605	34.945	2.44	1.43E-06
194.505	35.045	2.50	1.47E-06
194.405	35.145	2.54	1.50E-06
194.305	35.245	2.62	1.54E-06
194.205	35.345	2.70	1.59E-06
194.105	35.445	2.81	1.65E-06
194.005	35.545	2.80	1.65E-06
193.905	35.645	2.81	1.65E-06
193.805	35.745	2.89	1.70E-06
193.705	35.845	2.90	1.71E-06
193.605	35.945	2.83	1.67E-06
193.505	36.045	2.82	1.66E-06
193.405	36.145	2.66	1.57E-06
193.305	36.245	2.68	1.58E-06
193.205	36.345	2.64	1.55E-06
193.105	36.445	2.62	1.54E-06
193.005	36.545	2.60	1.53E-06
192.905	36.645	2.62	1.54E-06
192.805	36.745	2.72	1.60E-06
192.71	36.84	2.75	1.62E-06
192.61	36.94	2.77	1.63E-06
192.51	37.04	2.80	1.65E-06
192.41	37.14	2.80	1.65E-06
192.31	37.24	2.92	1.72E-06
192.21	37.34	2.99	1.76E-06
192.115	37.435	2.98	1.75E-06
192.015	37.535	3.00	1.76E-06
191.915	37.635	3.08	1.81E-06
191.815	37.735	3.20	1.88E-06

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR THE FORMER PLATTSBURGH AIR FORCE BASE, NEW YORK

Top of riser elevation (feet)	MW-02-017 Run 2 Up and Down - Average		
250.44			
Elevation	Depth	Mag Susc 10e-3 SI	Mag Susc
feet amsl	ft bgs	units	m3/kg

Top of riser elevation (feet)	MW-02-030 Run 2 Up and Down Average		
229.55			
	Depth	Mag Susc 10e-3 SI	Mag Susc
feet amsl	ft bgs	units	m3/kg
191.715	37.835	3.27	1.92E-06
191.615	37.935	3.28	1.93E-06
191.515	38.035	3.28	1.93E-06
191.415	38.135	3.33	1.96E-06
191.315	38.235	3.33	1.96E-06
191.215	38.335	3.37	1.98E-06
191.115	38.435	3.47	2.04E-06
191.015	38.535	3.48	2.05E-06
190.915	38.635	3.67	2.16E-06
190.815	38.735	3.86	2.27E-06
190.715	38.835	3.73	2.20E-06
190.615	38.935	3.53	2.07E-06
190.515	39.035	3.38	1.99E-06
190.415	39.135	3.49	2.05E-06
190.315	39.235	3.74	2.20E-06
190.215	39.335	3.69	2.17E-06
190.115	39.435	3.60	2.12E-06
190.015	39.535	3.37	1.98E-06
189.915	39.635	3.10	1.83E-06
189.815	39.735	3.30	1.94E-06
189.715	39.835	3.38	1.99E-06
189.615	39.935	3.58	2.11E-06
189.515	40.035	3.43	2.02E-06
189.42	40.13	3.20	1.88E-06
189.32	40.23	3.06	1.80E-06
189.22	40.33	3.30	1.94E-06
189.12	40.43	3.51	2.06E-06
189.02	40.53	3.49	2.05E-06
188.92	40.63	3.43	2.02E-06
188.825	40.725	3.29	1.93E-06
188.725	40.825	3.29	1.94E-06
188.625	40.925	3.52	2.07E-06
188.525	41.025	3.64	2.14E-06
188.425	41.125	3.54	2.08E-06
188.325	41.225	3.62	2.13E-06
188.225	41.325	3.51	2.07E-06
188.125	41.425	3.47	2.04E-06
188.025	41.525	3.45	2.03E-06
187.925	41.625	3.30	1.94E-06
187.825	41.725	3.14	1.85E-06
187.725	41.825	3.14	1.85E-06
187.625	41.925	3.06	1.80E-06
187.525	42.025	3.05	1.79E-06

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR THE FORMER PLATTSBURGH AIR FORCE BASE, NEW YORK

Top of riser elevation (feet)	MW-02-017 Run 2 Up and Down - Average			Top of riser elevation (feet)	MW-02-030 Run 2 Up and Down Average		
250.44				229.55			
Elevation	Depth	Mag Susc 10e-3 SI	Mag Susc		Depth	Mag Susc 10e-3 SI	Mag Susc
feet amsl	ft bgs	units	m3/kg	feet amsl	ft bgs	units	m3/kg
				187.425	42.125	2.90	1.70E-06
				187.325	42.225	2.84	1.67E-06
				187.225	42.325	2.83	1.66E-06
				187.125	42.425	2.78	1.64E-06
				187.025	42.525	2.82	1.66E-06
				186.925	42.625	2.81	1.65E-06
				186.825	42.725	2.90	1.71E-06
				186.725	42.825	3.00	1.77E-06
				186.625	42.925	3.12	1.83E-06
				186.525	43.025	3.15	1.86E-06
				186.425	43.125	3.19	1.88E-06
				186.325	43.225	3.25	1.91E-06
				186.225	43.325	3.39	2.00E-06
				186.125	43.425	3.49	2.05E-06
				186.03	43.52	3.41	2.01E-06
				185.93	43.62	3.33	1.96E-06
				185.83	43.72	3.06	1.80E-06
				185.73	43.82	2.91	1.71E-06
				185.63	43.92	2.92	1.72E-06
				185.535	44.015	2.96	1.74E-06
				185.435	44.115	2.78	1.64E-06
				185.335	44.215	2.63	1.55E-06
				185.235	44.315	2.55	1.50E-06
				185.135	44.415	2.61	1.54E-06
				185.035	44.515	2.72	1.60E-06
				184.935	44.615	2.60	1.53E-06
				184.835	44.715	2.47	1.45E-06
				184.735	44.815	2.34	1.38E-06
				184.635	44.915	2.23	1.31E-06
				184.535	45.015	2.14	1.26E-06
				184.435	45.115	1.98	1.17E-06
				184.335	45.215	1.97	1.16E-06
				184.235	45.315	1.85	1.09E-06
				184.135	45.415	1.74	1.03E-06
				184.035	45.515	1.70	9.99E-07
				183.935	45.615	1.62	9.50E-07
				183.835	45.715	1.71	1.01E-06
				183.735	45.815	1.66	9.78E-07
				183.635	45.915	1.73	1.02E-06
				183.535	46.015	1.78	1.05E-06
				183.435	46.115	1.82	1.07E-06
				183.335	46.215	1.76	1.04E-06
				183.235	46.315	1.88	1.10E-06

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR THE FORMER PLATTSBURGH AIR FORCE BASE, NEW YORK

Top of riser elevation (feet)	MW-02-017 Run 2 Up and Down - Average		
250.44			
Elevation	Depth	Mag Susc 10e-3 SI	Mag Susc
feet amsl	ft bgs	units	m3/kg

Top of riser elevation (feet)	MW-02-030 Run 2 Up and Down Average		
229.55			
	Depth	Mag Susc 10e-3 SI	Mag Susc
feet amsl	ft bgs	units	m3/kg
183.135	46.415	1.92	1.13E-06
183.035	46.515	2.03	1.19E-06
182.935	46.615	2.04	1.20E-06
182.835	46.715	2.04	1.20E-06
182.74	46.81	1.96	1.15E-06
182.64	46.91	2.00	1.18E-06
182.54	47.01	1.99	1.17E-06
182.44	47.11	1.84	1.08E-06
182.34	47.21	1.70	1.00E-06
182.24	47.31	1.64	9.64E-07
182.145	47.405	1.63	9.58E-07
182.045	47.505	1.65	9.72E-07
181.945	47.605	1.63	9.59E-07
181.845	47.705	1.50	8.82E-07
181.745	47.805	1.55	9.11E-07
181.645	47.905	1.58	9.29E-07
181.545	48.005	1.70	1.00E-06
181.445	48.105	1.83	1.08E-06
181.345	48.205	1.73	1.02E-06
181.245	48.305	1.68	9.90E-07
181.145	48.405	1.72	1.01E-06
181.045	48.505	1.87	1.10E-06
180.945	48.605	2.07	1.22E-06
180.845	48.705	2.16	1.27E-06
180.745	48.805	2.09	1.23E-06
180.645	48.905	2.05	1.20E-06
180.545	49.005	2.14	1.26E-06
180.445	49.105	2.18	1.28E-06
180.345	49.205	2.13	1.25E-06
180.245	49.305	2.03	1.19E-06
180.13	49.42	1.94	1.14E-06
180.045	49.505	1.82	1.07E-06
179.945	49.605	1.79	1.05E-06
179.845	49.705	1.75	1.03E-06
179.745	49.805	1.83	1.08E-06
179.645	49.905	1.99	1.17E-06
179.545	50.005	1.55	9.12E-07
179.45	50.1	2.08	1.22E-06
179.35	50.2	2.12	1.25E-06
179.25	50.3	2.15	1.27E-06
179.15	50.4	2.21	1.30E-06
179.05	50.5	2.27	1.33E-06
178.95	50.6	2.22	1.31E-06

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR THE FORMER PLATTSBURGH AIR FORCE BASE, NEW YORK

Top of riser elevation (feet) 250.44

MW-02-017 Run 2 Up and Down - Average

Elevation feet amsl	Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg

Top of riser elevation (feet) 229.55

MW-02-030 Run 2 Up and Down Average

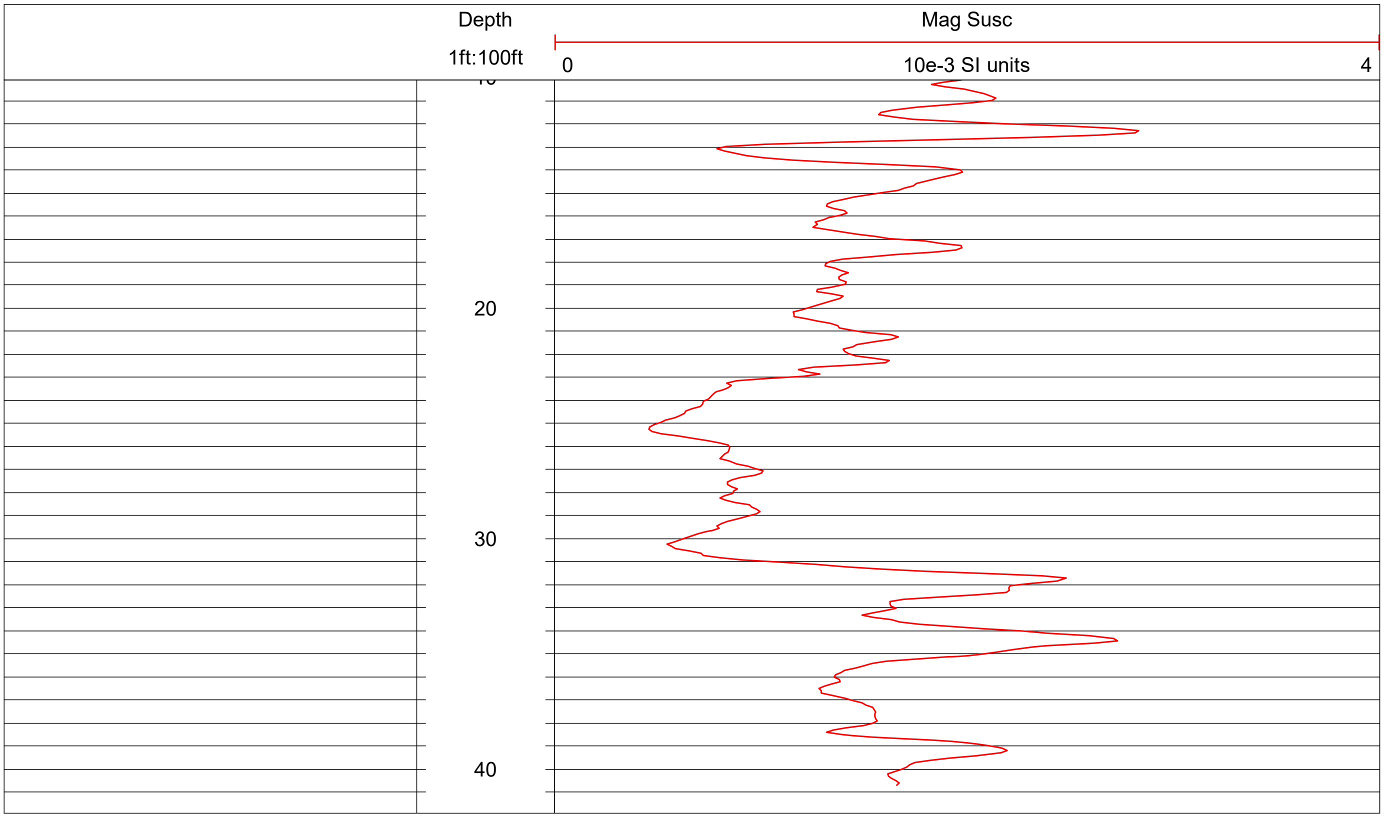
Elevation feet amsl	Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
178.855	50.695	2.16	1.27E-06
178.755	50.795	2.10	1.24E-06
178.655	50.895	2.12	1.25E-06
178.555	50.995	2.08	1.22E-06
178.455	51.095	2.07	1.22E-06
178.355	51.195	2.07	1.22E-06
178.255	51.295	1.99	1.17E-06
178.155	51.395	1.88	1.11E-06
178.055	51.495	1.81	1.07E-06
177.955	51.595	1.71	1.01E-06
177.855	51.695	1.72	1.01E-06
177.755	51.795	1.75	1.03E-06
177.655	51.895	1.75	1.03E-06
177.555	51.995	1.84	1.08E-06
177.455	52.095	1.80	1.06E-06
177.355	52.195	1.91	1.13E-06
177.255	52.295	1.98	1.16E-06
177.155	52.395	2.00	1.18E-06
177.055	52.495	2.05	1.20E-06
176.955	52.595	2.06	1.21E-06
176.855	52.695	2.03	1.20E-06
176.755	52.795	2.06	1.21E-06
176.64	52.91	2.07	1.22E-06
176.555	52.995	1.92	1.13E-06
176.455	53.095	2.00	1.18E-06
176.355	53.195	1.92	1.13E-06
176.255	53.295	1.97	1.16E-06
176.16	53.39	2.01	1.18E-06
176.06	53.49	2.07	1.21E-06
175.95	53.6	2.05	1.20E-06

WIEDEMEIER & ASSOCIATES

PROJECT	ESTCP 201584
LOCATION	Former Plattsburgh AFB
WELL	MW-02-017 - Down - Run 2
LOGGER	Todd Wiedemeier
DATE	June 6, 2016

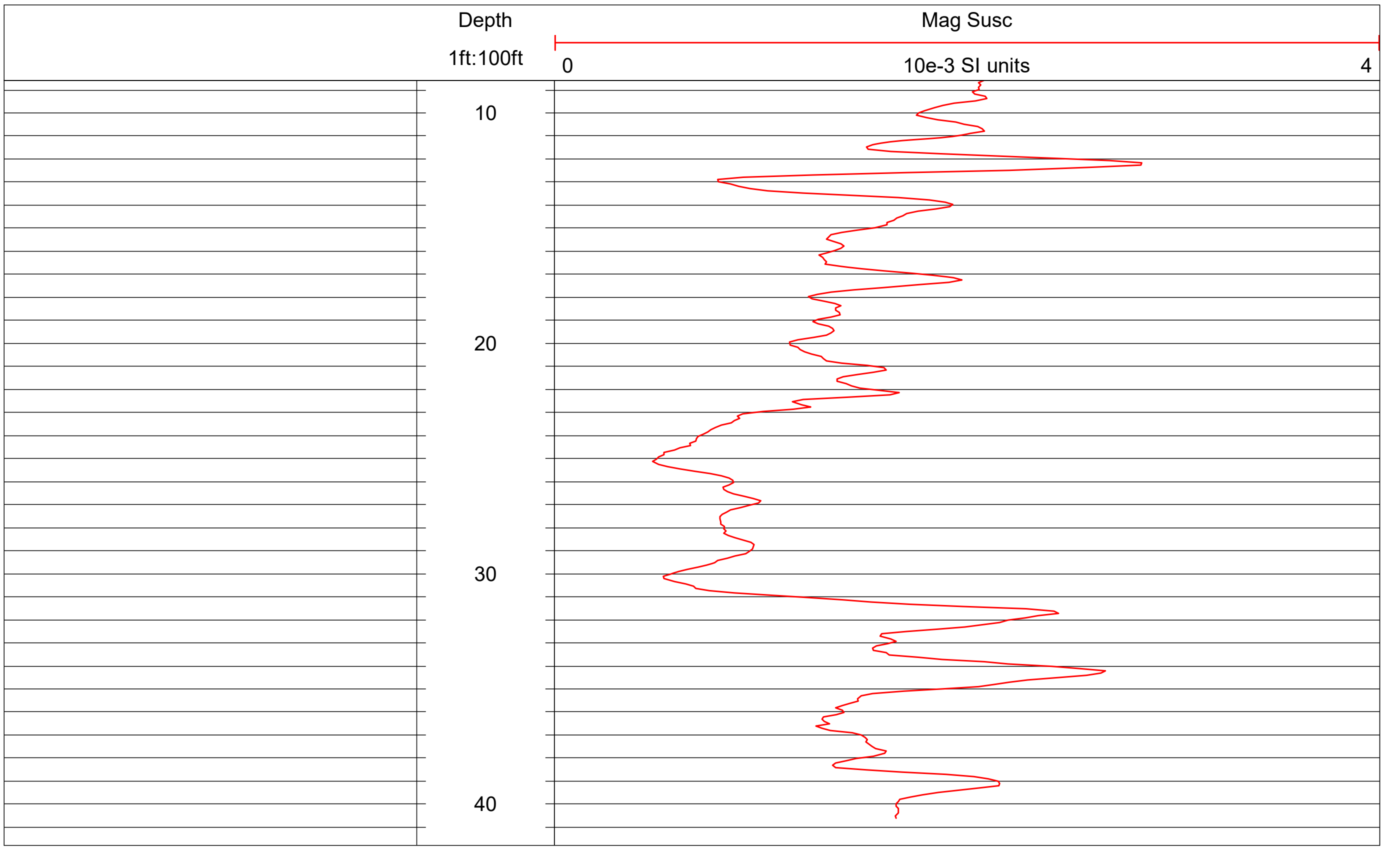
TOOL	HMA-453-S
CALIBRATION DATE/TIME	6/6/16 - 13:55
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	Zero = 70.56, 5E-3 = 1152.19 cps
REMARKS	

Run 1 - Down had erronous data so Run 1 not used.



WIEDEMEIER & ASSOCIATES

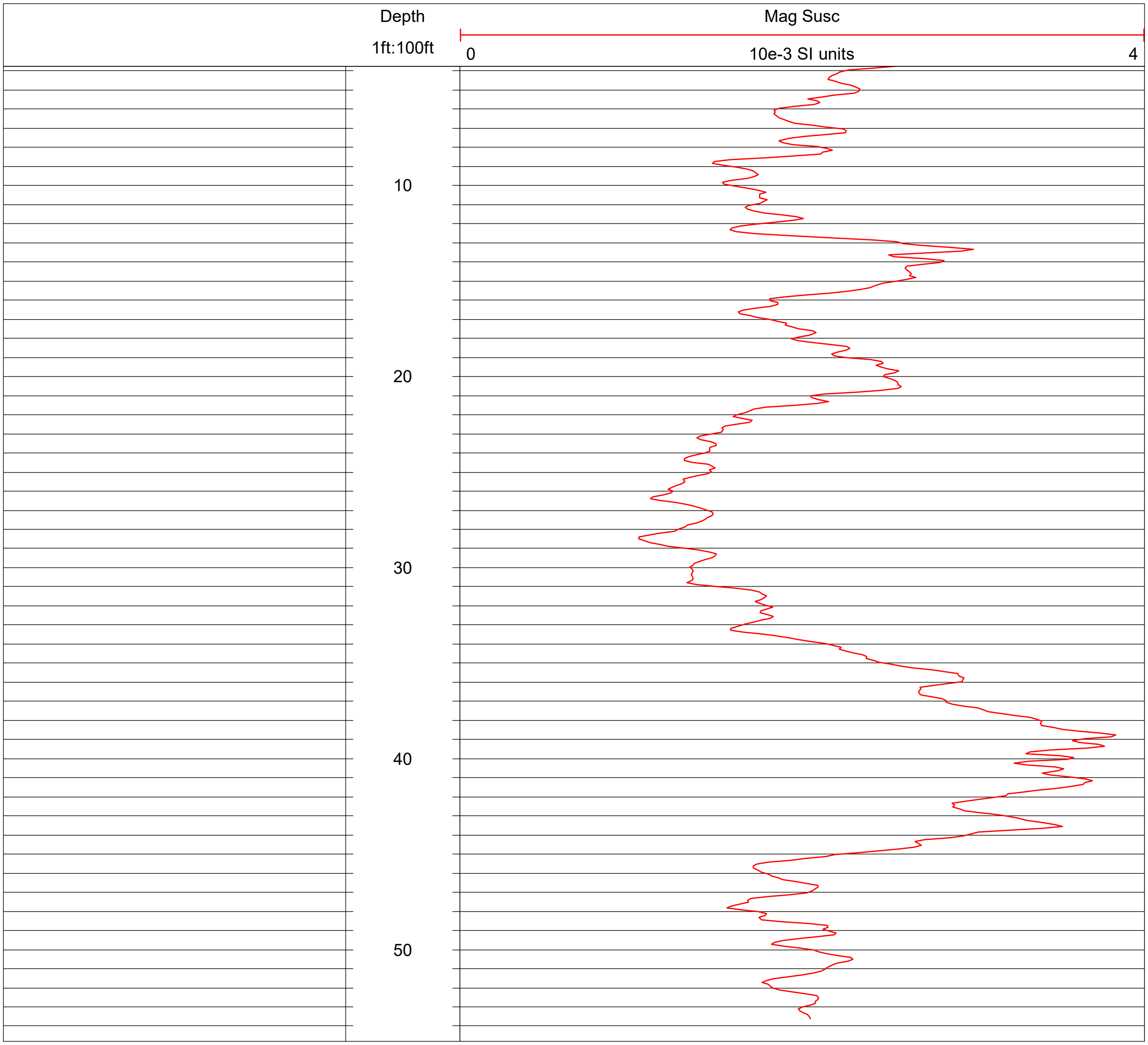
PROJECT	ESTCP 201584	TOOL	HMA-453-S
LOCATION	Former Plattsburgh AFB	CALIBRATION DATE/TIME	6/6/16 - 13:55
WELL	MW-02-017	CALIBRATION STANDARDS	0 and 5E-3 SI Units
LOGGER	Todd Wiedemeier	CALIBRATION RESULTS	Zero = 70.56, 5E-3 = 1152.19 cps
DATE	June 6, 2016	REMARKS	



PROJECT	ESTCP 201584
LOCATION	Former Plattsburgh AFB
WELL	MW-02-30 - Run 2-Down
LOGGER	Todd Wiedemeier
DATE	June 6, 2016

TOOL	HMA-453-S
CALIBRATION DATE/TIME	6/6/16 - 15:05
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	Zero = 79.94, 5E-3 = 1164.64 cps
REMARKS	

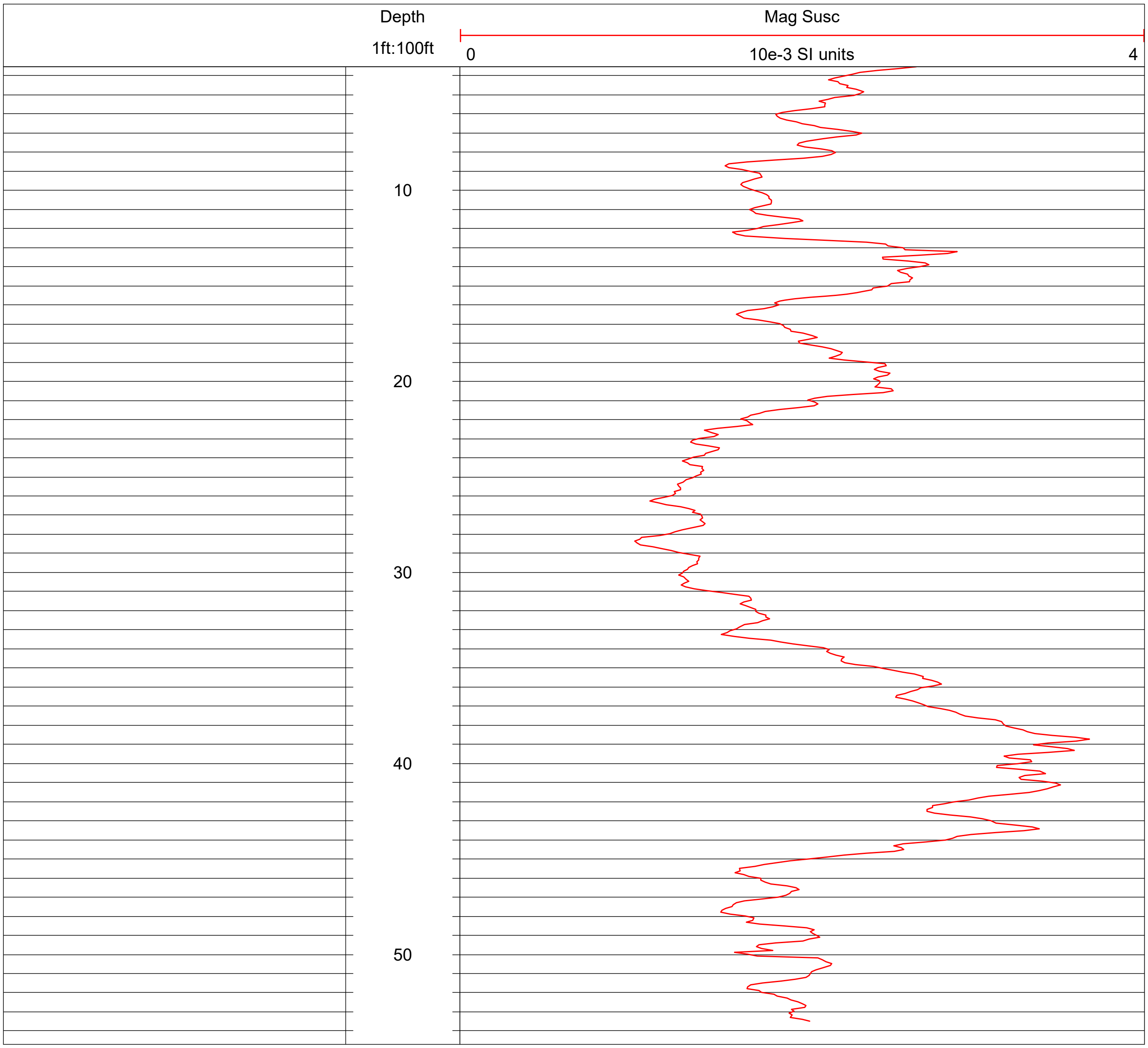
Run 1-Down had erronous data so Run 1 not used.



WIEDEMEIER & ASSOCIATES

PROJECT	ESTCP 201584
LOCATION	Former Plattsburgh AFB
WELL	MW-02-30 - Up - Run 2
LOGGER	Todd Wiedemeier
DATE	June 6, 2016

TOOL	HMA-453-S
CALIBRATION DATE/TIME	6/6/16 - 15:05
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	Zero = 79.94 cps, 5E-3 = 1164.64 cps
REMARKS	



FORMER HOPEWELL PRECISION SITE, HOPEWELL JUNCTION, NEW YORK

EPA-10D-Up/Down Average Sonde Data			EPA-12D-Up/Down Average Sonde Data			EPA-15D-Up/Down Average Sonde Data			EPA-16D-Up/Down Average Sonde Data			EPA-19S-Up/Down Average Sonde Data			EPA-21D-Up/Down Average Sonde Data		
Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)	Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)	Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)	Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)	Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)	Depth (ft bgs)	Mag Susc 10e-3 SI units	Mag Susc (m3/kg)
3.54	0.68	4.02E-07	3.78	0.18	1.03E-07	3.78	0.55	3.25E-07	3.67	0.94	5.51E-07	3.61	0.46	2.68E-07	3.54	0.58	3.42E-07
3.64	0.68	3.98E-07	3.88	0.15	8.56E-08	3.90	0.57	3.34E-07	3.77	0.92	5.42E-07	3.71	0.44	2.59E-07	3.64	0.47	2.79E-07
3.76	0.67	3.96E-07	3.98	0.21	1.25E-07	4.00	0.58	3.41E-07	3.87	1.04	6.09E-07	3.81	0.51	2.98E-07	3.76	0.48	2.83E-07
3.86	0.67	3.96E-07	4.08	0.30	1.75E-07	4.10	0.57	3.38E-07	3.97	1.19	6.98E-07	3.91	0.47	2.74E-07	3.86	0.44	2.60E-07
3.96	0.67	3.94E-07	4.17	0.36	2.11E-07	4.20	0.58	3.39E-07	4.07	1.36	7.99E-07	4.01	0.44	2.59E-07	3.96	0.46	2.69E-07
4.06	0.67	3.91E-07	4.27	0.40	2.38E-07	4.30	0.57	3.33E-07	4.17	1.58	9.30E-07	4.11	0.42	2.44E-07	4.06	0.43	2.52E-07
4.16	0.67	3.94E-07	4.37	0.39	2.31E-07	4.40	0.61	3.59E-07	4.27	1.68	9.89E-07	4.21	0.42	2.45E-07	4.16	0.47	2.78E-07
4.26	0.63	3.70E-07	4.45	0.48	2.80E-07	4.50	0.58	3.43E-07	4.37	1.73	1.02E-06	4.31	0.41	2.41E-07	4.26	0.46	2.69E-07
4.36	0.66	3.86E-07	4.55	0.49	2.89E-07	4.60	0.56	3.28E-07	4.47	1.76	1.04E-06	4.41	0.45	2.66E-07	4.36	0.47	2.78E-07
4.46	0.68	4.01E-07	4.65	0.55	3.23E-07	4.70	0.56	3.31E-07	4.57	1.57	9.22E-07	4.51	0.41	2.39E-07	4.46	0.45	2.63E-07
4.56	0.66	3.90E-07	4.75	0.56	3.28E-07	4.80	0.58	3.40E-07	4.67	1.36	8.03E-07	4.61	0.48	2.80E-07	4.56	0.44	2.61E-07
4.655	0.71	4.15E-07	4.85	0.59	3.46E-07	4.90	0.64	3.74E-07	4.77	1.26	7.39E-07	4.71	0.46	2.68E-07	4.66	0.46	2.73E-07
4.755	0.73	4.29E-07	4.95	0.54	3.15E-07	5.00	0.60	3.50E-07	4.87	1.17	6.87E-07	4.81	0.46	2.69E-07	4.76	0.47	2.75E-07
4.855	0.68	3.98E-07	5.05	0.56	3.29E-07	5.10	0.55	3.25E-07	4.97	1.02	5.99E-07	4.91	0.43	2.53E-07	4.86	0.46	2.72E-07
4.955	0.73	4.27E-07	5.15	0.63	3.68E-07	5.20	0.53	3.11E-07	5.07	0.90	5.29E-07	5.00	0.43	2.55E-07	4.96	0.44	2.60E-07
5.05	0.68	4.03E-07	5.25	0.62	3.67E-07	5.30	0.53	3.12E-07	5.17	0.69	4.07E-07	5.10	0.40	2.38E-07	5.05	0.42	2.46E-07
5.15	0.72	4.24E-07	5.35	0.67	3.96E-07	5.40	0.53	3.14E-07	5.27	0.67	3.92E-07	5.20	0.49	2.87E-07	5.15	0.44	2.57E-07
5.25	0.77	4.52E-07	5.45	0.60	3.55E-07	5.50	0.55	3.23E-07	5.37	0.55	3.26E-07	5.30	0.46	2.72E-07	5.25	0.42	2.49E-07
5.35	0.69	4.07E-07	5.57	0.50	2.94E-07	5.60	0.53	3.11E-07	5.47	0.50	2.96E-07	5.40	0.44	2.60E-07	5.35	0.43	2.55E-07
5.45	0.77	4.51E-07	5.65	0.49	2.88E-07	5.70	0.51	3.00E-07	5.57	0.44	2.60E-07	5.50	0.42	2.49E-07	5.45	0.40	2.33E-07
5.55	0.79	4.63E-07	5.75	0.45	2.66E-07	5.80	0.57	3.35E-07	5.67	0.34	2.00E-07	5.60	0.45	2.66E-07	5.55	0.45	2.64E-07
5.65	0.80	4.69E-07	5.85	0.47	2.77E-07	5.90	0.56	3.30E-07	5.77	0.36	2.09E-07	5.70	0.45	2.67E-07	5.65	0.43	2.53E-07
5.75	0.80	4.72E-07	5.95	0.46	2.71E-07	6.00	0.57	3.35E-07	5.87	0.41	2.39E-07	5.80	0.47	2.75E-07	5.75	0.39	2.30E-07
5.85	0.86	5.08E-07	6.05	0.41	2.42E-07	6.10	0.58	3.39E-07	5.97	0.38	2.21E-07	5.90	0.45	2.63E-07	5.85	0.42	2.45E-07
5.95	0.83	4.86E-07	6.15	0.37	2.20E-07	6.20	0.57	3.35E-07	6.07	0.42	2.49E-07	6.00	0.46	2.71E-07	5.95	0.42	2.45E-07
6.05	0.86	5.03E-07	6.25	0.34	2.01E-07	6.30	0.54	3.18E-07	6.16	0.43	2.52E-07	6.10	0.48	2.84E-07	6.05	0.41	2.41E-07
6.15	0.84	4.97E-07	6.35	0.35	2.08E-07	6.40	0.53	3.13E-07	6.26	0.39	2.28E-07	6.20	0.46	2.68E-07	6.15	0.38	2.26E-07
6.25	0.82	4.84E-07	6.45	0.35	2.05E-07	6.50	0.57	3.36E-07	6.36	0.36	2.11E-07	6.30	0.48	2.81E-07	6.25	0.39	2.28E-07
6.35	0.84	4.91E-07	6.55	0.36	2.14E-07	6.60	0.57	3.36E-07	6.46	0.34	2.00E-07	6.40	0.48	2.80E-07	6.35	0.40	2.37E-07
6.45	0.80	4.72E-07	6.65	0.38	2.21E-07	6.69	0.58	3.44E-07	6.56	0.27	1.60E-07	6.50	0.44	2.62E-07	6.45	0.43	2.53E-07
6.55	0.81	4.76E-07	6.745	0.32	1.90E-07	6.79	0.61	3.59E-07	6.66	0.28	1.67E-07	6.60	0.43	2.51E-07	6.55	0.41	2.41E-07
6.65	0.82	4.84E-07	6.845	0.34	2.00E-07	6.89	0.58	3.43E-07	6.76	0.27	1.57E-07	6.70	0.45	2.62E-07	6.65	0.42	2.49E-07
6.75	0.82	4.84E-07	6.945	0.32	1.90E-07	6.99	0.61	3.61E-07	6.86	0.29	1.70E-07	6.80	0.45	2.67E-07	6.75	0.40	2.36E-07
6.85	0.80	4.71E-07	7.045	0.31	1.85E-07	7.09	0.62	3.62E-07	6.96	0.25	1.49E-07	6.90	0.43	2.53E-07	6.85	0.40	2.37E-07
6.95	0.76	4.48E-07	7.145	0.28	1.64E-07	7.19	0.60	3.51E-07	7.06	0.21	1.23E-07	7.00	0.45	2.67E-07	6.95	0.38	2.24E-07
7.05	0.76	4.48E-07	7.245	0.29	1.68E-07	7.29	0.58	3.39E-07	7.16	0.19	1.15E-07	7.10	0.43	2.53E-07	7.05	0.41	2.39E-07
7.15	0.71	4.17E-07	7.345	0.30	1.74E-07	7.39	0.51	2.99E-07	7.26	0.23	1.35E-07	7.20	0.47	2.77E-07	7.15	0.42	2.47E-07
7.25	0.77	4.56E-07	7.44	0.27	1.56E-07	7.49	0.50	2.97E-07	7.36	0.24	1.44E-07	7.30	0.43	2.52E-07	7.25	0.40	2.33E-07
7.35	0.78	4.59E-07	7.54	0.26	1.55E-07	7.59	0.47	2.76E-07	7.46	0.25	1.45E-07	7.40	0.46	2.70E-07	7.35	0.41	2.38E-07
7.45	0.75	4.42E-07	7.64	0.33	1.93E-07	7.69	0.43	2.54E-07	7.56	0.25	1.48E-07	7.50	0.44	2.59E-07	7.45	0.40	2.36E-07
7.55	0.77	4.51E-07	7.74	0.26	1.55E-07	7.79	0.40	2.36E-07	7.66	0.25	1.50E-07	7.60	0.48	2.81E-07	7.55	0.48	2.82E-07
7.65	0.78	4.56E-07	7.84	0.25	1.45E-07	7.89	0.38	2.23E-07	7.76	0.26	1.51E-07	7.70	0.55	3.21E-07	7.65	0.41	2.43E-07
7.75	0.80	4.69E-07	7.94	0.26	1.56E-07	7.99	0.35	2.09E-07	7.86	0.29	1.70E-07	7.80	0.54	3.16E-07	7.75	0.41	2.42E-07
7.85	0.83	4.89E-07	8.04	0.28	1.66E-07	8.09	0.38	2.24E-07	7.96	0.36	2.11E-07	7.90	0.50	2.93E-07	7.85	0.41	2.44E-07
7.95	0.82	4.82E-07	8.14	0.31	1.80E-07	8.19	0.34	2.00E-07	8.06	0.37	2.15E-07	8.00	0.48	2.84E-07	7.95	0.45	2.66E-07
8.045	0.83	4.87E-07	8.24	0.28	1.66E-07	8.29	0.40	2.37E-07	8.16	0.36	2.11E-07	8.10	0.46	2.71E-07	8.05	0.41	2.42E-07
8.145	0.88	5.15E-07	8.34	0.32	1.90E-07	8.39	0.43	2.53E-07	8.26	0.38	2.23E-07	8.20	0.45	2.64E-07	8.15	0.43	2.55E-07

FORMER HOPEWELL PRECISION SITE, HOPEWELL JUNCTION, NEW YORK

EPA-10D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)
8.245	0.91	5.36E-07
8.34	0.94	5.52E-07
8.44	0.96	5.64E-07
8.54	0.91	5.33E-07
8.64	0.90	5.31E-07
8.74	0.89	5.26E-07
8.84	0.90	5.28E-07
8.94	0.94	5.55E-07
9.04	0.93	5.45E-07
9.14	0.96	5.62E-07
9.24	0.97	5.70E-07
9.34	0.98	5.75E-07
9.44	0.99	5.84E-07
9.54	1.03	6.05E-07
9.64	0.97	5.73E-07
9.74	0.96	5.64E-07
9.84	0.95	5.60E-07
9.94	0.98	5.75E-07
10.04	0.98	5.79E-07
10.14	0.99	5.83E-07
10.24	0.96	5.63E-07
10.34	0.97	5.70E-07
10.44	0.99	5.83E-07
10.54	0.96	5.64E-07
10.64	0.98	5.78E-07
10.74	1.00	5.87E-07
10.84	0.96	5.66E-07
10.94	0.95	5.60E-07
11.04	0.93	5.46E-07
11.14	0.97	5.70E-07
11.24	1.00	5.91E-07
11.335	1.04	6.09E-07
11.435	1.01	5.95E-07
11.535	0.94	5.53E-07
11.63	0.95	5.62E-07
11.73	1.04	6.11E-07
11.83	1.02	6.02E-07
11.93	1.00	5.90E-07
12.03	1.03	6.04E-07
12.13	1.00	5.88E-07
12.23	0.98	5.74E-07
12.33	0.97	5.72E-07
12.43	0.96	5.66E-07
12.53	0.87	5.14E-07
12.63	0.81	4.79E-07
12.73	0.77	4.53E-07
12.83	0.82	4.82E-07
12.93	0.76	4.48E-07

EPA-12D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)
8.44	0.32	1.86E-07
8.54	0.27	1.60E-07
8.64	0.29	1.68E-07
8.74	0.27	1.58E-07
8.84	0.35	2.04E-07
8.94	0.30	1.79E-07
9.04	0.31	1.81E-07
9.14	0.30	1.77E-07
9.24	0.31	1.85E-07
9.34	0.32	1.85E-07
9.44	0.28	1.65E-07
9.54	0.29	1.68E-07
9.64	0.28	1.66E-07
9.74	0.31	1.82E-07
9.84	0.33	1.92E-07
9.92	0.36	2.12E-07
10.04	0.30	1.77E-07
10.135	0.37	2.16E-07
10.235	0.33	1.95E-07
10.31	0.37	2.19E-07
10.435	0.36	2.10E-07
10.535	0.31	1.85E-07
10.635	0.35	2.06E-07
10.735	0.33	1.92E-07
10.83	0.34	1.98E-07
10.93	0.38	2.22E-07
11.03	0.38	2.21E-07
11.13	0.33	1.95E-07
11.23	0.32	1.90E-07
11.33	0.35	2.03E-07
11.43	0.41	2.43E-07
11.53	0.38	2.24E-07
11.63	0.42	2.49E-07
11.73	0.47	2.75E-07
11.83	0.54	3.21E-07
11.93	0.53	3.11E-07
12.03	0.58	3.43E-07
12.13	0.59	3.44E-07
12.23	0.54	3.18E-07
12.33	0.53	3.13E-07
12.43	0.40	2.35E-07
12.53	0.36	2.15E-07
12.63	0.34	1.99E-07
12.73	0.34	2.02E-07
12.83	0.32	1.88E-07
12.93	0.32	1.87E-07
13.03	0.31	1.85E-07
13.13	0.35	2.04E-07

EPA-15D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)
8.49	0.46	2.71E-07
8.59	0.42	2.49E-07
8.69	0.47	2.78E-07
8.79	0.50	2.94E-07
8.89	0.49	2.87E-07
8.99	0.46	2.70E-07
9.09	0.51	2.99E-07
9.19	0.46	2.73E-07
9.29	0.50	2.92E-07
9.39	0.47	2.78E-07
9.49	0.45	2.66E-07
9.59	0.45	2.62E-07
9.69	0.47	2.76E-07
9.79	0.49	2.90E-07
9.89	0.49	2.87E-07
9.98	0.46	2.73E-07
10.08	0.47	2.75E-07
10.18	0.47	2.79E-07
10.28	0.49	2.86E-07
10.38	0.45	2.67E-07
10.48	0.46	2.69E-07
10.58	0.47	2.75E-07
10.68	0.45	2.63E-07
10.78	0.44	2.61E-07
10.88	0.49	2.89E-07
10.98	0.49	2.87E-07
11.08	0.46	2.73E-07
11.18	0.45	2.63E-07
11.28	0.44	2.56E-07
11.38	0.40	2.38E-07
11.48	0.44	2.60E-07
11.58	0.46	2.72E-07
11.68	0.46	2.70E-07
11.78	0.43	2.53E-07
11.88	0.42	2.45E-07
11.98	0.42	2.45E-07
12.08	0.44	2.61E-07
12.18	0.45	2.63E-07
12.28	0.46	2.73E-07
12.38	0.44	2.60E-07
12.48	0.45	2.67E-07
12.58	0.45	2.65E-07
12.68	0.50	2.93E-07
12.78	0.43	2.52E-07
12.88	0.44	2.59E-07
12.98	0.46	2.69E-07
13.08	0.48	2.81E-07
13.18	0.46	2.70E-07

EPA-16D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)
8.36	0.43	2.54E-07
8.46	0.45	2.66E-07
8.56	0.47	2.77E-07
8.66	0.52	3.04E-07
8.76	0.47	2.78E-07
8.86	0.51	3.00E-07
8.96	0.48	2.81E-07
9.06	0.50	2.96E-07
9.16	0.53	3.13E-07
9.26	0.47	2.77E-07
9.36	0.48	2.84E-07
9.46	0.48	2.84E-07
9.55	0.48	2.80E-07
9.65	0.49	2.91E-07
9.75	0.43	2.53E-07
9.85	0.50	2.96E-07
9.95	0.48	2.85E-07
10.05	0.50	2.97E-07
10.15	0.50	2.93E-07
10.25	0.46	2.74E-07
10.35	0.48	2.83E-07
10.45	0.53	3.14E-07
10.55	0.50	2.96E-07
10.65	0.48	2.82E-07
10.75	0.50	2.93E-07
10.85	0.55	3.23E-07
10.95	0.50	2.96E-07
11.05	0.58	3.43E-07
11.15	0.56	3.27E-07
11.25	0.52	3.05E-07
11.35	0.52	3.05E-07
11.45	0.50	2.92E-07
11.55	0.53	3.11E-07
11.65	0.51	3.02E-07
11.75	0.53	3.13E-07
11.85	0.55	3.22E-07
11.95	0.53	3.11E-07
12.05	0.51	2.99E-07
12.15	0.49	2.90E-07
12.25	0.48	2.84E-07
12.35	0.47	2.79E-07
12.45	0.53	3.13E-07
12.55	0.51	3.02E-07
12.65	0.51	2.97E-07
12.75	0.50	2.94E-07
12.84	0.54	3.16E-07
12.94	0.53	3.11E-07
13.04	0.51	2.98E-07

EPA-19S-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)
8.29	0.46	2.74E-07
8.39	0.40	2.32E-07
8.49	0.43	2.54E-07
8.59	0.40	2.34E-07
8.69	0.40	2.36E-07
8.79	0.45	2.63E-07
8.89	0.42	2.50E-07
8.99	0.43	2.53E-07
9.09	0.40	2.34E-07
9.19	0.42	2.45E-07
9.29	0.42	2.47E-07
9.39	0.40	2.32E-07
9.49	0.45	2.67E-07
9.59	0.43	2.54E-07
9.69	0.42	2.49E-07
9.79	0.45	2.66E-07
9.89	0.46	2.71E-07
9.99	0.48	2.80E-07
10.09	0.50	2.93E-07
10.19	0.51	3.03E-07
10.29	0.56	3.28E-07
10.39	0.53	3.10E-07
10.49	0.53	3.12E-07
10.59	0.54	3.16E-07
10.69	0.51	3.02E-07
10.79	0.51	3.02E-07
10.89	0.49	2.89E-07
10.99	0.48	2.79E-07
11.09	0.48	2.85E-07
11.19	0.51	3.00E-07
11.29	0.52	3.04E-07
11.39	0.48	2.83E-07
11.49	0.50	2.96E-07
11.59	0.49	2.90E-07
11.68	0.47	2.79E-07
11.78	0.46	2.71E-07
11.88	0.49	2.88E-07
11.98	0.45	2.65E-07
12.08	0.48	2.81E-07
12.18	0.41	2.43E-07
12.28	0.44	2.61E-07
12.38	0.39	2.32E-07
12.48	0.37	2.18E-07
12.58	0.36	2.14E-07
12.68	0.33	1.91E-07
12.78	0.30	1.75E-07
12.88	0.28	1.62E-07
12.98	0.28	1.62E-07

EPA-21D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc 10e-3 SI units	Mag Susc (m3/kg)
8.25	0.44	2.61E-07
8.34	0.43	2.55E-07
8.44	0.40	2.35E-07
8.54	0.42	2.48E-07
8.64	0.37	2.19E-07
8.74	0.42	2.45E-07
8.84	0.42	2.45E-07
8.94	0.42	2.45E-07
9.04	0.41	2.41E-07
9.14	0.41	2.39E-07
9.24	0.41	2.39E-07
9.34	0.40	2.34E-07
9.44	0.45	2.63E-07
9.54	0.39	2.28E-07
9.64	0.43	2.54E-07
9.74	0.43	2.55E-07
9.84	0.44	2.60E-07
9.94	0.40	2.38E-07
10.04	0.42	2.47E-07
10.14	0.38	2.25E-07
10.24	0.46	2.68E-07
10.34	0.38	2.24E-07
10.44	0.40	2.38E-07
10.54	0.41	2.43E-07
10.64	0.40	2.33E-07
10.74	0.37	2.20E-07
10.84	0.40	2.36E-07
10.94	0.38	2.21E-07
11.04	0.39	2.29E-07
11.14	0.41	2.43E-07
11.24	0.38	2.24E-07
11.34	0.40	2.34E-07
11.44	0.40	2.36E-07
11.54	0.40	2.37E-07
11.63	0.44	2.57E-07
11.73	0.42	2.44E-07
11.83	0.44	2.60E-07
11.93	0.45	2.64E-07
12.03	0.42	2.45E-07
12.13	0.47	2.76E-07
12.23	0.49	2.87E-07
12.33	0.55	3.26E-07
12.43	0.53	3.14E-07
12.53	0.57	3.34E-07
12.63	0.60	3.55E-07
12.73	0.70	4.09E-07
12.83	0.63	3.72E-07
12.93	0.65	3.81E-07

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EPA-10D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)
13.03	0.75	4.41E-07
13.13	0.74	4.34E-07
13.23	0.67	3.95E-07
13.33	0.68	4.01E-07
13.43	0.70	4.09E-07
13.53	0.69	4.04E-07
13.63	0.64	3.76E-07
13.73	0.66	3.90E-07
13.83	0.65	3.81E-07
13.93	0.71	4.15E-07
14.03	0.69	4.08E-07
14.13	0.68	4.02E-07
14.23	0.62	3.66E-07
14.33	0.63	3.71E-07
14.43	0.67	3.96E-07
14.53	0.66	3.89E-07
14.625	0.67	3.93E-07
14.725	0.66	3.90E-07
14.825	0.66	3.85E-07
14.925	0.67	3.94E-07
15.02	0.66	3.88E-07
15.12	0.71	4.19E-07
15.22	0.73	4.29E-07
15.32	0.73	4.29E-07
15.42	0.72	4.22E-07
15.52	0.78	4.56E-07
15.62	0.81	4.74E-07
15.72	0.82	4.82E-07
15.82	0.85	5.02E-07
15.92	0.87	5.11E-07
16.02	0.93	5.47E-07
16.12	0.94	5.50E-07
16.22	0.94	5.51E-07
16.32	0.91	5.33E-07
16.42	0.85	4.97E-07
16.52	0.84	4.95E-07
16.62	0.89	5.21E-07
16.72	0.91	5.33E-07
16.82	0.92	5.41E-07
16.92	0.88	5.19E-07
17.02	0.87	5.14E-07
17.12	0.86	5.08E-07
17.22	0.84	4.93E-07
17.32	0.87	5.10E-07
17.42	0.89	5.21E-07
17.52	0.86	5.07E-07
17.62	0.78	4.60E-07
17.72	0.83	4.88E-07

EPA-12D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)
13.23	0.28	1.68E-07
13.33	0.37	2.18E-07
13.425	0.38	2.25E-07
13.525	0.39	2.32E-07
13.625	0.45	2.64E-07
13.725	0.44	2.58E-07
13.825	0.40	2.35E-07
13.925	0.42	2.50E-07
14.025	0.36	2.11E-07
14.12	0.32	1.89E-07
14.22	0.29	1.73E-07
14.32	0.37	2.15E-07
14.42	0.32	1.90E-07
14.52	0.31	1.82E-07
14.62	0.26	1.50E-07
14.72	0.26	1.53E-07
14.82	0.24	1.42E-07
14.92	0.28	1.64E-07
15.02	0.26	1.51E-07
15.12	0.27	1.59E-07
15.22	0.28	1.66E-07
15.32	0.29	1.68E-07
15.42	0.30	1.79E-07
15.52	0.31	1.80E-07
15.62	0.30	1.79E-07
15.72	0.29	1.70E-07
15.82	0.27	1.61E-07
15.92	0.35	2.05E-07
16.02	0.29	1.73E-07
16.12	0.27	1.60E-07
16.22	0.30	1.74E-07
16.32	0.34	1.98E-07
16.42	0.32	1.88E-07
16.52	0.36	2.13E-07
16.62	0.30	1.78E-07
16.715	0.34	1.97E-07
16.815	0.35	2.06E-07
16.915	0.37	2.17E-07
17.015	0.39	2.27E-07
17.115	0.39	2.31E-07
17.215	0.44	2.58E-07
17.315	0.37	2.19E-07
17.41	0.41	2.40E-07
17.51	0.34	1.98E-07
17.61	0.36	2.13E-07
17.71	0.41	2.41E-07
17.81	0.41	2.40E-07
17.91	0.45	2.63E-07

EPA-15D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)
13.27	0.46	2.73E-07
13.37	0.46	2.69E-07
13.47	0.48	2.85E-07
13.57	0.51	3.00E-07
13.67	0.47	2.76E-07
13.77	0.50	2.95E-07
13.87	0.52	3.05E-07
13.97	0.51	2.99E-07
14.07	0.51	2.98E-07
14.17	0.52	3.05E-07
14.27	0.57	3.33E-07
14.37	0.54	3.17E-07
14.47	0.58	3.41E-07
14.57	0.57	3.34E-07
14.67	0.48	2.83E-07
14.77	0.54	3.20E-07
14.87	0.53	3.13E-07
14.97	0.52	3.06E-07
15.07	0.48	2.80E-07
15.17	0.48	2.85E-07
15.27	0.45	2.62E-07
15.37	0.46	2.73E-07
15.47	0.44	2.57E-07
15.57	0.42	2.50E-07
15.67	0.44	2.58E-07
15.77	0.45	2.66E-07
15.87	0.40	2.37E-07
15.97	0.41	2.40E-07
16.07	0.40	2.37E-07
16.17	0.38	2.22E-07
16.27	0.42	2.45E-07
16.37	0.44	2.60E-07
16.47	0.39	2.29E-07
16.56	0.39	2.28E-07
16.66	0.37	2.15E-07
16.76	0.36	2.13E-07
16.86	0.38	2.25E-07
16.96	0.43	2.50E-07
17.06	0.40	2.36E-07
17.16	0.44	2.60E-07
17.26	0.41	2.44E-07
17.36	0.45	2.63E-07
17.46	0.43	2.50E-07
17.56	0.41	2.39E-07
17.66	0.43	2.53E-07
17.76	0.39	2.29E-07
17.86	0.43	2.51E-07
17.96	0.42	2.46E-07

EPA-16D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)
13.14	0.52	3.06E-07
13.24	0.50	2.94E-07
13.34	0.51	3.00E-07
13.44	0.48	2.83E-07
13.54	0.52	3.06E-07
13.64	0.49	2.86E-07
13.74	0.49	2.87E-07
13.84	0.50	2.95E-07
13.94	0.54	3.16E-07
14.04	0.53	3.11E-07
14.14	0.49	2.89E-07
14.24	0.49	2.91E-07
14.34	0.45	2.66E-07
14.44	0.49	2.90E-07
14.54	0.48	2.84E-07
14.64	0.48	2.80E-07
14.74	0.48	2.80E-07
14.84	0.48	2.84E-07
14.94	0.53	3.11E-07
15.04	0.53	3.11E-07
15.14	0.54	3.15E-07
15.24	0.52	3.08E-07
15.34	0.50	2.91E-07
15.44	0.49	2.87E-07
15.54	0.53	3.09E-07
15.64	0.48	2.83E-07
15.74	0.52	3.05E-07
15.84	0.52	3.07E-07
15.94	0.50	2.94E-07
16.04	0.52	3.05E-07
16.13	0.50	2.92E-07
16.23	0.51	2.98E-07
16.33	0.50	2.94E-07
16.43	0.48	2.81E-07
16.53	0.51	2.97E-07
16.63	0.50	2.94E-07
16.73	0.46	2.71E-07
16.83	0.47	2.74E-07
16.93	0.46	2.72E-07
17.03	0.44	2.59E-07
17.13	0.49	2.88E-07
17.23	0.48	2.81E-07
17.33	0.46	2.70E-07
17.43	0.53	3.10E-07
17.53	0.52	3.04E-07
17.63	0.44	2.61E-07
17.73	0.44	2.60E-07
17.83	0.48	2.84E-07

EPA-19S-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)
13.08	0.30	1.77E-07
13.18	0.29	1.70E-07
13.28	0.30	1.76E-07
13.38	0.29	1.70E-07
13.48	0.25	1.45E-07
13.58	0.28	1.67E-07
13.68	0.31	1.84E-07
13.78	0.30	1.79E-07
13.88	0.28	1.64E-07
13.98	0.34	1.98E-07
14.08	0.34	2.00E-07
14.18	0.29	1.72E-07
14.28	0.29	1.71E-07
14.38	0.29	1.71E-07
14.48	0.32	1.86E-07
14.58	0.28	1.64E-07
14.68	0.30	1.78E-07
14.78	0.28	1.63E-07
14.88	0.32	1.87E-07
14.97	0.28	1.67E-07
15.07	0.29	1.71E-07
15.17	0.34	2.00E-07
15.27	0.29	1.73E-07
15.37	0.28	1.63E-07
15.47	0.31	1.81E-07
15.57	0.32	1.87E-07
15.67	0.32	1.90E-07
15.77	0.29	1.73E-07
15.87	0.32	1.89E-07
15.97	0.32	1.89E-07
16.07	0.28	1.63E-07
16.17	0.32	1.88E-07
16.27	0.30	1.76E-07
16.37	0.32	1.90E-07
16.47	0.29	1.70E-07
16.57	0.28	1.63E-07
16.67	0.28	1.67E-07
16.77	0.26	1.56E-07
16.87	0.27	1.58E-07
16.97	0.31	1.85E-07
17.07	0.34	1.99E-07
17.17	0.36	2.09E-07
17.27	0.32	1.88E-07
17.37	0.35	2.03E-07
17.47	0.34	2.00E-07
17.57	0.36	2.10E-07
17.67	0.32	1.87E-07
17.77	0.30	1.75E-07

EPA-21D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc 10e-3 SI units	Mag Susc (m3/kg)
13.03	0.67	3.96E-07
13.13	0.65	3.82E-07
13.23	0.65	3.85E-07
13.33	0.69	4.07E-07
13.43	0.67	3.95E-07
13.53	0.63	3.70E-07
13.63	0.68	4.00E-07
13.73	0.66	3.90E-07
13.83	0.66	3.87E-07
13.93	0.65	3.84E-07
14.03	0.68	4.01E-07
14.13	0.64	3.76E-07
14.23	0.66	3.89E-07
14.33	0.67	3.95E-07
14.43	0.66	3.87E-07
14.53	0.72	4.22E-07
14.63	0.73	4.28E-07
14.73	0.65	3.82E-07
14.83	0.69	4.07E-07
14.93	0.69	4.05E-07
15.02	0.71	4.15E-07
15.12	0.70	4.13E-07
15.22	0.69	4.05E-07
15.32	0.69	4.08E-07
15.42	0.65	3.85E-07
15.52	0.69	4.04E-07
15.62	0.65	3.80E-07
15.72	0.68	3.99E-07
15.82	0.66	3.89E-07
15.92	0.67	3.93E-07
16.02	0.69	4.05E-07
16.12	0.73	4.32E-07
16.22	0.65	3.85E-07
16.32	0.66	3.86E-07
16.42	0.66	3.86E-07
16.52	0.65	3.83E-07
16.62	0.64	3.77E-07
16.72	0.68	3.97E-07
16.82	0.63	3.72E-07
16.92	0.67	3.93E-07
17.02	0.68	3.98E-07
17.12	0.69	4.08E-07
17.22	0.73	4.32E-07
17.32	0.72	4.23E-07
17.42	0.76	4.47E-07
17.52	0.69	4.07E-07
17.62	0.68	4.00E-07
17.72	0.68	3.99E-07

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EPA-10D-Up/Down Average Sonde Data			EPA-12D-Up/Down Average Sonde Data			EPA-15D-Up/Down Average Sonde Data			EPA-16D-Up/Down Average Sonde Data			EPA-19S-Up/Down Average Sonde Data			EPA-21D-Up/Down Average Sonde Data		
Depth	Mag Susc	Mag Susc	Depth	Mag Susc	Mag Susc	Depth	Mag Susc	Mag Susc	Depth	Mag Susc	Mag Susc	Depth	Mag Susc	Mag Susc	Depth	Mag Susc	Mag Susc
	(10e-3 SI			(10e-3 SI			(10e-3 SI			(10e-3 SI			(10e-3 SI			10e-3 SI	
(ft bgs)	units)	(m3/kg)	(ft bgs)	units)	(m3/kg)	(ft bgs)	units)	(m3/kg)	(ft bgs)	units)	(m3/kg)	(ft bgs)	units)	(m3/kg)	(ft bgs)	units	(m3/kg)
17.82	0.81	4.74E-07	18.01	0.42	2.48E-07	18.06	0.43	2.55E-07	17.93	0.47	2.75E-07	17.87	0.31	1.83E-07	17.82	0.61	3.59E-07
17.92	0.86	5.05E-07	18.11	0.42	2.49E-07	18.16	0.41	2.38E-07	18.03	0.47	2.74E-07	17.97	0.25	1.48E-07	17.92	0.57	3.34E-07
18.015	0.83	4.86E-07	18.21	0.47	2.76E-07	18.26	0.46	2.69E-07	18.13	0.50	2.92E-07	18.07	0.31	1.84E-07	18.02	0.58	3.44E-07
18.115	0.79	4.66E-07	18.31	0.40	2.35E-07	18.36	0.46	2.68E-07	18.23	0.50	2.94E-07	18.17	0.29	1.72E-07	18.12	0.55	3.25E-07
18.215	0.74	4.36E-07	18.41	0.42	2.48E-07	18.46	0.40	2.37E-07	18.33	0.51	3.00E-07	18.26	0.29	1.72E-07	18.22	0.59	3.45E-07
18.31	0.85	5.00E-07	18.51	0.46	2.72E-07	18.56	0.39	2.27E-07	18.43	0.51	2.98E-07	18.36	0.31	1.85E-07	18.31	0.56	3.29E-07
18.41	0.87	5.11E-07	18.61	0.42	2.48E-07	18.66	0.44	2.60E-07	18.53	0.47	2.78E-07	18.46	0.33	1.96E-07	18.41	0.56	3.31E-07
18.51	0.95	5.56E-07	18.71	0.45	2.62E-07	18.76	0.42	2.47E-07	18.63	0.50	2.97E-07	18.56	0.30	1.76E-07	18.51	0.49	2.89E-07
18.81	0.90	5.29E-07	18.81	0.45	2.63E-07	18.86	0.43	2.55E-07	18.73	0.46	2.71E-07	18.66	0.26	1.56E-07	18.61	0.51	2.99E-07
18.91	0.98	5.78E-07	18.91	0.42	2.49E-07	18.96	0.40	2.38E-07	18.83	0.47	2.77E-07	18.76	0.33	1.93E-07	18.71	0.49	2.90E-07
19.01	1.01	5.93E-07	19.01	0.42	2.49E-07	19.06	0.40	2.34E-07	18.93	0.49	2.89E-07	18.86	0.30	1.77E-07	18.81	0.50	2.96E-07
19.11	1.01	5.92E-07	19.11	0.43	2.55E-07	19.16	0.43	2.53E-07	19.03	0.51	3.02E-07	18.96	0.30	1.75E-07	18.91	0.49	2.91E-07
19.21	1.08	6.36E-07	19.21	0.43	2.52E-07	19.26	0.44	2.60E-07	19.13	0.49	2.88E-07	19.06	0.27	1.60E-07	19.01	0.53	3.10E-07
19.31	1.01	5.91E-07	19.31	0.43	2.55E-07	19.36	0.41	2.41E-07	19.23	0.50	2.91E-07	19.16	0.29	1.73E-07	19.11	0.50	2.93E-07
19.41	1.02	6.03E-07	19.41	0.40	2.37E-07	19.46	0.41	2.41E-07	19.33	0.52	3.05E-07	19.26	0.27	1.62E-07	19.21	0.48	2.81E-07
19.51	1.05	6.15E-07	19.51	0.44	2.57E-07	19.56	0.38	2.22E-07	19.43	0.51	3.01E-07	19.36	0.31	1.84E-07	19.31	0.54	3.20E-07
19.61	1.07	6.32E-07	19.61	0.44	2.61E-07	19.66	0.37	2.18E-07	19.52	0.50	2.92E-07	19.46	0.31	1.80E-07	19.41	0.49	2.86E-07
19.71	1.06	6.21E-07	19.71	0.45	2.63E-07	19.76	0.42	2.46E-07	19.62	0.47	2.76E-07	19.56	0.30	1.75E-07	19.51	0.50	2.96E-07
19.81	1.05	6.19E-07	19.81	0.45	2.63E-07	19.86	0.41	2.39E-07	19.72	0.51	3.00E-07	19.66	0.33	1.97E-07	19.61	0.45	2.65E-07
19.91	0.99	5.83E-07	19.91	0.49	2.88E-07	19.95	0.41	2.39E-07	19.82	0.49	2.88E-07	19.76	0.31	1.81E-07	19.71	0.48	2.83E-07
20.01	1.08	6.34E-07	20.005	0.45	2.67E-07	20.05	0.39	2.31E-07	19.92	0.53	3.14E-07	19.86	0.31	1.82E-07	19.81	0.51	3.01E-07
20.11	1.09	6.43E-07	20.105	0.44	2.57E-07	20.15	0.40	2.35E-07	20.02	0.48	2.85E-07	19.96	0.29	1.69E-07	19.91	0.49	2.90E-07
20.21	1.10	6.44E-07	20.205	0.47	2.75E-07	20.25	0.43	2.50E-07	20.12	0.53	3.12E-07	20.06	0.34	1.98E-07	20.01	0.45	2.66E-07
20.31	1.09	6.39E-07	20.305	0.46	2.71E-07	20.35	0.45	2.66E-07	20.22	0.53	3.12E-07	20.16	0.30	1.74E-07	20.11	0.48	2.80E-07
20.41	1.06	6.25E-07	20.405	0.44	2.56E-07	20.45	0.42	2.44E-07	20.32	0.52	3.05E-07	20.26	0.28	1.66E-07	20.21	0.46	2.71E-07
20.51	1.03	6.07E-07	20.505	0.46	2.70E-07	20.55	0.41	2.42E-07	20.42	0.49	2.88E-07	20.36	0.29	1.70E-07	20.31	0.48	2.85E-07
20.61	1.10	6.48E-07	20.605	0.42	2.46E-07	20.65	0.44	2.57E-07	20.52	0.54	3.18E-07	20.46	0.28	1.63E-07	20.41	0.47	2.77E-07
20.71	1.10	6.48E-07	20.705	0.42	2.46E-07	20.75	0.39	2.30E-07	20.72	0.48	2.85E-07	20.56	0.29	1.71E-07	20.51	0.45	2.63E-07
20.81	1.02	5.98E-07	20.8	0.40	2.34E-07	20.85	0.36	2.14E-07	20.82	0.51	2.98E-07	20.66	0.28	1.63E-07	20.61	0.48	2.83E-07
20.91	1.07	6.31E-07	20.9	0.42	2.47E-07	20.95	0.41	2.43E-07	20.92	0.52	3.05E-07	20.76	0.28	1.65E-07	20.71	0.48	2.85E-07
21.01	1.06	6.23E-07	21	0.37	2.17E-07	21.05	0.42	2.46E-07	21.02	0.50	2.92E-07	20.86	0.29	1.69E-07	20.81	0.50	2.95E-07
21.11	1.05	6.16E-07	21.1	0.44	2.60E-07	21.15	0.40	2.33E-07	21.12	0.53	3.11E-07	20.96	0.33	1.92E-07	20.91	0.44	2.57E-07
21.21	1.06	6.26E-07	21.2	0.43	2.51E-07	21.25	0.43	2.51E-07	21.22	0.50	2.94E-07	21.06	0.30	1.79E-07	21.01	0.39	2.32E-07
21.305	1.07	6.27E-07	21.3	0.40	2.34E-07	21.35	0.39	2.28E-07	21.32	0.52	3.03E-07	21.16	0.28	1.65E-07	21.11	0.44	2.61E-07
21.405	1.08	6.38E-07	21.4	0.40	2.38E-07	21.45	0.42	2.44E-07	21.42	0.54	3.20E-07	21.26	0.30	1.77E-07	21.21	0.44	2.58E-07
21.505	1.00	5.91E-07	21.5	0.38	2.26E-07	21.55	0.42	2.45E-07	21.52	0.57	3.36E-07	21.36	0.27	1.59E-07	21.31	0.49	2.86E-07
21.605	0.97	5.69E-07	21.6	0.44	2.57E-07	21.65	0.41	2.41E-07	21.62	0.53	3.14E-07	21.46	0.27	1.58E-07	21.41	0.45	2.65E-07
21.7	1.00	5.86E-07	21.7	0.44	2.57E-07	21.75	0.39	2.32E-07	21.72	0.48	2.83E-07	21.56	0.29	1.72E-07	21.51	0.46	2.71E-07
21.8	1.00	5.88E-07	21.8	0.40	2.34E-07	21.85	0.44	2.56E-07	21.82	0.47	2.75E-07	21.65	0.28	1.62E-07	21.61	0.45	2.65E-07
21.9	1.01	5.92E-07	21.9	0.40	2.38E-07	21.95	0.44	2.60E-07	21.92	0.51	2.99E-07	21.75	0.31	1.82E-07	21.70	0.49	2.88E-07
22	0.97	5.72E-07	22	0.44	2.62E-07	22.05	0.41	2.43E-07	22.02	0.53	3.11E-07	21.85	0.27	1.59E-07	21.80	0.48	2.82E-07
22.1	0.86	5.07E-07	22.1	0.42	2.50E-07	22.15	0.43	2.54E-07	22.12	0.57	3.38E-07	21.95	0.26	1.56E-07	21.90	0.47	2.79E-07
22.2	0.85	5.00E-07	22.2	0.43	2.53E-07	22.25	0.46	2.71E-07	22.22	0.62	3.65E-07	22.05	0.31	1.83E-07	22.00	0.42	2.47E-07
22.3	0.90	5.30E-07	22.3	0.37	2.19E-07	22.35	0.42	2.46E-07	22.32	0.57	3.36E-07	22.15	0.27	1.60E-07	22.10	0.45	2.63E-07
22.4	0.94	5.50E-07	22.4	0.37	2.19E-07	22.45	0.48	2.83E-07	22.42	0.58	3.40E-07	22.25	0.26	1.54E-07	22.20	0.40	2.35E-07
22.5	0.89	5.24E-07	22.5	0.37	2.17E-07	22.55	0.46	2.72E-07	22.52	0.56	3.28E-07	22.35	0.30	1.77E-07	22.30	0.45	2.63E-07
22.6	0.86	5.06E-07	22.6	0.39	2.32E-07	22.65	0.48	2.80E-07	22.62	0.50	2.92E-07	22.45	0.30	1.78E-07	22.40	0.46	2.68E-07
22.7	0.85	5.00E-07	22.7	0.40	2.36E-07	22.75	0.48	2.83E-07	22.72	0.50	2.91E-07	22.55	0.29	1.69E-07	22.50	0.44	2.57E-07

WIEDEMEIER & ASSOCIATES

FORMER HOPEWELL PRECISION SITE, HOPEWELL JUNCTION, NEW YORK

EPA-10D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)
22.8	0.85	5.01E-07
22.9	0.85	5.02E-07
23	0.88	5.17E-07
23.1	0.85	4.97E-07
23.2	0.76	4.47E-07
23.3	0.82	4.84E-07
23.4	0.82	4.80E-07
23.5	0.82	4.83E-07
23.6	0.83	4.85E-07
23.7	0.76	4.49E-07
23.8	0.74	4.32E-07
23.9	0.75	4.42E-07
24	0.76	4.44E-07
24.1	0.79	4.65E-07
24.2	0.81	4.79E-07
24.3	0.88	5.18E-07
24.4	0.91	5.37E-07
24.5	0.88	5.20E-07
24.6	0.85	5.01E-07
24.695	0.85	5.02E-07
24.795	0.83	4.90E-07
24.895	0.87	5.15E-07
24.99	0.81	4.74E-07
25.09	0.81	4.79E-07
25.19	0.77	4.52E-07
25.29	0.77	4.55E-07
25.39	0.75	4.41E-07
25.49	0.69	4.07E-07
25.59	0.69	4.04E-07
25.69	0.66	3.86E-07
25.79	0.62	3.67E-07
25.89	0.60	3.54E-07
25.99	0.55	3.21E-07
26.09	0.52	3.06E-07
26.19	0.53	3.12E-07
26.29	0.47	2.74E-07
26.39	0.50	2.96E-07
26.49	0.54	3.18E-07
26.59	0.52	3.08E-07
26.69	0.54	3.20E-07
26.79	0.59	3.45E-07
26.89	0.54	3.19E-07
26.99	0.52	3.06E-07
27.09	0.61	3.56E-07
27.19	0.61	3.59E-07
27.29	0.65	3.81E-07
27.39	0.66	3.86E-07
27.49	0.66	3.89E-07

EPA-12D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)
22.8	0.40	2.38E-07
22.9	0.38	2.24E-07
23	0.38	2.26E-07
23.1	0.40	2.33E-07
23.2	0.35	2.04E-07
23.3	0.36	2.11E-07
23.395	0.39	2.29E-07
23.495	0.41	2.40E-07
23.595	0.41	2.40E-07
23.695	0.37	2.15E-07
23.795	0.38	2.25E-07
23.895	0.38	2.25E-07
23.995	0.43	2.53E-07
24.09	0.39	2.32E-07
24.19	0.35	2.04E-07
24.29	0.36	2.09E-07
24.39	0.37	2.15E-07
24.49	0.37	2.18E-07
24.59	0.39	2.31E-07
24.69	0.41	2.40E-07
24.79	0.40	2.37E-07
24.89	0.36	2.10E-07
24.99	0.38	2.22E-07
25.09	0.45	2.63E-07
25.19	0.38	2.26E-07
25.29	0.36	2.10E-07
25.39	0.34	2.03E-07
25.49	0.36	2.10E-07
25.59	0.41	2.40E-07
25.69	0.37	2.18E-07
25.79	0.41	2.40E-07
25.89	0.37	2.17E-07
25.99	0.33	1.93E-07
26.09	0.34	2.01E-07
26.19	0.33	1.93E-07
26.29	0.36	2.11E-07
26.39	0.36	2.12E-07
26.49	0.35	2.07E-07
26.59	0.38	2.21E-07
26.685	0.35	2.05E-07
26.785	0.36	2.11E-07
26.885	0.37	2.17E-07
26.985	0.34	2.01E-07
27.085	0.40	2.35E-07
27.185	0.37	2.16E-07
27.285	0.38	2.25E-07
27.38	0.35	2.05E-07
27.48	0.36	2.14E-07

EPA-15D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)	
22.85	0.50	2.92E-07	
22.95	0.46	2.71E-07	
23.05	0.43	2.55E-07	
23.15	0.45	2.66E-07	
23.24	0.42	2.46E-07	
23.34	0.42	2.48E-07	
23.44	0.36	2.15E-07	
23.54	0.41	2.39E-07	
23.64	0.34	1.99E-07	
23.74	0.38	2.21E-07	
23.84	0.40	2.37E-07	
23.94	0.33	1.97E-07	
24.04	0.42	2.48E-07	
24.14	0.42	2.46E-07	
24.24	0.41	2.40E-07	
24.34	0.46	2.71E-07	
24.44	0.41	2.43E-07	
24.54	0.44	2.61E-07	
24.64	0.40	2.32E-07	
24.74	0.38	2.21E-07	
24.84	0.38	2.22E-07	
24.94	0.33	1.96E-07	
25.04	0.33	1.96E-07	
25.14	0.28	1.67E-07	
25.24	0.28	1.63E-07	
25.34	0.27	1.58E-07	
25.44	0.26	1.53E-07	
25.54	0.23	1.36E-07	
25.64	0.22	1.29E-07	
25.74	0.28	1.64E-07	
25.84	0.26	1.55E-07	
25.94	0.29	1.73E-07	
26.04	0.27	1.57E-07	
26.14	0.31	1.81E-07	
26.24	0.30	1.79E-07	
26.34	0.28	1.67E-07	
26.44	0.33	1.96E-07	#REF!
26.54	0.37	2.15E-07	
26.63	0.34	1.99E-07	
26.73	0.34	1.99E-07	
26.83	0.34	1.99E-07	
26.93	0.32	1.90E-07	
27.03	0.32	1.86E-07	
27.13	0.32	1.89E-07	
27.23	0.31	1.85E-07	
27.33	0.29	1.71E-07	
27.43	0.24	1.43E-07	
27.53	0.27	1.60E-07	

EPA-16D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)
22.81	0.49	2.86E-07
22.91	0.53	3.09E-07
23.01	0.52	3.04E-07
23.11	0.48	2.84E-07
23.21	0.50	2.97E-07
23.31	0.54	3.18E-07
23.41	0.50	2.96E-07
23.51	0.52	3.08E-07
23.61	0.52	3.06E-07
23.71	0.56	3.28E-07
23.81	0.51	2.99E-07
23.91	0.55	3.23E-07
24.01	0.54	3.17E-07
24.11	0.53	3.14E-07
24.21	0.53	3.14E-07
24.31	0.54	3.17E-07
24.41	0.52	3.06E-07
24.51	0.57	3.33E-07
24.61	0.53	3.09E-07
24.71	0.54	3.19E-07
24.81	0.52	3.07E-07
24.91	0.55	3.24E-07
25.01	0.57	3.34E-07
25.11	0.55	3.26E-07
25.21	0.46	2.69E-07
25.31	0.54	3.15E-07
25.41	0.54	3.18E-07
25.51	0.54	3.18E-07
25.61	0.53	3.13E-07
25.71	0.56	3.28E-07
25.81	0.53	3.11E-07
25.91	0.51	2.98E-07
26.01	0.47	2.78E-07
26.11	0.57	3.33E-07
26.20	0.52	3.09E-07
26.30	0.53	3.14E-07
26.40	0.51	2.99E-07
26.50	0.53	3.13E-07
26.60	0.48	2.85E-07
26.70	0.51	3.00E-07
26.80	0.56	3.27E-07
26.90	0.55	3.26E-07
27.00	0.54	3.18E-07
27.10	0.56	3.28E-07
27.20	0.56	3.32E-07
27.30	0.57	3.34E-07
27.40	0.54	3.17E-07
27.50	0.53	3.10E-07

EPA-19S-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)
22.65	0.30	1.76E-07
22.75	0.29	1.72E-07
22.85	0.28	1.67E-07
22.95	0.31	1.84E-07
23.05	0.32	1.88E-07
23.15	0.28	1.64E-07
23.25	0.28	1.65E-07
23.35	0.27	1.59E-07
23.45	0.30	1.76E-07
23.55	0.31	1.81E-07
23.65	0.33	1.96E-07
23.75	0.34	2.02E-07
23.85	0.34	1.98E-07
23.95	0.34	1.98E-07
	Mean	1.76E-07
	Count	71
	Confidence Level(	3.30E-09

EPA-21D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc 10e-3 SI units	Mag Susc (m3/kg)
22.60	0.44	2.61E-07
22.70	0.42	2.45E-07
22.80	0.43	2.51E-07
22.90	0.44	2.61E-07
23.00	0.46	2.72E-07
23.10	0.39	2.30E-07
23.20	0.40	2.36E-07
23.30	0.42	2.50E-07
23.40	0.41	2.39E-07
23.50	0.39	2.27E-07
23.60	0.42	2.48E-07
23.70	0.41	2.43E-07
23.80	0.45	2.67E-07
23.90	0.42	2.48E-07
24.00	0.43	2.54E-07
24.10	0.41	2.42E-07
24.20	0.38	2.21E-07
24.30	0.42	2.49E-07
24.40	0.41	2.43E-07
24.50	0.42	2.47E-07
24.60	0.43	2.51E-07
24.70	0.43	2.54E-07
24.80	0.44	2.58E-07
24.90	0.41	2.43E-07
24.99	0.44	2.56E-07
25.09	0.44	2.60E-07
25.19	0.45	2.65E-07
25.29	0.41	2.42E-07
25.39	0.44	2.58E-07
25.49	0.43	2.54E-07
25.59	0.48	2.81E-07
25.69	0.40	2.37E-07
25.79	0.44	2.58E-07
25.89	0.53	3.13E-07
25.99	0.55	3.23E-07
26.09	0.66	3.87E-07
26.19	0.63	3.70E-07
26.29	0.62	3.64E-07
26.39	0.54	3.16E-07
26.49	0.50	2.95E-07
26.59	0.46	2.73E-07
26.69	0.43	2.54E-07
26.79	0.39	2.32E-07
26.89	0.43	2.51E-07
26.99	0.41	2.43E-07
27.09	0.40	2.35E-07
27.19	0.48	2.81E-07
27.29	0.48	2.83E-07

FORMER HOPEWELL PRECISION SITE, HOPEWELL JUNCTION, NEW YORK

EPA-10D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)
27.59	0.62	3.66E-07
27.69	0.66	3.86E-07
27.79	0.64	3.78E-07
27.89	0.62	3.62E-07
27.985	0.59	3.49E-07
28.085	0.60	3.54E-07
28.185	0.60	3.53E-07
28.28	0.64	3.75E-07
28.38	0.62	3.62E-07
28.48	0.57	3.35E-07
28.58	0.56	3.31E-07
28.68	0.55	3.25E-07
28.78	0.54	3.18E-07
28.88	0.53	3.13E-07
28.98	0.51	3.02E-07
29.08	0.47	2.77E-07
29.18	0.46	2.68E-07
29.28	0.44	2.60E-07
29.38	0.44	2.61E-07
29.48	0.43	2.53E-07
29.58	0.44	2.57E-07
29.68	0.42	2.46E-07
29.78	0.45	2.64E-07
29.88	0.42	2.45E-07
29.98	0.46	2.68E-07
30.08	0.43	2.52E-07
30.18	0.41	2.42E-07
30.28	0.44	2.59E-07
30.38	0.51	3.00E-07
30.48	0.67	3.95E-07
30.58	0.75	4.39E-07
30.68	0.79	4.62E-07
30.78	0.83	4.91E-07
30.88	0.89	5.22E-07
30.98	0.91	5.32E-07
31.08	0.91	5.34E-07
31.18	0.84	4.92E-07
31.275	0.71	4.19E-07
31.375	0.69	4.09E-07
31.475	0.61	3.57E-07
31.57	0.57	3.34E-07
31.67	0.52	3.04E-07
31.77	0.50	2.95E-07
31.87	0.52	3.05E-07
31.97	0.56	3.32E-07
32.07	0.60	3.54E-07
32.17	0.54	3.20E-07
32.27	0.51	2.97E-07

EPA-12D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)
27.58	0.41	2.39E-07
27.68	0.42	2.48E-07
27.78	0.45	2.65E-07
27.88	0.42	2.45E-07
27.98	0.42	2.47E-07
28.08	0.49	2.90E-07
28.18	0.47	2.75E-07
28.28	0.46	2.72E-07
28.4	0.42	2.46E-07
28.48	0.40	2.36E-07
28.58	0.40	2.36E-07
28.68	0.38	2.25E-07
28.78	0.41	2.39E-07
28.88	0.41	2.43E-07
28.98	0.48	2.82E-07
29.06	0.53	3.12E-07
29.18	0.51	2.98E-07
29.28	0.60	3.52E-07
29.38	0.58	3.44E-07
29.48	0.57	3.33E-07
29.58	0.51	2.99E-07
29.68	0.44	2.59E-07
29.78	0.40	2.35E-07
29.9	0.36	2.13E-07
29.975	0.30	1.75E-07
30.075	0.24	1.41E-07
30.175	0.24	1.38E-07
30.275	0.25	1.45E-07
30.375	0.25	1.50E-07
30.475	0.23	1.34E-07
30.575	0.22	1.32E-07
30.675	0.25	1.47E-07
30.77	0.25	1.47E-07
30.87	0.25	1.46E-07
30.97	0.23	1.35E-07
31.07	0.24	1.43E-07
31.17	0.31	1.84E-07
31.27	0.29	1.74E-07
31.37	0.24	1.42E-07
31.47	0.22	1.30E-07
31.57	0.25	1.44E-07
31.67	0.22	1.30E-07
31.77	0.19	1.10E-07
31.87	0.15	8.91E-08
31.97	0.12	6.81E-08
32.07	0.12	7.34E-08
32.17	0.14	8.06E-08
32.27	0.15	8.68E-08

EPA-15D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)	
27.63	0.25	1.48E-07	
27.73	0.24	1.39E-07	
27.83	0.26	1.53E-07	
27.93	0.22	1.32E-07	
28.03	0.27	1.57E-07	
28.13	0.25	1.49E-07	
28.23	0.26	1.52E-07	#REF!
28.33	0.27	1.57E-07	
28.43	0.26	1.51E-07	
28.53	0.28	1.65E-07	
28.63	0.27	1.56E-07	
28.73	0.31	1.80E-07	
28.83	0.33	1.93E-07	
28.93	0.32	1.87E-07	
29.03	0.31	1.83E-07	#REF!
29.13	0.34	2.01E-07	
29.23	0.30	1.77E-07	
29.33	0.30	1.77E-07	
29.43	0.30	1.75E-07	
29.53	0.27	1.59E-07	
29.63	0.21	1.24E-07	
29.73	0.25	1.45E-07	
29.83	0.24	1.43E-07	
29.92	0.24	1.42E-07	
30.02	0.26	1.53E-07	
30.12	0.29	1.72E-07	
30.22	0.31	1.84E-07	
30.32	0.28	1.66E-07	
30.42	0.30	1.74E-07	
30.52	0.31	1.81E-07	#REF!
30.62	0.35	2.09E-07	
30.72	0.39	2.29E-07	
30.82	0.42	2.45E-07	
30.92	0.47	2.79E-07	
31.02	0.40	2.33E-07	
31.12	0.43	2.54E-07	
31.22	0.36	2.09E-07	
31.32	0.36	2.11E-07	
31.42	0.37	2.19E-07	
31.52	0.39	2.27E-07	#REF!
31.62	0.40	2.35E-07	
31.72	0.34	2.00E-07	
31.82	0.39	2.28E-07	
31.92	0.33	1.94E-07	
32.02	0.36	2.14E-07	
32.12	0.38	2.22E-07	
32.22	0.37	2.20E-07	
32.32	0.38	2.21E-07	

EPA-16D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)
27.60	0.55	3.25E-07
27.70	0.56	3.27E-07
27.80	0.58	3.41E-07
27.90	0.54	3.20E-07
28.00	0.55	3.25E-07
28.10	0.54	3.19E-07
28.20	0.57	3.38E-07
28.30	0.53	3.10E-07
28.40	0.56	3.29E-07
28.50	0.56	3.30E-07
28.60	0.52	3.08E-07
28.70	0.54	3.18E-07
28.80	0.53	3.11E-07
28.90	0.50	2.94E-07
29.00	0.56	3.32E-07
29.10	0.54	3.17E-07
29.20	0.54	3.15E-07
29.30	0.56	3.32E-07
29.40	0.57	3.33E-07
29.49	0.58	3.43E-07
29.59	0.58	3.41E-07
29.69	0.50	2.94E-07
29.79	0.55	3.24E-07
29.89	0.52	3.07E-07
29.99	0.55	3.24E-07
30.09	0.55	3.25E-07
30.19	0.55	3.21E-07
30.29	0.57	3.36E-07
30.39	0.54	3.16E-07
30.49	0.51	3.00E-07
30.59	0.51	2.99E-07
30.69	0.53	3.09E-07
30.79	0.55	3.21E-07
30.89	0.55	3.25E-07
30.99	0.55	3.25E-07
31.09	0.58	3.44E-07
31.19	0.55	3.26E-07
31.29	0.52	3.07E-07
31.39	0.54	3.16E-07
31.49	0.50	2.94E-07
31.59	0.54	3.17E-07
31.69	0.53	3.12E-07
31.79	0.57	3.33E-07
31.89	0.49	2.90E-07
31.99	0.49	2.90E-07
32.09	0.53	3.09E-07
32.19	0.53	3.13E-07
32.29	0.56	3.27E-07

EPA-19S-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)

EPA-21D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc 10e-3 SI units	Mag Susc (m3/kg)
27.39	0.48	2.80E-07
27.49	0.48	2.85E-07
27.59	0.47	2.75E-07
27.69	0.46	2.73E-07
27.79	0.45	2.67E-07
27.89	0.47	2.77E-07
27.99	0.51	2.99E-07
28.09	0.45	2.64E-07
28.19	0.47	2.78E-07
28.28	0.43	2.53E-07
28.38	0.42	2.48E-07
28.48	0.48	2.83E-07
28.58	0.45	2.64E-07
28.68	0.46	2.73E-07
28.78	0.43	2.52E-07
28.88	0.43	2.54E-07
28.98	0.46	2.68E-07
29.08	0.45	2.66E-07
29.18	0.47	2.76E-07
29.28	0.45	2.63E-07
29.38	0.51	3.00E-07
29.48	0.44	2.61E-07
29.58	0.45	2.62E-07
29.68	0.46	2.69E-07
29.78	0.43	2.52E-07
29.88	0.46	2.70E-07
29.98	0.41	2.38E-07
30.08	0.45	2.65E-07
30.18	0.44	2.61E-07
30.28	0.45	2.67E-07
30.38	0.42	2.49E-07
30.48	0.45	2.66E-07
30.58	0.45	2.62E-07
30.68	0.48	2.80E-07
30.78	0.42	2.46E-07
30.88	0.47	2.74E-07
30.98	0.46	2.68E-07
31.08	0.45	2.65E-07
31.18	0.43	2.51E-07
31.28	0.44	2.62E-07
31.38	0.44	2.60E-07
31.48	0.49	2.85E-07
31.57	0.41	2.40E-07
31.67	0.45	2.64E-07
31.77	0.46	2.70E-07
31.87	0.47	2.75E-07
31.97	0.44	2.59E-07
32.07	0.45	2.62E-07

FORMER HOPEWELL PRECISION SITE, HOPEWELL JUNCTION, NEW YORK

EPA-10D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)
32.37	0.51	2.99E-07
32.47	0.50	2.92E-07
32.57	0.45	2.65E-07
32.67	0.48	2.79E-07
32.77	0.43	2.53E-07
32.87	0.43	2.50E-07
32.97	0.38	2.22E-07
33.07	0.37	2.15E-07
33.17	0.39	2.30E-07
33.27	0.34	1.99E-07
33.37	0.33	1.94E-07
33.47	0.31	1.81E-07
33.57	0.34	1.97E-07
33.67	0.33	1.94E-07
33.77	0.29	1.73E-07
33.87	0.34	1.98E-07
33.97	0.34	2.01E-07
34.07	0.37	2.17E-07
34.17	0.40	2.37E-07
34.27	0.39	2.29E-07
34.37	0.42	2.47E-07
34.47	0.43	2.50E-07
34.565	0.47	2.77E-07
34.665	0.51	3.00E-07
34.765	0.49	2.88E-07
34.865	0.54	3.20E-07
34.96	0.60	3.54E-07
35.06	0.58	3.43E-07
35.16	0.62	3.62E-07
35.26	0.62	3.65E-07
35.36	0.68	3.97E-07
35.46	0.58	3.38E-07
35.56	0.64	3.74E-07
35.66	0.60	3.52E-07
35.76	0.64	3.79E-07
35.86	0.63	3.70E-07
35.96	0.65	3.85E-07
36.06	0.65	3.80E-07
36.16	0.62	3.66E-07
36.26	0.63	3.69E-07
36.36	0.63	3.69E-07
36.46	0.65	3.83E-07
36.56	0.65	3.81E-07
36.66	0.61	3.58E-07
36.76	0.64	3.78E-07
36.86	0.59	3.47E-07
36.96	0.63	3.71E-07
37.06	0.60	3.53E-07

EPA-12D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)
32.37	0.12	7.19E-08
32.47	0.16	9.61E-08
32.57	0.18	1.05E-07
32.67	0.21	1.22E-07
32.77	0.21	1.24E-07
32.87	0.18	1.06E-07
32.97	0.17	9.90E-08
33.07	0.16	9.67E-08
33.17	0.15	9.07E-08
33.27	0.19	1.12E-07
33.365	0.15	8.75E-08
33.465	0.17	9.89E-08
33.565	0.18	1.05E-07
33.665	0.17	9.75E-08
33.765	0.16	9.14E-08
33.865	0.14	8.05E-08
33.965	0.18	1.03E-07
34.06	0.14	8.30E-08
34.16	0.15	8.98E-08
34.26	0.14	8.25E-08
34.36	0.18	1.06E-07
34.46	0.18	1.07E-07
34.56	0.20	1.16E-07
34.66	0.25	1.46E-07
34.76	0.20	1.19E-07
34.86	0.22	1.29E-07
34.96	0.20	1.16E-07
35.04	0.19	1.09E-07
35.16	0.18	1.06E-07
35.26	0.14	8.08E-08
35.36	0.10	6.09E-08
35.46	0.19	1.11E-07
35.56	0.24	1.41E-07
35.66	0.29	1.72E-07
35.76	0.40	2.38E-07
35.86	0.39	2.27E-07
35.96	0.39	2.32E-07
36.06	0.35	2.05E-07
36.16	0.30	1.76E-07
36.26	0.24	1.39E-07
36.36	0.16	9.20E-08
36.46	0.14	8.09E-08
36.56	0.15	8.98E-08
36.655	0.17	9.77E-08
36.755	0.18	1.06E-07
36.855	0.20	1.17E-07
36.955	0.20	1.19E-07
37.055	0.19	1.11E-07

EPA-15D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)	
32.42	0.39	2.31E-07	
32.52	0.42	2.46E-07	#REF!
32.62	0.43	2.53E-07	
32.72	0.41	2.43E-07	
32.82	0.41	2.40E-07	
32.92	0.37	2.20E-07	
33.02	0.41	2.43E-07	
33.12	0.41	2.41E-07	
33.21	0.42	2.47E-07	
33.31	0.43	2.52E-07	
33.41	0.39	2.31E-07	#REF!
33.51	0.38	2.23E-07	
33.61	0.42	2.47E-07	
33.71	0.39	2.29E-07	
33.81	0.43	2.53E-07	
33.91	0.43	2.54E-07	
34.01	0.40	2.36E-07	
34.11	0.40	2.34E-07	
34.21	0.38	2.26E-07	
34.31	0.41	2.40E-07	
34.41	0.39	2.29E-07	
34.51	0.39	2.32E-07	
34.61	0.38	2.24E-07	
34.71	0.35	2.04E-07	
34.81	0.33	1.94E-07	
34.91	0.33	1.93E-07	
35.01	0.35	2.08E-07	
35.11	0.28	1.63E-07	
35.21	0.28	1.63E-07	
35.31	0.30	1.78E-07	
35.41	0.25	1.48E-07	
35.51	0.28	1.67E-07	#REF!
35.61	0.30	1.74E-07	
35.71	0.29	1.70E-07	
35.81	0.31	1.85E-07	
35.91	0.34	2.01E-07	
36.01	0.33	1.93E-07	
36.11	0.38	2.21E-07	
36.21	0.34	2.01E-07	
36.31	0.41	2.43E-07	
36.41	0.36	2.12E-07	
36.51	0.42	2.46E-07	
36.60	0.38	2.24E-07	
36.70	0.43	2.55E-07	
36.80	0.45	2.64E-07	
36.90	0.43	2.55E-07	
37.00	0.49	2.89E-07	
37.10	0.49	2.87E-07	

EPA-16D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)
32.39	0.52	3.07E-07
32.49	0.53	3.13E-07
32.59	0.53	3.15E-07
32.69	0.51	2.99E-07
32.78	0.51	3.02E-07
32.88	0.53	3.10E-07
32.98	0.54	3.18E-07
33.08	0.50	2.93E-07
33.18	0.54	3.16E-07
33.28	0.55	3.23E-07
33.38	0.48	2.82E-07
33.48	0.56	3.29E-07
33.58	0.55	3.22E-07
33.68	0.52	3.06E-07
33.78	0.50	2.92E-07
33.88	0.55	3.23E-07
33.98	0.50	2.93E-07
34.08	0.57	3.34E-07
34.18	0.58	3.40E-07
34.28	0.57	3.34E-07
34.38	0.58	3.39E-07
34.48	0.59	3.45E-07
34.58	0.60	3.55E-07
34.68	0.60	3.52E-07
34.78	0.59	3.46E-07
34.88	0.63	3.73E-07
34.98	0.56	3.29E-07
35.08	0.61	3.61E-07
35.18	0.62	3.62E-07
35.28	0.64	3.76E-07
35.38	0.66	3.86E-07
35.48	0.66	3.91E-07
35.58	0.66	3.89E-07
35.68	0.63	3.72E-07
35.78	0.71	4.15E-07
35.88	0.71	4.18E-07
35.98	0.66	3.87E-07
36.08	0.65	3.81E-07
36.17	0.62	3.68E-07
36.27	0.55	3.26E-07
36.37	0.54	3.20E-07
36.47	0.54	3.15E-07
36.57	0.46	2.68E-07
36.67	0.48	2.84E-07
36.77	0.48	2.84E-07
36.87	0.44	2.57E-07
36.97	0.45	2.62E-07
37.07	0.39	2.31E-07

EPA-19S-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)

EPA-21D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc 10e-3 SI units	Mag Susc (m3/kg)
32.17	0.48	2.82E-07
32.27	0.46	2.72E-07
32.37	0.49	2.87E-07
32.47	0.45	2.63E-07
32.57	0.44	2.61E-07
32.67	0.51	2.98E-07
32.77	0.50	2.96E-07
32.87	0.41	2.42E-07
32.97	0.40	2.38E-07
33.07	0.46	2.70E-07
33.17	0.46	2.72E-07
33.27	0.46	2.71E-07
33.37	0.55	3.23E-07
33.47	0.49	2.87E-07
33.57	0.51	3.01E-07
33.67	0.46	2.70E-07
33.77	0.45	2.65E-07
33.87	0.46	2.69E-07
33.97	0.48	2.81E-07
34.07	0.48	2.82E-07
34.17	0.43	2.54E-07
34.27	0.44	2.61E-07
34.37	0.43	2.55E-07
34.47	0.41	2.44E-07
34.57	0.44	2.58E-07
34.67	0.43	2.54E-07
34.77	0.43	2.54E-07
34.87	0.47	2.75E-07
34.96	0.47	2.74E-07
35.06	0.40	2.36E-07
35.16	0.46	2.72E-07
35.26	0.48	2.82E-07
35.36	0.44	2.61E-07
35.46	0.47	2.74E-07
35.56	0.43	2.54E-07
35.66	0.44	2.57E-07
35.76	0.46	2.68E-07
35.86	0.58	3.43E-07
	Mean	2.87E-07
	Count	204.00
	Confidence Level(95.0%)	6.75E-09

WIEDEMEIER & ASSOCIATES

FORMER HOPEWELL PRECISION SITE, HOPEWELL JUNCTION, NEW YORK

EPA-10D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)
37.16	0.64	3.75E-07
37.26	0.68	3.98E-07
37.36	0.63	3.68E-07
37.46	0.62	3.66E-07
37.56	0.62	3.64E-07
37.66	0.57	3.37E-07
37.76	0.58	3.44E-07
37.86	0.57	3.35E-07
37.955	0.58	3.40E-07
38.055	0.64	3.74E-07
38.155	0.63	3.73E-07
38.25	0.64	3.74E-07
38.35	0.60	3.51E-07
38.45	0.64	3.79E-07
38.55	0.64	3.78E-07
38.65	0.67	3.96E-07
38.75	0.66	3.88E-07
38.85	0.62	3.67E-07
38.95	0.64	3.75E-07
39.05	0.59	3.49E-07
39.15	0.56	3.32E-07
39.25	0.58	3.42E-07
39.35	0.63	3.71E-07
39.45	0.63	3.71E-07
39.55	0.57	3.34E-07
39.65	0.56	3.32E-07
39.75	0.55	3.25E-07
39.85	0.59	3.50E-07
39.95	0.60	3.51E-07
40.05	0.58	3.42E-07
40.15	0.57	3.38E-07
40.25	0.56	3.29E-07
40.35	0.61	3.56E-07
40.45	0.62	3.68E-07
40.55	0.62	3.63E-07
40.65	0.60	3.55E-07
40.75	0.59	3.47E-07
40.85	0.57	3.32E-07
40.95	0.59	3.45E-07
41.05	0.64	3.74E-07
41.15	0.67	3.94E-07
41.245	0.69	4.08E-07
41.345	0.65	3.82E-07
41.445	0.59	3.46E-07
41.54	0.64	3.74E-07
41.64	0.65	3.82E-07
41.74	0.67	3.91E-07
41.84	0.64	3.79E-07

EPA-12D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)
37.155	0.21	1.22E-07
37.255	0.25	1.48E-07
37.355	0.23	1.37E-07
37.45	0.30	1.76E-07
37.55	0.26	1.54E-07
37.65	0.23	1.35E-07
37.75	0.26	1.52E-07
37.85	0.23	1.35E-07
37.95	0.24	1.40E-07
38.05	0.21	1.24E-07
38.15	0.21	1.24E-07
38.25	0.25	1.47E-07
38.35	0.20	1.18E-07
38.45	0.23	1.36E-07
38.55	0.17	1.02E-07
38.65	0.24	1.41E-07
38.75	0.20	1.19E-07
38.85	0.20	1.19E-07
38.95	0.19	1.09E-07
39.05	0.20	1.16E-07
39.15	0.17	9.76E-08
39.25	0.23	1.36E-07
39.35	0.22	1.32E-07
39.45	0.15	8.86E-08
39.55	0.18	1.05E-07
39.65	0.16	9.44E-08
39.75	0.16	9.33E-08
39.85	0.15	8.92E-08
39.945	0.18	1.06E-07
40.045	0.18	1.08E-07
40.145	0.16	9.56E-08
40.245	0.16	9.68E-08
40.345	0.18	1.06E-07
40.445	0.20	1.17E-07
40.545	0.17	9.78E-08
40.645	0.15	9.10E-08
40.74	0.14	8.20E-08
40.84	0.13	7.43E-08
40.94	0.17	9.92E-08
41.04	0.15	9.07E-08
41.14	0.13	7.36E-08
41.24	0.16	9.29E-08
41.34	0.16	9.43E-08
41.44	0.16	9.64E-08
41.54	0.15	8.93E-08
41.64	0.15	8.90E-08
41.74	0.15	8.81E-08
41.84	0.13	7.91E-08

EPA-15D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)
37.20	0.49	2.88E-07
37.30	0.48	2.81E-07
37.40	0.48	2.83E-07
37.50	0.49	2.86E-07
37.60	0.49	2.90E-07
37.70	0.44	2.59E-07
37.80	0.47	2.74E-07
37.90	0.48	2.80E-07
38.00	0.43	2.56E-07
38.10	0.48	2.85E-07
38.20	0.48	2.80E-07
38.30	0.43	2.53E-07
38.40	0.42	2.47E-07
38.50	0.42	2.50E-07
38.60	0.46	2.69E-07
38.70	0.45	2.66E-07
38.80	0.44	2.61E-07
38.90	0.41	2.40E-07
39.00	0.40	2.38E-07
39.10	0.41	2.43E-07
39.20	0.45	2.62E-07
39.30	0.40	2.37E-07
39.40	0.36	2.11E-07
39.50	0.37	2.17E-07
39.60	0.29	1.71E-07
39.70	0.31	1.81E-07
39.77	0.40	2.38E-07
39.87	0.31	1.81E-07
39.97	0.30	1.77E-07
40.07	0.28	1.67E-07
40.17	0.26	1.53E-07
40.27	0.26	1.51E-07
40.37	0.26	1.51E-07

Mean	1.98E-07
Count	92
Confidence Level(95.0%)	7.50E-09

EPA-16D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)
37.17	0.38	2.26E-07
37.27	0.35	2.08E-07
37.37	0.35	2.04E-07
37.47	0.32	1.88E-07
37.57	0.33	1.97E-07
37.67	0.31	1.84E-07
37.77	0.37	2.15E-07
37.87	0.36	2.12E-07
37.97	0.34	1.97E-07
38.07	0.41	2.39E-07
38.17	0.37	2.19E-07
38.27	0.31	1.84E-07
38.37	0.34	2.00E-07
38.47	0.37	2.16E-07
38.57	0.34	1.97E-07
38.67	0.36	2.10E-07
38.77	0.34	2.02E-07
38.87	0.38	2.24E-07
38.97	0.39	2.31E-07
39.07	0.41	2.39E-07
39.17	0.41	2.43E-07
39.27	0.40	2.35E-07
39.37	0.40	2.36E-07
39.46	0.37	2.17E-07
39.56	0.41	2.41E-07
39.66	0.43	2.54E-07
39.76	0.45	2.63E-07
39.86	0.41	2.39E-07
39.96	0.37	2.16E-07
40.06	0.40	2.33E-07
40.16	0.35	2.06E-07
40.26	0.42	2.46E-07
40.36	0.39	2.30E-07
40.46	0.33	1.91E-07
40.56	0.31	1.79E-07
40.66	0.31	1.80E-07
40.76	0.28	1.65E-07
40.86	0.30	1.76E-07
40.96	0.29	1.72E-07
41.06	0.29	1.72E-07
41.16	0.34	2.00E-07
41.26	0.31	1.82E-07
41.36	0.33	1.94E-07
41.46	0.36	2.14E-07
41.56	0.34	2.02E-07
41.66	0.34	1.97E-07
41.76	0.37	2.19E-07
41.86	0.36	2.09E-07

EPA-19S-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)

EPA-21D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc 10e-3 SI units	Mag Susc (m3/kg)

FORMER HOPEWELL PRECISION SITE, HOPEWELL JUNCTION, NEW YORK

EPA-10D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)
41.94	0.65	3.85E-07
42.04	0.65	3.82E-07
42.14	0.67	3.95E-07
42.24	0.63	3.70E-07
42.34	0.65	3.85E-07
42.44	0.61	3.58E-07
42.54	0.63	3.68E-07
42.64	0.64	3.74E-07
42.74	0.65	3.81E-07
42.84	0.62	3.64E-07
42.94	0.61	3.61E-07
43.04	0.66	3.88E-07
43.14	0.67	3.92E-07
43.24	0.60	3.56E-07
43.34	0.64	3.74E-07
43.44	0.64	3.77E-07
43.54	0.73	4.27E-07
43.64	0.70	4.11E-07
43.74	0.68	3.99E-07
43.84	0.73	4.28E-07
43.94	0.71	4.18E-07
44.04	0.76	4.46E-07
44.14	0.78	4.59E-07
44.24	0.81	4.74E-07
44.34	0.79	4.66E-07
44.44	0.77	4.55E-07
44.535	0.72	4.23E-07
44.635	0.73	4.31E-07
44.735	0.73	4.29E-07
44.835	0.68	4.03E-07
44.93	0.75	4.39E-07
45.13	0.68	4.02E-07
45.23	0.67	3.92E-07
45.33	0.72	4.24E-07
45.43	0.73	4.28E-07
45.53	0.71	4.17E-07
45.63	0.76	4.46E-07
45.73	0.68	3.97E-07
45.83	0.69	4.05E-07
45.93	0.74	4.34E-07
46.03	0.72	4.23E-07
46.13	0.69	4.07E-07
46.23	0.65	3.81E-07
46.33	0.64	3.76E-07
46.43	0.61	3.56E-07
46.53	0.54	3.20E-07
46.63	0.52	3.04E-07
46.73	0.47	2.74E-07

EPA-12D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)
41.94	0.14	8.29E-08
42.04	0.15	8.67E-08
42.14	0.15	8.91E-08
42.24	0.16	9.22E-08
42.34	0.13	7.61E-08
42.44	0.14	8.32E-08
42.54	0.16	9.56E-08
42.64	0.15	8.77E-08
42.74	0.16	9.15E-08
42.84	0.18	1.05E-07
42.94	0.09	5.17E-08
	Mean	1.67E-07
	Count	224
	Confidence Level(95.0%)	8.99E-09

EPA-15D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)

EPA-16D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)
41.96	0.39	2.27E-07
42.06	0.36	2.14E-07
42.16	0.38	2.25E-07
42.26	0.39	2.29E-07
42.36	0.41	2.43E-07
42.46	0.42	2.45E-07
42.56	0.43	2.51E-07
42.66	0.42	2.50E-07
42.75	0.46	2.73E-07
42.85	0.48	2.85E-07
42.95	0.42	2.46E-07
43.05	0.44	2.60E-07
43.25	0.44	2.59E-07
43.35	0.44	2.61E-07
43.45	0.44	2.57E-07
43.55	0.46	2.69E-07
43.65	0.43	2.51E-07
43.75	0.43	2.55E-07
43.85	0.42	2.45E-07
43.95	0.46	2.71E-07
44.05	0.46	2.68E-07
44.15	0.40	2.37E-07
44.25	0.49	2.87E-07
44.35	0.47	2.75E-07
44.45	0.46	2.73E-07
44.55	0.48	2.80E-07
44.65	0.47	2.78E-07
44.75	0.49	2.87E-07
44.85	0.43	2.55E-07
44.95	0.44	2.60E-07
45.05	0.44	2.57E-07
45.15	0.42	2.46E-07
45.25	0.42	2.46E-07
45.35	0.36	2.13E-07
45.45	0.38	2.22E-07
45.55	0.38	2.24E-07
45.65	0.39	2.28E-07
45.75	0.37	2.16E-07
45.85	0.35	2.09E-07
45.95	0.40	2.37E-07
46.05	0.43	2.51E-07
46.14	0.41	2.43E-07
46.24	0.35	2.07E-07
46.34	0.39	2.32E-07
46.44	0.42	2.46E-07
46.54	0.38	2.26E-07
46.64	0.42	2.45E-07
46.74	0.42	2.49E-07

EPA-19S-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)

EPA-21D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc 10e-3 SI units	Mag Susc (m3/kg)

FORMER HOPEWELL PRECISION SITE, HOPEWELL JUNCTION, NEW YORK

EPA-10D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)
46.83	0.44	2.60E-07
46.93	0.45	2.63E-07
47.03	0.43	2.54E-07
47.13	0.40	2.34E-07
47.23	0.44	2.57E-07
47.33	0.40	2.36E-07
47.43	0.43	2.54E-07
47.53	0.48	2.83E-07
47.63	0.56	3.28E-07
47.73	0.60	3.51E-07
47.83	0.58	3.39E-07
47.925	0.59	3.50E-07
48.025	0.62	3.63E-07
48.125	0.66	3.86E-07
48.22	0.69	4.06E-07
48.32	0.68	4.01E-07
48.42	0.65	3.80E-07
48.52	0.66	3.88E-07
48.62	0.68	4.01E-07
48.72	0.70	4.15E-07
48.82	0.75	4.41E-07
48.92	0.76	4.46E-07
49.02	0.72	4.22E-07
49.12	0.75	4.40E-07
49.22	0.75	4.43E-07
49.32	0.70	4.10E-07
49.42	0.74	4.33E-07
49.52	0.69	4.05E-07
49.62	0.64	3.75E-07
49.72	0.68	3.98E-07
49.82	0.62	3.64E-07
49.92	0.61	3.57E-07
50.02	0.59	3.46E-07
50.12	0.54	3.16E-07
50.22	0.52	3.06E-07
50.32	0.48	2.84E-07
50.42	0.41	2.40E-07
50.52	0.39	2.30E-07
50.62	0.36	2.11E-07
50.72	0.35	2.05E-07
50.82	0.36	2.11E-07
50.92	0.31	1.85E-07
51.02	0.36	2.10E-07
51.12	0.36	2.15E-07
51.215	0.39	2.30E-07
51.315	0.39	2.28E-07
51.415	0.42	2.46E-07
51.51	0.41	2.42E-07

EPA-12D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)

EPA-15D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)

EPA-16D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)
46.84	0.42	2.50E-07
46.94	0.39	2.28E-07
47.04	0.41	2.42E-07
47.14	0.42	2.49E-07
47.24	0.41	2.41E-07
47.34	0.40	2.34E-07
47.44	0.42	2.45E-07
47.54	0.42	2.46E-07
47.64	0.44	2.58E-07
47.74	0.39	2.28E-07
47.84	0.45	2.62E-07
47.94	0.48	2.80E-07

Mean	2.84E-07
Count	273
Confidence Level(95.0%)	6.1E-09

EPA-19S-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc (10e-3 SI units)	Mag Susc (m3/kg)

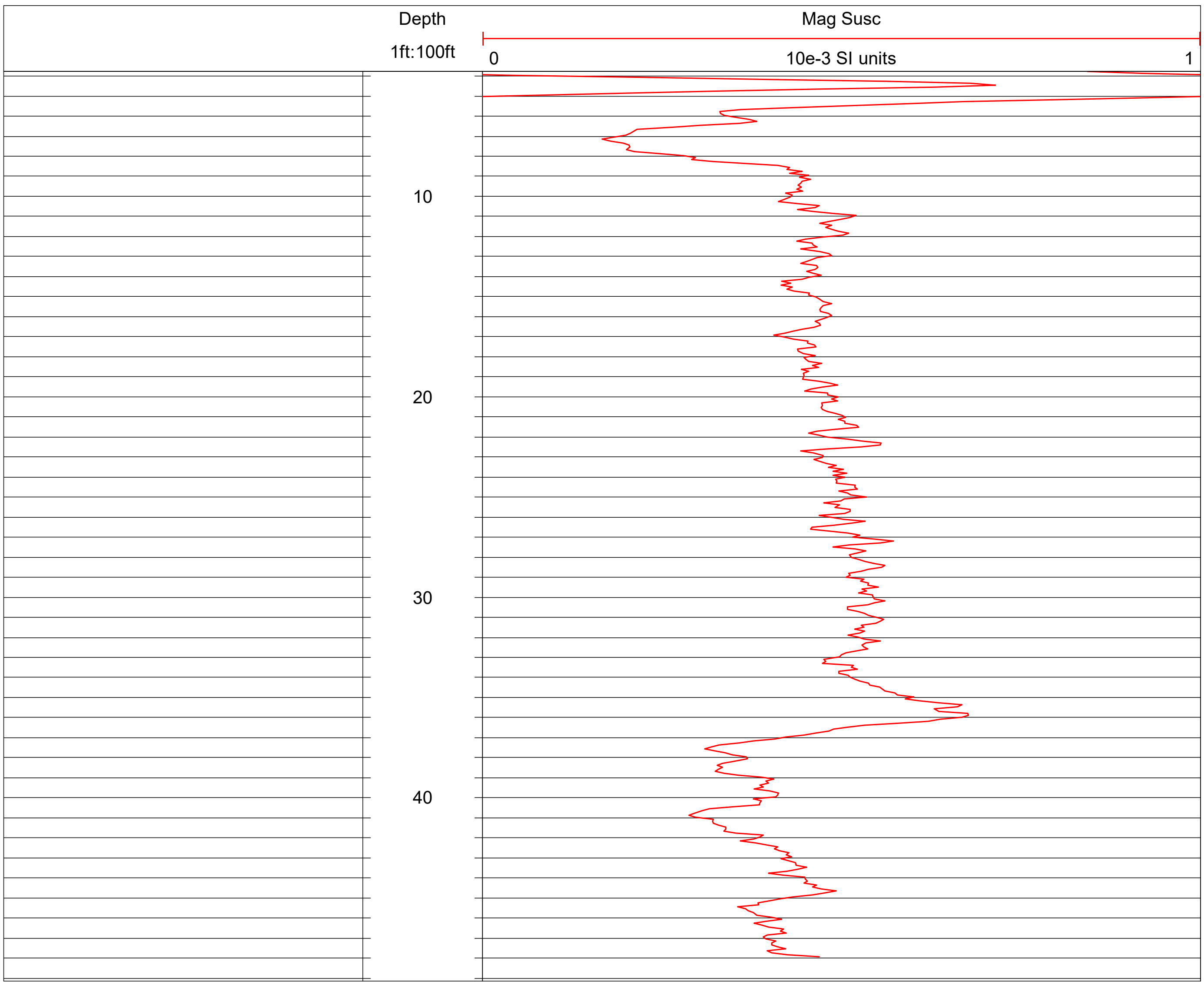
EPA-21D-Up/Down Average Sonde Data

Depth (ft bgs)	Mag Susc 10e-3 SI units	Mag Susc (m3/kg)

EPA-10D-Up/Down Average Sonde Data			EPA-12D-Up/Down Average Sonde Data			EPA-15D-Up/Down Average Sonde Data			EPA-16D-Up/Down Average Sonde Data			EPA-19S-Up/Down Average Sonde Data			EPA-21D-Up/Down Average Sonde Data		
Depth (ft bgs)	**Mag Susc** (10e-3 SI units)	**Mag Susc** (m3/kg)	**Depth** (ft bgs)	**Mag Susc** (10e-3 SI units)	**Mag Susc** (m3/kg)	**Depth** (ft bgs)	**Mag Susc** (10e-3 SI units)	**Mag Susc** (m3/kg)	**Depth** (ft bgs)	**Mag Susc** (10e-3 SI units)	**Mag Susc** (m3/kg)	**Depth** (ft bgs)	**Mag Susc** (10e-3 SI units)	**Mag Susc** (m3/kg)	**Depth** (ft bgs)	**Mag Susc** 10e-3 SI units	**Mag Susc** (m3/kg)
51.61	0.46	2.68E-07															
51.71	0.50	2.92E-07															
51.81	0.49	2.90E-07															
	Mean	3.47E-07															
	Count	258															
Confidence Level(95.0%)		8.47E-09															

PROJECT	ESTCP 201584
LOCATION	Hopewell Junction, NY
WELL	EPA-16D - Down
LOGGER	Todd Wiedemeier
DATE	June 8, 2016

TOOL	HMA-453-S
CALIBRATION DATE/TIME	6/8/16 -- 11:36
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	Zero = 70.532, 5E-3 = 1105.86
REMARKS	



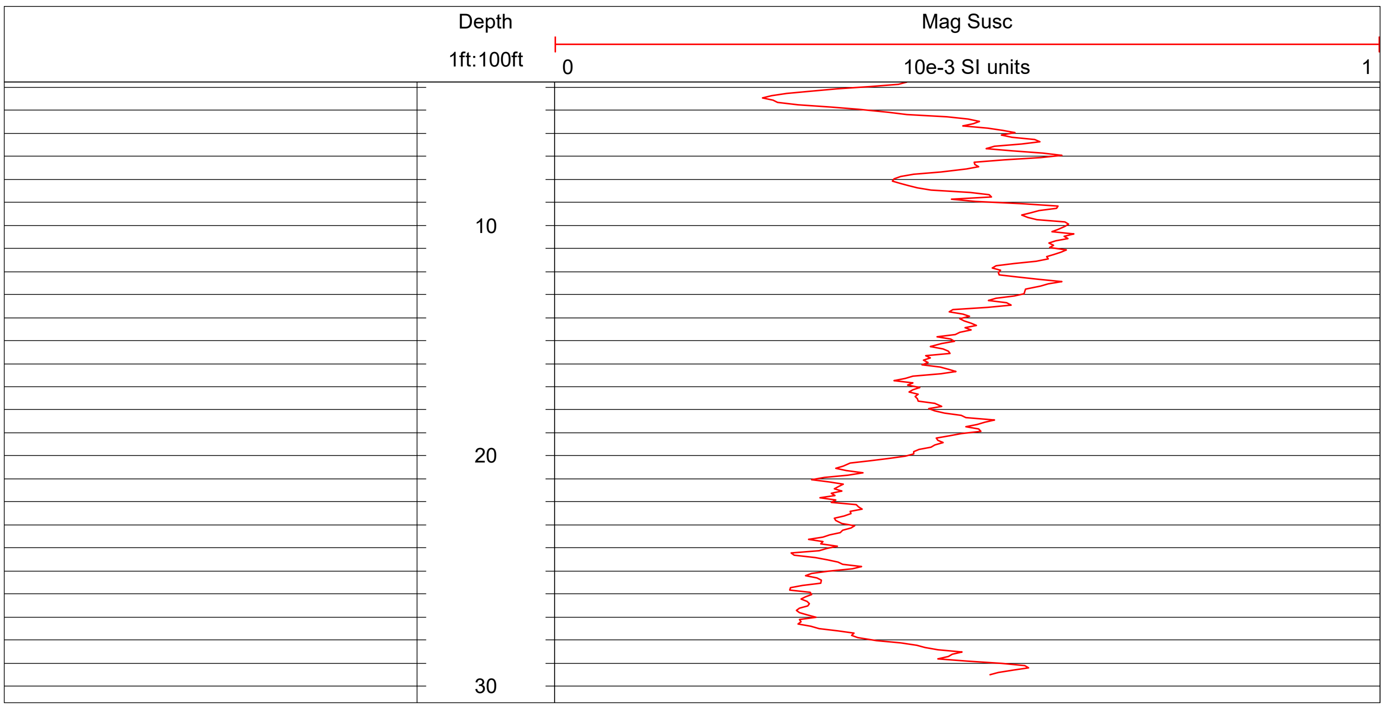
PROJECT	ESTCP 201584
LOCATION	Hopewell Junction, NY
WELL	EPA-16D -- Up
LOGGER	Todd Wiedemeier
DATE	June 8, 2016

TOOL	HMA-453-S
CALIBRATION DATE/TIME	6/8/16
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	Zero = 70.53, 5E-3 = 1105.86 cps
REMARKS	

WIEDEMEIER
& ASSOCIATES

PROJECT	ESTCP 201584
LOCATION	Hopewell Junction, NY
WELL	EPA-16S -- Down
LOGGER	Todd Wiedemeier
DATE	June 8, 2016

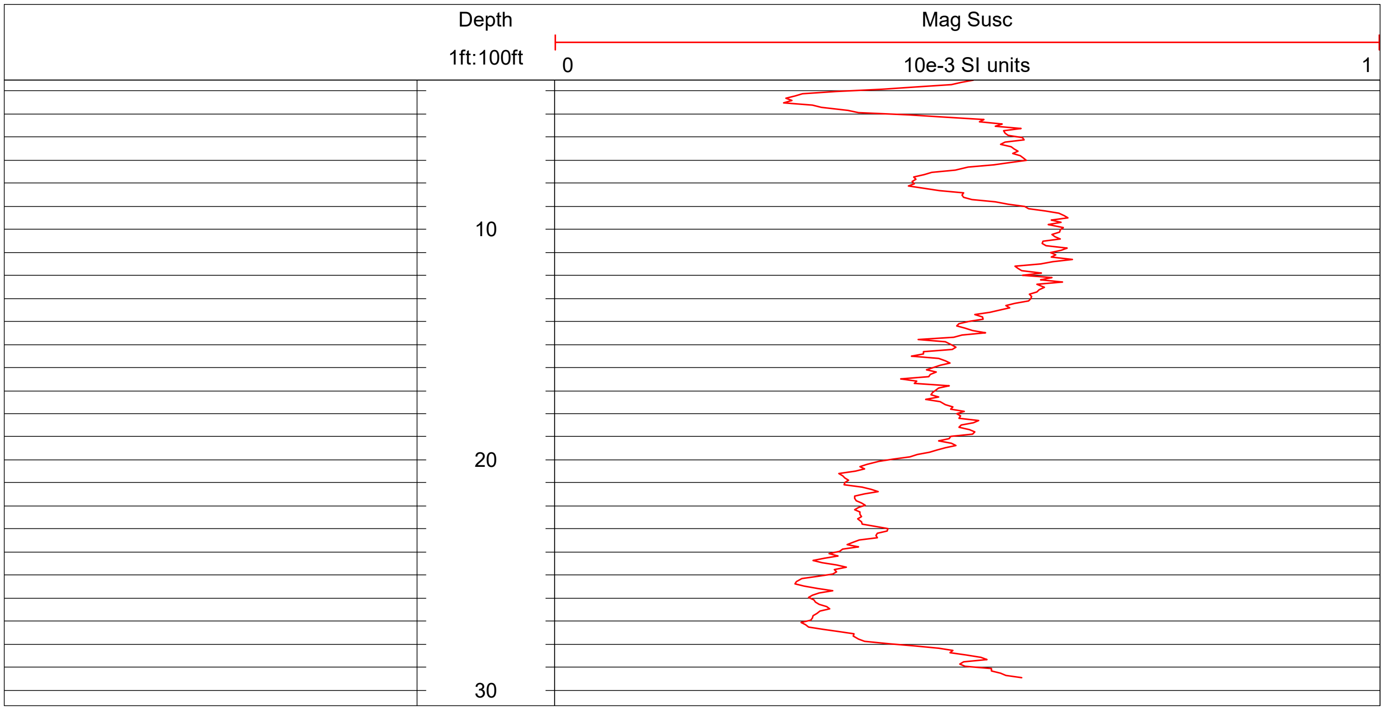
TOOL	HMA-453-S
CALIBRATION DATE/TIME	6/8/16 -- 11:36
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	Zero = 70.53, 5E-3 = 1105.86
REMARKS	



WIEDEMEIER & ASSOCIATES

PROJECT	ESTCP 201584
LOCATION	Hopewell Junction, NY
WELL	EPA-16S -- Up
LOGGER	Todd Wiedemeier
DATE	June 8, 2016

TOOL	HMA-453-S
CALIBRATION DATE/TIME	6/8/16 -- 11:36
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	Zero = 70.53, 5E-3 = 1105.86 cps
REMARKS	



WIEDEMEIER & ASSOCIATES

PROJECT	ESTCP 201584
LOCATION	Hopewell Junction, NY
WELL	EPA-15D -- Down
LOGGER	Todd Wiedemeier
DATE	June 8, 2016

TOOL	HMA-453-S
CALIBRATION DATE/TIME	6/8/16 -- 15:52
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	Zero = 75.065, 5E-3 = 1137.69 cps
REMARKS	

PROJECT ESTCP 201584

LOCATION Hopewell Junction, NY

WELL EPA-15D -- Up

LOGGER Todd Wiedemeier

DATE June 8, 2016

TOOL HMA-453-S

CALIBRATION DATE/TIME 6/8/16 -- 15:52

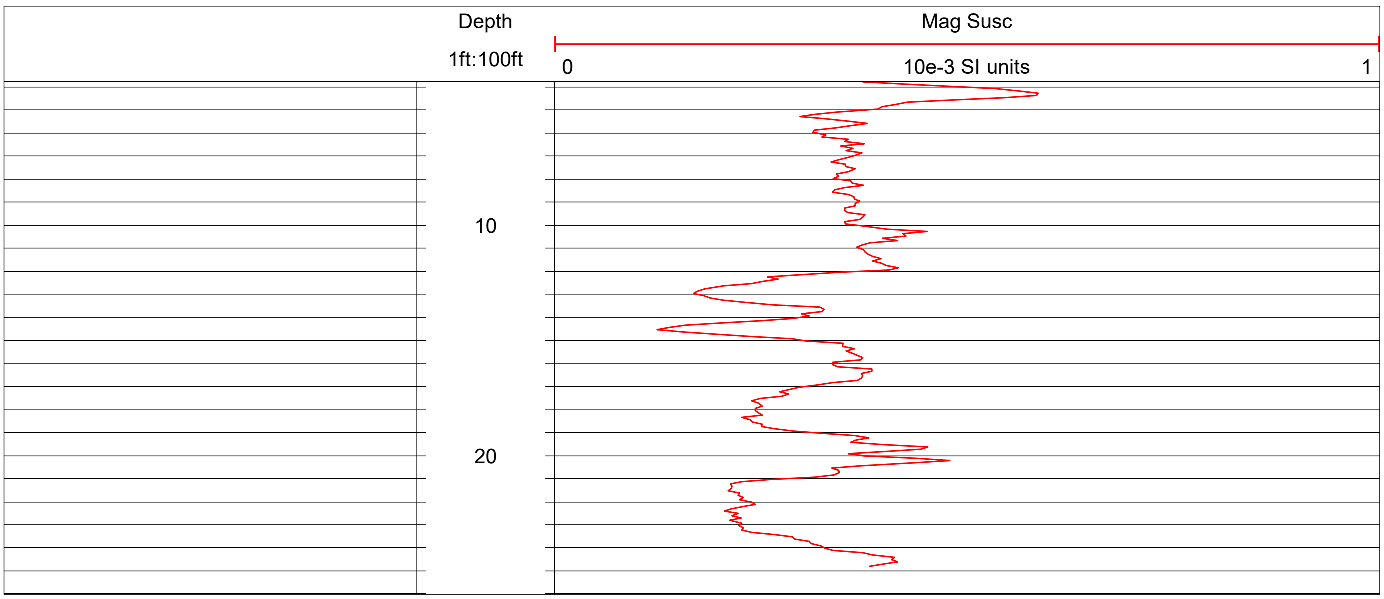
CALIBRATION STANDARDS 0 and 5E-3 SI Units

CALIBRATION RESULTS Zero = 75.065, 1137.69 cps

REMARKS

WIEDEMEIER & ASSOCIATES

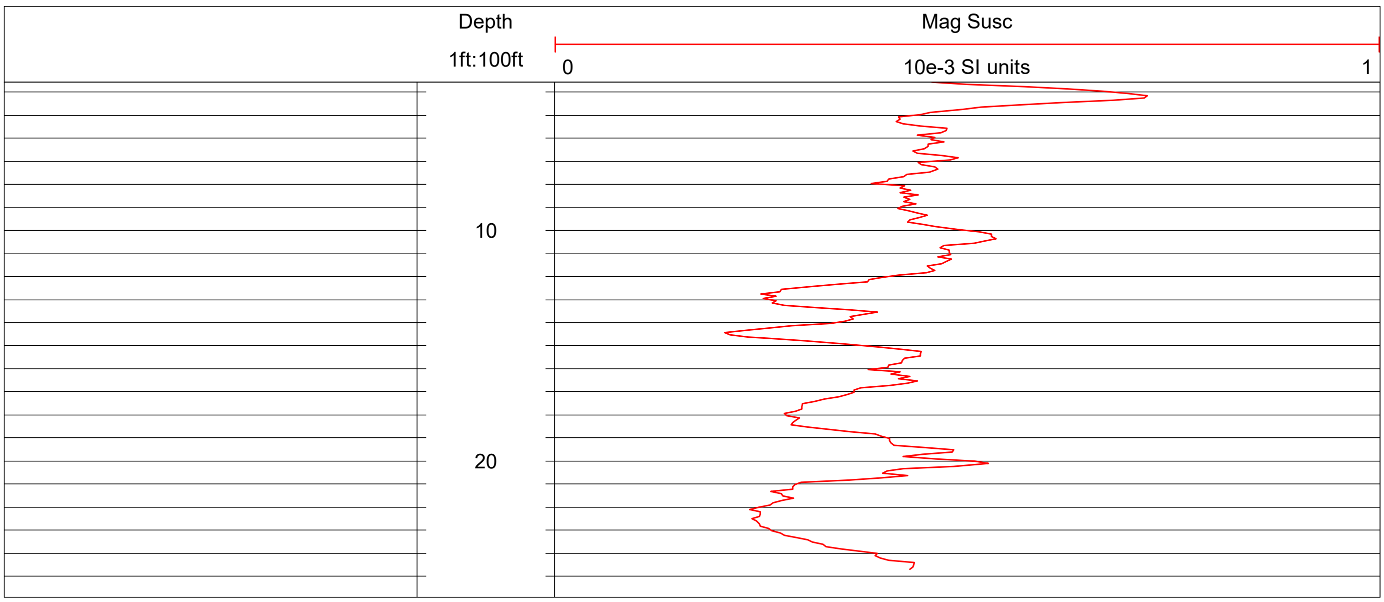
PROJECT	ESTCP 201584	TOOL	HMA-453-S
LOCATION	Hopewell Junction, NY	CALIBRATION DATE/TIME	6/8/16 -- 17:40
WELL	EPA-21S -- Down	CALIBRATION STANDARDS	0 and 5E-3 SI Units
LOGGER	Todd Wiedemeier	CALIBRATION RESULTS	Zero = 69.75, 5E-3 = 1140.53 cps
DATE	June 8, 2016	REMARKS	



WIEDEMEIER & ASSOCIATES

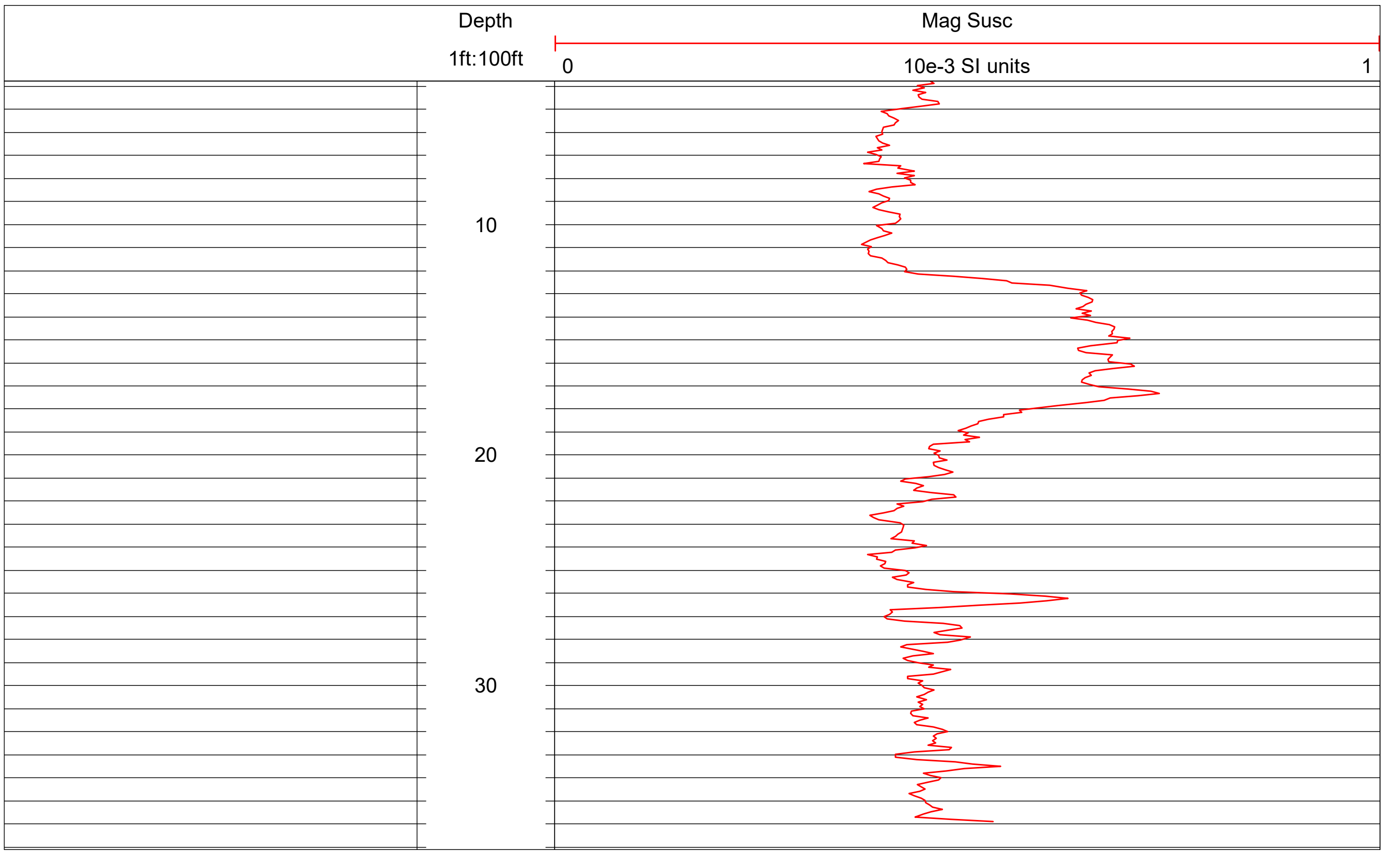
PROJECT	ESTCP 201584
LOCATION	Hopewell Junction, NY
WELL	EPA-21S -- Up
LOGGER	Todd Wiedemeier
DATE	June 8, 2016

TOOL	HMA-453-S
CALIBRATION DATE/TIME	6/8/16 -- 17:40
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	Zero = 69.75, 5E-3 = 1140.53 cps
REMARKS	



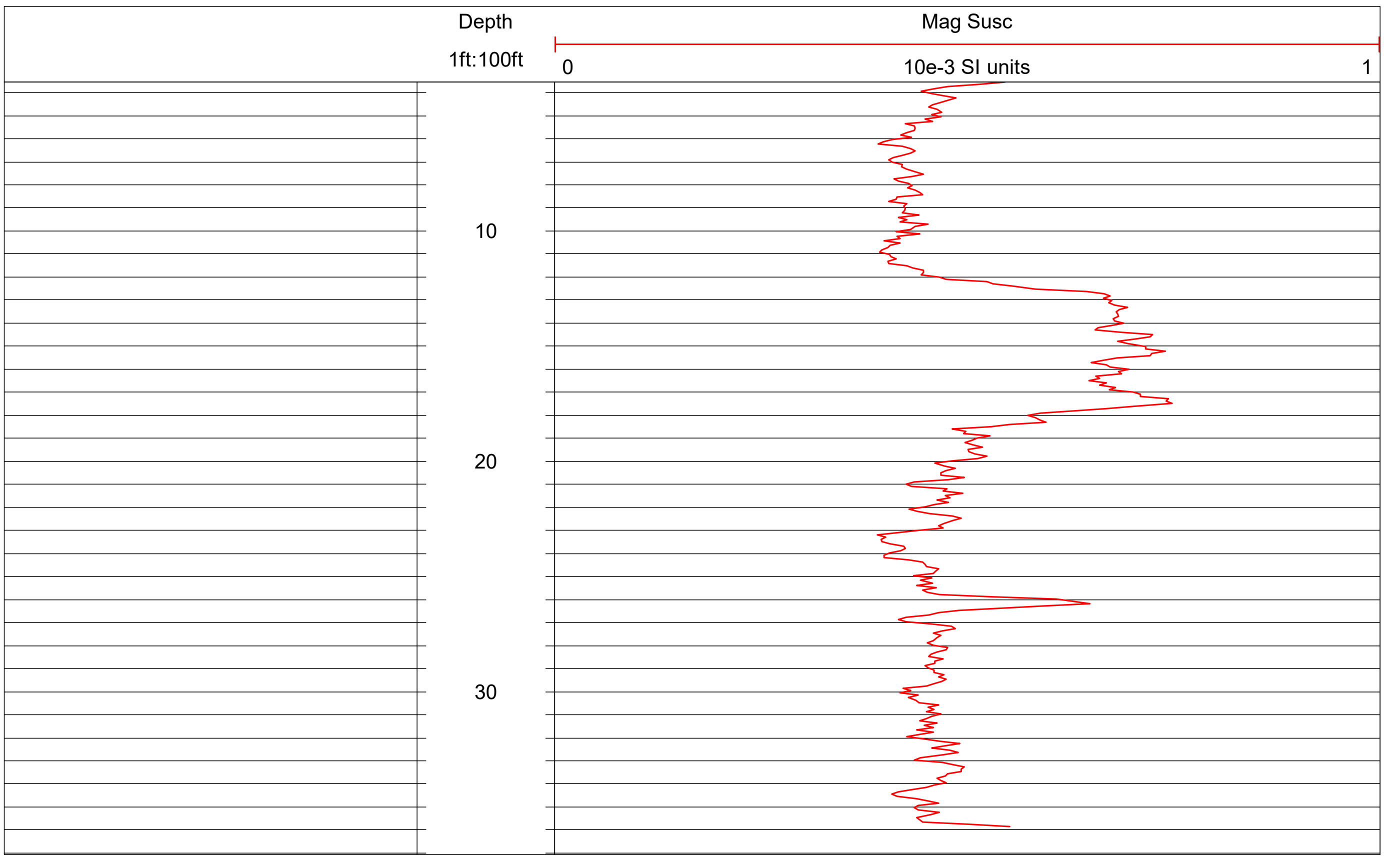
PROJECT	ESTCP 201584
LOCATION	Hopewell Junction, NY
WELL	EPA-21D -- Down
LOGGER	Todd Wiedemeier
DATE	June 8, 2016

TOOL	HMA-453-S
CALIBRATION DATE/TIME	6/8/16 -- 17:40
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	Zero = 69.75, 5E-3 = 1140.52 cps
REMARKS	



PROJECT	ESTCP 201584
LOCATION	Hopewell Junction, NY
WELL	EPA-21D -- Up
LOGGER	Todd Wiedemeier
DATE	June 8,2016

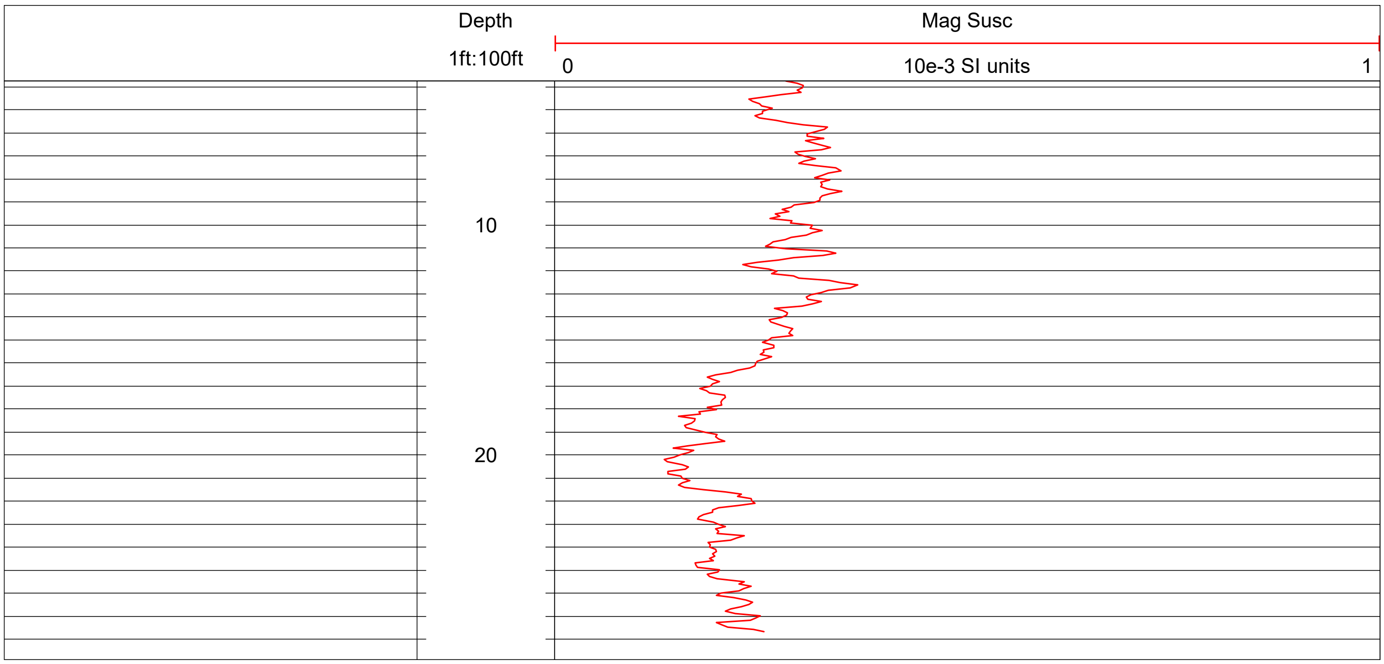
TOOL	HMA-453S
CALIBRATION DATE/TIME	6/8/16 -- 17:40
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	Zero = 69.75, 5E-3 = 1140.53 cps
REMARKS	



WIEDEMEIER & ASSOCIATES

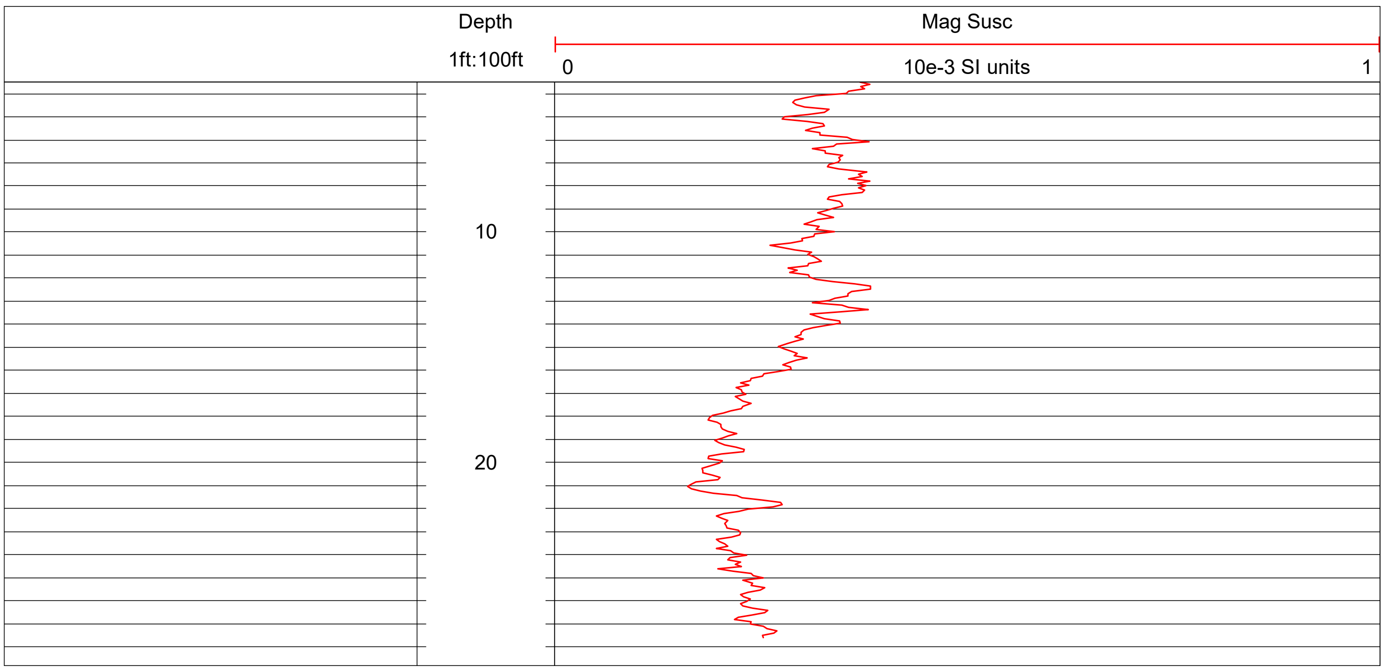
PROJECT	ESTCP 201584
LOCATION	Hopewell Junction, NY
WELL	EPA-12S Down
LOGGER	Todd Wiedemeier
DATE	June 9, 2016

TOOL	HMA-453-S
CALIBRATION DATE/TIME	6/9/16 -- 11:27
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	Zero = 97.5, 5E-3 = 1148.78 cps
REMARKS	



PROJECT	ESTCP 201584
LOCATION	Hopewell Junction, NY
WELL	EPA-12S Up
LOGGER	Todd Wiedemeier
DATE	June 9, 2016

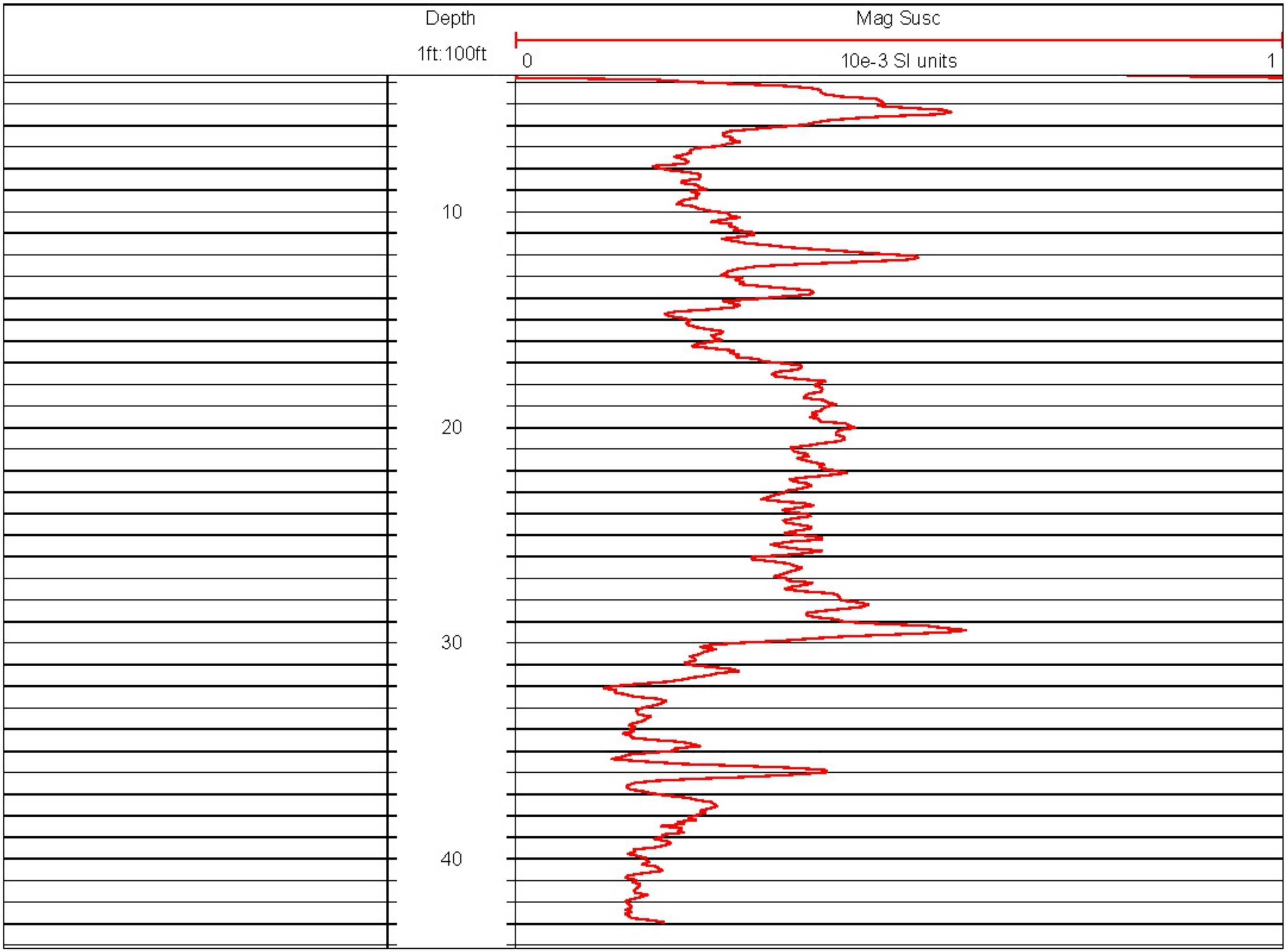
TOOL	HMA-453-S
CALIBRATION DATE/TIME	6/9/16 -- 11:27
CALIBRATION STANDARDS	0 and 5E-3
CALIBRATION RESULTS	Zero = 97.5, 5E-3 = 1148.78
REMARKS	



WIEDEMEIER & ASSOCIATES

PROJECT	ESTCP 201584
LOCATION	Hopewell Junction
WELL	EPA-12D Down
LOGGER	Todd Wiedemeier
DATE	6/9/2016

TOOL	HMA-453-S
CALIBRATION DATE/TIME	6/9//16 -- 11:27
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	Zero = 97.5, 5E-3 = 1148.78 cps
REMARKS	



WIEDEMEIER & ASSOCIATES

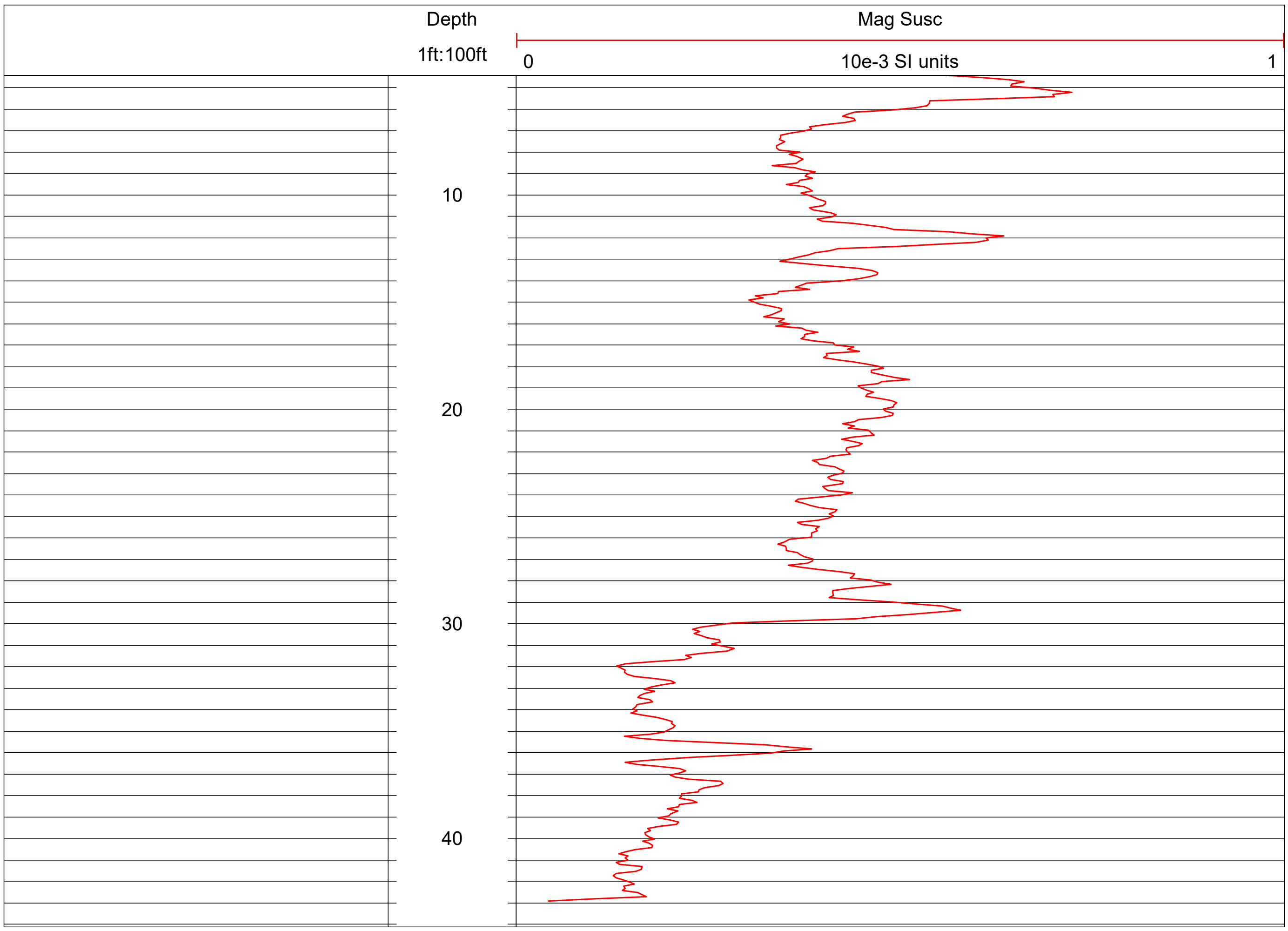
PROJECT	ESTCP 201584
LOCATION	Hopewell Junction
WELL	EPA-12D Down
LOGGER	Todd Wiedemeier
DATE	6/9/2016

TOOL	HMA-453-S
CALIBRATION DATE/TIME	6/9//16 -- 11:27
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	Zero = 97.5, 5E-3 = 1148.78 cps
REMARKS	

WIEDEMEIER
& ASSOCIATES

PROJECT	ESTCP 201584
LOCATION	Hopewell Junction, NY
WELL	EPA-12D - Up
LOGGER	Todd Wiedemeier
DATE	June 9, 2015

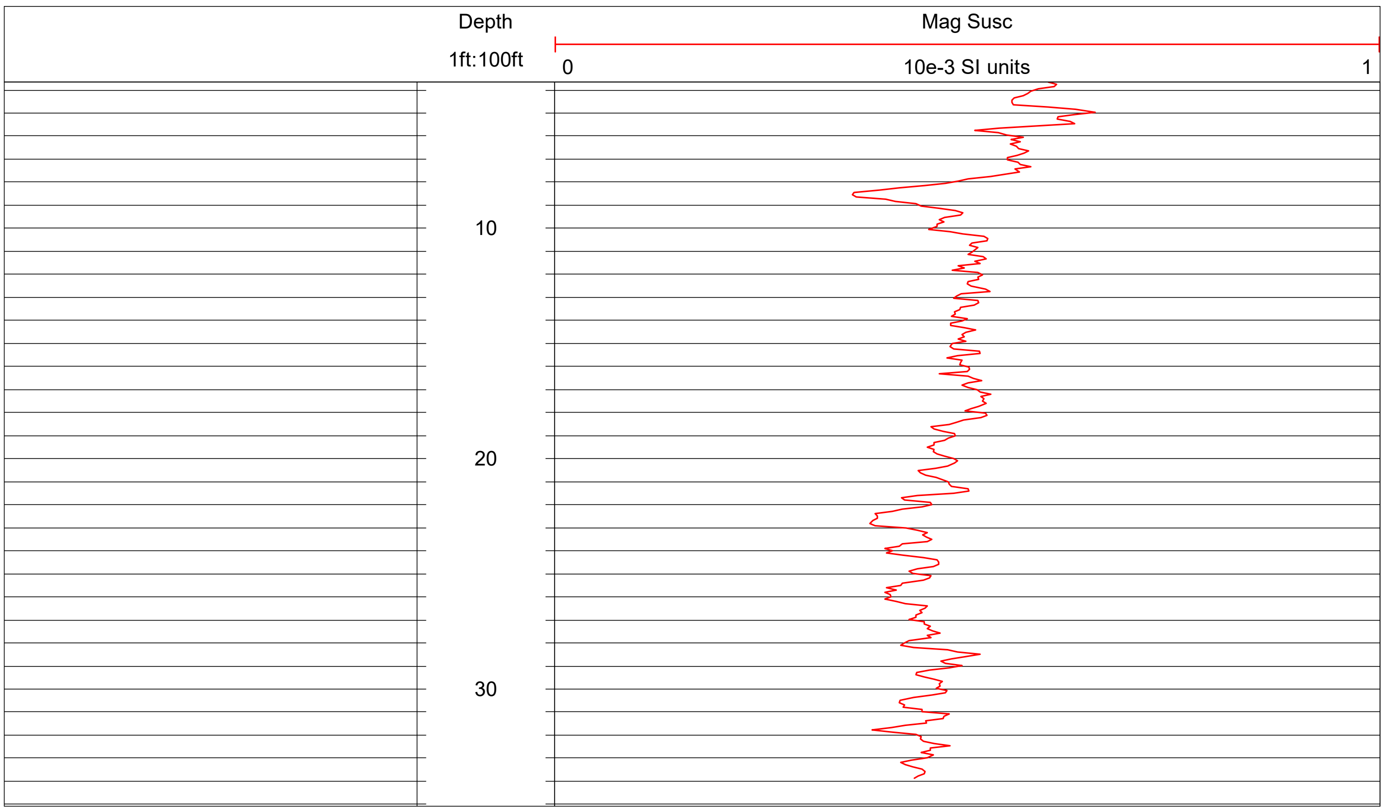
TOOL	HMA-453-S
CALIBRATION DATE/TIME	6/9/16 -- 11:27
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	Zero = 97.5, 5E-3 = 1148.78 cps
REMARKS	



WIEDEMEIER & ASSOCIATES

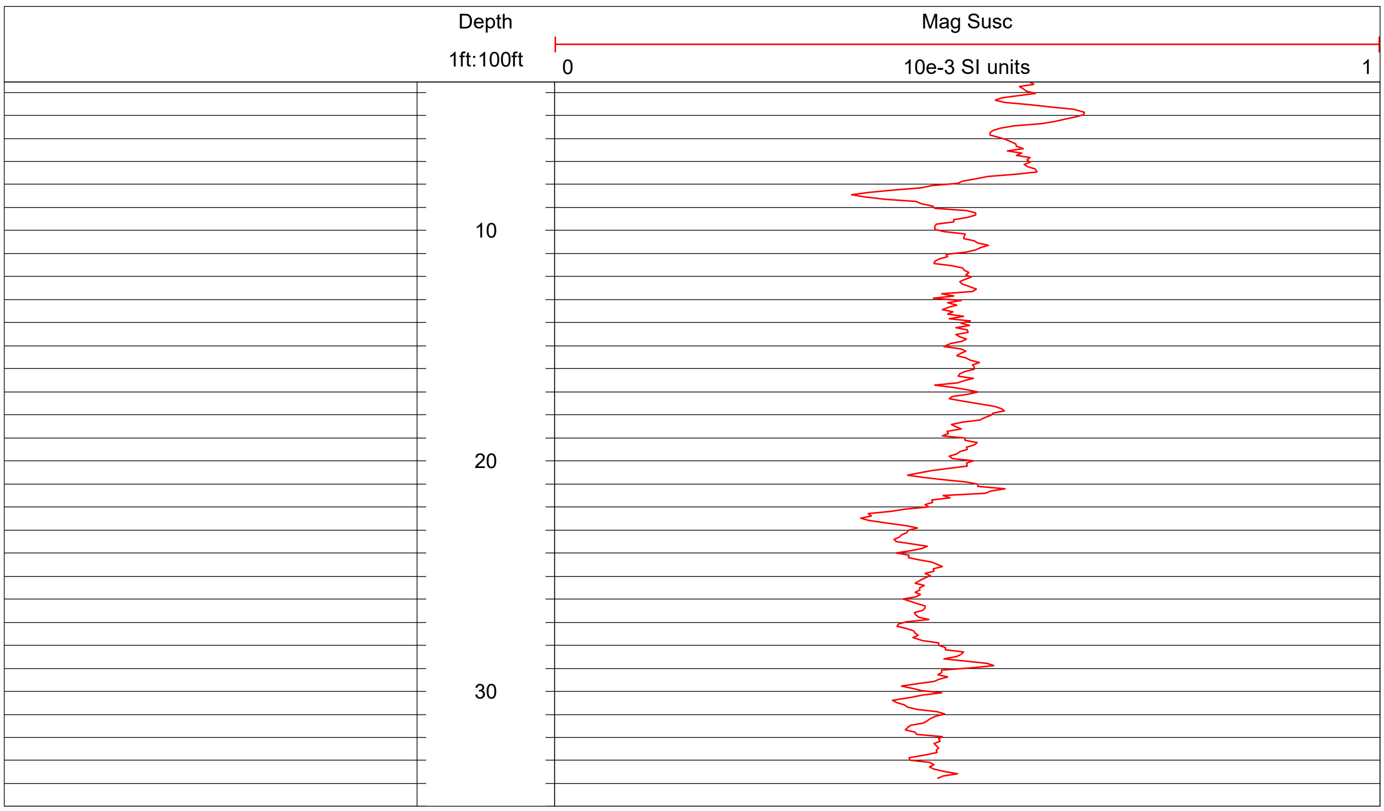
PROJECT	ESTCP 201584
LOCATION	Hopewell Junction, NY
WELL	EPA-10S - Down
LOGGER	Todd Wiedemeier
DATE	June 9, 2016

TOOL	HMA-453-S
CALIBRATION DATE/TIME	6/9/16 -- 15:16
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	Zero = 60.86, 5E-3 = 1151.1 cps
REMARKS	



PROJECT	ESTCP 201584
LOCATION	Hopewell Junction, NY
WELL	EPA-10S -- Up
LOGGER	Todd Wiedemeier
DATE	June 9, 2016

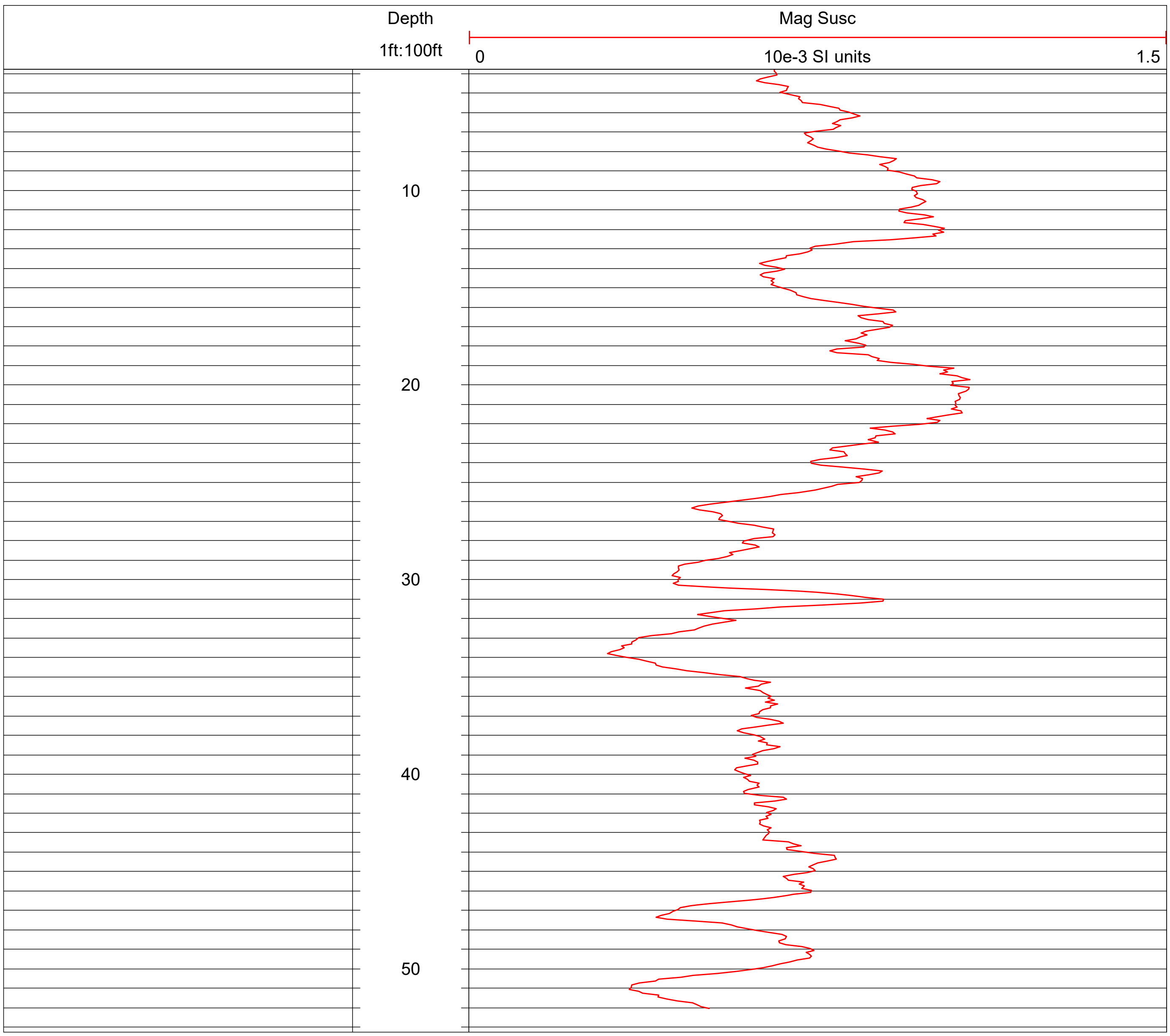
TOOL	HMA-453-S
CALIBRATION DATE/TIME	6/9/16 -- 15:16
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	Zero = 60.86, 1151.1 cps
REMARKS	



WIEDEMEIER & ASSOCIATES

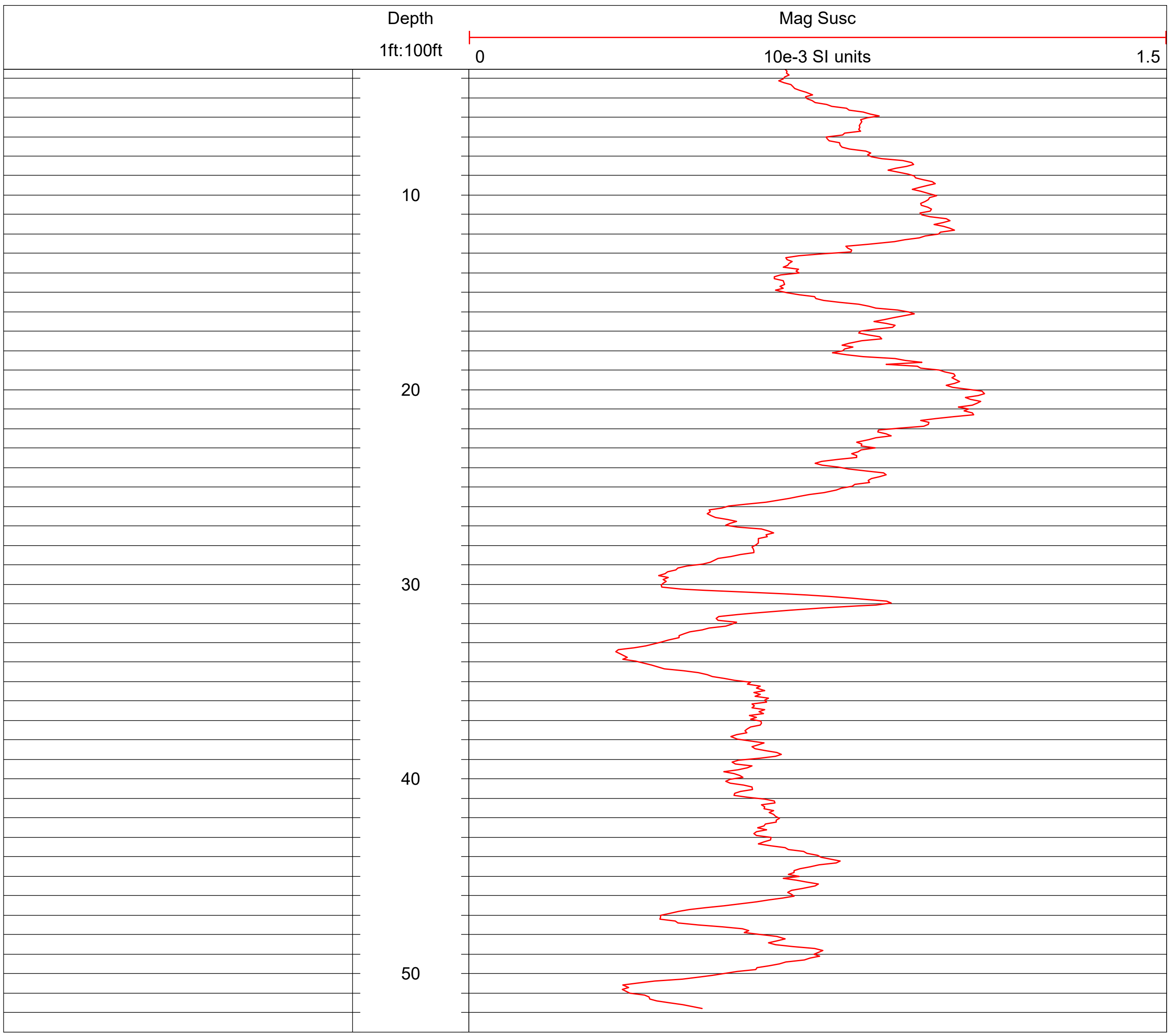
PROJECT	ESTCP 201584
LOCATION	Hopewell Junction, NY
WELL	EPA-10D - Down
LOGGER	Todd Wiedemeier
DATE	June 9, 2016

TOOL	HMW-453-S
CALIBRATION DATE/TIME	6/9/16 -- 15:16
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	Zero = 60.86, 5E-3 = 1151.1 cps
REMARKS	



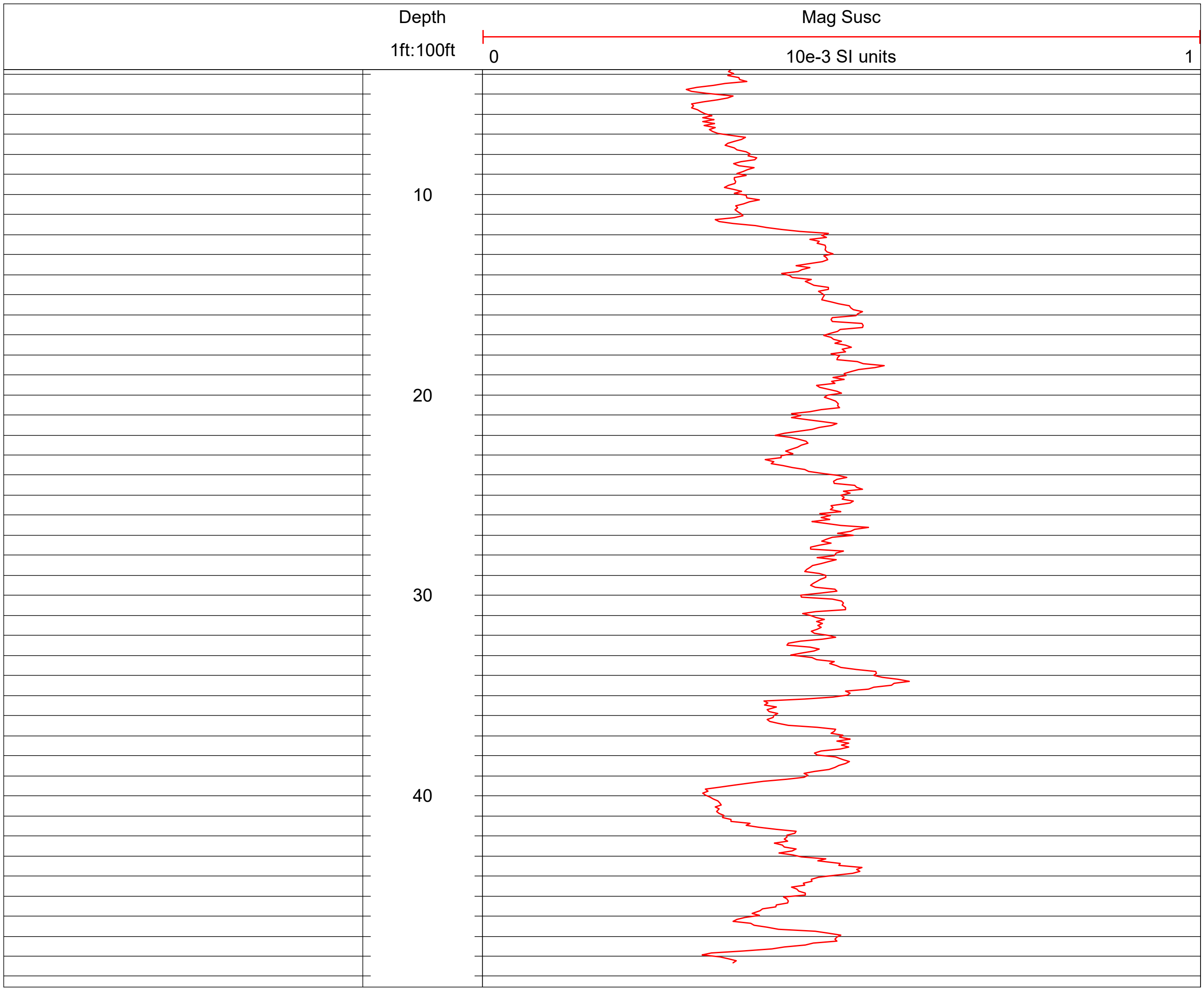
PROJECT	ESTCP 201584
LOCATION	Hopewell Junction, NY
WELL	EPA-10D -Up
LOGGER	Todd Wiedemeier
DATE	June 9, 2016

TOOL	Hma-453-S
CALIBRATION DATE/TIME	6/9/16 -- 15:16
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	Zero = 60.86, 5E-3 = 1151.1 cps
REMARKS	



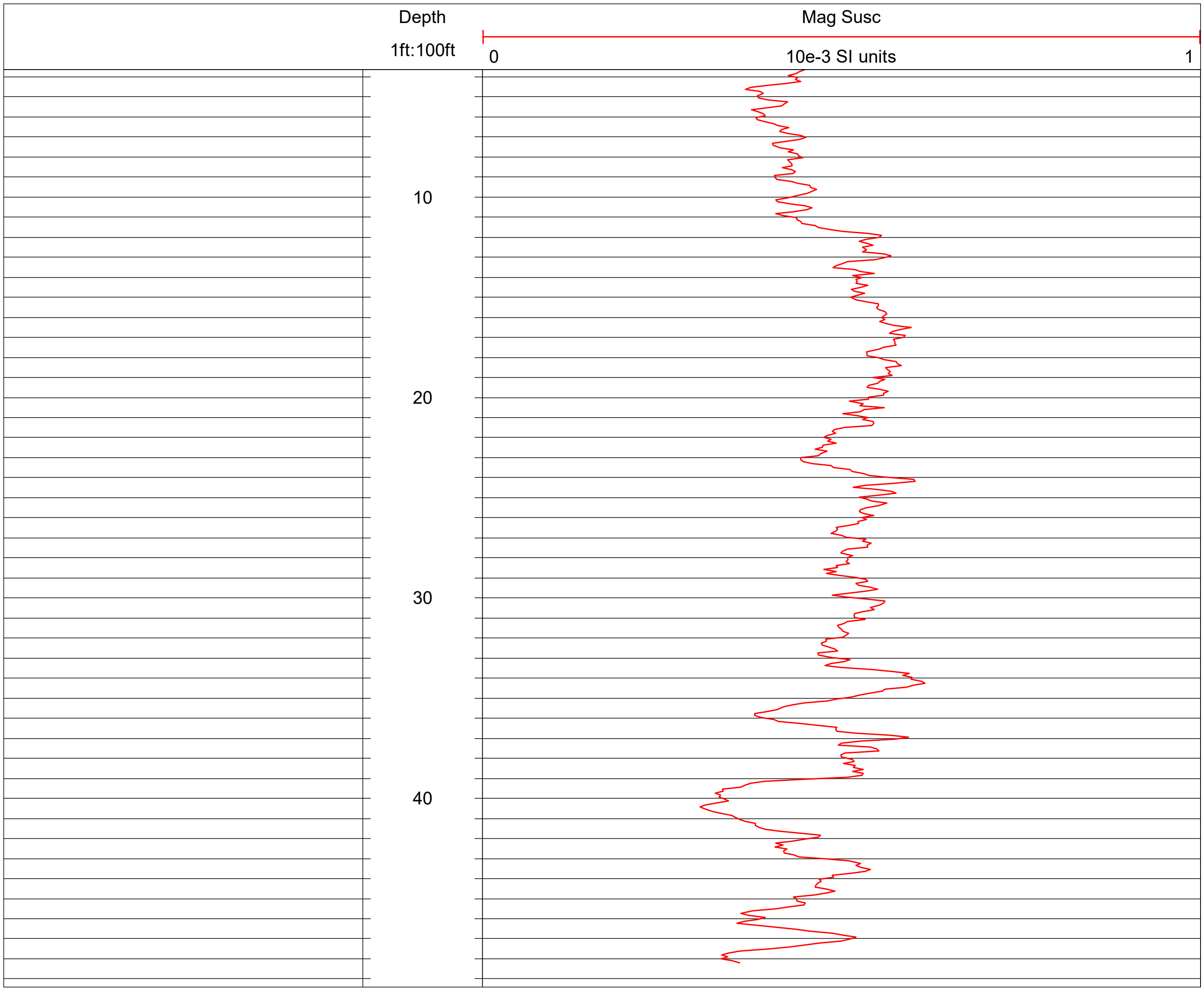
PROJECT	ESTCP 201584
LOCATION	Hopewell Junction, NY
WELL	EPA-19D -- Down
LOGGER	Todd Wiedemeier
DATE	June 10, 2016

TOOL	HMW-453-S
CALIBRATION DATE/TIME	
CALIBRATION STANDARDS	
CALIBRATION RESULTS	
REMARKS	



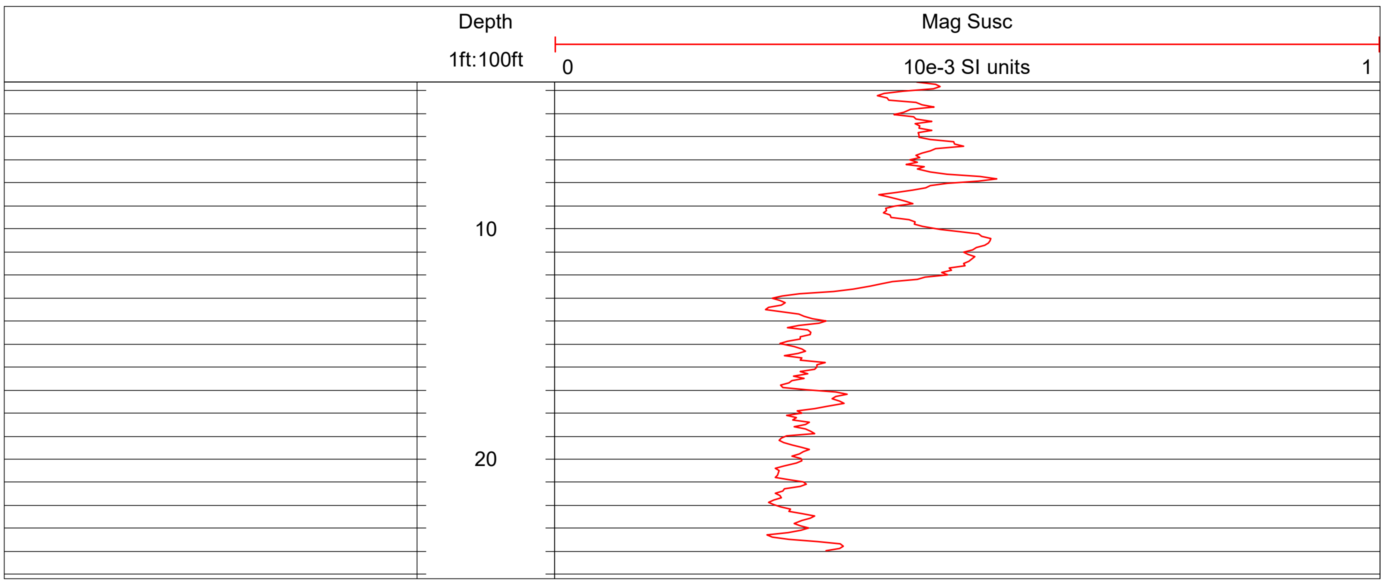
PROJECT	ESTCP 201584
LOCATION	Hopewell Junction, NY
WELL	EPA-19D -- Up
LOGGER	Todd Wiedemeier
DATE	June 10, 2016

TOOL	HMA-453-S
CALIBRATION DATE/TIME	6/10/16 -- 09:53
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	Zero = 65.7, 5E-3 = 1128.81 cps
REMARKS	



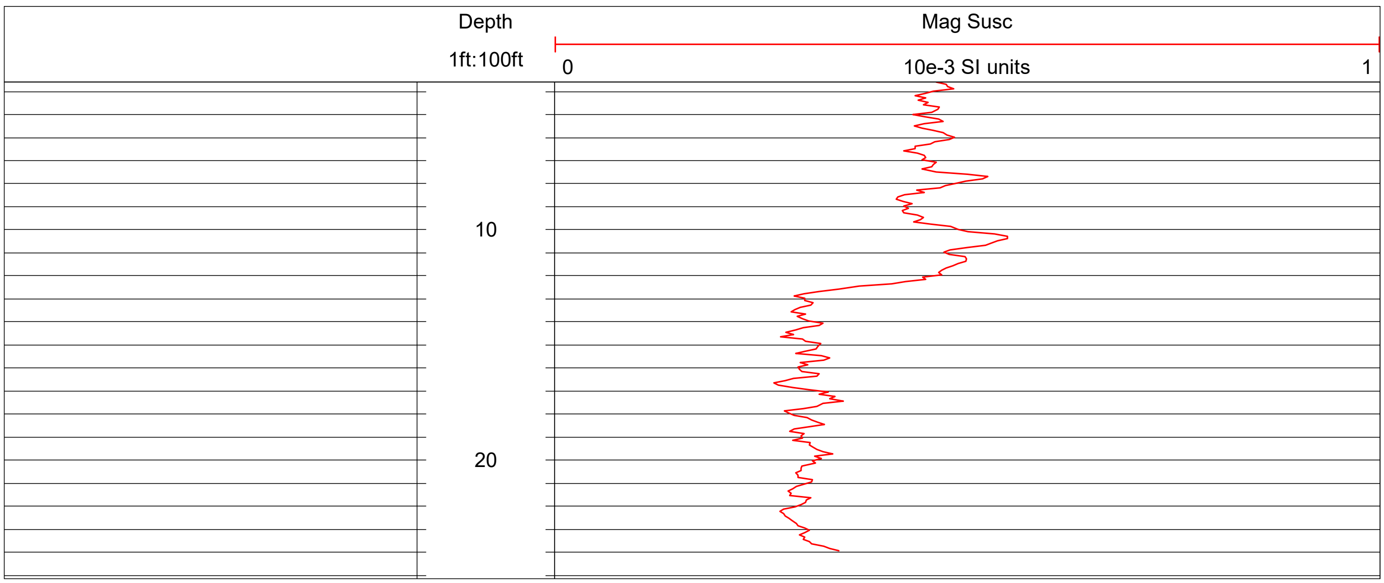
PROJECT	ESTCP 201584
LOCATION	Hopewell Junction, NY
WELL	EPA-19S -- Down
LOGGER	Todd Wiedemeier
DATE	June 10, 2016

TOOL	HMA-453-S
CALIBRATION DATE/TIME	6/10/16 -- 09:53
CALIBRATION STANDARDS	0 and 5E-3
CALIBRATION RESULTS	Zero = 65.7, 5E-3 = 1128.81 cps
REMARKS	



PROJECT	ESTCP 201584
LOCATION	Hopewell Junction, NY
WELL	EPA-19S -- Up
LOGGER	Todd Wiedemeier
DATE	June 10, 2016

TOOL	HMA-453-S
CALIBRATION DATE/TIME	6/10/16 -- 09:53
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	Zero = 65.7, 5E-3 = 1128.81 cps
REMARKS	



WIEDEMEIER & ASSOCIATES

PROJECT ESTCP 201584

LOCATION Hopewell Junction, NY

WELL EPA-8D - Down

LOGGER Todd Wiedemeier

DATE June 10, 2016

TOOL HMA-453-S

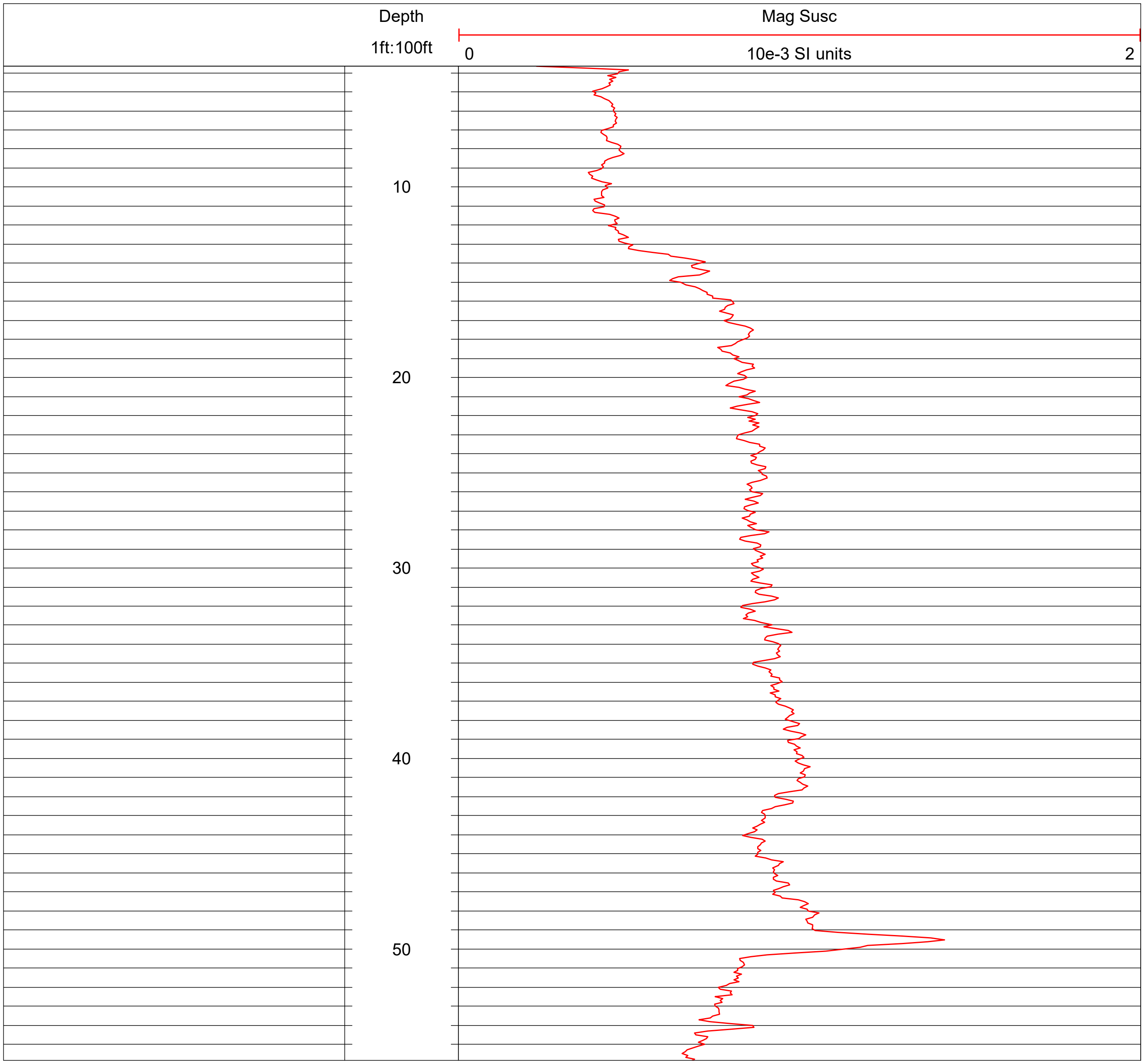
CALIBRATION DATE/TIME 6/10/16 -- 09:53

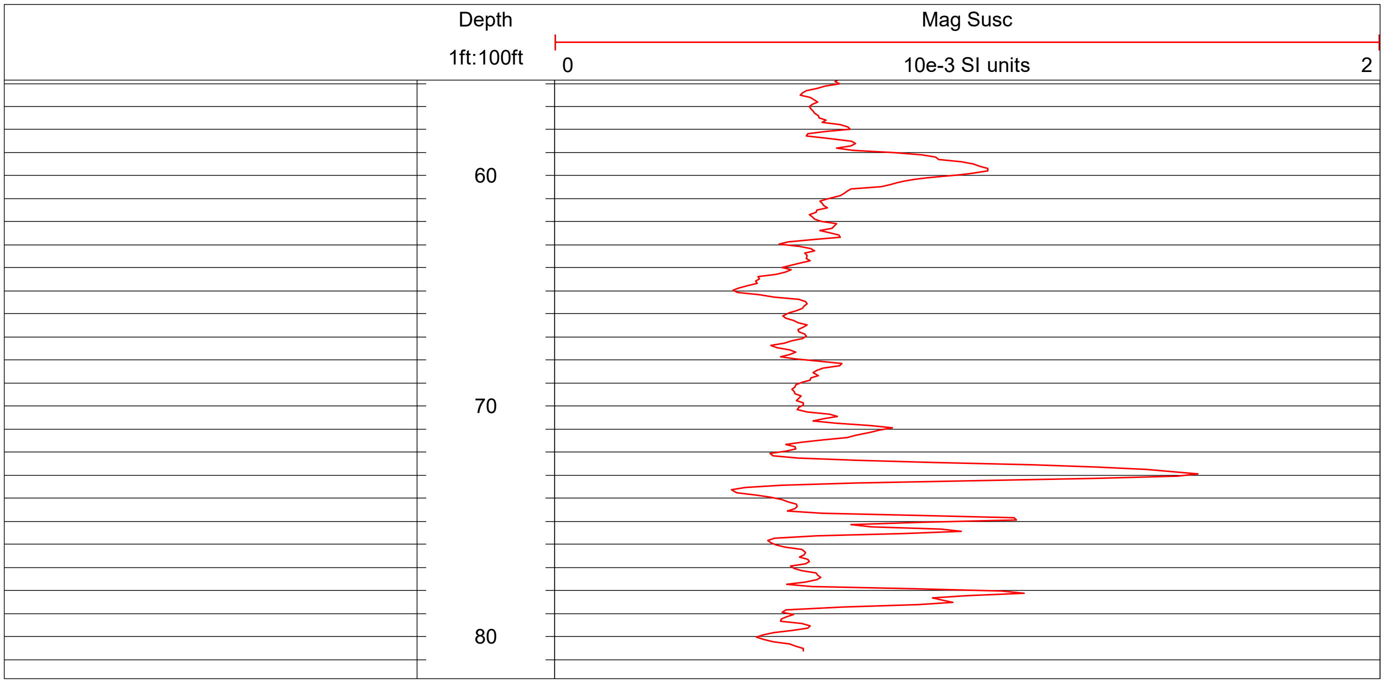
CALIBRATION STANDARDS 0 and 5E-3 SI Units

CALIBRATION RESULTS Zero = 65.7, 5E-3 = 1128.81 cps

REMARKS

Calibration from last well (EPA-19D) used at this location.



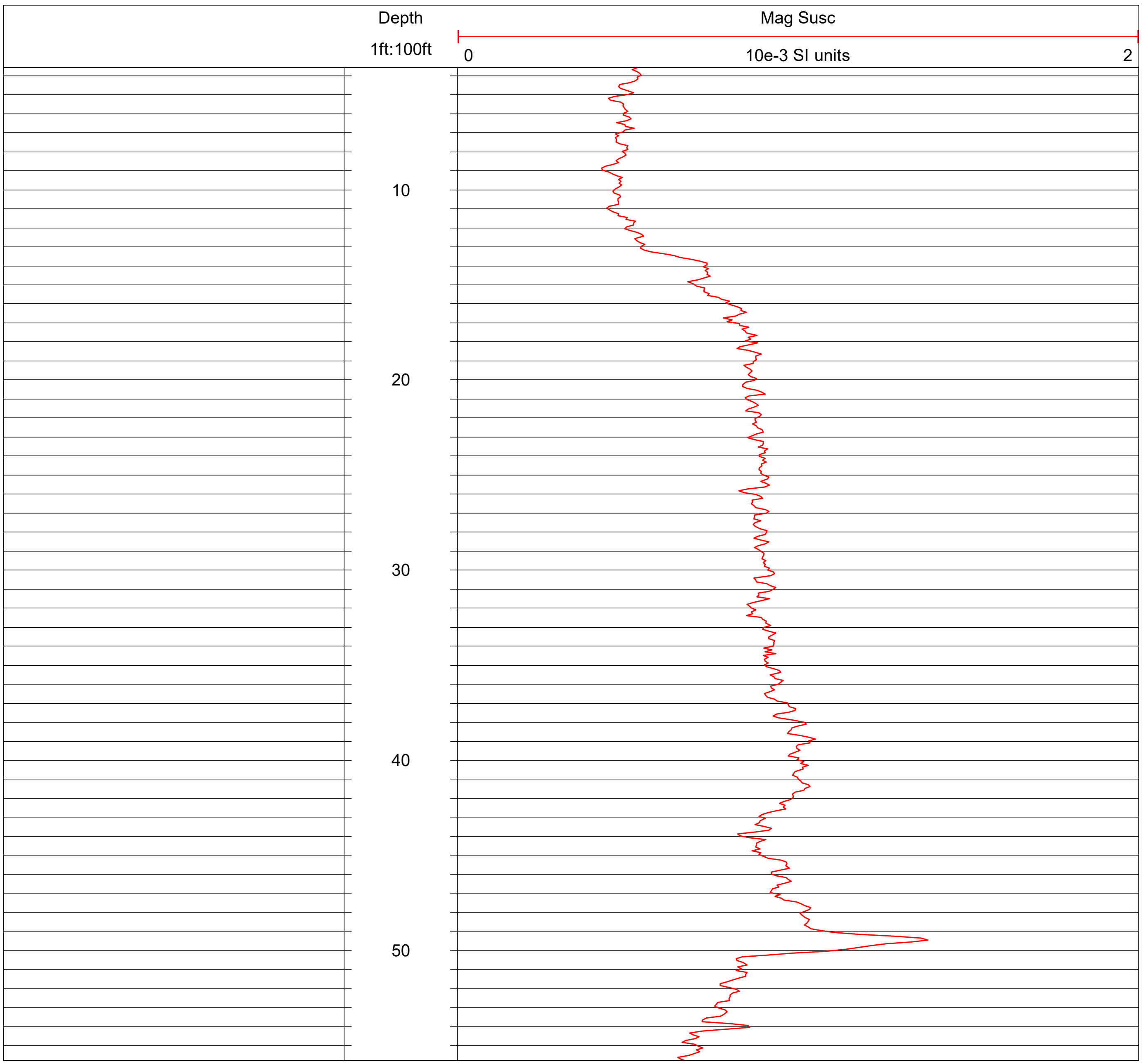

Depth
1ft:100ft
Mag Susc
0
10e-3 SI units
2
60
70
80

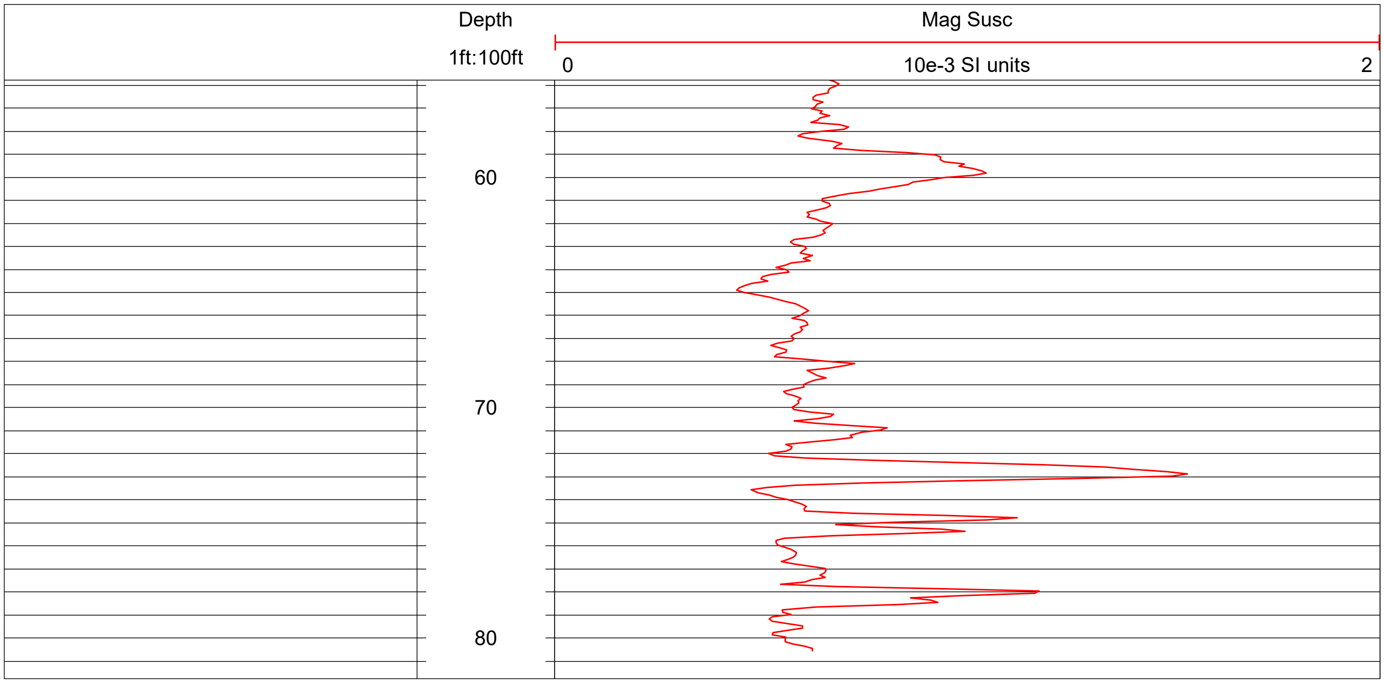
WIEDEMEIER & ASSOCIATES

PROJECT	ESTCP 201584
LOCATION	Hopewell Junction, NY
WELL	EPA-8D Up
LOGGER	Todd Wiedemeier
DATE	June 10, 2016

TOOL	HMA-453-S
CALIBRATION DATE/TIME	6/10/16 - 09:53
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	Zero = 65.7, 5E-3 = 1128.81
REMARKS	

Calibration from last well (EPA-19D) used at this location.




Depth
1ft:100ft
Mag Susc
0
10e-3 SI units
2
60
70
80

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
3.44	1.69055	9.94E-07
3.54	1.16235	6.84E-07
3.64	0.895231	5.27E-07
3.74	0.531828	3.13E-07
3.84	0.371208	2.18E-07
3.94	0.34978	2.06E-07
4.04	0.283215	1.67E-07
4.135	0.278451	1.64E-07
4.235	0.215895	1.27E-07
4.335	0.255615	1.5E-07
4.435	0.251539	1.48E-07
4.535	0.199511	1.17E-07
4.635	0.238739	1.4E-07
4.735	0.192836	1.13E-07
4.835	0.246782	1.45E-07
4.935	0.194686	1.15E-07
5.035	0.132187	7.78E-08
5.135	0.188122	1.11E-07
5.235	0.19569	1.15E-07
5.335	0.109956	6.47E-08
5.435	0.206306	1.21E-07
5.535	0.17163	1.01E-07
5.635	0.166942	9.82E-08
5.735	0.17498	1.03E-07
5.835	0.170584	1E-07
5.935	0.181353	1.07E-07
6.035	0.164262	9.66E-08
6.135	0.187772	1.1E-07
6.235	0.243613	1.43E-07
6.335	0.157469	9.26E-08
6.435	0.190972	1.12E-07
6.535	0.183463	1.08E-07
6.635	0.130419	7.67E-08
6.735	0.220579	1.3E-07
6.83	0.183959	1.08E-07
6.93	0.182316	1.07E-07
7.03	0.130899	7.7E-08
7.13	0.111387	6.55E-08
7.23	0.128301	7.55E-08
7.33	0.118673	6.98E-08
7.43	0.133415	7.85E-08

Average of Sonde Data =	2.46E-07
Count =	261
Confidence Level(95.0%) =	6.52E-09

WIEDEMEIER & ASSOCIATES

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
7.525	0.184472	1.09E-07
7.625	0.137897	8.11E-08
7.725	0.135017	7.94E-08
7.825	0.170448	1E-07
7.925	0.137141	8.07E-08
8.025	0.162297	9.55E-08
8.125	0.150722	8.87E-08
8.225	0.208968	1.23E-07
8.325	0.191417	1.13E-07
8.425	0.153666	9.04E-08
8.525	0.160186	9.42E-08
8.625	0.161213	9.48E-08
8.725	0.105271	6.19E-08
8.825	0.129586	7.62E-08
8.925	0.16234	9.55E-08
9.025	0.182686	1.07E-07
9.125	0.223996	1.32E-07
9.225	0.101517	5.97E-08
9.325	0.229676	1.35E-07
9.425	0.119332	7.02E-08
9.525	0.210713	1.24E-07
9.625	0.890024	5.24E-07
9.725	0.133057	7.83E-08
9.825	0.088556	5.21E-08
9.925	0.17221	1.01E-07
10.025	0.187223	1.1E-07
10.125	0.127135	7.48E-08
10.22	0.142682	8.39E-08
10.32	0.154721	9.1E-08
10.42	0.135821	7.99E-08
10.52	0.1444	8.49E-08
10.62	0.111748	6.57E-08
10.72	0.124625	7.33E-08
10.815	0.11761	6.92E-08
10.915	0.099482	5.85E-08
11.015	0.159061	9.36E-08
11.115	0.131129	7.71E-08
11.215	0.151866	8.93E-08
11.315	0.126367	7.43E-08
11.415	0.116297	6.84E-08
11.515	0.166098	9.77E-08

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
11.615	0.134975	7.94E-08
11.715	0.155294	9.13E-08
11.815	0.184898	1.09E-07
11.915	0.161222	9.48E-08
12.015	0.134097	7.89E-08
12.115	0.176131	1.04E-07
12.215	0.182179	1.07E-07
12.315	0.141896	8.35E-08
12.415	0.172663	1.02E-07
12.515	0.142215	8.37E-08
12.615	0.138053	8.12E-08
12.715	0.170079	1E-07
12.815	0.111963	6.59E-08
12.915	0.172664	1.02E-07
13.015	0.190196	1.12E-07
13.115	0.105279	6.19E-08
13.215	0.119774	7.05E-08
13.315	0.166831	9.81E-08
13.415	0.177746	1.05E-07
13.51	0.189258	1.11E-07
13.61	0.148565	8.74E-08
13.71	0.14231	8.37E-08
13.81	0.114136	6.71E-08
13.91	0.174597	1.03E-07
14.01	0.148307	8.72E-08
14.105	0.190885	1.12E-07
14.205	0.15769	9.28E-08
14.305	0.157931	9.29E-08
14.405	0.127977	7.53E-08
14.505	0.102739	6.04E-08
14.605	0.15465	9.1E-08
14.705	0.194658	1.15E-07
14.805	0.162563	9.56E-08
14.905	0.156581	9.21E-08
15.005	0.140754	8.28E-08
15.105	0.093629	5.51E-08
15.205	0.139335	8.2E-08
15.305	0.149177	8.78E-08
15.405	0.170509	1E-07
15.505	0.128606	7.57E-08
15.605	0.134787	7.93E-08

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
15.705	0.165646	9.74E-08
15.805	0.155248	9.13E-08
15.905	0.15047	8.85E-08
16.005	0.141743	8.34E-08
16.105	0.190799	1.12E-07
16.205	0.1051	6.18E-08
16.305	0.155201	9.13E-08
16.405	0.115882	6.82E-08
16.505	0.159931	9.41E-08
16.605	0.116253	6.84E-08
16.705	0.143407	8.44E-08
16.8	0.131416	7.73E-08
16.9	0.119013	7E-08
17	0.106058	6.24E-08
17.1	0.22728	1.34E-07
17.2	0.160029	9.41E-08
17.3	0.13231	7.78E-08
17.4	0.187613	1.1E-07
17.495	0.196514	1.16E-07
17.595	0.118814	6.99E-08
17.695	0.172558	1.02E-07
17.795	0.129523	7.62E-08
17.895	0.138826	8.17E-08
17.995	0.165395	9.73E-08
18.095	0.185824	1.09E-07
18.195	0.158265	9.31E-08
18.295	0.186449	1.1E-07
18.395	0.161006	9.47E-08
18.495	0.134713	7.92E-08
18.595	0.206029	1.21E-07
18.695	0.176227	1.04E-07
18.795	0.176474	1.04E-07
18.895	0.218374	1.28E-07
18.995	0.192614	1.13E-07
19.095	0.121349	7.14E-08
19.195	0.143974	8.47E-08
19.295	0.164899	9.7E-08
19.395	0.167512	9.85E-08
19.495	0.167066	9.83E-08
19.595	0.159554	9.39E-08
19.695	0.158398	9.32E-08

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23,
TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
19.795	0.139999	8.24E-08
19.895	0.133839	7.87E-08
19.995	0.137845	8.11E-08
20.09	0.178608	1.05E-07
20.19	0.153115	9.01E-08
20.29	0.1541	9.06E-08
20.39	0.182176	1.07E-07
20.49	0.156735	9.22E-08
20.59	0.154995	9.12E-08
20.69	0.191653	1.13E-07
20.785	0.20887	1.23E-07
20.885	0.211641	1.24E-07
20.985	0.140292	8.25E-08
21.085	0.210792	1.24E-07
21.185	0.177117	1.04E-07
21.285	0.19011	1.12E-07
21.385	0.136887	8.05E-08
21.485	0.165735	9.75E-08
21.585	0.191378	1.13E-07
21.685	0.146538	8.62E-08
21.785	0.16802	9.88E-08
21.885	0.176045	1.04E-07
21.985	0.129906	7.64E-08
22.085	0.147908	8.7E-08
22.185	0.128643	7.57E-08
22.285	0.19475	1.15E-07
22.385	0.146842	8.64E-08
22.485	0.14908	8.77E-08
22.585	0.152097	8.95E-08
22.685	0.169409	9.97E-08
22.785	0.17264	1.02E-07
22.885	0.123756	7.28E-08
22.985	0.162499	9.56E-08
23.085	0.200075	1.18E-07
23.185	0.167254	9.84E-08
23.285	0.154943	9.11E-08
23.385	0.184181	1.08E-07
23.48	0.198268	1.17E-07
23.58	0.188245	1.11E-07
23.68	0.140919	8.29E-08
23.78	0.142058	8.36E-08

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
23.88	0.204919	1.21E-07
23.98	0.177276	1.04E-07
24.075	0.190483	1.12E-07
24.175	0.19024	1.12E-07
24.275	0.183927	1.08E-07
24.375	0.262052	1.54E-07
24.475	0.234156	1.38E-07
24.575	0.26548	1.56E-07
24.675	0.263013	1.55E-07
24.775	0.273585	1.61E-07
24.875	0.314269	1.85E-07
24.975	0.308106	1.81E-07
25.075	0.303449	1.78E-07
25.175	0.293637	1.73E-07
25.275	0.311662	1.83E-07
25.375	0.294133	1.73E-07
25.475	0.264119	1.55E-07
25.575	0.274063	1.61E-07
25.675	0.187541	1.1E-07
25.775	0.165488	9.73E-08
25.875	0.230344	1.35E-07
25.975	0.130784	7.69E-08
26.075	0.184801	1.09E-07
26.175	0.159298	9.37E-08
26.275	0.155483	9.15E-08
26.375	0.208677	1.23E-07
26.475	0.204966	1.21E-07
26.575	0.178517	1.05E-07
26.675	0.264702	1.56E-07
26.77	0.207529	1.22E-07
26.87	0.15215	8.95E-08
26.97	0.198033	1.16E-07
27.07	0.21196	1.25E-07
27.17	0.239349	1.41E-07
27.27	0.187192	1.1E-07
27.37	0.210194	1.24E-07
27.465	0.207977	1.22E-07
27.565	0.176081	1.04E-07
27.665	0.211163	1.24E-07
27.765	0.163357	9.61E-08
27.865	0.188206	1.11E-07

**MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23,
TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH**

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
27.965	0.19021	1.12E-07
28.065	0.191763	1.13E-07
28.165	0.185928	1.09E-07
28.265	0.188269	1.11E-07
28.365	0.161797	9.52E-08
28.465	0.18384	1.08E-07
28.565	0.148928	8.76E-08
28.665	0.141839	8.34E-08
28.765	0.16783	9.87E-08
28.865	0.116424	6.85E-08
28.965	0.163746	9.63E-08
29.065	0.172129	1.01E-07
29.165	0.164264	9.66E-08
29.265	0.149646	8.8E-08
29.365	0.202507	1.19E-07
29.465	0.217	1.28E-07
29.565	0.167956	9.88E-08
29.665	0.251256	1.48E-07
29.765	0.188935	1.11E-07
29.865	0.200639	1.18E-07
29.965	0.20837	1.23E-07
30.065	0.187905	1.11E-07
30.16	0.219584	1.29E-07
30.26	0.226081	1.33E-07
30.36	0.237822	1.4E-07
30.46	0.176907	1.04E-07
30.56	0.198309	1.17E-07
30.66	0.231063	1.36E-07
30.755	0.174266	1.03E-07
30.855	0.197488	1.16E-07
30.955	0.235003	1.38E-07
31.055	0.199255	1.17E-07
31.155	0.231583	1.36E-07
31.255	0.229644	1.35E-07
31.355	0.190976	1.12E-07
31.455	0.205442	1.21E-07
31.555	0.233086	1.37E-07
31.655	0.208906	1.23E-07
31.755	0.193595	1.14E-07
31.855	0.161523	9.5E-08
31.955	0.240854	1.42E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
32.055	0.136932	8.05E-08
32.155	0.18696	1.1E-07
32.255	0.190284	1.12E-07
32.355	0.231281	1.36E-07
32.455	0.186595	1.1E-07
32.555	0.232083	1.37E-07
32.655	0.213346	1.25E-07
32.755	0.229872	1.35E-07
32.855	0.260838	1.53E-07
32.955	0.305811	1.8E-07
33.055	0.308947	1.82E-07
33.155	0.386698	2.27E-07
33.255	0.377791	2.22E-07
33.355	0.361354	2.13E-07
33.45	0.333117	1.96E-07
33.55	0.296979	1.75E-07
33.65	0.370701	2.18E-07
33.75	0.385629	2.27E-07
33.85	0.321451	1.89E-07
33.95	0.340719	2E-07
34.045	0.318301	1.87E-07
34.145	0.275612	1.62E-07
34.245	0.317718	1.87E-07
34.345	0.297132	1.75E-07
34.445	0.35727	2.1E-07
34.545	0.324578	1.91E-07
34.645	0.359298	2.11E-07
34.745	0.338536	1.99E-07
34.845	0.349008	2.05E-07
34.945	0.331007	1.95E-07
35.045	0.294981	1.74E-07
35.145	0.300083	1.77E-07
35.245	0.272628	1.6E-07
35.345	0.25286	1.49E-07
35.445	0.276348	1.63E-07
35.545	0.264852	1.56E-07
35.645	0.266528	1.57E-07
35.745	0.272631	1.6E-07
35.845	0.255697	1.5E-07
35.945	0.25155	1.48E-07
36.045	0.298896	1.76E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
36.145	0.29878	1.76E-07
36.245	0.262734	1.55E-07
36.345	0.250088	1.47E-07
36.445	0.296028	1.74E-07
36.545	0.281923	1.66E-07
36.645	0.293679	1.73E-07
36.74	0.274239	1.61E-07
36.84	0.24737	1.46E-07
36.94	0.288593	1.7E-07
37.04	0.24204	1.42E-07
37.14	0.235722	1.39E-07
37.24	0.227873	1.34E-07
37.34	0.311416	1.83E-07
37.435	0.2802	1.65E-07
37.535	0.279355	1.64E-07
37.635	0.273363	1.61E-07
37.735	0.280567	1.65E-07
37.835	0.273214	1.61E-07
37.935	0.279426	1.64E-07
38.035	0.325584	1.92E-07
38.135	0.282269	1.66E-07
38.235	0.260836	1.53E-07
38.335	0.321073	1.89E-07
38.435	0.244714	1.44E-07
38.535	0.259504	1.53E-07
38.635	0.311889	1.83E-07
38.735	0.265777	1.56E-07
38.835	0.213637	1.26E-07
38.935	0.169306	9.96E-08
39.035	0.182731	1.07E-07
39.135	0.190821	1.12E-07
39.235	0.177668	1.05E-07
39.335	0.175959	1.04E-07
39.435	0.148038	8.71E-08
39.535	0.174137	1.02E-07
39.635	0.181706	1.07E-07
39.735	0.229401	1.35E-07
39.835	0.18163	1.07E-07
39.935	0.198098	1.17E-07
40.03	0.210198	1.24E-07
40.13	0.211522	1.24E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
40.23	0.181153	1.07E-07
40.33	0.247498	1.46E-07
40.43	0.180063	1.06E-07
40.53	0.258182	1.52E-07
40.63	0.226563	1.33E-07
40.725	0.204097	1.2E-07
40.825	0.248561	1.46E-07
40.925	0.22087	1.3E-07
41.025	0.218235	1.28E-07
41.125	0.192843	1.13E-07
41.225	0.193795	1.14E-07
41.325	0.203776	1.2E-07
41.425	0.191026	1.12E-07
41.525	0.194844	1.15E-07
41.625	0.157564	9.27E-08
41.725	0.176001	1.04E-07
41.825	0.160095	9.42E-08
41.925	0.181204	1.07E-07
42.025	0.229058	1.35E-07
42.125	0.169196	9.95E-08
42.225	0.20913	1.23E-07
42.325	0.235077	1.38E-07
42.425	0.225658	1.33E-07
42.525	0.198064	1.17E-07
42.625	0.270756	1.59E-07
42.725	0.268367	1.58E-07
42.825	0.293318	1.73E-07
42.925	0.313423	1.84E-07
43.025	0.330232	1.94E-07
43.125	0.32806	1.93E-07
43.225	0.460502	2.71E-07
43.325	0.335455	1.97E-07
43.42	0.294187	1.73E-07
43.52	0.281201	1.65E-07
43.62	0.337865	1.99E-07
43.72	0.322038	1.89E-07
43.82	0.272793	1.6E-07
43.92	0.244768	1.44E-07
44.015	0.317103	1.87E-07
44.115	0.213985	1.26E-07
44.215	0.335133	1.97E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
44.315	0.341939	2.01E-07
44.415	0.379068	2.23E-07
44.515	0.310564	1.83E-07
44.615	0.405848	2.39E-07
44.715	0.446981	2.63E-07
44.815	0.433898	2.55E-07
44.915	0.407511	2.4E-07
45.015	0.415645	2.44E-07
45.115	0.464887	2.73E-07
45.215	0.464176	2.73E-07
45.315	0.489992	2.88E-07
45.415	0.396607	2.33E-07
45.515	0.433553	2.55E-07
45.615	0.430177	2.53E-07
45.715	0.38691	2.28E-07
45.815	0.377046	2.22E-07
45.915	0.349783	2.06E-07
46.015	0.292939	1.72E-07
46.115	0.384274	2.26E-07
46.215	0.31243	1.84E-07
46.315	0.285408	1.68E-07
46.415	0.27503	1.62E-07
46.515	0.293411	1.73E-07
46.615	0.216289	1.27E-07
46.71	0.315831	1.86E-07
46.81	0.259951	1.53E-07
46.91	0.270291	1.59E-07
47.01	0.266724	1.57E-07
47.11	0.263748	1.55E-07
47.21	0.325641	1.92E-07
47.31	0.271799	1.6E-07
47.405	0.310891	1.83E-07
47.505	0.28251	1.66E-07
47.605	0.338565	1.99E-07
47.705	0.289705	1.7E-07
47.805	0.287032	1.69E-07
47.905	0.309485	1.82E-07
48.005	0.274668	1.62E-07
48.105	0.288158	1.7E-07
48.205	0.284728	1.67E-07
48.305	0.24801	1.46E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
48.405	0.230483	1.36E-07
48.505	0.292099	1.72E-07
48.605	0.335671	1.97E-07
48.705	0.410309	2.41E-07
48.805	0.414168	2.44E-07
48.905	0.447929	2.63E-07
49.005	0.506946	2.98E-07
49.105	0.507579	2.99E-07
49.205	0.548586	3.23E-07
49.305	0.488968	2.88E-07
49.405	0.523458	3.08E-07
49.505	0.501876	2.95E-07
49.605	0.449906	2.65E-07
49.705	0.439492	2.59E-07
49.805	0.380148	2.24E-07
49.905	0.405645	2.39E-07
50.005	0.370831	2.18E-07
50.1	0.385053	2.27E-07
50.2	0.389286	2.29E-07
50.3	0.413855	2.43E-07
50.4	0.384105	2.26E-07
50.5	0.425872	2.51E-07
50.6	0.404955	2.38E-07
50.695	0.38839	2.28E-07
50.795	0.39916	2.35E-07
50.895	0.395056	2.32E-07
50.995	0.407516	2.4E-07
51.095	0.34356	2.02E-07
51.195	0.355765	2.09E-07
51.295	0.357398	2.1E-07
51.395	0.376339	2.21E-07
51.495	0.313477	1.84E-07
51.595	0.350217	2.06E-07
51.695	0.275413	1.62E-07
51.795	0.364554	2.14E-07
51.895	0.261889	1.54E-07
51.995	0.31873	1.87E-07
52.095	0.381515	2.24E-07
52.195	0.298874	1.76E-07
52.295	0.360606	2.12E-07
52.395	0.358296	2.11E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
52.495	0.320531	1.89E-07
52.595	0.423316	2.49E-07
52.695	0.298077	1.75E-07
52.795	0.343402	2.02E-07
52.895	0.3045	1.79E-07
52.995	0.34021	2E-07
53.095	0.341346	2.01E-07
53.195	0.37467	2.2E-07
53.295	0.360006	2.12E-07
53.39	0.362622	2.13E-07
53.49	0.321306	1.89E-07
53.59	0.340587	2E-07
53.69	0.34982	2.06E-07
53.79	0.312528	1.84E-07
53.89	0.280134	1.65E-07
53.99	0.363988	2.14E-07
54.085	0.344054	2.02E-07
54.185	0.32732	1.93E-07
54.285	0.352854	2.08E-07
54.385	0.406385	2.39E-07
54.485	0.261919	1.54E-07
54.585	0.358091	2.11E-07
54.685	0.380848	2.24E-07
54.785	0.352976	2.08E-07
54.885	0.311699	1.83E-07
54.985	0.371698	2.19E-07
55.085	0.359793	2.12E-07
55.185	0.361149	2.12E-07
55.285	0.356491	2.1E-07
55.385	0.430504	2.53E-07
55.485	0.445871	2.62E-07
55.585	0.451251	2.65E-07
55.685	0.477142	2.81E-07
55.785	0.509408	3E-07
55.885	0.502846	2.96E-07
55.985	0.434792	2.56E-07
56.085	0.470384	2.77E-07
56.185	0.487326	2.87E-07
56.285	0.455398	2.68E-07
56.385	0.439726	2.59E-07
56.485	0.458021	2.69E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
56.585	0.451129	2.65E-07
56.68	0.383152	2.25E-07
56.78	0.333775	1.96E-07
56.88	0.378335	2.23E-07
56.98	0.322348	1.9E-07
57.08	0.420463	2.47E-07
57.18	0.322137	1.89E-07
57.28	0.361742	2.13E-07
57.375	0.324968	1.91E-07
57.475	0.278814	1.64E-07
57.575	0.315342	1.85E-07
57.675	0.322766	1.9E-07
57.775	0.369596	2.17E-07
57.875	0.353895	2.08E-07
57.975	0.357912	2.11E-07
58.075	0.366868	2.16E-07
58.175	0.370795	2.18E-07
58.275	0.321029	1.89E-07
58.375	0.351829	2.07E-07
58.475	0.348939	2.05E-07
58.575	0.384775	2.26E-07
58.675	0.395831	2.33E-07
58.775	0.398589	2.34E-07
58.875	0.437301	2.57E-07
58.975	0.415324	2.44E-07
59.075	0.454978	2.68E-07
59.175	0.412349	2.43E-07
59.275	0.43958	2.59E-07
59.375	0.383352	2.26E-07
59.475	0.443898	2.61E-07
59.575	0.472325	2.78E-07
59.675	0.452333	2.66E-07
59.775	0.473192	2.78E-07
59.875	0.511072	3.01E-07
59.97	0.512558	3.02E-07
60.07	0.460286	2.71E-07
60.17	0.453628	2.67E-07
60.27	0.480501	2.83E-07
60.37	0.483029	2.84E-07
60.47	0.413162	2.43E-07
60.57	0.490979	2.89E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg		
60.665	0.452257	2.66E-07		
60.765	0.46171	2.72E-07		
60.865	0.440119	2.59E-07		
60.965	0.463071	2.72E-07		
61.065	0.369532	2.17E-07		
61.165	0.356235	2.1E-07		
61.265	0.377196	2.22E-07		
61.365	0.400768	2.36E-07		
61.465	0.377656	2.22E-07		
61.565	0.364577	2.14E-07		
61.665	0.439683	2.59E-07		
61.765	0.364588	2.14E-07		
61.865	0.351816	2.07E-07		
61.965	0.424172	2.5E-07		
62.065	0.391966	2.31E-07		
62.165	0.31597	1.86E-07		
62.265	0.34421	2.02E-07		
62.365	0.369003	2.17E-07		
62.465	0.41074	2.42E-07		
62.565	0.369417	2.17E-07		
62.665	0.371978	2.19E-07		
62.765	0.406147	2.39E-07		
62.865	0.395566	2.33E-07		
62.965	0.368151	2.17E-07		
63.065	0.372801	2.19E-07		
63.165	0.435814	2.56E-07		
63.265	0.409868	2.41E-07		
63.36	0.383783	2.26E-07		
63.46	0.397872	2.34E-07		
63.56	0.404306	2.38E-07	63.5	1.48E-07
63.66	0.403817	2.38E-07		
63.76	0.394369	2.32E-07		
63.86	0.35449	2.09E-07		
63.96	0.359019	2.11E-07		
64.055	0.398393	2.34E-07		
64.155	0.402836	2.37E-07		
64.255	0.418417	2.46E-07		
64.355	0.398882	2.35E-07		
64.455	0.477395	2.81E-07		
64.555	0.419277	2.47E-07		
64.655	0.401098	2.36E-07		

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23,
TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg		
64.76	0.440485	2.59E-07		
64.855	0.452978	2.66E-07		
64.955	0.421117	2.48E-07		
65.055	0.412648	2.43E-07		
65.155	0.464431	2.73E-07		
65.255	0.429502	2.53E-07		
65.355	0.447182	2.63E-07		
65.455	0.446488	2.63E-07		
65.555	0.48248	2.84E-07		
65.655	0.455947	2.68E-07		
65.755	0.43782	2.58E-07		
65.855	0.485215	2.85E-07		
65.955	0.440328	2.59E-07		
66.055	0.431187	2.54E-07		
66.155	0.440995	2.59E-07		
66.255	0.448309	2.64E-07		
66.355	0.453203	2.67E-07		
66.455	0.451867	2.66E-07		
66.555	0.467126	2.75E-07		
66.65	0.481437	2.83E-07		
66.75	0.428828	2.52E-07		
66.85	0.382799	2.25E-07		
66.95	0.408642	2.4E-07		
67.05	0.363043	2.14E-07		
67.15	0.407626	2.4E-07		
67.25	0.401995	2.36E-07		
67.345	0.37866	2.23E-07		
67.445	0.353613	2.08E-07		
67.545	0.333875	1.96E-07	67.5	1.04E-07
67.645	0.377981	2.22E-07		
67.745	0.368031	2.16E-07		
67.845	0.361423	2.13E-07		
67.945	0.35496	2.09E-07		
68.045	0.365711	2.15E-07		
68.145	0.353	2.08E-07		
68.245	0.326622	1.92E-07		
68.345	0.355203	2.09E-07		
68.445	0.400638	2.36E-07		
68.545	0.37758	2.22E-07		
68.645	0.405415	2.38E-07		
68.745	0.373552	2.2E-07		

WIEDEMEIER & ASSOCIATES

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg		
68.845	0.390506	2.3E-07		
68.95	0.402888	2.37E-07		
69.045	0.345534	2.03E-07		
69.145	0.40465	2.38E-07		
69.245	0.420465	2.47E-07		
69.345	0.378911	2.23E-07		
69.445	0.353995	2.08E-07		
69.545	0.358322	2.11E-07	69.5	2.41E-07
69.645	0.347283	2.04E-07		
69.745	0.386627	2.27E-07		
69.845	0.410628	2.42E-07		
69.94	0.349121	2.05E-07		
70.04	0.390858	2.3E-07		
70.14	0.375948	2.21E-07		
70.24	0.418147	2.46E-07		
70.34	0.390163	2.3E-07		
70.44	0.373892	2.2E-07		
70.54	0.421445	2.48E-07		
70.635	0.414119	2.44E-07		
70.735	0.436978	2.57E-07		
70.835	0.363067	2.14E-07		
70.935	0.406585	2.39E-07		
71.035	0.382411	2.25E-07		
71.135	0.416065	2.45E-07		
71.235	0.405206	2.38E-07		
71.335	0.415771	2.45E-07		
71.435	0.367034	2.16E-07		
71.535	0.414098	2.44E-07		
71.635	0.428533	2.52E-07		
71.735	0.389814	2.29E-07		
71.835	0.370541	2.18E-07		
71.935	0.393584	2.32E-07		
72.035	0.333899	1.96E-07		
72.135	0.372863	2.19E-07		
72.235	0.378106	2.22E-07		
72.335	0.389837	2.29E-07		
72.435	0.345501	2.03E-07		
72.535	0.347697	2.05E-07		
72.635	0.341784	2.01E-07		
72.735	0.339024	1.99E-07		
72.835	0.342489	2.01E-07		

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg		
72.935	0.321699	1.89E-07		
73.035	0.399241	2.35E-07		
73.135	0.389468	2.29E-07		
73.235	0.420887	2.48E-07		
73.33	0.351532	2.07E-07		
73.43	0.406913	2.39E-07		
73.53	0.420973	2.48E-07	73.5	3.31E-07
73.63	0.37668	2.22E-07		
73.73	0.395655	2.33E-07		
73.83	0.446811	2.63E-07		
73.93	0.32512	1.91E-07		
74.03	0.386659	2.27E-07		
74.125	0.420962	2.48E-07		
74.225	0.36964	2.17E-07		
74.325	0.376199	2.21E-07		
74.425	0.429619	2.53E-07		
74.525	0.379544	2.23E-07		
74.625	0.449337	2.64E-07		
74.725	0.366566	2.16E-07		
74.825	0.313485	1.84E-07		
74.925	0.37744	2.22E-07		
75.025	0.392215	2.31E-07		
75.125	0.344563	2.03E-07		
75.225	0.392514	2.31E-07		
75.325	0.300744	1.77E-07		
75.425	0.361991	2.13E-07		
75.525	0.310864	1.83E-07	75.5	2.25E-07
75.625	0.36547	2.15E-07		
75.725	0.3073	1.81E-07		
75.825	0.339051	1.99E-07		
75.925	0.387152	2.28E-07		
76.025	0.31965	1.88E-07		
76.125	0.300342	1.77E-07		
76.225	0.355817	2.09E-07		
76.325	0.278654	1.64E-07		
76.425	0.362817	2.13E-07		
76.525	0.402683	2.37E-07		
76.62	0.31843	1.87E-07		
76.72	0.341715	2.01E-07		
76.82	0.336069	1.98E-07		
76.92	0.376118	2.21E-07		

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MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg		
77.02	0.322801	1.9E-07		
77.12	0.359329	2.11E-07		
77.22	0.339018	1.99E-07		
77.315	0.340719	2E-07		
77.415	0.331051	1.95E-07		
77.515	0.365253	2.15E-07		
77.615	0.324135	1.91E-07		
77.715	0.342953	2.02E-07		
77.815	0.360668	2.12E-07		
77.915	0.354805	2.09E-07		
78.015	0.326627	1.92E-07		
78.115	0.367086	2.16E-07		
78.215	0.397451	2.34E-07		
78.315	0.386982	2.28E-07		
78.415	0.416728	2.45E-07		
78.515	0.336562	1.98E-07	78.5	4.72E-07
78.615	0.405609	2.39E-07		
78.715	0.389961	2.29E-07		
78.815	0.368274	2.17E-07		
78.915	0.338567	1.99E-07		
79.015	0.363692	2.14E-07		
79.115	0.418094	2.46E-07		
79.215	0.330828	1.95E-07		
79.315	0.393312	2.31E-07		
79.415	0.340206	2E-07		
79.515	0.301604	1.77E-07		
79.615	0.302413	1.78E-07		
79.715	0.347877	2.05E-07		
79.815	0.294669	1.73E-07		
79.91	0.279307	1.64E-07		
80.01	0.325141	1.91E-07		
80.11	0.344681	2.03E-07		
80.21	0.2994	1.76E-07		
80.31	0.320961	1.89E-07		
80.41	0.299564	1.76E-07		
80.51	0.373536	2.2E-07		
80.605	0.351233	2.07E-07		
80.705	0.397957	2.34E-07		
80.805	0.33567	1.97E-07		
80.905	0.381864	2.25E-07		
81.005	0.362138	2.13E-07		

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
81.105	0.361151	2.12E-07
81.205	0.340882	2.01E-07
81.305	0.378727	2.23E-07
81.405	0.408585	2.4E-07
81.505	0.36326	2.14E-07
81.605	0.366843	2.16E-07
81.705	0.3296	1.94E-07
81.805	0.329917	1.94E-07
81.905	0.410404	2.41E-07
82.005	0.376525	2.21E-07
82.105	0.382996	2.25E-07
82.205	0.419366	2.47E-07
82.305	0.408078	2.4E-07
82.405	0.428898	2.52E-07
82.505	0.506463	2.98E-07
82.605	0.471022	2.77E-07
82.705	0.453109	2.67E-07
82.805	0.467603	2.75E-07
82.905	0.550191	3.24E-07
83.005	0.441638	2.6E-07
83.105	0.452225	2.66E-07
83.205	0.43247	2.54E-07
83.3	0.434022	2.55E-07
83.4	0.432269	2.54E-07
83.5	0.48128	2.83E-07
83.6	0.528755	3.11E-07
83.7	0.497656	2.93E-07
83.8	0.48022	2.82E-07
83.895	0.538754	3.17E-07
83.995	0.579697	3.41E-07
84.095	0.541499	3.19E-07
84.195	0.631475	3.71E-07
84.295	0.684187	4.02E-07
84.395	0.636337	3.74E-07
84.495	0.583453	3.43E-07
84.595	0.671214	3.95E-07
84.695	0.628209	3.7E-07
84.795	0.635119	3.74E-07
84.895	0.628343	3.7E-07
84.995	0.581156	3.42E-07
85.095	0.53886	3.17E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg		
85.195	0.575722	3.39E-07		
85.295	0.556689	3.27E-07		
85.395	0.671196	3.95E-07		
85.495	0.587744	3.46E-07	85.5	9.37E-07
85.595	0.627879	3.69E-07	89.5	1.47E-07
85.695	0.5816	3.42E-07		
85.795	0.690807	4.06E-07		
85.895	0.715992	4.21E-07		
85.995	0.730151	4.3E-07		
86.095	0.763459	4.49E-07		
86.195	0.760655	4.47E-07		
86.295	0.672583	3.96E-07		
86.395	0.669032	3.94E-07		
86.495	0.69161	4.07E-07		
86.59	0.546369	3.21E-07		
86.69	0.487527	2.87E-07		
86.79	0.486377	2.86E-07		
86.89	0.442036	2.6E-07		
86.99	0.428098	2.52E-07		
87.09	0.460821	2.71E-07		
87.19	0.40068	2.36E-07		
87.285	0.458172	2.7E-07		
87.385	0.43236	2.54E-07		
87.485	0.462122	2.72E-07		
87.585	0.40397	2.38E-07		
87.685	0.473935	2.79E-07		
87.785	0.482139	2.84E-07		
87.885	0.446684	2.63E-07		
87.985	0.443307	2.61E-07		
88.085	0.451592	2.66E-07		
88.185	0.421443	2.48E-07		
88.285	0.436054	2.57E-07		
88.385	0.42118	2.48E-07		
88.485	0.46874	2.76E-07		
88.585	0.463045	2.72E-07		
88.685	0.445602	2.62E-07		
88.785	0.431397	2.54E-07		
88.885	0.421247	2.48E-07		
88.985	0.52103	3.06E-07		
89.085	0.408542	2.4E-07		
89.185	0.398879	2.35E-07		

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg		
89.285	0.446917	2.63E-07		
89.385	0.409891	2.41E-07		
89.485	0.37705	2.22E-07	89.5	1.47E-07
89.585	0.400587	2.36E-07		
89.685	0.409328	2.41E-07		
89.785	0.390412	2.3E-07		
89.885	0.372868	2.19E-07		
89.98	0.322846	1.9E-07		
90.08	0.364927	2.15E-07		
90.18	0.315034	1.85E-07		
90.28	0.351656	2.07E-07		
90.38	0.337452	1.99E-07		
90.48	0.37318	2.2E-07		
90.575	0.361626	2.13E-07		
90.675	0.411126	2.42E-07		
90.775	0.394517	2.32E-07		
90.875	0.348643	2.05E-07		
90.975	0.382733	2.25E-07		
91.075	0.405308	2.38E-07		
91.175	0.425441	2.5E-07		
91.275	0.446246	2.62E-07		
91.375	0.436132	2.57E-07		
91.475	0.421236	2.48E-07		
91.575	0.393538	2.31E-07		
91.675	0.38095	2.24E-07		
91.775	0.376694	2.22E-07		
91.875	0.362268	2.13E-07		
91.975	0.398765	2.35E-07		
92.075	0.361054	2.12E-07		
92.175	0.401029	2.36E-07		
92.275	0.37227	2.19E-07		
92.375	0.355707	2.09E-07		
92.475	0.382001	2.25E-07		
92.575	0.375171	2.21E-07		
92.675	0.376439	2.21E-07		
92.775	0.377916	2.22E-07		
92.875	0.373206	2.2E-07		
92.975	0.327521	1.93E-07		
93.075	0.427902	2.52E-07		
93.175	0.395651	2.33E-07		
93.27	0.395564	2.33E-07		

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MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
93.37	0.419232	2.47E-07
93.47	0.439699	2.59E-07
93.57	0.413612	2.43E-07
93.67	0.443265	2.61E-07
93.77	0.466475	2.74E-07
93.865	0.43879	2.58E-07
93.965	0.500116	2.94E-07
94.065	0.401844	2.36E-07
94.165	0.532446	3.13E-07
94.265	0.459886	2.71E-07
94.365	0.431298	2.54E-07
94.465	0.477186	2.81E-07
94.565	0.576939	3.39E-07
94.665	0.53026	3.12E-07
94.765	0.480921	2.83E-07
94.865	0.528892	3.11E-07
94.965	0.551821	3.25E-07
95.065	0.538989	3.17E-07
95.165	0.516325	3.04E-07
95.265	0.57691	3.39E-07
95.365	0.512112	3.01E-07
95.465	0.537247	3.16E-07
95.565	0.546681	3.22E-07
95.665	0.563588	3.32E-07
95.765	0.544448	3.2E-07
95.865	0.497408	2.93E-07
95.965	0.453594	2.67E-07
96.065	0.477012	2.81E-07
96.165	0.418455	2.46E-07
96.265	0.445185	2.62E-07
96.365	0.372669	2.19E-07
96.465	0.348088	2.05E-07
96.56	0.388704	2.29E-07
96.66	0.387686	2.28E-07
96.76	0.374193	2.2E-07
96.86	0.337382	1.98E-07
96.96	0.341595	2.01E-07
97.06	0.38175	2.25E-07
97.16	0.308598	1.82E-07
97.255	0.331314	1.95E-07
97.355	0.334107	1.97E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
97.455	0.353449	2.08E-07
97.555	0.371242	2.18E-07
97.655	0.330616	1.94E-07
97.755	0.358908	2.11E-07
97.855	0.318031	1.87E-07
97.955	0.364319	2.14E-07
98.055	0.322535	1.9E-07
98.155	0.357387	2.1E-07
98.255	0.317031	1.86E-07
98.355	0.363233	2.14E-07
98.455	0.315553	1.86E-07
98.555	0.323202	1.9E-07
98.655	0.316166	1.86E-07
98.755	0.351829	2.07E-07
98.855	0.297343	1.75E-07
98.955	0.319211	1.88E-07
99.055	0.314239	1.85E-07
99.155	0.331793	1.95E-07
99.255	0.346115	2.04E-07
99.355	0.360698	2.12E-07
99.455	0.352562	2.07E-07
99.555	0.356805	2.1E-07
99.655	0.288138	1.69E-07
99.755	0.301613	1.77E-07
99.855	0.311022	1.83E-07
99.95	0.289649	1.7E-07
100.05	0.333369	1.96E-07
100.15	0.340053	2E-07
100.25	0.364714	2.15E-07
100.35	0.385504	2.27E-07
100.45	0.355135	2.09E-07
100.545	0.36016	2.12E-07
100.645	0.330182	1.94E-07
100.745	0.338767	1.99E-07
100.845	0.362904	2.13E-07
100.945	0.333523	1.96E-07
101.045	0.346569	2.04E-07
101.145	0.344499	2.03E-07
101.245	0.3478	2.05E-07
101.345	0.345899	2.03E-07
101.445	0.297384	1.75E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
101.545	0.363253	2.14E-07
101.645	0.328006	1.93E-07
101.745	0.33699	1.98E-07
101.845	0.291209	1.71E-07
101.945	0.37544	2.21E-07
102.045	0.324126	1.91E-07
102.145	0.354278	2.08E-07
102.245	0.350843	2.06E-07
102.345	0.354006	2.08E-07
102.445	0.291329	1.71E-07
102.545	0.319908	1.88E-07
102.645	0.342731	2.02E-07
102.745	0.348639	2.05E-07
102.845	0.338655	1.99E-07
102.945	0.291948	1.72E-07
103.045	0.310279	1.83E-07
103.145	0.310931	1.83E-07
103.24	0.346294	2.04E-07
103.34	0.297098	1.75E-07
103.44	0.322831	1.9E-07
103.54	0.271142	1.59E-07
103.64	0.291359	1.71E-07
103.74	0.301061	1.77E-07
103.835	0.276009	1.62E-07
103.935	0.304645	1.79E-07
104.035	0.315928	1.86E-07
104.135	0.284906	1.68E-07
104.235	0.31094	1.83E-07
104.335	0.245145	1.44E-07
104.435	0.311396	1.83E-07
104.535	0.283976	1.67E-07
104.635	0.269176	1.58E-07
104.735	0.31068	1.83E-07
104.835	0.309702	1.82E-07
104.935	0.237091	1.39E-07
105.035	0.35967	2.12E-07
105.135	0.302475	1.78E-07
105.235	0.304077	1.79E-07
105.335	0.341521	2.01E-07
105.435	0.359386	2.11E-07
105.535	0.254863	1.5E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
105.635	0.28775	1.69E-07
105.735	0.286493	1.69E-07
105.835	0.276764	1.63E-07
105.935	0.252081	1.48E-07
106.035	0.305065	1.79E-07
106.135	0.289849	1.7E-07
106.235	0.300046	1.76E-07
106.335	0.249066	1.47E-07
106.435	0.281439	1.66E-07
106.53	0.325649	1.92E-07
106.63	0.297878	1.75E-07
106.73	0.294717	1.73E-07
106.83	0.296326	1.74E-07
106.93	0.352889	2.08E-07
107.03	0.301332	1.77E-07
107.13	0.282839	1.66E-07
107.225	0.328568	1.93E-07
107.325	0.337909	1.99E-07
107.425	0.288865	1.7E-07
107.525	0.313249	1.84E-07
107.625	0.269484	1.59E-07
107.725	0.326019	1.92E-07
107.825	0.31987	1.88E-07
107.925	0.301906	1.78E-07
108.025	0.302064	1.78E-07
108.125	0.314012	1.85E-07
108.225	0.245934	1.45E-07
108.325	0.316004	1.86E-07
108.425	0.296674	1.75E-07
108.525	0.370838	2.18E-07
108.625	0.274153	1.61E-07
108.725	0.304768	1.79E-07
108.825	0.264173	1.55E-07
108.925	0.333153	1.96E-07
109.025	0.30662	1.8E-07
109.125	0.294532	1.73E-07
109.225	0.300116	1.77E-07
109.325	0.367778	2.16E-07
109.425	0.3184	1.87E-07
109.525	0.329602	1.94E-07
109.625	0.278399	1.64E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
109.725	0.305155	1.8E-07
109.82	0.320084	1.88E-07
109.92	0.31155	1.83E-07
110.02	0.317185	1.87E-07
110.12	0.293078	1.72E-07
110.22	0.353803	2.08E-07
110.32	0.339908	2E-07
110.42	0.303533	1.79E-07
110.515	0.363863	2.14E-07
110.615	0.253043	1.49E-07
110.715	0.360272	2.12E-07
110.815	0.316136	1.86E-07
110.915	0.333553	1.96E-07
111.015	0.380103	2.24E-07
111.115	0.330965	1.95E-07
111.215	0.350055	2.06E-07
111.315	0.324116	1.91E-07
111.415	0.370236	2.18E-07
111.515	0.313515	1.84E-07
111.615	0.334472	1.97E-07
111.715	0.343802	2.02E-07
111.815	0.340327	2E-07
111.915	0.288235	1.7E-07
112.015	0.348662	2.05E-07
112.115	0.315615	1.86E-07
112.215	0.307946	1.81E-07
112.315	0.310528	1.83E-07
112.415	0.277398	1.63E-07
112.515	0.273634	1.61E-07
112.615	0.234211	1.38E-07
112.715	0.22542	1.33E-07
112.815	0.24262	1.43E-07
112.915	0.265339	1.56E-07
113.015	0.262394	1.54E-07
113.115	0.303201	1.78E-07
113.21	0.322111	1.89E-07
113.31	0.352111	2.07E-07
113.41	0.33093	1.95E-07
113.51	0.375522	2.21E-07
113.61	0.364042	2.14E-07
113.71	0.337864	1.99E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
113.805	0.285832	1.68E-07
113.905	0.310388	1.83E-07
114.005	0.308512	1.81E-07
114.105	0.33504	1.97E-07
114.205	0.273902	1.61E-07
114.305	0.340727	2E-07
114.405	0.336507	1.98E-07
114.505	0.349145	2.05E-07
114.605	0.289101	1.7E-07
114.705	0.293802	1.73E-07
114.805	0.332564	1.96E-07
114.905	0.288519	1.7E-07
115.005	0.298228	1.75E-07
115.105	0.278611	1.64E-07
115.205	-499.377	-0.00029
115.305	0.307625	1.81E-07
115.405	0.275727	1.62E-07
115.505	0.279304	1.64E-07
115.605	0.210019	1.24E-07
115.705	0.246157	1.45E-07
115.805	0.316753	1.86E-07
115.905	0.338947	1.99E-07
116.005	0.339875	2E-07
116.105	0.339263	2E-07
116.205	0.348804	2.05E-07
116.305	0.293225	1.72E-07
116.405	0.324615	1.91E-07
116.5	0.298925	1.76E-07
116.6	0.333	1.96E-07
116.7	0.321971	1.89E-07
116.8	0.345873	2.03E-07
116.9	0.301632	1.77E-07
117	0.307366	1.81E-07
117.1	0.363556	2.14E-07
117.195	0.331594	1.95E-07
117.295	0.308223	1.81E-07
117.395	0.282558	1.66E-07
117.495	0.309405	1.82E-07
117.595	0.307975	1.81E-07
117.695	0.328454	1.93E-07
117.795	0.331745	1.95E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
117.895	0.291751	1.72E-07
117.995	0.305501	1.8E-07
118.095	0.324362	1.91E-07
118.195	0.351742	2.07E-07
118.295	0.301811	1.78E-07
118.395	0.349432	2.06E-07
118.495	0.302582	1.78E-07
118.595	0.354227	2.08E-07
118.695	0.394539	2.32E-07
118.795	0.341568	2.01E-07
118.895	0.312831	1.84E-07
118.995	0.329462	1.94E-07
119.095	0.319278	1.88E-07
119.195	0.311056	1.83E-07
119.295	0.31928	1.88E-07
119.395	0.352479	2.07E-07
119.495	0.344974	2.03E-07
119.595	0.306659	1.8E-07
119.695	0.407106	2.39E-07
119.79	0.387387	2.28E-07
119.89	0.314047	1.85E-07
119.99	0.281449	1.66E-07
120.09	0.324541	1.91E-07
120.19	0.329055	1.94E-07
120.29	0.269045	1.58E-07
120.39	0.252851	1.49E-07
120.485	0.258035	1.52E-07
120.585	0.361141	2.12E-07
120.685	0.273249	1.61E-07
120.785	0.272622	1.6E-07
120.885	0.286272	1.68E-07
120.985	0.321095	1.89E-07
121.085	0.315024	1.85E-07
121.185	0.304502	1.79E-07
121.285	0.305612	1.8E-07
121.385	0.334845	1.97E-07
121.485	0.334691	1.97E-07
121.585	0.346591	2.04E-07
121.685	0.328583	1.93E-07
121.785	0.326508	1.92E-07
121.885	0.301409	1.77E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
121.985	0.337221	1.98E-07
122.085	0.272462	1.6E-07
122.185	0.328341	1.93E-07
122.285	0.349424	2.06E-07
122.385	0.340578	2E-07
122.485	0.389791	2.29E-07
122.585	0.35067	2.06E-07
122.685	0.297617	1.75E-07
122.785	0.336525	1.98E-07
122.885	0.344514	2.03E-07
122.985	0.293891	1.73E-07
123.085	0.345745	2.03E-07
123.18	0.326885	1.92E-07
123.28	0.328602	1.93E-07
123.38	0.343966	2.02E-07
123.48	0.393469	2.31E-07
123.58	0.340202	2E-07
123.68	0.347292	2.04E-07
123.775	0.354556	2.09E-07
123.875	0.380064	2.24E-07
123.975	0.380754	2.24E-07
124.075	0.470518	2.77E-07
124.175	0.386466	2.27E-07
124.275	0.437467	2.57E-07
124.375	0.433951	2.55E-07
124.475	0.453099	2.67E-07
124.575	0.430176	2.53E-07
124.675	0.360398	2.12E-07
124.775	0.36439	2.14E-07
124.875	0.398777	2.35E-07
124.975	0.377624	2.22E-07
125.075	0.332181	1.95E-07
125.175	0.403999	2.38E-07
125.275	0.367013	2.16E-07
125.375	0.381829	2.25E-07
125.475	0.366903	2.16E-07
125.575	0.39419	2.32E-07
125.675	0.359966	2.12E-07
125.775	0.367494	2.16E-07
125.875	0.353646	2.08E-07
125.975	0.350013	2.06E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
126.075	0.406193	2.39E-07
126.175	0.413652	2.43E-07
126.275	0.471322	2.77E-07
126.375	0.411116	2.42E-07
126.47	0.391354	2.3E-07
126.57	0.483967	2.85E-07
126.67	0.444288	2.61E-07
126.77	0.429173	2.52E-07
126.87	0.461874	2.72E-07
126.97	0.408713	2.4E-07
127.07	0.423453	2.49E-07
127.165	0.438433	2.58E-07
127.265	0.414233	2.44E-07
127.365	0.393096	2.31E-07
127.465	0.327476	1.93E-07
127.565	0.412627	2.43E-07
127.665	0.363737	2.14E-07
127.765	0.358951	2.11E-07
127.865	-499.3	-0.00029
127.965	0.416739	2.45E-07
128.065	0.370744	2.18E-07
128.165	0.373923	2.2E-07
128.265	0.437777	2.58E-07
128.365	0.362388	2.13E-07
128.465	0.369871	2.18E-07
128.565	0.388894	2.29E-07
128.665	0.385351	2.27E-07
128.765	0.389706	2.29E-07
128.865	0.351481	2.07E-07
128.965	0.362858	2.13E-07
129.065	0.345268	2.03E-07
129.165	0.415987	2.45E-07
129.265	0.378994	2.23E-07
129.365	0.387535	2.28E-07
129.465	0.434017	2.55E-07
129.565	0.422646	2.49E-07
129.665	0.408365	2.4E-07
129.76	0.407386	2.4E-07
129.86	0.411818	2.42E-07
129.96	0.391257	2.3E-07
130.06	0.372737	2.19E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
130.16	0.381495	2.24E-07
130.26	0.32429	1.91E-07
130.36	0.371584	2.19E-07
130.455	0.374748	2.2E-07
130.555	0.354969	2.09E-07
130.655	0.350544	2.06E-07
130.755	0.341564	2.01E-07
130.855	0.348428	2.05E-07
130.955	0.375096	2.21E-07
131.055	0.337162	1.98E-07
131.155	0.392228	2.31E-07
131.255	0.350435	2.06E-07
131.355	0.358496	2.11E-07
131.455	0.399305	2.35E-07
131.555	0.408295	2.4E-07
131.655	0.347643	2.04E-07
131.755	0.339785	2E-07
131.855	0.394764	2.32E-07
131.955	0.36722	2.16E-07
132.055	0.397178	2.34E-07
132.155	0.359392	2.11E-07
132.255	0.388646	2.29E-07
132.355	0.369505	2.17E-07
132.455	0.409344	2.41E-07
132.555	0.413114	2.43E-07
132.655	0.3868	2.28E-07
132.755	0.352656	2.07E-07
132.855	0.337367	1.98E-07
132.955	0.37962	2.23E-07
133.055	0.373604	2.2E-07
133.15	0.290965	1.71E-07
133.25	0.337894	1.99E-07
133.35	0.362131	2.13E-07
133.45	0.316057	1.86E-07
133.55	0.30641	1.8E-07
133.65	0.323178	1.9E-07
133.745	-499.334	-0.00029
133.845	0.299512	1.76E-07
133.945	0.267448	1.57E-07
134.045	0.309325	1.82E-07
134.145	0.393627	2.32E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
134.245	0.336544	1.98E-07
134.345	0.400723	2.36E-07
134.445	0.416286	2.45E-07
134.545	0.408376	2.4E-07
134.645	0.405543	2.39E-07
134.745	0.366202	2.15E-07
134.845	0.410824	2.42E-07
134.945	0.381677	2.25E-07
135.045	0.4116	2.42E-07
135.145	0.348924	2.05E-07
135.245	0.321813	1.89E-07
135.345	0.302649	1.78E-07
135.445	0.328303	1.93E-07
135.545	0.354102	2.08E-07
135.645	0.360537	2.12E-07
135.745	0.370393	2.18E-07
135.845	0.283626	1.67E-07
135.945	0.344627	2.03E-07
136.045	0.366277	2.15E-07
136.145	0.37656	2.22E-07
136.245	0.421838	2.48E-07
136.345	0.385732	2.27E-07
136.44	0.378714	2.23E-07
136.54	0.398099	2.34E-07
136.64	0.381395	2.24E-07
136.74	0.377	2.22E-07
136.84	0.384099	2.26E-07
136.94	0.389276	2.29E-07
137.04	0.421351	2.48E-07
137.135	0.407003	2.39E-07
137.235	0.390936	2.3E-07
137.335	0.3829	2.25E-07
137.435	0.405308	2.38E-07
137.535	0.385453	2.27E-07
137.635	0.386152	2.27E-07
137.735	0.409121	2.41E-07
137.835	0.407234	2.4E-07
137.935	0.404184	2.38E-07
138.035	0.448291	2.64E-07
138.135	0.384614	2.26E-07
138.235	0.348049	2.05E-07

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MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
138.335	0.343082	2.02E-07
138.435	0.362741	2.13E-07
138.535	0.34686	2.04E-07
138.635	0.369035	2.17E-07
138.735	0.366656	2.16E-07
138.835	0.412118	2.42E-07
138.935	0.323523	1.9E-07
139.035	0.402233	2.37E-07
139.135	0.406272	2.39E-07
139.235	0.364979	2.15E-07
139.335	0.392158	2.31E-07
139.435	0.377632	2.22E-07
139.535	0.382999	2.25E-07
139.635	0.417356	2.46E-07
139.735	0.415804	2.45E-07
139.83	0.423179	2.49E-07
139.93	0.400829	2.36E-07
140.03	0.379439	2.23E-07
140.13	0.434481	2.56E-07
140.23	0.407184	2.4E-07
140.33	0.48763	2.87E-07
140.425	0.410255	2.41E-07
140.525	0.430185	2.53E-07
140.625	0.424691	2.5E-07
140.725	0.460063	2.71E-07
140.825	0.431786	2.54E-07
140.925	0.425723	2.5E-07
141.025	0.408512	2.4E-07
141.125	0.3944	2.32E-07
141.225	0.402405	2.37E-07
141.325	0.401285	2.36E-07
141.425	0.397714	2.34E-07
141.525	0.415374	2.44E-07
141.625	0.392473	2.31E-07
141.725	0.430576	2.53E-07
141.825	0.432447	2.54E-07
141.925	0.424541	2.5E-07
142.025	0.415522	2.44E-07
142.125	0.432785	2.55E-07
142.225	0.423331	2.49E-07
142.325	0.450761	2.65E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
142.425	0.445793	2.62E-07
142.525	0.415752	2.45E-07
142.625	0.384252	2.26E-07
142.725	0.452163	2.66E-07
142.825	0.449667	2.65E-07
142.925	0.463165	2.72E-07
143.025	0.472348	2.78E-07
143.12	0.44892	2.64E-07
143.22	0.416258	2.45E-07
143.32	0.50097	2.95E-07
143.42	0.410656	2.42E-07
143.52	0.430391	2.53E-07
143.62	0.404329	2.38E-07
143.715	0.368427	2.17E-07
143.815	0.355138	2.09E-07
143.915	0.344335	2.03E-07
144.015	0.320244	1.88E-07
144.115	0.301484	1.77E-07
144.215	0.257188	1.51E-07
144.315	0.294032	1.73E-07
144.415	0.212717	1.25E-07
144.515	0.256875	1.51E-07
144.615	0.290322	1.71E-07
144.715	0.276815	1.63E-07
144.815	0.343131	2.02E-07
144.915	0.296046	1.74E-07
145.015	0.351385	2.07E-07
145.115	0.382893	2.25E-07
145.215	0.388206	2.28E-07
145.315	0.467565	2.75E-07
145.415	0.450562	2.65E-07
145.515	0.401603	2.36E-07
145.615	0.417844	2.46E-07
145.715	0.442571	2.6E-07
145.815	0.371499	2.19E-07
145.915	0.400954	2.36E-07
146.015	0.363923	2.14E-07
146.115	0.342509	2.01E-07
146.215	0.326831	1.92E-07
146.315	0.363915	2.14E-07
146.41	0.335086	1.97E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
146.51	0.271575	1.6E-07
146.61	0.295308	1.74E-07
146.71	0.349477	2.06E-07
146.81	0.284736	1.67E-07
146.91	0.24579	1.45E-07
147.01	0.268312	1.58E-07
147.105	0.303424	1.78E-07
147.205	0.317658	1.87E-07
147.305	0.250608	1.47E-07
147.405	0.317739	1.87E-07
147.505	0.273077	1.61E-07
147.605	0.23995	1.41E-07
147.705	0.252767	1.49E-07
147.805	0.313632	1.84E-07
147.905	0.337536	1.99E-07
148.005	0.307328	1.81E-07
148.105	0.299174	1.76E-07
148.205	0.318248	1.87E-07
148.305	0.322361	1.9E-07
148.405	0.352809	2.08E-07
148.505	0.326699	1.92E-07
148.605	0.437093	2.57E-07
148.705	0.5216	3.07E-07
148.805	-499.174	-0.00029
148.905	0.560386	3.3E-07
149.005	0.584708	3.44E-07
149.105	0.642153	3.78E-07
149.205	0.634393	3.73E-07
149.305	0.682707	4.02E-07
149.405	0.696599	4.1E-07
149.505	0.635418	3.74E-07
149.605	0.589906	3.47E-07
149.705	0.620046	3.65E-07
149.8	0.515826	3.03E-07
149.9	0.552915	3.25E-07
150	0.513105	3.02E-07
150.1	0.500958	2.95E-07
150.2	0.524597	3.09E-07
150.3	0.479885	2.82E-07
150.395	0.422907	2.49E-07
150.495	0.447615	2.63E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
150.595	0.393054	2.31E-07
150.695	0.408915	2.41E-07
150.795	0.420471	2.47E-07
150.895	0.409538	2.41E-07
150.995	0.450093	2.65E-07
151.095	0.419443	2.47E-07
151.195	0.414699	2.44E-07
151.295	0.369285	2.17E-07
151.395	0.415145	2.44E-07
151.495	-499.305	-0.00029
151.595	-499.325	-0.00029
151.695	0.384188	2.26E-07
151.795	0.411876	2.42E-07
151.895	0.41892	2.46E-07
151.995	0.354082	2.08E-07
152.095	0.336522	1.98E-07
152.195	0.293563	1.73E-07
152.295	0.410364	2.41E-07
152.395	0.328453	1.93E-07
152.495	0.311552	1.83E-07
152.595	0.312556	1.84E-07
152.695	0.321598	1.89E-07
152.795	0.320392	1.88E-07
152.895	0.318359	1.87E-07
152.995	0.306642	1.8E-07
153.09	0.319973	1.88E-07
153.19	0.277209	1.63E-07
153.29	0.289574	1.7E-07
153.39	0.270385	1.59E-07
153.49	0.326554	1.92E-07
153.59	0.302172	1.78E-07
153.685	0.357008	2.1E-07
153.785	0.391018	2.3E-07
153.885	0.430463	2.53E-07
153.985	0.398925	2.35E-07
154.085	0.352526	2.07E-07
154.185	0.353987	2.08E-07
154.285	0.370316	2.18E-07
154.385	0.324117	1.91E-07
154.485	0.324493	1.91E-07
154.585	0.319929	1.88E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
154.685	0.354378	2.08E-07
154.785	0.316184	1.86E-07
154.885	0.33583	1.98E-07
154.985	0.301831	1.78E-07
155.085	0.340815	2E-07
155.185	0.404168	2.38E-07
155.285	0.410924	2.42E-07
155.385	0.454476	2.67E-07
155.485	0.47175	2.78E-07
155.585	0.457997	2.69E-07
155.685	0.528588	3.11E-07
155.785	0.550022	3.24E-07
155.885	0.567023	3.34E-07
155.985	0.506218	2.98E-07
156.085	0.523177	3.08E-07
156.185	0.51908	3.05E-07
156.285	0.465793	2.74E-07
156.38	0.444142	2.61E-07
156.48	0.402206	2.37E-07
156.58	0.416249	2.45E-07
156.68	-499.386	-0.00029
156.78	0.307585	1.81E-07
156.88	0.239442	1.41E-07
156.98	0.296761	1.75E-07
157.075	0.278938	1.64E-07
157.175	0.254853	1.5E-07
157.275	0.226118	1.33E-07
157.375	0.291951	1.72E-07
157.475	-499.369	-0.00029
157.575	0.289621	1.7E-07
157.675	0.31094	1.83E-07
157.775	0.227888	1.34E-07
157.875	0.307046	1.81E-07
157.975	0.285732	1.68E-07
158.075	0.321239	1.89E-07
158.175	0.279214	1.64E-07
158.275	0.332734	1.96E-07
158.375	0.287036	1.69E-07
158.475	0.307287	1.81E-07
158.575	0.298631	1.76E-07
158.675	0.270235	1.59E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
158.775	0.284152	1.67E-07
158.875	0.310206	1.82E-07
158.975	0.267053	1.57E-07
159.075	0.249386	1.47E-07
159.175	0.239946	1.41E-07
159.275	0.258896	1.52E-07
159.375	0.243177	1.43E-07
159.475	0.321203	1.89E-07
159.575	0.289692	1.7E-07
159.675	0.328349	1.93E-07
159.77	0.306717	1.8E-07
159.87	0.285146	1.68E-07
159.97	0.397013	2.34E-07
160.07	0.328166	1.93E-07
160.17	0.345778	2.03E-07
160.27	0.322807	1.9E-07
160.365	0.327378	1.93E-07
160.465	0.297371	1.75E-07
160.565	0.267075	1.57E-07
160.665	0.297871	1.75E-07
160.765	0.290377	1.71E-07
160.865	0.313297	1.84E-07
160.965	0.264508	1.56E-07
161.065	0.251506	1.48E-07
161.165	0.290237	1.71E-07
161.265	0.289829	1.7E-07
161.365	0.331899	1.95E-07
161.465	0.318905	1.88E-07
161.565	0.289327	1.7E-07
161.665	0.297447	1.75E-07
161.765	0.327439	1.93E-07
161.865	0.363393	2.14E-07
161.965	0.326184	1.92E-07
162.065	0.321324	1.89E-07
162.165	0.34404	2.02E-07
162.265	0.378694	2.23E-07
162.365	0.360555	2.12E-07
162.465	0.331106	1.95E-07
162.565	0.319738	1.88E-07
162.665	0.282718	1.66E-07
162.765	0.283752	1.67E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
162.865	0.313191	1.84E-07
162.965	0.285993	1.68E-07
163.06	0.254772	1.5E-07
163.16	0.292126	1.72E-07
163.26	0.240691	1.42E-07
163.36	0.232379	1.37E-07
163.46	0.299246	1.76E-07
163.56	0.22578	1.33E-07
163.655	0.28437	1.67E-07
163.755	0.228372	1.34E-07
163.855	0.249512	1.47E-07
163.955	0.259389	1.53E-07
164.055	0.277922	1.63E-07
164.155	0.272779	1.6E-07
164.255	0.384993	2.26E-07
164.355	0.364208	2.14E-07
164.455	0.353037	2.08E-07
164.555	0.319216	1.88E-07
164.655	0.391346	2.3E-07
164.755	0.430978	2.54E-07
164.855	0.461884	2.72E-07
164.955	0.548894	3.23E-07
165.055	0.534855	3.15E-07
165.155	0.534284	3.14E-07
165.255	0.540587	3.18E-07
165.355	0.589182	3.47E-07
165.455	0.737611	4.34E-07
165.555	0.838933	4.93E-07
165.655	0.773635	4.55E-07
165.755	0.705218	4.15E-07
165.855	0.688216	4.05E-07
165.955	0.709301	4.17E-07
166.055	0.798363	4.7E-07
166.155	0.821935	4.83E-07
166.255	0.665809	3.92E-07
166.35	0.601414	3.54E-07
166.45	0.672024	3.95E-07
166.55	0.653572	3.84E-07
166.65	0.80357	4.73E-07
166.75	0.686177	4.04E-07
166.85	0.644766	3.79E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
166.95	0.594318	3.5E-07
167.045	0.546836	3.22E-07
167.145	0.543532	3.2E-07
167.245	0.533628	3.14E-07
167.345	0.51367	3.02E-07
167.445	0.463085	2.72E-07
167.545	0.475401	2.8E-07
167.645	0.467458	2.75E-07
167.745	0.474465	2.79E-07
167.845	0.398686	2.35E-07
167.945	0.47918	2.82E-07
168.045	0.479456	2.82E-07
168.145	0.522257	3.07E-07
168.245	0.490385	2.88E-07
168.345	0.566856	3.33E-07
168.445	0.550832	3.24E-07
168.545	0.568493	3.34E-07
168.645	0.531134	3.12E-07
168.745	0.575909	3.39E-07
168.845	0.592006	3.48E-07
168.945	0.55871	3.29E-07
169.045	0.526768	3.1E-07
169.145	0.523237	3.08E-07
169.245	0.553358	3.26E-07
169.345	0.523582	3.08E-07
169.445	0.465129	2.74E-07
169.545	0.447407	2.63E-07
169.64	0.410223	2.41E-07
169.74	0.507272	2.98E-07
169.84	0.470121	2.77E-07
169.94	0.42959	2.53E-07
170.04	0.427188	2.51E-07
170.14	0.429961	2.53E-07
170.24	0.427728	2.52E-07
170.335	0.449581	2.64E-07
170.435	0.472162	2.78E-07
170.535	0.680597	4E-07
170.635	0.715101	4.21E-07
170.735	0.814996	4.79E-07
170.835	0.827937	4.87E-07
170.935	0.855229	5.03E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23,
TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
171.035	0.95775	5.63E-07
171.135	1.05698	6.22E-07
171.235	0.974072	5.73E-07
171.335	0.857685	5.05E-07
171.435	0.774335	4.55E-07
171.535	0.788684	4.64E-07
171.635	0.731533	4.3E-07
171.735	0.762005	4.48E-07
171.835	0.641957	3.78E-07
171.935	0.581375	3.42E-07
172.035	0.598937	3.52E-07
172.135	0.68575	4.03E-07
172.235	0.68342	4.02E-07
172.335	0.742977	4.37E-07
172.435	0.629023	3.7E-07
172.535	0.609966	3.59E-07
172.635	0.576584	3.39E-07
172.735	0.581283	3.42E-07
172.835	0.498621	2.93E-07
172.935	-499.33	-0.00029
173.03	0.409573	2.41E-07
173.13	0.409907	2.41E-07
173.23	0.430676	2.53E-07
173.33	0.478363	2.81E-07
173.43	0.442377	2.6E-07
173.53	0.452553	2.66E-07
173.63	0.592488	3.49E-07
173.725	0.606647	3.57E-07
173.825	0.703227	4.14E-07
173.925	0.726773	4.28E-07
174.025	0.680825	4E-07
174.125	0.762029	4.48E-07
174.225	0.797775	4.69E-07
174.325	0.734023	4.32E-07
174.425	0.770725	4.53E-07
174.525	0.747142	4.39E-07
174.625	0.711265	4.18E-07
174.725	0.665588	3.92E-07
174.825	0.678453	3.99E-07
174.925	0.681018	4.01E-07
175.025	0.781957	4.6E-07

**MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23,
TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH**

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
175.125	0.756792	4.45E-07
175.225	0.680906	4.01E-07
175.325	0.753573	4.43E-07
175.425	0.816214	4.8E-07
175.525	0.744172	4.38E-07
175.625	0.719293	4.23E-07
175.725	0.723397	4.26E-07
175.825	0.722781	4.25E-07
175.925	0.698319	4.11E-07
176.025	0.681401	4.01E-07
176.125	0.714589	4.2E-07
176.225	0.675572	3.97E-07
176.32	0.677521	3.99E-07
176.42	0.773407	4.55E-07
176.52	0.674816	3.97E-07
176.62	0.738852	4.35E-07
176.72	0.734789	4.32E-07
176.82	0.752729	4.43E-07
176.92	0.856173	5.04E-07
177.015	0.888081	5.22E-07
177.115	0.86398	5.08E-07
177.215	0.889855	5.23E-07
177.315	0.875356	5.15E-07
177.415	0.80137	4.71E-07
177.515	0.779688	4.59E-07
177.615	0.80994	4.76E-07
177.715	0.664979	3.91E-07
177.815	0.712253	4.19E-07
177.915	0.727146	4.28E-07
178.015	0.648545	3.81E-07
178.115	0.602065	3.54E-07
178.215	0.560284	3.3E-07
178.315	0.579837	3.41E-07
178.415	0.584158	3.44E-07
178.515	0.604649	3.56E-07
178.615	0.573065	3.37E-07
178.715	0.625933	3.68E-07
178.815	0.582031	3.42E-07
178.915	0.606495	3.57E-07
179.015	0.692498	4.07E-07
179.115	0.657295	3.87E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
179.215	0.640593	3.77E-07
179.315	0.683987	4.02E-07
179.415	0.613885	3.61E-07
179.515	0.634522	3.73E-07
179.61	0.640595	3.77E-07
179.71	0.598446	3.52E-07
179.81	0.558519	3.29E-07
179.91	0.561111	3.3E-07
180.01	0.589418	3.47E-07
180.11	0.635891	3.74E-07
180.21	0.683734	4.02E-07
180.305	0.677305	3.98E-07
180.405	0.706926	4.16E-07
180.505	0.656131	3.86E-07
180.605	0.702227	4.13E-07
180.705	0.691032	4.06E-07
180.805	0.695052	4.09E-07
180.905	0.717829	4.22E-07
181.005	0.761316	4.48E-07
181.105	0.791133	4.65E-07
181.205	0.704512	4.14E-07
181.305	0.67222	3.95E-07
181.405	0.621721	3.66E-07
181.505	0.625192	3.68E-07
181.605	0.713794	4.2E-07
181.705	0.724367	4.26E-07
181.805	0.830539	4.89E-07
181.905	0.825079	4.85E-07
182.005	0.767333	4.51E-07
182.105	0.695222	4.09E-07
182.205	0.758945	4.46E-07
182.305	0.975257	5.74E-07
182.405	1.110565	6.53E-07
182.505	0.954735	5.62E-07
182.605	0.739485	4.35E-07
182.705	0.676087	3.98E-07
182.805	0.803123	4.72E-07
182.905	0.895525	5.27E-07
183	0.879399	5.17E-07
183.1	0.781068	4.59E-07
183.2	0.799227	4.7E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
183.3	0.874175	5.14E-07
183.4	0.831548	4.89E-07
183.5	0.896169	5.27E-07
183.6	0.961736	5.66E-07
183.695	0.906541	5.33E-07
183.795	0.899839	5.29E-07
183.895	0.839126	4.94E-07
183.995	0.807505	4.75E-07
184.095	0.763589	4.49E-07
184.195	-499.225	-0.00029
184.295	0.745284	4.38E-07
184.395	0.644056	3.79E-07
184.495	0.586578	3.45E-07
184.595	0.552464	3.25E-07
184.695	0.501722	2.95E-07
184.795	0.493384	2.9E-07
184.895	0.499852	2.94E-07
184.995	0.529564	3.12E-07
185.095	0.586035	3.45E-07
185.195	0.573993	3.38E-07
185.295	0.520718	3.06E-07
185.395	0.535747	3.15E-07
185.495	0.500985	2.95E-07
185.595	0.525644	3.09E-07
185.695	0.572536	3.37E-07
185.795	0.540208	3.18E-07
185.895	0.526131	3.09E-07
185.995	0.518963	3.05E-07
186.095	0.501033	2.95E-07
186.195	0.559723	3.29E-07
186.29	0.56412	3.32E-07
186.39	0.53404	3.14E-07
186.49	0.503572	2.96E-07
186.59	0.519747	3.06E-07
186.69	0.553958	3.26E-07
186.79	0.803551	4.73E-07
186.89	0.928286	5.46E-07
186.985	0.857858	5.05E-07
187.085	0.842875	4.96E-07
187.185	0.839566	4.94E-07
187.285	1.046329	6.15E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
187.385	1.158695	6.82E-07
187.485	0.962139	5.66E-07
187.585	0.814797	4.79E-07
187.685	0.670671	3.95E-07
187.785	0.796213	4.68E-07
187.885	0.801058	4.71E-07
187.985	0.58364	3.43E-07
188.085	0.538419	3.17E-07
188.185	0.431286	2.54E-07
188.285	0.464239	2.73E-07
188.385	0.430983	2.54E-07
188.485	0.4895	2.88E-07
188.585	0.589321	3.47E-07
188.685	0.650306	3.83E-07
188.785	0.716843	4.22E-07
188.885	0.72317	4.25E-07
188.985	0.688261	4.05E-07
189.085	0.703521	4.14E-07
189.185	0.761599	4.48E-07
189.285	0.891829	5.25E-07
189.385	1.017921	5.99E-07
189.485	1.039638	6.12E-07
189.58	0.974505	5.73E-07
189.68	1.0021	5.89E-07
189.78	1.008096	5.93E-07
189.88	1.070216	6.3E-07
189.98	0.986251	5.8E-07
190.08	0.835192	4.91E-07
190.18	0.811606	4.77E-07
190.275	0.847584	4.99E-07
190.375	0.856073	5.04E-07
190.475	0.814646	4.79E-07
190.575	0.668259	3.93E-07
190.675	0.692452	4.07E-07
190.775	0.721394	4.24E-07
190.875	0.71504	4.21E-07
190.975	0.730016	4.29E-07
191.075	0.751895	4.42E-07
191.175	0.760308	4.47E-07
191.275	0.758786	4.46E-07
191.375	0.705149	4.15E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23,
TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
191.475	0.684223	4.02E-07
191.575	0.671493	3.95E-07
191.675	0.606972	3.57E-07
191.775	0.5372	3.16E-07
191.875	0.580868	3.42E-07
191.975	0.602067	3.54E-07
192.075	0.677583	3.99E-07
192.175	0.685648	4.03E-07
192.275	0.755775	4.45E-07
192.375	0.746396	4.39E-07
192.475	0.783472	4.61E-07
192.575	0.887668	5.22E-07
192.675	0.872549	5.13E-07
192.775	0.803857	4.73E-07
192.875	0.788356	4.64E-07
192.97	0.803869	4.73E-07
193.07	0.730364	4.3E-07
193.17	0.644636	3.79E-07
193.27	0.618094	3.64E-07
193.37	0.560389	3.3E-07
193.47	0.561485	3.3E-07
193.57	0.715061	4.21E-07
193.665	0.707954	4.16E-07
193.765	0.666983	3.92E-07
193.865	0.73095	4.3E-07
193.965	0.705085	4.15E-07
194.065	0.665286	3.91E-07
194.165	0.745527	4.39E-07
194.265	0.682211	4.01E-07
194.365	0.660839	3.89E-07
194.465	0.628463	3.7E-07
194.565	0.596054	3.51E-07
194.665	0.546047	3.21E-07
194.765	0.454725	2.67E-07
194.865	0.501141	2.95E-07
194.965	0.427693	2.52E-07
195.065	0.491836	2.89E-07
195.165	0.513618	3.02E-07
195.265	0.579695	3.41E-07
195.365	0.545308	3.21E-07
195.465	0.520323	3.06E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
195.565	0.592295	3.48E-07
195.665	0.616741	3.63E-07
195.765	0.622106	3.66E-07
195.865	0.667865	3.93E-07
195.965	0.597519	3.51E-07
196.065	0.523698	3.08E-07
196.165	0.540061	3.18E-07
196.26	0.532842	3.13E-07
196.36	0.550044	3.24E-07
196.46	0.524365	3.08E-07
196.56	0.566826	3.33E-07
196.66	0.654785	3.85E-07
196.76	0.63708	3.75E-07
196.86	0.580475	3.41E-07
196.955	0.602651	3.55E-07
197.055	0.690901	4.06E-07
197.155	0.761238	4.48E-07
197.255	0.773148	4.55E-07
197.355	0.692967	4.08E-07
197.455	0.620953	3.65E-07
197.555	0.603573	3.55E-07
197.655	0.566306	3.33E-07
197.755	0.489977	2.88E-07
197.855	0.492752	2.9E-07
197.955	0.459574	2.7E-07
198.055	0.388547	2.29E-07
198.155	0.287272	1.69E-07
198.255	0.358676	2.11E-07
198.355	0.33586	1.98E-07
198.455	0.350137	2.06E-07
198.555	0.462332	2.72E-07
198.655	0.514336	3.03E-07
198.755	0.516809	3.04E-07
198.855	0.50531	2.97E-07
198.955	0.498643	2.93E-07
199.055	0.43219	2.54E-07
199.155	0.618645	3.64E-07
199.255	0.731103	4.3E-07
199.355	0.753419	4.43E-07
199.455	0.759007	4.46E-07
199.55	0.654921	3.85E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23,
TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
199.65	0.660961	3.89E-07
199.75	0.724408	4.26E-07
199.85	0.834201	4.91E-07
199.95	0.870937	5.12E-07
200.05	0.832355	4.9E-07
200.15	0.739491	4.35E-07
200.245	0.661784	3.89E-07
200.345	0.656561	3.86E-07
200.445	0.681786	4.01E-07
200.545	0.641195	3.77E-07
200.645	0.627736	3.69E-07
200.745	0.718276	4.23E-07
200.845	0.717097	4.22E-07
200.945	0.769756	4.53E-07
201.045	0.837796	4.93E-07
201.145	0.785704	4.62E-07
201.245	0.835949	4.92E-07
201.345	0.847627	4.99E-07
201.445	0.711571	4.19E-07
201.545	0.650178	3.82E-07
201.645	0.841109	4.95E-07
201.745	0.849189	5E-07
201.845	0.710185	4.18E-07
201.945	0.515027	3.03E-07
202.045	0.373515	2.2E-07
202.145	0.404392	2.38E-07
202.245	0.53065	3.12E-07
202.345	0.517974	3.05E-07
202.445	0.535171	3.15E-07
202.545	0.519303	3.05E-07
202.645	0.511605	3.01E-07
202.745	0.597729	3.52E-07
202.845	0.584541	3.44E-07
202.94	0.630366	3.71E-07
203.04	0.677933	3.99E-07
203.14	0.630015	3.71E-07
203.24	0.670818	3.95E-07
203.34	0.639776	3.76E-07
203.44	0.65789	3.87E-07
203.54	0.704181	4.14E-07
203.635	0.662283	3.9E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
203.735	0.602384	3.54E-07
203.835	0.632605	3.72E-07
203.935	0.55525	3.27E-07
204.035	0.57918	3.41E-07
204.135	0.566467	3.33E-07
204.235	0.545259	3.21E-07
204.335	0.542099	3.19E-07
204.435	0.493603	2.9E-07
204.535	0.503506	2.96E-07
204.635	0.437199	2.57E-07
204.735	0.470571	2.77E-07
204.835	0.574535	3.38E-07
204.935	0.602738	3.55E-07
205.035	0.538374	3.17E-07
205.135	0.484859	2.85E-07
205.235	0.508482	2.99E-07
205.335	0.691795	4.07E-07
205.435	0.925797	5.45E-07
205.535	0.821804	4.83E-07
205.635	0.660702	3.89E-07
205.735	0.646072	3.8E-07
205.835	0.666778	3.92E-07
205.935	0.774633	4.56E-07
206.035	0.82916	4.88E-07
206.135	0.688431	4.05E-07
206.23	0.63468	3.73E-07
206.33	0.650728	3.83E-07
206.43	0.647698	3.81E-07
206.53	0.609481	3.59E-07
206.63	0.545088	3.21E-07
206.73	0.488253	2.87E-07
206.83	0.486697	2.86E-07
206.925	0.514895	3.03E-07
207.025	0.539394	3.17E-07
207.125	0.585237	3.44E-07
207.225	0.569072	3.35E-07
207.325	0.520675	3.06E-07
207.425	0.431846	2.54E-07
207.525	0.434065	2.55E-07
207.625	0.461511	2.71E-07
207.725	0.505719	2.97E-07

WIEDEMEIER & ASSOCIATES

MASS MAGNETIC SUSCEPTIBILITY DATA FROM WELL D-23, TOOELE ARMY AMMUNITION DEPOT, TOOELE, UTAH

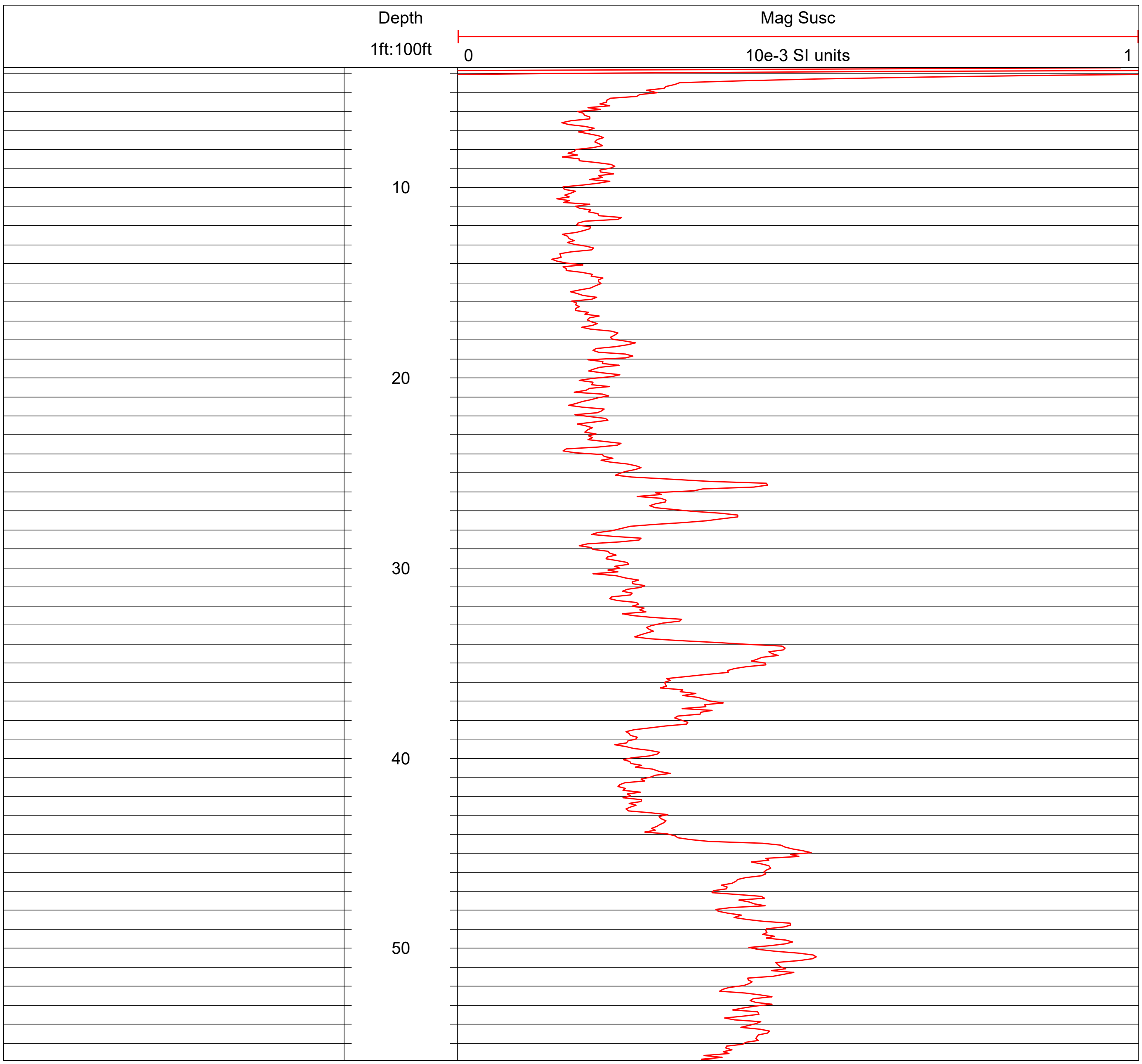
Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m3/kg
207.825	0.523851	3.08E-07
207.925	0.59776	3.52E-07
208.025	0.608457	3.58E-07
208.125	0.510087	3E-07
208.225	0.525836	3.09E-07
208.325	0.537279	3.16E-07
208.425	0.618975	3.64E-07
208.525	0.650798	3.83E-07
208.625	0.640392	3.77E-07
208.725	0.597685	3.52E-07
208.825	0.610317	3.59E-07
208.93	0.695498	4.09E-07
209.03	0.700919	4.12E-07
209.13	0.675432	3.97E-07
209.23	0.655904	3.86E-07
209.33	0.74349	4.37E-07
209.43	0.670265	3.94E-07
209.52	0.706701	4.16E-07
209.62	0.678592	3.99E-07
209.72	0.726418	4.27E-07
209.82	0.7568	4.45E-07
209.92	0.635666	3.74E-07
210.02	0.651881	3.83E-07
210.12	0.693402	4.08E-07
210.22	0.668349	3.93E-07
210.32	0.654885	3.85E-07
210.42	0.682838	4.02E-07
210.52	0.752626	4.43E-07
210.62	0.675642	3.97E-07
210.72	0.640173	3.77E-07
210.82	0.686351	4.04E-07

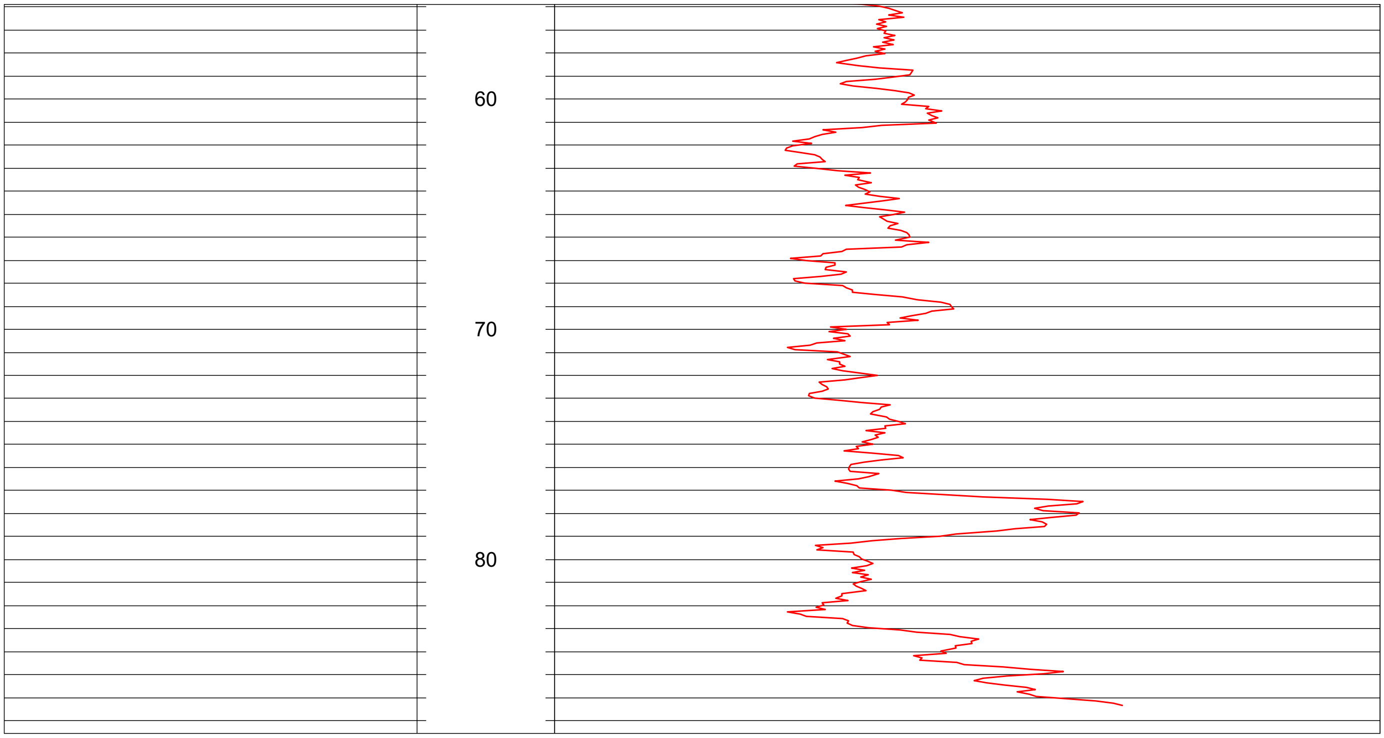
WIEDEMEIER & ASSOCIATES

PROJECT	ESTCP 201584
LOCATION	Tooele Army Ammunition Depot
WELL	D-20 Down
LOGGER	T.H. Wiedemeier
DATE	7/25/16

TOOL	HMA-453-S
CALIBRATION DATE/TIME	7/25/16
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	0 = 230 and 5E-3 = 1326.4 cps
REMARKS	

4" Well

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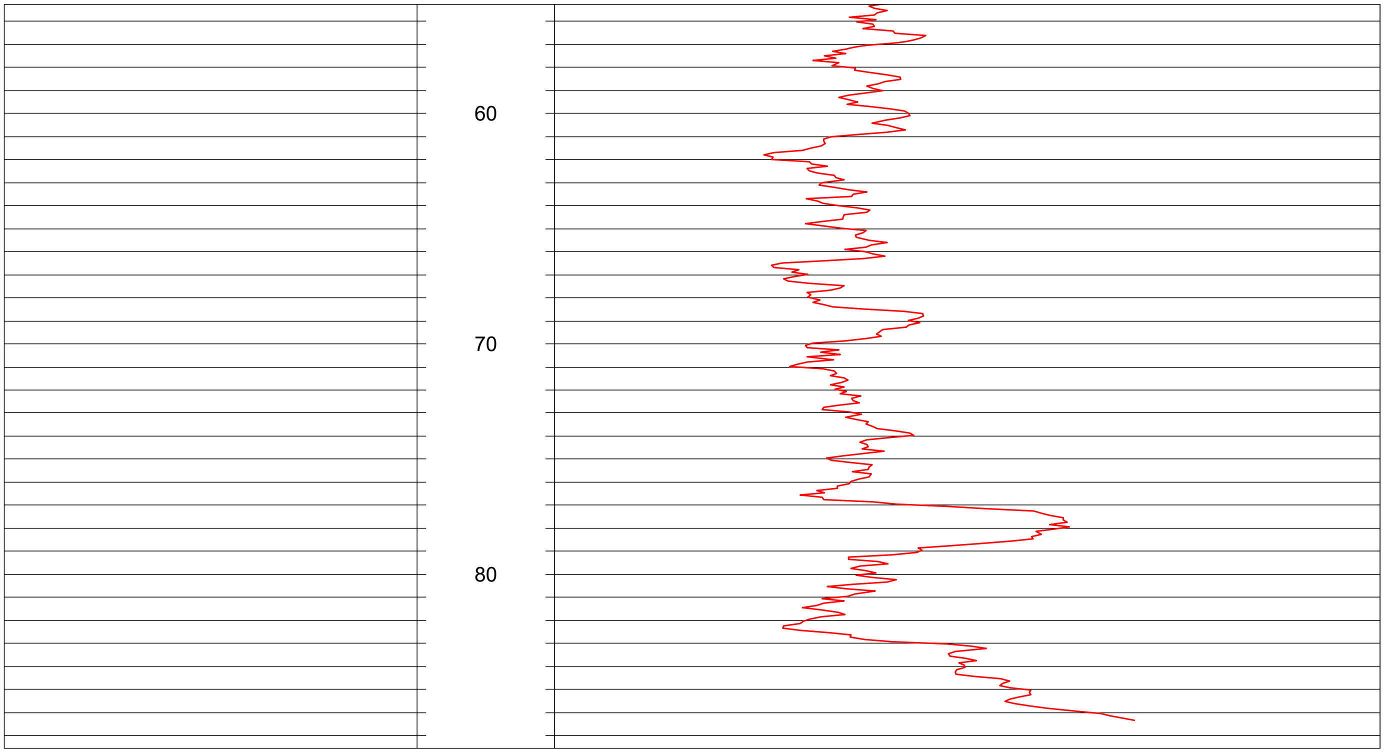
70
80

WIEDEMEIER & ASSOCIATES

PROJECT	ESTCP 201584
LOCATION	Tooele Army Ammunition Depot
WELL	D-20 Up
LOGGER	T.H. Wiedemeier
DATE	7/25/16

TOOL	HMA-453-S
CALIBRATION DATE/TIME	7/25/16
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	0 = 230 and 5E-3 = 1326.4 cps
REMARKS	4" Well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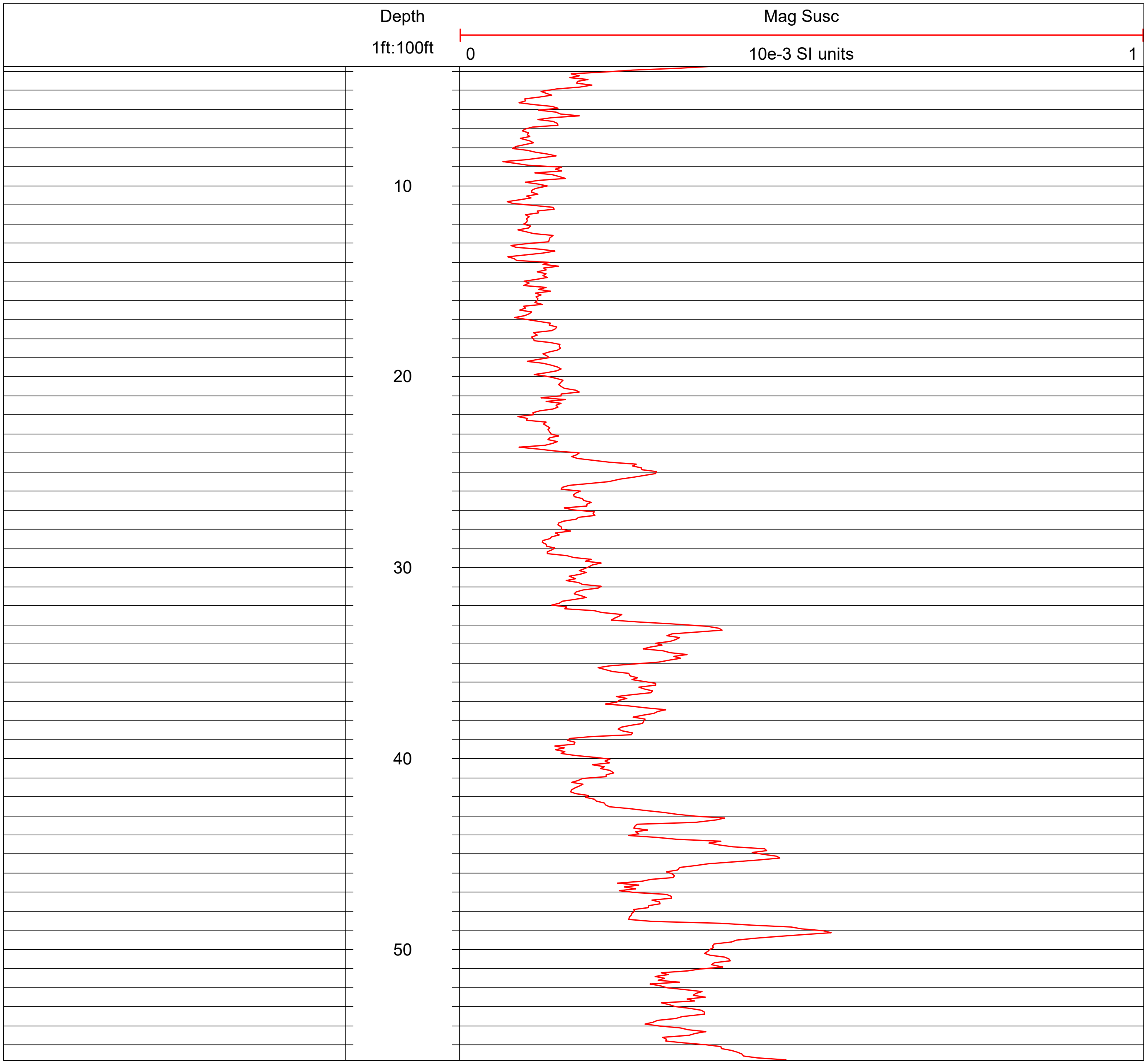
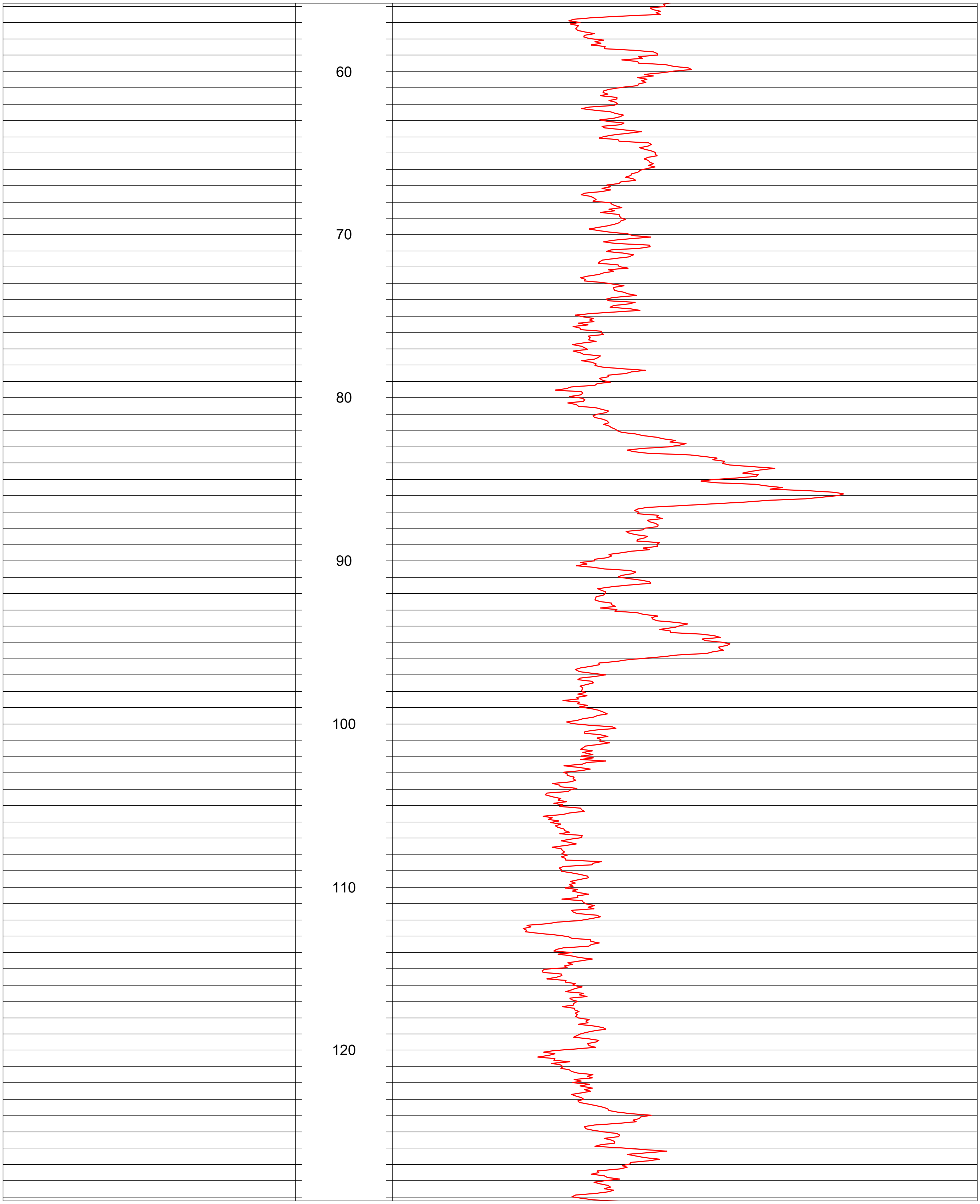
70
80

PROJECT	ESTCP 201584
LOCATION	Tooele Army Ammunition Depot
WELL	D-23 Down
LOGGER	T.H. Wiedemeier
DATE	7/25/16

TOOL	HMA-453-S
CALIBRATION DATE/TIME	7/25/16 - 13:20
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	0 = 230 and 5E-3 = 1326.4 cps
DEPTH TO WATER, TD	67.38 ft BTOC, 212 ft BGS
CASING INNER DIAMETER	4"
REMARKS	

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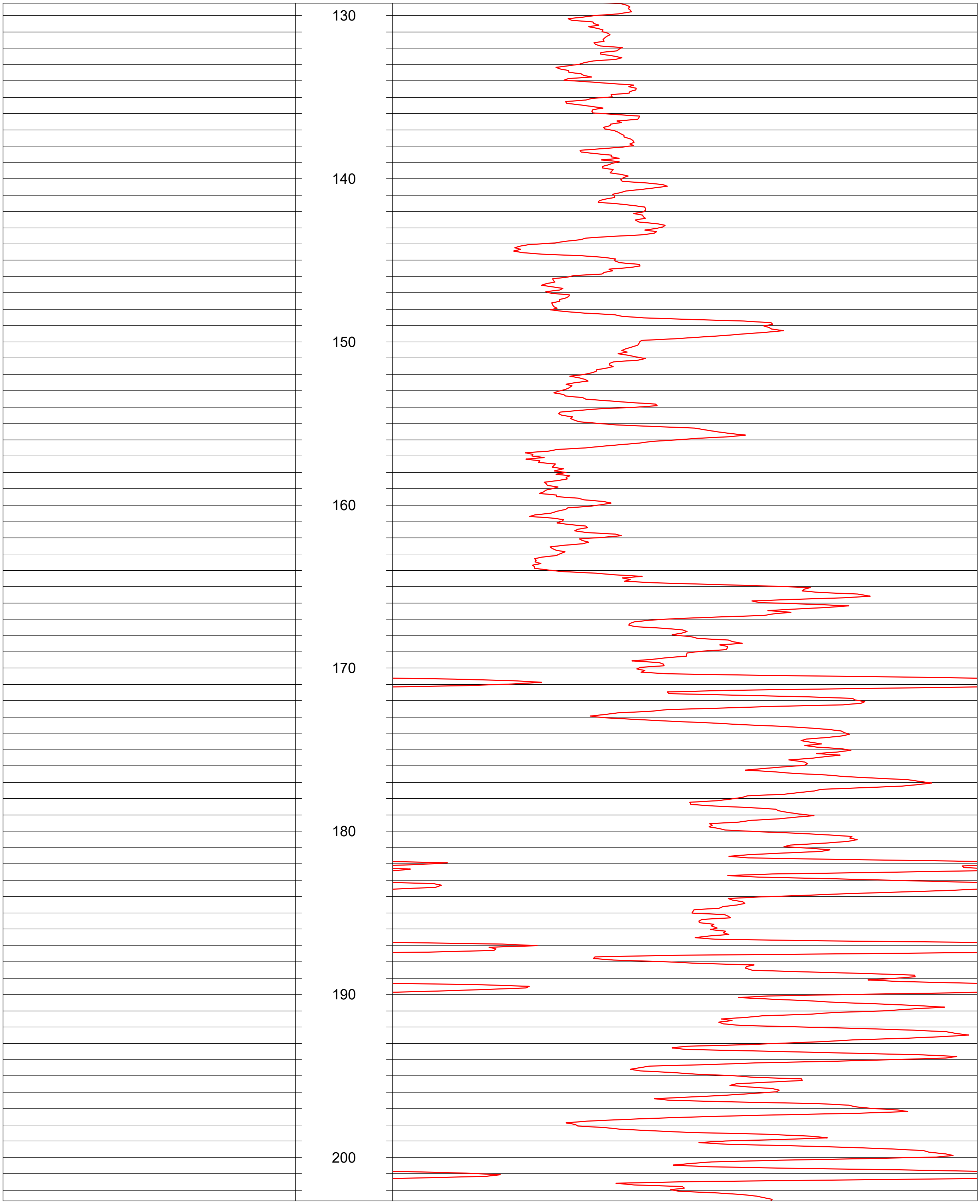
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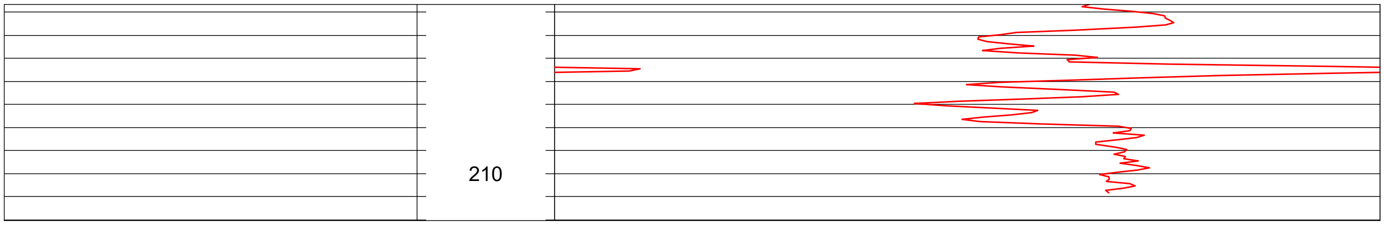
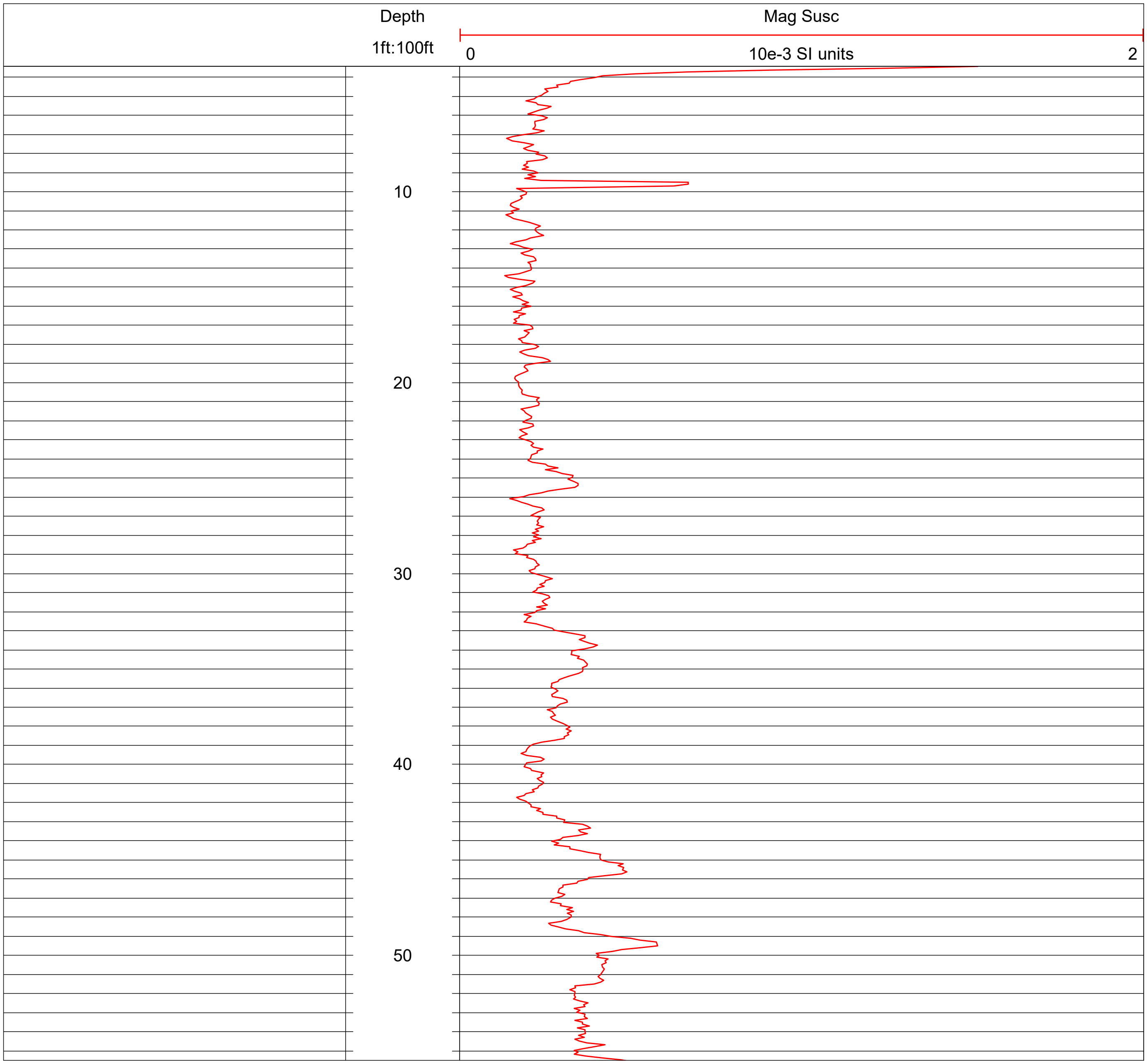
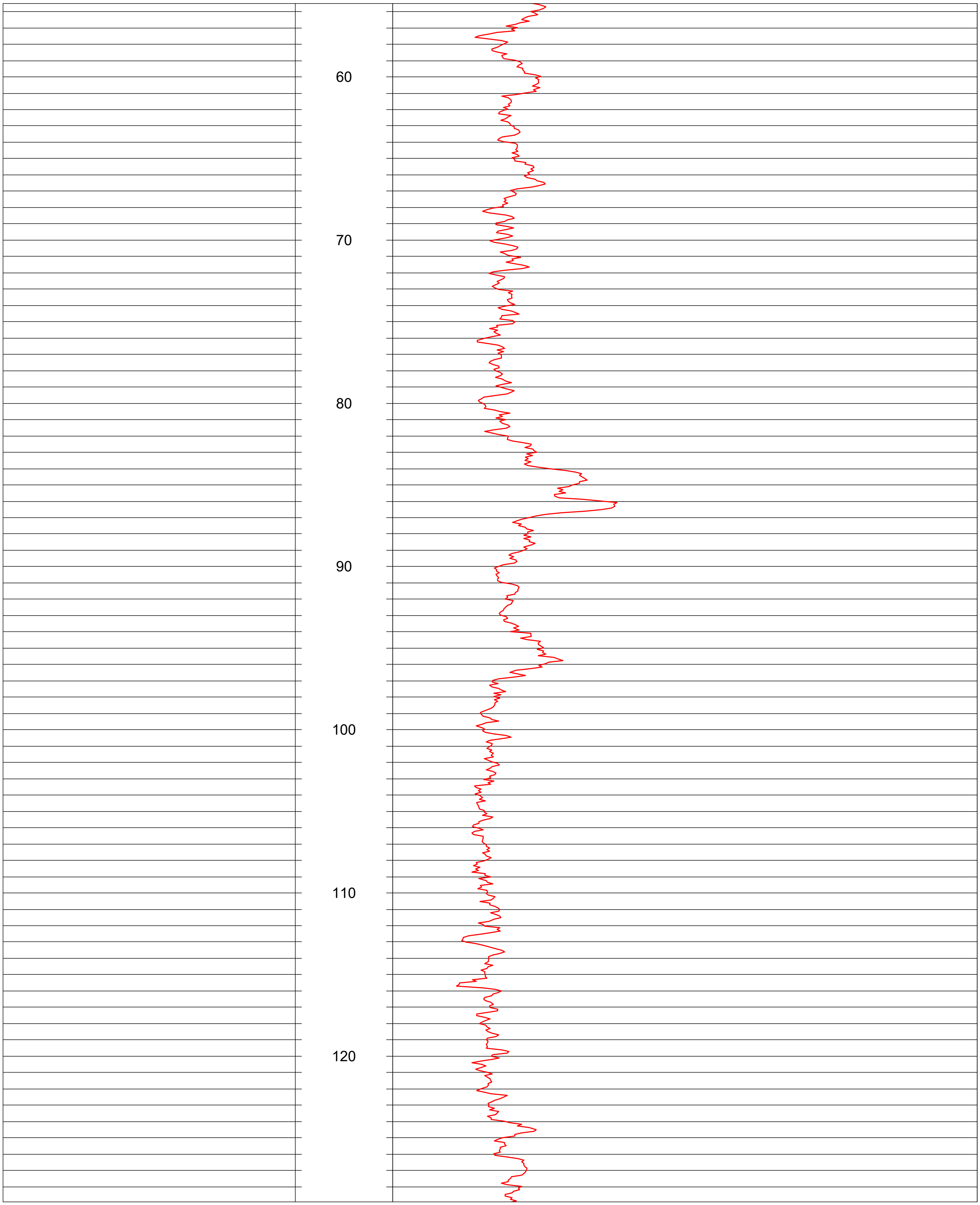
140
150
160
170
180
190
200


210

PROJECT	ESTCP 201584
LOCATION	Tooele Army Ammunition Depot
WELL	D-23 Up
LOGGER	T.H. Wiedemeier
DATE	7/25/16

TOOL	HMA-453-S
CALIBRATION DATE/TIME	7/25/16
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	0 = 230 and 5E-3 = 1326.4 cps
DEPTH TO WATER, TD	67.38 ft BTOC, 212 ft BGS
CASING INNER DIAMETER	4"
REMARKS	

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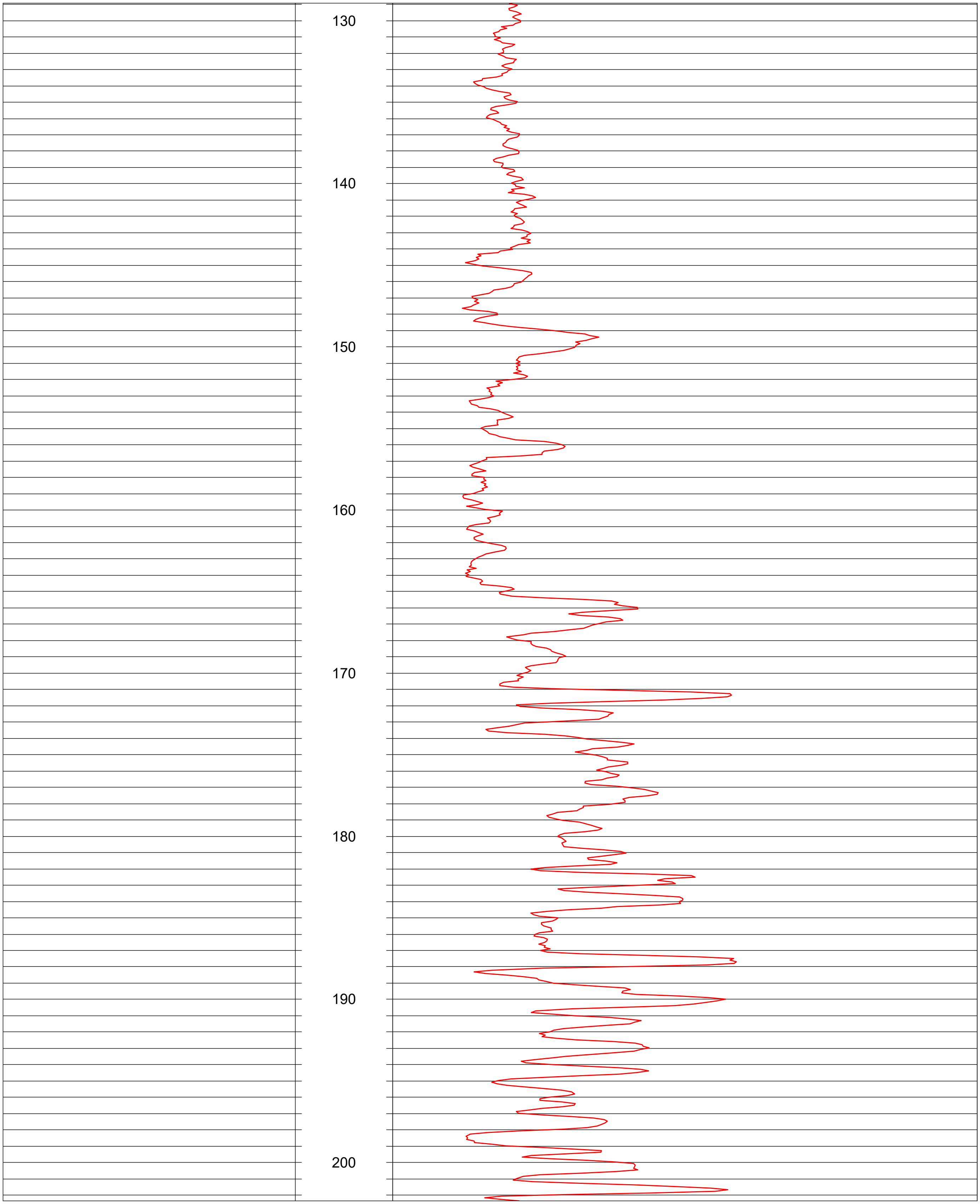
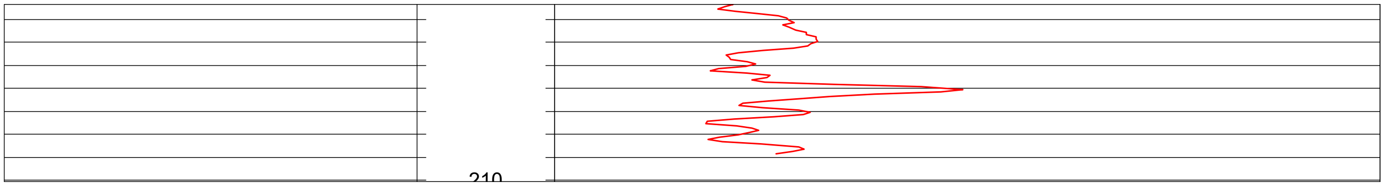
70
80
90
100
110
120

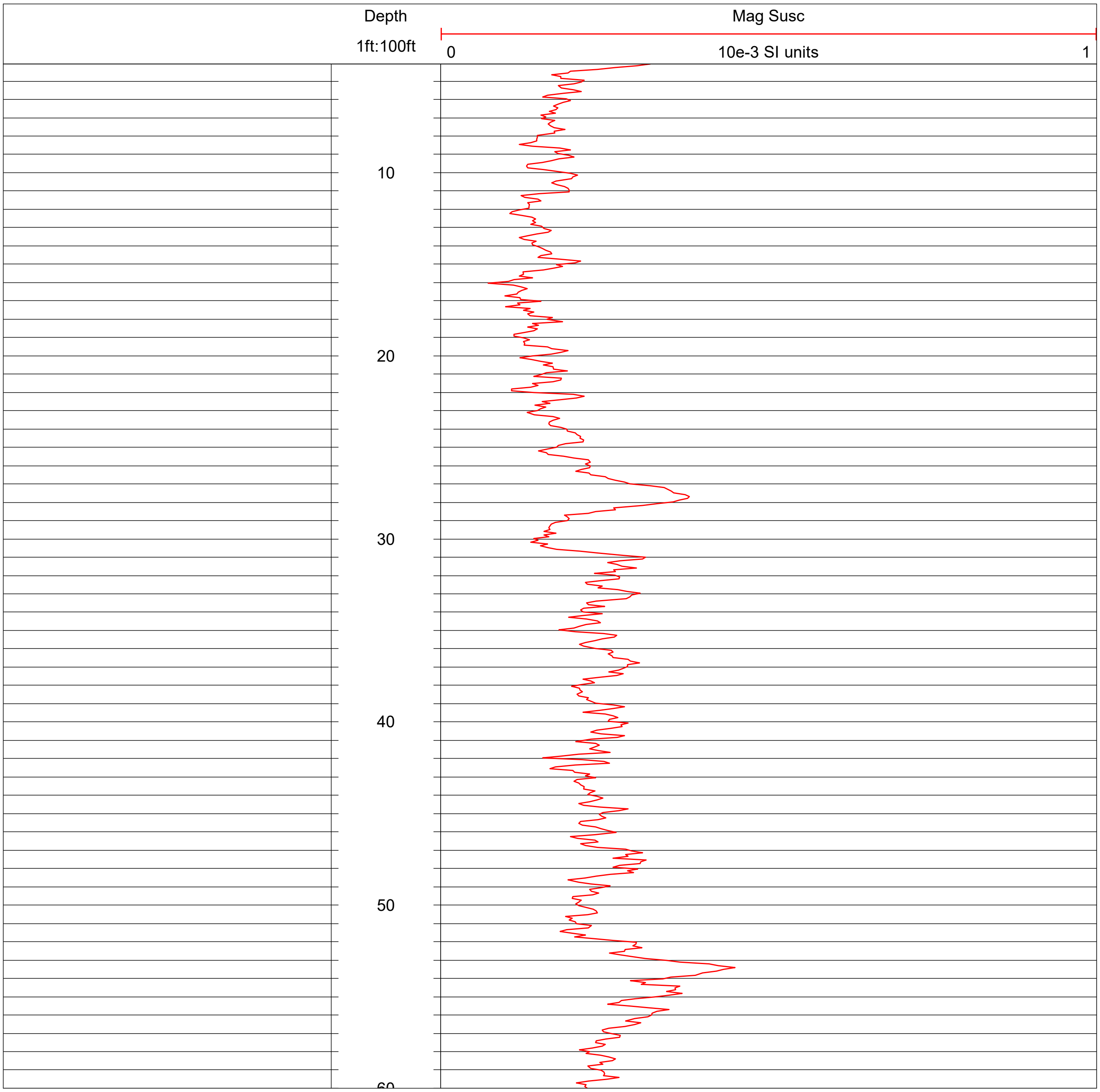

130
140
150
160
170
180
190
200

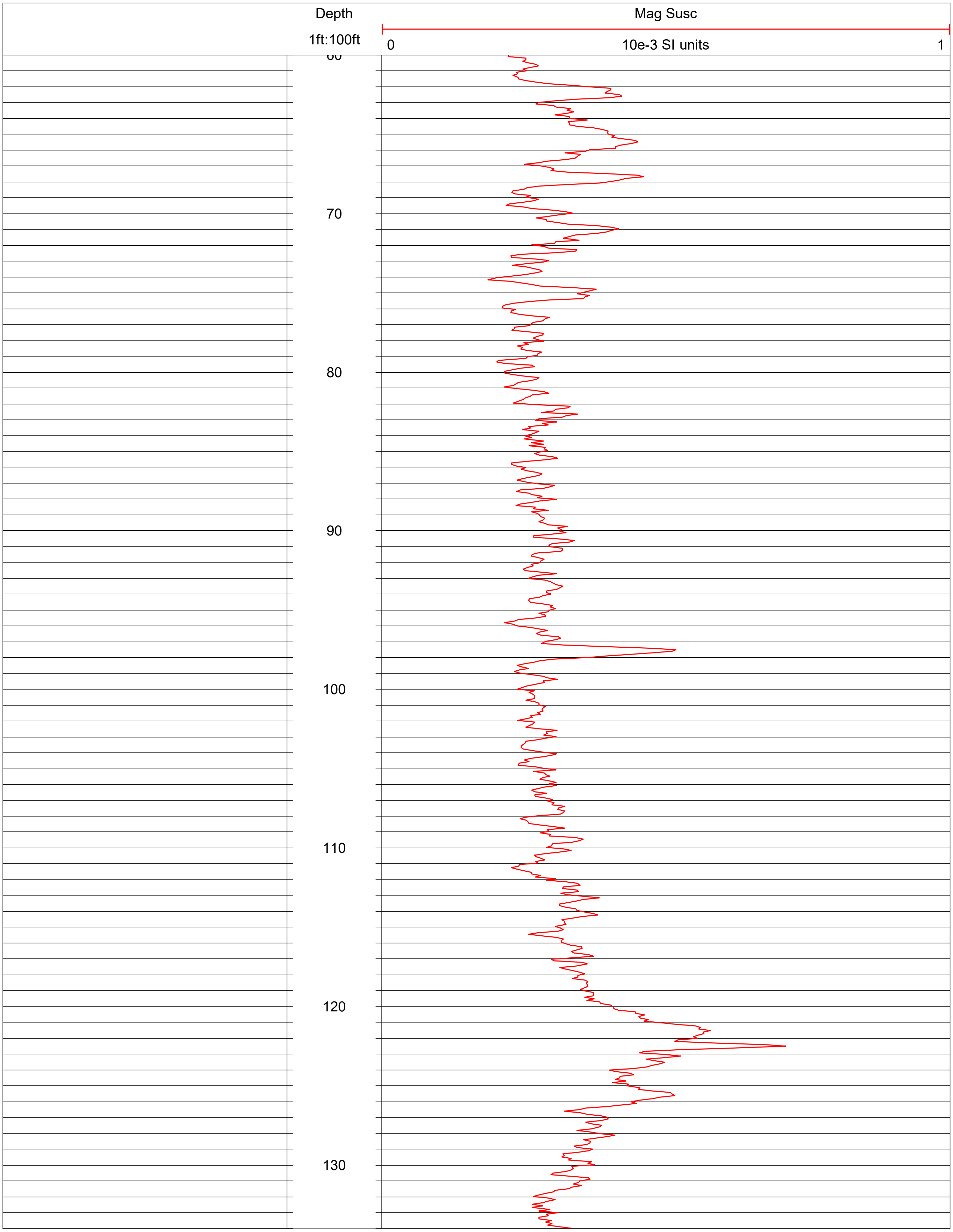

210

WIEDEMEIER & ASSOCIATES

PROJECT	ESTCP 201584
LOCATION	Tooele Army Ammunition Depot
WELL	D-25 Down
LOGGER	T.H. Wiedemeier
DATE	7/26/16

TOOL	HMA-453-S
CALIBRATION DATE/TIME	7/26/16 -- 10:23
CALIBRATION STANDARDS	0 and 5E-3
CALIBRATION RESULTS	0 = 236.4 and 5E-3 = 1433 cps
DEPTH TO WATER, TD	87.42 ft BTOC, 195 ft BGS
CASING INNER DIAMETER	4"
REMARKS	



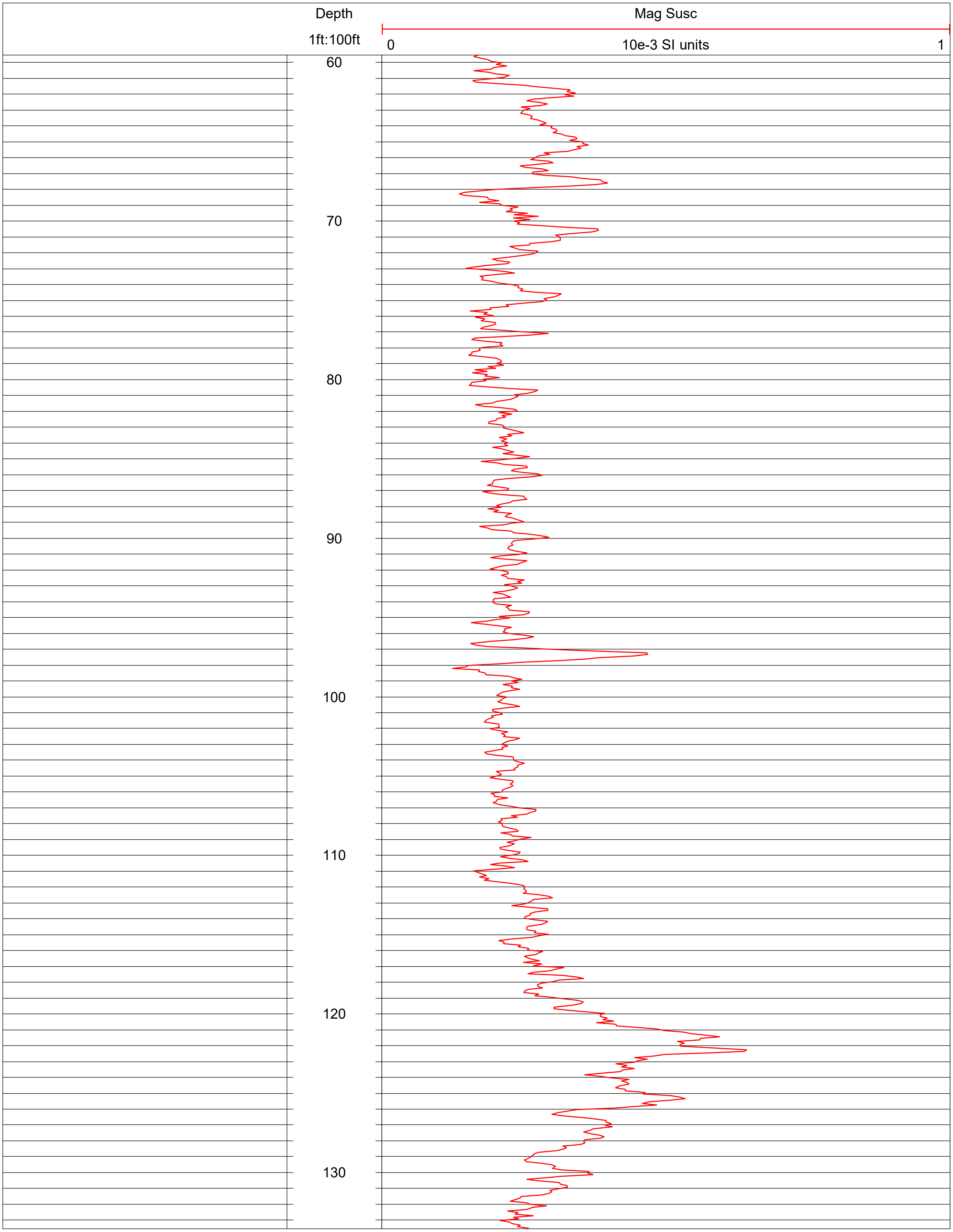

Depth
1ft:100ft
Mag Susc
0
10e-3 SI units
1
70
80
90
100
110
120
130


Depth
1ft:100ft
Mag Susc
0
10e-3 SI units
1
140
150
160
170
180
190

WIEDEMEIER & ASSOCIATES

PROJECT	ESTCP 201584
LOCATION	Tooele Army Ammunition Depot
WELL	D-25 Up
LOGGER	T.H. Wiedemeier
DATE	7/26/16

TOOL	HMA-453-S
CALIBRATION DATE/TIME	7/26/16 -- 10:23
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	0 = 236.4 and 5E-3 = 1433 cps
DEPTH TO WATER, TD	87.42 ft BTOC, 195 ft BGS
CASING INNER DIAMETER	4"
REMARKS	


Depth
1ft:100ft
Mag Susc
0
10e-3 SI units
1
60
70
80
90
100
110
120
130


Depth
1ft:100ft
Mag Susc
0
10e-3 SI units
1
140
150
160
170
180
190

WIEDEMEIER & ASSOCIATES

PROJECT ESTCP 201584

LOCATION Tooele Army Ammunition Depot

WELL D-19 Down

LOGGER TH Wiedemeier

DATE 7/26/16

TOOL HMA-453-S

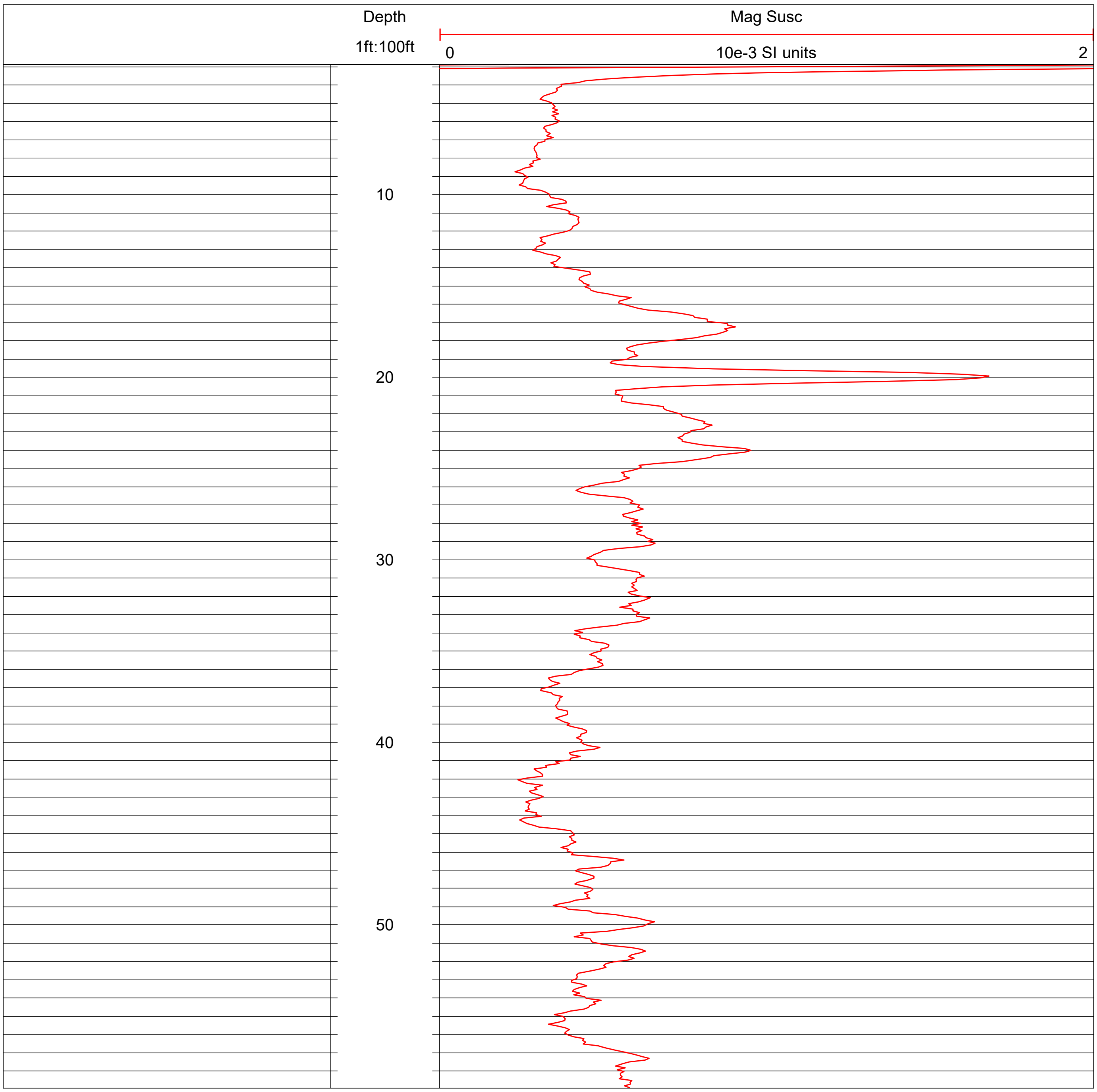
CALIBRATION DATE/TIME 7/26/16 - 14:44

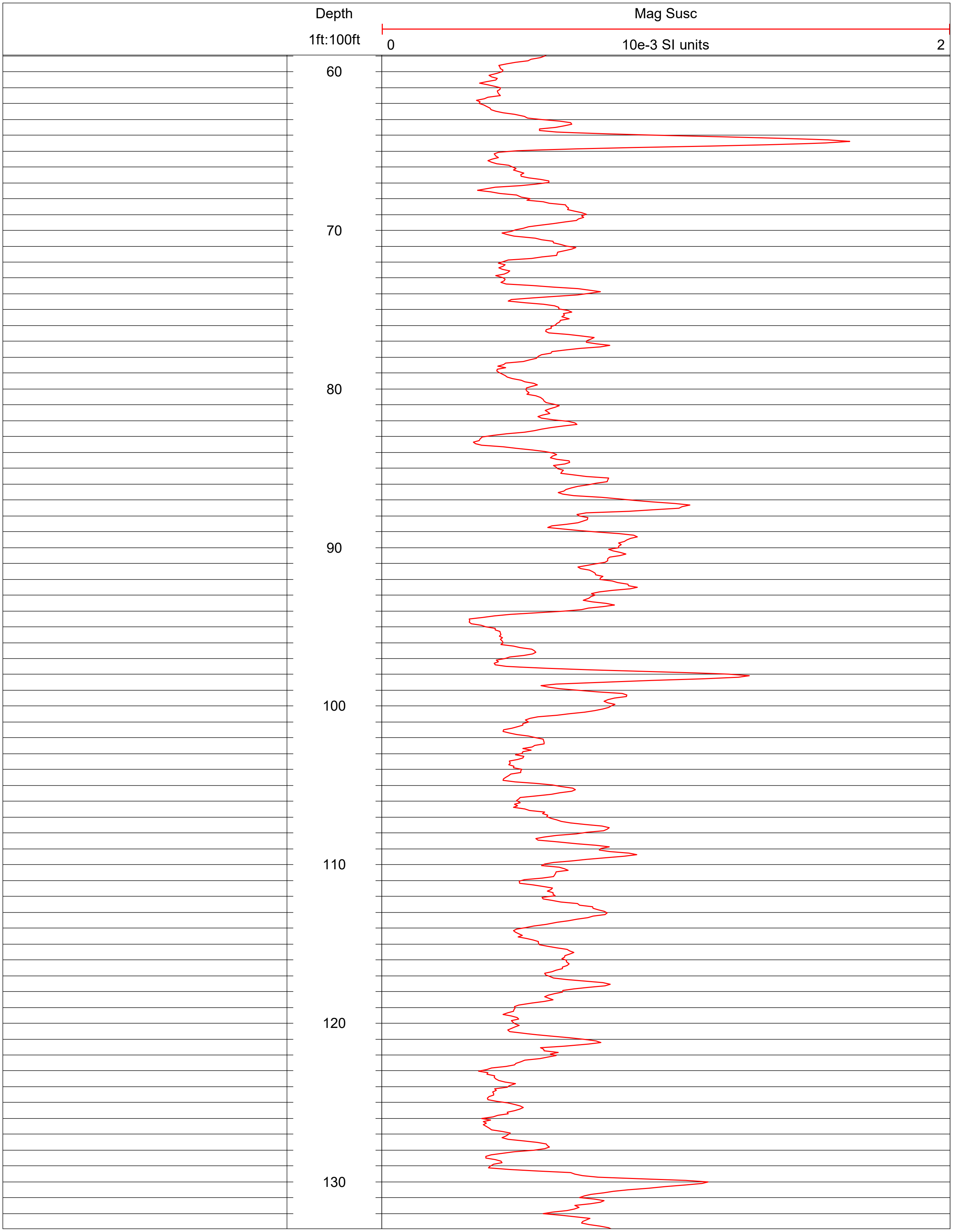
CALIBRATION STANDARDS 0 and 5E-3 SI Units

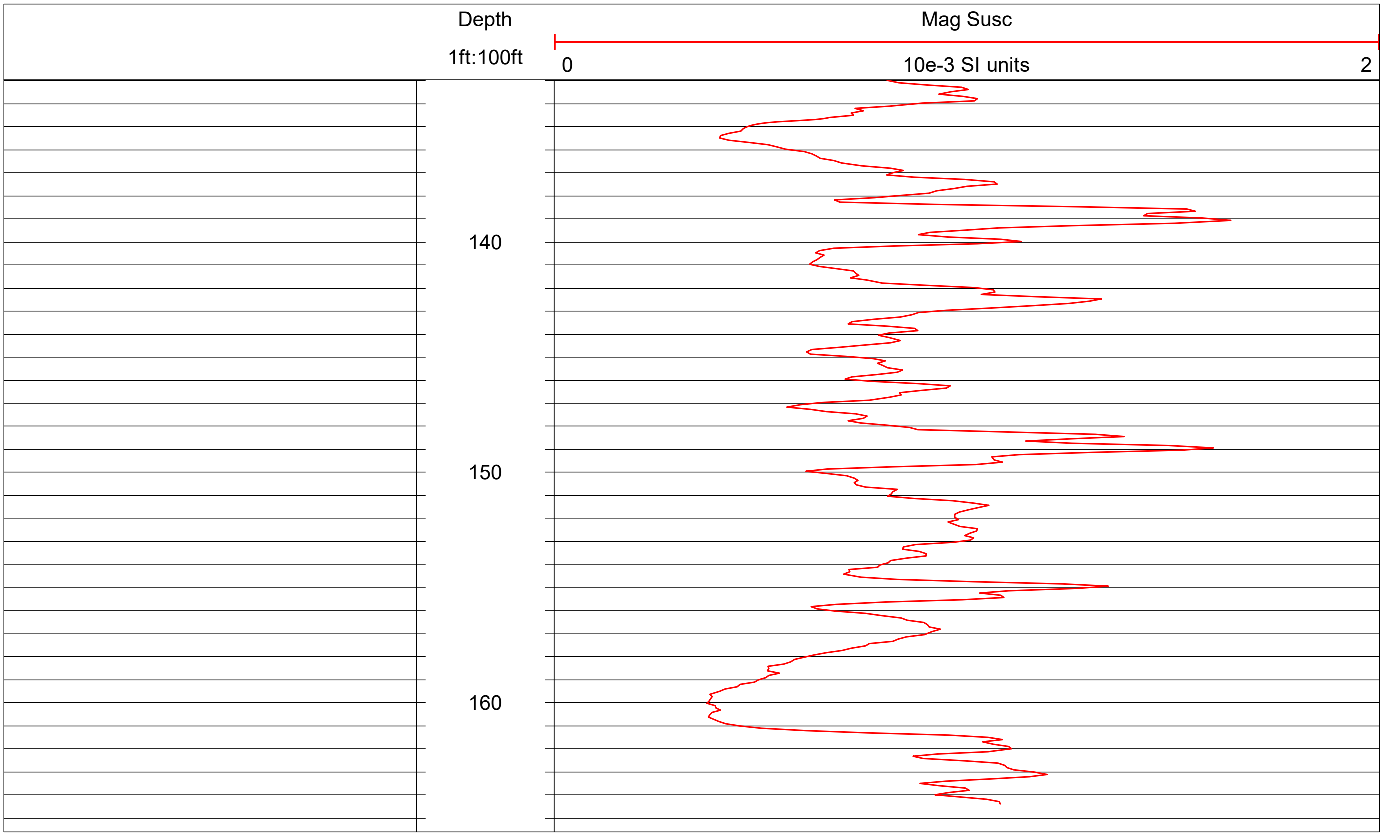
CALIBRATION RESULTS -- Did not record

REMARKS

4" Well



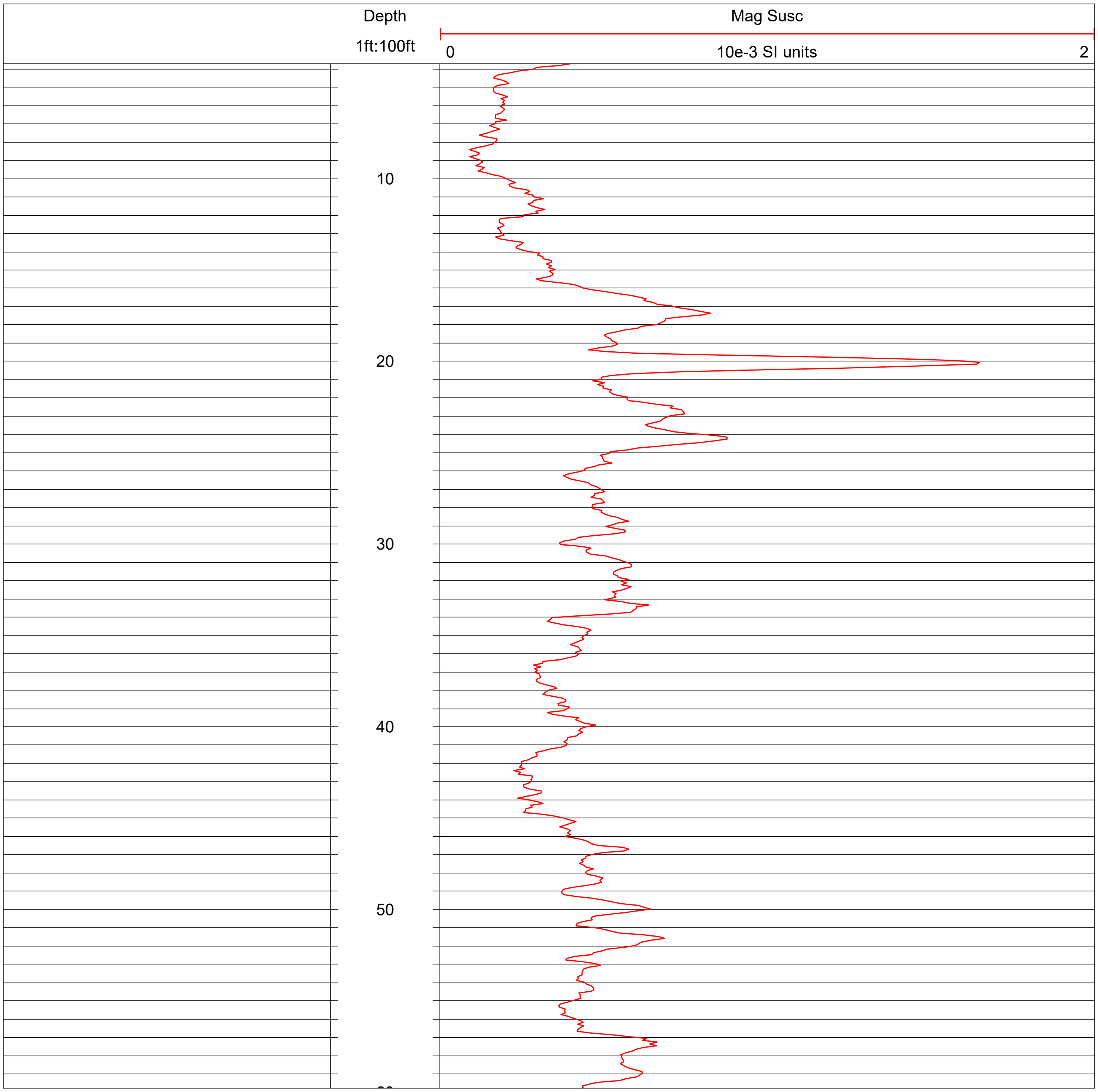

Depth
1ft:100ft
Mag Susc
0
10e-3 SI units
2
60
70
80
90
100
110
120
130

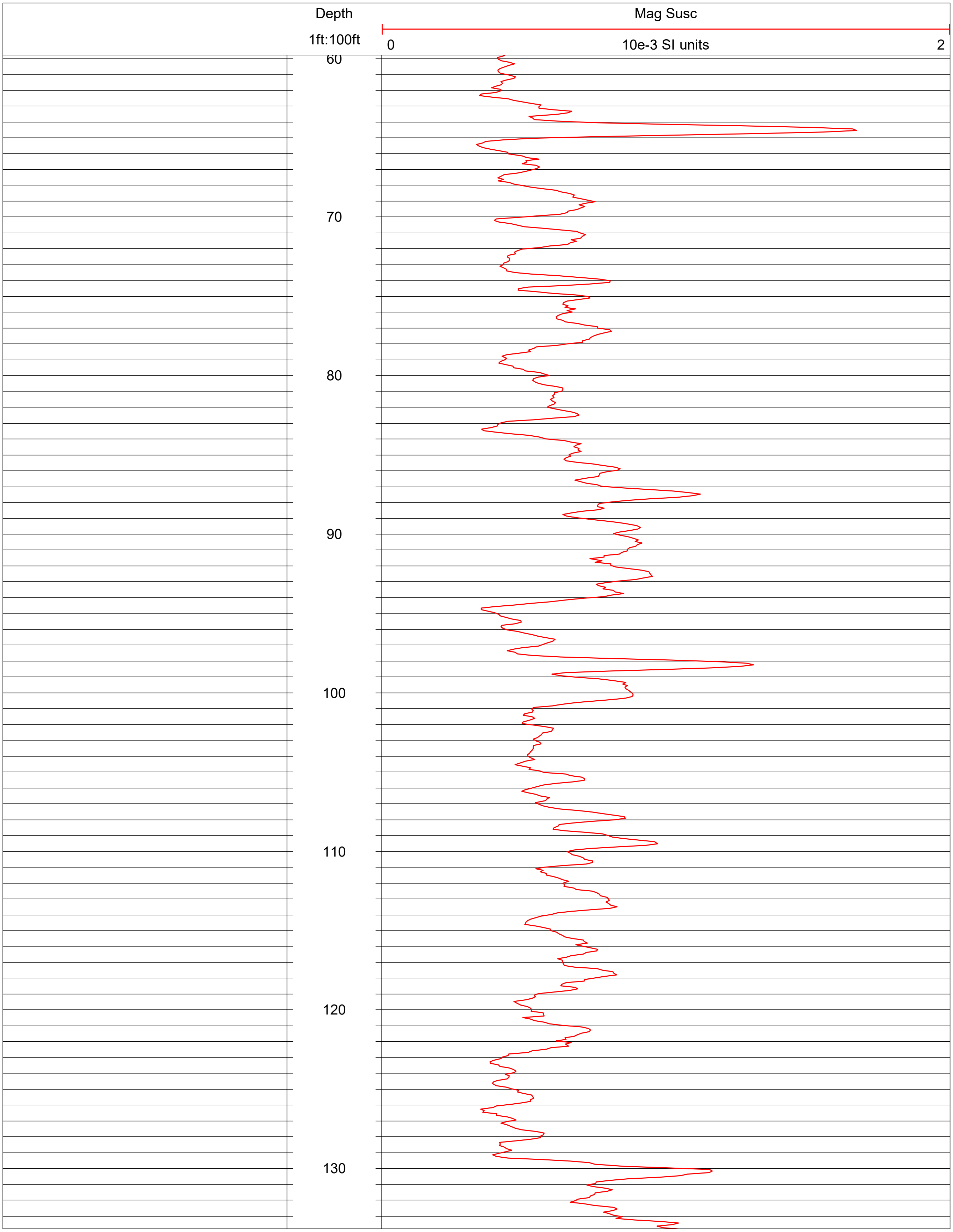

Depth
1ft:100ft
Mag Susc
0
10e-3 SI units
2
140
150
160

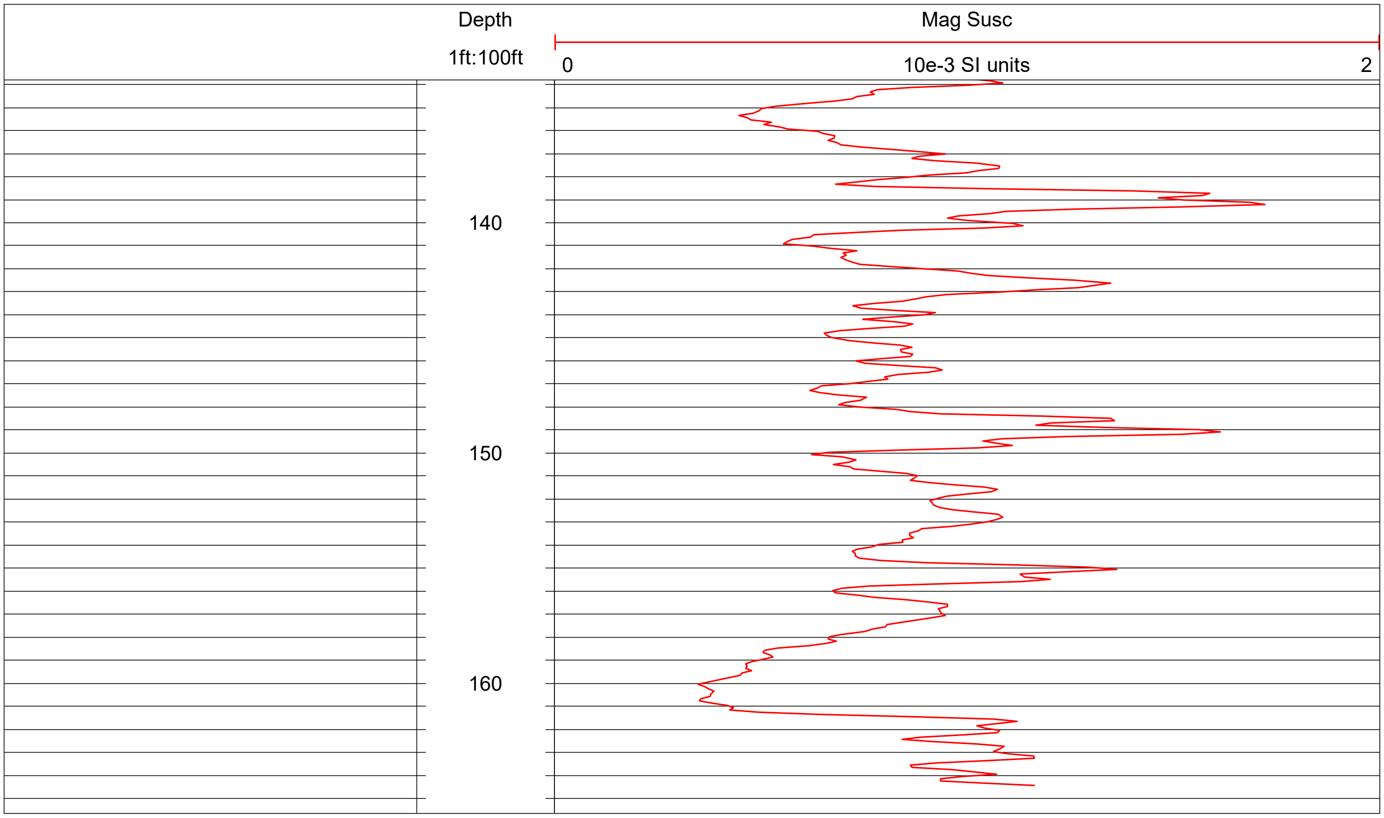
WIEDEMEIER
& ASSOCIATES

PROJECT	ESTCP 201584
LOCATION	Tooele Army Ammunition Depot
WELL	D-19 Up
LOGGER	TH Wiedemeier
DATE	7/26/16

TOOL	HMA-453-S
CALIBRATION DATE/TIME	7/26/16 - 14:44
CALIBRATION STANDARDS	0 and 5E-3
CALIBRATION RESULTS	Not Recorded
REMARKS	
	4" Well




Depth
1ft:100ft
Mag Susc
0
10e-3 SI units
2
60
70
80
90
100
110
120
130


Depth
1ft:100ft
Mag Susc
0
10e-3 SI units
2
140
150
160

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR HILL AFB-OU10, HILL AFB, UTAH

U10-025

Depth ft bgs	Mag Susc m^3/kg
3.60	2.19E-07
3.69	2.80E-07
3.79	2.56E-07
3.89	2.79E-07
3.99	2.77E-07
4.09	2.42E-07
4.19	2.46E-07
4.29	2.69E-07
4.39	2.44E-07
4.49	2.47E-07
4.59	2.91E-07
4.69	2.70E-07
4.79	2.49E-07
4.89	2.84E-07
4.99	2.74E-07
5.09	2.36E-07
5.19	2.63E-07
5.29	2.85E-07
5.39	2.34E-07
5.49	2.40E-07
5.59	2.35E-07
5.69	2.32E-07
5.79	2.62E-07
5.89	2.38E-07
5.99	2.54E-07
6.09	2.50E-07
6.19	2.51E-07
6.29	2.48E-07
6.39	2.36E-07
6.49	2.36E-07
6.59	3.17E-07
6.69	2.73E-07
6.79	2.74E-07
6.89	3.44E-07
6.99	3.78E-07
7.08	3.39E-07
7.18	3.46E-07
7.28	2.72E-07
7.38	3.10E-07
7.48	3.60E-07
7.58	3.44E-07
7.68	3.13E-07
7.78	3.00E-07
7.88	2.75E-07
7.98	2.56E-07
8.08	2.81E-07
8.18	2.94E-07
8.28	2.44E-07
8.38	2.65E-07
8.48	2.82E-07
8.58	2.93E-07
8.68	2.83E-07
8.78	2.79E-07
8.88	2.68E-07
8.98	2.91E-07
9.08	2.43E-07
9.18	2.89E-07
9.28	2.86E-07
9.38	3.06E-07
9.48	3.20E-07
9.58	2.88E-07
9.68	2.54E-07
9.78	2.27E-07
9.88	3.07E-07
9.98	2.99E-07
10.08	3.02E-07
10.18	2.69E-07
10.28	2.78E-07
10.37	2.77E-07
10.47	2.79E-07
10.57	3.04E-07
10.67	3.09E-07
10.77	2.81E-07
10.87	2.83E-07
10.97	3.13E-07
11.07	3.31E-07
11.17	3.12E-07
11.27	3.21E-07
11.37	3.29E-07
11.47	3.64E-07
11.57	2.85E-07
11.67	2.66E-07
11.77	2.98E-07
11.87	3.20E-07

U10-043

Depth ft bgs	Mag Susc m^3/kg	
3.72	1.03E-06	
3.82	9.56E-07	
3.92	8.58E-07	
4.02	8.65E-07	
4.12	7.80E-07	
4.22	8.17E-07	
4.32	8.77E-07	
4.42	7.65E-07	
4.52	6.55E-07	
4.62	5.24E-07	
4.71	4.48E-07	
4.81	4.55E-07	
4.91	3.56E-07	
5.01	3.03E-07	
5.11	2.47E-07	
5.21	2.99E-07	Above 5.21 feet
5.31	2.88E-07	interference from
5.41	3.13E-07	Metal Surface Casing
5.51	2.96E-07	
5.61	3.05E-07	
5.71	3.02E-07	
5.81	3.30E-07	
5.91	3.09E-07	
6.01	3.46E-07	
6.11	2.78E-07	
6.21	3.12E-07	
6.31	2.97E-07	
6.41	3.11E-07	
6.51	3.09E-07	
6.61	2.88E-07	
6.71	2.72E-07	
6.81	2.71E-07	
6.91	3.13E-07	
7.01	2.82E-07	
7.11	2.59E-07	
7.21	2.58E-07	
7.31	2.67E-07	
7.41	2.26E-07	
7.51	2.44E-07	
7.61	2.24E-07	
7.71	1.91E-07	
7.81	1.92E-07	
7.91	2.03E-07	
8.00	1.94E-07	
8.10	1.59E-07	
8.20	2.03E-07	
8.30	2.04E-07	
8.40	2.33E-07	
8.50	2.03E-07	
8.60	2.43E-07	
8.70	2.44E-07	
8.80	2.41E-07	
8.90	2.66E-07	
9.00	2.42E-07	
9.10	2.60E-07	
9.20	3.25E-07	
9.30	3.05E-07	
9.40	3.01E-07	
9.50	2.93E-07	
9.60	2.46E-07	
9.70	2.59E-07	
9.80	2.69E-07	
9.90	2.51E-07	
10.00	2.31E-07	
10.10	2.11E-07	
10.20	2.16E-07	
10.30	2.03E-07	
10.40	2.21E-07	
10.50	2.15E-07	
10.60	2.11E-07	
10.70	2.31E-07	
10.80	2.00E-07	
10.90	2.43E-07	
11.00	2.35E-07	
11.10	2.00E-07	
11.20	2.35E-07	
11.30	2.28E-07	
11.39	2.37E-07	
11.49	2.56E-07	
11.59	2.43E-07	
11.69	2.04E-07	
11.79	2.45E-07	
11.89	2.20E-07	
11.99	2.11E-07	

U10-51 SONDE DATA AND STATS

Depth ft bgs	Mag Susc m^3/kg	
3.40	9.90E-07	
3.50	7.04E-07	
3.60	4.97E-07	
3.70	3.86E-07	
3.80	3.69E-07	
3.90	2.59E-07	
4.00	2.83E-07	Above 4 Feet
4.10	1.92E-07	interference from
4.20	2.13E-07	Metal Surface Casing
4.30	1.95E-07	
4.40	1.79E-07	
4.50	2.42E-07	
4.60	1.69E-07	
4.70	1.31E-07	
4.80	2.14E-07	
4.90	1.86E-07	
5.00	1.56E-07	
5.10	1.88E-07	
5.20	2.11E-07	
5.30	1.79E-07	
5.40	1.72E-07	
5.50	2.90E-07	
5.60	2.63E-07	
5.70	1.66E-07	
5.80	1.94E-07	
5.90	2.17E-07	
6.00	2.49E-07	
6.09	1.49E-07	
6.19	2.32E-07	
6.29	1.86E-07	
6.39	1.58E-07	
6.49	1.67E-07	
6.59	1.50E-07	
6.69	1.76E-07	
6.79	1.75E-07	
6.89	2.45E-07	
6.99	1.98E-07	
7.09	2.36E-07	
7.19	2.26E-07	
7.29	2.19E-07	
7.39	2.76E-07	
7.49	1.70E-07	
7.59	2.14E-07	
7.69	2.13E-07	
7.79	2.73E-07	
7.89	1.87E-07	
7.99	1.62E-07	
8.09	2.27E-07	
8.19	2.19E-07	
8.29	2.01E-07	
8.39	2.24E-07	
8.49	1.40E-07	
8.59	2.39E-07	
8.69	3.06E-07	
8.79	2.45E-07	
8.89	2.43E-07	
8.99	2.19E-07	
9.09	1.85E-07	
9.19	2.20E-07	
9.29	2.53E-07	
9.39	2.25E-07	
9.48	2.65E-07	
9.58	2.27E-07	
9.68	2.05E-07	
9.78	2.45E-07	
9.88	2.35E-07	
9.98	2.09E-07	
10.08	2.97E-07	
10.18	2.06E-07	
10.28	2.05E-07	
10.38	3.15E-07	
10.48	1.93E-07	
10.58	2.32E-07	
10.68	3.28E-07	
10.78	2.18E-07	
10.88	2.51E-07	
10.98	2.17E-07	
11.08	1.96E-07	
11.18	2.59E-07	
11.28	1.61E-07	
11.38	2.26E-07	
11.48	2.49E-07	
11.58	2.48E-07	
11.68	1.94E-07	

WIEDEMEIER & ASSOCIATES

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR HILL AFB-OU10, HILL AFB, UTAH

U10-025

Depth ft bgs	Mag Susc m^3/kg
11.97	3.38E-07
12.07	3.79E-07
12.17	3.31E-07
12.27	3.68E-07
12.37	3.70E-07
12.47	3.51E-07
12.57	4.04E-07
12.67	4.14E-07
12.77	4.18E-07
12.87	4.04E-07
12.97	4.64E-07
13.07	4.28E-07
13.17	4.50E-07
13.27	4.67E-07
13.37	4.49E-07
13.47	5.38E-07
13.57	5.77E-07
13.66	5.78E-07
13.76	4.74E-07
13.86	4.82E-07
13.96	4.90E-07
14.06	5.03E-07
14.16	5.01E-07
14.26	3.98E-07
14.36	3.65E-07
14.46	3.38E-07
14.56	3.23E-07
14.66	3.24E-07
14.76	3.83E-07
14.86	3.77E-07
14.96	3.28E-07
15.06	3.32E-07
15.16	3.82E-07
15.26	3.54E-07
15.36	3.41E-07
15.46	3.67E-07
15.56	3.47E-07
15.66	3.82E-07
15.76	3.56E-07
15.86	3.54E-07
15.96	3.69E-07
16.06	3.53E-07
16.16	3.92E-07
16.26	3.43E-07
16.36	3.49E-07
16.46	3.59E-07
16.56	3.94E-07
16.66	3.39E-07
16.76	3.54E-07
16.86	3.45E-07
16.96	3.52E-07
17.05	3.42E-07
17.15	3.57E-07
17.25	3.32E-07
17.35	3.39E-07
17.45	3.70E-07
17.55	3.96E-07
17.65	3.52E-07
17.75	3.63E-07
17.85	3.27E-07
17.95	2.78E-07
18.05	3.19E-07
18.15	3.53E-07
18.25	3.65E-07
18.35	2.76E-07
18.45	2.79E-07
18.55	2.58E-07
18.65	2.65E-07
18.75	2.60E-07
18.85	2.82E-07
18.95	2.95E-07
19.05	3.04E-07
19.15	2.79E-07
19.25	3.05E-07
19.35	2.85E-07
19.45	2.93E-07
19.55	3.28E-07
19.65	3.07E-07
19.75	3.33E-07
19.85	3.50E-07
19.95	3.48E-07
20.05	3.24E-07
20.15	3.36E-07
20.25	3.38E-07

U10-043

Depth ft bgs	Mag Susc m^3/kg
12.09	2.35E-07
12.19	2.50E-07
12.29	2.69E-07
12.39	2.81E-07
12.49	2.85E-07
12.59	2.79E-07
12.69	2.87E-07
12.79	2.34E-07
12.89	2.64E-07
12.99	2.81E-07
13.09	2.90E-07
13.19	2.73E-07
13.29	2.84E-07
13.39	2.55E-07
13.49	2.40E-07
13.59	2.52E-07
13.69	2.58E-07
13.79	2.36E-07
13.89	2.51E-07
13.99	2.59E-07
14.09	2.38E-07
14.19	2.30E-07
14.29	2.47E-07
14.39	2.41E-07
14.49	2.62E-07
14.59	2.35E-07
14.68	2.73E-07
14.78	2.57E-07
14.88	2.44E-07
14.98	2.52E-07
15.08	2.09E-07
15.18	2.56E-07
15.28	2.81E-07
15.38	2.53E-07
15.48	2.63E-07
15.58	2.80E-07
15.68	2.71E-07
15.78	2.61E-07
15.88	2.51E-07
15.98	2.66E-07
16.08	2.91E-07
16.18	2.64E-07
16.28	2.54E-07
16.38	2.72E-07
16.48	2.70E-07
16.58	2.76E-07
16.68	2.66E-07
16.78	3.00E-07
16.88	2.80E-07
16.98	3.01E-07
17.08	3.04E-07
17.18	2.93E-07
17.28	2.91E-07
17.38	2.93E-07
17.48	2.57E-07
17.58	2.57E-07
17.68	2.67E-07
17.78	3.22E-07
17.88	3.07E-07
17.97	2.86E-07
18.07	2.71E-07
18.17	2.76E-07
18.27	2.52E-07
18.37	2.67E-07
18.47	2.88E-07
18.57	2.78E-07
18.67	2.56E-07
18.77	2.50E-07
18.87	2.78E-07
18.97	2.68E-07
19.07	2.66E-07
19.17	2.63E-07
19.27	2.84E-07
19.37	2.24E-07
19.47	2.73E-07
19.57	2.41E-07
19.67	2.19E-07
19.77	1.87E-07

Mean	2.59E-07
Standard Error	2.77E-09
Median	2.59E-07
Mode	#N/A

U10-51 SONDE DATA AND STATS

Depth ft bgs	Mag Susc m^3/kg
11.78	1.71E-07
11.88	2.24E-07
11.98	2.40E-07
12.08	2.49E-07
12.18	2.53E-07
12.28	2.68E-07
12.38	2.15E-07
12.48	2.01E-07
12.58	2.26E-07
12.68	2.13E-07
12.78	2.74E-07
12.87	2.23E-07
12.97	2.30E-07
13.07	2.52E-07
13.17	2.13E-07
13.27	1.98E-07
13.37	1.44E-07
13.47	2.30E-07
13.57	1.98E-07
13.67	2.54E-07
13.77	2.40E-07
13.87	2.04E-07
13.97	1.86E-07
14.07	2.95E-07
14.17	2.19E-07
14.27	2.92E-07
14.37	3.08E-07
14.47	2.59E-07
14.57	3.57E-07
14.67	2.91E-07
14.77	3.35E-07
14.87	3.45E-07
14.97	4.01E-07
15.07	3.34E-07
15.17	3.46E-07
15.27	3.78E-07
15.37	4.18E-07
15.47	4.21E-07
15.57	3.84E-07
15.67	3.82E-07
15.77	3.66E-07
15.87	3.88E-07
15.97	3.70E-07
16.07	3.37E-07
16.17	3.32E-07
16.27	2.98E-07
16.36	4.00E-07
16.46	3.98E-07
16.56	4.50E-07
16.66	5.04E-07
16.76	4.91E-07
16.86	4.45E-07
16.96	4.40E-07
17.06	4.37E-07
17.16	4.23E-07
17.26	3.11E-07
17.36	3.32E-07
17.46	3.20E-07
17.56	2.96E-07
17.66	2.93E-07
17.76	3.18E-07
17.86	2.74E-07
17.96	2.85E-07
18.06	2.51E-07
18.16	2.62E-07
18.26	2.31E-07
18.36	2.95E-07
18.46	1.88E-07
18.56	2.67E-07
18.66	2.44E-07
18.76	2.28E-07
18.86	2.92E-07
18.96	3.10E-07
19.06	2.93E-07
19.16	3.44E-07
19.26	2.60E-07
19.36	2.97E-07
19.46	3.50E-07
19.56	2.67E-07
19.66	2.44E-07
19.75	2.85E-07
19.85	2.82E-07
19.95	2.86E-07
20.05	2.89E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR HILL AFB-OU10, HILL AFB, UTAH

U10-025

Depth ft bgs	Mag Susc m^3/kg
20.34	3.39E-07
20.44	3.54E-07
20.54	3.40E-07
20.64	3.47E-07
20.74	3.84E-07
20.84	3.58E-07
20.94	3.66E-07
21.04	3.45E-07
21.14	3.72E-07
21.24	3.64E-07
21.34	3.77E-07
21.44	3.31E-07
21.54	3.20E-07
21.64	3.56E-07
21.74	3.64E-07
21.84	3.78E-07
21.94	3.35E-07
22.04	3.47E-07
22.14	3.40E-07
22.24	3.51E-07
22.34	3.70E-07
22.44	3.76E-07
22.54	3.78E-07
22.64	3.63E-07
22.74	3.90E-07
22.84	3.95E-07
22.94	3.73E-07
23.04	3.69E-07
23.14	4.23E-07
23.24	3.94E-07
23.34	4.00E-07
23.44	3.75E-07
23.54	3.38E-07
23.63	3.33E-07
23.73	3.09E-07
23.83	3.55E-07
23.93	3.30E-07
24.03	2.93E-07
24.13	3.11E-07
24.23	2.84E-07
24.33	2.78E-07
24.43	3.00E-07
24.53	3.36E-07
24.63	3.10E-07
24.73	2.79E-07
24.83	2.71E-07
24.93	2.92E-07
25.03	2.93E-07
25.13	2.83E-07
25.23	2.91E-07
25.33	2.90E-07
25.43	3.19E-07
25.53	2.95E-07
25.63	3.15E-07
25.73	2.95E-07
25.83	3.18E-07
25.93	3.12E-07
26.03	3.13E-07
26.13	3.13E-07
26.23	2.97E-07
26.33	3.10E-07
26.43	2.73E-07
26.53	2.76E-07
26.63	2.80E-07
26.73	3.18E-07
26.83	2.80E-07
26.92	2.86E-07
27.02	2.99E-07
27.12	2.99E-07
27.22	3.39E-07
27.32	3.20E-07
27.42	2.98E-07
27.52	2.99E-07
27.62	3.16E-07
27.72	2.70E-07
27.82	2.54E-07
27.92	2.73E-07
28.02	2.55E-07
28.12	2.78E-07
28.22	2.63E-07
28.32	2.42E-07
28.42	2.90E-07
28.52	2.93E-07
28.62	2.81E-07

U10-043

Depth ft bgs	Mag Susc m^3/kg
Standard Deviation	3.36E-08
Sample Variance	1.13E-15
Kurtosis	-0.10717
Skewness	-0.19807
Range	1.87E-07
Minimum	1.59E-07
Maximum	3.46E-07
Sum	3.8E-05
Count	147
Confidence Level(95.0%)	5.48E-09

U10-51 SONDE DATA AND STATS

Depth ft bgs	Mag Susc m^3/kg
20.15	3.13E-07
20.25	2.97E-07
20.35	2.95E-07
20.45	2.74E-07
20.55	2.99E-07
20.65	3.10E-07
20.75	2.12E-07
20.85	2.88E-07
20.95	2.43E-07
21.05	2.74E-07
21.15	2.31E-07
21.25	2.52E-07
21.35	2.81E-07
21.45	2.78E-07
21.55	2.50E-07
21.65	3.11E-07
21.75	2.80E-07
21.85	2.03E-07
21.95	2.70E-07
22.05	2.74E-07
22.15	2.60E-07
22.25	2.41E-07
22.35	3.14E-07
22.45	2.26E-07
22.55	2.97E-07
22.65	2.73E-07
22.75	2.99E-07
22.85	2.66E-07
22.95	3.15E-07
23.05	3.12E-07
23.15	2.75E-07
23.24	3.33E-07
23.34	2.86E-07
23.44	2.53E-07
23.54	2.82E-07
23.64	3.22E-07
23.74	3.16E-07
23.84	3.23E-07
23.94	2.64E-07
24.04	3.18E-07
24.14	2.77E-07
24.24	3.42E-07
24.34	2.53E-07
24.44	2.20E-07
24.54	2.91E-07
24.64	2.74E-07
24.74	2.86E-07
24.84	3.31E-07
24.94	3.09E-07
25.04	2.97E-07
25.14	3.04E-07
25.24	2.68E-07
25.34	3.24E-07
25.44	2.74E-07
25.54	3.53E-07
25.64	2.74E-07
25.74	2.53E-07
25.84	2.39E-07
25.94	2.79E-07
26.04	2.51E-07
26.14	2.81E-07
26.24	2.22E-07
26.34	2.46E-07
26.44	2.45E-07
26.54	3.09E-07
26.63	2.98E-07
26.73	2.45E-07
26.83	2.50E-07
26.93	2.77E-07
27.03	2.79E-07
27.13	2.89E-07
27.23	1.82E-07
27.33	2.39E-07
27.43	2.47E-07
27.53	1.89E-07
27.63	2.62E-07
27.73	2.13E-07
27.83	2.32E-07
27.93	2.62E-07
28.03	2.69E-07
28.13	2.92E-07
28.23	2.33E-07
28.33	1.71E-07
28.43	1.62E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR HILL AFB-OU10, HILL AFB, UTAH

U10-025		U10-043		U10-51 SONDE DATA AND STATS	
Depth ft bgs	**Mag Susc m^3/kg**	**Depth ft bgs**	**Mag Susc m^3/kg**	**Depth ft bgs**	**Mag Susc m^3/kg**
28.72	2.65E-07			28.53	2.69E-07
28.82	2.72E-07			28.63	2.11E-07
28.92	2.75E-07			28.73	1.83E-07
29.02	2.82E-07			28.83	2.20E-07
29.12	2.84E-07			28.93	1.93E-07
29.22	2.82E-07			29.03	2.22E-07
29.32	2.86E-07			29.13	2.74E-07
29.42	2.98E-07			29.23	2.40E-07
29.52	2.86E-07			29.33	2.60E-07
29.62	2.66E-07			29.43	2.47E-07
29.72	2.54E-07			29.53	3.54E-07
29.82	2.69E-07			29.63	2.69E-07
29.92	2.53E-07			29.73	2.71E-07
30.02	2.65E-07			29.83	2.65E-07
30.12	2.76E-07			29.93	2.44E-07
30.22	2.57E-07			30.02	2.58E-07
30.31	2.52E-07			30.12	2.57E-07
30.41	3.06E-07			30.22	2.55E-07
30.51	2.70E-07			30.32	2.20E-07
30.61	2.72E-07			30.42	2.12E-07
30.71	2.69E-07			30.52	2.52E-07
30.81	2.81E-07			30.62	2.06E-07
30.91	2.81E-07			30.72	2.97E-07
31.01	2.76E-07			30.82	2.61E-07
31.11	2.60E-07			30.92	2.43E-07
31.21	2.70E-07			31.02	2.28E-07
31.31	2.48E-07			31.12	2.63E-07
31.41	2.47E-07			31.22	2.79E-07
31.51	2.85E-07			31.32	2.52E-07
31.61	2.46E-07			31.42	2.13E-07
31.71	2.54E-07			31.52	2.58E-07
31.81	2.87E-07			31.62	2.52E-07
31.91	2.57E-07			31.72	2.71E-07
32.01	2.63E-07			31.82	2.28E-07
32.11	2.78E-07			31.92	2.47E-07
32.21	2.94E-07			32.02	2.46E-07
32.31	2.94E-07			32.12	2.22E-07
32.41	3.07E-07			32.22	2.42E-07
32.51	2.87E-07			32.32	2.78E-07
32.61	2.58E-07			32.42	2.45E-07
32.71	2.98E-07			32.52	2.64E-07
32.81	2.82E-07			32.62	3.00E-07
32.91	2.97E-07			32.72	2.33E-07
33.01	2.89E-07			32.82	2.13E-07
33.11	2.77E-07			32.92	1.96E-07
33.21	2.76E-07			33.02	2.62E-07
33.31	2.62E-07			33.12	3.02E-07
33.41	3.05E-07			33.22	2.15E-07
33.51	2.76E-07			33.32	2.45E-07
33.60	2.52E-07			33.42	2.73E-07
33.70	2.84E-07			33.51	2.75E-07
33.80	2.84E-07			33.61	2.55E-07
33.90	2.91E-07			33.71	2.51E-07
34.00	2.73E-07			33.81	2.05E-07
34.10	2.32E-07			33.91	2.81E-07
34.20	2.66E-07			34.01	2.29E-07
34.30	2.63E-07			34.11	1.99E-07
34.40	3.03E-07			34.21	2.45E-07
34.50	2.65E-07			34.31	2.78E-07
34.60	2.59E-07			34.41	3.07E-07
34.70	2.53E-07			34.51	2.16E-07
34.80	2.54E-07			34.61	2.45E-07
34.90	2.64E-07			34.71	3.02E-07
35.00	2.68E-07			34.81	2.57E-07
35.10	2.67E-07			34.91	2.59E-07
35.20	2.84E-07			35.01	2.55E-07
35.30	2.63E-07			35.11	2.61E-07
35.40	2.55E-07			35.21	2.62E-07
35.50	2.74E-07			35.31	2.89E-07
35.60	2.84E-07			35.41	2.58E-07
35.70	2.84E-07			35.51	3.00E-07
35.80	2.70E-07			35.61	2.68E-07
35.90	3.00E-07			35.71	2.56E-07
36.00	2.77E-07			35.81	3.02E-07
36.10	2.84E-07			35.91	3.02E-07
36.20	2.82E-07			36.01	2.51E-07
36.30	2.77E-07			36.11	2.88E-07
36.40	2.96E-07			36.21	3.08E-07
36.50	2.92E-07			36.31	2.72E-07
36.60	2.89E-07			36.41	2.87E-07
36.70	3.05E-07			36.51	2.99E-07
36.80	2.82E-07			36.61	2.84E-07
36.90	2.97E-07			36.71	2.57E-07
36.99	3.02E-07			36.81	2.69E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR HILL AFB-OU10, HILL AFB, UTAH

U10-025

Depth ft bgs	Mag Susc m^3/kg
37.09	3.10E-07
37.19	2.86E-07
37.29	3.41E-07
37.39	2.80E-07
37.49	3.10E-07
37.59	3.33E-07
37.69	3.11E-07
37.79	3.30E-07
37.89	2.91E-07
37.99	2.93E-07
38.09	2.89E-07
38.19	3.54E-07
38.29	3.62E-07
38.39	3.11E-07
38.49	3.17E-07
38.59	3.18E-07
38.69	3.49E-07
38.79	3.55E-07
38.89	3.64E-07
39.02	3.84E-07
39.12	3.67E-07
39.22	3.82E-07
39.32	4.05E-07
39.42	4.33E-07
39.52	4.31E-07
39.62	4.32E-07

Mean	3.16E-07
Standard Error	3.39E-09
Median	3.01E-07
Mode	#N/A
Standard Deviation	5.83E-08
Sample Variance	3.4E-15
Kurtosis	3.15558
Skewness	1.411555
Range	3.59E-07
Minimum	2.19E-07
Maximum	5.78E-07
Sum	9.36E-05
Count	296
Confidence Level(95.0%)	6.67E-09

U10-043

Depth ft bgs	Mag Susc m^3/kg

U10-51 SONDE DATA AND STATS

Depth ft bgs	Mag Susc m^3/kg
36.90	3.08E-07
37.00	2.30E-07
37.10	2.49E-07
37.20	3.40E-07
37.30	3.06E-07
37.40	2.67E-07
37.50	2.96E-07
37.60	2.84E-07
37.70	2.52E-07
37.80	2.83E-07
37.90	2.65E-07
38.00	2.88E-07
38.10	2.79E-07
38.20	3.50E-07
38.30	2.85E-07
38.40	2.50E-07
38.50	3.02E-07
38.60	2.52E-07
38.70	2.63E-07
38.80	2.48E-07
38.90	2.49E-07
39.00	2.57E-07
39.10	2.44E-07
39.20	2.97E-07
39.30	2.85E-07
39.40	3.25E-07
39.50	3.02E-07
39.60	2.19E-07
39.70	3.08E-07
39.80	2.55E-07
39.90	2.68E-07
40.00	2.58E-07
40.10	3.02E-07
40.20	2.56E-07
40.30	2.45E-07
40.39	2.77E-07
40.49	3.09E-07
40.59	3.03E-07
40.69	2.82E-07
40.79	3.38E-07
40.89	2.75E-07
40.99	2.65E-07
41.09	2.56E-07
41.19	2.86E-07
41.29	2.42E-07
41.39	2.73E-07
41.49	2.68E-07
41.59	3.07E-07
41.69	2.97E-07
41.79	3.20E-07
41.89	2.89E-07
41.99	2.45E-07
42.09	3.02E-07
42.19	2.91E-07
42.29	3.13E-07
42.39	2.42E-07
42.49	2.81E-07
42.59	2.70E-07
42.69	2.65E-07
42.79	2.86E-07
42.89	2.90E-07
42.99	3.79E-07
43.09	3.14E-07
43.19	3.23E-07
43.29	3.16E-07
43.39	2.71E-07
43.49	2.69E-07
43.59	3.05E-07
43.69	2.40E-07
43.78	2.52E-07
43.88	3.24E-07
43.98	3.50E-07
44.08	2.90E-07
44.18	2.44E-07
44.28	2.65E-07
44.38	3.42E-07
44.48	3.25E-07
44.58	3.57E-07
44.68	3.13E-07
44.78	2.82E-07
44.88	2.56E-07
44.98	2.72E-07
45.08	2.92E-07
45.18	2.78E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR HILL AFB-OU10, HILL AFB, UTAH

U10-025		U10-043		U10-51 SONDE DATA AND STATS	
Depth	Mag Susc	Depth	Mag Susc	Depth	Mag Susc
ft bgs	m^3/kg	ft bgs	m^3/kg	ft bgs	m^3/kg
				45.28	2.85E-07
				45.38	2.54E-07
				45.48	2.71E-07
				45.58	2.67E-07
				45.68	2.62E-07
				45.78	2.55E-07
				45.88	3.03E-07
				45.98	2.74E-07
				46.08	3.02E-07
				46.18	3.21E-07
				46.28	2.72E-07
				46.38	2.95E-07
				46.48	3.04E-07
				46.58	3.33E-07
				46.68	2.98E-07
				46.78	3.49E-07
				46.88	3.10E-07
				46.98	3.02E-07
				47.08	2.54E-07
				47.17	3.45E-07
				47.27	3.01E-07
				47.37	3.17E-07
				47.47	2.84E-07
				47.57	2.99E-07
				47.67	2.47E-07
				47.77	3.06E-07
				47.87	2.75E-07
				47.97	2.87E-07
				48.07	3.27E-07
				48.17	3.02E-07
				48.27	3.66E-07
				48.37	3.72E-07
				48.47	3.58E-07
				48.57	3.56E-07
				48.67	3.20E-07
				48.77	3.62E-07
				48.87	3.88E-07
				48.97	4.03E-07
				49.07	4.15E-07
				49.17	4.22E-07
				49.27	3.87E-07
				49.37	3.50E-07
				49.47	3.51E-07
				49.57	3.83E-07
				49.67	3.22E-07
				49.77	2.32E-07
				49.87	3.94E-07
				49.97	2.70E-07
				50.07	2.93E-07
				50.17	3.03E-07
				50.27	2.85E-07
				50.37	2.91E-07
				50.47	2.08E-07
				50.57	3.39E-07
				50.66	3.07E-07
				50.76	3.75E-07
				50.86	2.78E-07
				50.96	2.43E-07
				51.06	2.40E-07
				51.16	2.63E-07
				51.26	3.27E-07
				51.36	2.78E-07
				51.46	2.76E-07
				51.56	2.92E-07
				51.66	2.71E-07
				51.76	2.36E-07
				51.86	3.29E-07
				51.96	2.99E-07
				52.06	2.57E-07
				52.16	3.09E-07
				52.26	3.15E-07
				52.36	2.30E-07
				52.46	3.12E-07
				52.56	3.50E-07
				52.66	2.83E-07
				52.76	2.53E-07
				52.86	2.92E-07
				52.96	3.27E-07
				53.06	2.78E-07
				53.16	3.26E-07
				53.26	3.04E-07
				53.36	2.61E-07
				53.46	2.46E-07
				53.56	2.10E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR HILL AFB-OU10, HILL AFB, UTAH

U10-025		U10-043		U10-51 SONDE DATA AND STATS	
Depth	Mag Susc	Depth	Mag Susc	Depth	Mag Susc
ft bgs	m^3/kg	ft bgs	m^3/kg	ft bgs	m^3/kg
				53.66	2.85E-07
				53.76	2.63E-07
				53.86	3.16E-07
				53.96	2.54E-07
				54.05	3.07E-07
				54.15	2.49E-07
				54.25	2.56E-07
				54.35	2.69E-07
				54.45	2.26E-07
				54.55	2.54E-07
				54.65	2.78E-07
				54.75	2.91E-07
				54.85	2.86E-07
				54.95	3.14E-07
				55.05	3.55E-07
				55.15	2.98E-07
				55.25	2.88E-07
				55.35	3.23E-07
				55.45	2.60E-07
				55.55	3.54E-07
				55.65	3.39E-07
				55.75	2.47E-07
				55.85	3.19E-07
				55.95	2.72E-07
				56.05	2.95E-07
				56.15	2.80E-07
				56.25	2.34E-07
				56.35	2.94E-07
				56.45	3.07E-07
				56.55	3.53E-07
				56.65	2.34E-07
				56.75	2.94E-07
				56.85	2.79E-07
				56.95	2.48E-07
				57.05	2.44E-07
				57.15	2.18E-07
				57.25	2.80E-07
				57.35	2.56E-07
				57.45	2.43E-07
				57.54	2.41E-07
				57.64	2.51E-07
				57.74	2.35E-07
				57.84	2.36E-07
				57.94	2.69E-07
				58.04	2.86E-07
				58.14	2.64E-07
				58.24	1.97E-07
				58.34	2.76E-07
				58.44	2.52E-07
				58.54	2.68E-07
				58.64	2.79E-07
				58.74	2.39E-07
				58.84	3.05E-07
				58.94	2.66E-07
				59.04	3.12E-07
				59.14	2.86E-07
				59.24	2.95E-07
				59.34	2.83E-07
				59.44	2.34E-07
				59.54	2.89E-07
				59.64	3.19E-07
				59.74	2.87E-07
				59.84	2.97E-07
				59.94	3.69E-07
				60.04	3.13E-07
				60.14	2.86E-07
				60.24	2.67E-07
				60.34	2.99E-07
				60.44	2.48E-07
				60.54	2.77E-07
				60.64	3.11E-07
				60.74	2.27E-07
				60.84	2.87E-07
				60.93	2.86E-07
				61.03	2.50E-07
				61.13	2.59E-07
				61.23	2.23E-07
				61.33	3.08E-07
				61.43	2.91E-07
				61.53	2.59E-07
				61.63	2.70E-07
				61.73	2.53E-07
				61.83	2.56E-07
				61.93	2.97E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR HILL AFB-OU10, HILL AFB, UTAH

U10-025		U10-043		U10-51 SONDE DATA AND STATS	
Depth ft bgs	Mag Susc m^3/kg	Depth ft bgs	Mag Susc m^3/kg	Depth ft bgs	Mag Susc m^3/kg
				62.03	2.75E-07
				62.13	2.28E-07
				62.23	2.17E-07
				62.33	2.44E-07
				62.43	2.59E-07
				62.53	2.75E-07
				62.63	3.08E-07
				62.73	2.32E-07
				62.83	2.72E-07
				62.93	2.33E-07
				63.03	2.88E-07
				63.13	2.88E-07
				63.23	2.40E-07
				63.33	2.67E-07
				63.43	2.52E-07
				63.53	3.18E-07
				63.63	2.40E-07
				63.73	2.43E-07
				63.83	2.72E-07
				63.93	2.58E-07
				64.03	2.43E-07
				64.13	2.57E-07
				64.23	2.34E-07
				64.32	1.73E-07
				64.42	2.72E-07
				64.52	2.59E-07
				64.62	2.61E-07
				64.72	2.86E-07
				64.82	2.23E-07
				64.92	2.99E-07
				65.02	2.54E-07
				65.12	2.64E-07
				65.22	2.76E-07
				65.32	3.08E-07
				65.42	2.59E-07
				65.52	2.81E-07
				65.62	2.65E-07
				65.72	2.60E-07
				65.82	2.74E-07
				65.92	2.56E-07
				66.02	2.75E-07
				66.12	2.48E-07
				66.22	2.81E-07
				66.32	2.87E-07
				66.42	2.27E-07
				66.52	2.70E-07
				66.62	2.48E-07
				66.72	2.76E-07
				66.82	2.60E-07
				66.92	2.19E-07
				67.02	2.35E-07
				67.12	2.62E-07
				67.22	2.98E-07
				67.32	2.50E-07
				67.42	3.08E-07
				67.52	2.33E-07
				67.62	2.18E-07
				67.72	2.45E-07
				67.81	2.17E-07
				67.91	2.19E-07
				68.01	2.67E-07
				68.11	2.22E-07
				68.21	2.92E-07
				68.31	2.13E-07
				68.41	2.46E-07
				68.51	2.63E-07
				68.61	2.37E-07
				68.71	2.46E-07
				68.81	2.69E-07
				68.91	1.77E-07
				69.01	2.47E-07
				69.11	2.54E-07
				69.21	2.68E-07
				69.31	2.61E-07
				69.41	2.31E-07
				69.51	2.45E-07
				69.61	2.95E-07
				69.71	2.66E-07
				69.81	2.84E-07
				69.91	2.33E-07
				70.01	2.71E-07
				70.11	2.82E-07
				70.21	3.27E-07
				70.31	2.33E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR HILL AFB-OU10, HILL AFB, UTAH

U10-025		U10-043		U10-51 SONDE DATA AND STATS	
Depth	Mag Susc	Depth	Mag Susc	Depth	Mag Susc
ft bgs	m^3/kg	ft bgs	m^3/kg	ft bgs	m^3/kg
				70.41	2.33E-07
				70.51	2.66E-07
				70.61	3.08E-07
				70.71	2.70E-07
				70.81	2.66E-07
				70.91	2.14E-07
				71.01	2.73E-07
				71.11	3.02E-07
				71.20	3.43E-07
				71.30	2.91E-07
				71.40	2.50E-07
				71.50	2.93E-07
				71.60	2.75E-07
				71.70	2.83E-07
				71.80	3.26E-07
				71.90	2.38E-07
				72.00	2.83E-07
				72.10	2.81E-07
				72.20	3.16E-07
				72.30	2.65E-07
				72.40	2.39E-07
				72.50	2.84E-07
				72.60	2.93E-07
				72.70	2.56E-07
				72.80	2.64E-07
				72.90	2.64E-07
				73.00	2.94E-07
				73.10	3.00E-07
				73.20	3.12E-07
				73.30	2.22E-07
				73.40	3.03E-07
				73.50	1.97E-07
				73.60	2.87E-07
				73.70	2.38E-07
				73.80	2.68E-07
				73.90	2.61E-07
				74.00	2.76E-07
				74.10	2.86E-07
				74.20	3.08E-07
				74.30	2.37E-07
				74.40	3.00E-07
				74.50	2.65E-07
				74.60	2.66E-07
				74.69	2.74E-07
				74.79	2.47E-07
				74.89	2.71E-07
				74.99	2.80E-07
				75.09	2.80E-07
				75.19	2.08E-07
				75.29	2.67E-07
				75.39	1.99E-07
				75.49	1.95E-07
				75.59	2.61E-07
				75.69	2.43E-07
				75.79	2.37E-07
				75.89	2.69E-07
				75.99	2.69E-07
				76.09	2.46E-07
				76.19	2.59E-07
				76.29	2.46E-07
				76.39	2.36E-07
				76.49	2.78E-07
				76.59	2.53E-07
				76.69	2.84E-07
				76.79	2.45E-07
				76.89	2.91E-07
				76.99	2.82E-07
				77.09	1.96E-07
				77.19	2.74E-07
				77.29	2.45E-07
				77.39	2.27E-07
				77.49	2.47E-07
				77.59	2.42E-07
				77.69	2.84E-07
				77.79	2.96E-07
				77.89	2.64E-07
				77.99	3.04E-07
				78.08	2.68E-07
				78.18	2.59E-07
				78.28	2.77E-07
				78.38	2.82E-07
				78.48	2.46E-07
				78.58	2.02E-07
				78.68	2.99E-07

WIEDEMEIER & ASSOCIATES

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR HILL AFB-OU10, HILL AFB, UTAH

U10-025		U10-043		U10-51 SONDE DATA AND STATS	
Depth ft bgs	Mag Susc m^3/kg	Depth ft bgs	Mag Susc m^3/kg	Depth ft bgs	Mag Susc m^3/kg
				78.78	3.04E-07
				78.88	2.89E-07
				78.98	2.81E-07
				79.08	2.91E-07
				79.18	3.17E-07
				79.28	2.29E-07
				79.38	2.49E-07
				79.48	2.47E-07
				79.58	2.44E-07
				79.68	2.93E-07
				79.78	2.17E-07
				79.88	2.36E-07
				79.98	2.68E-07
				80.08	2.26E-07
				80.18	2.83E-07
				80.28	2.85E-07
				80.38	2.79E-07
				80.48	3.18E-07
				80.58	2.44E-07
				80.68	2.33E-07
				80.78	2.72E-07
				80.88	3.34E-07
				80.98	2.31E-07
				81.08	2.83E-07
				81.18	3.08E-07
				81.28	2.62E-07
				81.38	3.35E-07
				81.47	2.49E-07
				81.57	2.69E-07
				81.67	2.35E-07
				81.77	2.60E-07
				81.87	2.85E-07
				81.97	2.81E-07
				82.07	2.58E-07
				82.17	2.97E-07
				82.27	3.05E-07
				82.37	2.87E-07
				82.47	2.64E-07
				82.57	2.49E-07
				82.67	2.64E-07
				82.77	2.74E-07
				82.87	3.02E-07
				82.97	3.19E-07
				83.07	2.81E-07
				83.17	2.89E-07
				83.27	2.74E-07
				83.37	2.46E-07
				83.47	2.32E-07
				83.57	3.42E-07
				83.67	3.00E-07
				83.77	2.74E-07
				83.87	2.74E-07
				83.97	3.00E-07
				84.07	2.87E-07
				84.17	2.42E-07
				84.27	2.59E-07
				84.37	2.46E-07
				84.47	2.35E-07
				84.57	2.18E-07
				84.67	2.70E-07
				84.77	3.13E-07
				84.87	2.87E-07
				84.96	2.37E-07
				85.06	2.45E-07
				85.16	2.37E-07
				85.26	2.30E-07
				85.36	2.63E-07
				85.46	2.92E-07
				85.56	2.70E-07
				85.66	3.09E-07
				85.76	2.87E-07
				85.86	2.20E-07
				85.96	2.11E-07
				86.06	2.66E-07
				86.16	2.12E-07
				86.26	3.13E-07
				86.36	2.72E-07
				86.46	2.57E-07
				86.56	2.80E-07
				86.66	2.59E-07
				86.76	2.86E-07
				86.86	2.19E-07
				86.96	2.54E-07
				87.06	2.69E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR HILL AFB-OU10, HILL AFB, UTAH

U10-025		U10-043		U10-51 SONDE DATA AND STATS	
Depth	Mag Susc	Depth	Mag Susc	Depth	Mag Susc
ft bgs	m^3/kg	ft bgs	m^3/kg	ft bgs	m^3/kg
				87.16	2.55E-07
				87.26	2.17E-07
				87.36	2.63E-07
				87.46	1.63E-07
				87.56	3.10E-07
				87.66	2.18E-07
				87.76	1.76E-07
				87.86	2.72E-07
				87.96	1.95E-07
				88.06	1.94E-07
				88.16	2.90E-07
				88.26	1.81E-07
				88.35	2.25E-07
				88.45	2.25E-07
				88.55	2.64E-07
				88.65	2.18E-07
				88.75	2.60E-07
				88.85	2.37E-07
				88.95	2.42E-07
				89.05	2.21E-07
				89.15	1.81E-07
				89.25	2.42E-07
				89.35	1.90E-07
				89.45	2.17E-07
				89.55	2.18E-07
				89.65	1.97E-07
				89.75	2.20E-07
				89.85	2.43E-07
				89.95	2.46E-07
				90.05	2.76E-07
				90.15	2.26E-07
				90.25	2.09E-07
				90.35	2.41E-07
				90.45	2.61E-07
				90.55	2.37E-07
				90.65	1.92E-07
				90.75	1.89E-07
				90.85	1.84E-07
				90.95	2.37E-07
				91.05	2.18E-07
				91.15	2.02E-07
				91.25	1.89E-07
				91.35	2.29E-07
				91.45	1.87E-07
				91.55	1.90E-07
				91.65	1.83E-07
				91.75	1.86E-07
				91.84	2.43E-07
				91.94	2.18E-07
				92.04	2.35E-07
				92.14	1.82E-07
				92.24	2.31E-07
				92.34	2.72E-07
				92.44	1.75E-07
				92.54	1.81E-07
				92.64	1.61E-07
				92.74	1.81E-07
				92.84	2.32E-07
				92.94	2.69E-07
				93.04	1.84E-07
				93.14	2.08E-07
				93.24	1.74E-07
				93.34	2.08E-07
				93.44	1.91E-07
				93.54	2.49E-07
				93.64	1.60E-07
				93.74	1.98E-07
				93.84	2.15E-07
				93.94	1.73E-07
				94.04	2.45E-07
				94.14	1.62E-07
				94.24	1.94E-07
				94.34	1.98E-07
				94.44	2.23E-07
				94.54	1.98E-07
				94.64	2.08E-07
				94.74	2.00E-07
				94.84	1.90E-07
				94.94	1.76E-07
				95.04	2.62E-07
				95.14	1.70E-07
				95.23	1.76E-07
				95.33	1.83E-07
				95.43	1.90E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR HILL AFB-OU10, HILL AFB, UTAH

U10-025		U10-043		U10-51 SONDE DATA AND STATS	
Depth	Mag Susc	Depth	Mag Susc	Depth	Mag Susc
ft bgs	m^3/kg	ft bgs	m^3/kg	ft bgs	m^3/kg
				95.53	1.94E-07
				95.63	1.76E-07
				95.73	2.25E-07
				95.83	2.11E-07
				95.93	2.38E-07
				96.03	2.26E-07
				96.13	1.62E-07
				96.23	2.61E-07
				96.33	1.90E-07
				96.43	2.12E-07
				96.53	2.38E-07
				96.63	1.80E-07
				96.73	1.78E-07
				96.83	1.93E-07
				96.93	2.61E-07
				97.03	1.99E-07
				97.13	1.96E-07
				97.23	2.00E-07
				97.33	1.90E-07
				97.43	2.21E-07
				97.53	2.56E-07
				97.63	2.53E-07
				97.73	3.47E-07
				97.83	3.35E-07
				97.93	2.84E-07
				98.03	3.42E-07
				98.13	3.13E-07
				98.23	3.07E-07
				98.33	3.08E-07
				98.43	2.06E-07
				98.53	2.33E-07
				98.62	2.44E-07
				98.72	2.67E-07
				98.82	2.49E-07
				98.92	2.22E-07
				99.02	2.29E-07
				99.12	1.99E-07
				99.22	2.53E-07
				99.32	2.69E-07
				99.42	2.02E-07
				99.52	2.33E-07
				99.62	2.32E-07
				99.72	2.65E-07
				99.82	2.72E-07
				99.92	2.30E-07
				100.02	2.36E-07
				100.12	2.36E-07
				100.22	2.27E-07
				100.32	2.52E-07
				100.42	1.75E-07
				100.52	2.30E-07
				100.62	2.58E-07
				100.72	2.44E-07
				100.82	3.05E-07
				100.92	1.92E-07
				101.02	2.32E-07
				101.12	2.39E-07
				101.22	2.61E-07
				101.32	2.42E-07
				101.42	2.72E-07
				101.52	2.82E-07
				101.62	2.26E-07
				101.72	3.03E-07
				101.82	2.82E-07
				101.92	2.68E-07
				102.02	2.87E-07
				102.21	2.61E-07
				102.31	2.22E-07
				102.41	3.05E-07
				102.51	2.45E-07
				102.61	3.50E-07
				102.71	3.17E-07
				102.81	2.93E-07
				102.91	2.90E-07
				103.01	2.57E-07
				103.11	3.37E-07
				103.21	3.02E-07
				103.31	2.29E-07
				103.41	2.74E-07
				103.51	2.77E-07
				103.61	3.66E-07
				103.71	3.13E-07
				103.81	2.92E-07
				103.91	2.92E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR HILL AFB-OU10, HILL AFB, UTAH

U10-025		U10-043		U10-51 SONDE DATA AND STATS	
Depth	Mag Susc	Depth	Mag Susc	Depth	Mag Susc
ft bgs	m^3/kg	ft bgs	m^3/kg	ft bgs	m^3/kg
				104.01	3.24E-07
				104.11	2.79E-07
				104.21	3.57E-07
				104.31	3.11E-07
				104.41	3.79E-07
				104.51	3.31E-07
				104.61	3.28E-07
				104.71	3.39E-07
				104.81	3.04E-07
				104.91	3.10E-07
				105.01	3.43E-07
				105.11	3.19E-07
				105.21	3.09E-07
				105.31	3.04E-07
				105.41	2.88E-07
				105.50	2.26E-07
				105.60	3.56E-07
				105.70	2.42E-07
				105.80	2.34E-07
				105.90	3.06E-07
				106.00	3.08E-07
				106.10	2.69E-07
				106.20	2.32E-07
				106.30	2.63E-07
				106.40	2.54E-07
				106.50	2.48E-07
				106.60	1.92E-07
				106.70	2.35E-07
				106.80	2.81E-07
				106.90	3.11E-07
				107.00	3.14E-07
				107.10	2.76E-07
				107.20	2.92E-07
				107.30	2.31E-07
				107.40	2.12E-07
				107.50	2.97E-07
				107.60	2.52E-07
				107.70	2.56E-07
				107.80	2.68E-07
				107.90	1.74E-07
				108.00	2.16E-07
				108.10	2.60E-07
				108.20	2.65E-07
				108.30	1.92E-07
				108.40	2.83E-07
				108.50	2.71E-07
				108.60	2.51E-07
				108.70	2.17E-07
				108.80	2.47E-07
				108.90	2.85E-07
				108.99	2.29E-07
				109.09	2.87E-07
				109.19	2.43E-07
				109.29	2.85E-07
				109.39	2.31E-07
				109.49	3.17E-07
				109.59	2.67E-07
				109.69	2.72E-07
				109.79	2.84E-07
				109.89	2.14E-07
				109.99	2.62E-07
				110.09	2.30E-07
				110.19	2.86E-07
				110.29	2.41E-07
				110.39	2.18E-07
				110.49	2.39E-07
				110.59	2.56E-07
				110.69	3.15E-07
				110.79	2.35E-07
				110.89	2.34E-07
				110.99	2.36E-07
				111.09	2.24E-07
				111.19	2.25E-07
				111.29	2.59E-07
				111.39	2.07E-07
				111.49	1.77E-07
				111.59	1.88E-07
				111.69	2.00E-07
				111.79	2.31E-07
				111.89	2.74E-07
				111.99	2.72E-07
				112.09	2.23E-07
				112.19	2.12E-07
				112.29	1.83E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR HILL AFB-OU10, HILL AFB, UTAH

U10-025		U10-043		U10-51 SONDE DATA AND STATS	
Depth ft bgs	Mag Susc m^3/kg	Depth ft bgs	Mag Susc m^3/kg	Depth ft bgs	Mag Susc m^3/kg
				112.38	1.74E-07
				112.48	1.81E-07
				112.58	2.09E-07
				112.68	2.34E-07
				112.78	2.05E-07
				112.88	2.28E-07
				112.98	2.12E-07
				113.08	2.73E-07
				113.18	2.11E-07
				113.28	2.01E-07
				113.38	2.26E-07
				113.48	2.13E-07
				113.58	3.02E-07
				113.68	2.75E-07
				113.78	2.37E-07
				113.88	2.10E-07
				113.98	1.77E-07
				114.08	2.18E-07
				114.18	2.48E-07
				114.28	1.92E-07
				114.38	2.06E-07
				114.48	2.32E-07
				114.58	2.42E-07
				114.68	2.00E-07
				114.78	2.41E-07
				114.88	2.31E-07
				114.98	2.09E-07
				115.08	1.58E-07
				115.18	1.61E-07
				115.28	1.60E-07
				115.38	1.86E-07
				115.48	2.32E-07
				115.58	2.04E-07
				115.68	1.85E-07
				115.77	1.81E-07
				115.87	2.01E-07
				115.97	2.11E-07
				116.07	2.24E-07
				116.17	1.98E-07
				116.27	2.09E-07
				116.37	1.30E-07
				116.47	2.29E-07
				116.57	2.40E-07
				116.67	1.41E-07
				116.77	2.21E-07
				116.87	1.85E-07
				116.97	1.93E-07
				117.07	2.07E-07
				117.17	2.37E-07
				117.27	2.42E-07
				117.37	2.00E-07
				117.47	1.88E-07
				117.57	2.30E-07
				117.67	1.77E-07
				117.77	2.22E-07
				117.87	1.96E-07
				117.97	2.24E-07
				118.07	2.38E-07
				118.17	2.08E-07
				118.27	1.94E-07
				118.37	2.62E-07
				118.47	1.78E-07
				118.57	2.57E-07
				118.67	2.13E-07
				118.77	1.56E-07
				118.87	1.74E-07
				118.97	1.86E-07
				119.07	2.05E-07
				119.17	2.37E-07
				119.26	2.23E-07
				119.36	1.78E-07
				119.46	1.82E-07
				119.56	1.75E-07
				119.66	2.07E-07
				119.76	2.18E-07
				119.86	1.18E-07
				119.96	1.98E-07
				120.06	1.49E-07
				120.16	1.90E-07
				120.26	2.58E-07
				120.36	1.91E-07
				120.46	1.73E-07
				120.56	2.51E-07
				120.66	2.36E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR HILL AFB-OU10, HILL AFB, UTAH

U10-025		U10-043		U10-51 SONDE DATA AND STATS	
Depth	Mag Susc	Depth	Mag Susc	Depth	Mag Susc
ft bgs	m^3/kg	ft bgs	m^3/kg	ft bgs	m^3/kg
				120.76	2.22E-07
				120.86	1.57E-07
				120.96	1.82E-07
				121.06	1.95E-07
				121.16	1.37E-07
				121.26	2.67E-07
				121.36	1.98E-07
				121.46	2.32E-07
				121.56	2.31E-07
				121.66	2.01E-07
				121.76	1.67E-07
				121.86	1.89E-07
				122.06	2.19E-07
				122.16	1.32E-07
				122.26	1.36E-07
				122.36	2.32E-07
				122.46	2.13E-07
				122.56	1.58E-07
				122.65	1.57E-07
				122.75	2.35E-07
				122.85	2.13E-07
				122.95	1.81E-07
				123.05	2.12E-07
				123.15	2.13E-07
				123.25	1.85E-07
				123.35	2.07E-07
				123.45	2.19E-07
				123.55	2.18E-07
				123.65	2.24E-07
				123.75	1.82E-07
				123.85	1.92E-07
				123.95	1.89E-07
				124.05	1.24E-07
				124.15	2.33E-07
				124.25	1.63E-07
				124.35	1.37E-07
				124.45	1.73E-07
				124.55	1.78E-07
				124.65	1.59E-07
				124.75	2.22E-07
				124.85	2.22E-07
				124.95	1.96E-07
				125.05	2.18E-07
				125.15	1.63E-07
				125.25	2.05E-07
				125.35	1.37E-07
				125.45	1.51E-07
				125.55	1.67E-07
				125.65	1.90E-07
				125.75	1.45E-07
				125.85	2.03E-07
				125.95	2.21E-07
				126.05	1.40E-07
				126.14	2.31E-07
				126.24	1.27E-07
				126.34	2.00E-07
				126.44	1.69E-07
				126.54	2.36E-07
				126.64	2.12E-07
				126.74	1.89E-07
				126.84	1.76E-07
				126.94	1.61E-07
				127.04	2.33E-07
				127.14	1.65E-07
				127.24	2.05E-07
				127.34	1.65E-07
				127.44	1.92E-07
				127.54	1.88E-07
				127.64	2.30E-07
				127.74	2.06E-07
				127.84	1.93E-07
				127.94	1.92E-07
				128.04	2.12E-07
				128.14	1.90E-07
				128.24	2.02E-07
				128.34	2.30E-07
				128.44	1.79E-07
				128.54	1.62E-07
				128.64	1.92E-07
				128.74	2.07E-07
				128.84	1.63E-07
				128.94	1.68E-07
				129.04	1.64E-07
				129.14	1.64E-07

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MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR HILL AFB-OU10, HILL AFB, UTAH

U10-025		U10-043		U10-51 SONDE DATA AND STATS	
Depth ft bgs	Mag Susc m^3/kg	Depth ft bgs	Mag Susc m^3/kg	Depth ft bgs	Mag Susc m^3/kg
				129.24	1.73E-07
				129.34	1.96E-07
				129.44	1.53E-07
				129.53	1.58E-07
				129.63	1.81E-07
				129.73	1.96E-07
				129.83	1.63E-07
				129.93	2.42E-07
				130.03	1.84E-07
				130.13	2.36E-07
				130.23	2.00E-07
				130.33	1.76E-07
				130.43	1.75E-07
				130.53	2.32E-07
				130.63	2.24E-07
				130.73	1.96E-07
				130.83	2.14E-07
				130.93	2.02E-07
				131.03	1.56E-07
				131.13	1.96E-07
				131.23	1.84E-07
				131.33	1.81E-07
				131.43	2.19E-07
				131.53	2.21E-07
				131.63	1.77E-07
				131.73	1.97E-07
				131.83	2.03E-07
				131.93	2.05E-07
				132.03	2.40E-07
				132.13	2.00E-07
				132.23	2.03E-07
				132.33	2.00E-07
				132.43	1.82E-07
				132.53	1.97E-07
				132.63	1.83E-07
				132.73	1.70E-07
				132.83	2.00E-07
				132.92	1.84E-07
				133.02	2.02E-07
				133.12	1.88E-07
				133.22	1.79E-07
				133.32	1.98E-07
				133.42	2.35E-07
				133.52	1.89E-07
				133.62	1.48E-07
				133.72	1.89E-07
				133.82	1.68E-07
				133.92	1.58E-07
				134.02	1.49E-07
				134.12	2.04E-07
				134.22	1.82E-07
				134.32	1.74E-07
				134.42	2.17E-07
				134.52	1.89E-07
				134.62	2.41E-07
				134.72	1.78E-07
				134.82	1.94E-07
				134.92	2.02E-07
				135.02	1.95E-07
				135.12	1.81E-07
				135.22	1.93E-07
				135.32	1.95E-07
				135.42	1.52E-07
				135.52	1.79E-07
				135.62	1.96E-07
				135.72	2.28E-07
				135.82	9.68E-08
				135.92	1.65E-07
				136.02	2.28E-07
				136.12	1.86E-07
				136.22	2.20E-07
				136.32	1.83E-07
				136.41	1.18E-07
				136.51	1.99E-07
				136.61	1.74E-07
				136.71	2.05E-07
				136.81	1.80E-07
				136.91	1.75E-07
				137.01	6.85E-08
				137.11	1.51E-07
				137.21	1.55E-07
				137.31	1.46E-07
				137.41	1.03E-07
				137.51	1.60E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR HILL AFB-OU10, HILL AFB, UTAH

U10-025		U10-043		U10-51 SONDE DATA AND STATS	
Depth	Mag Susc	Depth	Mag Susc	Depth	Mag Susc
ft bgs	m^3/kg	ft bgs	m^3/kg	ft bgs	m^3/kg
				137.61	1.99E-07
				137.71	2.21E-07
				137.81	1.56E-07
				137.91	1.19E-07
				138.01	2.06E-07
				138.11	1.94E-07
				138.21	1.97E-07
				138.31	2.31E-07
				138.41	1.98E-07
				138.51	1.69E-07
				138.61	6.48E-08
				138.71	2.14E-07
				138.81	2.14E-07
				138.91	2.30E-07
				139.01	2.07E-07
				139.11	1.66E-07
				139.21	1.98E-07
				139.31	1.62E-07
				139.41	1.87E-07
				139.51	1.73E-07
				139.61	2.11E-07
				139.71	1.55E-07
				139.80	2.13E-07
				139.90	1.68E-07
				140.00	1.93E-07
				140.10	2.08E-07
				140.20	1.67E-07
				140.30	1.90E-07
				140.40	2.07E-07
				140.50	1.73E-07
				140.60	2.08E-07
				140.70	2.62E-07
				140.80	1.76E-07
				140.90	1.74E-07
				141.00	2.49E-07
				141.10	1.56E-07
				141.20	1.74E-07
				141.30	1.37E-07
				141.40	1.21E-07
				141.50	1.67E-07
				141.60	1.95E-07
				141.70	1.99E-07
				141.80	2.12E-07
				141.90	2.10E-07
				142.00	1.81E-07
				142.10	2.22E-07
				142.20	1.68E-07
				142.30	2.07E-07
				142.40	2.09E-07
				142.50	1.63E-07
				142.60	1.99E-07
				142.70	1.68E-07
				142.80	1.55E-07
				142.90	1.57E-07
				143.00	1.48E-07
				143.10	1.36E-07
				143.20	1.90E-07
				143.29	2.07E-07
				143.39	2.08E-07
				143.49	1.67E-07
				143.59	2.72E-07
				143.69	2.12E-07
				143.79	1.60E-07
				143.89	2.01E-07
				143.99	2.00E-07
				144.09	1.82E-07
				144.19	1.32E-07
				144.29	1.91E-07
				144.39	2.02E-07
				144.49	1.87E-07
				144.59	1.69E-07
				144.69	2.00E-07
				144.79	2.30E-07
				144.89	2.10E-07
				144.99	1.79E-07
				145.09	1.74E-07
				145.19	1.51E-07
				145.29	2.04E-07
				145.39	1.49E-07
				145.49	2.31E-07
				145.59	2.35E-07
				145.69	1.57E-07
				145.79	1.37E-07
				145.89	2.41E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR HILL AFB-OU10, HILL AFB, UTAH

U10-025		U10-043		U10-51 SONDE DATA AND STATS	
Depth	Mag Susc	Depth	Mag Susc	Depth	Mag Susc
ft bgs	m^3/kg	ft bgs	m^3/kg	ft bgs	m^3/kg
				145.99	2.13E-07
				146.09	2.12E-07
				146.19	1.83E-07
				146.29	2.29E-07
				146.39	2.00E-07
				146.49	1.84E-07
				146.59	2.00E-07
				146.68	1.54E-07
				146.78	1.66E-07
				146.88	2.13E-07
				146.98	2.46E-07
				147.08	2.58E-07
				147.18	1.83E-07
				147.28	1.86E-07
				147.38	1.54E-07
				147.48	1.87E-07
				147.58	1.61E-07
				147.68	1.74E-07
				147.78	1.78E-07
				147.88	2.00E-07
				147.98	1.31E-07
				148.08	2.26E-07
				148.18	2.03E-07
				148.28	2.34E-07
				148.38	2.13E-07
				148.48	1.77E-07
				148.58	2.39E-07
				148.68	2.28E-07
				148.78	2.30E-07
				148.88	1.98E-07
				148.98	1.61E-07
				149.08	2.21E-07
				149.18	2.59E-07
				149.28	1.99E-07
				149.38	1.84E-07
				149.48	1.82E-07
				149.58	1.83E-07
				149.68	1.98E-07
				149.78	1.99E-07
				149.88	1.91E-07
				149.98	2.33E-07
				150.07	1.75E-07
				150.17	1.49E-07
				150.27	1.48E-07
				150.37	1.85E-07
				150.47	2.04E-07
				150.57	1.76E-07
				150.67	1.77E-07
				150.77	2.02E-07
				150.87	1.97E-07
				150.97	1.99E-07
				151.07	1.99E-07
				151.17	2.34E-07
				151.27	1.65E-07
				151.37	2.24E-07
				151.47	2.07E-07
				151.57	1.69E-07
				151.67	1.42E-07
				151.77	2.37E-07
				151.87	2.54E-07
				151.97	1.40E-07
				152.07	2.86E-07
				152.17	1.62E-07
				152.27	1.73E-07
				152.37	3.02E-07
				152.47	1.94E-07
				152.57	2.82E-07
				152.67	2.00E-07
				152.77	2.29E-07
				152.87	1.92E-07
				152.97	1.93E-07
				153.07	1.91E-07
				153.17	2.00E-07
				153.27	1.53E-07
				153.37	1.81E-07
				153.47	1.92E-07
				153.56	1.19E-07
				153.66	2.07E-07
				153.76	2.14E-07
				153.86	1.85E-07
				153.96	1.94E-07
				154.06	2.33E-07
				154.16	1.75E-07
				154.26	1.91E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR HILL AFB-OU10, HILL AFB, UTAH

U10-025		U10-043		U10-51 SONDE DATA AND STATS	
Depth	Mag Susc	Depth	Mag Susc	Depth	Mag Susc
ft bgs	m^3/kg	ft bgs	m^3/kg	ft bgs	m^3/kg
				154.36	1.90E-07
				154.46	1.49E-07
				154.56	1.77E-07
				154.66	1.82E-07
				154.76	1.93E-07
				154.86	1.84E-07
				154.96	2.06E-07
				155.06	1.45E-07
				155.16	1.51E-07
				155.26	2.15E-07
				155.36	2.25E-07
				155.46	1.59E-07
				155.56	2.00E-07
				155.66	2.05E-07
				155.76	1.77E-07
				155.86	1.45E-07
				155.96	2.35E-07
				156.06	1.71E-07
				156.16	1.89E-07
				156.26	2.10E-07
				156.36	2.58E-07
				156.46	2.06E-07
				156.56	1.74E-07
				156.66	2.09E-07
				156.76	2.26E-07
				156.86	2.12E-07
				156.95	1.94E-07
				157.05	1.76E-07
				157.15	2.17E-07
				157.25	1.69E-07
				157.35	2.01E-07
				157.45	2.20E-07
				157.55	1.66E-07
				157.65	1.98E-07
				157.75	2.14E-07
				157.85	1.91E-07
				157.95	2.06E-07
				158.05	1.63E-07
				158.15	1.73E-07
				158.25	2.59E-07
				158.35	2.30E-07
				158.45	2.25E-07
				158.55	1.95E-07
				158.65	1.73E-07
				158.75	2.46E-07
				158.85	1.60E-07
				158.95	1.85E-07
				159.05	1.48E-07
				159.15	1.72E-07
				159.25	2.08E-07
				159.35	2.14E-07
				159.45	1.69E-07
				159.55	1.69E-07
				159.65	1.75E-07
				159.75	1.42E-07
				159.85	2.03E-07
				159.95	1.69E-07
				160.05	1.78E-07
				160.15	2.34E-07
				160.25	1.88E-07
				160.35	2.44E-07
				160.44	2.00E-07
				160.54	2.36E-07
				160.64	2.26E-07
				160.74	2.23E-07
				160.84	2.02E-07
				160.94	1.88E-07
				161.04	1.84E-07
				161.14	2.32E-07
				161.24	1.68E-07
				161.34	2.26E-07
				161.44	1.90E-07
				161.54	1.54E-07
				161.64	2.21E-07
				161.74	1.88E-07
				161.84	2.19E-07
				161.94	1.49E-07
				162.04	2.02E-07
				162.14	2.40E-07
				162.24	2.15E-07
				162.34	1.79E-07
				162.44	2.02E-07
				162.54	1.99E-07
				162.64	2.00E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR HILL AFB-OU10, HILL AFB, UTAH

U10-025

Depth ft bgs	Mag Susc m^3/kg

U10-043

Depth ft bgs	Mag Susc m^3/kg

U10-51 SONDE DATA AND STATS

Depth ft bgs	Mag Susc m^3/kg
162.74	1.86E-07
162.84	2.05E-07
162.94	2.03E-07
163.04	2.14E-07
163.14	1.86E-07
163.24	2.81E-07
163.34	2.47E-07
163.44	2.17E-07
163.54	1.87E-07
163.64	2.27E-07
163.74	1.94E-07
163.83	1.90E-07
163.93	1.66E-07
164.03	2.04E-07
164.13	1.99E-07
164.23	1.51E-07
164.33	1.69E-07
164.43	2.39E-07
164.53	2.58E-07
164.63	2.15E-07
164.73	2.27E-07
164.83	1.98E-07
164.93	2.39E-07
165.03	2.18E-07
165.13	2.54E-07
165.23	2.80E-07
165.33	2.78E-07
165.43	2.52E-07
165.53	2.95E-07
165.63	3.16E-07
165.73	2.92E-07
165.83	2.49E-07
165.93	2.99E-07
166.03	3.30E-07
166.13	2.88E-07
166.23	2.90E-07
166.33	2.90E-07
166.43	3.65E-07
166.53	2.76E-07
166.63	3.04E-07
166.73	2.87E-07
166.83	3.52E-07
166.93	2.98E-07
167.03	3.65E-07
167.13	3.46E-07
167.22	3.30E-07
167.32	2.84E-07
167.42	3.56E-07
167.52	2.95E-07
167.62	3.46E-07
167.72	3.34E-07
167.82	2.54E-07
167.92	2.76E-07
168.02	3.21E-07
168.12	2.74E-07
168.22	2.93E-07
168.32	2.70E-07
168.42	2.78E-07
168.52	2.72E-07
168.62	2.86E-07
168.72	3.47E-07
168.82	3.00E-07
168.92	2.87E-07
169.02	3.46E-07
169.12	3.35E-07
169.22	2.88E-07
169.32	3.72E-07
169.42	3.24E-07
169.52	3.09E-07
169.62	2.99E-07
169.72	2.75E-07
169.82	2.83E-07
169.92	3.24E-07
170.02	3.58E-07
170.12	2.64E-07
170.22	2.95E-07
170.32	2.98E-07
170.42	3.12E-07
170.52	3.27E-07
170.62	3.34E-07
170.71	3.29E-07
170.81	2.95E-07
170.91	2.99E-07
171.01	3.06E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR HILL AFB-OU10, HILL AFB, UTAH

U10-025		U10-043		U10-51 SONDE DATA AND STATS	
Depth ft bgs	Mag Susc m^3/kg	Depth ft bgs	Mag Susc m^3/kg	Depth ft bgs	Mag Susc m^3/kg
				171.11	3.55E-07
				171.21	3.04E-07
				171.31	2.90E-07
				171.41	3.04E-07
				171.51	2.95E-07
				171.61	2.93E-07
				171.71	3.12E-07
				171.81	3.46E-07
				171.91	2.94E-07
				172.01	2.83E-07
				172.11	3.41E-07
				172.21	3.16E-07
				172.31	2.65E-07
				172.41	2.49E-07
				172.51	3.04E-07
				172.61	2.79E-07
				172.71	2.97E-07
				172.81	2.35E-07
				172.91	2.81E-07
				173.01	2.95E-07
				173.11	2.46E-07
				173.21	3.04E-07
				173.31	2.95E-07
				173.41	2.69E-07
				173.51	3.12E-07
				173.61	2.86E-07
				173.71	2.95E-07
				173.81	2.98E-07
				173.91	3.08E-07
				174.01	3.45E-07
				174.10	3.52E-07
				174.20	3.04E-07
				174.30	2.92E-07
				174.40	2.41E-07
				174.50	2.95E-07
				174.60	2.57E-07
				174.70	2.59E-07
				174.80	2.64E-07
				174.90	2.67E-07
				175.00	3.07E-07
				175.10	2.64E-07
				175.20	2.22E-07
				175.30	2.57E-07
				175.40	2.25E-07
				175.50	2.89E-07
				175.60	2.68E-07
				175.70	2.04E-07
				175.80	1.88E-07
				175.90	2.62E-07
				176.00	2.37E-07
				176.10	2.13E-07
				176.20	1.93E-07
				176.30	2.10E-07
				176.40	2.51E-07
				176.50	2.31E-07
				176.60	2.44E-07
				176.70	2.08E-07
				176.80	2.09E-07
				176.90	2.29E-07
				177.00	2.47E-07
				177.10	1.89E-07
				177.20	1.63E-07
				177.30	1.84E-07
				177.40	1.84E-07
				177.50	2.33E-07
				177.59	2.44E-07
				177.69	2.10E-07
				177.79	2.08E-07
				177.89	2.16E-07
				177.99	1.89E-07
				178.09	2.62E-07
				178.19	2.06E-07
				178.29	2.31E-07
				178.39	2.04E-07
				178.49	2.00E-07
				178.59	1.55E-07
				178.69	2.16E-07
				178.79	1.67E-07
				178.89	2.16E-07
				178.99	2.49E-07
				179.09	2.32E-07
				179.19	2.06E-07
				179.29	2.21E-07
				179.39	1.96E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR HILL AFB-OU10, HILL AFB, UTAH

U10-025		U10-043		U10-51 SONDE DATA AND STATS	
Depth ft bgs	Mag Susc m^3/kg	Depth ft bgs	Mag Susc m^3/kg	Depth ft bgs	Mag Susc m^3/kg
				179.49	1.94E-07
				179.59	1.89E-07
				179.69	2.00E-07
				179.79	2.07E-07
				179.89	1.79E-07
				179.99	2.65E-07
				180.09	2.09E-07
				180.19	2.15E-07
				180.29	2.27E-07
				180.39	2.45E-07
				180.49	2.09E-07
				180.59	1.82E-07
				180.69	1.65E-07
				180.79	2.48E-07
				180.89	2.01E-07
				180.98	1.98E-07
				181.08	2.27E-07
				181.18	1.89E-07
				181.28	2.13E-07
				181.38	2.41E-07
				181.48	2.01E-07
				181.58	1.81E-07
				181.68	2.40E-07
				181.78	1.92E-07
				181.88	1.91E-07
				181.98	1.96E-07
				182.08	1.66E-07
				182.18	1.71E-07
				182.28	2.40E-07
				182.38	2.78E-07
				182.48	2.34E-07
				182.58	2.55E-07
				182.68	1.92E-07
				182.78	1.88E-07
				182.88	1.81E-07
				182.98	1.49E-07
				183.08	1.79E-07
				183.18	2.47E-07
				183.28	2.10E-07
				183.38	2.23E-07
				183.48	2.10E-07
				183.58	1.92E-07
				183.68	2.10E-07
				183.78	1.80E-07
				183.88	2.13E-07
				183.98	2.09E-07
				184.08	2.11E-07
				184.18	1.54E-07
				184.28	2.19E-07
				184.37	2.02E-07
				184.47	2.29E-07
				184.57	2.52E-07
				184.67	2.20E-07
				184.77	2.07E-07
				184.87	2.31E-07
				184.97	1.83E-07
				185.07	1.73E-07
				185.17	1.83E-07
				185.27	1.78E-07
				185.37	2.46E-07
				185.47	1.99E-07
				185.57	1.96E-07
				185.67	2.22E-07
				185.77	1.87E-07
				185.87	2.29E-07
				185.97	2.26E-07
				186.07	2.13E-07
				186.17	2.52E-07
				186.27	2.19E-07
				186.37	2.37E-07
				186.47	1.99E-07
				186.57	2.48E-07
				186.67	2.16E-07
				186.77	1.97E-07
				186.87	2.55E-07
				186.97	1.87E-07
				187.07	1.59E-07
				187.17	2.56E-07
				187.27	2.19E-07
				187.37	2.26E-07
				187.47	1.90E-07
				187.57	2.44E-07
				187.67	2.03E-07
				187.77	1.67E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR HILL AFB-OU10, HILL AFB, UTAH

U10-025		U10-043		U10-51 SONDE DATA AND STATS	
Depth	Mag Susc	Depth	Mag Susc	Depth	Mag Susc
ft bgs	m^3/kg	ft bgs	m^3/kg	ft bgs	m^3/kg
				187.86	1.92E-07
				187.96	1.83E-07
				188.06	2.09E-07
				188.16	2.01E-07
				188.26	2.09E-07
				188.36	1.53E-07
				188.46	2.11E-07
				188.56	1.99E-07
				188.66	2.30E-07
				188.76	1.60E-07
				188.86	1.65E-07
				188.96	1.54E-07
				189.06	2.07E-07
				189.16	1.61E-07
				189.26	2.11E-07
				189.36	1.99E-07
				189.46	1.62E-07
				189.56	2.53E-07
				189.66	1.95E-07
				189.76	2.00E-07
				189.86	1.97E-07
				189.96	1.90E-07
				190.06	1.83E-07
				190.16	1.67E-07
				190.26	1.67E-07
				190.36	1.83E-07
				190.46	2.05E-07
				190.56	1.81E-07
				190.66	1.52E-07
				190.76	1.62E-07
				190.86	2.01E-07
				190.96	1.65E-07
				191.06	1.73E-07
				191.16	1.59E-07
				191.25	2.61E-07
				191.35	1.24E-07
				191.45	1.88E-07
				191.55	1.57E-07
				191.65	2.05E-07
				191.75	1.63E-07
				191.85	1.32E-07
				191.95	1.46E-07
				192.05	2.02E-07
				192.15	1.51E-07
				192.25	1.63E-07
				192.35	1.64E-07
				192.45	1.74E-07
				192.55	1.24E-07
				192.65	1.90E-07
				192.75	1.62E-07
				192.85	1.32E-07
				192.95	1.40E-07
				193.05	1.66E-07
				193.15	1.66E-07
				193.25	1.80E-07
				193.35	1.61E-07
				193.45	1.38E-07
				193.55	1.93E-07
				193.65	1.50E-07
				193.75	1.59E-07
				193.85	1.57E-07
				193.95	1.31E-07
				194.05	2.06E-07
				194.15	1.90E-07
				194.25	1.55E-07
				194.35	1.12E-07
				194.45	2.12E-07
				194.55	1.44E-07
				194.65	1.81E-07
				194.74	1.12E-07
				194.84	1.55E-07
				194.94	1.76E-07
				195.04	1.33E-07
				195.14	1.45E-07
				195.24	1.57E-07
				195.34	1.56E-07
				195.44	1.61E-07
				195.54	2.15E-07
				195.64	1.51E-07
				195.74	1.13E-07
				195.84	1.48E-07
				195.94	1.73E-07
				196.04	1.21E-07
				196.14	1.55E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR HILL AFB-OU10, HILL AFB, UTAH

U10-025		U10-043		U10-51 SONDE DATA AND STATS	
Depth	Mag Susc	Depth	Mag Susc	Depth	Mag Susc
ft bgs	m^3/kg	ft bgs	m^3/kg	ft bgs	m^3/kg
				196.24	1.52E-07
				196.34	1.54E-07
				196.44	1.74E-07
				196.54	1.78E-07
				196.64	1.69E-07
				196.74	2.02E-07
				196.84	1.83E-07
				196.94	1.42E-07
				197.04	1.18E-07
				197.14	1.84E-07
				197.24	1.62E-07
				197.34	1.72E-07
				197.44	1.63E-07
				197.54	1.65E-07
				197.64	7.98E-08
				197.74	2.23E-07
				197.84	1.20E-07
				197.94	1.48E-07
				198.04	1.84E-07
				198.13	1.40E-07
				198.23	1.62E-07
				198.33	1.91E-07
				198.43	1.82E-07
				198.53	1.75E-07
				198.63	1.85E-07
				198.73	2.08E-07
				198.83	1.44E-07
				198.93	1.20E-07
				199.03	2.12E-07
				199.13	1.76E-07
				199.23	2.06E-07
				199.33	1.89E-07
				199.43	1.84E-07
				199.53	1.77E-07
				199.63	1.49E-07
				199.73	1.56E-07
				199.83	1.41E-07
				199.93	1.38E-07
				200.03	1.85E-07
				200.13	1.48E-07
				200.23	2.23E-07
				200.33	1.30E-07
				200.43	1.06E-07
				200.53	1.94E-07
				200.63	1.84E-07
				200.73	1.56E-07
				200.83	1.83E-07
				200.93	1.40E-07
				201.03	1.26E-07
				201.13	1.97E-07
				201.23	1.94E-07
				201.33	2.05E-07
				201.43	1.88E-07
				201.52	1.77E-07
				201.62	1.61E-07
				201.72	1.27E-07
				201.82	1.94E-07
				201.92	1.85E-07
				202.02	1.37E-07
				202.12	1.61E-07
				202.22	1.39E-07
				202.32	2.05E-07
				202.42	1.79E-07
				202.52	1.48E-07
				202.62	1.57E-07
				202.72	1.75E-07
				202.82	1.68E-07
				202.92	2.02E-07
				203.02	1.82E-07
				203.12	1.45E-07
				203.22	1.58E-07
				203.32	2.01E-07
				203.42	1.45E-07
				203.52	1.76E-07
				203.62	1.48E-07
				203.72	1.33E-07
				203.82	1.52E-07
				203.92	1.89E-07
				204.02	1.60E-07
				204.12	1.57E-07
				204.22	1.69E-07
				204.32	1.33E-07
				204.42	2.25E-07
				204.52	2.23E-07

MASS MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR HILL AFB-OU10, HILL AFB, UTAH

U10-025

Depth ft bgs	Mag Susc m^3/kg

U10-043

Depth ft bgs	Mag Susc m^3/kg

U10-51 SONDE DATA AND STATS

Depth ft bgs	Mag Susc m^3/kg
204.62	1.10E-07
204.72	1.55E-07
204.82	1.77E-07
204.92	1.66E-07
205.01	1.55E-07
205.11	2.30E-07
205.21	1.71E-07
205.31	2.32E-07
205.41	1.62E-07
205.51	1.82E-07
205.61	2.11E-07
205.71	1.66E-07
205.81	1.89E-07
205.91	1.88E-07
206.01	1.60E-07
206.11	1.83E-07
206.21	1.81E-07
206.31	2.39E-07
206.41	1.63E-07
206.51	1.19E-07
206.61	1.51E-07
206.71	1.55E-07
206.81	1.23E-07
206.91	1.75E-07
207.01	1.81E-07
207.11	1.58E-07

SUMMARY STATS FOR THE SHALLOW INTERVAL - 4-33 feet bgs

Mean	2.61E-07
Standard Error	3.59E-09
Median	2.53E-07
Mode	#N/A
Standard Deviation	6.14E-08
Sample Variance	3.77E-15
Kurtosis	1.625866
Skewness	0.903494
Range	3.73E-07
Minimum	1.31E-07
Maximum	5.04E-07
Sum	7.62E-05
Count	292
Confidence Level(95.0%)	7.07E-09

SUMMARY STATS FOR THE DEEP INTERVAL 50-185 ft

Mean	2.33E-07
Standard Error	1.37E-09
Median	2.31E-07
Mode	2.59E-07
Standard Deviation	5.05E-08
Sample Variance	2.55E-15
Kurtosis	-0.36649
Skewness	0.20777
Range	3.14E-07
Minimum	6.48E-08
Maximum	3.79E-07
Sum	0.000315
Count	1352
Confidence Level(95.0%)	2.7E-09

WIEDEMEIER & ASSOCIATES

PROJECT	ESTCP 201584
LOCATION	Hill AFB Operable Unit 10
WELL	U10-025 Up - Run 1
LOGGER	T.H. Wiedemeier
DATE	7/27/16

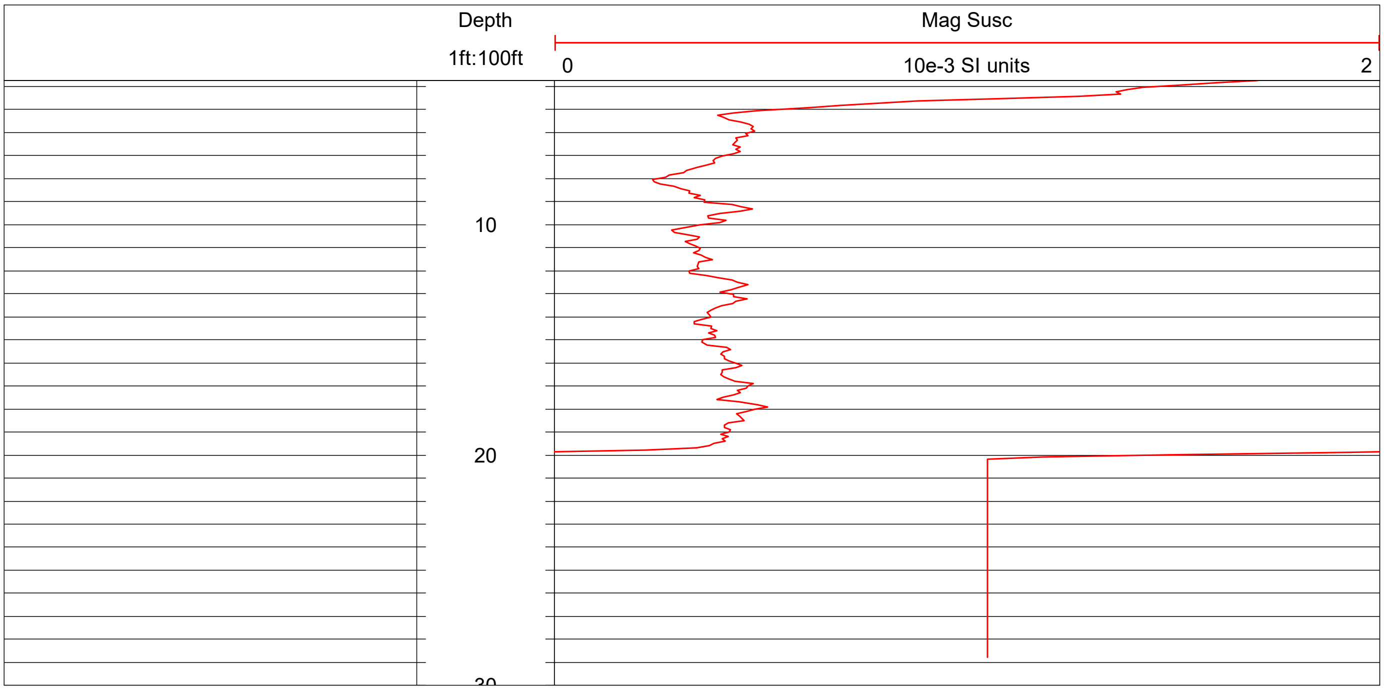
TOOL	HMA-453-S
CALIBRATION DATE/TIME	7/27/16 -- 16:25
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	0 = 224.375 and 5E-3 = 1281.87 cps
DEPTH TO WATER, TD	14.45 ft BTOC; 41.87 ft BGS
CASING INNER DIAMETER	2"
REMARKS	

PROJECT	ESTCP 201584	TOOL	HMA-453-S
LOCATION	Hill AFB Operable Unit 10	CALIBRATION DATE/TIME	7/27/16 -- 16:25
WELL	U10-025 Down Run 2	CALIBRATION STANDARDS	0 and 5E-3 SI Units
LOGGER	T.H. Wiedemeier	CALIBRATION RESULTS	0 = 224.38 and 5E-3 = 1281.87
DATE	7/27/16	DEPTH TO WATER, TD	14.45 ft BTOC; 41.87 ft BGS
		CASING INNER DIAMETER	2"
		REMARKS	

PROJECT	ESTCP 201584
LOCATION	Hill AFB Operable Unit 10
WELL	U10-025 Up - Run 2
LOGGER	T.H. Wiedemeier
DATE	7/27/16

TOOL	HMA-453-S
CALIBRATION DATE/TIME	7/27/16 -- 1625
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	0 = 224.38 and 5E-3 = 1281.87
DEPTH TO WATER, TD	14.45 ft BTOC; 41.87 ft BGS
CASING INNER DIAMETER	2"
REMARKS	

PROJECT	ESTCP 201584
LOCATION	Hill AFB Operable Unit 10
WELL	U10-043 Down
LOGGER	T.H. Wiedemeier
DATE	7/27/16
TOOL	HMA-453-S
CALIBRATION DATE/TIME	7/27/16 -- 11:10
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	0=213.33 and 5E-3 = 1335.6 cps
DEPTH TO WATER, TD	10.55 ft BTOC, 30.38 ft BGS
CASING INNER DIAMETER	2
REMARKS	Strange Response at 20 ft BGS. Metal in Well?



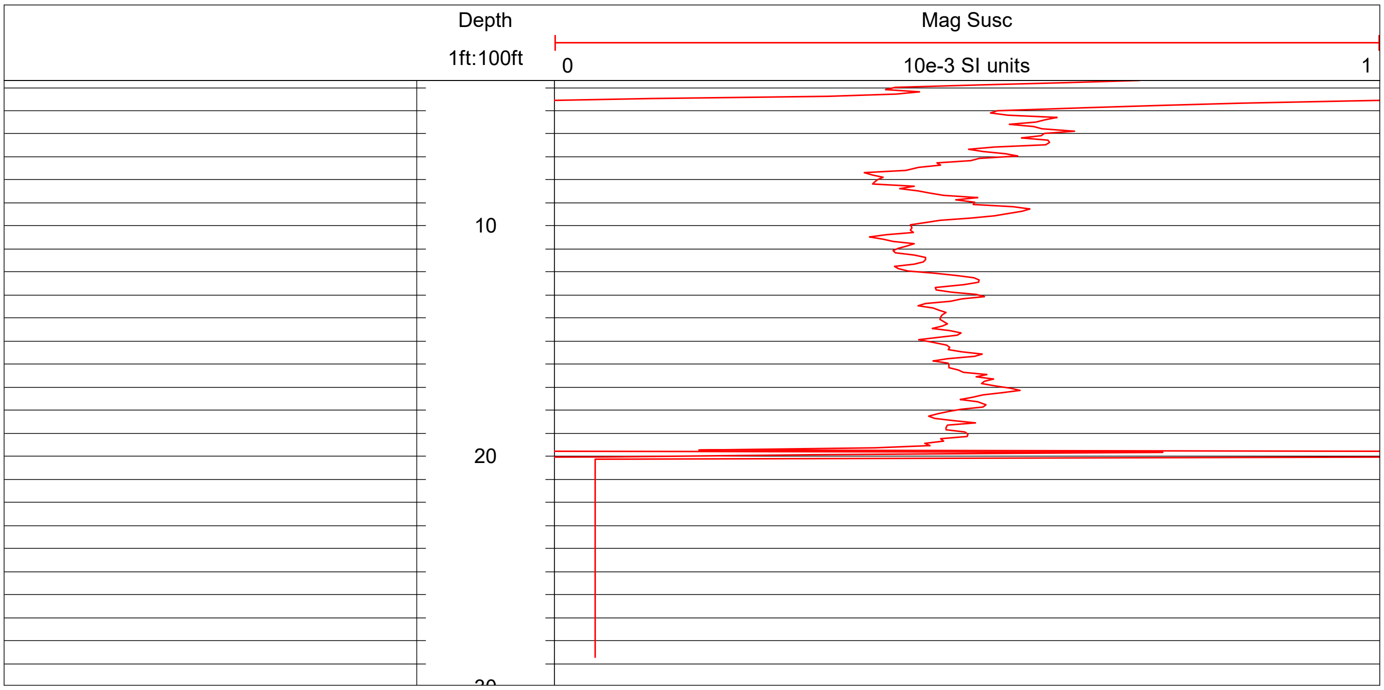
WIEDEMEIER & ASSOCIATES

PROJECT	ESTCP 201584
LOCATION	Hill AFB Operable Unit 10
WELL	U10-043 Up
LOGGER	T.H. Wiedemeier
DATE	7/27/16

TOOL	HMA-453-S
CALIBRATION DATE/TIME	7/27/16, 11:10
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	0 = 213.33 and 5E-3 = 1335.6 cps
DEPTH TO WATER, TD	10.55 ft BTOC, 30.38 ft BGS
CASING INNER DIAMETER	2"

REMARKS

Metal in well at ~20 ft BGS

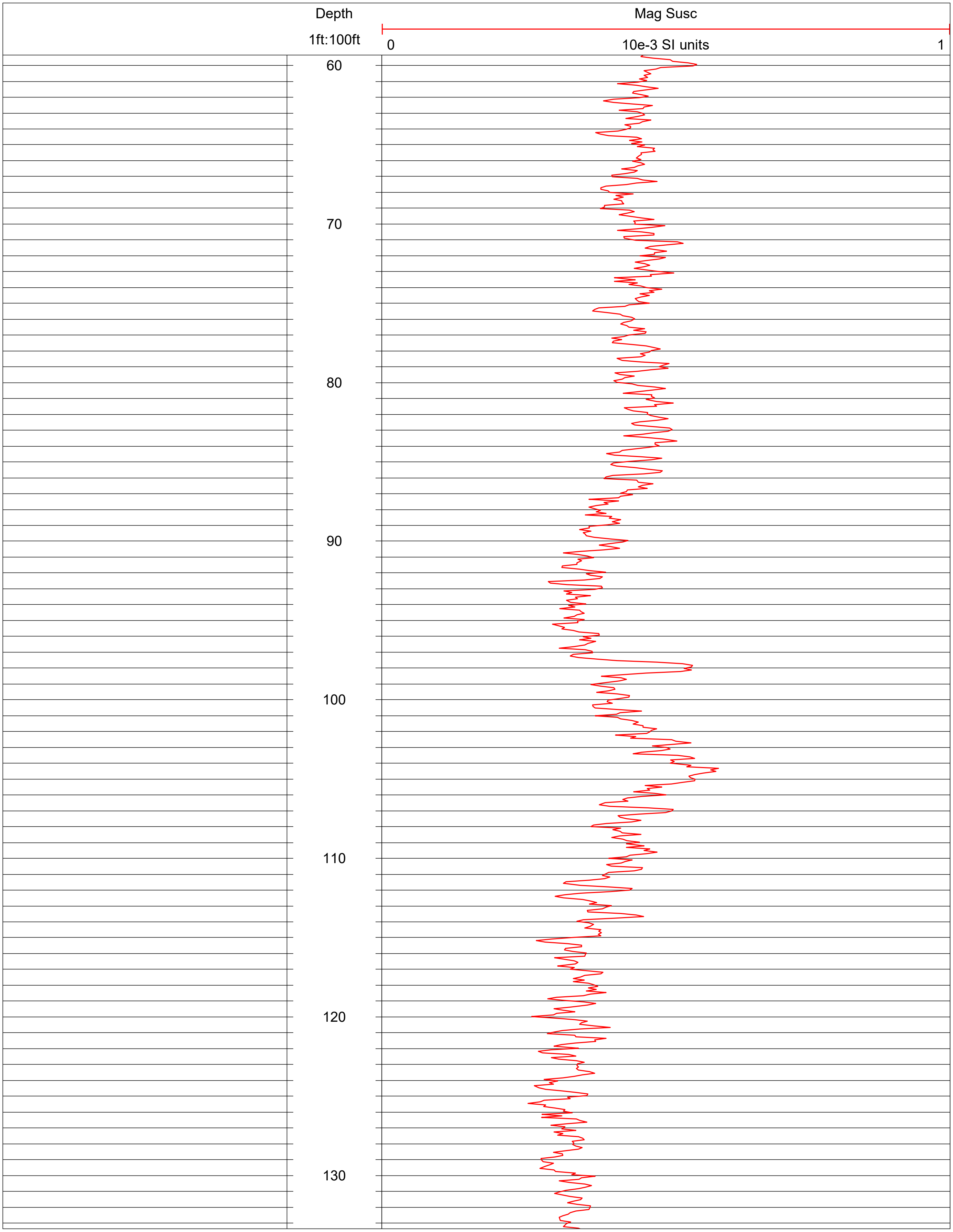


WIEDEMEIER & ASSOCIATES

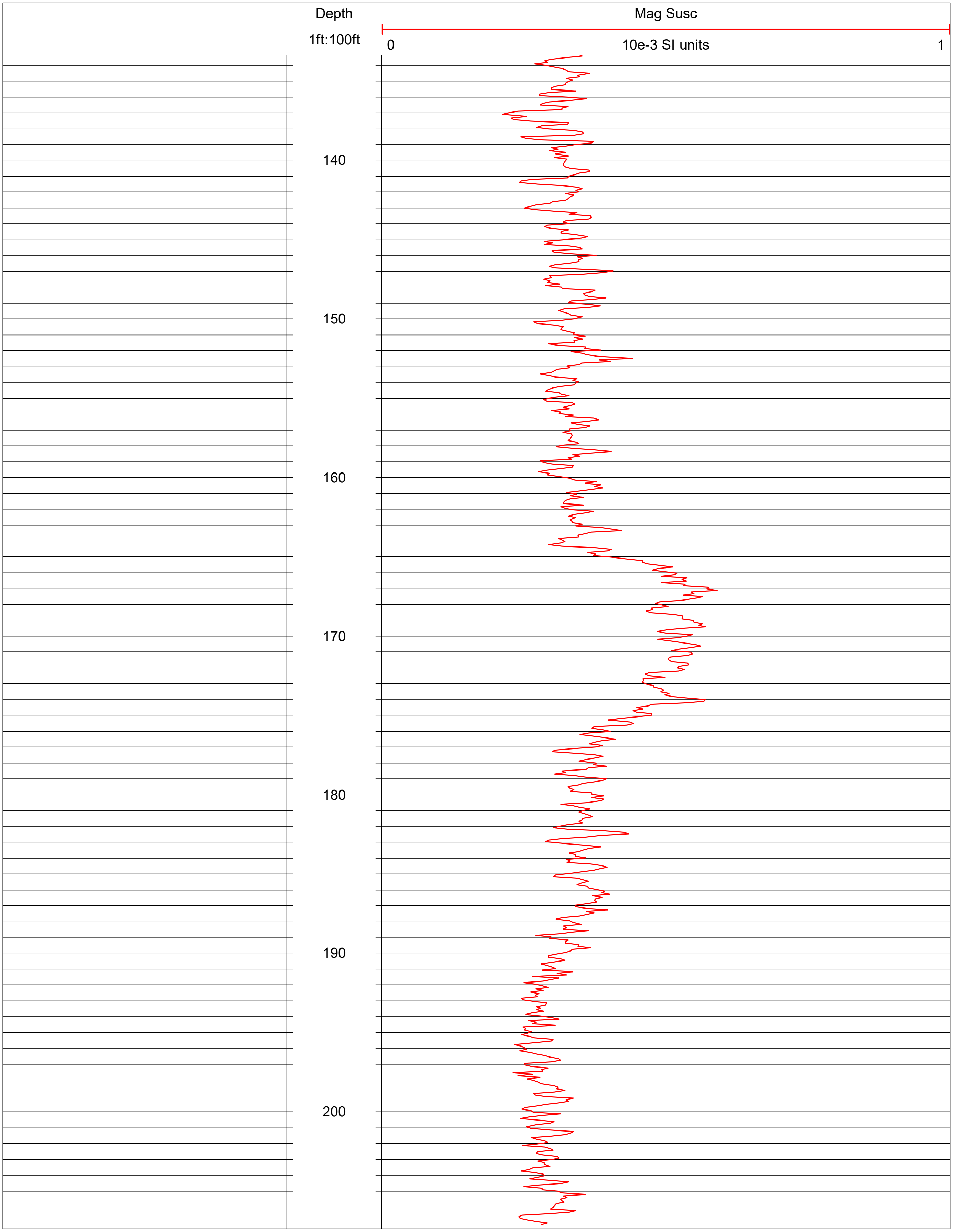
PROJECT	ESTCP 201584
LOCATION	Hill AFB Operable Unit 10
WELL	U10-051 Up
LOGGER	T.H. Wiedemeier
DATE	7/27/16 at 19:03

TOOL	HMA-453-S
CALIBRATION DATE/TIME	7/27/16, 16:25
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	0 = 224.375 and 5E-3 = 1281.87 cps
DEPTH TO WATER, TD	
CASING INNER DIAMETER	4"
REMARKS	

Used U10-025 Calib because of overhead wires and transformer



Depth
1ft:100ft
Mag Susc
0
10e-3 SI units
1
60
70
80
90
100
110
120
130


Depth
1ft:100ft
Mag Susc
0
10e-3 SI units
1
140
150
160
170
180
190
200

	Depth	Mag Susc
	1ft:100ft	0 10e-3 SI units 1

MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR WELL OU2-043 HILL AFB OU-2

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m^3/kg
3.53	0.206945	1.21732E-07
3.63	0.281035	1.65315E-07
3.73	0.235039	1.38258E-07
3.84	0.215387	1.26698E-07
3.94	0.1795885	1.0564E-07
4.04	0.1878875	1.10522E-07
4.135	0.1530485	9.00285E-08
4.235	0.1680189	9.88346E-08
4.335	0.2198645	1.29332E-07
4.435	0.18366	1.08035E-07
4.535	0.2198005	1.29294E-07
4.635	0.196391	1.15524E-07
4.735	0.2159235	1.27014E-07
4.835	0.190641	1.12142E-07
4.935	0.217026	1.27662E-07
5.035	0.217414	1.27891E-07
5.135	0.1753915	1.03171E-07
5.235	0.225085	1.32403E-07
5.335	0.1740585	1.02387E-07
5.435	0.1982115	1.16595E-07
5.535	0.218373	1.28455E-07
5.635	0.2184505	1.285E-07
5.735	0.193147	1.13616E-07
5.835	0.2068045	1.2165E-07
5.935	0.2367195	1.39247E-07
6.03	0.1849475	1.08793E-07
6.13	0.215298	1.26646E-07
6.23	0.2270895	1.33582E-07
6.33	0.2061265	1.21251E-07
6.43	0.2049035	1.20531E-07
6.53	0.2253525	1.3256E-07
6.63	0.1863265	1.09604E-07
6.73	0.1899375	1.11728E-07
6.83	0.190751	1.12206E-07
6.93	0.17973	1.05724E-07
7.03	0.261364	1.53744E-07
7.13	0.1732625	1.01919E-07
7.23	0.207729	1.22194E-07
7.33	0.196908	1.15828E-07
7.425	0.217219	1.27776E-07
7.525	0.1984745	1.1675E-07
7.625	0.21287	1.25218E-07
7.725	0.1920775	1.12987E-07
7.825	0.25823	1.519E-07
7.925	0.2001545	1.17738E-07
8.025	0.2395705	1.40924E-07
8.125	0.2436885	1.43346E-07

MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR WELL OU2-043
HILL AFB OU-2

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m^3/kg
8.225	0.2268185	1.33423E-07
8.325	0.247283	1.45461E-07
8.425	0.2484425	1.46143E-07
8.525	0.2667115	1.56889E-07
8.625	0.250434	1.47314E-07
8.725	0.235691	1.38642E-07
8.825	0.2476585	1.45681E-07
8.925	0.3062105	1.80124E-07
9.025	0.28471	1.67476E-07
9.125	0.2980755	1.75339E-07
9.225	0.3088785	1.81693E-07
9.325	0.2840735	1.67102E-07
9.42	0.2992635	1.76037E-07
9.52	0.25577	1.50453E-07
9.62	0.3359045	1.97591E-07
9.72	0.3434735	2.02043E-07
9.82	0.33217	1.95394E-07
9.92	0.27773	1.63371E-07
10.02	0.361375	2.12574E-07
10.12	0.3503825	2.06107E-07
10.22	0.3296415	1.93907E-07
10.32	0.3482175	2.04834E-07
10.42	0.2894955	1.70291E-07
10.52	0.3163575	1.86093E-07
10.62	0.318099	1.87117E-07
10.72	0.286294	1.68408E-07
10.815	0.2656335	1.56255E-07
10.915	0.3237865	1.90463E-07
11.015	0.2822255	1.66015E-07
11.115	0.28905	1.70029E-07
11.215	0.3266695	1.92159E-07
11.315	0.2829115	1.66419E-07
11.415	0.329946	1.94086E-07
11.515	0.27559	1.62112E-07
11.615	0.305425	1.79662E-07
11.715	0.27033	1.59018E-07
11.815	0.220557	1.29739E-07
11.915	0.283389	1.66699E-07
12.015	0.3372505	1.98383E-07
12.115	0.3042295	1.78959E-07
12.215	0.2692945	1.58409E-07
12.315	0.275889	1.62288E-07
12.415	0.3529025	2.0759E-07
12.515	0.345433	2.03196E-07
12.615	0.281335	1.65491E-07
12.71	0.3244135	1.90831E-07
12.81	0.3209475	1.88793E-07

MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR WELL OU2-043 HILL AFB OU-2

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m^3/kg
12.91	0.360913	2.12302E-07
13.01	0.2858065	1.68121E-07
13.11	0.392107	2.30651E-07
13.21	0.3810905	2.24171E-07
13.31	0.387758	2.28093E-07
13.41	0.3712485	2.18381E-07
13.51	0.389948	2.29381E-07
13.61	0.3857895	2.26935E-07
13.71	0.451197	2.6541E-07
13.81	0.4643955	2.73174E-07
13.91	0.443728	2.61016E-07
14.01	0.4958385	2.9167E-07
14.105	0.4494485	2.64381E-07
14.205	0.430615	2.53303E-07
14.305	0.4320525	2.54149E-07
14.405	0.4429225	2.60543E-07
14.505	0.376105	2.21238E-07
14.605	0.4177145	2.45714E-07
14.705	0.3722625	2.18978E-07
14.805	0.4107165	2.41598E-07
14.905	0.428343	2.51966E-07
15.005	0.4414135	2.59655E-07
15.105	0.407592	2.3976E-07
15.205	0.346134	2.03608E-07
15.305	0.392078	2.30634E-07
15.405	0.4580905	2.69465E-07
15.505	0.381892	2.24642E-07
15.605	0.3659755	2.1528E-07
15.705	0.362373	2.13161E-07
15.805	0.393872	2.31689E-07
15.905	0.4050095	2.38241E-07
16	0.3931615	2.31271E-07
16.1	0.363765	2.13979E-07
16.2	0.3461415	2.03613E-07
16.3	0.4744665	2.79098E-07
16.4	0.4670225	2.74719E-07
16.5	0.515486	3.03227E-07
16.6	0.426028	2.50605E-07
16.7	0.3713985	2.1847E-07
16.8	0.3841925	2.25996E-07
16.9	0.4553695	2.67864E-07
17	0.431301	2.53706E-07
17.1	0.4355795	2.56223E-07
17.2	0.42476	2.49859E-07
17.3	0.3778755	2.2228E-07
17.4	0.414637	2.43904E-07
17.495	0.4197255	2.46897E-07

WIEDEMEIER & ASSOCIATES

MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR WELL OU2-043
HILL AFB OU-2

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m^3/kg
17.595	0.427253	2.51325E-07
17.695	0.4362835	2.56637E-07
17.795	0.402828	2.36958E-07
17.895	0.3716895	2.18641E-07
17.995	0.42081	2.47535E-07
18.095	0.448994	2.64114E-07
18.195	0.4925965	2.89763E-07
18.295	0.578711	3.40418E-07
18.395	0.5069765	2.98221E-07
18.495	0.504192	2.96584E-07
18.595	0.5145565	3.0268E-07
18.695	0.5540725	3.25925E-07
18.795	0.45717	2.68924E-07
18.895	0.479401	2.82001E-07
18.995	0.4430365	2.6061E-07
19.095	0.4784665	2.81451E-07
19.195	0.405122	2.38307E-07
19.295	0.407267	2.39569E-07
19.39	0.4062565	2.38974E-07
19.49	0.3405105	2.003E-07
19.59	0.409796	2.41056E-07
19.69	0.4354275	2.56134E-07
19.79	0.432488	2.54405E-07
19.89	0.4496335	2.6449E-07
19.99	0.385124	2.26544E-07
20.09	0.417604	2.45649E-07
20.19	0.4346445	2.55673E-07
20.29	0.42724	2.51318E-07
20.39	0.4858235	2.85779E-07
20.49	0.4465095	2.62653E-07
20.59	0.3803225	2.23719E-07
20.69	0.346421	2.03777E-07
20.785	0.2844175	1.67304E-07
20.885	0.2767415	1.62789E-07
20.985	0.247473	1.45572E-07
21.085	0.2020735	1.18867E-07
21.185	0.1595515	9.38538E-08
21.285	0.1166708	6.86299E-08
21.385	0.158861	9.34476E-08
21.485	0.1462765	8.6045E-08
21.585	0.136482	8.02835E-08
21.685	0.1111761	6.53977E-08
21.785	0.1230828	7.24016E-08
21.885	0.2048615	1.20507E-07
21.985	0.23032635	1.35486E-07
22.085	0.3219955	1.89409E-07
22.185	0.279094	1.64173E-07

WIEDEMEIER & ASSOCIATES

MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR WELL OU2-043
HILL AFB OU-2

Depth	Mag Susc	Mag Susc
ft bgs	10e-3 SI units	m^3/kg
22.285	0.254495	1.49703E-07
22.385	0.2693045	1.58414E-07
22.485	0.3369405	1.982E-07
22.585	0.328369	1.93158E-07
22.68	0.297388	1.74934E-07
22.78	0.219047	1.28851E-07
22.88	0.1344725	7.91015E-08
22.98	0.1552365	9.13156E-08
23.08	0.1664855	9.79326E-08
23.18	0.1565505	9.20885E-08
23.28	0.2275135	1.33831E-07
23.38	0.1518585	8.93285E-08
23.48	0.2158085	1.26946E-07
23.58	0.2083395	1.22553E-07
23.68	0.245417	1.44363E-07
23.78	0.2811895	1.65406E-07
23.88	0.3111005	1.83E-07
23.98	0.312463	1.83802E-07
24.075	0.4066485	2.39205E-07
24.175	0.453674	2.66867E-07
24.275	0.438149	2.57735E-07
24.375	0.4347685	2.55746E-07
24.475	0.4434965	2.6088E-07
24.575	0.3895695	2.29159E-07
24.675	0.3908015	2.29883E-07
24.775	0.3644165	2.14363E-07
24.875	0.3574375	2.10257E-07
24.975	0.273459	1.60858E-07
25.075	0.3059105	1.79947E-07
25.175	0.299719	1.76305E-07
25.275	0.3231925	1.90113E-07
25.375	0.3642185	2.14246E-07
25.475	0.349047	2.05322E-07
25.575	0.292398	1.71999E-07
25.675	0.344726	2.0278E-07
25.775	0.3359575	1.97622E-07
25.875	0.3194735	1.87926E-07
25.97	0.297649	1.75088E-07
26.07	0.303819	1.78717E-07
26.17	0.2750915	1.61819E-07
26.27	0.2997945	1.7635E-07
26.37	0.285384	1.67873E-07
26.47	0.2883815	1.69636E-07
26.57	0.309782	1.82225E-07
26.67	0.29281	1.72241E-07
26.77	0.293942	1.72907E-07
26.87	0.285026	1.67662E-07

MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR WELL OU2-043
HILL AFB OU-2

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m^3/kg
26.97	0.314637	1.85081E-07
27.07	0.29139	1.71406E-07
27.17	0.3479575	2.04681E-07
27.27	0.342658	2.01564E-07
27.365	0.2946815	1.73342E-07
27.465	0.403155	2.3715E-07
27.565	0.3693985	2.17293E-07
27.665	0.413222	2.43072E-07
27.765	0.3536495	2.08029E-07
27.865	0.292689	1.7217E-07
27.965	0.3641545	2.14209E-07
28.065	0.3495185	2.05599E-07
28.165	0.411663	2.42155E-07
28.265	0.3259255	1.91721E-07
28.365	0.369658	2.17446E-07
28.465	0.3247645	1.91038E-07
28.565	0.352418	2.07305E-07
28.665	0.3892065	2.28945E-07
28.765	0.3562605	2.09565E-07
28.865	0.357698	2.10411E-07
28.965	0.380116	2.23598E-07
29.065	0.3341305	1.96547E-07
29.165	0.365273	2.14866E-07
29.265	0.38359	2.25641E-07
29.36	0.3649765	2.14692E-07
29.46	0.3355565	1.97386E-07
29.56	0.289534	1.70314E-07
29.66	0.2411365	1.41845E-07
29.76	0.2544805	1.49694E-07
29.86	0.299897	1.7641E-07
29.96	0.1941405	1.142E-07
30.06	0.28707	1.68865E-07
30.16	0.2082705	1.22512E-07
30.26	0.24991	1.47006E-07
30.36	0.2455895	1.44464E-07
30.46	0.272966	1.60568E-07
30.56	0.224944	1.3232E-07
30.66	0.2667355	1.56903E-07
30.755	0.2603885	1.5317E-07
30.855	0.223761	1.31624E-07
30.955	0.2201545	1.29503E-07
31.055	0.282127	1.65957E-07
31.155	0.286082	1.68284E-07
31.255	0.3063935	1.80231E-07
31.355	0.2846055	1.67415E-07
31.455	0.282684	1.66285E-07
31.555	0.2669585	1.57034E-07

MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR WELL OU2-043 HILL AFB OU-2

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m^3/kg
31.655	0.276376	1.62574E-07
31.755	0.2960155	1.74127E-07
31.855	0.2533745	1.49044E-07
31.955	0.2455895	1.44464E-07
32.055	0.2427895	1.42817E-07
32.155	0.283364	1.66685E-07
32.255	0.258953	1.52325E-07
32.355	0.2981545	1.75385E-07
32.455	0.2156045	1.26826E-07
32.555	0.266842	1.56966E-07
32.65	0.2512115	1.47771E-07
32.75	0.233804	1.37532E-07
32.85	0.2496045	1.46826E-07
32.95	0.2776805	1.63341E-07
33.05	0.3065445	1.8032E-07
33.15	0.25075	1.475E-07
33.25	0.262473	1.54396E-07
33.35	0.246935	1.45256E-07
33.45	0.2153215	1.2666E-07
33.55	0.266699	1.56882E-07
33.65	0.298939	1.75846E-07
33.75	0.209965	1.23509E-07
33.85	0.269489	1.58523E-07
33.95	0.293948	1.72911E-07
34.045	0.2503865	1.47286E-07
34.145	0.218163	1.28331E-07
34.245	0.2650415	1.55907E-07
34.345	0.258747	1.52204E-07
34.445	0.2899835	1.70579E-07
34.545	0.2827925	1.66349E-07
34.645	0.264738	1.55728E-07
34.745	0.28702	1.68835E-07
34.845	0.307141	1.80671E-07
34.945	0.3233605	1.90212E-07
35.045	0.337236	1.98374E-07
35.145	0.275176	1.61868E-07
35.245	0.284355	1.67268E-07
35.345	0.2733275	1.60781E-07
35.445	0.322218	1.8954E-07
35.545	0.293047	1.72381E-07
35.645	0.3175735	1.86808E-07
35.745	0.31929	1.87818E-07
35.845	0.359404	2.11414E-07
35.94	0.2972425	1.74849E-07
36.04	0.3095445	1.82085E-07
36.14	0.335939	1.97611E-07
36.24	0.342204	2.01296E-07

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MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR WELL OU2-043
HILL AFB OU-2

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m^3/kg
36.34	0.3275575	1.92681E-07
36.44	0.3407265	2.00427E-07
36.54	0.343403	2.02002E-07
36.64	0.353614	2.08008E-07
36.74	0.3296745	1.93926E-07
36.84	0.384416	2.26127E-07
36.94	0.324342	1.90789E-07
37.04	0.3239965	1.90586E-07
37.14	0.3144665	1.8498E-07
37.24	0.33769	1.98641E-07
37.335	0.3205715	1.88571E-07
37.435	0.3416095	2.00947E-07
37.535	0.340249	2.00146E-07
37.635	0.3088075	1.81651E-07
37.735	0.2739955	1.61174E-07
37.835	0.316225	1.86015E-07
37.935	0.3829525	2.25266E-07
38.035	0.3372875	1.98404E-07
38.135	0.3759425	2.21143E-07
38.235	0.3549475	2.08793E-07
38.335	0.291574	1.71514E-07
38.435	0.3522515	2.07207E-07
38.535	0.392149	2.30676E-07
38.635	0.4008645	2.35803E-07
38.735	0.36	2.11765E-07
38.835	0.3722505	2.18971E-07
38.935	0.334177	1.96575E-07
39.035	0.3498265	2.0578E-07
39.135	0.3599125	2.11713E-07
39.23	0.354996	2.08821E-07
39.33	0.3568275	2.09899E-07
39.43	0.349371	2.05512E-07
39.53	0.300241	1.76612E-07
39.63	0.3190605	1.87683E-07
39.73	0.324732	1.91019E-07
39.83	0.2964065	1.74357E-07
39.93	0.3090635	1.81802E-07
40.03	0.2444835	1.43814E-07
40.13	0.325648	1.91558E-07
40.23	0.3116165	1.83304E-07
40.33	0.307962	1.81154E-07
40.43	0.3054205	1.79659E-07
40.53	0.318734	1.87491E-07
40.63	0.2687945	1.58114E-07
40.725	0.263684	1.55108E-07
40.825	0.2752175	1.61893E-07
40.925	0.298448	1.75558E-07

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MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR WELL OU2-043 HILL AFB OU-2

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m^3/kg
41.025	0.290412	1.70831E-07
41.125	0.2752865	1.61933E-07
41.225	0.3462435	2.03673E-07
41.325	0.2939245	1.72897E-07
41.425	0.3087205	1.816E-07
41.525	0.32238	1.89635E-07
41.625	0.299374	1.76102E-07
41.725	0.3066565	1.80386E-07
41.825	0.319521	1.87954E-07
41.925	0.3947665	2.32216E-07
42.025	0.3033325	1.78431E-07
42.125	0.304931	1.79371E-07
42.225	0.323157	1.90092E-07
42.325	0.3166115	1.86242E-07
42.425	0.293698	1.72764E-07
42.525	0.2783145	1.63714E-07
42.62	0.2573975	1.5141E-07
42.72	0.3034155	1.7848E-07
42.82	0.290978	1.71164E-07
42.92	0.3624555	2.13209E-07
43.02	0.358581	2.1093E-07
43.12	0.3467115	2.03948E-07
43.22	0.346128	2.03605E-07
43.32	0.3733095	2.19594E-07
43.42	0.373141	2.19495E-07
43.52	0.3338605	1.96389E-07
43.62	0.3332615	1.96036E-07
43.72	0.309044	1.81791E-07
43.82	0.353718	2.08069E-07
43.92	0.423136	2.48904E-07
44.015	0.424504	2.49708E-07
44.115	0.4045055	2.37944E-07
44.215	0.3964745	2.3322E-07
44.315	0.366134	2.15373E-07
44.415	0.367519	2.16188E-07
44.515	0.3244785	1.9087E-07
44.615	0.326501	1.92059E-07
44.715	0.332277	1.95457E-07
44.815	0.303699	1.78646E-07
44.915	0.321197	1.88939E-07
45.015	0.3707915	2.18113E-07
45.115	0.346539	2.03846E-07
45.215	0.3896315	2.29195E-07
45.315	0.3940625	2.31801E-07
45.415	0.3251295	1.91253E-07
45.515	0.387536	2.27962E-07
45.615	0.4725705	2.77983E-07

MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR WELL OU2-043 HILL AFB OU-2

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m^3/kg
45.715	0.3769535	2.21737E-07
45.815	0.435333	2.56078E-07
45.91	0.4344595	2.55564E-07
46.01	0.457011	2.6883E-07
46.11	0.3904885	2.29699E-07
46.21	0.3786275	2.22722E-07
46.31	0.494612	2.90948E-07
46.41	0.536664	3.15685E-07
46.51	0.5797885	3.41052E-07
46.61	0.595356	3.50209E-07
46.71	0.629452	3.70266E-07
46.81	0.58078	3.41635E-07
46.91	0.55903	3.28841E-07
47.01	0.567297	3.33704E-07
47.11	0.532653	3.13325E-07
47.21	0.4007815	2.35754E-07
47.305	0.3976025	2.33884E-07
47.405	0.441467	2.59686E-07
47.505	0.4660515	2.74148E-07
47.605	0.515719	3.03364E-07
47.705	0.426044	2.50614E-07
47.805	0.3578725	2.10513E-07
47.905	0.414495	2.43821E-07
48.005	0.453628	2.6684E-07
48.105	0.428247	2.5191E-07
48.205	0.406783	2.39284E-07
48.305	0.4497985	2.64587E-07
48.405	0.418546	2.46204E-07
48.505	0.438326	2.57839E-07
48.605	0.435894	2.56408E-07
48.705	0.4164235	2.44955E-07
48.805	0.3874965	2.27939E-07
48.905	0.3734005	2.19647E-07
49.005	0.335272	1.97219E-07
49.105	0.3721975	2.1894E-07
49.2	0.318547	1.87381E-07
49.3	0.3534595	2.07917E-07
49.4	0.409203	2.40708E-07
49.5	0.369827	2.17545E-07
49.6	0.343503	2.02061E-07
49.7	0.456818	2.68716E-07
49.8	0.4146235	2.43896E-07
49.9	0.4056755	2.38633E-07
50	0.3035825	1.78578E-07
50.1	0.2997215	1.76307E-07
50.2	0.333067	1.95922E-07
50.3	0.356175	2.09515E-07

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MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR WELL OU2-043 HILL AFB OU-2

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m^3/kg
50.4	0.3483675	2.04922E-07
50.5	0.341626	2.00956E-07
50.6	0.349736	2.05727E-07
50.695	0.33322	1.96012E-07
50.795	0.3980615	2.34154E-07
50.895	0.3399465	1.99969E-07
50.995	0.3844025	2.26119E-07
51.095	0.412965	2.42921E-07
51.195	0.4320355	2.54139E-07
51.295	0.4216305	2.48018E-07
51.395	0.4046875	2.38051E-07
51.495	0.433148	2.54793E-07
51.595	0.4324835	2.54402E-07
51.695	0.456132	2.68313E-07
51.795	0.462979	2.72341E-07
51.895	0.4845745	2.85044E-07
51.995	0.4198115	2.46948E-07
52.095	0.4700165	2.7648E-07
52.195	0.4076065	2.39769E-07
52.295	0.45797	2.69394E-07
52.395	0.4136455	2.43321E-07
52.495	0.4261235	2.50661E-07
52.59	0.4936355	2.90374E-07
52.69	0.478889	2.81699E-07
52.79	0.5035605	2.96212E-07
52.89	0.450261	2.64859E-07
52.99	0.4557445	2.68085E-07
53.09	0.4002385	2.35434E-07
53.19	0.2994895	1.7617E-07
53.29	0.3282535	1.9309E-07
53.39	0.262226	1.54251E-07
53.49	0.303073	1.78278E-07
53.59	0.20689	1.217E-07
53.69	0.2819625	1.6586E-07
53.79	0.289067	1.70039E-07
53.89	0.342586	2.01521E-07
53.985	0.471986	2.77639E-07
54.085	0.4516005	2.65647E-07
54.185	0.512605	3.01532E-07
54.285	0.552195	3.24821E-07
54.385	0.526153	3.09502E-07
54.485	0.523868	3.08158E-07
54.585	0.522869	3.0757E-07
54.685	0.5307715	3.12219E-07
54.785	0.38574	2.26906E-07
54.885	0.3509325	2.06431E-07
54.985	0.300757	1.76916E-07

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MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR WELL OU2-043 HILL AFB OU-2

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m^3/kg
55.085	0.2526665	1.48627E-07
55.185	0.2089425	1.22907E-07
55.285	0.1865875	1.09757E-07
55.385	0.248458	1.46152E-07
55.485	0.2518925	1.48172E-07
55.585	0.226915	1.33479E-07
55.685	0.199759	1.17505E-07
55.785	0.206361	1.21389E-07
55.88	0.204251	1.20148E-07
55.98	0.254694	1.4982E-07
56.08	0.2077955	1.22233E-07
56.18	0.224286	1.31933E-07
56.28	0.2549685	1.49981E-07
56.38	0.202451	1.19089E-07
56.48	0.2068615	1.21683E-07
56.58	0.2478725	1.45807E-07
56.68	0.238387	1.40228E-07
56.78	0.232473	1.36749E-07
56.88	0.2185695	1.2857E-07
56.98	0.2190385	1.28846E-07
57.08	0.2554445	1.50261E-07
57.18	0.260741	1.53377E-07
57.275	0.2605895	1.53288E-07
57.375	0.2143045	1.26061E-07
57.475	0.194694	1.14526E-07
57.575	0.2269005	1.33471E-07
57.675	0.220087	1.29463E-07
57.775	0.2307885	1.35758E-07
57.875	0.2144875	1.26169E-07
57.975	0.2099025	1.23472E-07
58.075	0.2352915	1.38407E-07
58.175	0.23249	1.36759E-07
58.275	0.246225	1.44838E-07
58.375	0.187206	1.10121E-07
58.475	0.239136	1.40668E-07
58.575	0.2438095	1.43417E-07
58.675	0.2265205	1.33247E-07
58.775	0.223692	1.31584E-07
58.875	0.205593	1.20937E-07
58.975	0.2370595	1.39447E-07
59.075	0.19824	1.16612E-07
59.17	0.277939	1.63494E-07
59.27	0.230417	1.35539E-07
59.37	0.23677	1.39276E-07
59.47	0.270546	1.59145E-07
59.57	0.291874	1.71691E-07
59.67	0.197759	1.16329E-07

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MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR WELL OU2-043 HILL AFB OU-2

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m^3/kg
59.77	0.223827	1.31663E-07
59.87	0.2314095	1.36123E-07
59.97	0.2009335	1.18196E-07
60.07	0.2134085	1.25534E-07
60.17	0.244335	1.43726E-07
60.27	0.255067	1.50039E-07
60.37	0.2499205	1.47012E-07
60.47	0.2607995	1.53411E-07
60.57	0.26286	1.54624E-07
60.665	0.248222	1.46013E-07
60.765	0.2926445	1.72144E-07
60.865	0.267583	1.57402E-07
60.965	0.315314	1.85479E-07
61.065	0.2863555	1.68444E-07
61.165	0.303608	1.78593E-07
61.265	0.3376215	1.98601E-07
61.365	0.3471055	2.0418E-07
61.465	0.307772	1.81042E-07
61.565	0.37711	2.21829E-07
61.665	0.3842255	2.26015E-07
61.765	0.419468	2.46746E-07
61.865	0.4776325	2.8096E-07
61.965	0.428495	2.52056E-07
62.065	0.446117	2.62422E-07
62.165	0.433488	2.54993E-07
62.265	0.373502	2.19707E-07
62.365	0.3739455	2.19968E-07
62.465	0.461624	2.71544E-07
62.56	0.409549	2.40911E-07
62.66	0.3867835	2.2752E-07
62.76	0.407234	2.39549E-07
62.86	0.4059495	2.38794E-07
62.96	0.4128595	2.42859E-07
63.06	0.4849235	2.85249E-07
63.16	0.5119305	3.01136E-07
63.26	0.4097725	2.41043E-07
63.36	0.3779165	2.22304E-07
63.46	0.366654	2.15679E-07
63.56	0.303848	1.78734E-07
63.66	0.343178	2.01869E-07
63.76	0.3638055	2.14003E-07
63.86	0.381222	2.24248E-07
63.955	0.4366815	2.56871E-07
64.055	0.347488	2.04405E-07
64.155	0.324117	1.90657E-07
64.255	0.3431345	2.01844E-07
64.355	0.349367	2.0551E-07

MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR WELL OU2-043 HILL AFB OU-2

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m^3/kg
64.455	0.3440665	2.02392E-07
64.555	0.329488	1.93816E-07
64.655	0.2754985	1.62058E-07
64.755	0.286569	1.6857E-07
64.855	0.3697385	2.17493E-07
64.955	0.5380605	3.16506E-07
65.055	0.7964185	4.68481E-07
65.155	0.7333685	4.31393E-07
65.255	0.5832075	3.43063E-07
65.355	0.474028	2.7884E-07
65.455	0.4890575	2.87681E-07
65.555	0.6628825	3.89931E-07
65.655	0.672658	3.95681E-07
65.755	0.5566925	3.27466E-07
65.85	0.4106795	2.41576E-07
65.95	0.3436135	2.02126E-07
66.05	0.3307775	1.94575E-07
66.15	0.2780185	1.6354E-07
66.25	0.291217	1.71304E-07
66.35	0.2266585	1.33329E-07
66.45	0.280347	1.6491E-07
66.55	0.265972	1.56454E-07
66.65	0.287578	1.69164E-07
66.75	0.2212295	1.30135E-07
66.85	0.2518565	1.48151E-07
66.95	0.212215	1.24832E-07
67.05	0.2219855	1.3058E-07
67.15	0.2537845	1.49285E-07
67.245	0.2313825	1.36107E-07
67.345	0.300611	1.7683E-07
67.445	0.288328	1.69605E-07
67.545	0.214172	1.25984E-07
67.645	0.2767535	1.62796E-07
67.745	0.2890645	1.70038E-07
67.845	0.2357945	1.38703E-07
67.945	0.2973495	1.74911E-07
68.045	0.291741	1.71612E-07
68.145	0.302658	1.78034E-07
68.245	0.326179	1.9187E-07
68.345	0.335946	1.97615E-07
68.445	0.3660455	2.15321E-07
68.545	0.374503	2.20296E-07
68.645	0.4424955	2.60291E-07
68.745	0.399339	2.34905E-07
68.845	0.3835805	2.25636E-07
68.945	0.3799035	2.23473E-07
69.045	0.307075	1.80632E-07

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MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR WELL OU2-043
HILL AFB OU-2

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m^3/kg
69.14	0.5124825	3.0146E-07
69.24	0.5614525	3.30266E-07
69.34	0.5588205	3.28718E-07
69.44	0.5983855	3.51991E-07
69.54	0.5962205	3.50718E-07
69.64	0.6619505	3.89383E-07
69.74	0.718509	4.22652E-07
69.84	0.6643795	3.90811E-07
69.94	0.513932	3.02313E-07
70.04	0.581996	3.42351E-07
70.14	0.549429	3.23194E-07
70.24	0.525723	3.09249E-07
70.34	0.4906315	2.88607E-07
70.44	0.4339655	2.55274E-07
70.54	0.465659	2.73917E-07
70.635	0.368162	2.16566E-07
70.735	0.336003	1.97649E-07
70.835	0.3111575	1.83034E-07
70.935	0.2869805	1.68812E-07
71.035	0.317124	1.86544E-07
71.135	0.29161	1.71535E-07
71.235	0.2725195	1.60306E-07
71.335	0.222315	1.30774E-07
71.435	0.2325365	1.36786E-07
71.535	0.2369945	1.39409E-07
71.635	0.2598875	1.52875E-07
71.735	0.2359805	1.38812E-07
71.835	0.2381795	1.40106E-07
71.935	0.2147185	1.26305E-07
72.035	0.1664375	9.79044E-08
72.135	0.1723885	1.01405E-07
72.235	0.2175405	1.27965E-07
72.335	0.215327	1.26663E-07
72.435	0.266256	1.56621E-07
72.53	0.3170495	1.865E-07
72.63	0.3893445	2.29026E-07
72.73	0.3959555	2.32915E-07
72.83	0.495881	2.91695E-07
72.93	0.445277	2.61928E-07
73.03	0.4669425	2.74672E-07
73.13	0.601525	3.53838E-07
73.23	0.775928	4.56428E-07
73.33	0.816988	4.80581E-07
73.43	0.796385	4.68462E-07
73.53	0.646552	3.80325E-07
73.63	0.7327525	4.31031E-07
73.73	0.779208	4.58358E-07

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MAGNETIC SUSCEPTIBILITY DATA FROM THE SONDE FOR WELL OU2-043
HILL AFB OU-2

Depth ft bgs	Mag Susc 10e-3 SI units	Mag Susc m^3/kg
73.83	0.764918	4.49952E-07
73.925	0.731292	4.30172E-07
74.025	0.598151	3.51854E-07
74.125	0.57523	3.38371E-07
74.225	0.478722	2.81601E-07
74.325	0.5078705	2.98747E-07
74.425	0.5637845	3.31638E-07
74.525	0.550171	3.2363E-07
74.625	0.493536	2.90315E-07
74.725	0.4330455	2.54733E-07
74.825	0.4703225	2.7666E-07
74.925	0.5624055	3.30827E-07
75.025	0.5846205	3.43894E-07
75.125	0.4396415	2.58613E-07
75.225	0.401451	2.36148E-07
75.325	0.463215	2.72479E-07
75.425	0.556859	3.27564E-07
75.525	0.713106	4.19474E-07
75.625	0.6917535	4.06914E-07
75.725	0.554234	3.2602E-07
75.82	0.571498	3.36175E-07
75.92	0.6142295	3.61311E-07
76.02	0.6412985	3.77234E-07
76.12	0.6213655	3.65509E-07
76.22	0.4889545	2.8762E-07
76.32	0.405896	2.38762E-07
76.42	0.3612215	2.12483E-07
76.52	0.355089	2.08876E-07
76.62	0.2730235	1.60602E-07
76.72	0.241892	1.42289E-07
76.82	0.2510315	1.47666E-07
76.92	0.2157155	1.26891E-07
77.02	0.242629	1.42723E-07
77.12	0.1812195	1.066E-07
77.215	0.1925315	1.13254E-07
77.315	0.164939	9.70229E-08
77.415	0.1905445	1.12085E-07
77.515	0.1884875	1.10875E-07
77.63	0.210123	1.23602E-07
77.73	0.254327	1.49604E-07

Average for Sonde =	2.8551E-07
Count =	51
Confidence Level(95.0%) =	3.11533E-08

WIEDEMEIER & ASSOCIATES

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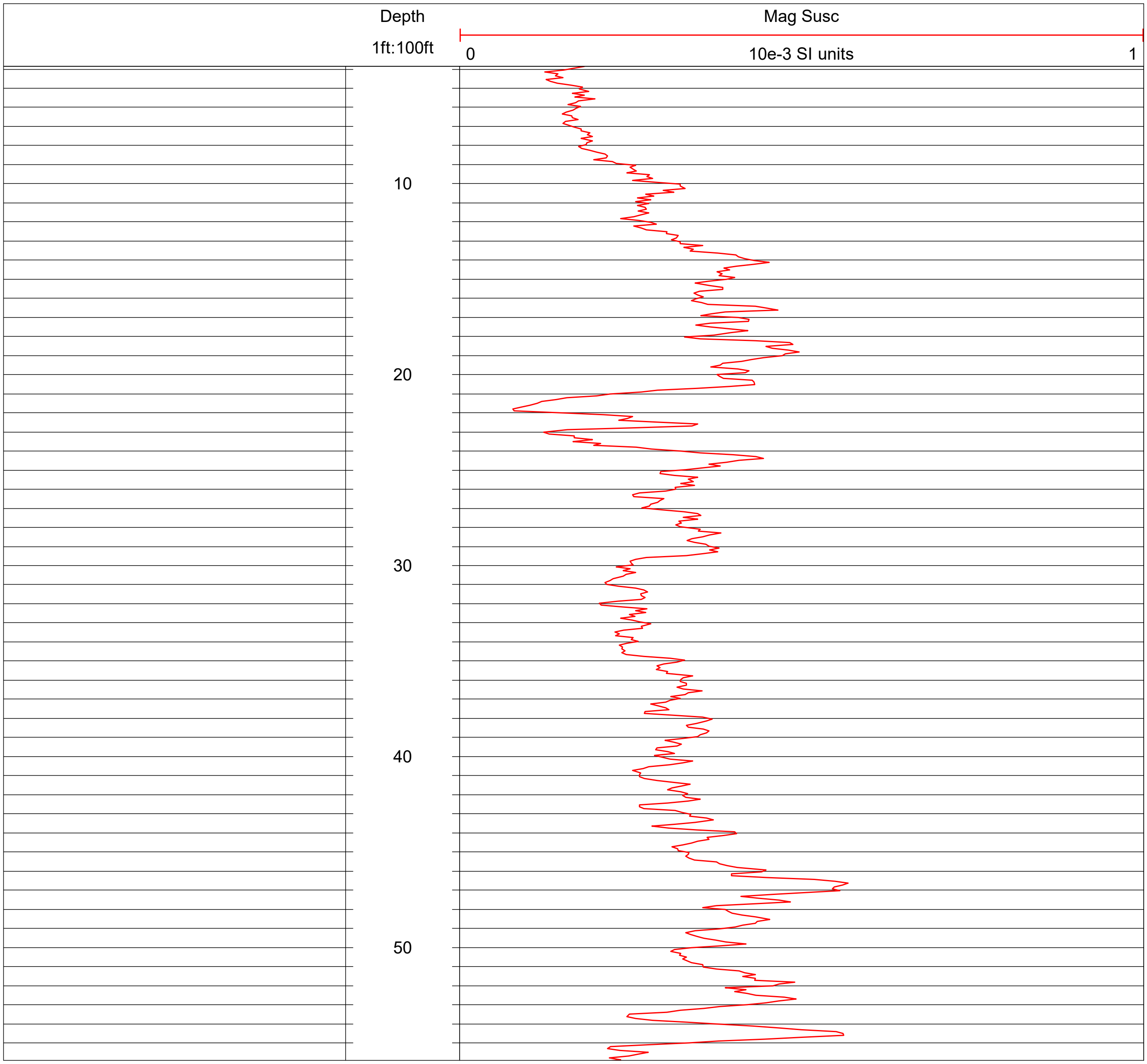
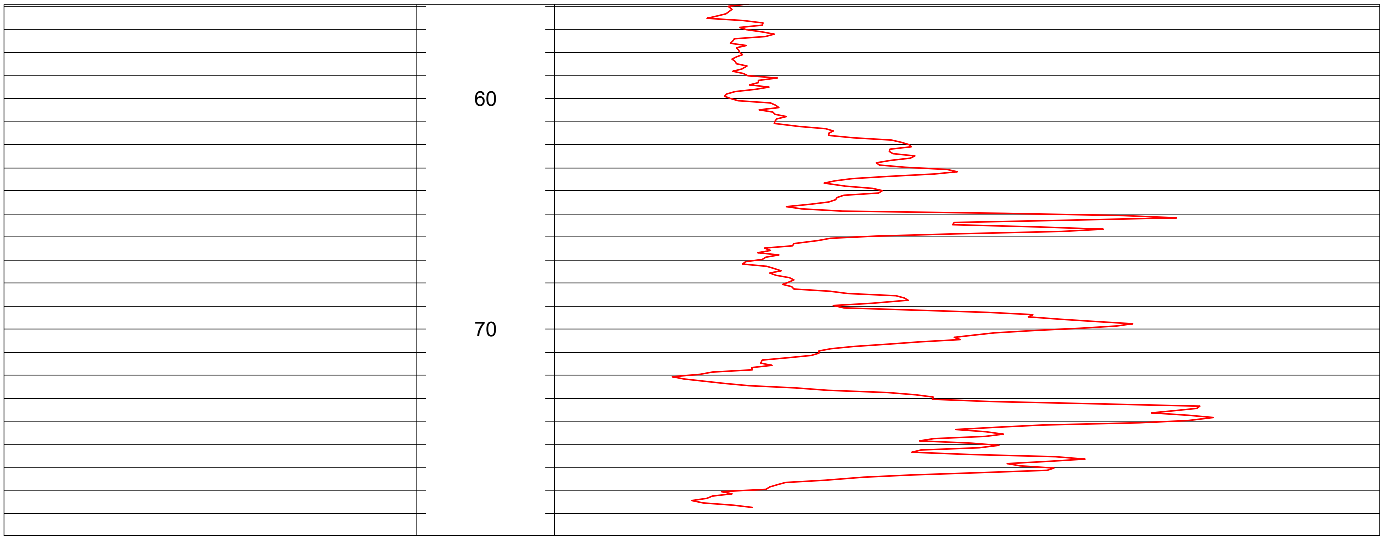
PROJECT	ESTCP 201584
LOCATION	Hill AFB Operable Unit 2
WELL	U02-43 Down
LOGGER	T.H. Wiedemeier
DATE	7/29/16

TOOL	HMA-435-S
CALIBRATION DATE/TIME	7/29/16 -- 09:25
CALIBRATION STANDARDS	0 and 5E-3 SI Units
CALIBRATION RESULTS	0 =
DEPTH TO WATER, TD	41.3 ft BTOC, 81.88 ft BTOC
CASING INNER DIAMETER	4"
REMARKS	

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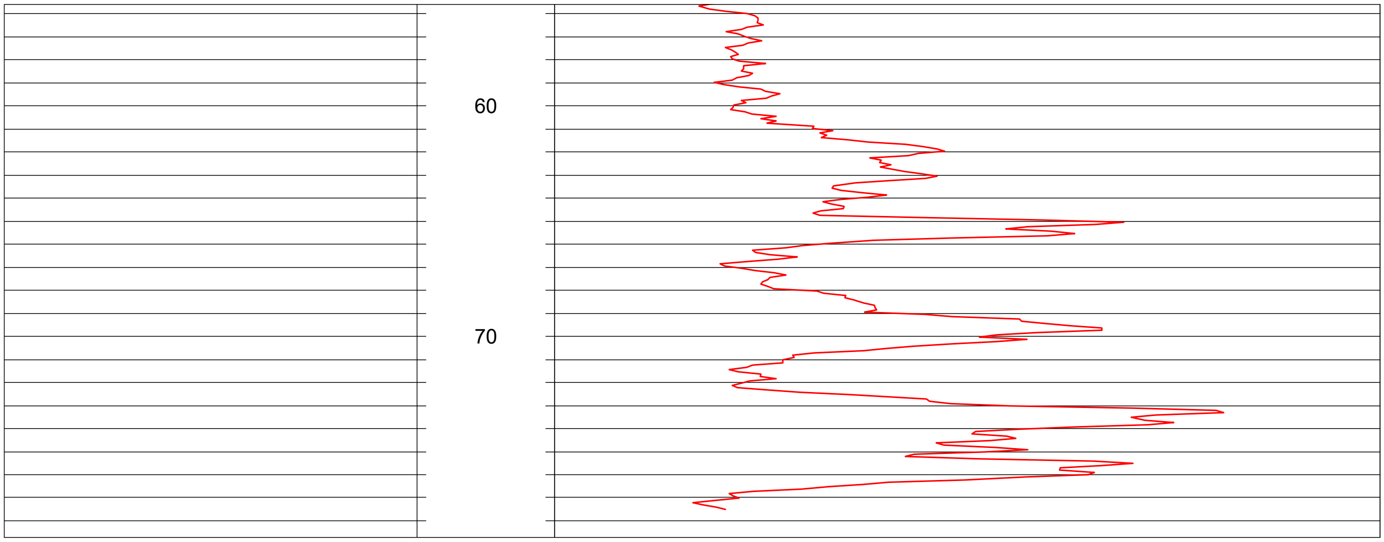
WIEDEMEIER & ASSOCIATES

PROJECT	ESTCP 201584
LOCATION	Hill AFB Operable Unit 2
WELL	U02-43
LOGGER	T.H. Wiedemeier
DATE	7/29/16

TOOL	HMA-453-S
CALIBRATION DATE/TIME	7/29/16, 09:25
CALIBRATION STANDARDS	0 and 5E-3
CALIBRATION RESULTS	0 =
DEPTH TO WATER, TD	41.30
CASING INNER DIAMETER	4"
REMARKS	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APPENDIX D SUPPLEMENTAL MATERIAL RELATED TO THE ^{14}C-TCE ASSAY

D.1 Twin Cities Army Ammunition Plant

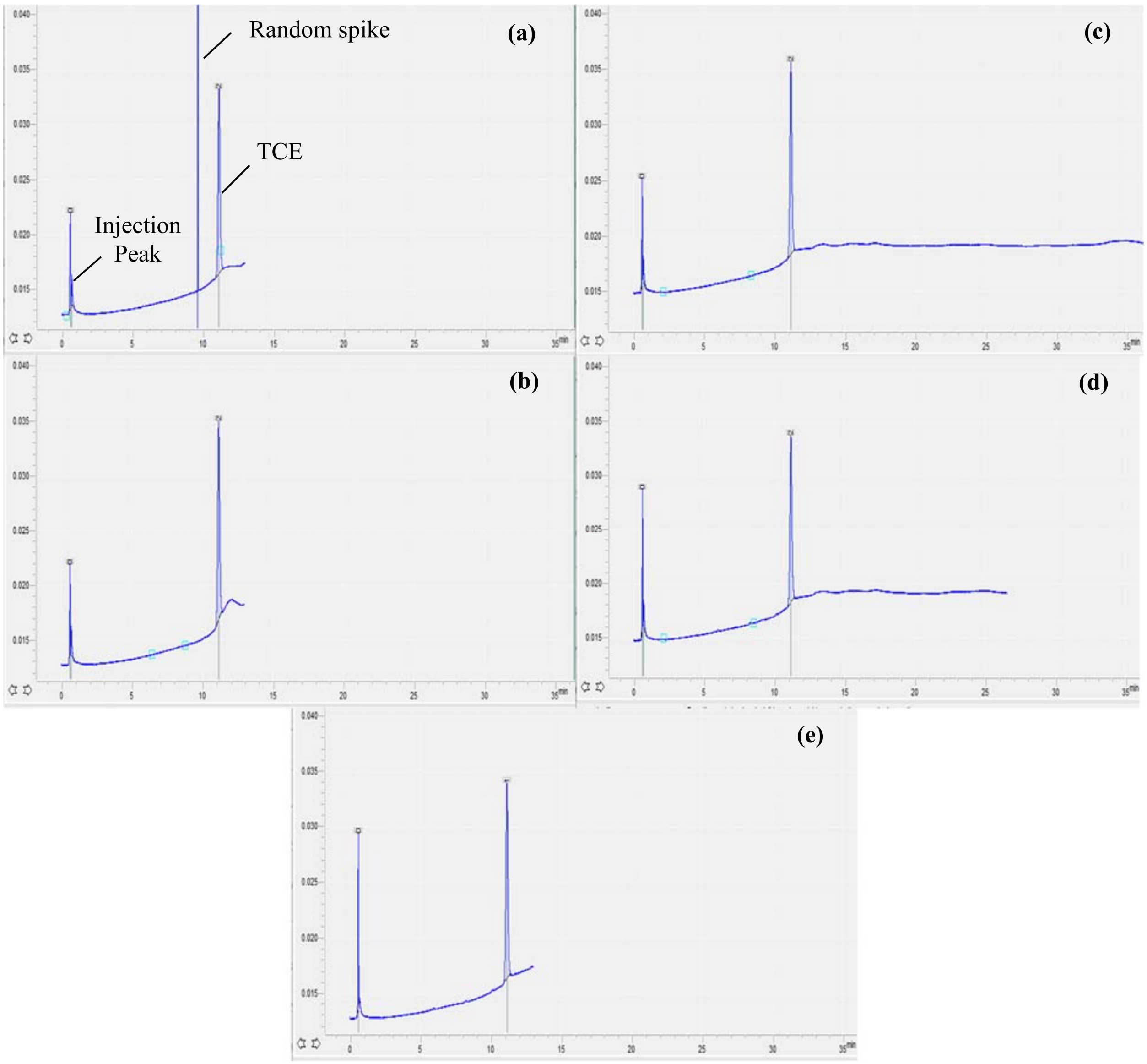


Figure D.1. GC chromatographs from TCAAP at Day 0 showing (a) 01U108, bottle 1; (b) 01U108, bottle 2; (c) 01U108, bottle 3; (d) 01U115, bottle 1; and (e) 01U115, bottle 3 using 0.5 mL headspace injections onto a packed column connected to the GC FID. The residence time for TCE was determine using an external standard. Y-axis is measured in volts (V) and x-axis in min. These wells did not have significant VOCs in the initial headspace sampling, so the final chromatographs at Day 46 are not shown. The leftmost, smaller peak represents the injection peak and the rightmost, larger peak represents TCE as shown in panel (a) for an example.

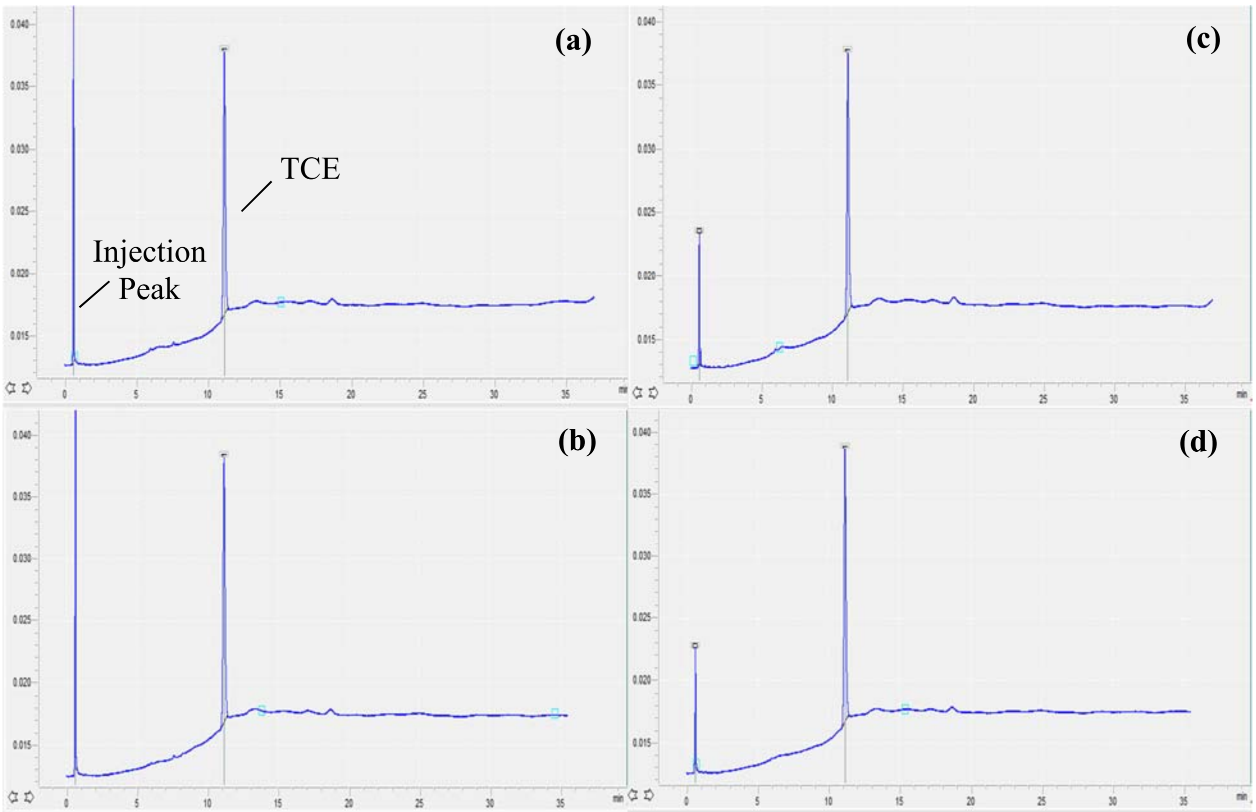


Figure D.2. GC chromatographs from TCAAP at Day 0 showing (a) 32PTLW12, bottle 2; (b) 32PTLW12, bottle 3; (c) 35PTLW13, bottle 1; and (d) 35PTLW13, bottle 2 using 0.5 mL headspace injections onto a packed column connected to the GC FID. The residence time for TCE was determine using an external standard. Y-axis is measured in volts (V) and x-axis in min. These wells did not have significant VOCs in the initial headspace sampling, so the final chromatographs at Day 46 are not shown. The leftmost, smaller peak represents the injection peak and the rightmost, larger peak represents TCE as shown in panel (a) for an example.

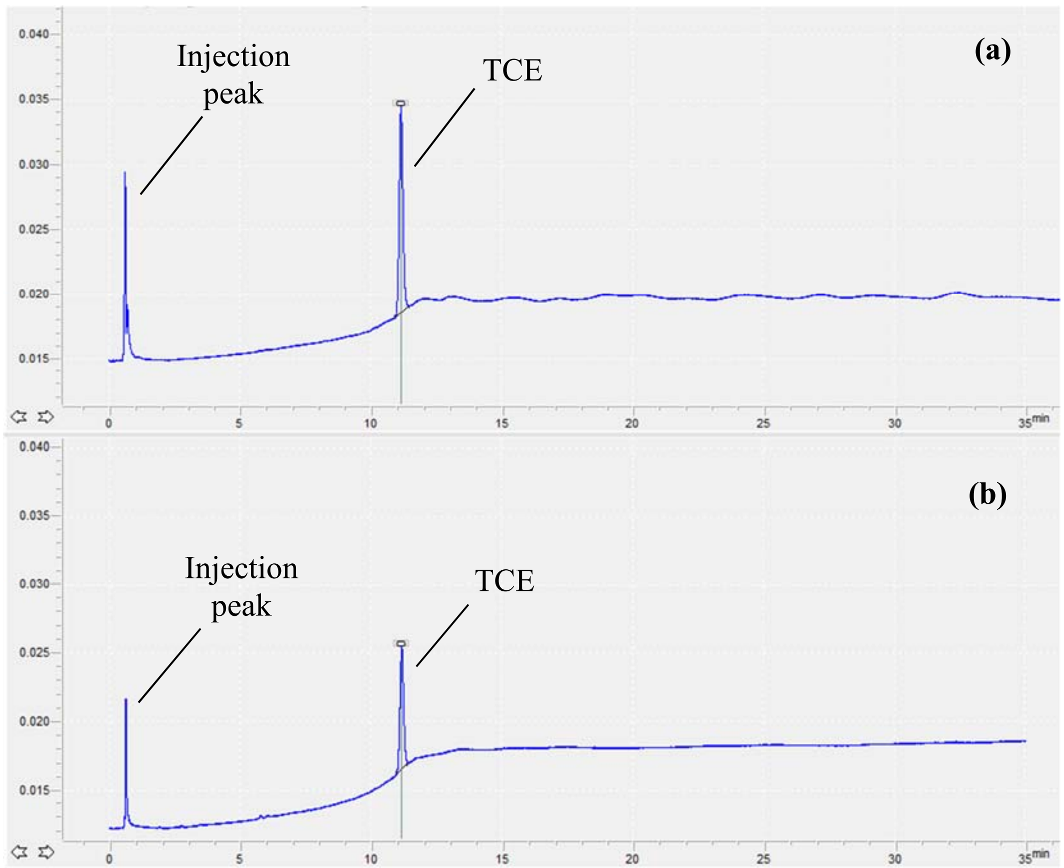


Figure D.3. GC chromatographs from TCAAP, well 01U115, bottle 2. Panel (a) shows Day 0 and (b) shows Day 40 measurements taken using 0.5 mL headspace injections onto a packed column connected to the GC FID. The residence time for TCE was determine using an external standard. Y-axis is measured in volts (V) and x-axis in min.

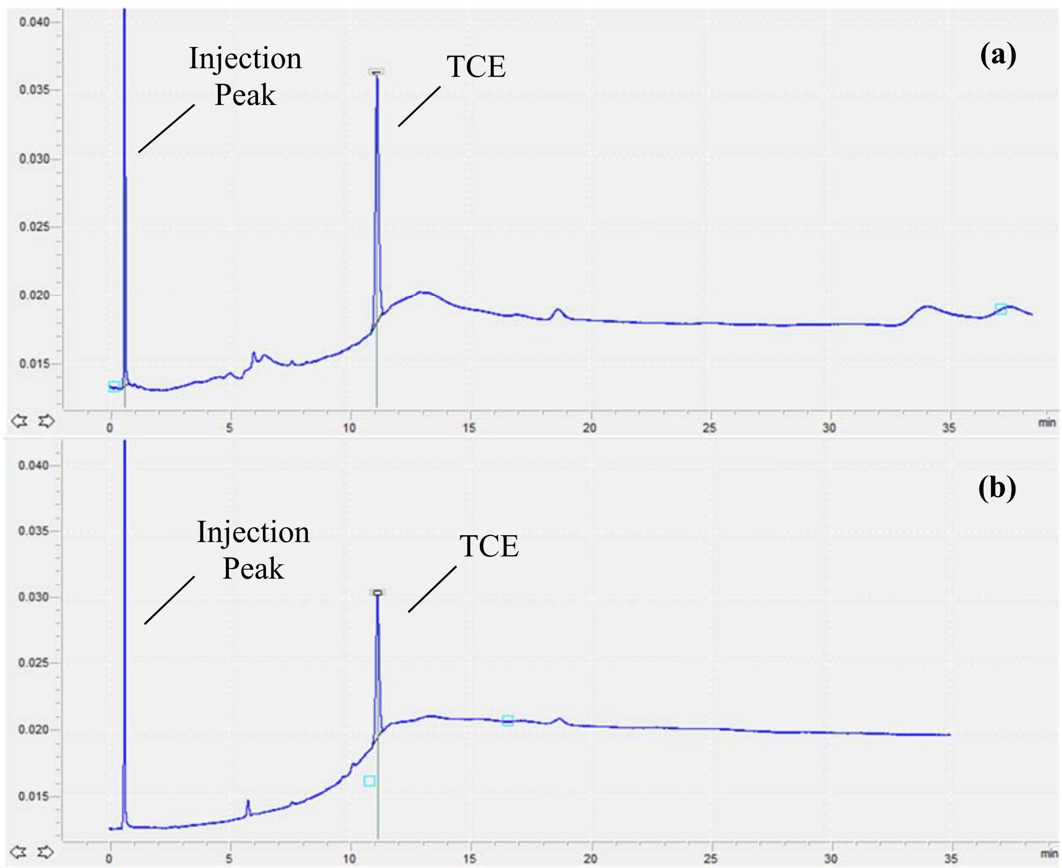


Figure D.4. GC chromatographs from TCAAP, well 01U117, bottle 1. Panel (a) shows Day 0 and (b) shows Day 40 measurements taken using 0.5 mL headspace injections onto a packed column connected to the GC FID. The residence time for TCE was determine using an external standard. Y-axis is measured in volts (V) and x-axis in min.

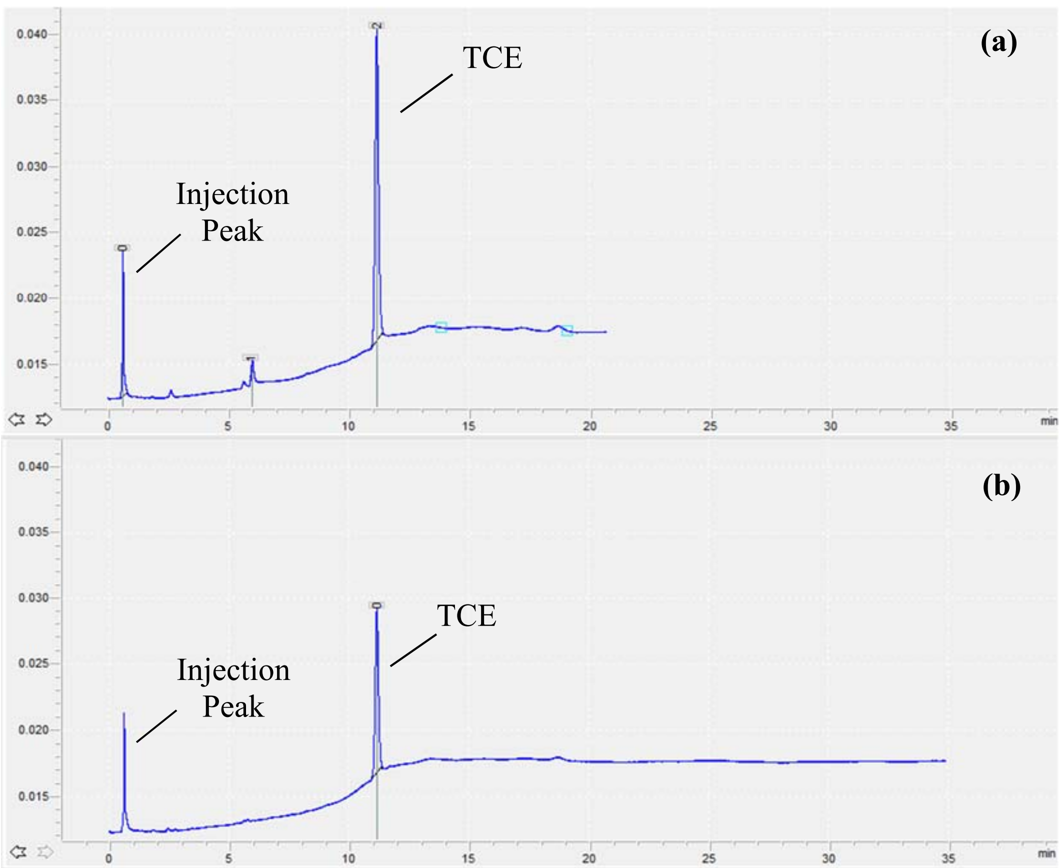


Figure D.5. GC chromatographs from TCAAP, well 01U119, bottle 3. Panel (a) shows Day 0 and (b) shows Day 40 measurements taken using 0.5 mL headspace injections onto a packed column connected to the GC FID. The residence time for TCE was determine using an external standard. Y-axis is measured in volts (V) and x-axis in min.

D.2 Plattsburgh Air Force Base

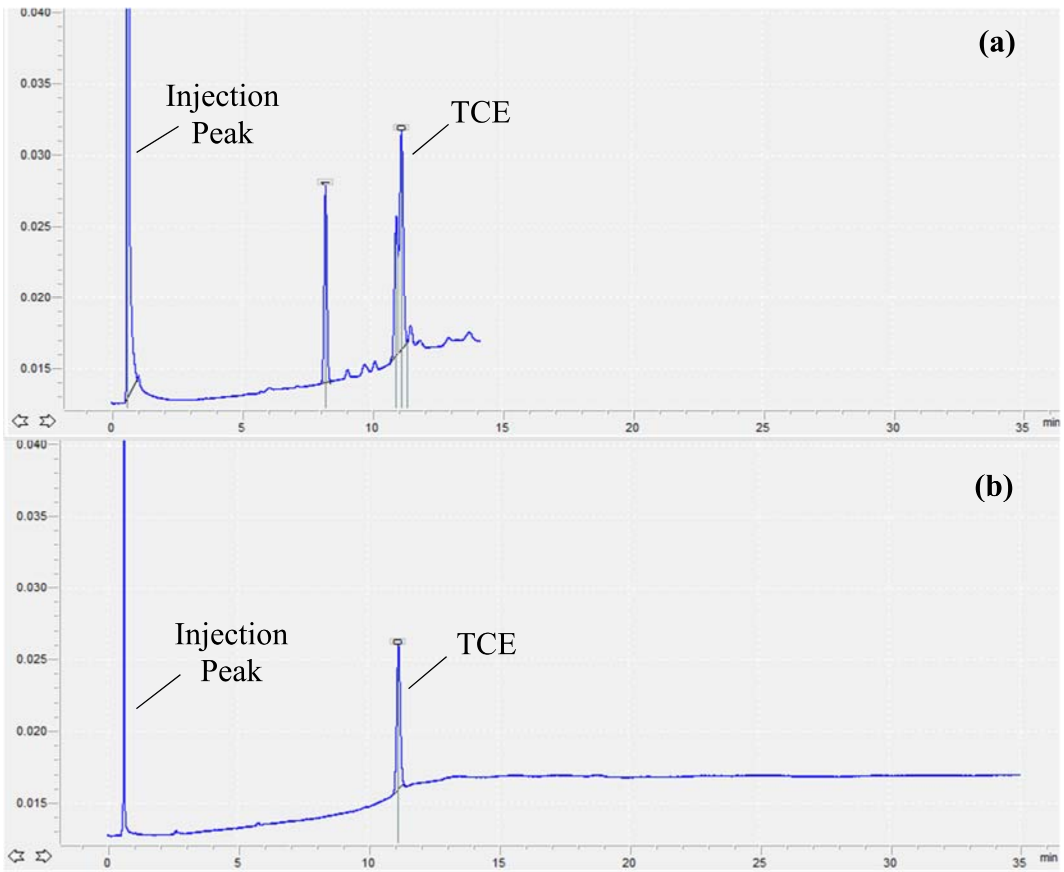


Figure D.6. GC chromatographs from Plattsburgh, well MW-02-006, bottle 1. Panel (a) shows Day 0 and (b) shows Day 40 measurements taken using 0.5 mL headspace injections onto a packed column connected to the GC FID. The residence time for TCE was determine using an external standard. Y-axis is measured in volts (V) and x-axis in min.

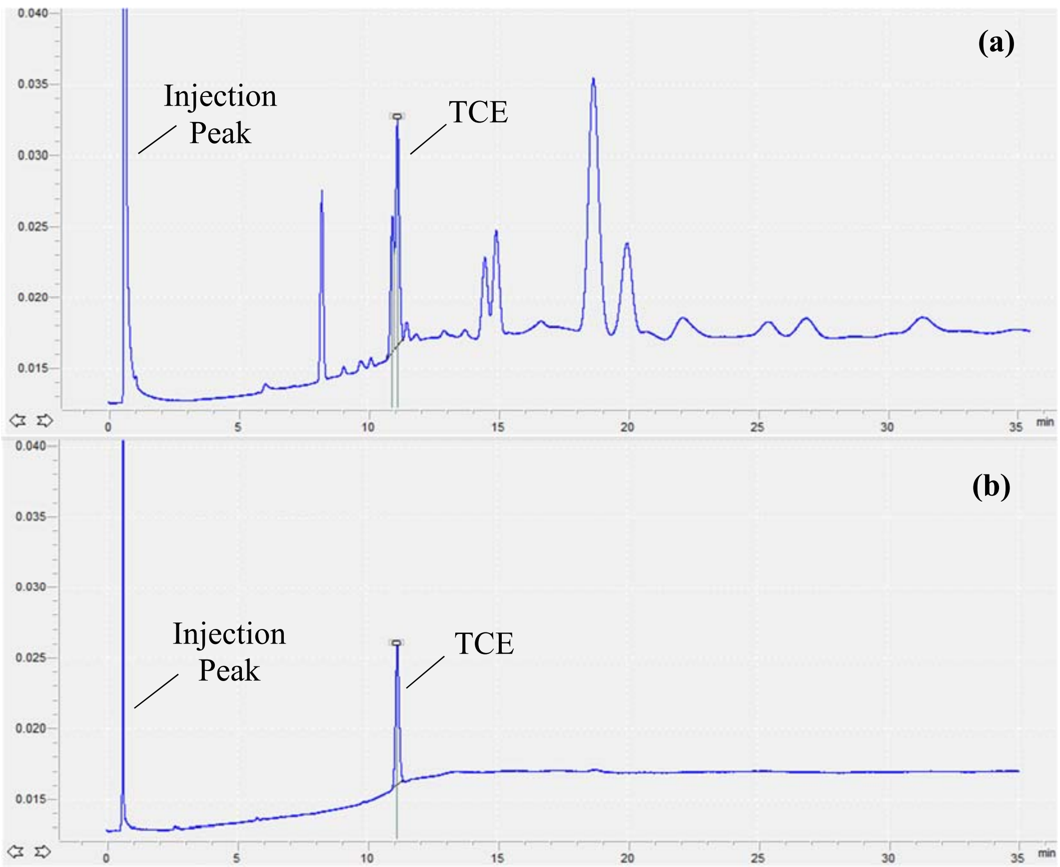


Figure D.7. GC chromatographs from Plattsburgh, well MW-02-006, bottle 2. Panel (a) shows Day 0 and (b) shows Day 40 measurements taken using 0.5 mL headspace injections onto a packed column connected to the GC FID. The residence time for TCE was determine using an external standard. Y-axis is measured in volts (V) and x-axis in min.

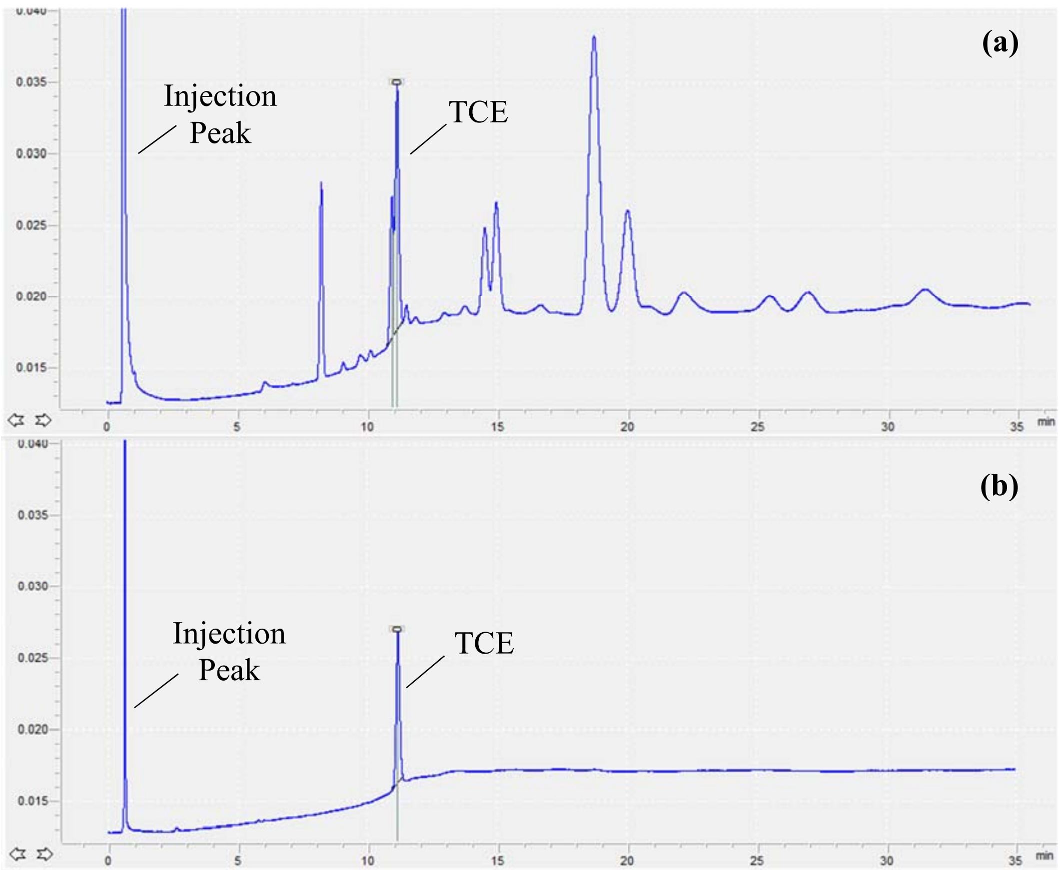
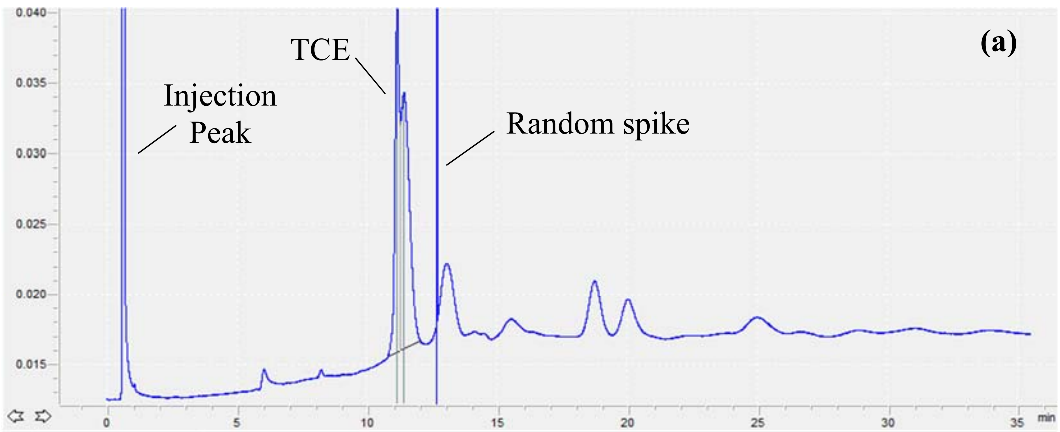


Figure D.8. GC chromatographs from Plattsburgh, well MW-02-006, bottle 3. Panel (a) shows Day 0 and (b) shows Day 40 measurements taken using 0.5 mL headspace injections onto a packed column connected to the GC FID. The residence time for TCE was determine using an external standard. Y-axis is measured in volts (V) and x-axis in min.



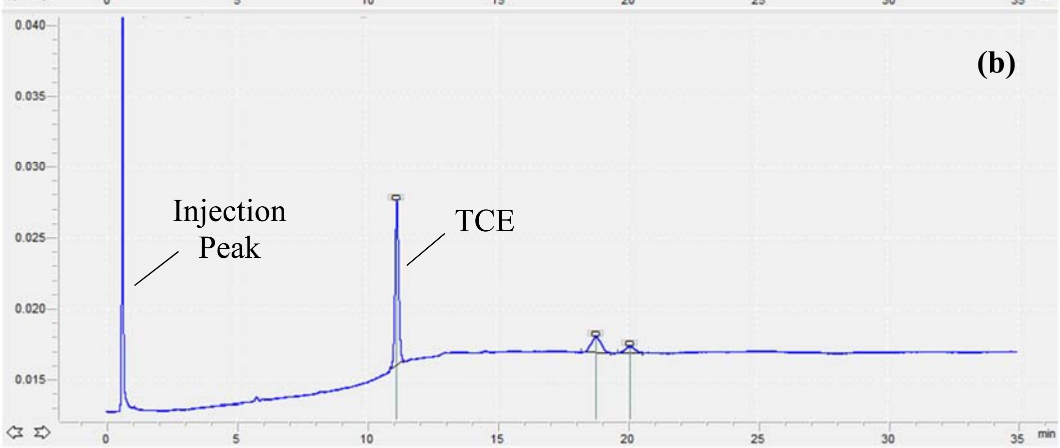


Figure D.9. GC chromatographs from Plattsburgh, well MW-02-019, bottle 1. Panel (a) shows Day 0 and (b) shows Day 40 measurements taken using 0.5 mL headspace injections onto a packed column connected to the GC FID. The residence time for TCE was determine using an external standard. Y-axis is measured in volts (V) and x-axis in min.

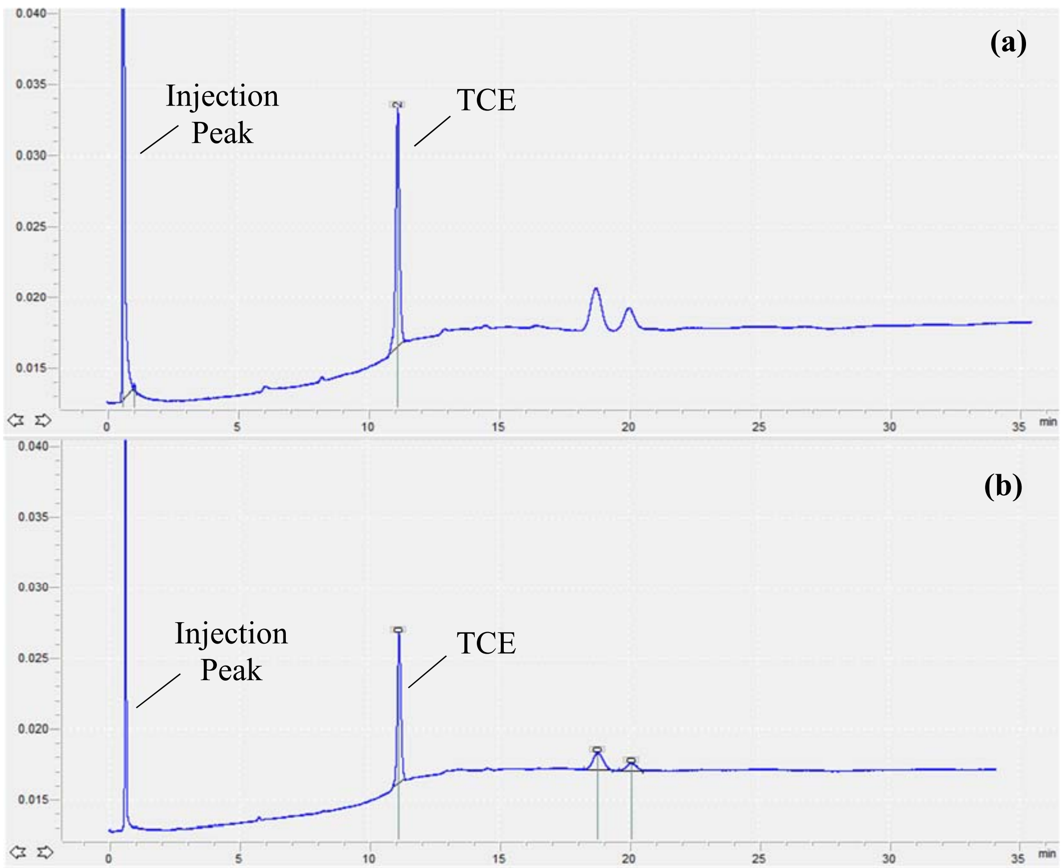


Figure D.10. GC chromatographs from Plattsburgh, well MW-02-019, bottle 2. Panel (a) shows Day 0 and (b) shows Day 40 measurements taken using 0.5 mL headspace injections onto a packed column connected to the GC FID. The residence time for TCE was determine using an external standard. Y-axis is measured in volts (V) and x-axis in min.

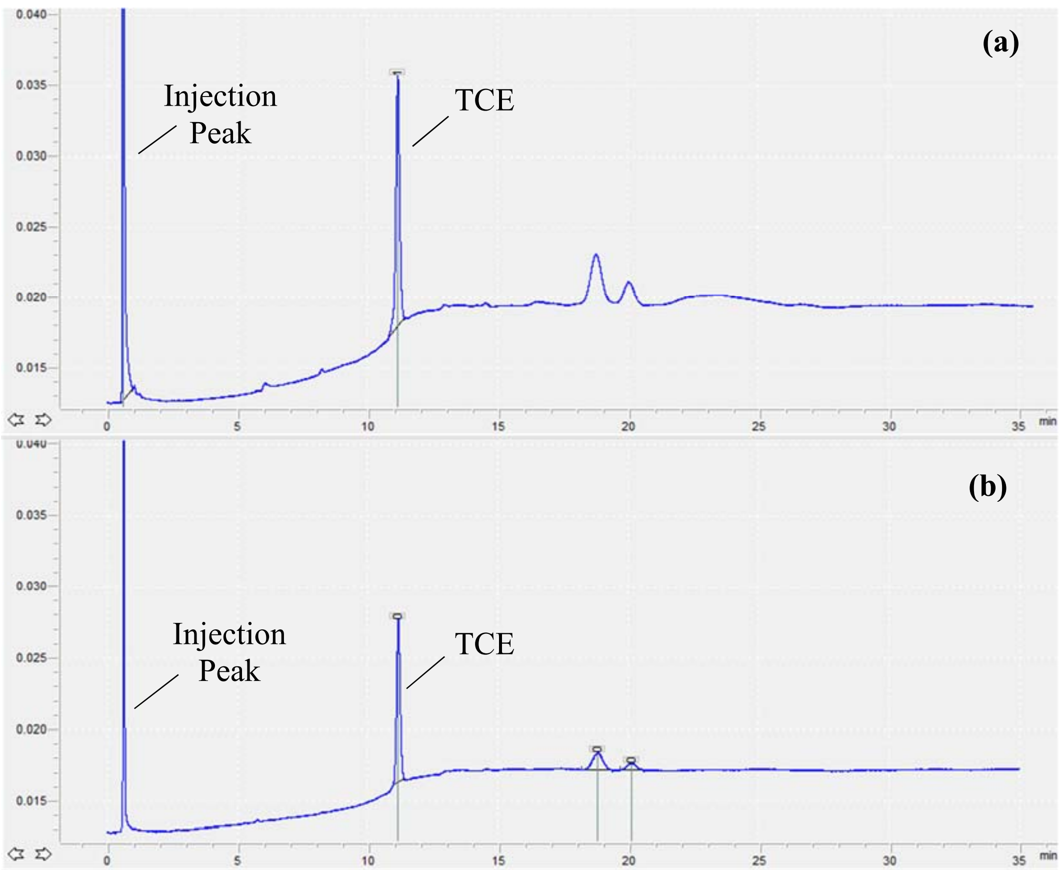


Figure D.11. GC chromatographs from Plattsburgh, well MW-02-019, bottle 3. Panel (a) shows Day 0 and (b) shows Day 40 measurements taken using 0.5 mL headspace injections onto a packed column connected to the GC FID. The residence time for TCE was determine using an external standard. Y-axis is measured in volts (V) and x-axis in min.

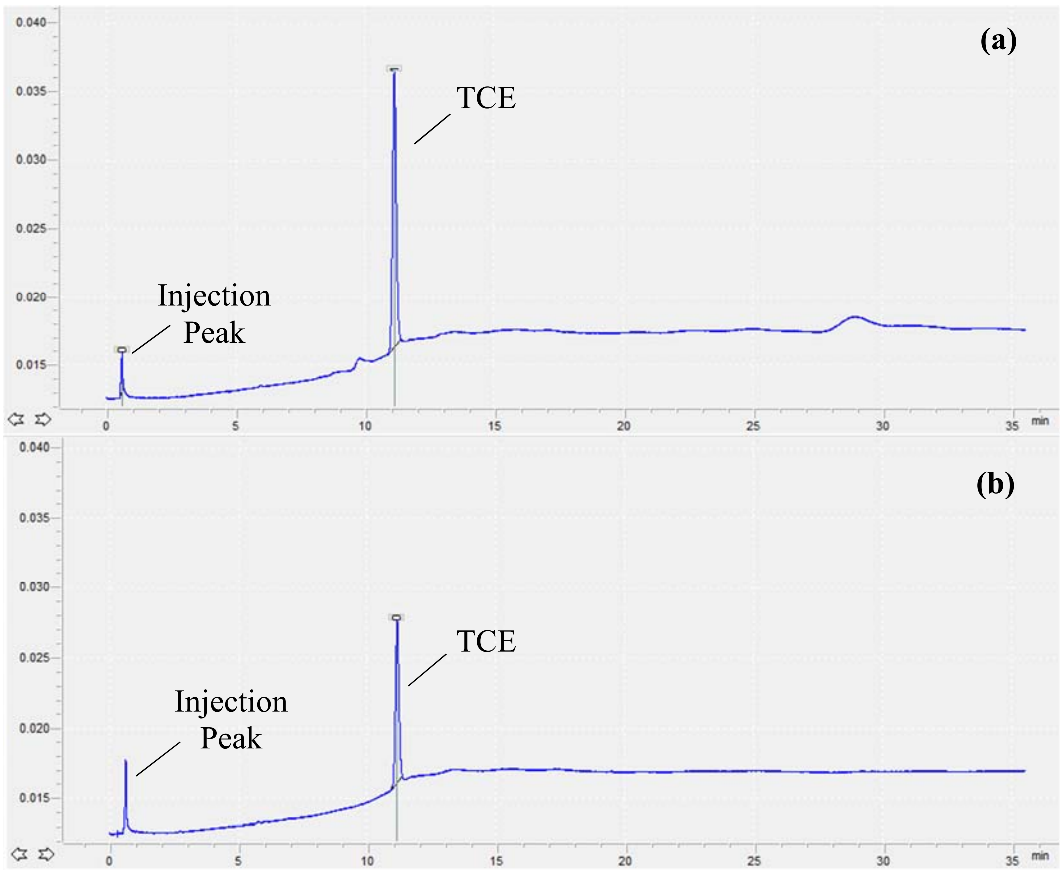


Figure D.12. GC chromatographs from Plattsburgh, well 32PTLW12, bottle 1. Panel (a) shows Day 0 and (b) shows Day 40 measurements taken using 0.5 mL headspace injections onto a packed column connected to the GC FID. The residence time for TCE was determine using an external standard. Y-axis is measured in volts (V) and x-axis in min.

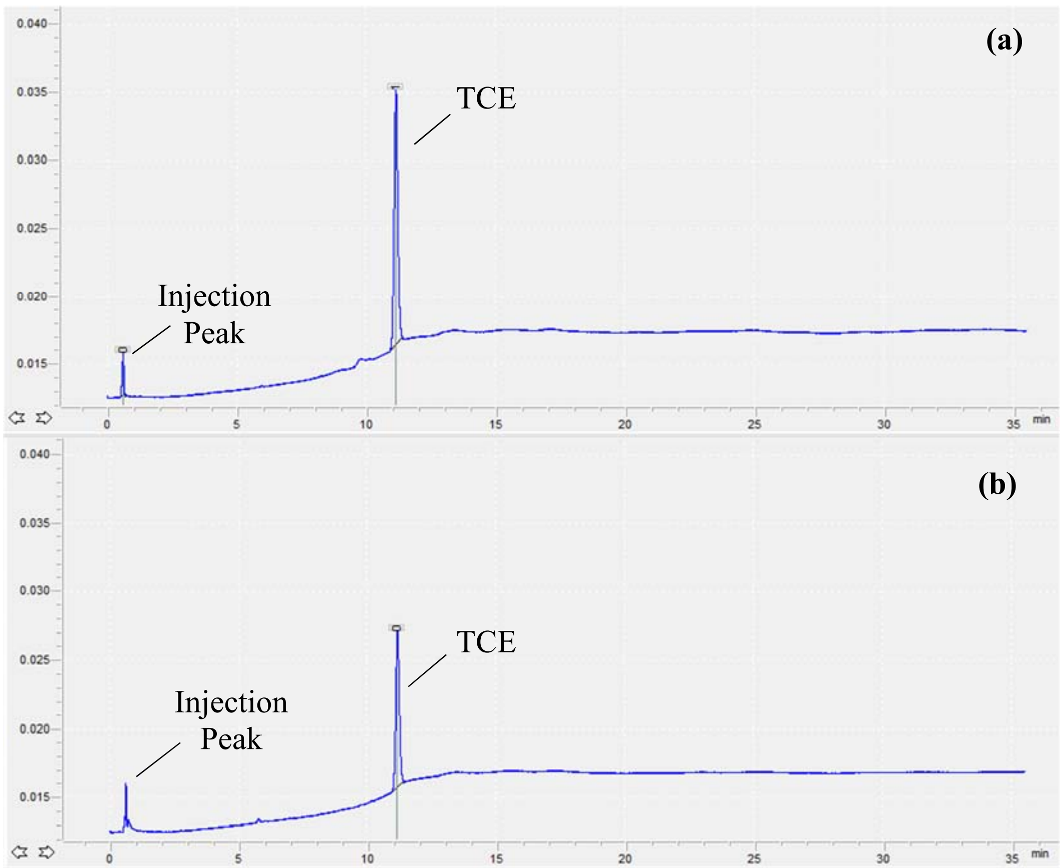


Figure D.13. GC chromatographs from Plattsburgh, well 32PTLW12, bottle 2. Panel (a) shows Day 0 and (b) shows Day 40 measurements taken using 0.5 mL headspace injections onto a packed column connected to the GC FID. The residence time for TCE was determine using an external standard. Y-axis is measured in volts (V) and x-axis in min.

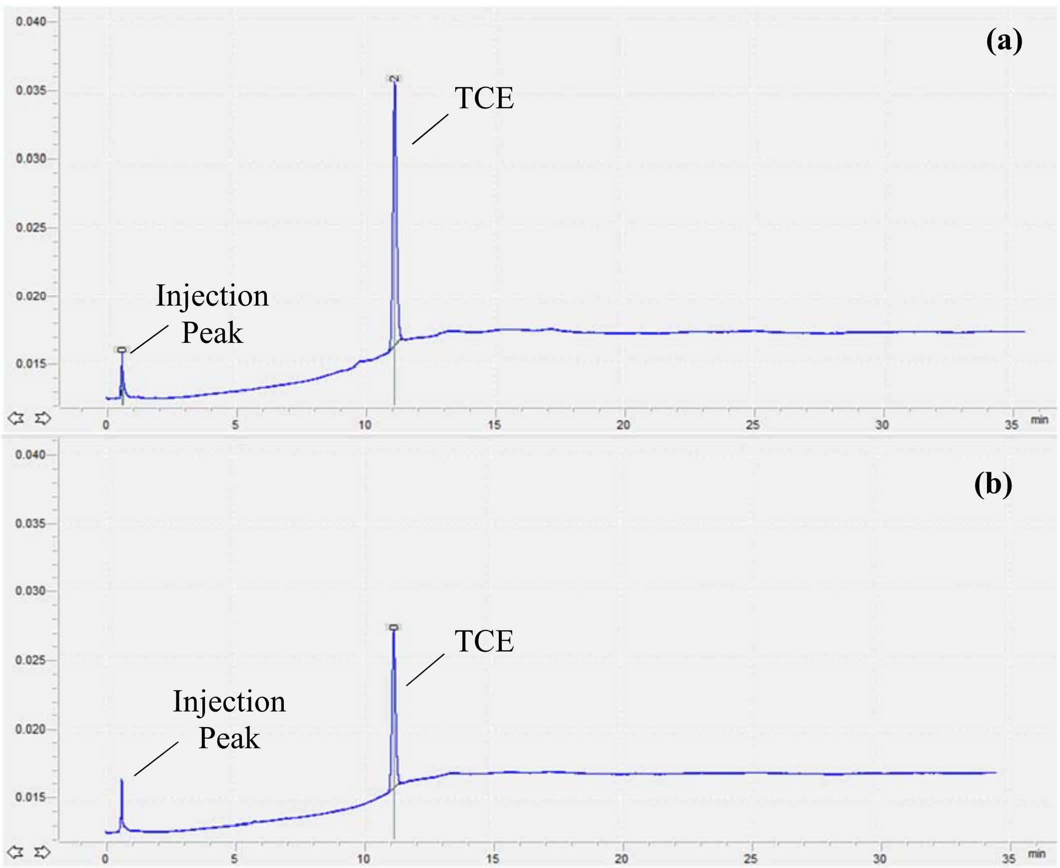


Figure D.14. GC chromatographs from Plattsburgh, well 32PTLW12, bottle 3. Panel (a) shows Day 0 and (b) shows Day 40 measurements taken using 0.5 mL headspace injections onto a packed column connected to the GC FID. The residence time for TCE was determine using an external standard. Y-axis is measured in volts (V) and x-axis in min.

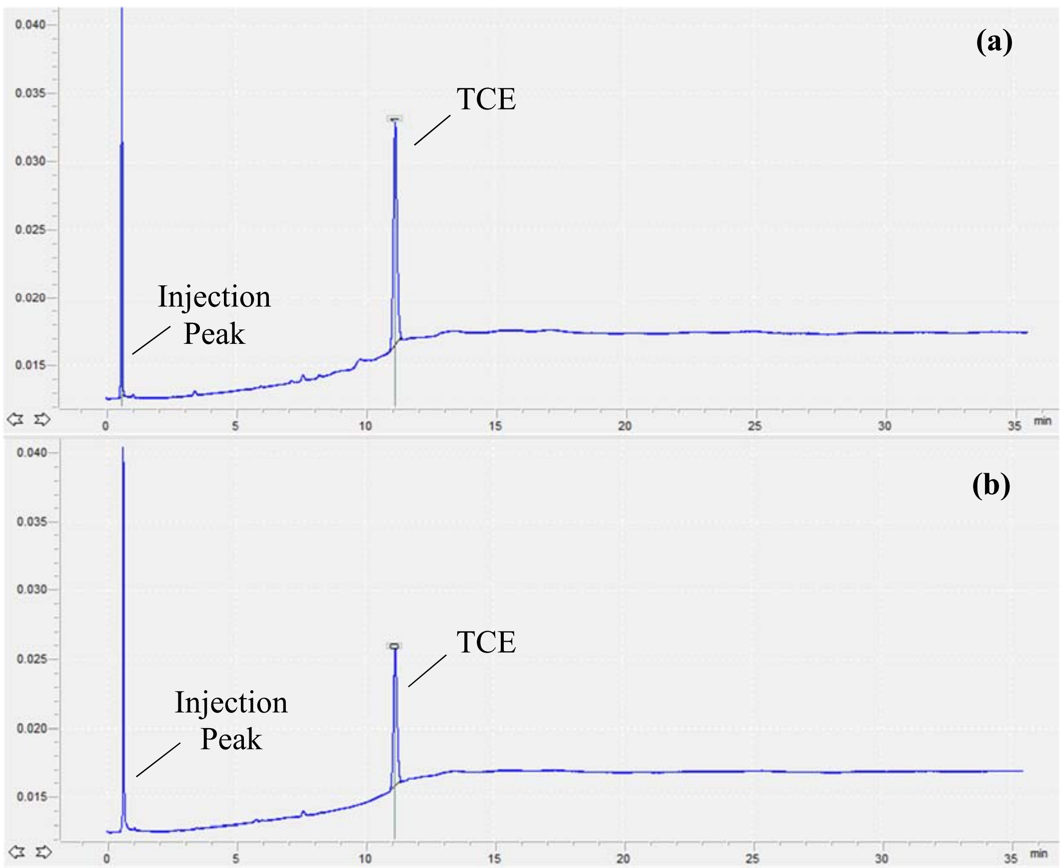


Figure D.15. GC chromatographs from Plattsburgh, well 35PTLW13, bottle 1. Panel (a) shows Day 0 and (b) shows Day 40 measurements taken using 0.5 mL headspace injections onto a packed column connected to the GC FID. The residence time for TCE was determine using an external standard. Y-axis is measured in volts (V) and x-axis in min.

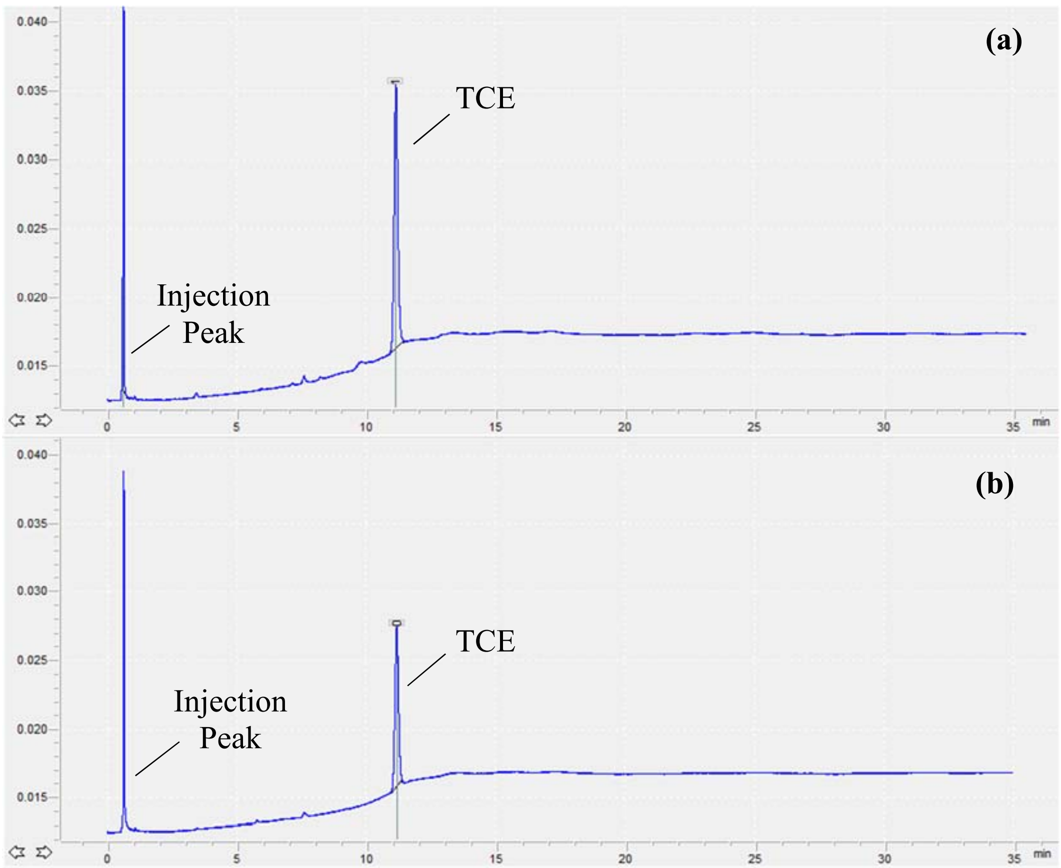


Figure D.16. GC chromatographs from Plattsburgh, well 35PTLW13, bottle 2. Panel (a) shows Day 0 and (b) shows Day 40 measurements taken using 0.5 mL headspace injections onto a packed column connected to the GC FID. The residence time for TCE was determine using an external standard. Y-axis is measured in volts (V) and x-axis in min.

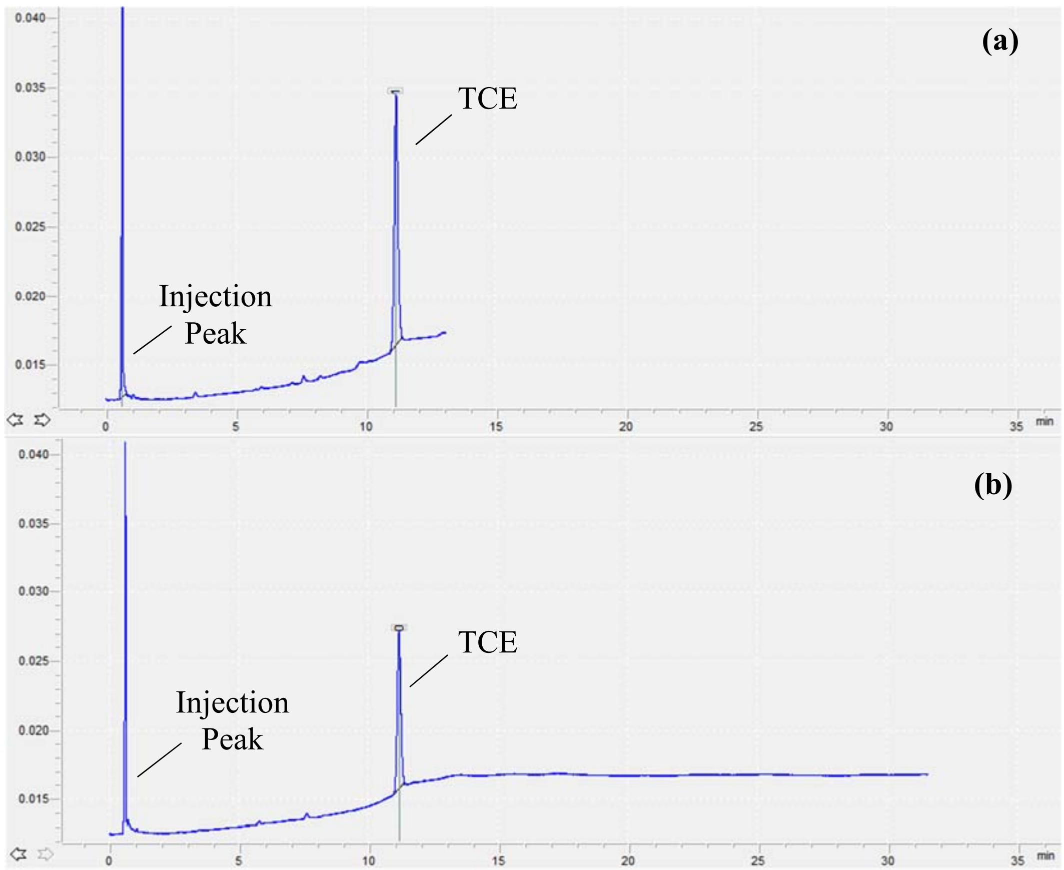


Figure D.17. GC chromatographs from Plattsburgh, well 35PTLW13, bottle 3. Panel (a) shows Day 0 and (b) shows Day 40 measurements taken using 0.5 mL headspace injections onto a packed column connected to the GC FID. The residence time for TCE was determine using an external standard. Y-axis is measured in volts (V) and x-axis in min.

D.3 Hopewell Precision Superfund Site

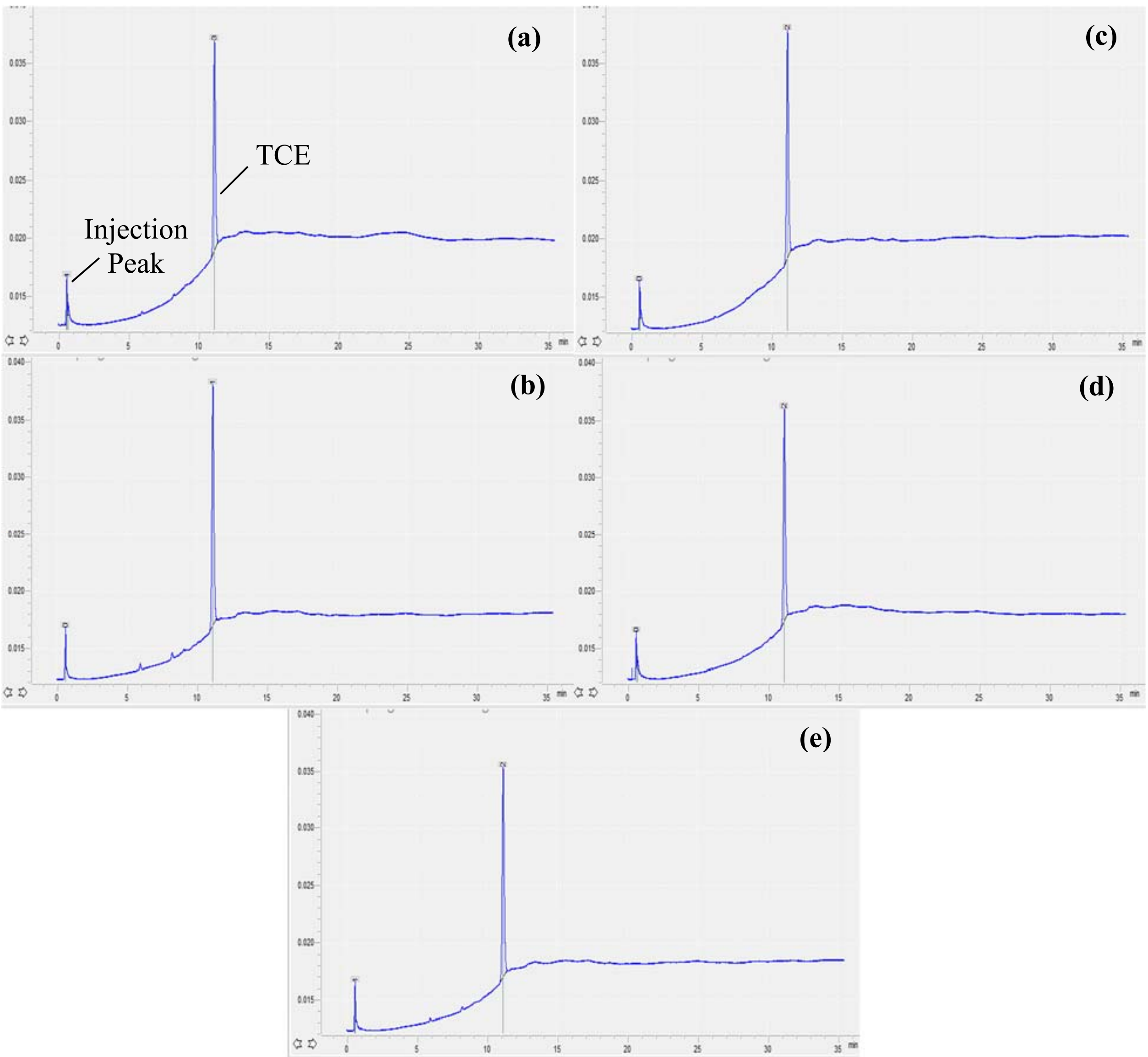


Figure D.18. GC chromatographs from Hopewell at Day 0 showing (a) EPA-16S, bottle 2; (b) EPA-16S, bottle 3; (c) EPA-15D, bottle 1; (d) EPA-15D, bottle 2; and (e) EPA-15D, bottle 3 using 0.5 mL headspace injections onto a packed column connected to the GC FID. The residence time for TCE was determine using an external standard. Y-axis is measured in volts (V) and x-axis in min. These wells did not have significant VOCs in the initial headspace sampling, so the final chromatographs at Day 46 are not shown. The leftmost, smaller peak represents the injection peak and the rightmost, larger peak represents TCE as shown in panel (a) for an example.

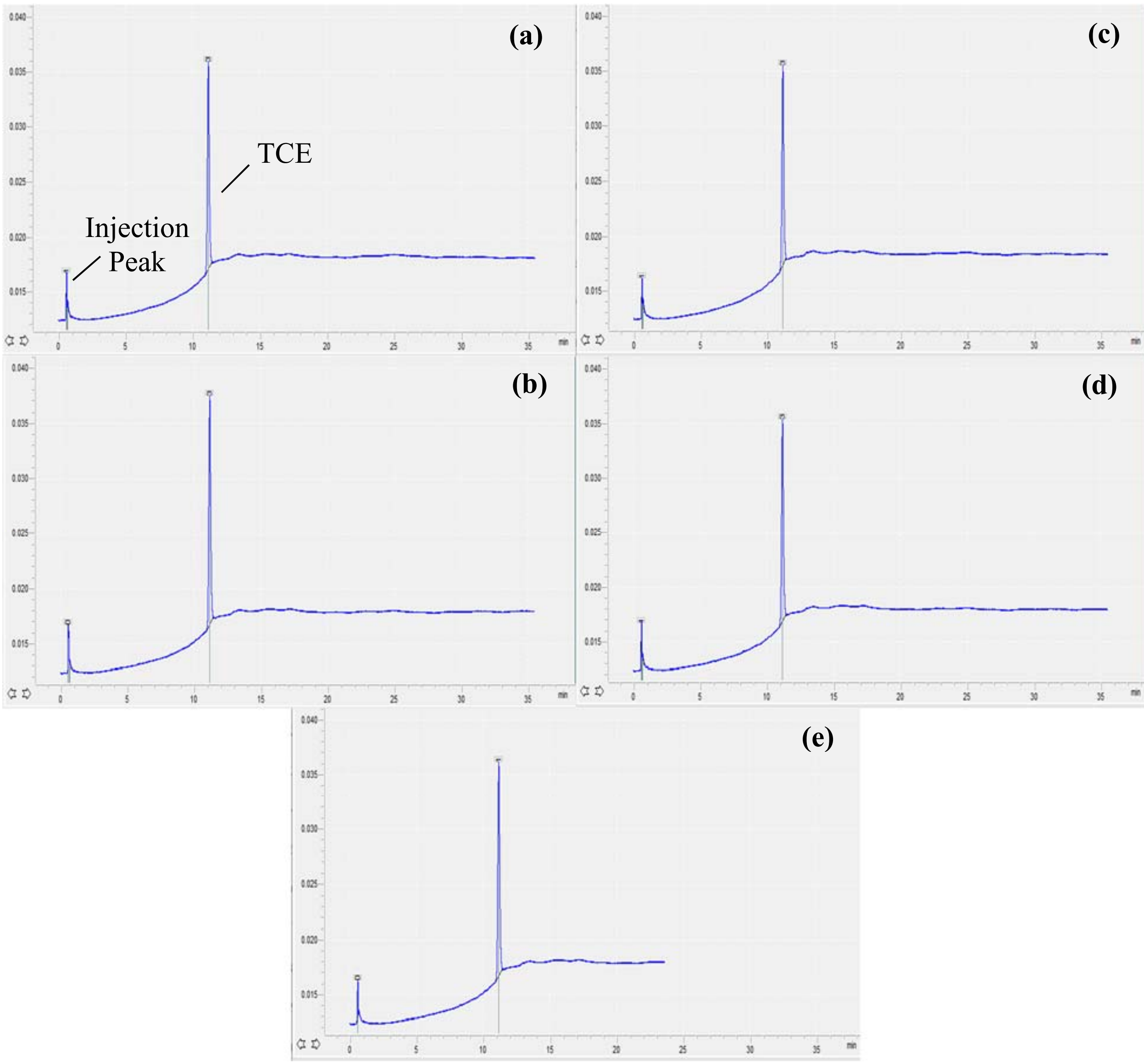


Figure D.19. GC chromatographs from Hopewell at Day 0 showing (a) EPA-12S, bottle 2; (b) EPA-12S, bottle 3; (c) EPA-10S, bottle 1; (d) EPA-10S, bottle 2; and (e) EPA-10S, bottle 3 using 0.5 mL headspace injections onto a packed column connected to the GC FID. The residence time for TCE was determine using an external standard. Y-axis is measured in volts (V) and x-axis in min. These wells did not have significant VOCs in the initial headspace sampling, so the final chromatographs at Day 46 are not shown. The leftmost, smaller peak represents the injection peak and the rightmost, larger peak represents TCE as shown in panel (a) for an example.

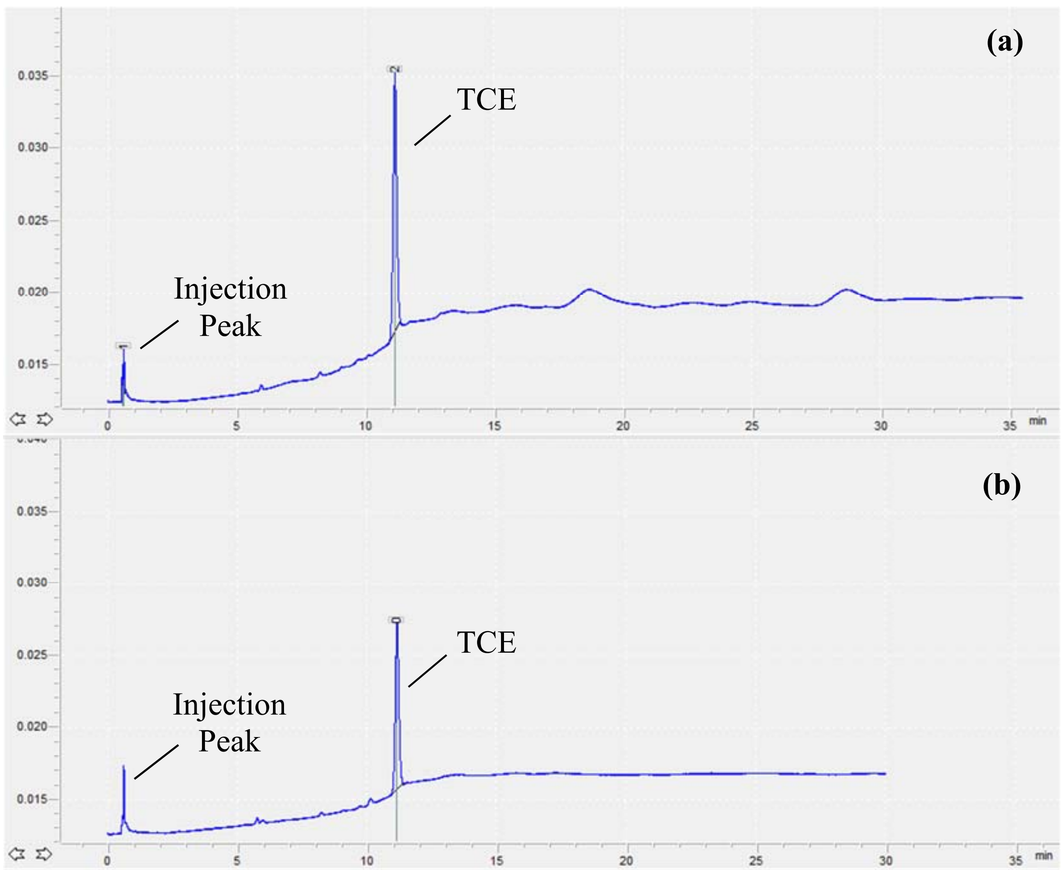


Figure D.20. GC chromatographs from Hopewell, well EPA-16S, bottle 1. Panel (a) shows Day 0 and (b) shows Day 40 measurements taken using 0.5 mL headspace injections onto a packed column connected to the GC FID. The residence time for TCE was determine using an external standard. Y-axis is measured in volts (V) and x-axis in min.

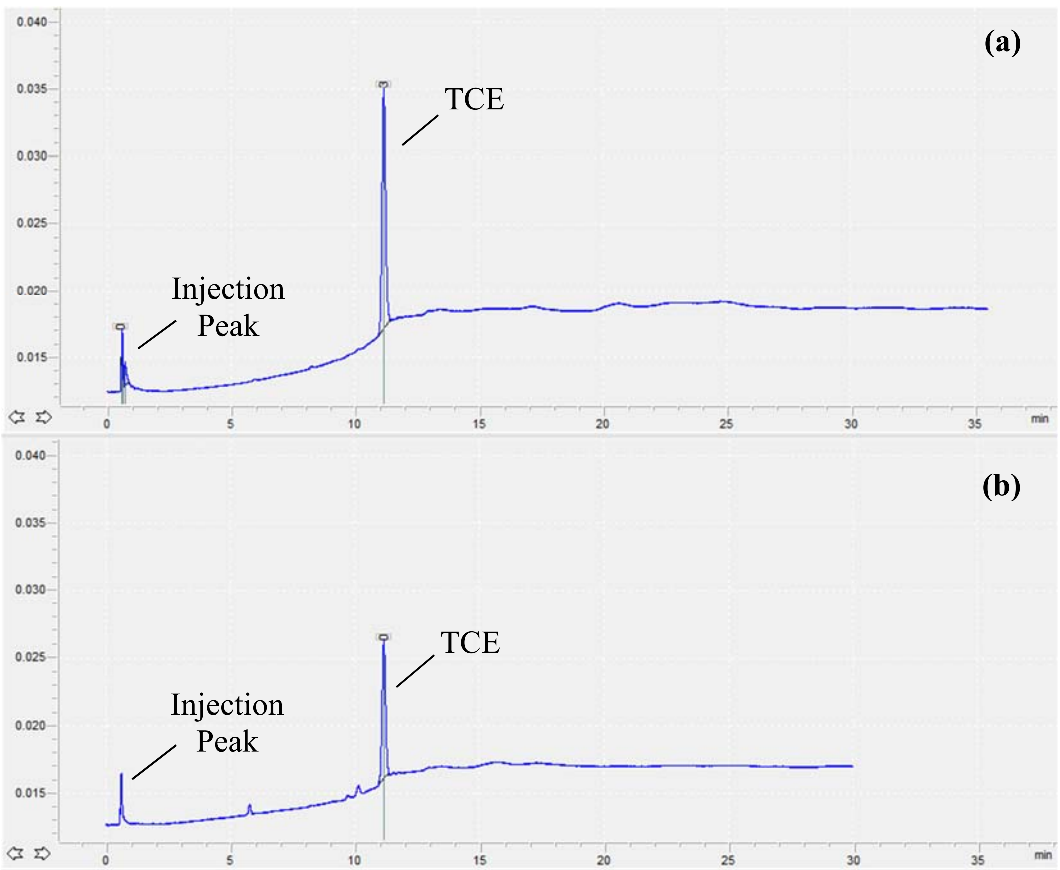


Figure D.21. GC chromatographs from Hopewell, well EPA-12S. Panel (a) shows Day 0 and (b) shows Day 40 measurements taken using 0.5 mL headspace injections onto a packed column connected to the GC FID. The residence time for TCE was determine using an external standard. Y-axis is measured in volts (V) and x-axis in min.

D.4 Tooele Army Depot

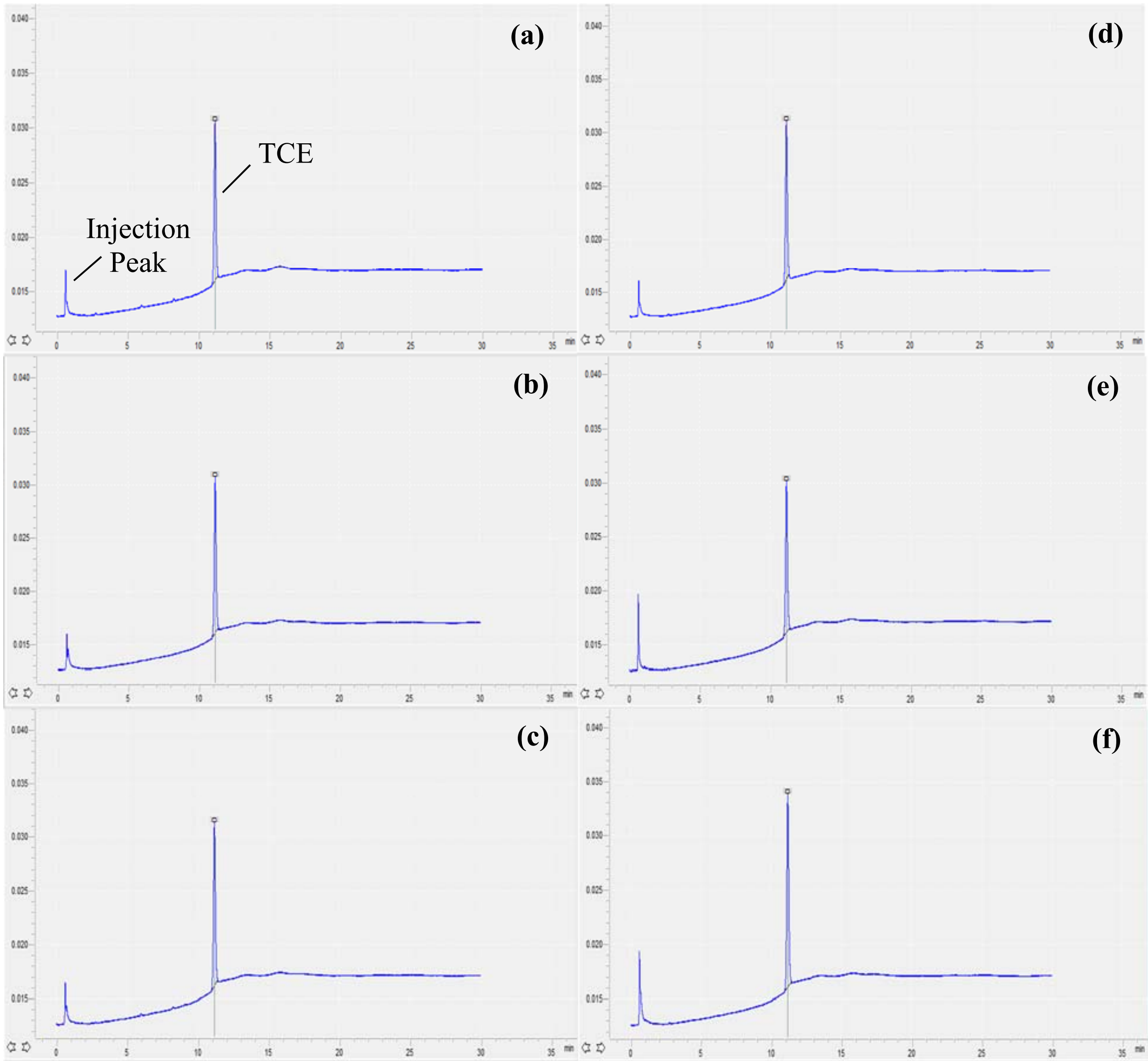


Figure D.22. GC chromatographs from Tooele at Day 0 showing (a) D-20, bottle 1; (b) D-20, bottle 2; (c) D-20, bottle 3; (d) D-23, bottle 1; (e) D-23, bottle 2; and (f) D-23, bottle 3 using 0.5 mL headspace injections onto a packed column connected to the GC FID. The residence time for TCE was determine using an external standard. Y-axis is measured in volts (V) and x-axis in min. These wells did not have significant VOCs in the initial headspace sampling, so the final chromatographs at Day 46 are not shown. The leftmost, smaller peak represents the injection peak and the rightmost, larger peak represents TCE as shown in panel (a) for an example.

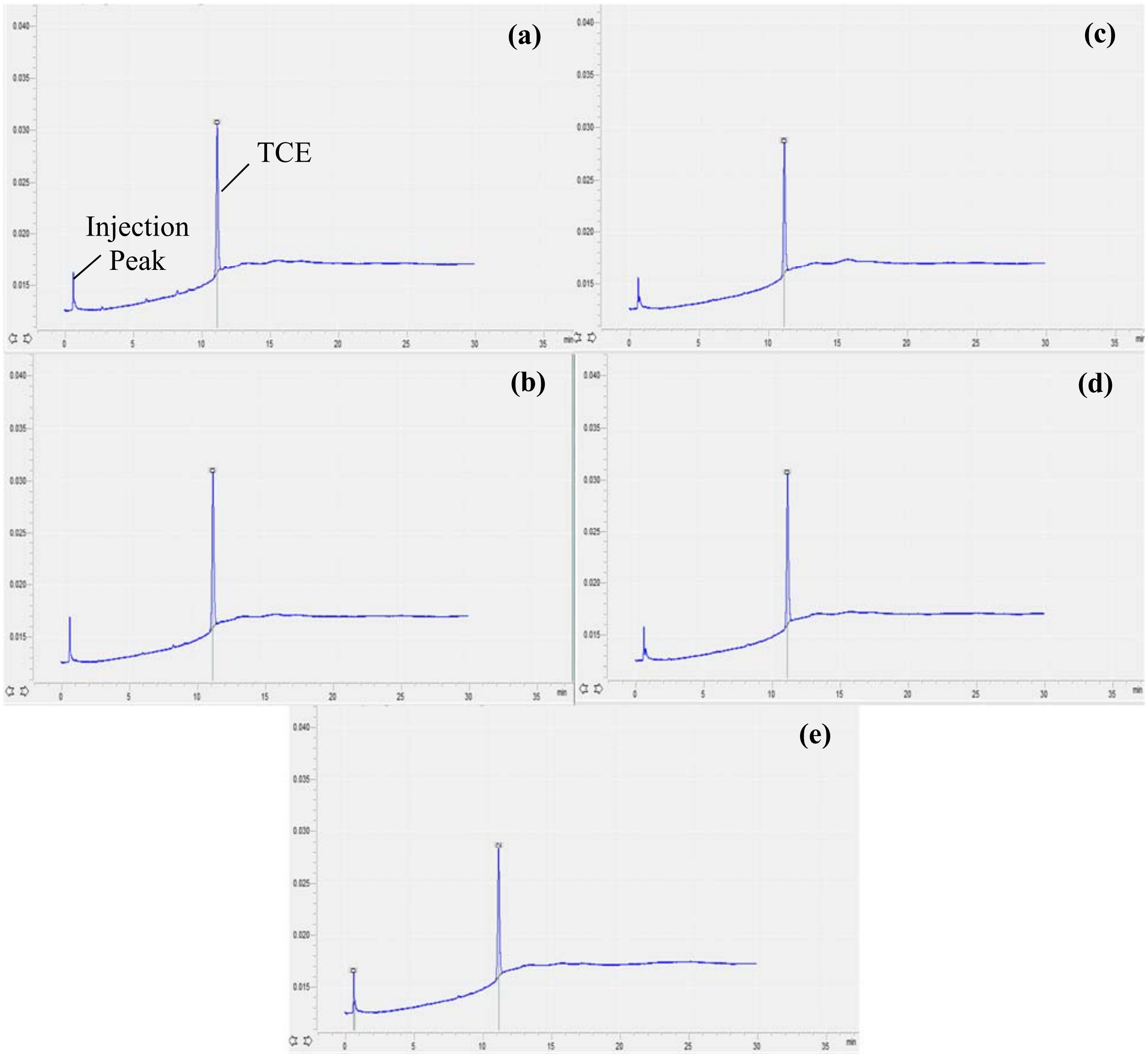


Figure D.23. GC chromatographs from Tooele at Day 0 showing (a) D-25, bottle 1; (b) D-25, bottle 2; (c) D-19, bottle 1; (d) D-19, bottle 2; and (e) D-19, bottle 3 using 0.5 mL headspace injections onto a packed column connected to the GC FID. The residence time for TCE was determine using an external standard. Y-axis is measured in volts (V) and x-axis in min. These wells did not have significant VOCs in the initial headspace sampling, so the final chromatographs at Day 46 are not shown. The leftmost, smaller peak represents the injection peak and the rightmost, larger peak represents TCE as shown in panel (a) for an example

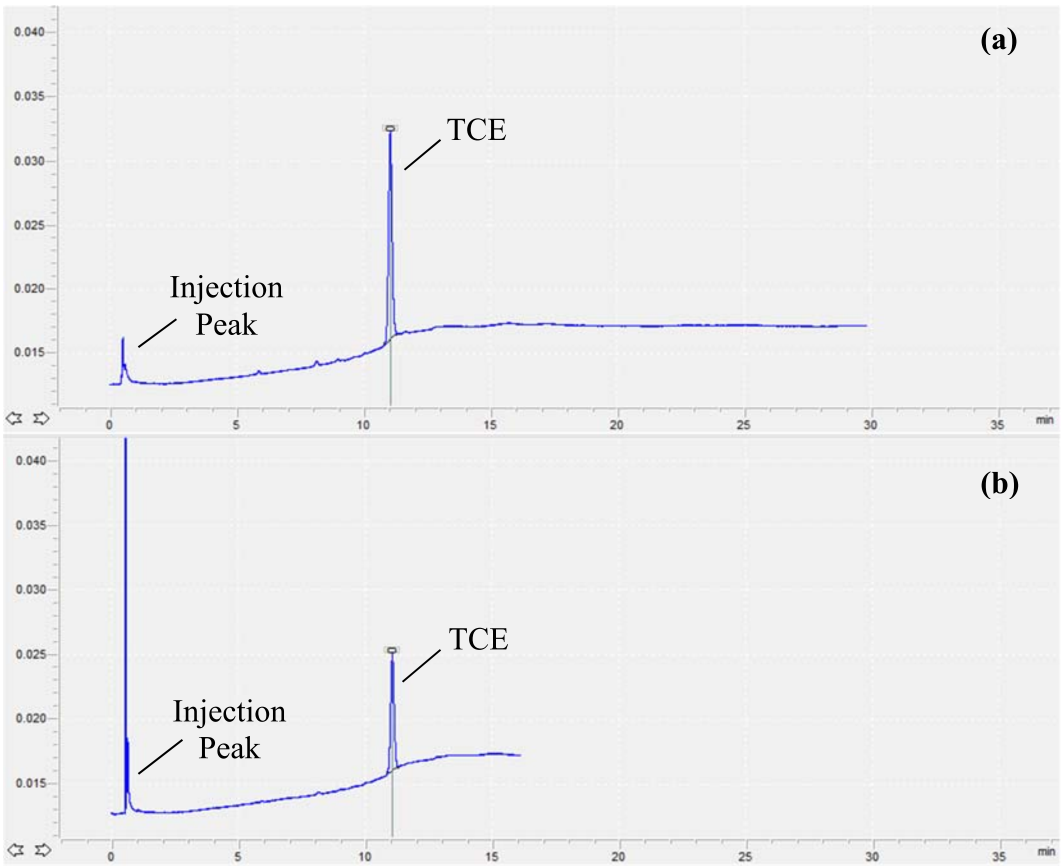


Figure D.24. GC chromatographs from Tooele, well D-25, bottle 3. Panel (a) shows Day 0 and (b) shows Day 46 measurements taken using 0.5 mL headspace injections onto a packed column connected to the GC FID. The residence time for TCE was determine using an external standard. Y-axis is measured in volts (V) and x-axis in min.

D.5 Hill Air Force Base

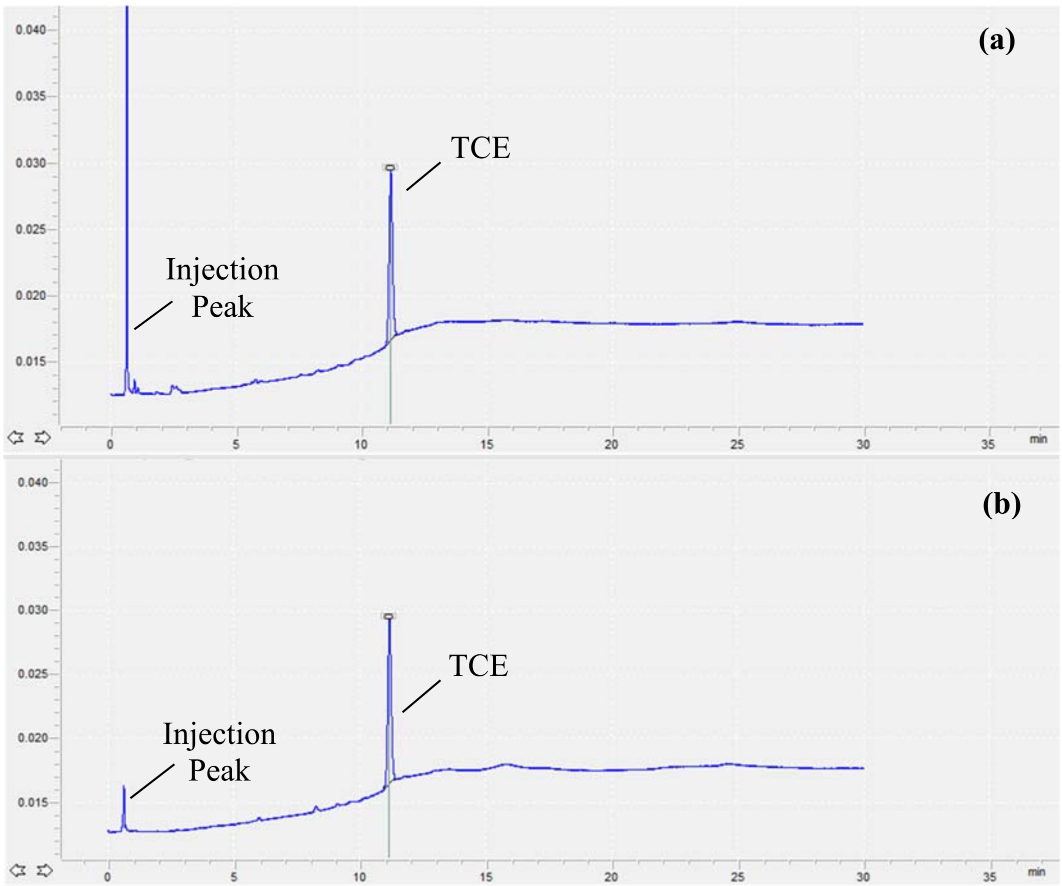


Figure D.25. GC chromatographs from Hill at Day 0 showing (a) U10-019, bottle 3 and (b) U10-025, bottle 2 using 0.5 mL headspace injections onto a packed column connected to the GC FID. The residence time for TCE was determine using an external standard. Y-axis is measured in volts (V) and x-axis in min. These wells did not have significant VOCs in the initial headspace sampling, so the final chromatographs at Day 46 are not shown.

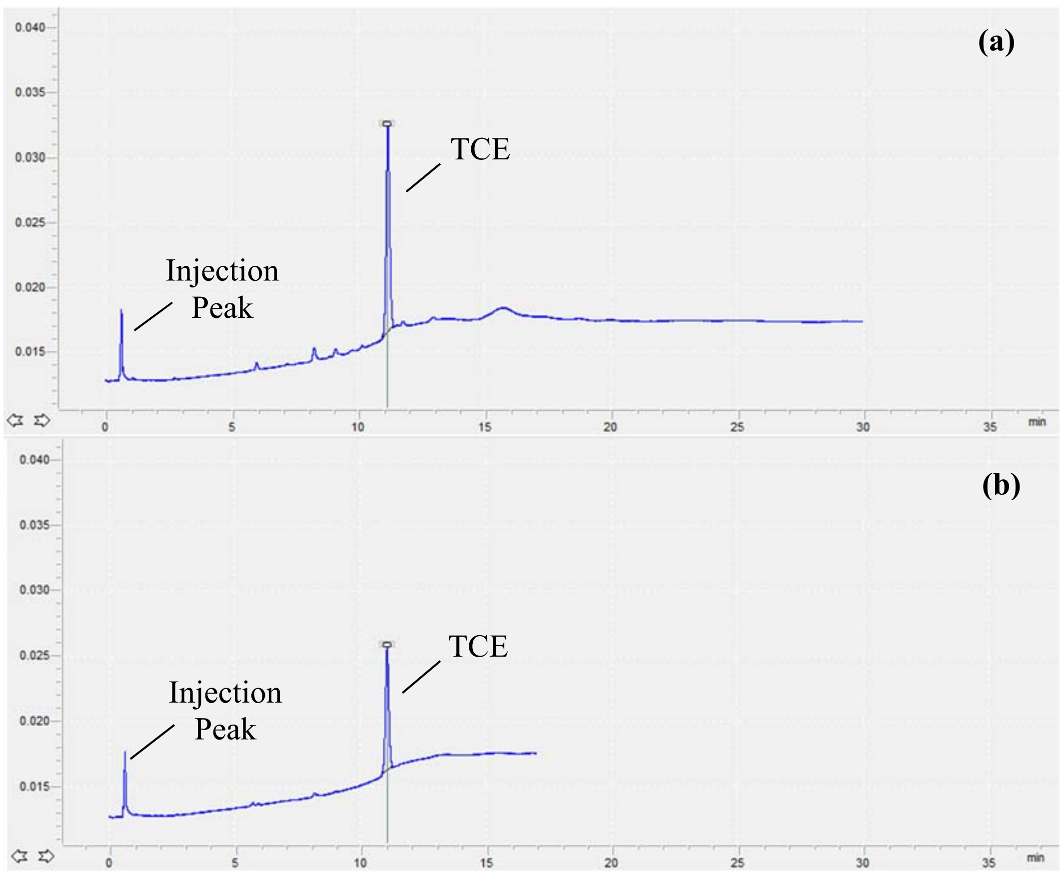


Figure D.26. GC chromatographs from Hill, well U10-043, bottle 1. Panel (a) shows Day 0 and (b) shows Day 46 measurements taken using 0.5 mL headspace injections onto a packed column connected to the GC FID. The residence time for TCE was determine using an external standard. Y-axis is measured in volts (V) and x-axis in min.

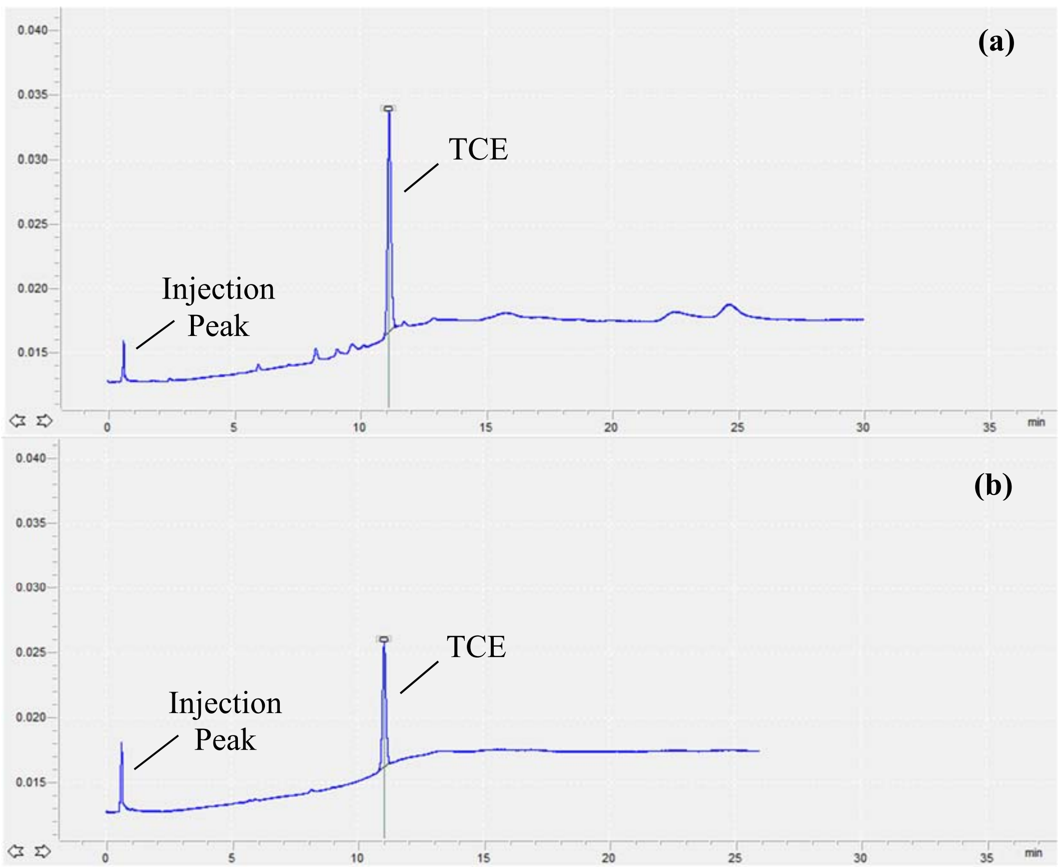


Figure D.27. GC chromatographs from Hill, well U10-043, bottle 2. Panel (a) shows Day 0 and (b) shows Day 46 measurements taken using 0.5 mL headspace injections onto a packed column connected to the GC FID. The residence time for TCE was determine using an external standard. Y-axis is measured in volts (V) and x-axis in min.

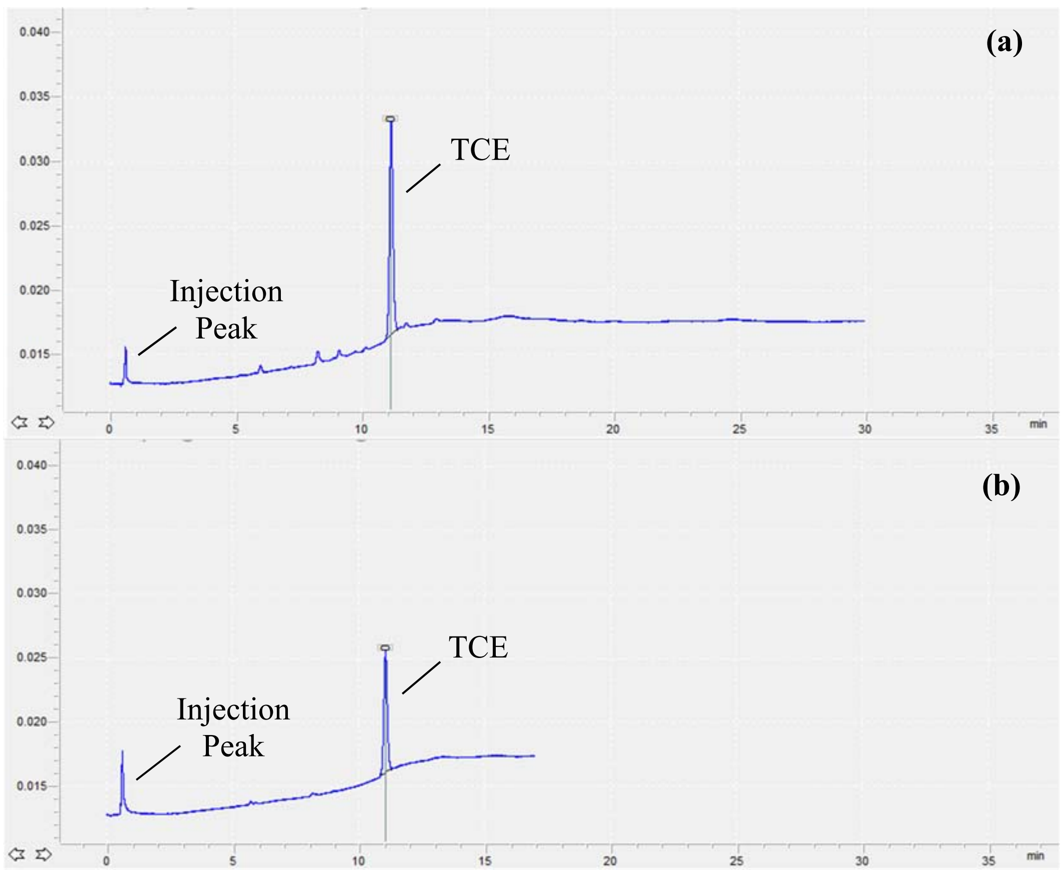


Figure D.28. GC chromatographs from Hill, well U10-043, bottle 3. Panel (a) shows Day 0 and (b) shows Day 46 measurements taken using 0.5 mL headspace injections onto a packed column connected to the GC FID. The residence time for TCE was determine using an external standard. Y-axis is measured in volts (V) and x-axis in min.

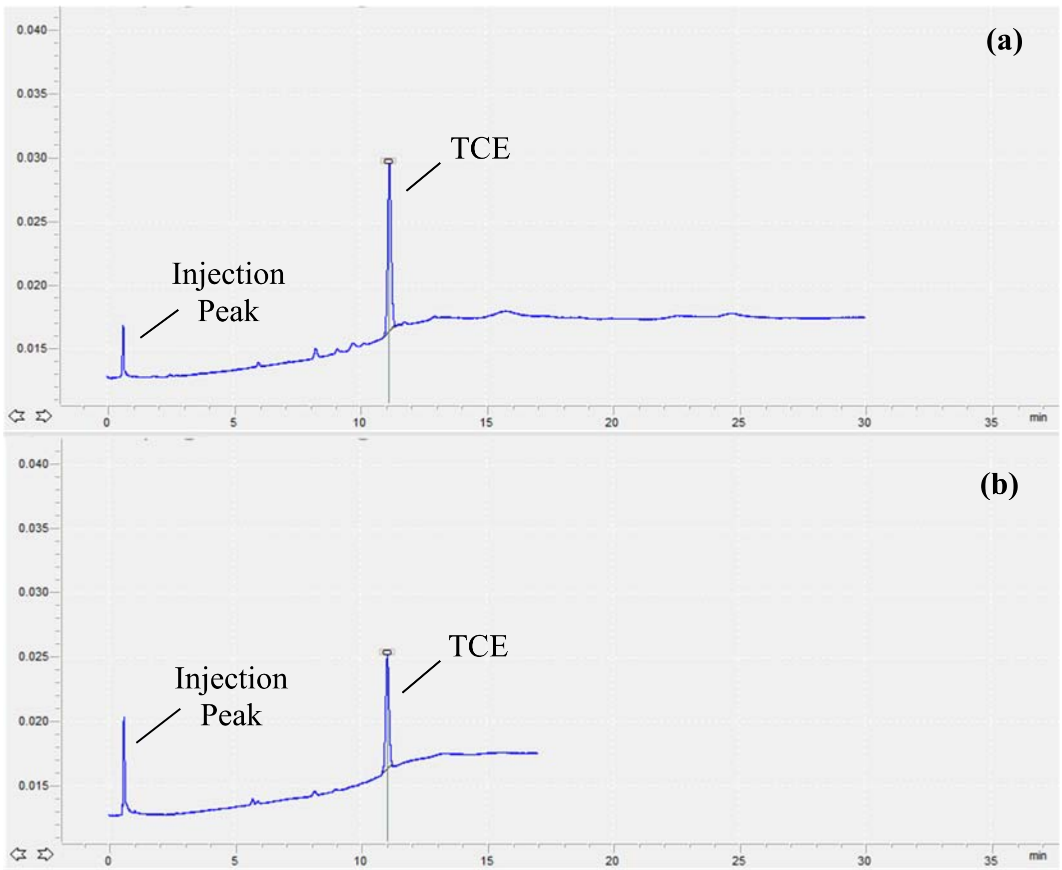


Figure D.29. GC chromatographs from Hill, well U10-025, bottle 1. Panel (a) shows Day 0 and (b) shows Day 46 measurements taken using 0.5 mL headspace injections onto a packed column connected to the GC FID. The residence time for TCE was determine using an external standard. Y-axis is measured in volts (V) and x-axis in min.

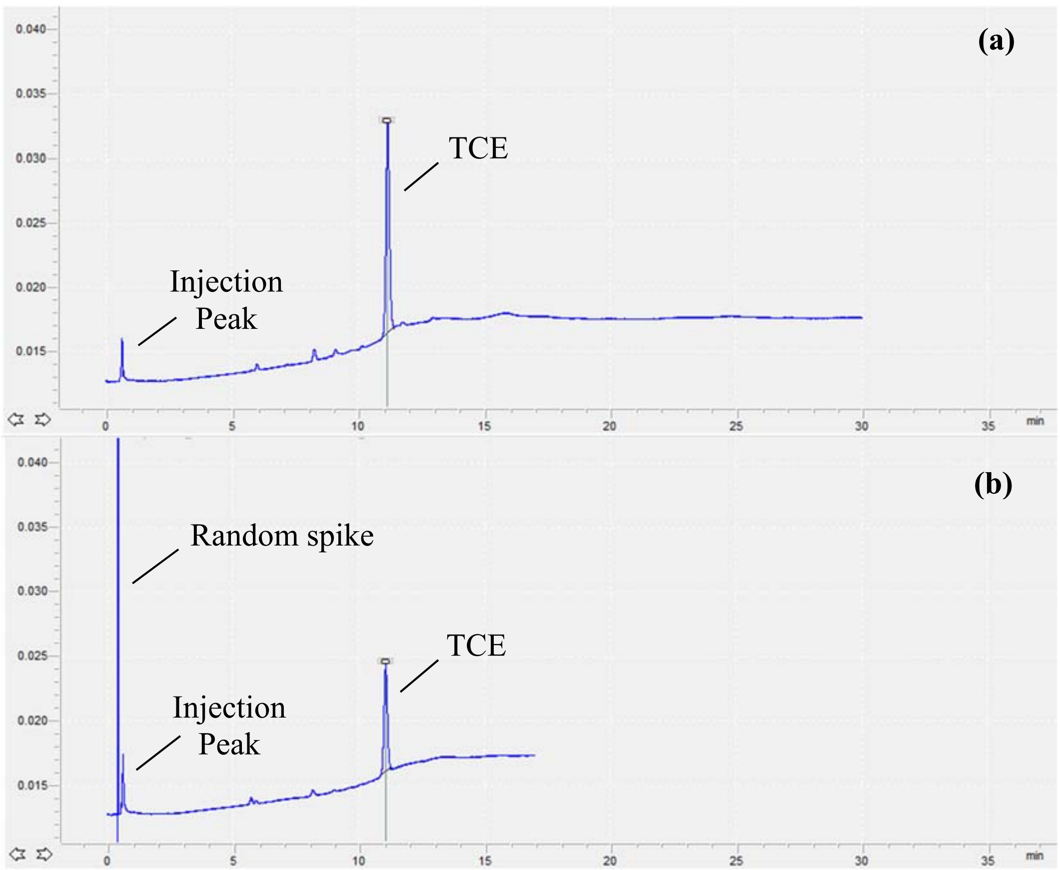


Figure D.30. GC chromatographs from Hill, well U10-025, bottle 3. Panel (a) shows Day 0 and (b) shows Day 46 measurements taken using 0.5 mL headspace injections onto a packed column connected to the GC FID. The residence time for TCE was determine using an external standard. Y-axis is measured in volts (V) and x-axis in min.

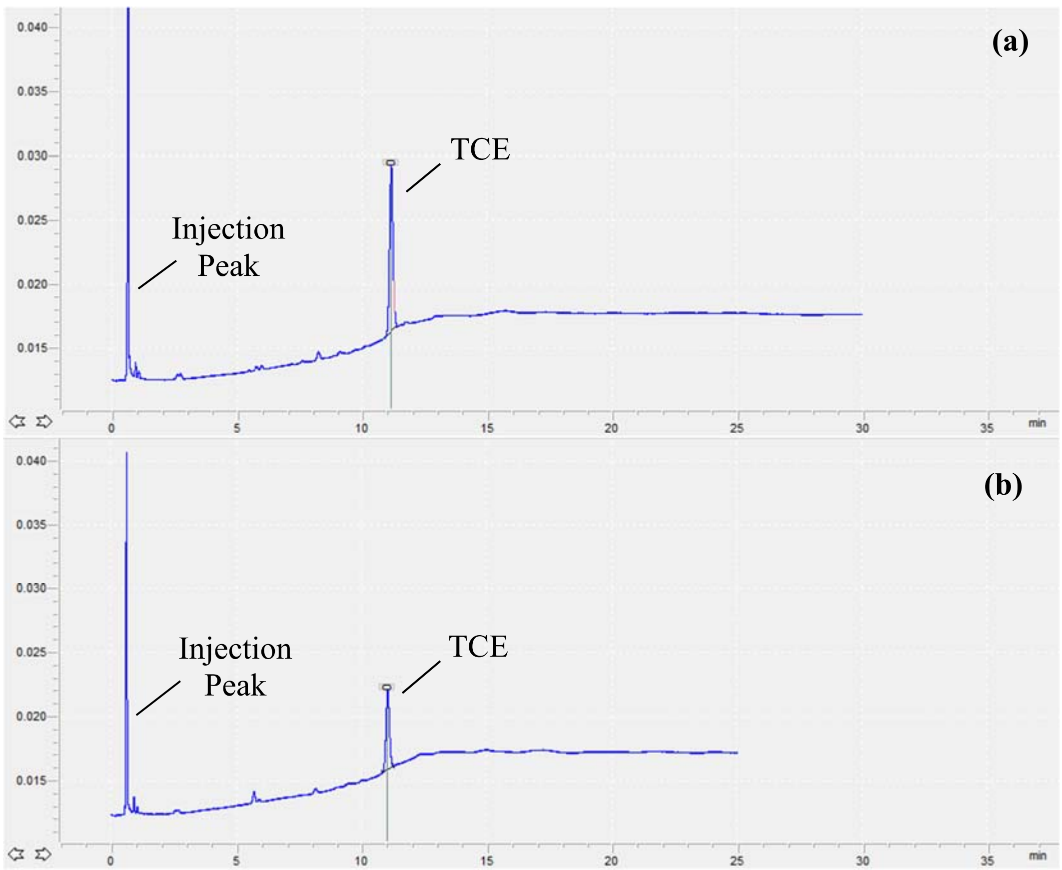


Figure D.31. GC chromatographs from Hill, well U10-019, bottle 1. Panel (a) shows Day 0 and (b) shows Day 46 measurements taken using 0.5 mL headspace injections onto a packed column connected to the GC FID. The residence time for TCE was determine using an external standard. Y-axis is measured in volts (V) and x-axis in min.

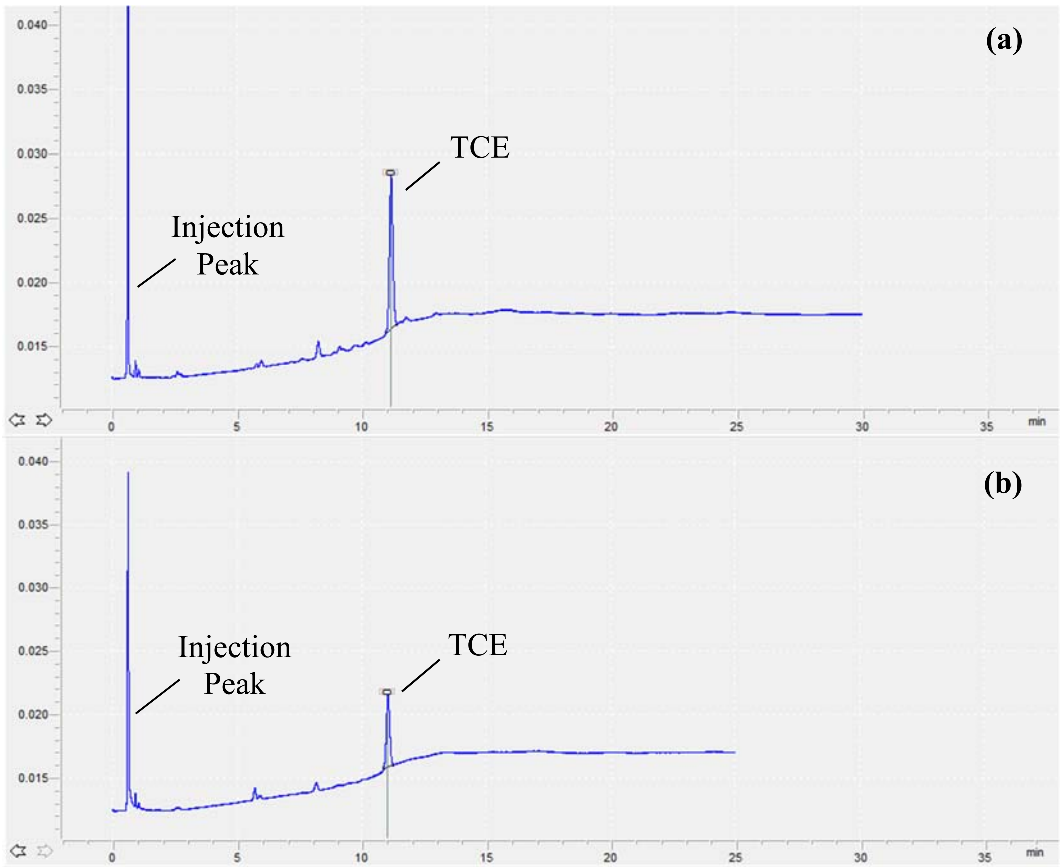


Figure D.32. GC chromatographs from Hill, well U10-019, bottle 2. Panel (a) shows Day 0 and (b) shows Day 46 measurements taken using 0.5 mL headspace injections onto a packed column connected to the GC FID. The residence time for TCE was determine using an external standard. Y-axis is measured in volts (V) and x-axis in min.

D.6 MATLAB Script for Model

```
%   Original:   07/16/16
%   Modified:   01/20/17
%
%   Author: James Mills
%
%   Purpose of script: This script will run a nonlinear regression
%   model for experimental data that involves the cometabolism of TCE.
%   The goal of the program is to solve for a first order rate constant
%   using the least squares method. Additionally, confidence intervals and
%   standard deviation for the rate constant will be included. This
%   script will rely on multiple different functions in a stepwise manner
%   because of the dynamic volume changes that occur during the experiment,
%   which affect the concentration of TCE and its distribution between the
%   aqueous and gaseous phases.

function experimentalModelReportEdit
%   Dimensionaless Henry's Law constant for TCE
H_c = 0.349;

%   Liquid removed with each sampling event (3.1 mL)
V_lr = 3.1;

%   Gas removed with each sampling event (1.0 mL)
V_gr = 1.0;

%   Total volume of serum bottle (160 mL)
V_tot = 160;

%   Create on/off switchs so user can easily change sections of code
CSV = 'off';

%*************************  Data collection  ************************

%   Obtain folder and file paths
scriptPath = cd;    % Current directory of MATLAB file
%   Have user select Excel data file through dialogue box
[baseName,dirPath] = uigetfile({'*.xlsx';'*.xls'},'Select a file');
fileName = fullfile(dirPath, baseName);     % Full file path of Excel WB

%   Change to directory where Excel data files reside
cd(dirPath);

%   Gather all sheet names from Excel data file
[~, sheets] = xlsfinfo(fileName);



%   For certain sheet names in selected file, list name and associated
```

```matlab
%   numerical index value, separated by a tab.
fprintf('\n')   % Add new line
for t = 1:length(sheets) % Iterate over all sheets

    %   If model is in sheetname, skip this sheet
    if not(isempty(strfind(char(sheets(t)),'Model')))
        continue
    end

    %   If sheet name contains certain identifier, then print to MATLAB
    %   command window with appropriate sheet index for user to select
    if not(isempty(strfind(char(sheets(t)),'well #'))) || ...
            not(isempty(strfind(char(sheets(t)),'A WC'))) || ...
            not(isempty(strfind(char(sheets(t)),'FS GW Hill'))) || ...
            not(isempty(strfind(char(sheets(t)),'Propano'))) || ...
            not(isempty(strfind(char(sheets(t)),'Room'))) || ...
            not(isempty(strfind(char(sheets(t)),'Ice'))) || ...
            not(isempty(strfind(char(sheets(t)),'WC Test'))) || ...
            not(isempty(strfind(char(sheets(t)),'Twin Lakes'))) || ...
            not(isempty(strfind(char(sheets(t)),'Tooele Rock Controls')))

        fprintf('%s \t %d',char(sheets(t)),t)
        fprintf('\n')
    end
end

%   Prompt user for numerical input to select appropriate sheet and
%   assign selected sheet to variable
fprintf('\n')   % Add new line
prompt = 'Enter numerical value for sheet desired --> ';
sheetName = input(prompt);

%   Read selected sheet from Excel data file to get raw data
[~,~,raw] = xlsread(fileName,sheetName);

%   Determine size of raw data set from selected sheet
[row,col] = size(raw);

%   Preallocate memory with zeros
sparInd = zeros(3,2);
dayInd = zeros(3,2);

%   Iterate over selected data matrix to find certain data indices for
%   dpm and day entries
countRow = 0;   % Counter to be updated in loop
    % Iterate over columns in raw data
    for j = 1:col


        % Iterate over rows in raw data
        for m = 1:row
```

```
            %   Search sheet for exact string match, then get sparge
            %   data indices and day indices using offsets from
            %   location of exact string match
            if strcmp('Sparged alkaline liquid (3.0 mL)',raw(m,j))
                countRow = countRow + 1;    % Update counter

                %   Sparge data start indices
                sparInd(countRow,1) = m+3;  % +3 is offset for sparge rows
                sparInd(countRow,2) = j+4;  % +4 is offset for sparge cols

                %   Day data start indices
                dayInd(countRow,1) = m+3;   % +3 is offset for day rows
                dayInd(countRow,2) = j+1;   % +1 is offset for day cols
            end

            %   Find exact string in sheet and get measured
            %   concentration data
            cMeasStr = ['Calculated total activity remaining '...
                'in bottle from direct counts'];

            %   Measured concentration data from offsets in sheets with 3
            %   bottles
            if strcmp(cMeasStr,raw(m,j))
                C_ototm = cell2mat([raw(m+3,5), raw(m+3,12),raw(m+3,19)]);
            end

            %   Find exact match in sheet, then get initial volume
            %   measurements using offsets in sheets with 3 bottles
            if strncmp(raw(m,j),'Volume of Liquid',15)
                V_iL(1,:) = cell2mat([raw(m,2),raw(m,9),raw(m,16)]);
            end
        end
    end

%   While data is numeric, update dpm and day data into matrices
for k = 1:length(sparInd)
    count2 = 0;     % Counter to be updated
    rowCount = 1;   % Another counter to be updated
    while isnumeric(cell2mat(raw(sparInd(k,1)+count2,sparInd(k,2))))&& ...
            cell2mat(raw(sparInd(k,1)+count2,sparInd(k,2))) ~= 0 &&...
            not(isnan(cell2mat(raw(sparInd(k,1)+count2,sparInd(k,2)))))

        dpmData(rowCount,k) = cell2mat(raw(sparInd(k,1)+count2,sparInd(k,2)));
        dayData(rowCount,k) = cell2mat(raw(dayInd(k,1)+count2,dayInd(k,2)));
        count2 = count2 + 1; % Update counter

        rowCount = rowCount + 1; % Update counter
    end
end
%************************  End data collection  ***********************
```

```
%************************  Initial case  ******************************

%   Print number of sparge samples in data set
fprintf('\n %s %d \n','n =',length(dpmData))

%   Experimental data for days from time zero and dpm at each
%   sampling event per bottle
%   If IIA well #1 or VB well #1, then remove last data points
if strcmp(char(sheets(sheetName)),'IIA well #1')|| ...
        strcmp(char(sheets(sheetName)),'VB well #1')
    fprintf(2,'\nsuccess IIA1 or VB1\n')
    dpm = dpmData(1:end-1,:);   % x data
    days = dayData(1:end-1,:);  % y data

%   For storage test (Room Temp, Ice A ,Ice B) ask user to shorten data to
%   4 days or leave all data
elseif strcmp(char(sheets(sheetName)),'Room Temp')|| ...
        strcmp(char(sheets(sheetName)),'Ice A')||...
        strcmp(char(sheets(sheetName)),'Ice B')
    fprintf(2,'\nsuccess storage\n')
    prompt2 = input('0-4 days (y/n) --> ','s');
    if strcmp(prompt2,'y')
        dpm = dpmData(1:end-3,:);   % x data
        days = dayData(1:end-3,:);  % y data
    else
        dpm = dpmData(1:end,:);   % x data
        days = dayData(1:end,:);  % y data
    end
%   Else include entire data set collected from worksheet
else
    dpm = dpmData(1:end,:);   % x data
    days = dayData(1:end,:);  % y data
end

%   Remove average dpm on initial reading from dpm data set for sorted
%   Tooele Rock controls (well D-20) because some values lower than initial
%   values
if strcmp(char(sheets(sheetName)),'Tooele Rock Controls')
    fprintf(2,'\nsuccess TRC\n')
    sortDpm = sort(dpm,'ascend');
    aveSortedDpm = mean(sortDpm(1,:));
    dpm = dpm - aveSortedDpm;




%   Else remove average of initial data sparge sample data points
%   from data set
else
    aveInitDpm = mean(dpm(1,:));
```

```
    dpm = dpm - aveInitDpm;
end

dpm(dpm<0) = 0;     % if negative value, then update as zero in matrix

%   Get values for gas volume using difference between total and liquid
V_ig(1,:) = V_tot - V_iL(1,:);

%   Determine length of data set using time interval data
dataLength = length(days);

%   Calculate liquid volume in bottles after each sampling event
for q = 1:3
    %   Iterate over data of one bottle at a time
    for j = 2:dataLength
        %   Update liquid volume between sampling events
        V_iL((j),q) = V_iL((j-1),q) - V_lr;
    end
end

%   Update dpm values to reflect all experimental products in bottle
dpm =(dpm)./3.*V_iL;

%   Preallocate memory with zeros
C_ilb = zeros(1,length(C_ototm));
dpmLiq = zeros(1,length(C_ototm));
dpmGas = zeros(1,length(C_ototm));
totDpmRem = zeros(1,length(C_ototm));
C_itotp = zeros(1,length(C_ototm));
C_ila = zeros(1,length(C_ototm));
delta_ip = zeros(1,length(C_ototm));
sumDelta_ip = zeros(1,length(C_ototm));

    % Initial case in model, when t = 0
    for k = 1:length(C_ototm)

        %   Multiply total 14C concentration by percent aqueous to
        %   determine liquid concentration in bottles
        C_ilb(1,k) = C_ototm(k).*(V_iL(1,k)/(V_iL(1,k)+(V_ig(k).*H_c)));

        %   Dpm removed from aqueous phase
        dpmLiq(1,k) = C_ilb(k).*(V_lr./V_iL(1,k));




        %   Dpm removed from gaseous phase. Remove only part for the
        %   controls because no O2 checks performed. Remove full for all
        %   experimental bottles because O2 checks performed.
        % Controls
        if not(isempty(strfind(char(sheets(sheetName)),'A WC'))) ||...
```

```
                not(isempty(strfind(char(sheets(sheetName)),'FS GW Hill'))) || ...
                not(isempty(strfind(char(sheets(sheetName)),'Tooele Rock Controls')))
            dpmGas(1,k) = (C_ototm(k)- C_ilb(k)).*(((V_gr./2)./(V_ig(k))));
        % Experimental bottles


        else
            dpmGas(1,k) = (C_ototm(k)- C_ilb(k)).*(((V_gr./2)./(V_ig(k)))...
                + ((V_gr./2)./(V_ig(k)+ V_lr)));
        end

        %   Total dpm removed
        totDpmRem(1,k) = dpmLiq(1,k) + dpmGas(1,k);

        %   Final, predicted 14C total conc after sampling event
        C_itotp(1,k) = C_ototm(k) - totDpmRem(1,k);

        %   Final 14C liquid conc per bottle after sampling event
        C_ila(1,k) = C_itotp(1,k).* ((V_iL(1,k)-V_lr)./...
            ((V_iL(1,k)-V_lr)+((V_tot-(V_iL(1,k)-V_lr)).*H_c)));

        %   There are no initial products formed when t = 0
        delta_ip(1,k) = 0;
        sumDelta_ip(1,k) = 0;
    end
%*************************  End initial case  ***********************

%**********************  Case II, when t >= 1  *********************

%   Create a function for Case II of the model, when t >= 1
    function yData = caseII(k,xData)

    yData = zeros(dataLength,3);

    %   This loop allows the index to shift to data for next bottle
    for n = 1:3

        %   Loop range iterates over data of one bottle at a time
        for i = 2:dataLength

            %   Change in time between sampling events
            deltaT = xData(i)-xData(i-1);


            %   Update gas volume between sampling events
            V_ig(i,n) = V_ig((i-1),n) + V_lr;
            %   Determine products formed during incubation between
            %   sampling events
            delta_ip(i,n) = C_ila(i-1,n).*(1-exp(-k.*deltaT));

            %   Cumulative products formed during entire incubation since
```

```
            %   14C spiking or t = 0
            sumDelta_ip(i,n) = delta_ip(i,n) + sumDelta_ip(i-1,n);

            %   Initial 14C liquid conc before sampling event
            C_ilb(i,n) = C_ila((i-1),n)- delta_ip(i,n);


            %   Dpm removed from aqueous phase
            dpmLiq(i,n) = C_ilb(i,n).*(V_lr./V_iL(i,n));

            %   Dpm removed from gaseous phase. Remove only part for the
            %   controls because no O2 checks performed. Remove full for all
            %   experimental bottles because O2 checks performed.
            % Controls
            if not(isempty(strfind(char(sheets(sheetName)),'A WC'))) ||...
                    not(isempty(strfind(char(sheets(sheetName)),'FS GW Hill'))) || ...
                    not(isempty(strfind(char(sheets(sheetName)),'Tooele Rock
Controls')))
                dpmGas(i,n) = (C_itotp(i-1,n)- C_ilb(i,n)).*...
                    (((V_gr./2)./(V_ig(i,n))));
            % Experimental bottles
            else
                dpmGas(i,n) = (C_itotp(i-1,n)- C_ilb(i,n)).*...
                    (((V_gr./2)./(V_ig(i,n)))+((V_gr./2)./(V_ig(i,n)+ V_lr)));
            end

            %   Total dpm removed
            totDpmRem(i,n) = dpmLiq(i,n) + dpmGas(i,n);

            %   Final, predicted 14C liquid concentration after sampling
            C_itotp(i,n) = C_itotp(i-1,n)-totDpmRem(i,n)-delta_ip(i,n);

            %   Percent aqueous
            perAq = (V_iL(i,n)-V_lr)./...
                ((V_iL(i,n)-V_lr)+((V_tot-(V_iL(i,n)-V_lr)).*H_c));

            %   Final, 14C liquid conc after sampling
            C_ila(i,n) = C_itotp(i,n).*perAq;
            yData(i,n) = sumDelta_ip(i,n);
        end
    end
    end
%**************************  End case II  ****************************

%**************************  Model output  ***************************
%   First order rate constant based 20 year half life estimation
k = 9.489e-5;     % d^-1

%   Use nonlinear regression to determine value for first order
%   rate constant, k
opts = optimset('Display','off');
```

```
[rateCons,~,resid,~,~,~,J] = lsqcurvefit(@caseII,k,days,dpm,[],[],opts);

%   Determine confidence intervals and standard deviation on rate constant
[ciDays, se] = nlparciSE(rateCons,resid,'Jacobian',J);
ciYears = ciDays*365;

rateConsYr = rateCons*365;
std = (se*(3*length(dpmData))^(0.5))*365;
fprintf('\n %s %.5d \n','std =',std)

%   Print values to command window with units
fprintf('\n %s \n',char(sheets(sheetName)))
fprintf('\n %s %.3d %s %.3d %s \n','k =', (rateConsYr),char(177),...
    ((rateConsYr)-ciYears(1)),'y^-1');
fprintf('\n %s %.3f %s %s %.3f %s %.3f %s \n','half life =',...
    log(2)/(rateConsYr),char(177),'[',...
      (log(2)/(rateConsYr))-(log(2)./(ciYears(2))),',',...
      (log(2)./(ciYears(1)))-(log(2)/(rateConsYr)),'] yr');

%   Create CSV file so output data easily to manipulate using copy and paste
%   in MS Excel program
if strcmp(CSV,'on')
    fName = char(sheets(sheetName));    % filename
    restName = 'Model&AdjExpData';      % rest of name

    % Includes model data (sumDelta_ip) and experimental data (dpm)
    % as single, reshaped matrices (1 col by x rows)
    totData = [reshape(sumDelta_ip,[],1),reshape(dpm,[],1)];

    % Create a CSV file and write in headers
    fid = fopen(strcat(fName,restName,'.csv'),'w');
    fprintf(fid, '%s \n %s \n', fName,...
        'DPM data per bottle from experimental and model data');
    fprintf(fid, '%s %s %s \n', 'Model DPM',',','Experimental DPM');
    fclose(fid);
    % Append rest of data below headers in file
    dlmwrite(strcat(fName,restName,'.csv'),totData,'-append')
end
%   Change folder back to origin of MATLAB file, so script is callable
cd(scriptPath);
end
```

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APPENDIX E   APPLICATION OF MOLECULAR BIOLOGICAL TOOLS

ACRONYMS

DO	dissolved oxygen
EAP	enzyme activity probes
HDPE	high density polyethylene
L	liters
m	time in minutes
ORP	oxidation-reduction potential

PURPOSE

Successful application of enzyme activity probes requires that groundwater and sediments are sampled in a specific manner to minimize exposure to exogenous oxygen during shipment to the laboratory. This procedure describes the approach for collecting microbial samples for enzyme probe analysis.

SCOPE

This procedure provides instruction for sampling personnel to collect groundwater for the enzyme probe analysis. Sample quantities, containers, preservatives, handling procedures, and shipping instructions are contained within this procedure. In addition, methods for staining bacterial cells with enzyme activity probes are included.

GROUNDWATER SAMPLE COLLECTION FOR ENZYME ACTIVITY PROBE ANALYSIS

- ***Groundwater sampling procedure***

A microbial groundwater sample for enzyme probes is collected in a sterile bottle as an unaltered groundwater sample. Requirements for microbial sample containers, preservation, and holding times are summarized in Table 2.

Table 2. Sample containers, preservation, holding time, and shipping addresses.

Sample Container	Preservation	Holding Time
Four separate -1L sterile HDPE bottles collected with zero headspace from each sampling location.	4°C Stored on ice (preferably blue ice or frozen gel packs).	Samples must be shipped on the same day as collection. Ship samples priority overnight express.

This field method involves collecting four liters (1L) of groundwater at the well-head using sterile techniques. The lab will provide sterile bottles for sample collection. It is important to fill the bottles using low groundwater flow (1 to 4 L/min), in order to minimize turbulence and unnecessary exposure to the atmosphere during filling. Groundwater samples will be collected into the sterile one-liter (1L) bottles and filled to no-headspace. Use the following procedure to ensure no headspace:

- Fill the 1L bottles and form a meniscus at the top of the bottle.
- Fill the cap with groundwater, then screw on the bottle cap tightly, so as to fill the bottle with no headspace or bubbles. There may be a small amount of headspace that, if filled as requested, is minimal.
- Seal the bottle caps with parafilm and/or tape to minimize potential for exposure to air.
- Label each bottle with a unique sample number, the sample location, date and time of sample collection, sampling depth, groundwater temperature, client, and sampler.
- Place each bottle into a self-sealing plastic bag. Make sure the plastic bag is sealed shut (e.g. Ziploc bag)
- Pack the bottles UPRIGHT on ice (preferably blue ice or frozen gel packs) immediately following sampling and store/ship at 4°C. If samples have to be packed on cubed ice, PLEASE double or triple bag the ice separate from the samples. FedEx has refused to ship coolers in the past because they were “leaking”.

SAMPLE HANDLING AND SHIPPING

Use the following general guidance for sample packaging:

Each sample container should be placed in a self-sealing plastic bag prior to placement in the cooler. Make sure each plastic bag is sealed shut.

The bottles should be packed upright within the cooler with sufficient blue ice or frozen gel packs such that they maintain approximately 4°C during shipment.

Pack the bottles tightly in the coolers so there is absolutely no movement. Add packaging materials to fill void space within the cooler. Include COC forms and other appropriate sample collection documentation in a self-sealing plastic bag.

Seal the cooler with strapping tape.

STAINING PROCEDURES

Aromatic Oxygenase Activity

Follow the procedures described in Lee et al. (2008). Process each of the four separate 1-liter samples from each well. Filter 100 mL from each sample through nine different 0.22 μm, 25 mm diameter, black, polycarbonate filters. Incubate three of the nine filters in a solution containing 5 mM of phenylacetylene for 10 minutes. Incubate three of the nine filters in a solution containing 5 mM of *trans*-cinnamonitrile for 10 minutes. Incubate three of the nine filters in a solution containing 5 mM of 3-hydroxyphenylacetylene for 10 minutes. Mount the filters on a glass microscope slide with non-fluorescent immersion oil and a cover slip, and examined for fluorescent cells by epifluorescent microscopy. For each slide, count a minimum of 20 random fields, and calculate the average number of fluorescent cells per field. Then calculate the abundance of cells accumulating a fluorescent product. The abundance is the average number of fluorescent cells in a field under the microscope, divided by the surface area of the field counted, then multiplied the surface area of the filter, and then divided the volume of sample passed through the filter. Filter and assay a culture of *Pseudomonas putida* F1 as a positive control to verify EAP signal.

sMMO Enzyme Activity

Follow the procedures described in Wymore et al. (2007). Filter groundwater from each sample onto 25mm Supor filters, and placed into separate glass Petri plates. Pipet 1.0-mL of 5mM coumarin solution in phosphate buffer onto each filter, and incubate for 10 minutes at room temperature. Following the incubation, use phosphate buffer to wash the product from each filter. Determine relative fluorescence (excitation wavelength 338 nm, emission wavelength 450 nm) using a fluorescence spectrophotometer, with a quartz cuvette of 1 cm path length. Filter a culture of *Methylosinus trichosporium* OB3b as a positive control to verify the signal from coumarin.

REFERENCES

Lee, M. H., S.C. Clingenpeel, O.P. Leiser, R.A. Wymore, K.S. Sorenson, M.E. Watwood, 2008, Activity-dependent labeling of oxygenase enzymes in a trichloroethene-contaminated groundwater site, *Environ. Pollut*., 153 (2008) 238-246.

Puls, R.W. and M.J. Barcelona, 1996, *Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedure*, EPA/540/S-95/504, 12 pp.

Wymore, R. A., M.H. Lee, W.K. Keener, A.R. Miller, F.S. Colwell, M.E. Watwood, K.S. Sorenson, Field Evidence for Intrinsic Aerobic Chlorinated Ethene Cometabolism by Methanotrophs Expressing Soluble Methane Monooxygenase, *Bioremediation J*., 11 (2007) 125-139.

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APPENDIX F PROTOCOL TO CONDUCT THE ^{14}C-TCE ASSAY

This appendix is summarized from: QUANTIFICATION OF TCE CO-OXIDATION IN GROUNDWATER USING A ^{14}C-ASSAY, which is a thesis presented to the Graduate School of Clemson University, in partial fulfillment of the requirements for the degree of Master of Science in Environmental Engineering and Earth Sciences, by James C. Mills IV, August 2017.

The procedures described in this appendix must only be carried out in a laboratory that is licensed to receive, store, and use radiolabeled substances.

ABBREVIATIONS & ACRONYMS

ACS	American Chemical Society
AFB	air force base
DDI	distilled deionized
dpm	disintegrations per minute
FID	flame ionization detector
FSGW	filter-sterilized groundwater
GC	gas chromatograph
LSC	liquid scintillation cocktail
PTFE	polytetrafluoroethylene
TCD	thermal conductivity detector
TCE	trichloroethylene
VOA	volatile organic analysis

Preparation of stock solutions

Prepare a **^{14}C-TCE stock solution**. Ionizing radiation from decay of ^{14}C causes radiolysis of water molecules to produce free radicals that degrade the ^{14}C- TCE to produce products that would be interpreted in the assay as biological cooxidation products (Schmidt et al., 1985; Field et al, 2004). To minimize abiotic degradation through radiolysis, create a stock solution that reduces the specific activity of the ^{14}C.

Among other potential suppliers, ^{14}C-TCE (1.0 mCi) is available through custom-synthesis from Moravek Biochemicals, Inc. (Brea, CA, USA). It is shipped dissolved in acetonitrile. The ^{14}C-TCE sample should be shipped on dry-ice for over-night delivery. Add approximately 30 mL of Distilled Deionized (DDI) water that is saturated with TCE to an autoclaved 60- mL clear glass Volatile Organic Analysis (VOA) vial. Puncture the flame-seal on the shipment Pyrex distillation trap that contains the ^{14}C-TCE using a clean, blunt metal rod and hammer. Then immediately add the contents of the distillation trap container to the vial containing the Distilled Deionized (DDI) water that is saturated with TCE. Rinse the shipment container three times with TCE saturated DDI water, collecting the rinse in the VOA vial to a final volume of ~60 mL. Seal the VOA vial with a Mininert™ valve and store the **^{14}C-TCE stock solution** at 10 ± 2 °C.

To determine the concentration of TCE, prepare a **TCE stock solution** consisting of 25 µL neat TCE dissolved in 125 mL methanol. Tare the container that will contain the TCE stock solution. Weight the container with the methanol and subtract the tare weight to determine the mass of the methanol. Transfer the TCE with a microliter syringe. Weight the syringe used to transfer the TCE with and without the TCE to determine the amount of TCE added to the methanol (± 0.0001 g). Express the concentration of TCE in the stock solution as the mass TCE per mass of **TCE stock solution.**

To evaluate the separation ^{14}C-TCE and acetonitrile during chromatography, prepare a **TCE/Acetonitrile stock solution** containing 1.0 mL acetonitrile, 1.0 mL saturated TCE (ACS grade), and 99 mL Distilled Deionized (DDI) water in a 160-mL glass serum bottle capped with a PTFE-faced gray butyl rubber septum and aluminum crimp cap. Prepare an **Acetonitrile alone stock solution** containing 1.0 mL acetonitrile, and 99 mL Distilled Deionized (DDI) water in a 160-mL glass serum bottle capped with a PTFE-faced gray butyl rubber septum and aluminum crimp cap. Place the solutions on an orbital shaker table (98 ± 2 RPM) for 1 hour to equilibrate the aqueous and gaseous phases.

Use ScintiSafe™ Plus 50 % Cocktail (Fischer Scientific) or equivalent for Liquid Scintillation Counting. To minimize any losses of ^{14}C from volatilization, the Liquid Scintillation Cocktail is contained in a **specially prepared 20-mL Scintillation Vial**. The vial is prepared by drilling a hole (2.38 mm) in the polypropylene scintillation cap and placing a PTFE-faced gray butyl rubber septum inside the cap, with the PTFE facing the Scintillation Cocktail. The hole is used to accept the syringe needle that introduces the sample to the Cocktail through the septum.

Preparation of a gas chromatograph to measure O_2 in the headspace of serum bottles

Pack a stainless-steel column with 100/120 Carbosieve S-II support (Supelco) and install on a gas chromatograph (GC) with a thermal conductivity detector (TCD). Supply N_2 at a flow rate of approximately 50.5 ± 0.2 mL/min as the carrier and reference gas. Use an isothermal temperature program of 105 °C; O_2 should elute at 3.3 min. Inject 0.5 mL of room air to determine the response factor (% O_2 per GC peak area unit) of the GC TCD.

Other column packings and temperature programs may be adequate.

Modification of a gas chromatograph to add ^{14}C-TCE to the serum bottles

Use gas chromatography to separate ^{14}C-TCE from impurities (including acetonitrile) in the **^{14}C-TCE stock solution** following the approach of Darlington et al. (2008). Pack a stainless-steel gas chromatography column (44 m x 3.175 mm) with 1 % SP-1000 on 60/80 Carbopack-B (Supelco). Such a column is adequate to separate the ^{14}C-TCE from the impurities.

Connect the end of the column to a four-port valve in the gas chromatograph (GC) oven. Position the valve so that the valve can be used to direct the flow of carrier gas to either a flame ionization detector (FID) or to a stainless-steel tube that exits the oven and can be used to deliver the flow of carrier gas to the headspace of a serum bottle. The tubing should terminate with in a threaded Luer-Lok™ fitting for attachment of a sterile needle, through which the purified ^{14}C-TCE can be injected into the serum bottle. The configuration is depicted in Figure F1.

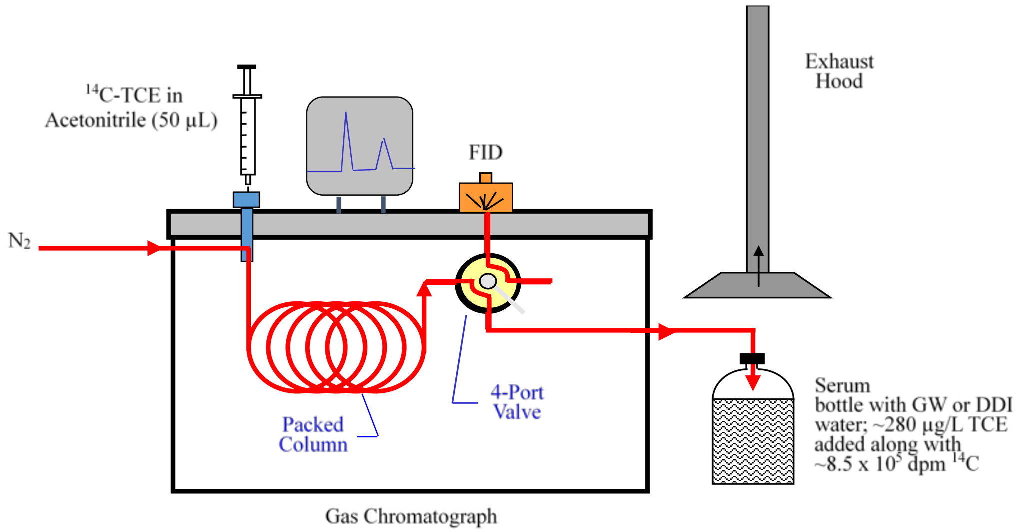

***Figure F1**. Experimental setup for use of a GC column to purify the 14C-TCE stock solution before addition to the serum bottles. Use of the 4-port valve allows for a quick transition between delivering the column effluent to the FID for measurements of analytes and delivering the effluent into the serum bottles, as illustrated.*

Use high purity N_2 as the carrier gas at a flow rate of 33.5 ± 0.5 mL/min. The temperature program should be 60 °C for 2 min, increasing at 20 °C per min to 150 °C, then increasing at 10 °C to 200 °C and hold at 200 °C for 28.5 min. The extended hold time at 200 °C is designed to ensure that impurities did not accumulate on the column.

Under the conditions described above, the expected elution time for the purified TCE is 9.6 to 11.1 min. During this time window of 1.5 minutes, the four-port valve will be used to direct the flow of carrier gas into the headspace of a serum bottle.

Other column packings and temperature programs may be adequate. Confirm that the packing and program that are employed are adequate by comparing the chromatogram produced when 0.5 mL of headspace from the **TCE/Acetonitrile stock solution** or the **Acetonitrile alone stock solution** is injected into the GC. A comparison of the two chromatograms will distinguish the acetonitrile peak from the TCE peak. The time window used to deliver ~50 mL of carrier gas to the serum bottle should contain the TCE peak, and acetonitrile should not be present in the carrier gas in the time window when TCE is delivered to the headspace of the serum bottle.

Calibrate the gas chromatograph used to add ^{14}C-TCE to the serum bottles to TCE

Use microliter syringes to inject volumes of the **TCE stock solution** ranging from 10 – 200 µL into 100 mL of DDI water in 160-mL glass serum bottles. Determine the masses of the **TCE stock solution** added to the DDI bottles by weighing the syringe before and after the TCE stock solution is added to the serum bottles (± 0.0001 g). Calculate the mass of TCE added to each bottle by multiplying the mass of TCE stock solution added by the concentration of TCE in the stock solution. Place the bottles on an orbital shaker table (98 ± 2 RPM) for 1 hour to facilitate establishment of equilibrium between the headspace and liquid phases. Take 0.5 mL of headspace from each bottle with a 1.0 mL gas-tight syringe and inject into the GC. Create a calibration curve that compares area of the TCE peak to the amount of TCE added to the bottles. An example calibration curve is presented in Figure F2.

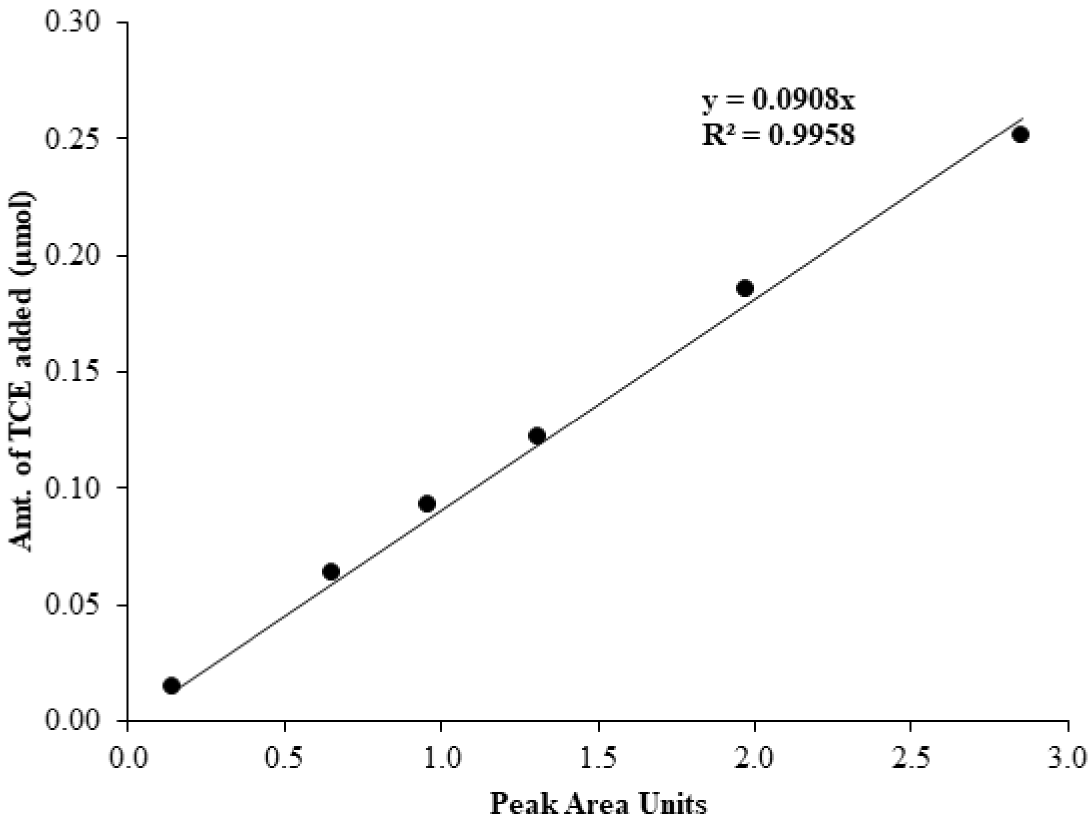

Figure F2. *A calibration curve to determine the amount of TCE remaining the serum bottles based on analysis of 0.5 mL of headspace from the bottles. The y-intercept on the linear regression linear was set to 0 µmol. The amount of TCE added to each bottle was determined through gravimetric analysis. Peak area units are units used in the GC computer software to identify the area under the peak.*

Prepare a sparging apparatus

The central and critical measurement in the assay is the accumulation of ^{14}C-labelled transformation products of biological cooxidation. The initial transformation products are a series of organic acids including chloral, 2,2,2-trichloroethanol, trichloroacetic acid, dichloroacetic acid, glyoxylic acid, and formic acid (Wackett, 1995). These chemicals can be metabolized by bacteria to other polar compounds and ultimately to carbon dioxide. While TCE is a neutral compound and can be easily purged from water, the cooxidation degradation products and their further degradation products are polar compounds or anions at high pH. They do not purge from water with a high pH.

The assay measures the accumulation of ^{14}C from ^{14}C-TCE into material that does not purge from strongly alkaline solution. For the assay to be reproducible, the purging must be done under standard conditions.

To carry this out, construct a purging apparatus with following properties. Sparging is done from 20 mL scintillation vials. Create a custom holder that tilts the vials at a 30^{o} angle from vertical. This can be conveniently done by drilling holes in a block of wood. Figure F3 shows a purging apparatus that was constructed at Clemson University and used by James Mills for his thesis research.

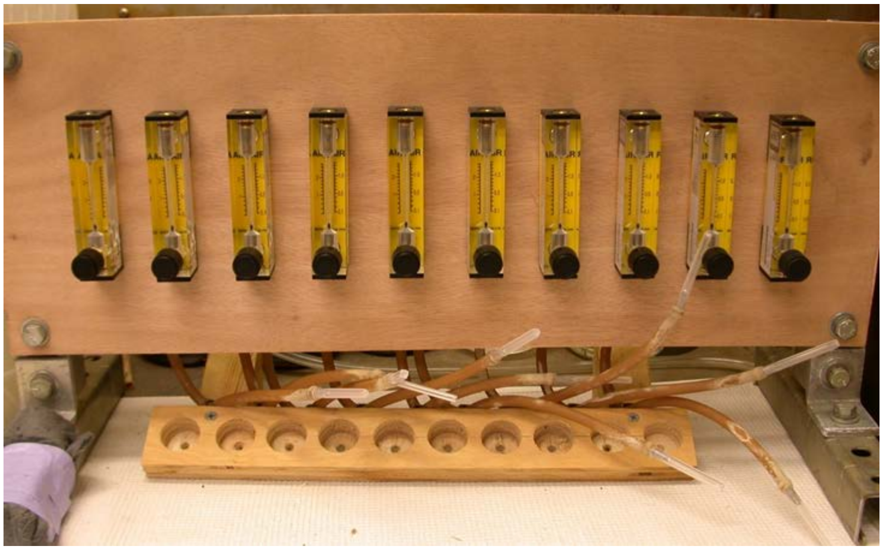

Figure F3. Custom sparging apparatus setup. The flow rate of N_2 gas is controlled using air flow meters connected to thin-walled latex rubber tubing ending with sterilized, disposable needles. The flow meters were connected in parallel behind wooden panel, so that there is only one inlet for N_2 gas. The sparge vials were tilted on a 30-degree angle using a custom wooden holder to ensure complete contact of N_2 gas and liquid.

Construct a manifold so that N_2 gas is passed through flow meters that are capable of regulating the flow to 550 ±50 mL a minute. There is one flow meter for each sample that is sparged. The flow passes through tubing to disposable syringe needles that are inserted in the deepest portion of the vial being sparged.

Take field samples

In the laboratory, wash and clean 160 mL glass serum bottles, dry, and loosely fit PTFE-faced septa and aluminum crimp caps to the bottles. Autoclave the bottles with septa and caps in place at 121 ^{o}C for 20 minutes. Weigh the autoclaved bottles with their respective septa, cap, and labels (± 0.01 g). Prepare four 160 mL serum bottles and one 1.0 L plastic bottle for each well. Prepare one bottle with 100 mL of water and cap the bottle with the respective PTFE-faced septa and seal with the aluminum crimp cap. This bottle will be used as a comparison bottle to judge the amount of water collected into the sample bottles in the field. Ship the bottles to the field site.

At the well head, replace any sample tubing used to pump ground water with fresh tubing. Decontaminate any down-hole pumps before use. If possible, remove at least three well volumes of groundwater to get a representative sample.

Using aseptic precautions, pump water from the well and directly add at least 100 mL of groundwater to four sterilized 160 mL glass serum bottles. Add water to the sample bottles until height of water collected matches or exceeds the height in the comparison bottle. Immediately cap the sample bottles with their respective PTFE-faced septa and seal with the aluminum crimp cap. Check to see the caps can be twisted on the serum bottles. If the camp can be twisted, crimp harder until it cannot be twisted. Then fill the 1.0 L plastic bottle with groundwater.

Store all the samples on ice. Ship the samples the same day as collected for next day arrival at the laboratory where the assay will be conducted. Ship the samples with enough ice to ensure that they will arrive at the laboratory at a temperature ≤ 4 ^{o}C.

Adding ^{14}C-TCE to the Bottles

Immediately upon receipt at the laboratory, warm the bottles to room temperature (22 ± 2 ^{o}C), quiescently in the dark, for approximately 24 h before addition of the ^{14}C-TCE stock solution.

For water from a given well, prepare triplicate serum bottles. The fourth bottle collected in the field is a spare. Filter water from the 1.0 L bottle through a sterile 0.2 μ filter into a sterile container. Using aseptic precautions, add 100 mL of the sterilized water to three 160 mL serum bottles and seal with a PTFE-faced septa and aluminum crimp cap as described above. These bottles are the filter sterilized groundwater controls (FSGW).

Record the mass of bottles (± 0.01 g) to determine the amount of water in each bottle. Subtract the filled weight from the tared weight. Assume 1.0 g of water has a volume of 1.0 mL. If the volume of water exceeds 101 mL, use aseptic precautions to remove enough water to bring the final volume within the range of 100 to 101 mL. Record the final mass of the filled bottle.

To determine amount of ^{14}C in the **^{14}C-T^{1}CE stock solution**, inject 25 µL of the **^{14}C-TCE stock solution** directly into 15 mL of Liquid Scintillation Cocktail in a 20-mL scintillation vial. Then count the vial in a Scintillation Counter.

Remove 50 mL headspace from each 160-mL serum bottle filled with ~100 mL water using a 100-mL gas-tight syringe. Inject an aliquot of the **^{14}C-TCE stock solution** (50 µL) onto the column of the GC prepared to add ^{14}C-TCE to the bottles and record the time (day, hour, minute, second). With the four-port valve in the position that supplies carrier gas to the FID, insert the syringe needle into the sample bottle or control bottle. Over the time interval from 9.6 to 11.1 minutes after injection of the **^{14}C-TCE stock solution** into the GC, switch the position of the four-port valve to direct the flow of carrier gas to the sample bottle, then switch the valve to direct flow back to the FID detector and remove the sample bottle or control bottle from the syringe needle.

After the ^{14}C-TCE is added to bottles with groundwater samples and the FSGW immediately invert the bottles to reduce diffusional losses and place them on an orbital shaker table (98 ± 2 RPM) for approximately 1 h to facilitate establishment of equilibrium between the headspace and liquid phases.

After 1 hr of equilibration, record the time (day, hour, minute), and then sample 0.5 mL of headspace from each bottle using a gas-tight syringe and inject directly into 15 mL of Liquid Scintillation Cocktail in a **specially prepared 20-mL scintillation vial** as described above. Flush the gas-tight syringe at least five times with air between sampling events.

Inject approximately 3 mL of room air into the serum bottle using a 5-mL syringe. This will compensate for the volume of the subsequent liquid samples. Record time (day, hour, minute), then sample 0.1 mL of water from each bottle using a liquid syringe and inject directly into 15 mL of Liquid Scintillation Cocktail in a **specially prepared 20-mL scintillation vial**. Then count the vial in a Scintillation Counter.

The decays per minute (dpm) in these samples are used to calculate the total amount of ^{14}C added to each serum bottle.

Sample 0.5 mL of the headspace from each bottle and inject into the GC that was prepared to add ^{14}C-TCE to the bottles. Position the four-port valve to direct flow of carrier gas to the FID detector during the entire chromatogram. Record the area of the TCE peak and use the calibration curve (an example is depicted in Figure F2) to determine the amount of TCE in the serum bottle. Addition of ^{14}C-TCE should result in a TCE level of 0.2 to 0.3 µmol per bottle, or an aqueous phase concentration of 214 to 322 µg/L when taking into account partitioning between the headspace and liquid phases.

Using 5 mL liquid syringe, withdraw a 3- mL liquid sample from each serum bottle. Flush the syringe at least 5 times between sampling events. Record the time (day, hour, minute). This sample will be used to determine the amount of ^{14}C that cannot be spared from the water at high pH. Transfer the sample to a 20-mL scintillation vial, then add 12 µL 8 M NaOH with a 100 µL liquid syringe. Check the pH with a pH strip to make sure it is above pH 10.5. If it is not, add more NaOH solution. Place the vial in the sparging apparatus and sparge with N2 gas at 550 ± 50 mL per minute for 30 minutes. Then add 15 of Liquid Scintillation Cocktail and count the vial in a Scintillation Counter.

Scintillation Counting

Count beta radiation using a scintillation counter with an ultra-low-level spectrometer and lead shielding to block external cosmic radiation. Prepare a quench correction curve and convert counts per minute to decays per minute.

The headspace and liquid samples from the serum bottles can be counted as soon as they are collected. Store the sparged alkaline liquid samples quiescently in the dark for approximately 24 h before counting to reduce chemilumenscence that is caused by mixing a sample with high pH with the Liquid Scintillation Cocktail.

Long Term Incubation

Incubate the serum bottles quiescently in the dark, at room temperature. In addition to the time zero sample described above, sample seven times over a period of 40 to 46 d. Recommended intervals are 3, 7, 14, 21, 28, 35, and 42 days after ^{14}C-TCE is added to the bottles.

At each sampling event, weigh the serum bottles after the water samples have been taken to calculate the reduction in volume of water, and corresponding increase in the volume of headspace in the bottle that was caused by the removal of the water sample.

At each sampling event, conduct the following sampling to determine the total ^{14}C remaining. Collect a 0.5 mL headspace sample and add the sample to 15 mL of Liquid Scintillation Cocktail in a **specially prepared 20-mL Scintillation Vial**, and then count beta decays on a Liquid Scintillation Counter. Collect a 0.1 mL liquid sample, add to 15 mL Liquid Scintillation Cocktail in a **specially prepared 20-mL Scintillation Vial**, and then count beta decays on a Liquid Scintillation Counter.

At each sampling event, collect a 3.0 mL aqueous phase sample and dispense to a 20 mL Scintillation Vial. Add NaOH to pH ≥10.5, and sparge with N_2 at 550 ± 50 mL per minute for 30 minutes. Add 15 mL of Liquid Scintillation Cocktail, store at room temperature in the dark for 24 hours, then count beta decays on a Liquid Scintillation Counter.

At each sampling event, determine if the supply of oxygen is limiting to biological cooxidation of TCE. Collect a 0.5 mL of the headspace from the bottles containing groundwater, and analyze for O_2 using the GC with a TCD.

If the concentration of oxygen is less than 5% (v/v), stop further incubation of the bottle, and do not use data from the current samples in calculations of the rate constant.

Calculations to extract a first order rate constant

Figure F4 provides an overview of the procedure used to extract the first order rate constants. The figure presents the quantity of ^{14}C-TCE in the water in the serum bottle as a function of time in the assay. Only the ^{14}C-TCE in the water is subject to co-oxidation by oxygenase enzymes. The first point is labeled $C_{l,0,b}$. This refers to the *original* concentration of ^{14}C in the *liquid* (water) in the bottle, *before* the samples are taken.

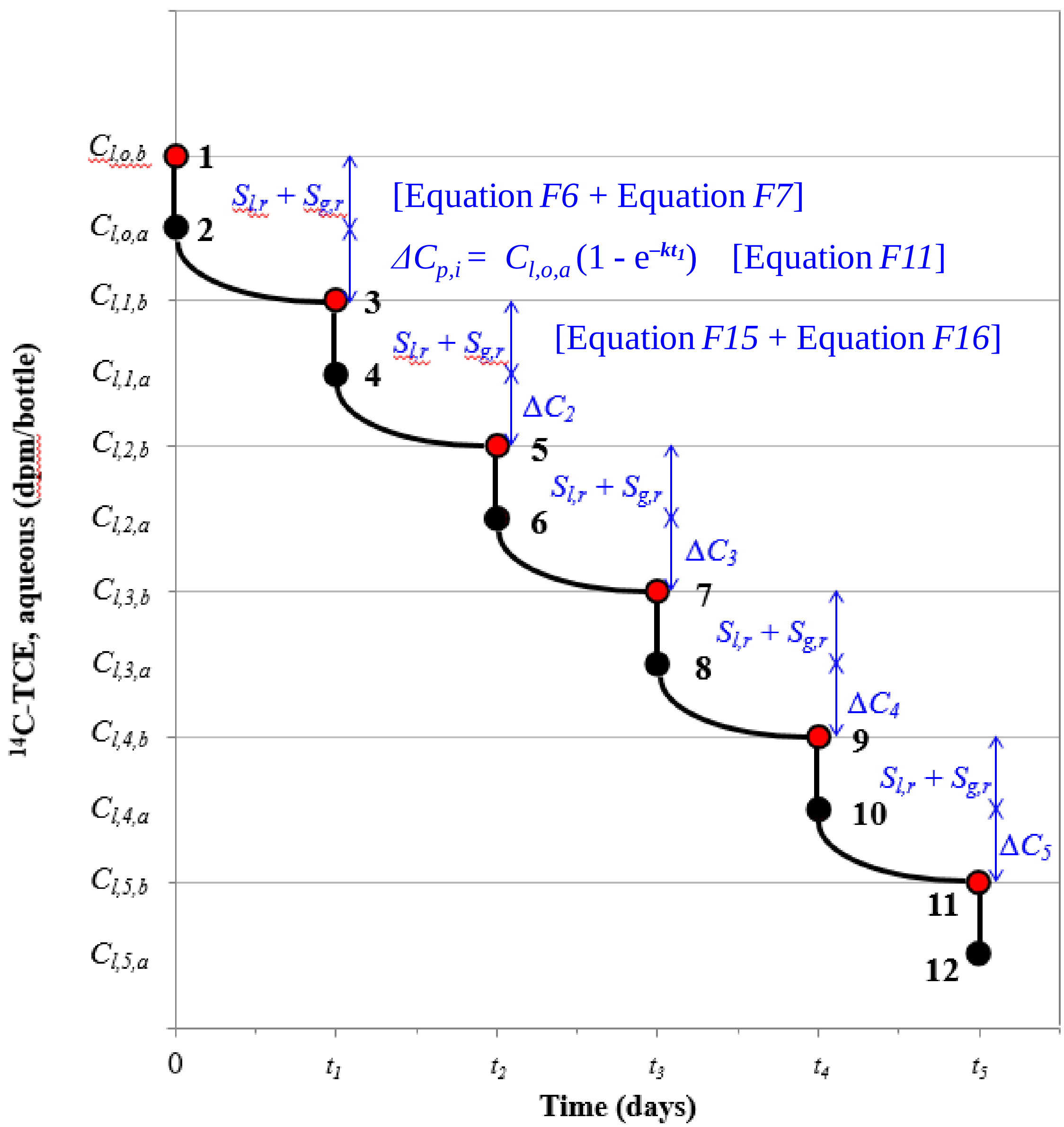

Figure F4. *General overview of sampling events and respective equations used to generate first-order rate constants. The red circles indicate the ^{14}C in the aqueous phase before sampling and the black circles indicate the ^{14}C in the aqueous phase after sampling.*

^{14}C Calculations for Conditions at Time Zero

To begin the assay, the serum bottle is weighed to determine the mass of water in the bottle, and the volume of *liquid* (which is water) in the bottle ($V_{l,b}$). The volume of the water is subtracted from the total volume (160 mL) to calculate the volume of *gas* in the headspace of the *bottle* ($V_{g,b}$). The following equation are used to calculate the total amount of ^{14}C present per bottle at the beginning of the assay ($C_{tot,o}$), based on measurements taken before incubation began:

$$C_{tot,0} = \frac{S_l}{V_{l,s}} \cdot V_{l,b} + \frac{S_h}{V_{g,s}} \cdot V_{g,b} \qquad (F1)$$

where $C_{tot,0}$ = total dpm in a serum bottle; S_l = dpm in liquid sample; $V_{l,s}$ = volume of liquid sample (0.1 mL); and $V_{l,b}$ = volume of liquid in a serum bottle (~100 mL); S_h = dpm in a headspace sample; $V_{g,s}$ = volume of headspace sample (0.5 mL); $V_{g,b}$ = volume of headspace in a serum bottle (160mL - $V_{l,b}$).

The *original* concentration of ^{14}C-TCE in *liquid* in the bottles *before* sampling ($C_{l,o,b}$) are calculated based on the total ^{14}C-TCE present at the beginning of the assay ($C_{tot,0}$) and Henry's Law. From Henry's Law:

$$H_c = \frac{C_{g,o,b}}{V_{g,b}} \bigg/ \frac{C_{l,o,b}}{V_{l,b}} \qquad (F2)$$

where $C_{g,o,b}$ = total dpm in headspace *gas* in the serum bottle *before* sampling, $C_{l,o,b}$ = total dpm in the *liquid* (water) in the serum bottle *before* sampling, $V_{l,b}$ = the original volume of *liquid* in the bottle (~100 mL); $V_{g,b}$ is the original volume of *gas* in the headspace of the bottle (~60 mL); and H_c is the dimensionless Henry's Law constant for TCE (0.349 at 23 °C, Gossett, J.M., 1987.

Due to the law of conservation of mass and the distribution of phases in the serum bottles:

$$C_{g,o,b} = C_{tot,o} - C_{l,o,b} \qquad (F3)$$

where $C_{tot,0}$ = total dpm in the bottle (determined using Equation *F1*).

Substituting equation *F3* in equation *F2*, and solving for $C_{l,o,b}$ produces equation *F4*.

$$C_{l,o,b} = C_{tot,o}\left(\frac{V_{l,b}}{V_{l,b} + V_{g,b}H_c}\right) \qquad (F4)$$

$\underline{C_{l,o,b}}$ <u>in equation *F4* corresponds to point 1 on Figure F4.</u>

The sampling removed some of the ^{14}C. The sampling also removed some of the water from the serum bottle, which changed the ratio of water to gas and thus the distribution of ^{14}C-TCE between the headspace and water in the serum bottle. Calculate the effect of removing the samples on the concentration of ^{14}C in the water in the serum bottle before incubation. The dpm removed due to withdrawal of the liquid at time zero ($S_{l,r}$) are calculated as follows:

$$S_{l,r} = C_{l,o,b}\left(\frac{V_{l,r}}{V_{l,b}}\right) \qquad (F5)$$

where $V_{l,r}$ = volume of liquid sample removed (3.1 mL = 3.0 mL for the sparging test + 0.1 mL for direct addition to the Liquid Scintillation Cocktail); and $V_{l,b}$ = the initial volume of liquid in the bottle (~100 mL).

^{14}C is also removed during gas sampling. For the groundwater bottles, gas samples were removed to determine the total ^{14}C in the headspace (0.5 mL) and to measure O_2 (0.5 mL). The amount of ^{14}C removed in these samples ($S_{g,r}$) is calculated as follows:

$$S_{g,r} = \left(C_{tot,o} - C_{l,o,b}\right)\left(\frac{V_{g,r}(0.5)}{V_{g,b}} + \frac{V_{g,r}(0.5)}{V_{g,b} + V_{l,r}}\right) \qquad (F6)$$

where $V_{g,r}$ = total volume of gas removed at a sampling event (1.0 mL); and $V_{g,b}$ = total volume of gas in the bottle before the samples were removed.

For the DDI water controls and FSGW controls, only one headspace sample is removed per sampling event. To determine the total ^{14}C in the headspace; it is not necessary to measure O_2 in these bottles. Consequently, the amount of ^{14}C removed in the gas phase of the controls simplified to:

$$S_{g,r} = \left(C_{tot,o} - C_{l,o,b}\right)\left(\frac{V_{g,r}}{V_{g,b}}\right) \qquad (F7)$$

where $V_{g,r}$ = total volume of gas removed at a sampling event (0.5 mL).
The total ^{14}C removed during each sampling event ($S_{tot,r}$) is:

$$S_{tot,r} = S_{l,r} + S_{g,r} \qquad (F8)$$

Equation *F8* is used to determine the vertical line from point 1 to 2 in Figure F4.

The calculated ^{14}C-TCE concentration in the bottle after the initial sampling event ($C_{tot,o,a}$) is:

$$C_{tot,o,a} = (C_{tot,o}) - \left(S_{tot,r}\right) \qquad (F9)$$

Therefore, the ^{14}C-TCE liquid concentration in the bottle after the initial sampling event ($C_{l,o,a}$) is the product of $C_{tot,o,a}$ and the fraction of TCE in the aqueous phase. Correcting for the changes in the volume of liquid after sampling, and following the logic of equation *F4*:

$$C_{l,o,a} = C_{tot,o,a}\left(\frac{V_{l,b} - V_{l,r}}{(V_{l,b} - V_{l,r}) + \left(V_{tot} - (V_{l,b} - V_{l,r})\right) \times H_C}\right) \qquad (F10)$$

where V_{tot} = total volume of the serum bottles (160 mL).

<u>$C_{l,o,a}$ in equation *F8* is Point 2 in Figure F4.</u>

Production of ^{14}C Degradation Products based on a First Order Rate Constant

The *predicted* increase in ^{14}C products formed during incubation between sampling points ($\Delta C_{p,i}$) is calculated by evaluating first-order degradation reaction kinetics using the value for the previous ^{14}C-TCE concentration in the aqueous phase ($C_{l,i-1,a}$) and the pseudo first-order rate constant (k):

$$\Delta C_{p,i} = C_{l,i-1,a}\left(1 - e^{-k(t_i - t_{i-1})}\right) \qquad (F11)$$

where t_i represents the time elapsed since ^{14}C-TCE is added to the serum bottles at each i*ndividual* sequential sampling time as depicted in the x-axis of Figure F4.

Equation *F11* represents the curved path from points 2 to 3, 4 to 5, 6 to 7, 8 to 9, and 10 to 11 in Figure F4. Values of ($\Delta C_{p,i}$) are represented by Δ_1, Δ_2, Δ_3, Δ_4, and Δ_5 for individual sampling times t_1, t_2, t_3, t_4, and t_5 in Figure F4.

Prediction of the accumulated ^{14}C degradation products in the serum bottle at particular sampling event ($\Sigma\Delta C_{p,i}$) is calculated as the sum of ($\Delta C_{p,i}$) and the previous summation of the products ($\sum\Delta C_{p,i-1}$):

$$\Sigma\Delta C_{p,i} = \Delta C_{p,i} + \Sigma\Delta C_{p,i-1} \qquad (F12)$$

where $i \geq 1$.

The calculation of the accumulation of degradation products ($\Sigma\Delta C_{p,i}$) depends on the previous values for ^{14}C-TCE in the liquid phase in the serum bottles ($C_{l,i,a}$), and the values of ($C_{l,i,a}$) are influenced by ^{14}C-TCE that is removed from the bottles during sampling. It is necessary to correct ($C_{l,i,a}$) for sampling. In each time step, 3.1 mL of water is removed for analysis. As a result, the volume of liquid before sampling in each time step ($V_{l,i}$) is calculated as follows;

$$V_{l,i} = V_{l,i-1} - 3.1\ mL \qquad (F13)$$

where $i \geq 1$, and $V_{l,1-1} = V_{l,0} = V_{l,b}$.

The volume of air in the headspace before sampling in each time step is calculated as follows:

$$V_{g,i} = V_{g,i-1} + 3.1\ mL \qquad (F14)$$

where $i \geq 1$, and $V_{g,1-1} = V_{g,0} = V_{g,b}$.

In each time step, The amount of ^{14}C removed due to withdrawal of the liquid ($S_{l,r}$) is calculated as follows:

$$S_{l,r} = C_{l,i,b}\left(\frac{V_{l,r}}{V_{l,i}}\right) \qquad (F15)$$

where $V_{l,r}$ = volume of liquid sample removed (3.1 mL = 3.0 mL for the sparging test + 0.1 mL for direct addition to LSC).

The amount of ^{14}C removed from the gas in the experimental bottles is calculated as follows:

$$S_{g,r} = (C_{tot,i-1} - C_{l,i,b})\left(\frac{V_{g,r}(0.5)}{V_{g,i}} + \frac{V_{g,r}(0.5)}{V_{g,i} + V_{l,r}}\right) \qquad (F16)$$

where $V_{g,r}$ = volume of gas sample removed (0.5 mL for Liquid Scintillation Counting plus 0.5 mL for O_2 determination). No oxygen sample is taken from the DDI water and FSGW control bottles, and $S_{g,r}$ is calculated as follows:

$$S_{g,r} = (C_{tot,i-1} - C_{l,i,b})\left(\frac{V_{g,r}}{V_{g,i}}\right) \qquad (F17)$$

where $V_{g,r}$ = 0.5 mL.

The total removal due to sampling ($S_{tot,r}$) corresponds to:

$$S_{tot,r} = S_{l,r} + S_{g,r} \qquad (F18)$$

<u>The total removal due to sampling is represented by the vertical lines between points 3 to 4, 5 to 6, 7 to 8, 9 to 10, and 11 to 12 in Figure F4.</u>

The combined effect of sampling and biodegradation on the amount of ^{14}C in the liquid phase in the bottles at the end of a time period ($C_{l,i,b}$) is calculated in two steps. First, the combined effect on the total amount of ^{14}C in the bottle ($C_{tot,i}$) is calculated, and then Henry's Law is applied to calculate the effect on the ^{14}C in the liquid phase. The value of $C_{tot,i}$ is calculated as follows:

$$C_{tot,i} = C_{tot,i-1} - S_{t,r} - \Delta C_{p,i} \qquad (F19)$$

where $i \geq 1$, and $C_{tot,1-1} = C_{tot,0} = C_{tot,o}$ as described in equation S1.

Following the logic in equation *F3*, the value of $C_{l,i,a}$ is calculated from $C_{tot,i}$ as follows:

$$C_{l,i,a} = C_{tot,i}\left(\frac{V_{l,i}}{V_{l,i} + V_{g,i} \times H_C}\right) \qquad (F20)$$

where $i \geq 1$.

Equation *F20* is used to determine points 4, 6, 8, 10, and 12 in Figure F4.

In addition, $\Delta C_{p,i}$ (Equation 11) is used to determine the concentration of ^{14}C-TCE in the liquid phase ($C_{l,i,b}$):

$$C_{l,i,b} = C_{l,i-1,a} - \Delta C_{p,i} \qquad (F21)$$

where $i \geq 1$, and $C_{l,1-1,a} = C_{l,0,a} = C_{l,o,a}$ as described in equation *F10*.

Equation *F21* corresponds to points 3, 5, 7, 9 and 11 in Figure F4.

Direct Measurement of ^{14}C Degradation Products

Collate the data collected on the amount of ^{14}C in that could not be purged from a 3.0 mL sample of water from the serum bottles. The dpm that could not be purged is the quantity of transformation products in the sample ($\Sigma\Delta C_p$) that accumulated in the water up to that individual sampling time. Subtract the dpm in the 3.0 mL sample at time zero ($\Sigma\Delta C_o$) from the dpm at each individual sampling period ($\Sigma\Delta C_p$) to produce a corrected value for the dpm that had accumulated in degradation products ($\Sigma\Delta C_{p,c}$).

$$\Sigma\Delta C_{p,c} = \Sigma\Delta C_p - \Sigma\Delta C_o \qquad (S22)$$

The *measured* dpm in transformation products that accumulated in the serum bottle ($\Sigma\Delta C_{m,i}$) by the i^{th} sampling period is calculated as follows:

$$\Sigma\Delta C_{m,i} = \Sigma\Delta C_{p,c} * V_{l,i}/V_{ps} \qquad (S23)$$

Where $V_{l,i}$ is the volume of liquid in the serum bottle before the i^{th} sample is taken, and V_{ps} is the volume of the purged sample (3.0 mL), and $i \geq 1$.

Extract a First Order Rate Constant

A spreadsheet titled **14C RESULTS example.xlsx** is provided as a separate file. The spreadsheet is a template that illustrates the calculations discussed above that can be used to extract a first order rate constant from the data provided by the assay. The template applies the calculations to model data provided from the ^{14}C assay of groundwater and filter-sterilized groundwater from monitoring well MW-02-019 at the former Plattsburgh AFB.

Populate the tabs ***data groundwater*** and ***data FSGW*** with data from your assay. Then examine the tabs ***Model, Groundwater*** and ***Model, FSGW***. Examine the data input to cells **E6** to **E9**, and correct if necessary. It may be necessary to adjust the number of rows corresponding to time steps, based on the time steps in your assay. Examine the data in column **U** and **V** of tab ***Model, Groundwater*** and column **T** of tab ***Model, FSGW*** to ensure that the summary data were copied over correctly from the ***data groundwater*** and ***data FSGW*** tabs.

To extract a first order rate constant for co-oxidation of TCE (k), enter an initial value of k in cell **E2** of Tab ***Model, Groundwater*** and in cell **E2** of tab ***Model, FSGW.*** This is a guess or estimate. Then use the Solver application in the Data Analysis menu of Excel to extract a value of k that minimizes the sum of the squares of the differences between the measured values of ^{14}C in transformation products (ΣΔCm,i) and the predicted values for ^{14}C in transformation products (ΣΔCp,i). The sum of squares is cell **Y68** of Tab ***Model, Groundwater*** and cell ***W30*** of Tab ***Model, Groundwater*** in the example spreadsheet.

The spreadsheet also provides a chart comparing the model provided by the best fit value of k to the actual data for groundwater and a second chart comparing the model provided by the best fit value of k to the actual data for the filter sterilized groundwater controls.

Following equation *S24*, the net rate constant for biological cooxidation (k_{net}) is the rate constant for the water samples minus the rate constants for the filter sterilized controls.

$$k_{net} = k_{water\ samples} - k_{FSGW} = 0.159 - 0.029\ per\ year = 0.13\ per\ year \qquad \text{(S24)}$$

In the example, the rate constant for the water samples was 0.159 per year and the rate constant for the FSGW controls was 0.029 per year. The rate constant for biological cooxidation is 0.13 per year.

Use a Student's t-test to determine if the rate constant for the groundwater samples is statistically different from the FSGW control ($\alpha = 0.05$). If it is different, calculate a confidence interval for the net rate by propagation of error using the standard deviations of the rate constants.

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