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# WORK PLAN IN SITU BIOREMEDIATION OF CHLORINATED SOLVENTS AT THE FORMER WASTEWATER TREATMENT PLANT AREA SOLID WASTE MANAGEMENT UNIT 1 NAS PENSACOLA FL

3/10/2010

SOLUTIONS-IES

# WORK PLAN

# *IN SITU* BIOREMEDIATION OF CHLORINATED SOLVENTS IN GROUNDWATER AT SWMU 1 NAVAL AIR STATION PENSACOLA, FLORIDA

Prepared for:

**NAVFAC Southeast**
Jacksonville, Florida 32212

Prepared by:

**Solutions-IES, Inc.**
1101 Nowell Rd.
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Phone: 919-873-1060; Fax: 919-873-1074

**Solutions-IES Project No. 3911.09A3.NAVF**

**March 2010**

Solutions-IES
Industrial & Environmental Services

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March 10, 2010

Ms. Camille Stein
Florida Department of Environmental Protection
Hazardous Waste Regulation Section
2600 Blairstone Road; MS4560
Tallahassee, Florida 32399-2400

**Re.: Work Plan for In Situ Bioremediation of Chlorinated Solvents**
**SWMU 1, NAS Pensacola, Pensacola, Florida**
**EPA ID: FL9 170 024 567**
**Solutions-IES Project No. 3911.09A2.NAVF**

Dear Ms. Stein:

Please find enclosed two copies of a Work Plan for *In Situ* Bioremediation of Chlorinated Solvents in Groundwater at SWMU1, Naval Air Station Pensacola. This work plan has been submitted on behalf of our Client, Naval Facilities Engineering Command Southeast, for your review and approval.

If you have any questions or need any additional information, please feel free to contact us at (919) 873-1060.

Yours truly,
**Solutions-IES**

Jessica L. Keener

Jessica L. Keener
Project Manager

Enclosure

cc: Greg Campbell, NAS Pensacola (1 copy)
Myrna Martinez, NAVFAC SE (1 copy)
Mike Singletary, NAVFAC SE (1 copy)
Leanna Woods-Poon, NAVFAC SE (1 copy)

## PROFESSIONAL REVIEW CERTIFICATION

The Work Plan for injection of an emulsified oil product, AquaBupH™, to treat chlorinated solvents in groundwater described in this document was prepared under the direction of the undersigned Professional Engineer. If conditions are determined to exist that differ from those described, the undersigned should be notified to evaluate the effects of the reported findings.

The document was prepared based on the results of site information regarding the groundwater conditions at the Solid Waste Management Unit No. 1 (SWMU 1), Wastewater Treatment Plant, Naval Air Station, Pensacola, Escambia County, FL (NAS Pensacola). Facility identification is FL 9170024567.

This document was prepared as required under the authorization of NAVFAC Contract No. N69450-09-C-0069. Information regarding the design and implementation of the study has been prepared in accordance with rules 62-522, F.A.C., Ground Water Permitting and Monitoring and 62-528, F.A.C., Underground Injection Control (UIC), for Class V, Group 4 UIC wells. The recommended action should not be construed to apply to any other site.

JODY L. OVERMYER
LICENSE
No. 70887
STATE OF
FLORIDA
PROFESSIONAL ENGINEER

Signature of Registered P.E.

Jody E. Overmyer, P.E./70887
Name of Registered P.E. and FL. License Number
(Solutions-IES, Inc., Raleigh, NC)

03.09.10
Date

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# 1.0 INTRODUCTION

Solutions-IES, Inc. was contracted by the Naval Facilities Engineering Command Southeast (NAVFAC SE) to design, construct and monitor a full-scale remedial system for the treatment of chlorinated volatile organic compounds (CVOCs) in groundwater in the area of the Solid Waste Management Unit 1 (SWMU 1), Wastewater Treatment Plant (WWTP), Naval Air Station (NAS), Pensacola, Florida (**Figure 1**). Solutions-IES recommended an *in situ* remedial approach that involves injection of a commercially available organic substrate into the aquifer to enhance the bioremediation of trichloroethene (TCE), *cis*-1,2-dichloroethene (*c*DCE), and vinyl chloride (VC) in the source area. A pilot-scale bioremediation test was completed in 2008 that evaluated treatment of CVOCs in groundwater using the recommended approach. The results of the pilot study indicated that use of an organic substrate with a pH amendment has the potential to successfully reduce CVOC concentrations at this site. This work plan presents a brief background of the site conditions, the full-scale system design and implementation steps.

# 2.0 BACKGROUND AND SITE HISTORY

The following site information was summarized from the following historical reports provided by NAVFAC SE.

U.S. Geological Survey, 2006, *Natural and Enhanced Attenuation of Benzene, Chlorobenzenes and Chlorinated Ethenes, Wastewater Treatment Plant, NAS Pensacola*, 2006 Annual Report, U.S. Geological Survey, Columbia, South Carolina.

U.S. Geological Survey, 2005, *Natural and Enhanced Attenuation of Benzene, Chlorobenzenes and Chlorinated Ethenes, Wastewater Treatment Plant, NAS Pensacola*, 2005 Annual Report, U.S. Geological Survey, Columbia, South Carolina.

The WWTP at SWMU 1 received industrial wastewater from onsite operations from 1941 through 1971. The industrial waste was generated during electroplating and paint removal operations conducted in the 1950s and 1960s. Waste received at the plant included organic solvents (chlorinated ethenes, benzene, and chlorobenzenes), phenols, chromium electroplating wastes (cyanide and heavy metals), and waste from chemical conversion process for aluminum. Drying beds were used to dewater sludge which resulted in contamination of soils and groundwater in the area. In 1971, the WWTP was upgraded to segregate industrial and domestic waste streams.

These impacts were addressed as part of a RCRA clean-up effort which included source removal and monitored natural attenuation (MNA). The drying beds were excavated to a depth of 6 feet below ground surface (ft bgs) and the excavated material was disposed of as hazardous waste. The excavation was backfilled with clean sand and capped with high-density asphalt. A sulfuric acid spill was also reported to have occurred upgradient of the source area during the 1980's. A pump-and-treat system was installed in 1986 to address the remaining groundwater impacts as part of the closure activities. The system proved to be ineffective for plume treatment. The pump-and-treat system was discontinued in 1997 and additional monitoring activities were undertaken to assess the natural attenuation processes.

In 1998, an *in situ* chemical oxidation (ISCO) treatment was implemented to address existing groundwater impacts in the source area. Approximately 4,000 gallons of 50% hydrogen peroxide and an equivalent volume of ferrous iron catalyst solution (i.e., Fenton's Reagent) were injected in the surficial aquifer. A decrease in concentration of TCE in the source area was initially observed. However, concentrations have rebounded to near pre-injection levels in monitoring well USGS-5.

Solutions-IES conducted a pilot scale injection in 2008 and 2009 to evaluate the effectiveness of using an emulsified oil product with added buffers to stimulate anaerobic reductive dechlorination of CVOCs in groundwater in the source area. This work was summarized in a Pilot Study Completion Report (Solutions-IES, 2009). Information obtained from the study has been used to develop a full scale bioremediation plan to treat groundwater across a larger portion of the source area.

## 3.0 SITE CHARACTERISTICS AND PILOT TEST RESULTS

An illustration of the TCE groundwater plume as provided by NAVFAC is shown in **Figure 2**. Elevated concentrations of TCE suggest the presence of DNAPL in the aquifer although no free-product was observed during the pilot test. The concentration of TCE in source area monitoring well AE-01 measured in 2009 was approximately 19,000 μg/L, and concentrations of degradation products *c*DCE and VC were reported as approximately 1,000 μg/L and 3,000 μg/L, respectively. A summary of the groundwater concentration data obtained during the pilot between July 2008 and March 2009 is provided in **Table 1**.

The pH of groundwater in SWMU-1 was measured to be between 3.5 and 6.4. As with most microbial processes, groundwater pH can affect the performance of dehalorespiration. Dehalorespiring bacteria are pH sensitive and dechlorination rates decline below a pH of 6. Other conditions recognized at SWMU 1

that may be limiting reductive dechlorination include sulfate concentrations as high as 7,500 mg/L, lack of organic substrate for microbial growth and a limited population of dehalorespiring bacteria.
The bioremediation efforts will be focused within the surficial aquifer which is composed of Quaternary marine and fluvial terrace sediments. The material has been described as fine to medium grained sands to a depth of approximately 40 ft bgs. The surficial aquifer is underlain by a layer of lower-permeability silts and clays of marine origin which act as a confining bed to permeable sands and gravel in the confined aquifer system below. The confined aquifer is known as the main producing zone and has been used for water supply in the past.

In 2009, the average depth to groundwater in SWMU 1 ranged from 3.8 to 4.2 ft bgs in the study area. The shallow groundwater flow at the site mimics the local topography and generally flows to the north-northeast towards Pensacola Bay which serves as a discharge for both aquifers. The average hydraulic gradient across the area was measured to be 0.001 ft/ft resulting in a relatively low groundwater flow velocity . An upward hydraulic gradient exists between the lower confined and surficial aquifers.

The aquifer within the study area is predominantly anaerobic. The dominant oxidation-reduction (redox) reactions occurring in this area are iron and sulfate reduction. Ferrous iron concentrations (390 mg/L) and low pH (~3 to 6) are attributed to a sulfuric acid spill which occurred upgradient of the source area in the 1980s. Studies by the USGS indicate that natural attenuation processes have not been affected by the previous remedial activities (USGS, 2006).

The results of the pilot study were useful for determining that a buffered emulsified oil substrate could work. The commercial product, AquaBuph™, obtained from EOS Remediation, Inc. of Raleigh, NC, was able to modify the groundwater pH to a more neutral range which allowed for enhanced reductive dechlorination to occur where it had previously been limited. However, the pilot study also showed that additional up-front testing was warranted prior to implementing an expanded, full-scale treatment.

## 3.1 SEPTEMBER 2009 INVESTIGATION WORK

### 3.1.1 Soil Assessment

Solutions-IES mobilized to the site in September 2009 to collect groundwater and soil samples to provide additional data on aquifer conditions in support of a full-scale injection design. Solutions-IES contracted a Florida licensed well contractor, Enviro-Pro-Tech (EPT), to advance five soil borings within the study area using a direct-push drill rig. The borings were designated SB-1, SB-2, SI-03, SI-04 and SI-05

(**Figure 3**). Continuous soil samples were collected using Geoprobe® Macro-Core® sleeves from 25 to 45 ft bgs to identify the sand-silt interface and determine the appropriate target treatment interval. The borings designated as SB-1 and SB-2 were completed within the pilot study injection area to see if elevated levels of acid volatile sulfides (AVS) and chromium reducible sulfide (CRS) were present which would indicate the possibility of abiotic activity.

Soil samples were also collected from each boring at discrete depths ranging from 35 to 45 ft bgs for laboratory analysis. Soil samples were collected and submitted for the following analyses:

- Eight soil samples were submitted for laboratory total organic carbon (TOC) analysis to Test America Laboratory in Pensacola, Florida;
- Six soil samples were submitted for analysis of the complete suite of constituents identified as the Aqueous and Mineral Intrinsic Biodegradation Assessment (AMIBA) package which includes: AVS, CRS, weak acid soluble metals (iron and manganese), strong acid soluble metals (iron and manganese), and bioavailable ferric iron and manganese to Microseeps Laboratory in Pittsburgh, Pennsylvania ; and
- Ten samples from the 36 to 42 ft bgs interval of borings SB-1, SB-2, SI-03, SI-04 and SI-05 were collected to be used in a bench-scale laboratory study designed to determine the oil retention capacity and alkalinity of the aquifer materials at the Lab of Environmental Engineering in the Department of Civil, Construction and Environmental Engineering at NCSU (CCEE-NCSU) under the direction of Dr. Robert C. Borden, P.E. Samples from the same interval were also submitted for separate analysis of soil pH, alkalinity and grain size analysis.

A summary of the soil sampling analytical results is provided in **Table 2**.

Visual observations made in the field and grain size analysis results indicated that a sharp contact between the homogenous sands and the silty sand exists at approximately 40 ft bgs. At approximately 42 ft bgs, another sharp change exists between the silty sands and a tight, marine clay.

The pH measured in sediment samples ranged from 3.85 to 8.89. Boring SB-2 was intentionally located in close proximity to the Pilot Test AquaBupH™ injection area surrounding monitor well AE-01. The samples collected from SB-2 showed high pH levels (6.3-8.89) indicating that the buffering material injected during the pilot study had reached this location. The organic content of the sediment samples was low and AMIBA results indicate that little iron and manganese exists within the aquifer materials. This was supported by the visual description of the material as white sands with no evidence of iron oxide staining. This is possibly attributable to long exposure to acidic groundwater.

### 3.1.2 Groundwater Assessment

The borings installed at locations SI-03, SI-04 and SI-05 were converted to 2-inch diameter PVC monitoring wells and will become part of the performance monitoring network. The borings installed at locations SB1 and SB-2 were converted to 1-inch diameter PVC wells to be used as injection wells during the next phase of work. The wells were constructed with 10 feet of 0.010-inch slotted PVC screened across the sand-silt interface to a depth of 42 ft bgs. The new wells were developed and above grade protective covers were placed around the monitoring wells.

Groundwater samples were collected from each of the new monitoring wells (SI-03, SI-04 and SI-05) as well as existing monitoring wells AE-01, AE-02, SI-01, SI-02 and GM-66R. The samples were submitted to Test America Laboratory for the following analyses.

- Volatile Organic Compounds via method 8260B;
- Total organic carbon, total carbon and total inorganic carbon via method 415.1;
- Acidity (method SM 2310B) and alkalinity (method 310.1);
- Major cations (iron, manganese, sodium, potassium, magnesium, and calcium) via method 6010B;
- Chloride via method 325.2;
- Sulfate (method 375.4) and total sulfide (method SM 4500); and
- pH via method 150.1.

In addition, groundwater samples were submitted to MicroSeeps for analysis of methane, ethane and ethene. Dissolved oxygen and pH were measured using field meters. The groundwater analytical results from the pilot study and the September 2009 sampling event are summarized in **Table 1**.

Groundwater samples collected from source area well AE-01 indicated that while TCE concentrations had initially dropped following the 2008 injection activities, they have rebounded to pre-injection levels (19,000 µg/L). Concentrations of degradation products *c*DCE and VC have increased as compared to pre-injection levels indicating that some degradation has occurred in this area. The pH has remained slightly elevated at 4.35 as compared to 3.67 pre-injection. It should be noted that the TCE concentration also increased in pilot study background well GM-66R from 2,760 µg/L pre-injection to 4,400 µg/L in September 2009. TCE concentrations the other wells adjacent to the pilot study injection area (SI-01 and SI-02) remain at lower levels than were measured pre-injection. However, concentrations of the degradation daughter products remains low although the pH values in these wells remain higher than the pre-injection pH at these locations.

Groundwater samples collected from the new monitoring wells SI-03 and SI-04 exhibited TCE concentrations of 67 µg/L and 21 µg/L, respectively, which helps define the lateral extent of the plume New monitoring well SI-05, located within the presumed source area had a TCE concentration of 980 µg/L and a pH of 6.36.

Samples indicate that with the exception of the newly installed wells at SI-03, SI-04 and SI-05, the acidity of the groundwater is high, 1,000 mg/L to 5,100 mg/L. This indicates that additional buffer material will need to be added during the injection activities to overcome the acidity and raise the pH to suitable levels for biodegradation.

### 3.1.3 Laboratory Studies

A portion of the aquifer material collected in the Macro-Core® from each boring was sealed and submitted to CCEE-NCSU laboratory for column studies. The material was mixed and a composite sample from each boring was measured for pH. The material from all borings was then mixed prior to placement in a clear plastic PVC column. Samples were collected from material in the influent, middle and effluent portions of the column for analysis of alkalinity and volatile solids content. De-aired water was flushed through each column to saturate the aquifer material. A dilute AquaBupH™ solution was then flushed through the column. The influent, middle and effluent portions of the column were again sampled for acidity and volatile solids to determine the distribution of the oil and buffer through the aquifer material.

The flow rates achieved during the water flush indicated that the material is highly permeable. The volatile solids measured after injection showed that oil was distributed throughout the length of the column. Alkalinity results indicated that the buffer material was also distributed throughout the column although more buffer was retained near the column influent. The total amount of oil estimated to be required for the target treatment area is 7,000 pounds (lb) and the base requirement for sediment and groundwater is 26,500 equivalents. The 42 drums of AquaBupH™ estimated for treatment based upon contaminant concentrations would provide 8,000 lb of oil and 47,000 base equivalents. While this is more than the required amount suggested by the column studies, the additional material should result in increased effectiveness over an extended period of time. A detailed summary of the laboratory column studies is presented in **Appendix A**.

# 4.0 *IN SITU* REMEDIAL DESIGN

## 4.1 REMEDIATION OBJECTIVES

The primary objective of the system is to inject a buffered, biodegradable injectable emulsified oil substrate to stimulate the anaerobic reductive dechlorination of CVOCs and reduce existing concentrations in the source zone of SWMU 1. Results of the pilot test suggest that use of AquaBupH™ has the potential to achieve this objective. The introduction of the AquaBupH™ will be used to create anaerobic conditions, raise the groundwater pH and enhance the growth of indigenous microorganisms capable of degrading chlorinated solvents.

The Florida GCTL for TCE is 3 µg/L. The eventual goal of the groundwater remediation program would be to reach this target concentration. Groundwater monitoring will be conducted for a period of one year following injection to assess the performance of the treatment. Based on the performance of the Pilot Test, within this time period, it is unlikely that this target will be reached throughout the entire plume although some areas with lower starting concentrations may reach this goal. The objectives are to engineer the TCE-impacted portion of the aquifer to promote enhanced reductive dechlorination. Evidence for success will be reduction of the concentration of TCE and the formation of biodegradation daughter products across the entire plume. The goal is also to entrain sufficient residual buffered substrate throughout the treatment zone that will continue supporting bioactivity beyond the immediate monitoring period.

## 4.2 SUBSTRATE DESCRIPTION

AquaBupH™ is purchased as a concentrated emulsion composed of emulsified edible oil, alkaline solids, emulsifiers, micronutrients and preservatives. A vitamin B-12 supplement is also supplied by the manufacturer to further stimulate dechlorinating microorganisms. Information on the chemical properties of AquaBupH™ is found on the MSDS sheets provided in **Appendix B.**

AquaBupH™ is typically diluted in the field and then injected into the aquifer. Because of its droplet and particle size and surface charge characteristics, AquaBupH™ can be distributed away from the injection site to immediately impact the desired volume of aquifer. The edible oil initially degrades aerobically, consuming any oxygen dissolved in the aquifer. Once anaerobic conditions are established, the oil continues to ferment, releasing hydrogen and acetate used by specialized bacteria to reductively

dechlorinate CVOCs. In the process, TCE degrades to *c*DCE by the removal of one chlorine atom. The process continues with *c*DCE being degraded to VC and VC being degraded to ethene, the non-toxic metabolic end-product.

## 4.3 INJECTION DESIGN

As discussed in Section 3.1.3, the amount of AquaBupH™ included in the system design was determined based upon the concentrations of the target compounds, concentrations of various biodegradation and geochemical parameters, results of a laboratory column study and hydrogeologic conditions within the injection area. **The laboratory study described in Appendix A** provides a discussion of these parameters and the estimated volume of oil and buffer required.

Prior to initiating injection activities, Solutions-IES will collect a set of baseline groundwater samples from existing monitoring wells AE-01, AE-02, USGS-5, GM-66R, GM-67, SI-01, SI-03, SI-04 and SI-05 to establish groundwater conditions prior to injection. Details on the groundwater sampling procedures and proposed analyses are provided in Section 6.0.

The injection will be performed using temporary injection wells screened from 36 – 41 ft bgs. Solutions-IES will coordinate with a Florida-licensed well contractor to obtain well construction permits prior to mobilization to the site. Each injection well will be constructed of 1-inch PVC well materials. In lieu of a sand pack, the natural formation will be allowed to collapse around the well casing. Any remaining annular space will be filled with a bentonite seal to the ground surface. The design layout includes 52 injection locations installed approximately 7.5 feet on-center. The injection wells will be installed in two groups. The first group of 36 wells will be installed in five lines oriented generally perpendicular to groundwater flow as shown on **Figure 4**. Wells will be installed approximately 7.5 ft on-center in each line. These locations were selected to provide broad coverage of the presumed source area, based on plume maps and interpretations provided by NAVFAC. A conceptual cross-section illustrating the proposed injection depths is provided as **Figure 5**.

Following installation, groundwater samples will be collected from each of the 36 wells and monitored for pH (in the field) and TCE (by the CCEE-NCSU using an equivalent GC methodology for screening). The results of these rapid-screening analyses will be used to decide where to place the remaining 16 injection points. The objective would be to provide additional AquabupH™ in areas where the pH is lowest and/or the TCE concentration is highest, thereby achieving greater coverage of areas needing more

attention. Approximate locations of the remaining 16 injection wells are illustrated in **Figure 4,** but will be altered based upon the field screening conducted during installation of the first 36 injection wells.

The AquaBupH™ concentrate will be diluted with potable water prior to injecting the emulsion into the subsurface. Ultimately, the 42 drums of AquabupH™ will be diluted to a final volume of 16,250 gallons with potable water (diluted to approximately 10% of initial concentrate) and injected into the 52 1-inch diameter wells (312 gallons per well). Solutions-IES will coordinate with NAS Pensacola to identify a suitable water source (e.g., a fire hydrant) for use in the injection process. Pre-treatment of the water to be used for dilution is not planned. Distribution of the substrate away from the injection points and into the formation will be performed by the continuous injection of diluted AquaBupH™ emulsion into the aquifer until the design volume is achieved.

Injection will occur by manifolding a group of 8 or 9 injection wells together. The wells will be staggered so that injection will not be conducted into wells immediately adjacent to each other. A Dosatron metering system will be used to dilute the concentration AquaBupH™ and measure injection volumes and flow rates. A flow rate of approximately 5 gpm is estimated based upon the injection activities conducted during the pilot study. During injection, Solutions-IES will monitor the water levels in nearby existing monitoring wells. Water levels in these wells will be monitored before, once during, and immediately upon termination of the injection to evaluate whether groundwater mounding has occurred and, if so, how widespread it is observed. This information will be used to help evaluate the impact and effectiveness of the injection process.

## 5.0 SITE RESTORATION AND INVESTIGATION-DERIVED WASTE

After the required volume of substrate has been injected, the temporary injection wells will be removed and the remaining borehole will be abandoned. Abandonment will be completed by a Florida-licensed well contractor by allowing the aquifer material to fill the void space in each borehole and adding a cement-bentonite grout to the surface. No injection wells will be left after the injection phase is complete.

Solid waste generated by the implementation of this treatment technology will include empty drums, buckets, hoses, well materials, and miscellaneous trash. All materials are non-hazardous and will be disposed of in coordination with NAS Pensacola requirements. Soil derived from well installation will be

drummed, labeled and staged on-site. Water used to rinse drums of AquaBupH™ and pumps, hoses and other injection equipment will be containerized and disposed of via the sanitary sewer. Well water derived from developing the temporary injection wells will be containerized. The disposal of containerized water and soil will be coordinated with representatives of the NAS Environmental Department.

## 6.0 PERFORMANCE MONITORING

Solutions-IES will perform a baseline round of groundwater monitoring within one week prior to substrate injection and four additional post-injection monitoring events following full-scale injections. The sampling will be conducted in accordance with the Quality Assurance Project Plan and Sampling and Analysis Plan (QAPP/SAP) developed for this work (**Appendix C**). The sampling matrix used for site characterization and proposed for baseline and subsequent performance monitoring events is provided in the QAPP/SAP and as **Table 4**.

For planning purposes we have assumed monitoring will occur at 2, 4, 8, and 12 months post-injection. However, sampling frequency may be adjusted based on the monitoring results. The baseline and subsequent performance monitoring will include low-flow sampling of groundwater from eight wells within the treatment area (AE-01, USGS-5, GM-66R, GM-67, SI-01, SI-03, SI-04 and SI-05) and one well (AE-02) outside of the treatment area (**Figure 3**). At each of the five events, groundwater samples from all nine wells will be analyzed in accordance with the "regular" monitoring regime as follows:

- Field Measurements: pH, ORP, specific conductance, temperature, and turbidity using calibrated field meters as well as DO and sulfide by Chemetrics® field-test ampoules.
- Laboratory Analytical: VOCs; TC, TOC and TIC; major cations (total Na, K, Mn, Mg, Ca, Fe); anions ($Cl^-$, $SO_4^{+2}$, $S^-$); lab pH, alkalinity (if pH > 8.2) or acidity (if pH< 8.2), methane, ethane and ethene.

As part of the "expanded' characterization and monitoring, samples from five monitor wells (e.g., AE-01, SI-01, SI-03, SI-04, and SI-05) will also be submitted for analysis of volatile fatty acids (VFAs) by ion chromatography Method AM23G and compound specific isotope analysis (CSIA) for TCE, *c*DCE and VC. Five groundwater samples will also be collected for microbial census and enzyme analyses including eubacteria (EUB), *Dehalococcoides spp.* (qDHC), TCE Reductase (qTCE R-ase), VC reductase (qVC-R-ase), *Dehalobacter spp.* (qDHB), methanogens (qMGN), *Dehalococcoides* sp. strain BAV1 (BAV1), BAV1 vinyl chloride reductase gene (BVC) and iron-reducing and sulfate-reducing bacteria. The same

five monitor wells will then be analyzed at 4 months and 12 months for the same "expanded" performance monitoring parameters. All sampling will be conducted in accordance with the QAPP/SAP included as **Appendix C**.

## 7.0 REPORTING

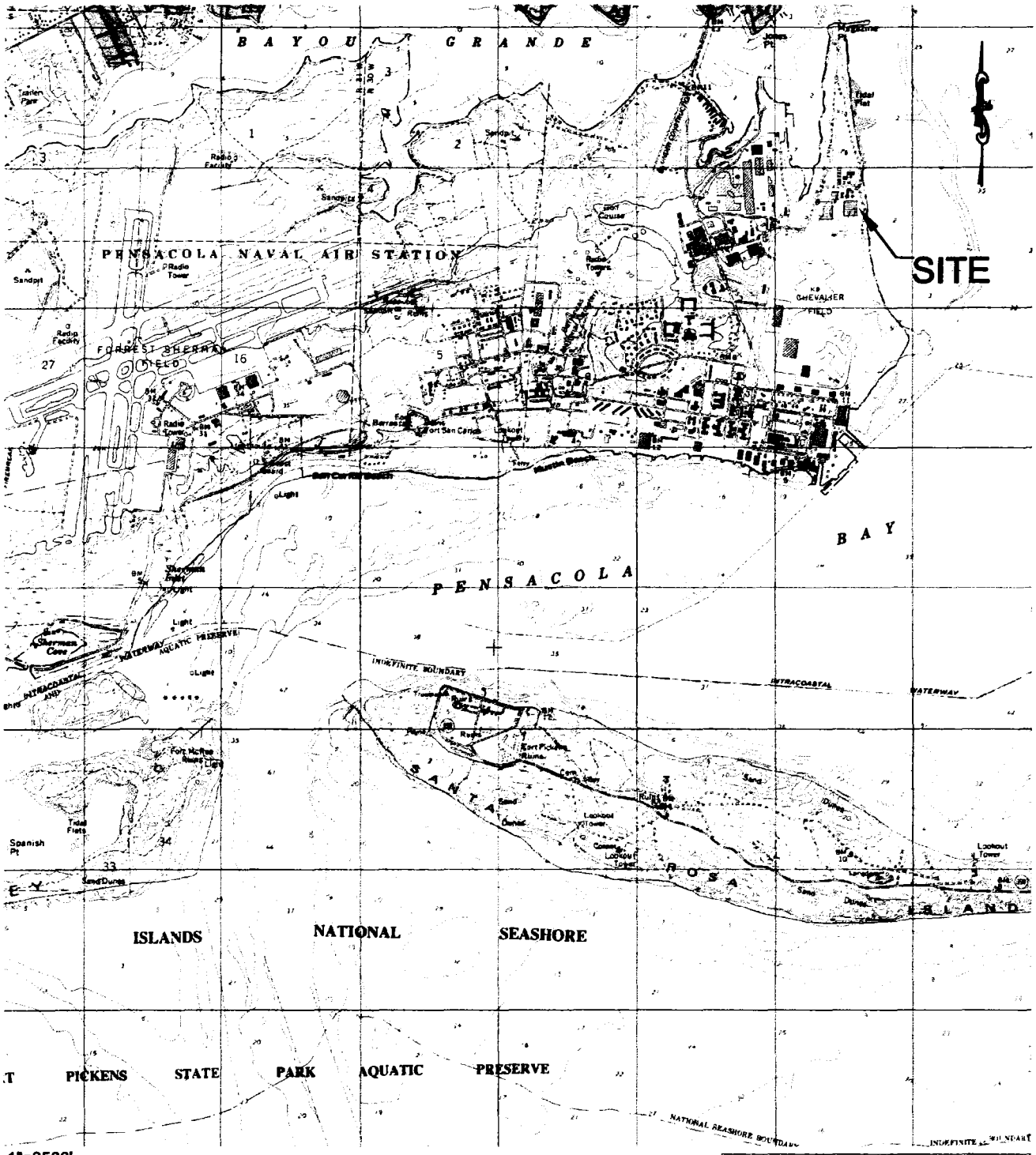
Solutions-IES will compile the pre-injection (baseline) groundwater data along with the injection details and the first post-injection performance monitoring results into the first quarterly technical memorandum. The first memo will be submitted within 30 days of completing the first post-injection sampling event. The first technical memo will provide information on volumes of AquaBupH™ utilized, an "as-built" drawing of the injection locations, and other pertinent information concerning the injection process, as well as photographs taken during the set-up and injection processes. Because of the 6-week laboratory turnaround time required for CSIA analysis, these results will be included only if they are available in time for the submittal.

Subsequent technical memoranda will be submitted on a similar schedule as best as practicable. Each technical memo will document the performance of the system and include time series graphs of contaminants of concern, relevant MNA parameters and microbial indicators. In addition, a description of the field activities, discussion of the field and laboratory results, tables summarizing the current and historical information will be included. Conclusions and recommendations for optimization of the monitoring program and future remedial activities will be included, if the data prove it necessary.

## 8.0 IMPLEMENTATION SCHEDULE

Solutions-IES will begin coordination of fieldwork upon approval from FDEP of this work plan and fieldwork will proceed within 30 days of approval. As described in **Section 7.0**, post-injection monitoring will be conducted at approximately 2, 4, 8, 12 months post-injection. An injection completion report will be submitted within 45 days of receipt of all analytical results following the last quarterly monitoring event.

# FIGURES




REFERENCE:
USGS 7.5 MINUTE TOPOGRAPHIC MAP
FORT BARRANCAS, FLORIDA, 1965.
(PHOTOREVISED 1994)

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SITE LOCATION MAP
BIOREMEDIATION WORK PLAN
NAVAL AIR STATION
PENSACOLA, FLORIDA

FIGURE:
1

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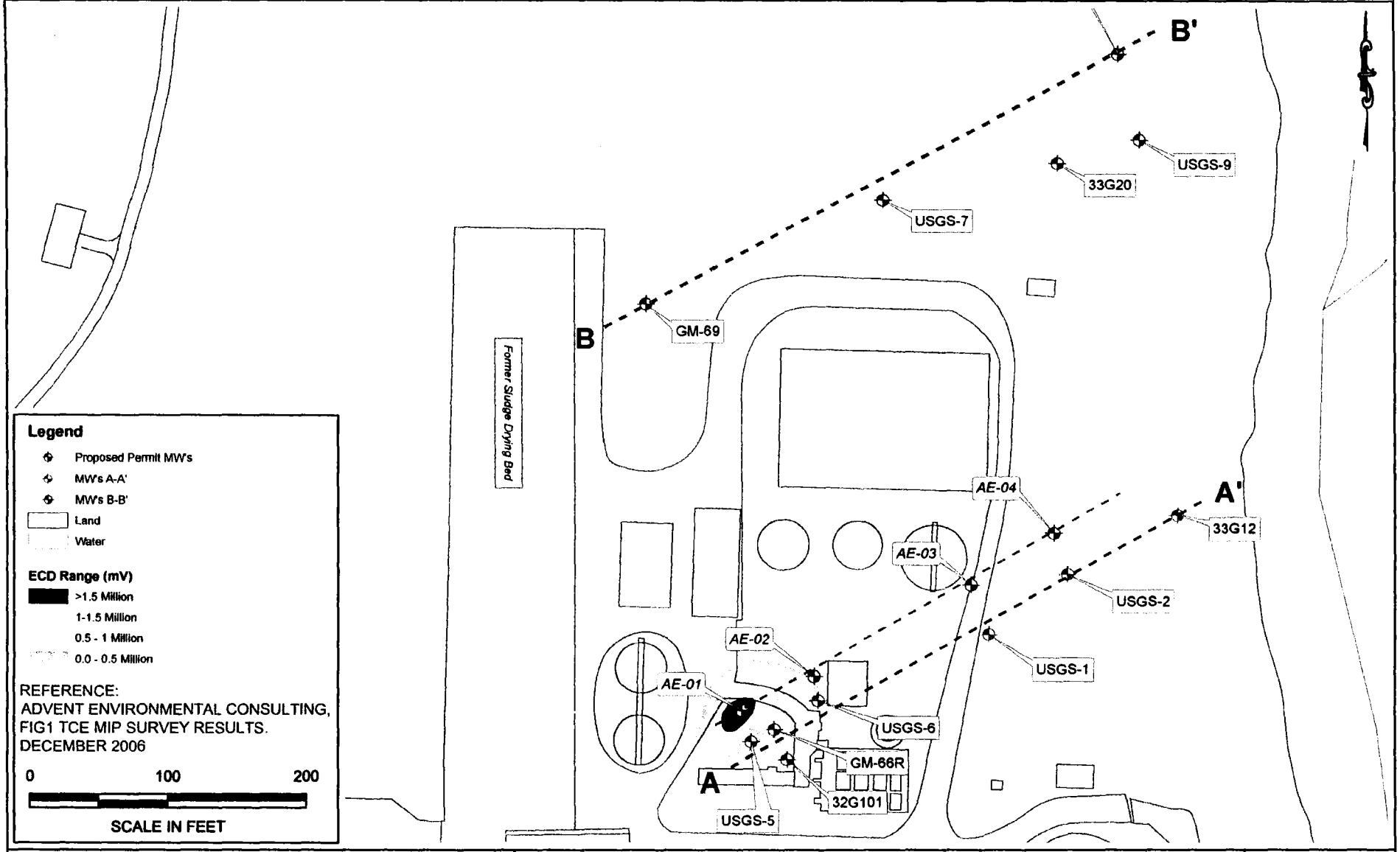
| FIGURE 2.PDF | JANUARY 2010 | JLK | JLK | HRG | 3911.09A3.NAVF |





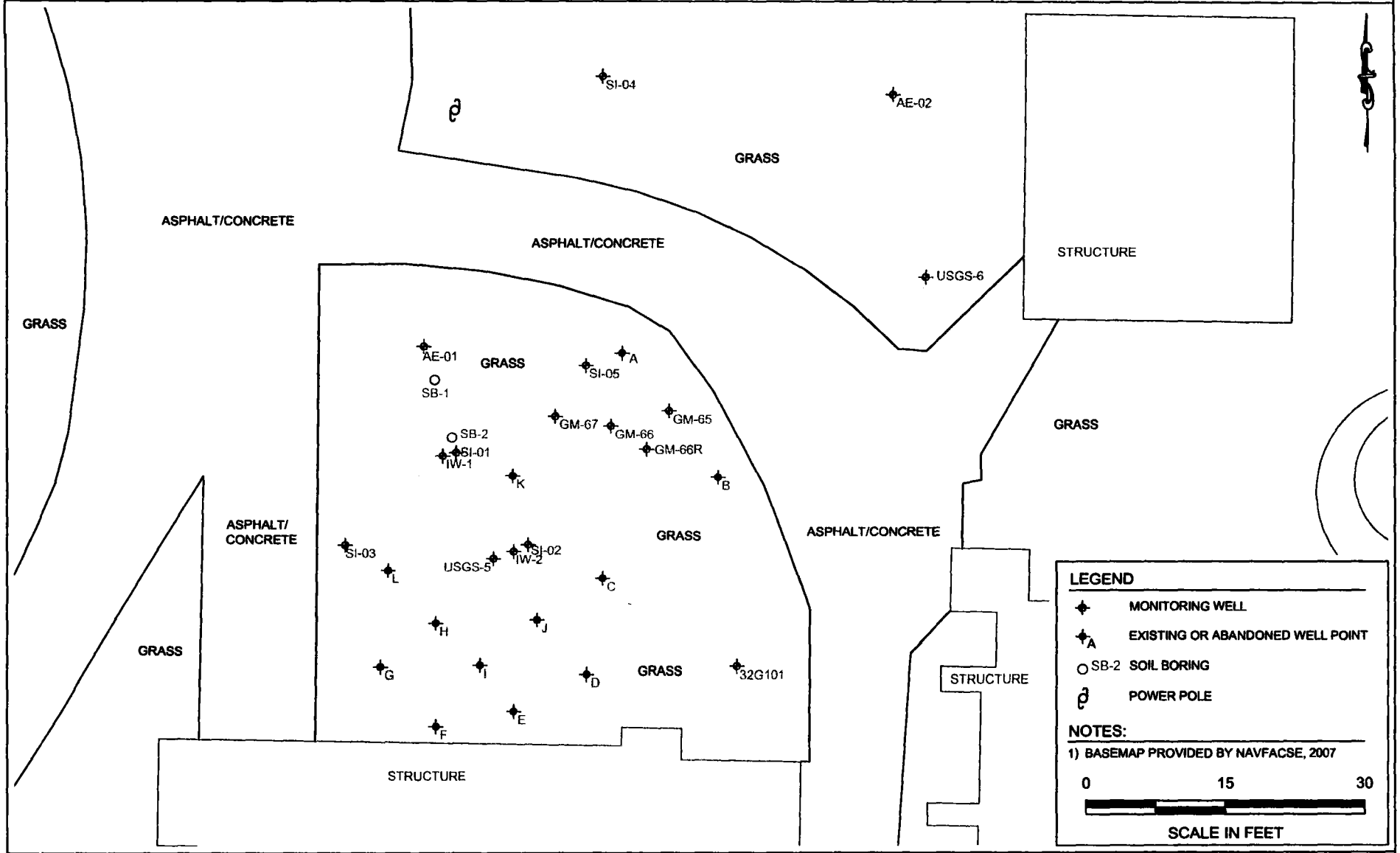
Solutions-IES
Industrial & Environmental Services
1101 NOWELL ROAD
RALEIGH, NORTH CAROLINA 27607
TEL.: (919) 873-1060 FAX.: (919) 873-1074


TCE PLUME MAP
BIOREMEDIATION WORK PLAN
NAS PENSACOLA
PENSACOLA, FLORIDA

FIGURE:

2

| FILE | DATE | PROJECT MANAGER | CHECKED BY | DRAFTER | PROJECT NUMBER |
|---|---|---|---|---|---|
| FIGURE 3.PDF | JANUARY 2010 | JLK | JLK | HRG | 3911.09A3.NAVF |





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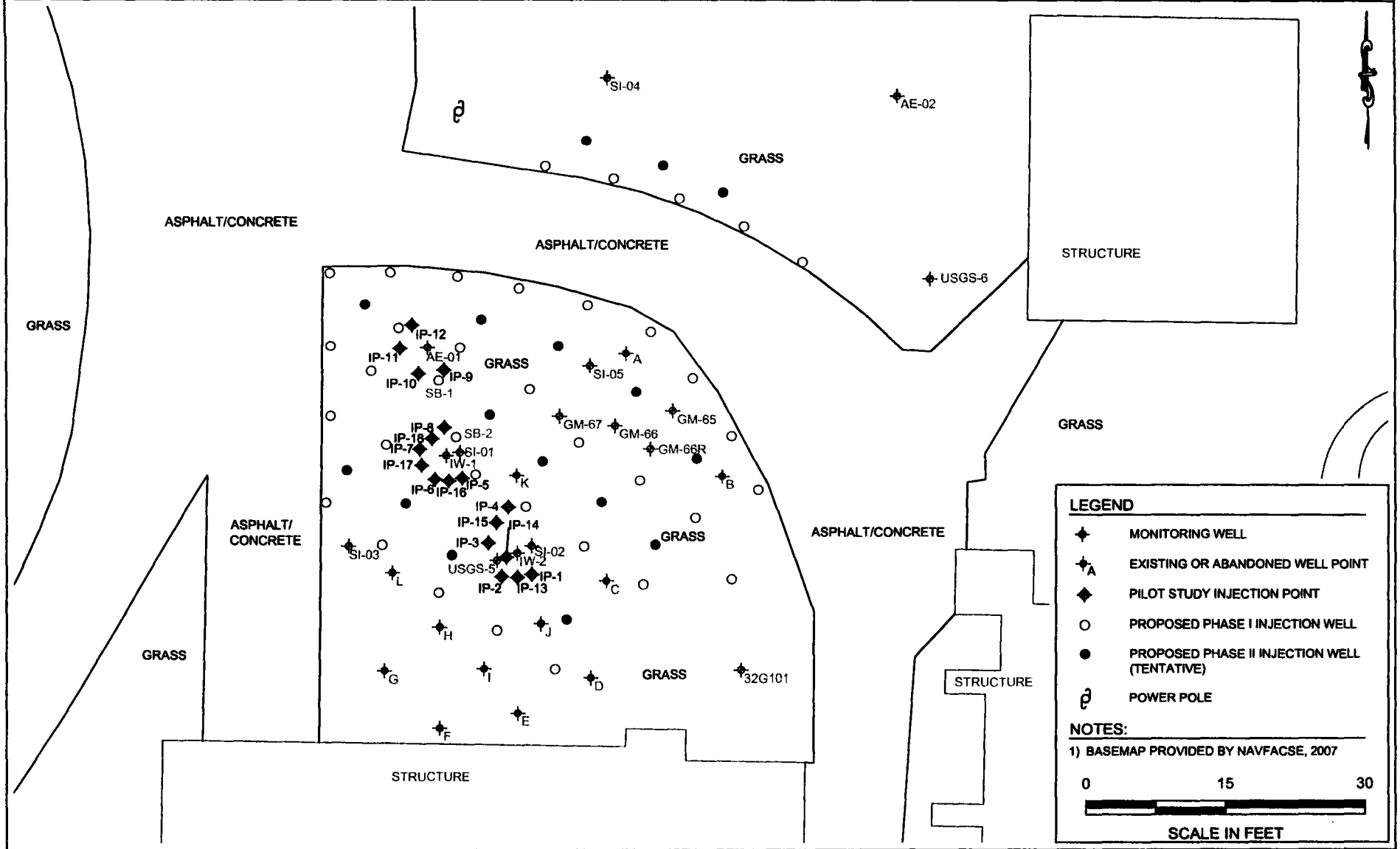
SWMU1 SITE MAP
BIOREMEDIATION WORK PLAN
NAS PENSACOLA
PENSACOLA, FLORIDA

FIGURE:

3

| FILE | DATE | PROJECT MANAGER | CHECKED BY | DRAFTER | PROJECT NUMBER |
|---|---|---|---|---|---|
| FIGURE 4.PDF | JANUARY 2010 | JLK | JLK | HRG | 3911.09A3.NAVF |





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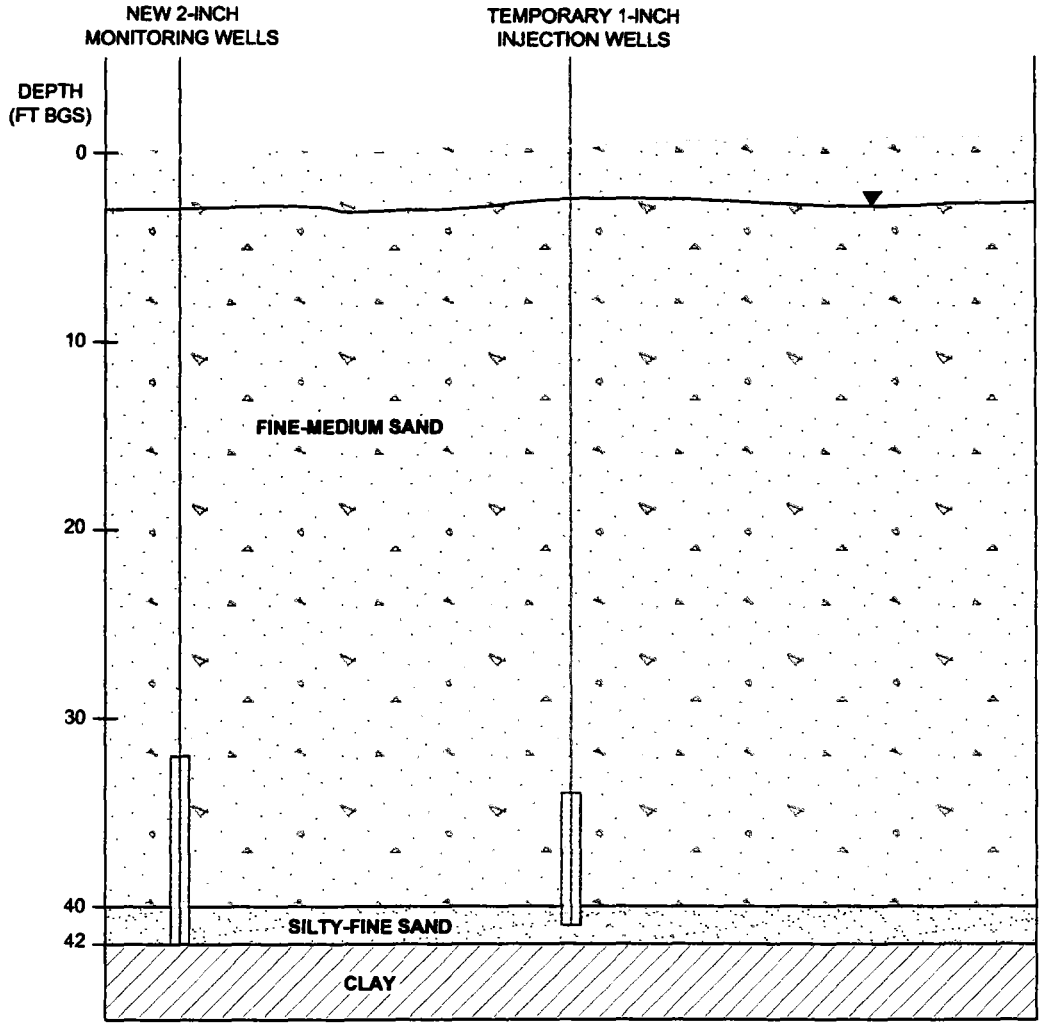
PROPOSED INJECTION WELL LAYOUT
BIOREMEDIATION WORK PLAN
NAS PENSACOLA
PENSACOLA, FLORIDA

FIGURE:

4




PROJECT NUMBER 3911.09A3.NAVF

DRAFTER HRG

CHECKED BY JLK

PROJECT MANAGER JLK

DATE JANUARY 2010

FILE FIGURE 5.pdf

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RALEIGH, NORTH CAROLINA 27607
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CONCEPTUAL CROSS-SECTION
BIOREMEDIATION WORK PLAN
NAVAL AIR STATION
PENSACOLA, FLORIDA

FIGURE:
5

T:\Project Files\NAS Pensacola\cadd\NASPensacola-Basemap.dwg, 5, 1:1

# TABLES

**TABLE 1**
**SUMMARY OF GROUNDWATER ANALYTICAL DATA**
NAS PENSACOLA
PENSACOLA, FLORIDA
SOLUTIONS-IES PROJECT NO.: 3911.09A3.NAVF

| Well ID | Sample Date | Chlorinated Aliphatics | | | | | | | Light Hydrocarbon Gasses | | | Total Organic Carbon (mg/L) | Total Carbon (mg/L) | Total Inorganic Carbon (mg/L) | Inorganics | | | | | | | | | Acidity (mg/L) | Alkalinity | pH (SU) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | PCE (µg/L) | TCE (µg/L) | *cis* 1,2-DCE (µg/L) | *trans* 1,2-DCE (µg/L) | 1,1-DCE (µg/L) | Vinyl Chloride (µg/L) | 1,1-DCA (µg/L) | Methane (µg/L) | Ethane (µg/L) | Ethene (µg/L) | | | | Calcium (mg/L) | Iron (mg/L) | Magnesium (mg/L) | Manganese (mg/L) | Potassium (mg/L) | Sodium (mg/L) | Chloride (mg/L) | Sulfate (mg/L) | Sulfide (mg/L) | | | |
| AE-01 | 7/15/2008 | 10.1 | 18,300 | 877 | 5.47 | 69.7 | 94.4 | 10.4 | 2,328.60 | 20.91 | 3.68 | 4.75 | 4.75 | -- | -- | -- | -- | -- | -- | -- | -- | 4,710 | -- | -- | -- | 3.67 |
| | 11/24/2008 | ND | 420 | 320 | 19.0 | 12.0 | 3,500 | 2.1 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 6.97 |
| | 3/24/2009 | <50 | 10,000 | 1,200 | <50 | <50 | 1,300 | <50 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 4.28 |
| | 9/17/2009 | <500 | 19,000 | 1,000 | <500 | 79 J | 3,000 | <500 | 2,300 | 23 | 370 | 480 | 530 | 49 | 210 | 140 | 640 | 1.3 | 86 | 970 | 760 | 5,900 | 78 | 2,000 | -- | 4.35 |
| AE-02 | 9/16/2009 | <100 | 2,500 | 180 | <100 | 25 J | 14 | <100 | 4,400 | 35 | 1.1 | 5.9 | 83 | 77 | 260 | 170 | 220 | 1.3 | 91 | 1,100 | | 4,300 | 2.5 | 1,500 | -- | 4.07 |
| SI-01 | 7/15/2008 | 2.66 | 4,150 | 250 | 0.71 | 40.3 | 9.03 | 8.2 | 1,598.80 | 14.5 | 0.21 | 5.36 | 5.36 | -- | -- | -- | -- | -- | -- | -- | -- | 4,180 | -- | -- | -- | 3.56 |
| | 11/24/2008 | 4 | 7,200 | 1,200 | 1.8 | 20.0 | 46.0 | 5.5 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 4.75 |
| | 3/24/2009 | <12 | 2,800 | 560 | <12 | <12 | <12 | <12 | 1,084 | 7 | 13 | 2,500 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 3,100 | <0.036 | -- | -- | 5.93 |
| | 9/16/2009 | <120 | 3,900 | 780 | <120 | <120 | <120 | <120 | 3,300 | 23 | 71 | 310 | 3,300 | 210 | 98 | 8.1 | 1,100 | 0.4 | 63 | 890 | 1,300 | 2,800 | 85 | 1,000 | -- | 6.26 |
| SI-02 | 7/15/2008 | 0.93 | 1,640 | 106 | 0.64 | 7.29 | 0.65 | 14.2 | 2,255.40 | 20.89 | 0.28 | 6.26 | 6.26 | -- | -- | -- | -- | -- | -- | -- | -- | 10,500 | -- | -- | -- | 3.44 |
| | 11/24/2008 | ND | 290 | 140 | ND | 5.3 | ND | 9.2 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 4.42 |
| | 3/24/2009 | <2.5 | 440 | 120 | <2.5 | <2.5 | <2.5 | 9.6 I | 2409 | 11 | 1 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 4.01 |
| | 9/16/2009 | <10 | 360 | 110 | <10 | <10 | <10 | 9.3 | 3,100 | 11 | 1.2 | 1,200 | 1,500 | 230 | 220 | 390 | 680 | 6.6 | 92 | 900 | 810 | 7,500 | 40 | 5,100 | -- | 4.09 |
| SI-03 | 9/23/2009 | <0.5 | 67 | 16 | <0.5 | <0.5 | <0.5 | 0.99 I | NA | NA | NA | 4.7 | 66 | 61 | 210 | 36 | 76 | 0.45 | 29 | 570 | 920 | 810 | 1.1 | 250 | 8.3 | 5.08 |
| SI-04 | 9/17/2009 | <5 | 16 | 1.5 J | <5 | <5 | <5 | 0.65 J | 480 | 3.3 | 0.38 | 3.6 | 32 | 29 | 180 | 48 | 53 | 0.61 | 21 | 410 | 670 | 690 | <1.0 | 120 | -- | 5.94 |
| | 9/24/2009 | <0.5 | 21 | 3.0 I | <0.5 | <0.5 | <0.5 | 0.9 I | NA | NA | NA | 4.1 | 50 | 46 | 260 | 56 | 77 | 0.71 | 29 | 510 | 760 | 880 | <1.0 | 240 | 82 | 6.27 |
| SI-05 | 9/24/2009 | <2.5 | 980 | 150 | <2.5 | 12 I | <2.5 | <2.5 | NA | NA | NA | 26 | 99 | 26 | 260 | 19 | 97 | 0.5 | 36 | 630 | 990 | 750 | 11 | 390 | 260 | 6.36 |
| GM-66R | 7/15/2008 | 2.35 | 2,760 | 207 | 0.98 | 31.9 | 2.81 | 15.6 | 2,838.70 | 26.44 | 0.12 | 6.66 | 6.66 | -- | -- | -- | -- | -- | -- | -- | -- | 5,850 | -- | -- | -- | 3.42 |
| | 3/24/2009 | <12 | 4,000 | 260 | <12 | 24 I | <12 | 14 I | 2,345.7 | 22.92 | 0.56 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 3.31 |
| | 9/17/2009 | <120 | 4,400 | 220 | <120 | 28 | <120 | <120 | 4,100 | 22 | 0.14 | 330 | 490 | 160 | 160 | 290 | 220 | 1.3 | 66 | 700 | 790 | 5,300 | 81 | 4,800 | -- | 3.46 |

Notes:
(µg/L) - Micrograms per liter
(mg/L) - Milligrams per liter
SU - Standard units
Samples collected from July 2008 through March 2009 were collected as part of the Pilot Study.

**TABLE 2**
**SUMMARY OF SOIL ANALYTICAL DATA**
NAS PENSACOLA
PENSACOLA, FLORIDA
SOLUTIONS-IES PROJECT NO.: 3911.09A3.NAVF

| Site ID | Depth (ft) | Color | Texture/ characteristic | pH | foc (%) |
|---|---|---|---|---|---|
| **UPGRADIENT** | | | | | |
| SI-03 | 36-40 | creamy | Sandy, uniform in particle size | 6.43 | 0.081 j |
| SI-03 | 37-38 | creamy, brown | Sandy, uniform in particle size | 5.89 | -- |
| SI-03 | 41-43 | gray | Sandy, uniform in particle size | 3.88 | -- |
| SI-03 | 40-44 | gray, creamy | Sandy, uniform in particle size | 3.85 | 0.11 |
| **SOURCE AREA** | | | | | |
| SB-1 | 36-37 | creamy , white | Sandy, uniform in particle size | 4.94 | -- |
| SB-1 | 37.5-40 | light brown | Sandy, uniform in particle size | 4.65 | <0.1 |
| SB-1 | 39.9 | light gray, creamy | Sandy, uniform in particle size, smells like sewage | 3.96 | -- |
| SB-2 | 37.5-40 | light brown | Sandy, uniform in particle size | 6.3 | <0.1 |
| SB-2 | 38.5-39 | creamy | Sandy, uniform in particle size | 6.37 | -- |
| SB-2 | 40-42 | dark gray | Sandy, uniform in particle size, smells like sewage, seems finer than sample 3 | 8.34 | -- |
| SB-2 | 40-42 | light gray | Sandy, uniform in particle size, smells like sewage | 8.89 | -- |
| SI-05 | 39-40 | white , gray | Sandy, uniform in particle size, smells like sewage | 4.46 | -- |
| SI-05 | 36-40 | -- | -- | -- | 0.1 |
| SI-05 | 40-44 | -- | -- | -- | <0.1 |
| SI-05 | 41-42 | gray | Sandy, uniform in particle size | 4.65 | |
| **DOWNGRADIENT** | | | | | |
| SI-04 | 36-40 | white | Sandy, uniform in particle size | 4.35 | <0.1 |
| SI-04 | 39-40 | gray, creamy | Sandy, uniform in particle size | 3.95 | -- |
| SI-04 | 40-44 | gray, creamy | Sandy, uniform in particle size | 4.15 | 0.19 |
| SI-04 | 41-43 | light gray | Sandy, uniform in particle size | 7.2 | -- |

Notes:

foc - fraction of organic carbon

-- Analysis not conducted

Samples collected 9/24/09

**TABLE 3**
**SUMMARY OF AMIBA ANALYSIS DATA**
NAS PENSACOLA
PENSACOLA, FLORIDA
SOLUTIONS-IES PROJECT NO.: 3911.09A3.NAVF

| Sample ID | Depth (ft bgs) | Acid Volatile Sulfide | Bio-Available Ferric Iron | Bio-Available Manganese | Chromium Extractable Sulfide | Oxidized Iron | Strong Acid Divalent Mn | Strong Acid Ferric Iron | Strong Acid Soluble Ferrous Iron | Weak Acid Soluble Divalent Mn | Weak Acid Soluble Ferric Iron | Weak Acid Soluble Ferrous Iron |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SB-1 | 37.5-40 | <0.1220 | <6.1 | <6.1 | <0.12 | <6.1 | <24 | <24 | <24 | <12 | <12 | <12 |
| SB-2 | 37.5-40 | <0.1205 | **11.2** | <6 | **0.22** | <6 | <24 | <24 | <24 | <12 | <12 | **15** |
| SI-04 | 36-40 | <0.1205 | **11.1** | <6 | <0.12 | <6 | <24 | <24 | <24 | <12 | <12 | <12 |
| SI-04 | 40-44 | <0.1205 | **35.8** | <6 | **0.19** | <6 | <24 | **44** | **200** | <12 | <12 | **65** |
| SI-03 | 36-40 | <0.1205 | **9.3** | <6 | <0.1 | <6 | <24 | <24 | <24 | <12 | <12 | **12** |
| SI-03 | 40-44 | <0.1220 | <6.1 | <6.1 | **0.24** | <6.1 | <24 | <24 | <24 | <12 | <12 | **25** |

Notes:

All results are in milligrams per kilogram (mg/kg)

ft bgs - feet below ground surface

**TABLE 4**
**SAMPLE COLLECTION SUMMARY**
NAS PENSACOLA
PENSACOLA, FLORIDA
SOLUTIONS-IES PROJECT NO.: 3911.09A3.NAVF

| Laboratory | Analysis and Method | Matrix | QA Sample Types | # QA Samples | # Sampling Locations | Pre-Injection Baseline - Expanded | 1st Post-Injection Performance Monitoring (2 months) | 2nd Post-Injection Performance Monitoring-Expanded (4 months) | 3rd Post-Injection Performance Monitoring (8 months) | 4th Post-Injection Performance Monitoring - Expanded (12 months) | Total Number of Samples |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Microbial Insights | EBAC, DHC, TCE R-dase, VC R-dase, BAV1, BVC, DHB, IRB/SRB, qMGN | Groundwater | -- | 0 | 5 | 5 | 0 | 5 | 0 | 5 | 15 |
| Test America | VOCs - 8260 | Groundwater | TB & Dup. | 2 | 9 | 11 | 11 | 11 | 11 | 11 | 55 |
| | Sulfate - 375.4 | Groundwater | Dup. | 1 | 9 | 10 | 10 | 10 | 10 | 10 | 50 |
| | TOC - 415.1 | Groundwater | Dup. | 1 | 9 | 10 | 10 | 10 | 10 | 10 | 50 |
| | TC & TIC - 415.1 | Groundwater | Dup. | 1 | 9 | 10 | 10 | 10 | 10 | 10 | 50 |
| | Acidity - SM2310B | Groundwater | Dup. | 1 | 9 | 10 | 10 | 10 | 10 | 10 | 50 |
| | Sulfide, Total -- SM4500 S2F | Groundwater | Dup. | 1 | 9 | 10 | 10 | 10 | 10 | 10 | 50 |
| | Iron, Total - 6010B | Groundwater | Dup. | 1 | 9 | 10 | 10 | 10 | 10 | 10 | 50 |
| | Manganese, Total - 6010B | Groundwater | Dup. | 1 | 9 | 10 | 10 | 10 | 10 | 10 | 50 |
| | Sodium, Total - 6010B | Groundwater | Dup. | 1 | 9 | 10 | 10 | 10 | 10 | 10 | 50 |
| | Potassium, Total - 6010B | Groundwater | Dup. | 1 | 9 | 10 | 10 | 10 | 10 | 10 | 50 |
| | Magnesium, Total - 6010B | Groundwater | Dup. | 1 | 9 | 10 | 10 | 10 | 10 | 10 | 50 |
| | Calcium, Total - 6010B | Groundwater | Dup. | 1 | 9 | 10 | 10 | 10 | 10 | 10 | 50 |
| | Chloride, Total 325.2 | Groundwater | Dup. | 1 | 9 | 10 | 10 | 10 | 10 | 10 | 50 |
| | pH - 150.1 | Groundwater | Dup. | 1 | 9 | 10 | 10 | 10 | 10 | 10 | 50 |
| | Alkalinity - 310.1 | Groundwater | Dup. | 1 | 9 | 10 | 10 | 10 | 10 | 10 | 50 |
| Chemetrics Kits | Dissolved Oxygen | Groundwater | -- | 0 | 9 | 9 | 9 | 9 | 9 | 9 | 45 |
| | Sulfide | Groundwater | -- | 0 | 9 | 9 | 9 | 9 | 9 | 9 | 45 |
| MicroSeeps | Stable Isotopes (TCE, cDCE, VC) | Groundwater | -- | 0 | 0 | 5 | 0 | 5 | 0 | 5 | 15 |
| | VFAs by Ion Chromatography | Groundwater | -- | 0 | 0 | 5 | 0 | 5 | 0 | 5 | 15 |
| | Methane, ethane, ethene (MEE) | Groundwater | Dup. | 1 | 9 | 10 | 10 | 10 | 10 | 10 | 50 |

Monitor Wells (9) for Regular Monitoring: AE-02 (background), AE-01, USGS-5, GM-66R, GM-67, SI-01, SI-03, SI-04 and SI-05.
Monitor Wells (5) for Expanded Monitoring: AE-01, SI-01, SI-03, SI-04 and SI-05.

Acronyms:

| | | | |
|---|---|---|---|
| EBAC | Eubacteria | TOC | Total Organic Carbon |
| DHC | Dehalococcoides spp. | TC | Total Carbon |
| TCE R-Dase | Trichloroethene Reductive Dehalogenase | TIC | Total Inorganic Carbon |
| VC R-Dase | Vinyl Chloride Reductive Dehalogenase | VFAs | Volatile Fatty Acids |
| BAV1 | Strain of Dehalococcoides spp. | | |
| BVC | BAV1 VC R-dase | | |
| DHB | Dehalobacter spp. | | |
| IRB/SRB | Iron and Sulfate Reducing | | |
| qMGN | Methanogens | | |

# APPENDIX A

## LABORATORY STUDIES AND REMEDIAL SYSTEM DESIGN

# Appendix A
# Laboratory Studies and Remedial System Design
# SWMU-1 Naval Air Station Pensacola (NASP)

## Introduction

A series of laboratory studies were conducted in Fall 2009 in support of the planned in situ bioremediation activities to treat chlorinated solvents in groundwater within Solid Waste Management Unit 1 (SWMU-1) - Wastewater Treatment Plant (WWTP) area at the Naval Air Station in Pensacola, Florida. The selected remedy consists of injecting an emulsified oil substrate containing a pH buffering agent (AquabupH™) into the source area to adjust aquifer pH and enhance biotic degradation of trichloroethene (TCE), *cis*-1,2-dichloroethene (cDCE) and vinyl chloride (VC). This appendix describes these laboratory studies and how this information was used in planning the full-scale design.

## Laboratory Studies

Sediment Characteristics

Solutions-IES, Inc. personnel mobilized to the site on September 19, 2009 and collected a series of soil cores by Direct Push Technology (DPT) at the following location: SB-1, SB-2, SI-03, SI-04, SI-05 at depths varying from 36 to 44 feet below ground surface (ft bgs). Core material was collected in clear plastic tubes. In all borings, an abrupt transition from homogeneous uniform sand to silty-sand was observed at approximately 40 ft bgs.

Samples of aquifer material were shipped on ice to Solutions-IES, Inc. offices in Raleigh, NC for laboratory studies. In the lab, the cores were emptied, mixed and subsampled for pH and particle size distribution. pH was measured by transferring 10 g of moist sediment to a small plastic cup, adding 25 mL of deionized (DI) water to form a slurry, and then measuring pH after 5 minutes using a standard probe. Particle size analysis was performed with a Beckman Coulter LS13 320 multi-wavelength laser particle size analyzer following manufacturer's instructions.

Laboratory analytical results for the samples are summarized in Table 1 and Figure 1. All of the materials collected from 36 to 40 ft bgs were uniform sands with very little fine grained material. In contrast, samples collected below 40 ft contained significant amounts of silt and some clay. The homogeneous sands were light gray to white in color with no evidence of iron oxide coatings, possibly due to the extended exposure to the acidic groundwater. Samples collected from SB-1, SB-2 and SI-05 had a strong 'sewage' odor indicating that prior treatment with emulsified oil during the pilot study phase had reached that location. Samples from SB-2 had a high pH (8.3-8.9) indicating that $Mg(OH)_2$ present in the AquabupH™ had reached that location. However, samples SB-1 and SI-05 had a pH less than 5 indicating the $Mg(OH)_2$ had not reached these two locations.

**Table 1. Laboratory Analysis of SWMU-1 Samples of Aquifer Material**

| Site ID | Depth (ft) | Color | Odor | pH | D10 (micron) | D50 (micron) | D90 (micron) |
|---|---|---|---|---|---|---|---|
| **SI-04** | 41-43 | light gray | None | 7.20 | NA | NA | NA |
| **SB-2** | 40-42 | dark gray | Sewage | 8.34 | 3 | 15 | 315 |
| **SB-2** | 40-42 | light gray | Sewage | 8.89 | 7 | 220 | 469 |
| **SI-03** | 41-43 | gray | None | 3.88 | 140 | 285 | 472 |
| **SB-1** | 39.9 | light gray, creamy | Sewage | 3.96 | 242 | 421 | 678 |
| **SB-1** | 36-37 | creamy , white | None | 4.94 | 237 | 428 | 699 |
| **SI-03** | 37-38 | creamy, brown | None | 5.89 | 248 | 405 | 613 |
| **SI-04** | 39-40 | gray, creamy | None | 3.95 | 234 | 406 | 649 |
| **SI-05** | 41-42 | gray | None | 4.65 | 9 | 303 | 529 |
| **SI-05** | 39-40 | white , gray | Sewage | 4.46 | 237 | 415 | 672 |
| **SI-03** | 40-44 | gray, creamy | None | 3.85 | 183 | 290 | 468 |
| **SB-1** | 37.5-40 | light brown | None | 4.65 | 253 | 435 | 687 |
| **SB-2** | 37.5-40 | light brown | None | 6.30 | 220 | 357 | 595 |
| **SI-04** | 40-44 | gray, creamy | None | 4.15 | 183 | 311 | 504 |
| **SI-04** | 36-40 | white | None | 4.35 | 208 | 385 | 648 |
| **SI-03** | 36-40 | creamy | None | 6.43 | 220 | 398 | 638 |
| **SB-2** | 38.5-39 | creamy | None | 6.37 | 233 | 370 | 592 |

NA – grain size analysis not performed

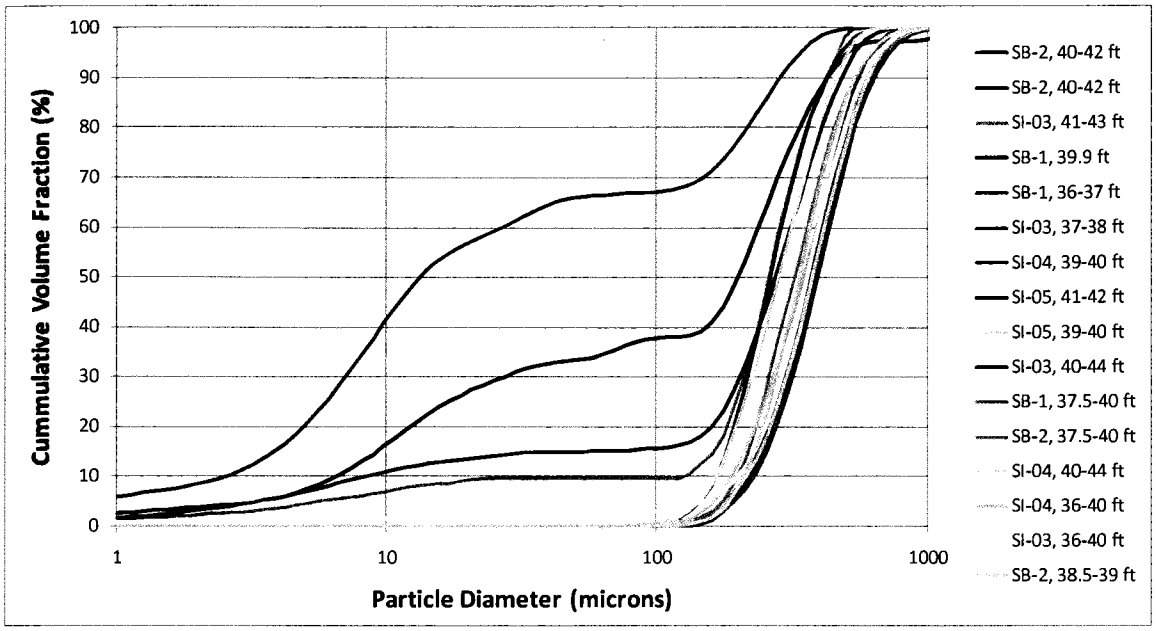


Figure 1 Results of subsurface material particle size analyses

Sediment Acidity Measurement

The acidity of four samples was measured by adding 25 g moist sediment to seven replicate flasks, amending with varying amounts of 0.5 N NaOH, and diluting to 50 mL with DI water. The samples were allowed to equilibrate for 24 hours and then the pH was measured. Results of these measurements are presented in Figure 2.

The acidity of the samples was relatively low, considering the low initial pH. The total amount of base required to reach pH = 8.0 varied from 0.01 to 0.05 meq/g dry sediment with significantly more base required for the SI-03 41-43 ft sample due to the higher cation exchange capacity of the more silty material. The target pH of 8.0 used in this analysis is slightly higher than would be optimum for bioremediation. However, a slightly higher target pH was selected to provide some conservatism to the analysis.

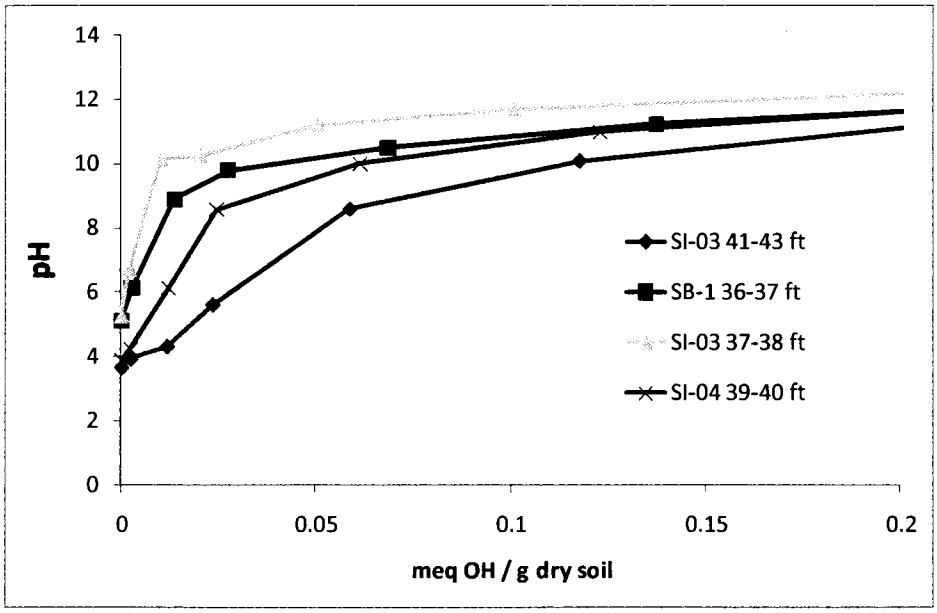


Figure 2 pH versus NaOH addition to aquifer material

Column Tests

Laboratory column studies were run to evaluate the transport and retention of AquabupH™ in the homogeneneous sand. A clear plastic PVC column (11 inch long x 1 inch dia.) was first packed with sample SI-04 collected from 39 – 40 ft bgs ($D_{50}$ = 0.4 mm, $D_{10}$ = 0.23 mm). The column was then treated as follows: (a) pump 140 mL of deaired water through the column to saturate; (b) pump 140 mL of 28% dilution of AquabupH™ emulsion/buffer through the column; (c) pump an additional 140 mL deaired water through the column; (d) section the column into three parts (influent, middle and effluent ends); and (e) measure volatile solids (VS) content and alkalinity of the sediment samples. VS was determined by weight loss on ignition for 1 hour at 550 °C. Alkalinity was determined by titration of a sediment samples to pH=4.5 with 1 N HCl.

Overall, the column test went very smoothly. During the initial plain water flush, the follow rate varied from 22 to 30 mL/min. During the AquabupH™ injection, the flow dropped to about 5 mL/min, but then recovered to 20 mL/min during the post-injection flush. The decline in flow during the AquabupH™ injection is presumably due to the higher viscosity of this material compared to plain water. All of the flowrates observed during the column test were relatively high, indicative of the high permeability of this material. It is not unusual for the flow rate to drop below 1 mL/min during emulsion injection into more fine grained sands.

Figure 3 shows photographs of the columns before and after AquabupH™ injection. Prior to injection, the sediment was a light grey color. After injection, the entire length of the column was significantly lighter in color indicating the emulsified oil and/or Mg(OH)2 particles had been transported through the entire length of the column.

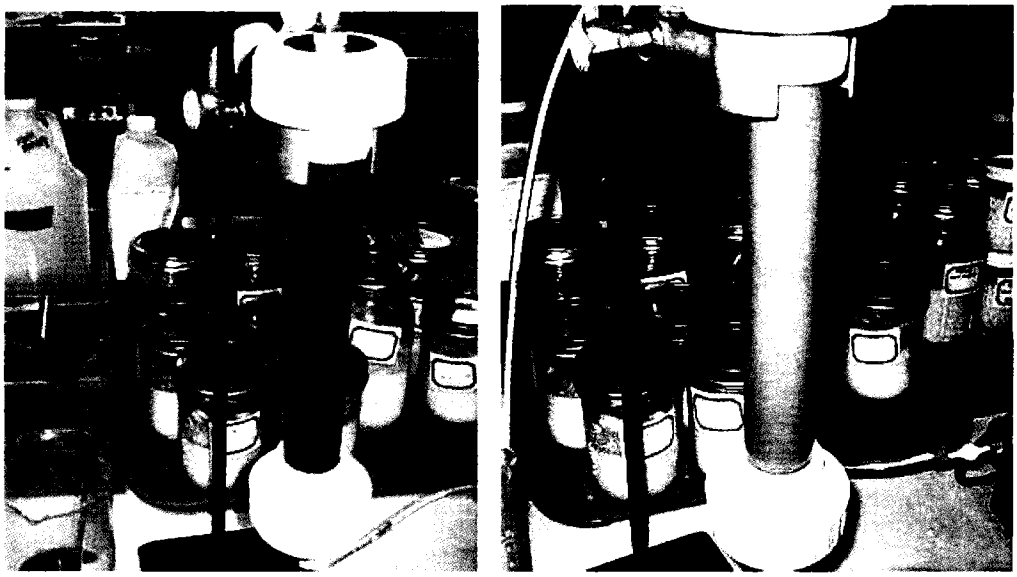

Figure 3 Photographs of columns before and after flushing with AquabupH

Results of the post-injection sediment analyses are shown in Table 2. The volatile solids of the sediment was 0.0021 (±0.0001) prior to emulsion injection and increased to 0.009 – 0.014 g/g. This indicates that oil was distributed throughout the full length of the column and the oil retention of the sediment is 0.007 – 0.012 g/g. The acidity of the sediment was between 0.005 and 0.01 meq/g (i.e. -0.005 to -0.01 alkalinity) prior to injection. Alkalinity increased to 0.1 meq/g in the column inlet and 0.016-0.017 meq/g in the middle and column effluent. This indicates that sufficient buffer was distributed throughout the entire length of the column. However, significantly more buffering material was retained near the column influent than in more downgradient areas.

**Table 2 Analysis of sediment samples after completion of column test**

| Sample Location | Volatile Solids | Alkalinity |
|---|---|---|
| | g/g | meq/g |
| Influent | 0.009 | 0.102 |
| Middle | 0.011 | 0.016 |
| Effluent | 0.014 | 0.017 |
| Average | 0.011 | 0.045 |

Remediation System Design

The SWMU-1 remediation system should be designed to provide sufficient emulsified oil to coat the aquifer sediments and sufficient buffer to neutralized the sediment and groundwater acidity. In the section below, calculations are presented to estimate the required amount of oil and buffer.

The target treatment zone is estimated to be approximately 40 ft wide perpendicular to groundwater flow, 50 ft long parallel to groundwater flow and extend from 35 to 40 ft bgs (5 ft thick) resulting in a total treatment volume of 10,000 $ft^3$. Assuming a bulk density of 120 $lb/ft^3$, 1.2 million lb of sediment will be treated. Assuming a porosity of 0.25, the pore volume (PV) of the treatment zone is 2,500 $ft^3$ or 18,750 gallons. The average oil retention in the column test was 0.011 lb/lb (range =0.009 to 0.014 lb/lb). Assuming a mass scaling factor of 0.5 (inject 50% of the maximum amount that can be retained), 7,000 lb of oil will be required to treat this area. The average buffer retention in the column test was 0.045 meq/g which results in a buffer retention of 54,000 equivalents within the treatment zone.

The total amount of buffer required for this project is equal to the total acidity of the treatment zone sediment plus the acidity of any groundwater that passes through the treatment zone over the design life of the project. The average acidity of the homogeneous sands was about 0.01 meq/g, which is equivalent to 5,500 equivalents within the treatment zone. The measured groundwater acidity (see Table 1) varied between 50 and 5000 mg/L as $CaCO_3$ with an average of about 1500 mg/L as $CaCO_3$ (30 $eq/m^3$). For design purposes, we have assumed a design life of ten years and a groundwater flow velocity of 50 ft/yr (1 PV will be flushed through the treatment zone per year). This results in 187,500 gallons (700 $m^3$) of ground water requiring treatment. The average amount of base required to neutralize the groundwater is then 21,000 equivalents.

In summary, the total amount of oil and base required is estimated to be

- Average oil requirement for sediment = 7,000 lb
- Average base requirement for sediment = 5,500 eq
- Average base requirement for groundwater = 21,000 eq
- Base requirement for sediment + groundwater = 26,500 eq

During the preliminary planning for this project, 42 drums of AquabupH™ were estimated to be required to treat SWMU-1. AquabupH™ contains 40% by weight oil and provides 2.3 eq/lb of acid neutralizing capacity. The 42 drums of AquabupH™ would then provide 8,000 lb of oil and 47,000 base equivalents. The oil provided by the AquabupH™ is slightly more than required for good treatment. However, providing a small excess of oil will increase treatment longevity and contact efficiency. The base provided is significantly greater than that required. However in prior pilot tests, we have had considerable difficulty in raising the pH up to within a range suitable for bioremediation. As a result, there may be significant benefits to providing some excess of buffer above and beyond the minimum amount calculated. The maximum buffer retention within the treatment zone is estimated to be 54,000 eq, so downgradient migration of excess buffer is not expected to be a problem.

Based on the results presented above, 42 drums of AquabupH™ are expected to provide good treatment for the TCE contaminated portion of SWMU-1. The 42 drums of AquabupH™ should be diluted to a final volume of 16,250 gallons with potable water (diluted to approximately 10% of initial concentrate) and injected into 52 small diameter wells (312 gallons per well). The 16,250 gallons is equivalent to 0.87 pore volumes of fluid within the 5 ft injection interval and is expected to provide good distribution of the AquabupH™. The injection wells will be installed in two groups. The first group of 36 wells will be installed as four barriers oriented generally perpendicular to groundwater flow as shown on Figure 4. Wells will be installed approximately 7.5 ft on-center in each barrier. Following installation, groundwater samples will be collected from each of the 36 wells and monitored for pH (in the field) and TCE (in a non-certified lab using a screening procedure). Locations for installation of the remaining 16 wells will be selected to provide additional AquabupH™ in areas where the pH is lowest and/or the TCE concentration

is highest. All the wells will be installed within the 40 ft wide by 50 ft long area designated as the target treatment zone.

We anticipate the wells will be injected in groups of 8 or 9 wells at one time. Assuming an injection flowrate of 5 gpm/well, this will require a potable water supply of 40 to 45 gpm. Assuming the 5 gpm/well flowrate can be maintained, up to 9 wells could be injected in 3-4 hours.

# APPENDIX B

## AQUABUPH™ MATERIAL SAFETY DATA SHEETS

## MATERIAL SAFETY DATA SHEET

**EOS® AquaBu*pH*™ (EOS® 501-1)**

D.O.T. HAZARD CLASSIFICATION: NONE

| ---HMIS---- | |
|---|---|
| HEALTH | 1 |
| FLAMMABILITY | 0 |
| REACTIVITY | 0 |
| PERSONAL PROTECTION | J PPE |

MANUFACTURER'S NAME
EOS Remediation, Inc
1101 Nowell Road
Raleigh,NC 27607
www.EOSRemediation.com
(919) 873-2204

DATE OF PREPARATION
9/18/2006 Rev. Date: 2/18/2008

## SECTION I - PRODUCT IDENTIFICATION

PRODUCT NAME: **EOS® AquaBu*pH*™**
PRODUCT CLASS: **Vegetable Oil Based Emulsion With Alkali Solids**
CAS NUMBER: **Mixture**

## SECTION II - COMPOSITION

| COMPONENT(S) | % BY WEIGHT | CAS NO. | EXPOSURE LIMIT OSHA PEL | EXPOSURE LIMIT ACGIH TLV - TWA |
|---|---|---|---|---|
| Soybean Oil | 35.9 ± 2 | 8001-22-7 | 15 mg/m3 | NA |
| Sodium Lactate / Lactic Acid | 2.4 ± 0.2 | 867-56-1 | | |
| Food Additives / Emulsifiers / Preservatives (Proprietary) | 6.1± 0.2 | | | |
| Extracts (Proprietary) | 1.2 ± 0.2 | | | |
| Ultra-fine Grade Alkali Solids | 19.5 ± 0.5 | | | |
| Water | Balance | | | |

## SECTION III - HAZARDS IDENTIFICATION

*EMERGENCY OVERVIEW:* Product contains mechanical irritants to skin, eyes and respiratory tract and may present a nuisance dust hazard if allowed to dry out. Avoid breathing dust. Avoid contact with skin. Wear protective clothing including gloves, goggles or safety glasses with side shields and NIOSH approved dust mask. Magnesium oxide FUME may be generated in a reducing environment when temperatures exceed 1,700°C (3,092°F).

*EFFECTS OF ACUTE EXPOSURE:* Ingestion generally causes purging of the bowels, however, swallowing large amounts may lead to bowel obstruction. If allowed to dry out, dust may irritate eyes, skin, nasal passages


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and respiratory tract. If heated over 1700°C (in a reducing environment), inhalation of freshly generated magnesium oxide fume may result in metal fume fever.

*EFFECTS OF CHRONIC EXPOSURE:* No data available.

*SIGNS AND SYMPTOMS OF EXPOSURE:*

EYE CONTACT: redness, tearing, conjunctivitis
SKIN CONTACT: drying, chapping, dermatitis

*MEDICAL CONIDTIONS GENERALLY AGGRAVATED BY EXPOSURE:* As with any exposure to any environment without adequate personal protection, inhalation of magnesium oxide dust or fume may aggravate any pre-existing respiratory disease; prolonged/frequent skin contact may lead to dermatitis.

## SECTION IV - FIRST AID MEASURES

*INHALATION*: Remove to fresh air immediately. Do not permit exposed person to remain in dusty environment without adequate respiratory protection. Treat metal fume fever with bed rest and treat for fever and pain.

*EYE CONTACT*: Do not rub eyes. Wash eyes under slowly running water for at least fifteen minutes, making sure eyes are held wide open and moven slowly in every direction. Ensure no solid particles remain in creases of eyelids. If so, continue to wash. If irritation persists, consult an ophthalmologist.

*SKIN CONTACT*: Remove from source of irritation. Remove contaminated clothing and wash affected area thoroughly with a mild soap and water. Wash contaminated clothing before reusing.

*INGESTION*: Treat symptomatically. If bowel obstruction occurs, immediately consult a physician.

## SECTION V - FIRE AND EXPLOSION HAZARD DATA

FLASH POINT: >300°F

FLAMMABLE LIMITS: NOT ESTABLISHED

EXTINGUISHING MEDIA: Dry chemical, foam, halon, $CO_2$, water spray (fog). Water stream may splash burning liquid and spread fire.

SPECIAL FIRE FIGHTING PROCEDURES: Use water spray to cool drums exposed to fire.

UNUSUAL FIRE AND EXPLOSION HAZARDS: Firefighters should use self-contained breathing apparatus to avoid exposure to smoke and vapor.

## SECTION VI - ACCIDENTAL RELEASES

SPILL CLEAN-UP PROCEDURES: Remove sources of ignition, ventilate enclosed spaces, contain spill to smallest area possible. Stop leak if possible. Pick up small spills with absorbent materials such as paper towels,

"Oil Dry", sand or dirt. Recover large spills for salvage or disposal. Wash hard surfaces with safety solvent or detergent to remove remaining oil film. Greasy nature will result in a slippery surface.

## SECTION VII - HANDLING & STORAGE

Store **EOS® AquaBu*pH*™** in closed containers between 50°F (10°C) and 120°F (48.8°C). Keep away from oxidizing agents, excessive heat, and ignition sources. Store and use in well ventilated areas. Do not store or use near heat, spark, or flame. Do not puncture, drag, or slide container. Drum is not a pressure vessel; never use pressure to empty. Consumption of food and beverages should be avoided in work area where product is being used. After handling, wash hands and face thoroughly with soap and water before eating, drinking or smoking.

## SECTION VIII - EXPOSURE CONTROLS / PERSONAL PROTECTION

RESPIRATORY PROTECTION: If vapors or mists are generated, wear a NIOSH approved organic vapor/mist respirator.

PROTECTIVE CLOTHING: Safety glasses, goggles, or face shield recommended to protect eyes from mists or splashing. PVC coated gloves recommended to prevent skin contact.

OTHER PROTECTIVE MEASURES: Employees must practice good personal hygiene, washing exposed areas of skin several times daily and laundering contaminated clothing before re-use.

## SECTION IX - PHYSICAL & CHEMICAL PROPERTIES

| | |
|---|---|
| Boiling Point: | 212°F |
| Specific Gravity ($H_20$ = 1): | 1.17 to 1.22 |
| pH | ~8.5 - 10 saturated solution |
| Vapor Pressure: | Not Established |
| Percent Volatile By Volume (%): | 30 - 35 (as water) |
| Vapor Density: | Heavier than Air |
| Evaporation Rate: | Not Established |
| Solubility In Water: | Miscible |
| Physical State | Oil-In-Water Emulsion with an Aqueous Slurry |
| Appearance and Odor: | Off-White Liquid with Vegetable Oil Odor |

## SECTION X - STABILITY & REACTIVITY

GENERAL: This product is stable and hazardous polymerization will not occur.

INCOMPATIBLE MATERIALS AND CONDITIONS TO AVOID: Strong oxidizing agents and strong acids

HAZARDOUS DECOMPOSITION PRODUCTS: Combustion produces carbon monoxide, carbon dioxide along with thick smoke. If heated over 1700°C (in a reducing environment), inhalation of freshly generated magnesium oxide fume may result in metal fume fever.

## SECTION XI - TOXICOLOGICAL INFORMATION

Composed of Food-Grade ingredients (e.g., vegetable oil that is generally recognized as safe (GRAS) mixed with alkali solids for pH adjustment).

Name of Toxicologally Synergistic Products: None known.

Irritancy of Product: No data available.

Considered Carcinogenic By: NTP? No IARC? No OSHA? No

## SECTION XII - ECOLOGICAL INFORMATION

Contains biodegradable ingeredients for promoting bacterial activity in soil and groundwater. The following data is provided for ultra-fine grade alkali solids portion of the mixture:

LC50 of 284 to 285 mg/L for daphnia (*D. magna*)
LC50 of 319 to 511 mg/L for fathead minnow (*P. promelas*)
LC50 of 1,293 to 1,517 mg/L for rainbow trout

## SECTION XIII - DISPOSAL CONSIDERATIONS

Dispose according to local, state/provincial and federal regulations.

If discarded in its purchased form, this product would not be classified as a hazardous waste either by listing or characterization.

## SECTION XIV - TRANSPORTATION INFORMATION

DOT Shipping Name: Not regulated under DOT

DOT Classification: Not applicable

NMFC (National Motor Freight Classification):
Identification Number: 145100
Shipping Classification: 65

Special Shipping Information: No special precautions. Shippers and transporters may need to meet packaging and transportation requirements for certain oils and respective quantities under CFR 49 § 130.

## SECTION XV - REGULATORY INFORMATION

CERCLA Hazardous Substance: No

SARA Title III:

Under the provisions of Title 111, Section 311/312 of the Superfund Amendments and Reauthorizations Act, this product is classified into the following hazard categories: **None**

Section 313 – Emissions Reporting: This product does **not** contain Section 313 reportable ingredients.

Section 302- Extremely Hazardous Substances: This product is not listed.

## SECTION XVI - OTHER INFORMATION

| | | | | |
|---|---|---|---|---|
| NFPA Ratings: | Health: 1 | Flammability: 0 | Reactivity: 0 | Other: |
| HMIS Ratings: | Health: 1 | Flammability: 0 | Reactivity: 0 | PPE: J |

Safety & Risk Phrases:

| | |
|---|---|
| R 20/22 | Harmful by inhalation and if swallowed |
| R 36/37/38 | Irritaing to eyes, respiratory system and skin |
| S26 | In case of contact with eyes, rinse immediately with plenty of water and seek medical advice |
| S36 | Wear suitable protective clothing |
| S39 | Wear eye / face protection |

The information contained herein is based on available data and is believed to be correct. However, EOS Remediation, Inc. makes no warranty, expressed or implied, regarding the accuracy of this data or the results to be obtained thereof. This information and product are furnished on the condition that the person receiving them shall make his/her own determination as to the suitability of the product for his/her particular purpose.

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## *New Product Announcement for In Situ Bioremediation from EOS Remediation, Inc.*

# EOS® AquaBu*pH*™

EOS Remediation is pleased to announce the addition of a new product to the EOS® family of bioremediation products. **EOS® AquaBu*pH*™**, patent pending, is based on the same proven technology found in our other EOS® products. The new product formulation specifically addresses the need for low-cost *in situ* treatment of acidic aquifers contaminated with chlorinated solvents, perchlorate, RDX, TNT and other recalcitrant chemicals.

**EOS® AquaBu*pH*™** incorporates the proven EOS® Process patented technology. As with our other bioremediation products, **EOS® AquaBu*pH*™** includes rapidly biodegradable substrates to jump start bacterial growth, slow-release biodegradable substrates to support long-term respiration, and a suite of nutrients for enhancing the growth of halorespiring and other indigenous bacteria. In addition, **EOS® AquaBu*pH*™** includes alkali solids, making it an ideal product for *in situ* bioremediation of contaminated sites having an acidic pH.

A major consideration associated with any *in situ* acid neutralization program is maintaining the neutralizing agent in suspension. Many agents generate sludges and/or have large particle sizes that can both cause large permeability losses that effectively grout your aquifer. **EOS® AquaBu*pH*™** contains a concentrated, stable, highly reactive aqueous suspension. As with all of our products, **EOS® AquaBu*pH*™** is conveniently available in drums, totes or bulk tankers to meet the needs of your individual site. **EOS® AquaBu*pH*™** is specifically designed for the critical application of an *in situ* acid neutralization program. Compared to other chemicals available for aquifer conditioning, **EOS® AquaBu*pH*™** offers superior performance in usage, handling, maintenance, storage and safety.

### Buffered pH Control

*In situ* anaerobic treatment of acidic aquifers contaminated with chlorinated solvents, perchlorate, RDX, TNT and other recalcitrant chemicals frequently requires optimizing the pH. Bacteria prefer a neutral pH range. The natural buffering capacity of **EOS® AquaBu*pH*™** reduces the potential to

exceed the optimal pH range. Compared with products such as hydrated lime and caustic soda that can develop a pH of 12 and 14, respectively, **EOS® AquaBu*pH*™** will only develop a maximum pH of 8.5. One pound **EOS® AquaBu*pH*™** has the equivalent capacity of:

- 0.32 pounds hydrated lime ($Ca(OH)_2$)
- 0.34 pounds caustic soda ($NaOH$)
- 0.45 pounds soda ash ($Na_2CO_3$)
- 0.69 pounds sodium bicarbonate ($NaHCO_3$)

**EOS® AquaBu*pH*™ Advantages:**

- Cost-Effective
- Effective with Acidic Aquifers
- Low Soluble Salt Build-up
- pH = 9.5; Prevents Over Treatment (maximum pH of 8.5 in most aquifers)
- Electron Donor
  - Includes Rapidly Biodegradable Substrates
  - Includes Slow-Release Biodegradable Substrates
  - Includes Nutrients
- Bulk density ~ 9.3 lbs/gal
- Environmentally Safe
- Freezing Point 32 °F
- Easy to Handle
- Readily Available

**ABOUT EOS REMEDIATION**

EOS Remediation, founded in 2002, offers a family of proven, bioremediation products that lead the industry by being scientifically researched, independently validated and achieving consistent on-site success. By letting science lead product direction, EOS Remediation has been – and remains – the cutting-edge provider of bioremediation products. Our suite of products reengineers the groundwater environment by promoting biotransformation of contaminants into non-toxic end products. EOS scientists, who are known worldwide, actively participate in product advancement and are routinely involved with client projects. EOS Remediation combines excellent education and responsive customer service, further ensuring superior performance. For more information call us at 888.873.2204 or visit www.EOSRemediation.com.

†EOS® is a registered trademark of EOS Remediation, Inc.
††Exclusive license agreement with Solutions-IES (www.solutions-ies.com) under U.S. Patent # 6,398,960 , European Union Patent # EP 1 315 675 and several other pending international patents. Solutions-IES (woman-owned, 8a/SDB-certified) is available for design and implementation, if requested.

**NOTICE**

The information contained herein is, to the best of our knowledge and belief, accurate. Any recommendations or suggestions made are without warranty or guarantee of results since conditions of handling and of use are beyond our control: we, therefore, assume no liability for loss or damage incurred by following these suggestions. EOS Remediation warrants only that this product will meet the specifications set forth, any other representation or warranty, either expressed or implied, is specifically disclaimed including **warranties of fitness for a particular purpose and of merchantability**. EOS Remediation's only obligation shall be to replace such quantity of the product proved to be defective before using. User shall determine the suitability of the product for user's intended application and user assumes all risk and liability whatsoever in connection therewith. EOS Remediation shall not be liable in tort, contract or under any theory for any loss or damage, incidental or consequential, arising out of the use of or the inability to use the product.

# APPENDIX C

## QUALITY ASSURANCE PROJECT PLAN AND SAMPLING AND ANALYSIS PLAN

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Figure 1 Organizational Chart

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# QAPP Preparation

**Prepared by: Jessica L. Keener**

Jessica L. Keener

03/08/10

Solutions-IES Project Manager | Date

**Reviewed and Approved by: M. Tony Lieberman**

M. Tony Lieberman

03/08/10

Solutions-IES Project QA/QC Manager | Date

## 1.0 PURPOSE AND SCOPE

The Work Plan outlines the procedures for constructing and implementing the *in situ* bioremediation project at the NAS Pensacola Site. The purpose of this Sampling and Analysis Plan (SAP) / Quality Assurance Project Plan (QAPP) is to provide guidelines that, when followed, will optimize the potential to obtain high quality field and laboratory data during the implementation and monitoring of the enhanced bioremediation pilot system. This SAP/ QAPP describes methodologies for sampling and analysis of environmental media, proper record keeping protocols, data quality objectives, and procedures for data review. The overall objective of the QA program is to obtain and evaluate project-specific data that are accurate, precise, complete, adequately documented, and representative of actual field conditions to allow verification of the performance of the enhanced *in situ* anaerobic bioremediation technology for treating chlorinated solvents in groundwater.

## 2.0 PROJECT ORGANIZATION

**Figure 1** provides the organizational chart for the project. The roles and responsibilities of relevant project personnel are summarized below.

Project Manager: Responsible for providing overall project direction, coordination with NAVFACE SE and FDEP, and final review and approval of reports. Additionally responsible for project coordination, scheduling, budget management, technical oversight, and report preparation.

Senior Project Advisor/Consultant: Responsible for providing technical design direction.

QA Officer: Responsible for ongoing review, monitoring, auditing, and evaluation of the field and laboratory QA/QC program. Final review of project deliverables.

Field Services Manager: Responsible for implementation of field QA/QC procedures, oversight of field team, and coordination with subcontractors.

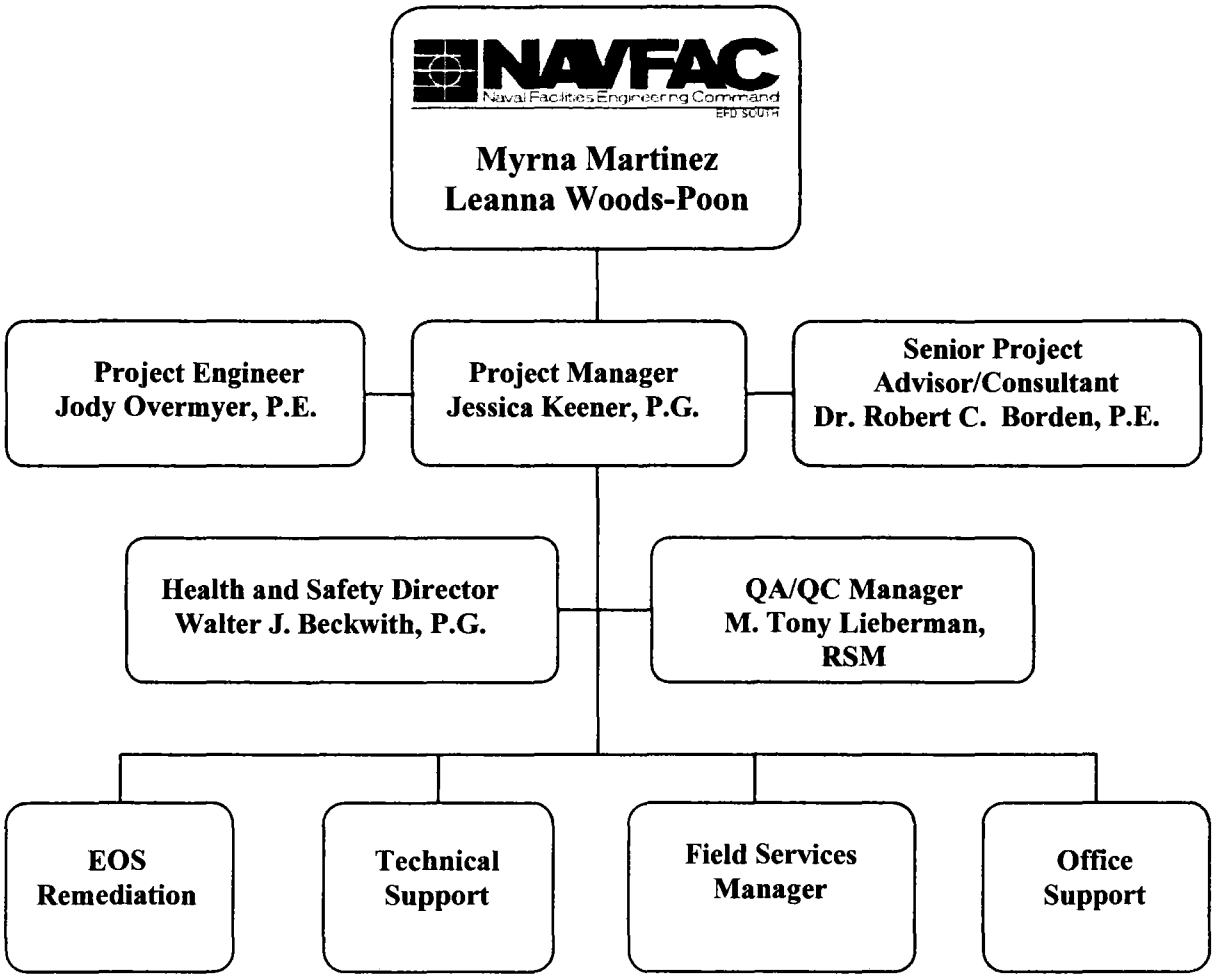



**Figure 1. Organizational Chart**

## 3.0 DATA QUALITY OBJECTIVES

The overall quality assurance objective is to ensure that data of known and acceptable quality are produced during the pilot study. Proper execution of each task will yield reliable data that are representative of media and conditions measured and are useful for meeting the intended project objectives. Data Quality Objectives (DQOs) are statements of the level of uncertainty that a decision maker is willing to accept in results derived from environmental data. These are developed for specific projects.

## 3.1 OBJECTIVES FOR WATER-LEVEL MEASUREMENTS

Water-level measurement is a critical aspect of any groundwater evaluation. Water-level measurements are required during the course of the project to evaluate the impact of injection on the water table during injection as well as consistency of the natural elevation of the aquifer pre- and post-injection. Water levels will be measured by sampling team personnel during all sampling events. Water levels will be measured with an electronic measuring device. Water-level measurements will be recorded to the nearest one-hundredth of a foot, and the data will be referenced to surveyed top of casing data to determine groundwater elevations. The downhole water level tape will be cleaned and decontaminated between wells as described in Section 6.2 of this QAPP.

## 3.2 OBJECTIVES FOR FIELD MEASUREMENTS IN AQUEOUS MEDIA

Field analyses will be performed on aqueous samples collected from monitoring wells in accordance with the Work Plan. Measurements of pH, temperature, and specific conductance will be collected to assure that an adequate purge has been achieved prior to actual sample collection and to evaluate changes in aquifer conditions during the course of the project. Quality assurance objectives for these parameters are presented as follows:

- pH – Measurements remain constant within 0.2 standard units.
- Specific Conductance - Measurements vary by no more than 5 percent.
- Temperature - Measurements remain constant within 0.2 degrees.

Descriptions of the calibration and measuring procedures for these field instruments are provided in Section 5.1.

## 3.3 OBJECTIVES FOR AMBIENT AIR AND VOLATILE GAS MONITORING

Field analyses of ambient air quality will be performed as part of the site-specific health and safety program. Field measurements will be performed with a Photoionization Detector (PID) containing an 11.7 eV bulb. The calibration and measurement procedures for the instrument are described in Section 5.1.2. Ambient air quality will be performed during drilling operations and sampling activities. Details regarding the upper limits and response actions are detailed in the HASP developed for this project.

## 3.4 OBJECTIVES FOR MEDIA SAMPLE ANALYSES

The analytical level is appropriate for the following data uses that are applicable to this project:

- Site characterization;
- Injection design;
- Monitoring during implementation.

The QA objectives for precision and accuracy established by contract laboratories are available upon request.

## 4.0 QC CHECKS, AND CORRECTIVE ACTION

### 4.1 FIELD QUALITY ASSURANCE AND QUALITY CONTROL CHECKS

Solutions-IES will collect field quality control (QC) samples during implementation of field activities to assess the quality of field procedures, preservation reagents, and sample bottles and the reliability of sample shipping and storage procedures. Trip blanks will be prepared by the laboratory and shipped and analyzed for each cooler containing volatile organic compound (VOC) samples.

As part of the overall project QA program, field duplicate samples, trip blank samples, and temperature blank samples will be collected for selected constituents. These field QC samples will be collected at the same time as the field samples and in the same type of containers. The QC samples will be handled in an identical manner as the field samples and shipped to the laboratory for analysis of the same constituents by the same analytical procedures as the field samples.

Field QC samples will include one or more of the following:

- Field Duplicates – Sample aliquots taken from the same sampling device (tubing, Geoprobe sleeve, etc.) and sent to the same analytical laboratory for identical analyses. Field Duplicates will be prepared at a frequency of one per 10 samples per media-type sampled.
- Trip Blanks – Laboratory prepared water in appropriately preserved containers which accompany sample bottles from time of shipment to the site until samples are sent back to the laboratory for analyses. Trip blanks are used in association with samples for VOC analysis at a frequency of one per cooler per shipment.
- Temperature Blanks – Temperature blanks consist of small plastic bottles of water, filled at the laboratory, and shipped with the sample containers. One temperature blank will be placed in each cooler returned with samples to the laboratory. The laboratory custodian will measure the temperature of the cooler at the time it is received by the laboratory and record the result on the chain-of-custody form. Temperature blanks are not labeled.
- Field QC samples will be labeled accordingly:
  - Field Duplicates – DUP- (1,2,3…)
  - Trip and Temperature Blanks – Usually arrive pre-labeled, but, if not, they are labeled as TB- (1,2,3…)

### 4.2 LABORATORY QUALITY ASSURANCE AND QUALITY CONTROL CHECKS

The analytical chemistry contract laboratories for this project (Test America Laboratory and Microseeps Laboratory) will demonstrate the ability to produce acceptable results using the procedures recommended by the analytical method. The data will be evaluated by the laboratory based on the following criteria (as appropriate for organic and inorganic chemical analyses):

- Method performance is evaluated using the following QC checks:
  - Calibration curve linearity
  - Blank contamination
  - Initial and continuing calibration standards
  - Spike recoveries (matrix and surrogate)
  - Relative Percent Differences (RPDs) between matrix spikes and matrix spike duplicates, samples and laboratory duplicates
  - Recoveries of laboratory control samples and independent QC check samples

- Percent recovery of internal standards
- Percent recovery of surrogate compounds
- Adequacy of detection limits obtained
- Precision of replicate analyses

The molecular biology test (MBT) laboratory for this project is Microbial Insights. The method performance checks and other recovery checks conducted by analytical chemistry laboratories do not apply to MBT analyses. Specific QA/QC procedures are included in each laboratory's QA/QC Plan which is available upon request.

## 4.3 PERFORMANCE AND SYSTEM AUDITS

Performance audits monitor the accuracy and precision of the analytical systems through the submission and analysis of control samples. System audits assess how closely the QAPP is adhered to during all phases of field data collection, sample collection, sample shipping, sample analyses, and data reduction and reporting. These audits may be conducted if it is deemed necessary. Performance and system audits for sampling and analysis operations consist of review of field and laboratory procedures and QA systems and review of equipment for sampling, calibration, and measurement.

### 4.3.1 Field System Audit

Solutions-IES' field team leader may evaluate the performance of field personnel and general field operations in progress. The auditor will compare the performance of the field team during field activities (such as water-level measurements and sample collection) with the procedures specified in the QAPP.

### 4.3.2 Performance Evaluation Audits

A performance evaluation (PE) audit evaluates a laboratory's ability to obtain an accurate and precise answer in the analysis of a known check sample by a specific analytical method. Following the analytical data validation, a PE audit of the laboratory may be requested and conducted by Solutions-IES. This audit may be conducted if it is determined that the QA data provided in the analytical data package is outside acceptance criteria control limits. These PE audits may include a review of all raw data developed by the laboratory and not reported (laboratory non-reportables) and the submission of blind spike check samples for the analysis of the parameters in question. These check samples may be submitted disguised as field samples, in which case the laboratory will not know the purpose of the samples, or the samples may be obvious (known) check samples (USEPA or NIST traceable).

PE audits also may be conducted by reviewing the laboratory's results from "round-robin" certification testing and/or USEPA CLP evaluation samples. An additional component of PE audits includes the review and evaluation of raw data generated from the analysis of PE samples and actual field samples that may be in question.

## 4.4 INSTRUMENT PREVENTIVE MAINTENANCE

### 4.4.1 Field Equipment

Records of calibration and preventive maintenance performed while collecting samples will be documented on field forms or in the field log book for this project during sampling. Solutions-IES standard procedures for calibration and operation of field equipment are provided are available upon request. All personnel have been trained in the correct operation and maintenance of the field equipment and have hands-on experience with the equipment on multiple sites.

### 4.4.2 Laboratory Equipment

All instruments must be operating properly at all times to obtain reliable analytical data. To ensure that instruments are operating properly, rigorous maintenance and trouble-shooting procedures must be followed.

All laboratory instruments, including inductively coupled plasma spectrometers, graphite furnace and cold-vapor atomic absorption spectrophotometers, gas chromatographs, and gas chromatography/mass spectrometry (GC/MS) systems, and others, undergo regular maintenance as prescribed in the manufacturer's operations manual for each of the instruments. Trouble-shooting procedures also are carried out for each instrument according to instructions in the operations manual. Specific preventative maintenance procedures are presented in the contract laboratories' QA/QC Plans which are available upon request. Deviations from acceptable limits will be noted in a case narrative that accompanies each analytical report.

## 4.5 ASSESSMENT OF DATA PRECISION, ACCURACY, AND COMPLETENESS

Brief descriptions of protocols that will be used to assess the precision, accuracy and completeness of the analytical data are provided below. Detailed methods used to assess precision and accuracy of data by the analytical laboratory are provided in their QA/QC Plans.

### 4.5.1 Precision

Precision is an estimate of the reproducibility of a method, and it may be estimated by several statistical tests, including the coefficient of variation and the relative percent difference (RPD) between duplicate samples. For the field sampling activities, precision will be evaluated by calculating the RPD for laboratory and field duplicate samples. The calculated RPD then will be compared to the precision criteria established by the laboratory for analysis of laboratory duplicates.

### 4.5.2 Accuracy

The accuracy of a method is an estimate of the difference between the true value and the determined mean value. Certain QC samples, such as laboratory control samples, reagent water spike samples, QC check samples, matrix spike samples, and surrogate spike samples, have known concentrations prior to analysis. By comparing the percent recovery of the analysis of these samples to the known true value, it is possible to measure the accuracy of the analysis.

The laboratory collects recovery data for each of these parameters from approximately 30 analytical batches during routine analysis. The percent recovery data are averaged and the standard deviation of the percent recoveries is calculated. Ranges are established as practical control limits based on the desired

level of confidence. Control charts are constructed, and the calculated range becomes the practical control limits used by the laboratory until another set of data is developed and new control limits are calculated.

### 4.5.3 Completeness

Data completeness will be expressed both as the percentage of total tests conducted that are deemed valid and as the percentage of the total tests required in the scope of work that are deemed valid.

## 4.6 DATA REDUCTION AND VALIDATION

The contract laboratories will utilize USEPA precision and accuracy criteria as guidance for data validation. Specific objectives for accuracy (percent recovery) and precision (relative percent difference) of the analytical measurements are presented in the laboratory's QA/QC Plans. Additional documentation of analytical QA data will be available upon request to the laboratory to support validation conclusions and data usability determinations if increased defensibility of laboratory report data is required.

### 4.6.1 Review of Field Data Package

The field data package will be reviewed by Solutions-IES for completeness and accuracy. The field data package includes all of the field records and measurements developed by the sampling team personnel. Failure in any of these areas may result in data being invalidated. The field data package review procedures will consist of:

- A review of field data contained in the sampling logs for accuracy and completeness.
- A verification that samples, field duplicates, and trip blanks were properly prepared, preserved, and identified.
- A check of field analyses for equipment calibration and instrument condition.
- A review of the chain-of-custody forms for proper completion, signatures of field personnel, and the laboratory sample custodian and dates.

### 4.6.2 Validation of the Analytical Data Package

Validation of the analytical data package will be performed by each laboratory. The validation steps will be performed by applying, where appropriate, the most current USEPA Laboratory Data Validation Functional Guidelines For Evaluating Inorganics Analyses (USEPA 2/94) and Organic Analyses (USEPA 12/94), and the precision and accuracy statements specified in the laboratory QA/QC Plan. Third party, outside data validation, is not a part of this project.

The analytical data package validation procedure will include:

- A comparison of the data package to the reporting level requirement to ensure completeness in the analytical data package.
- A comparison of sampling dates, sample extraction dates, and analysis dates to check that samples were extracted and/or analyzed within proper holding times.
- A review of the field and laboratory blanks to evaluate possible contamination sources.
- A review of QC check sample spike results and expected values (initial and continuing calibration verification standards) for inorganics analysis, to ensure that the recoveries are within the established control limits specified in the Laboratory QA/QC Plan.

- A review of the field replicate sample data, to check the precision of the chemical analyses and field sample collection techniques. Laboratory duplicates for solid and water matrices, if available, will also be reviewed.
- A review of the surrogate spike results and expected values for organic analyses to ensure that recoveries are within the control limits specified in the Laboratory QA/QC Plan.
- A review of the matrix and matrix duplicate spike results and expected values for inorganic and organic analyses to ensure that recoveries are within the established control limits specified in the Laboratory QA/QC Plan.

## 4.7 CORRECTIVE ACTION

### 4.7.1 Field Conditions

Field personnel are responsible for ensuring that field instruments are functioning properly, that work progresses satisfactorily, and that work is performed in compliance with this QAPP. If a problem is detected by the field personnel, the Solutions-IES Project Manager shall be notified immediately by the Field Services Manager, at which time the problem will be investigated further and corrective action will begin.

### 4.7.2 Laboratory Corrective Action

Data evaluations necessary to verify proper analytical function must be performed as early as possible in the analysis program within the time constraints imposed by individual analysis procedures. Laboratory corrective actions are noted in the laboratories' QA/QC Plans that are available upon request.

### 4.7.3 Reporting of Corrective Actions

A written report describing the nature of a corrective action case with an evaluation of the cause, if known, and the action taken, will be prepared by the Solutions-IES Field Services Manager or Project Manager. The report will be distributed to the Solutions-IES Project Manager (if not preparing the report).

All corrective actions taken by the contracted laboratory will be reported to the Solutions-IES Project Manager. The laboratory will include in each data package a discussion of the problems encountered and corrective actions taken. In addition, the laboratories will maintain a file for Solutions-IES' review that documents all corrective actions taken regardless of whether the actions performed were pertinent to the analysis of sample from Solutions-IES' project.

# 5.0 ANALYTICAL PROCEDURES

## 5.1 FIELD ANALYTICAL PROCEDURES

Groundwater parameters including DO, ORP, conductivity, pH, temperature, turbidity and water levels will be measured in the field. During soil boring and well installation, ambient air conditions will be monitored as part of the health and safety program.

### 5.1.1 Field Meter Usage

Field SOPs have been developed to provide a uniform basis for calibration of field meters and to ensure continuity between field personnel. Calibration of field equipment, such as pH meters, DO meters, ORP meters, specific conductance meters and PIDs will be performed according to the procedures outlined in the equipment instruction manuals. Calibration of field equipment will be conducted each day the equipment is used in the field prior to use. Results of the calibrations will be recorded in the field log book. Copies of Solutions-IES' SOPs for field equipment are available upon request. Wherever possible, the same field meters should be used to monitor from event to event.

### 5.1.2 Headspace Analysis

The following methodology will be followed when measuring organic vapors emitted from soil samples collected from the Macro-Core® sleeves.

Procedure:

1. Soil samples are collected from the Geoprobe® sleeve and a portion of the sample is packaged in a resealable plastic bag. The bag is sealed maintaining a headspace and labeled to identify the boring number and sample collection depth.
2. The plastic bag containing the sample should be shaken to allow for the volatilization of soil gases into the available headspace.
3. Calibrate and prepare PID for use.
4. After approximately 20 minutes in ambient conditions, carefully open the top of the plastic bag, taking care not to release any trapped gases, and insert the PID probe. Allow headspace gases to be drawn through the unit.
5. Record the highest response obtained on the appropriate sampling log or in the field log book.
6. Seal the plastic bag.
7. Allow instrument to return to zero and repeat procedure for next sample.

## 5.2 Laboratory Analytical Procedures

The analytical procedures and reporting limits used during the implementation of the Work Plan are presented in Table 6-1. Analyses of samples collected will be performed by Test America Laboratories, Microbial Insights, and Microseeps Laboratory in accordance with protocols and procedures established by the USEPA. The calibration procedures and calibration frequency employed by the contracted laboratories are described in their QA/QC Plans.

# 6.0 SAMPLING AND ANALYSIS PLAN

## 6.1 GROUNDWATER SAMPLING

Groundwater samples will be collected on a quarterly basis from select groundwater monitoring wells to evaluate the performance of the injection. Samples will be collected prior to injection activities to develop a baseline from which to identify trends. Samples will then be collected a several intervals for a period of one year. Groundwater samples will be collected from a total of nine on-site monitoring wells located within and downgradient from the treatment area. **Table 1** summarizes the groundwater sample locations and analysis to be performed as part of the sampling events.

### 6.1.2 Groundwater Sample Collection Procedures

Groundwater samples will be collected from on-site monitoring wells to evaluate the effectiveness of the full-scale remediation. Nine existing monitoring wells were selected based on their locations with respect to the plume's configuration and flow direction at the site. Five of these monitoring well will be sampled as part of the standard baseline and post-injection monitoring. Four additional wells will be sampled during the baseline and select post-injection monitoring events for an expanded suite of analytes as described in Table 1. Three additional monitoring wells were installed for performance monitoring purposes.

Groundwater sample collection will be accomplished in three steps: (1) measurement of the water level in the well, (2) purging of water from well casing; and (3) collection of samples for analysis. Purging of water will be performed with a peristaltic pump utilizing low-flow methodology. Solutions-IES' SOP for low-flow purging and sampling is available upon request. Purging will be conducted in accordance with the Florida Department of Environmental Protection (FDEP) sampling protocol (FDEP 2008). Purging of each well will continue until field parameters have stabilized. Field parameters including pH, temperature, turbidity, and specific conductance will be measured every three to five minutes until these parameters stabilize. The criteria to be used to determine stabilization is as follows:

- Temperature: $\pm$0.2° C;
- pH: $\pm$0.2 Standard Units;
- Specific Conductance: $\pm$5.0% of reading; and
- Turbidity: $\leq$20 NTU (or $\pm$ 5 NTUs or 10%).

Field measurements will be recorded in the logbook and on field forms provided for this project. After an adequate purge is achieved, the groundwater samples will be collected in the appropriate laboratory-prepared sample containers. Certain samples must be preserved at the time of sampling. The sample bottles will have the appropriate preservative added to the bottle by the laboratory prior to shipment to the site. Care will be taken to prevent water to fill bottles and overflow to minimize potential dilution of preservatives. Immediately after collection, the sample containers will be placed on ice in an insulated cooler at 4 °C for shipment to the laboratory.

### 6.1.3 Sample Collection for Volatile Organic Compounds

All groundwater samples will be collected utilizing low-flow sampling methodology. Groundwater samples collected for VOC analysis will be the last sample collected from each sampling location. The peristaltic pump will be used to fill the sampling tubing with groundwater. The pump will be stopped and the groundwater in the tubing will be retained in the tubing. The tubing will be quickly removed from the well. Groundwater in the tubing will be allowed to gravity drain into the sample container, minimizing aeration of the sample. Sample containers will be filled and sealed without headspace.

### 6.1.4 Sample Collection for Microbial Analysis

Groundwater samples will be collected to determine the existence of the bacterial populations and enzyme function within the pilot study including: *Dehalococcoides spp.* ethenogenes (*DHC*), *Dehalococcoides spp.* strain BAV1 (BAV 1), total eubacteria (EBAC), iron and sulfate reducing bacteria (IRB/SRB), *Dehalobacter spp.* (DHB), TCE reductase, VC reductase and BAV1 VC reductase (BVC). Samples for bacteria enumeration will be evaluated using an approach known as quantitative real-time polymerase chain reaction (qPCR), to determine if the bacteria populations are present and quantify the population size. In addition, RNA will be extracted to evaluate if the genes responsible for reductive dechlorination are being expressed in the existing populations.

Groundwater will be pumped through a bio-filter to trap any existing biological material. The filter will be connected in-line with the peristaltic pump. Approximately 1 to 2 liters of groundwater will be pumped through each filter. Due to potential clogging, multiple filters may be required to reach the required volume. The total volume of water passed through each filter will be recorded prior to submitting the filters for analysis. An SOP for sampling with the bio-filter is provided in QAPP/SAP **Appendix C.1.**

## 6.2 SOIL SAMPLING

In order to confirm the target treatment zone within the unconsolidated aquifer, continuous sampling of the aquifer material will be conducted from five soil borings. Samples will be collected from the Geoprobe® using 2 to 3- foot long Macro-Core® sleeves. The sleeves will be cut in half and the material will be described utilizing the Unified Soil Classification System (USCS) by an experienced Geologist. Additional information such as degree of compaction, staining and identifiable odors will be documented in the field log book. Select samples will be collected for head-space analysis as described in Section 5.1.2. Soil samples will not be submitted for laboratory analysis.

Following the completion of field activities, lithological information will be transferred to a boring log to be developed for each soil boring. The boring log will include a description of the lithology, sample intervals collected and results of the head-space analysis.

## 6.3 EQUIPMENT CLEANING AND DECONTAMINATION PROCEDURES

Sampling equipment cleaning procedures will be conducted in accordance with procedures specified in the Field Branches Quality System and Technical Procedures (USEPA Region 4, SESDPROC-205-R1, November 1, 2007). The cleaning procedures specified in this section are to be used by sampling personnel to decontaminate sampling and other field equipment prior to use and in between sampling locations.

Deionized water will be used during cleaning procedures for field equipment and to prepare soap solutions. The laboratory detergent used for equipment decontamination will be a standard brand of phosphate-free laboratory detergent such as Alquinox™ or Liquinox™. When possible, equipment will be decontaminated at a central staging area. Solutions and rinse water will be collected and disposed of with the other wastewater generated during this work.

# 7.0 INSTALLATION AND MEASUREMENT OF MONITORING WELLS AND TEMPORARY INJECTION WELLS

## 7.1 WELL INSTALLATION

Direct-push Geoprobe® technology will be used to advance boreholes for soil sample collection and temporary well installation. The temporary injection wells will be constructed of 1-inch diameter PVC casing and screens. The natural sand formation will be allowed to collapse around the well screen and riser. The remaining annular space will be filled with bentonite to a thickness of at least 3-feet.

Borings will also be advanced using Hollow-Stem drilling techniques for monitoring well construction. The monitoring wells will be constructed of 2-inch diameter PVC casing and screens. New well casing and screens will be used and will be connected via threaded joints. A natural or artificial filter pack will

extend to approximately 2 feet above the top of the well screen. The annular space between the casing and the borehole wall will be filled with a neat cement grout. Neat cement grouts should be mixed using no more than 6 gallons of water per 94-lb bag of Type 1 Portland cement. The addition of bentonite (5 to 10 percent) to the cement grout is generally used to delay the "setting" time and may not be needed in all applications. The specific mixtures and other types of cement and/or grout proposed should be evaluated on a case by case basis by the field geologist. An above ground protective casing should be installed around each permanent monitoring well. Concrete should be placed into the pad forms and into the borehole (on top of the grout) in one operation making a contiguous unit. The size of the concrete surface pad is dependent on the well casing size.

### 7.2 WELL DEVELOPMENT

A newly completed monitoring well should not be developed for at least 24 hours after the surface completion is installed. This will allow sufficient time for the well materials to cure before development procedures are initiated. The main purpose of developing new monitoring wells is to remove the residual materials remaining in the wells after installation has been completed, and to try to reestablish the natural hydraulic flow conditions of the formations which may have been disturbed by well construction around the immediate vicinity of each well. A new monitoring well should be developed until the column of water in the well is free of visible sediment, and the pH, temperature, turbidity, and specific conductivity have stabilized.

Caution should be taken when using high rate pumps and/or large volume air compressors during well development because excessive high rate pumping and high air pressures can damage or destroy the well screen and filter pack. The onsite geologist should make the decision as to the development completion of each well. All field decisions should be documented in the field log book.

## 8.0 SAMPLE CUSTODY, HANDLING, AND SHIPMENT

### 8.1 FIELD RECORDS

The key aspect of documenting sample custody is thorough record keeping. Daily records will be completed in the field logbook and on field forms provided for this project during field activities to document the collection of samples. All documents will be completed in ink, dated, and signed by the field person conducting the work. A copy of the field forms to be used for this project is provided in **Appendix C.2**.

### 8.2 SAMPLE LABELING

Samples collected for chemical analysis will be fully labeled at the time of collection. At a minimum, the sample label information will include the sample identification, the date and time of collection, sample matrix, the analyses requested, the preservatives used, and the initials of the personnel collecting the sample. The sample collection data and the information contained on the label will be recorded on the field forms or in the field logbook as the samples are collected.

### 8.3 SAMPLE CONTAINER CUSTODY

All sample containers to be provided by the subcontract laboratories for this project will be new, pre-cleaned, and pre-baked according to the procedures specified in the analytical methods. If the laboratory doing the MBTs provides pre-sterilized jars, it should be noted and the containers handled appropriately in the field. All containers will be shipped from the laboratories to the designated location by common

carrier in sealed coolers. The laboratory will include a shipping form listing all containers shipped and the purpose of each container.

### 8.4 SAMPLE CUSTODY, SHIPMENT, AND LABORATORY RECEIPT

All samples will be maintained in the custody of the sampling personnel. At the end of each sampling day prior to the transfer of the samples off-site, chain-of-custody entries will be made for all samples using the standard chain-of-custody form. All information on the chain-of-custody form and the sample container labels will be checked against the sample field log entries and samples will be recounted before leaving the sampling site. Upon transfer of custody, the chain-of-custody form will be signed and dated by the sample team leader. Because common carriers (Federal Express, Airborne Express, etc.) will not sign chain-of-custody forms, the forms will be sealed in the cooler prior to shipping. All chain-of-custody forms sent to the laboratory must be signed and dated by the sample team member shipping the samples.

Upon receipt of the samples at the laboratory, the laboratory sample custodian will note the condition of each sample received as well as any questions or observations concerning sample integrity. The laboratory custodian will also measure the temperature of the samples by measuring the temperature of the Temperature Blank that was placed in each cooler. The temperature will be recorded on the chain-of-custody form. The laboratory sample custodian also will maintain a sample-tracking record that will follow each sample through all stages of laboratory processing. The sample tracking records will document sample removal from storage as well as the date of sample extraction or preparation and sample analysis. These records will be used to determine compliance with handling and holding time requirements. Samples will be stored by the laboratory in their original containers in refrigerators designated by the contracted laboratories.

## 9.0 HANDLING AND DISPOSAL OF INVESTIGATION-DERIVED WASTE

The types of investigation-derived waste (IDW) expected to be generated during the technology demonstration project include:

- personal protective equipment (PPE), including disposable gloves, booties, etc.;
- drill cuttings from the installation of wells and borings;
- groundwater removed during well development and well purging/evacuation;
- spent equipment cleaning fluids, such as detergent solution, and rinse water; and
- clean materials including cardboard boxes, plastic sheeting and rinsed drums. These will be handled as non-hazardous solid waste and will be disposed of on site.

IDW will be properly contained in 55-gallon drums. Solutions-IES will coordinate with the NAS Environmental Department to locate a proper storage area for the drums pending waste characterization and subsequent disposal.

## 10.0 REFERENCES

Florida Department of Environmental Protection (FDEP), 2008. *DEP Standard Operating Procedures for Groundwater Sampling, DEP FS2200 SOP 001/01.* December.

U.S. Environmental Protection Agency (USEPA), 1996. *Environmental Compliance Branch Standard Operating Procedures and Quality Assurance Manual.* Region IV, Environmental Services Division, Athens, GA. May 2001.

U.S. Environmental Protection Agency (USEPA), 1994. *National Functional Guidelines for Organic Data Review. USEPA Contract Laboratory Program.* December.

U.S. Environmental Protection Agency (USEPA), 1994. *National Functional Guidelines for Inorganic Data Review. USEPA Contract Laboratory Program.* February.U.S. Environmental Protection Agency (USEPA), 1988. *Laboratory Data Validation Functional Guidelines for Evaluating Inorganics Analyses.* USEPA Hazardous Site Evaluation Division. July. U.S. Environmental Protection Agency (USEPA), 1986. *Test Methods for Evaluating Solid Waste.* Third Edition with Revisions and Updates – SW-846. Office of Solid Waste and Emergency Response, Washington, DC. November.

# TABLES

**TABLE 1**
**SAMPLE LOCATIONS AND ANALYTICAL SUMMARY**
NAS PENSACOLA
PENSACOLA, FLORIDA
SOLUTIONS-IES PROJECT NO.: 3911.09A3.NAVF

| Laboratory | Analysis and Method | Matrix | QA Sample Types | # QA Samples | # Sampling Locations/ Intervals | September 2009 Initial Data Collection | Pre-Injection Baseline - Expanded | 1st Post-Injection Performance Monitoring (2 months) | 2nd Post-Injection Performance Monitoring- Expanded (4 months) | 3rd Post-Injection Performance Monitoring (8 months) | 4th Post-Injection Performance Monitoring - Expanded (12 months) | Total Number of Samples |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Microbial Insights | EBAC, DHC, TCE R-dase, VC R-dase, BAV1, BVC, DHB, IRB/SRB, MGN | Groundwater | -- | 0 | 5 | 0 | 5 | 0 | 5 | 0 | 5 | 15 |
| Test America | VOCs - 8260 | Groundwater | TB & Dup. | 2 | 9 | 11 | 11 | 11 | 11 | 11 | 11 | 66 |
| | Sulfate - 375.4 | Groundwater | Dup. | 1 | 9 | 10 | 10 | 10 | 10 | 10 | 10 | 60 |
| | TOC - 415.1 | Groundwater | Dup. | 1 | 9 | 10 | 10 | 10 | 10 | 10 | 10 | 60 |
| | TC & TIC - 415.1 | Groundwater | Dup. | 1 | 9 | 10 | 10 | 10 | 10 | 10 | 10 | 60 |
| | Acidity - SM2310B | Groundwater | Dup. | 1 | 9 | 10 | 10 | 10 | 10 | 10 | 10 | 60 |
| | Sulfide, Total -- SM4500 S2F | Groundwater | Dup. | 1 | 9 | 10 | 10 | 10 | 10 | 10 | 10 | 60 |
| | Iron, Total - 6010B | Groundwater | Dup. | 1 | 9 | 10 | 10 | 10 | 10 | 10 | 10 | 60 |
| | Manganese, Total - 6010B | Groundwater | Dup. | 1 | 9 | 10 | 10 | 10 | 10 | 10 | 10 | 60 |
| | Sodium, Total - 6010B | Groundwater | Dup. | 1 | 9 | 10 | 10 | 10 | 10 | 10 | 10 | 60 |
| | Potassium, Total - 6010B | Groundwater | Dup. | 1 | 9 | 10 | 10 | 10 | 10 | 10 | 10 | 60 |
| | Magnesium, Total - 6010B | Groundwater | Dup. | 1 | 9 | 10 | 10 | 10 | 10 | 10 | 10 | 60 |
| | Calcium, Total - 6010B | Groundwater | Dup. | 1 | 9 | 10 | 10 | 10 | 10 | 10 | 10 | 60 |
| | Chloride, Total 325.2 | Groundwater | Dup. | 1 | 9 | 10 | 10 | 10 | 10 | 10 | 10 | 60 |
| | pH - 150.1 | Groundwater | Dup. | 1 | 9 | 10 | 10 | 10 | 10 | 10 | 10 | 60 |
| | Alkalinity - 310.1 | Groundwater | Dup. | 1 | 9 | 10 | 10 | 10 | 10 | 10 | 10 | 60 |
| Test America | TOC -415.1 | Soil | Dup. | 1 | 6 | 7 | -- | -- | -- | -- | 7 | 14 |
| | Alkalinity - 310.1 | Soil | Dup. | 1 | 6 | 7 | -- | -- | -- | -- | 7 | 14 |
| | Soil pH | Soil | Dup. | 1 | 6 | 7 | -- | -- | -- | -- | 7 | 14 |
| Chemetrics Kits | Dissolved Oxygen | Groundwater | -- | 0 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 54 |
| | Sulfide | Groundwater | -- | 0 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 54 |
| MicroSeeps | AMIBA | Soil | -- | 0 | 6 | 6 | -- | -- | -- | -- | 6 | 12 |
| | Stable Isotopes (TCE, cDCE, VC) | Groundwater | -- | 0 | 0 | 0 | 5 | 0 | 5 | 0 | 5 | 15 |
| | VFAs by Ion Chromatography | Groundwater | -- | 0 | 0 | 0 | 5 | 0 | 5 | 0 | 5 | 15 |
| | Methane, ethane, ethene (MEE) | Groundwater | Dup. | 1 | 9 | 10 | 10 | 10 | 10 | 10 | 10 | 60 |
| Geotechnologies | Grain Size Analysis (200 wash + hydrometer) | Soil | -- | 0 | 12 | 12 | -- | -- | -- | -- | -- | 12 |

Monitor Wells (9) for Regular Monitoring: AE-02 (background), AE-01, USGS-5, GM-66R, GM-67, SI-01, SI-03, SI-04 and SI-05.
Monitor Wells (5) for Expanded Monitoring: AE-01, SI-01, SI-03, SI-04 and SI-05.
AMIBA includes: Acid Volatile Sulfides, Chromium Extractable Sulfides, Stong Acid Soluble Metals, Weak Acid Soluble Metals, Bioavailable Ferric Iron, and Bioavailable Manganese.

Acronyms:

| | |
|---|---|
| EBAC | Eubacteria |
| DHC | Dehalococcoides spp. |
| TCE R-Dase | Trichloroethene Reductive Dehalogenase |
| VC R-Dase | Vinyl Chloride Reductive Dehalogenase |
| BAV1 | Strain of Dehalococcoides spp. |
| BVC | BAV1 VC R-dase |
| DHB | Dehalobacter spp. |
| IRB/SRB | Iron and Sulfate Reducing |
| MGN | Methanogens |
| TOC | Total Organic Carbon |
| TC | Total Carbon |
| TIC | Total Inorganic Carbon |
| VFAs | Volatile Fatty Acids |

**TABLE 2**
**Sample Bottleware, Preservation, and Holding Times**

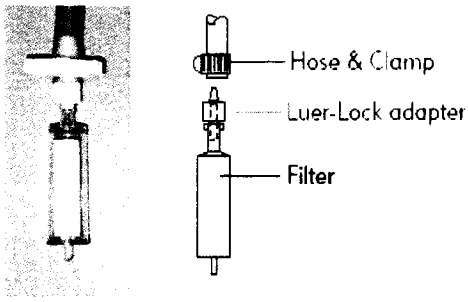
| Analyte | AnalyticalMethod | Reporting Limit | Sample Volume | Sample Container | Preservation | Holding Time |
|---|---|---|---|---|---|---|
| Volatile Organic Compounds | EPA 8260B | 1 µg/L | 3 – 40 mL | Glass volatile organic analysis (VOA) vials | Cool to 4° C; HCl to pH<2; zero headspace | 14 days |
| Sulfate | EPA 300.0 | 2.0 mg/L | 1 L | Plastic | Cool to 4° C; Unpreserved | 28 days |
| Total Organic Carbon | EPA 9060A | 1.0 mg/L | 250 mL | Amber, glass bottle | Cool to 4° C; HCl to pH<2 | 28 days |
| Methane, Ethane, Ethene | AM20GAX | 0.2 µg/L | 2 - 40 mL | Glass VOA vials | Cool to 4° C; unpreserved; zero headspace | 28 days |
| Volatile Fatty Acids | RSK 175 | 0.01 to 0.7 ppm | 2 – 40 mL | Glass VOA vials | Cool to 4° C | 14 days |
| Stable Isotopes | Isotope Ratio Mass Spectrometry | NA | 3 – 40 mL | Glass VOA vials | Cool to 4° C; HCl to pH<2; zero headspace | 14 days |
| Total Eubacteria | qEBAC | NA | 1-2 L | Bio-Flow Sampler Filter | None | NA |
| DHC, BAV1, IRB/SRB, DHB, MGN | qPCR | NA | 1-2 L | Bio-Flow Sampler Filter | None | NA |
| Enzymes (TCE R-Dase, VC R-Dase, BVC) | qBAV1 qTCE qBVC | NA | 2-4 L (1-2L through each filter) | Bio-Flow Sampler Filter (2 filters total) | 3 mL | NA |

# APPENDIX C.1
# BIO-FILTER SAMPLING SOP

microbialinsights

# Bio-Flo – DNA Sampling Protocol

## Sampling Instructions




1. Purge the well.
2. Prepare the pump (Peristaltic preferred, Grundfos, or air bladder) as normal. Use the clamp provided to ensure a leak-proof connection.
3. Remove the filter from Falcon tube.
4. Attach the inlet of the filter with a 1/4" - 5/16" inner diameter (I.D.) tubing using the clamp to secure.
5. Place the filter within a receiving container so that the amount of water filtered can be measured accurately.
6. The amount of water filtered will vary depending upon the turbidity of the water. We recommend filtering 1-2 L
7. Record the volume of water that passed through the filter, and then submit the filter for analysis. The water may then be discarded. Please cap the filter on both ends. The thinner end should be closed with the red rubber cap and the thicker end should be closed with the clear luer plug.

Note: If the filter clogs before 1L has been filtered, record how much water was passed through the first filter, and then collect an additional filter, also recording the volume of water that went through the second filter. In this case, both filters are then submitted for testing. For each location there should be **no more than 2 filters** used and there is no need to filter more than 2L of water.

*To Submit Sample:*

1. Place the filter in the Falcon tube provided.
2. Affix the label to the Falcon tube and note the amount of water that passed through the filter, the well location, sampling date, and the analyses requested.

## Shipping Instructions

*:kaging Samples:*

1. Samples should be shipped in a cooler with ice or blue ice for next day delivery. If regular ice is used, the ice should be double bagged.
2. A chain of custody form must be included with each shipment of samples. Access our chain of custody at www.microbe.com

*Shipment for Weekday Delivery:*

Samples for weekday delivery should be shipped to:

Sample Custodian
Microbial Insights, Inc.
2340 Stock Creek Blvd.
Rockford, TN 37853-3044
(865) 573-8188

*Shipment for Saturday Delivery:*

Coolers to be delivered on Saturday must be sent to our FedEx Drop Location. To ensure proper handling the following steps must be taken:

1. FedEx shipping label should be marked under (6) Special Handling, check Hold Saturday,
2. The cooler must be taped with FedEx SATURDAY tape.
3. The shipping label must be filled out with the Drop Location address below. Our laboratory name must be on the address label.
4. You MUST call Microbial Insights, Inc. with the tracking number of the package on Friday (prior to 4pm Eastern Time) to arrange for Saturday pickup. Without proper labeling and the tracking number, there is no guarantee that the samples will be collected

Samples for Saturday delivery should be shipped to:

Microbial Insights, Inc.
FedEx Drop Location
10601 Murdock Road
Knoxville, TN 37932
(865) 300-8053 or (865) 384-4005

**Note:** Samples received for Saturday Delivery will be frozen immediately upon receipt by Microbial Insights staff to minimize changes in the microbial community.

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Rockford, TN 37853-3044
Phone: 865.573.8188
Fax: 865.573.8133
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microbialinsights

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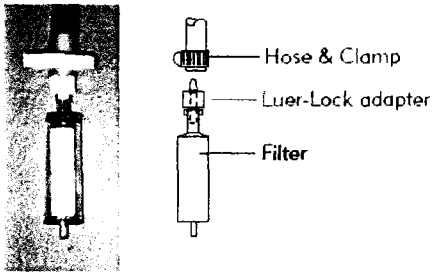
Email: info@microbe.com

## Bio-Flo Sampling Instruction — Q-Expression (RNA) /DGGE (RNA)

1. Prepare the pump (Peristaltic preferred, Grundfos, or air bladder) as normal. Use the clamp provided to ensure a leak-proof connection.
2. Remove the filter from Falcon tube.
3. Attach the inlet of the filter with a 1/4" - 5/16" inner diameter (I.D.) tubing using the clamp to secure.
4. Place the filter within a receiving container so that the amount of water filtered can be measured accurately.
5. The amount of water filtered will vary depending upon the turbidity of the water. We recommend filtering 1-2 L
6. Record the volume of water that passed through the filter, and then submit **the filter** for analysis. The water may then be discarded.




**Note:** If the filter clogs before 1L has been filtered, record how much water passed through the first filter, and then collect an additional filter, also recording the volume of water that went through the second filter. In this case, **Both filters** are then submitted for testing. For each location there should be **no more than 2 filters** used and there is no need to filter more than 2L of water.

7. **Immediately following collection, it is VITAL that each filter is preserved with 3mL of preservative.** Using the 3mL syringes (provided) load the syringe with 3mL of preservative, attach the filter onto the end of the syringe, and inject. After injection immediately place the filter back in a Falcon tube and store within a cooler.

### *To Submit Sample:*

1. Place the filter in the Falcon tube provided.
2. The label affixed to the Falcon tube should note the **amount of water** that passed through the filter, the **well location, sampling date,** and the **analyses requested.**

### *Shipping Instructions*

***Packaging Samples:***

1. Samples should be shipped in a cooler with ice or blue ice, with next day delivery. If regular ice is used, the ice should be double bagged.
2. A chain of custody form must be included with each shipment of samples. Access our chain of custody at www.microbe.com

***Shipment for Weekday Delivery:***

*Samples for weekday delivery should be shipped to:* **Sample Custodian**
**Microbial Insights, Inc.**
2340 Stock Creek Blvd.
Rockford, TN 37853-3044
(865) 573-8188

***Shipment for Saturday Delivery:***

Coolers to be delivered on **Saturday** must be sent to our FedEx Drop Location. To ensure proper handling the following steps must be taken:

1. FedEx shipping label should be marked under (6) Special Handling, check **Hold Saturday**,
2. The cooler must be taped with **FedEx SATURDAY tape.**
3. The shipping label must be filled out with the Drop Location address below. **Our laboratory name** must be on the address label.
4. You **MUST** call Microbial Insights, Inc. on Friday (prior to 4pm Eastern Time) to arrange for Saturday pickup. You must provide **the Tracking # of the package**. Without proper labeling and the tracking number, there is no guarantee that the samples will be collected

*Samples for Saturday delivery should be shipped to:* **Microbial Insights, Inc.**
FedEx Drop Location
1601 Murdock Road
Knoxville, TN 37932
(865) 300-8053 or
(865) 384-4005

# APPENDIX C.2
# FIELD FORM

# GROUNDWATER SAMPLING LOG

| SITE NAME: | SITE LOCATION: |
|---|---|

| WELL NO: | SAMPLE ID: | DATE: |
|---|---|---|

## PURGING DATA

| WELL DIAMETER (inches): | TUBING DIAMETER (inches): | WELL SCREEN INTERVAL DEPTH: feet to feet | STATIC DEPTH TO WATER (feet): | PURGE PUMP TYPE OR BAILER: |
|---|---|---|---|---|

**WELL VOLUME PURGE: 1 WELL VOLUME** = (TOTAL WELL DEPTH – STATIC DEPTH TO WATER) X WELL CAPACITY
only fill out if applicable)
= ( feet – feet) X gallons/foot = gallons

**EQUIPMENT VOLUME PURGE: 1 EQUIPMENT VOL.** = PUMP VOLUME + (TUBING CAPACITY X TUBING LENGTH) + FLOW CELL VOLUME
(only fill out if applicable)
= gallons + ( gallons/foot X feet) + gallons = gallons

| INITIAL PUMP OR TUBING DEPTH IN WELL (feet): | FINAL PUMP OR TUBING DEPTH IN WELL (feet): | PURGING INITIATED AT: | PURGING ENDED AT: | TOTAL VOLUME PURGED (gallons): |
|---|---|---|---|---|

| TIME | VOLUME PURGED (gallons) | CUMUL. VOLUME PURGED (gallons) | PURGE RATE (gpm) | DEPTH TO WATER (feet) | pH (standard units) | TEMP. (°C) | COND. (µmhos/cm or µS/cm) | DISSOLVED OXYGEN (circle mg/L or % saturation) | TURBIDITY (NTUs) | COLOR (describe) | ODOR (describe) |
|---|---|---|---|---|---|---|---|---|---|---|---|
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**WELL CAPACITY** (Gallons Per Foot): **0.75"** = 0.02; **1"** = 0.04; **1.25"** = 0.06; **2"** = 0.16; **3"** = 0.37; **4"** = 0.65; **5"** = 1.02; **6"** = 1.47; **12"** = 5.88
**TUBING INSIDE DIA. CAPACITY** (Gal./Ft.): **1/8"** = 0.0006; **3/16"** = 0.0014; **1/4"** = 0.0026; **5/16"** = 0.004; **3/8"** = 0.006; **1/2"** = 0.010; **5/8"** = 0.016

## SAMPLING DATA

| SAMPLED BY (PRINT) / AFFILIATION: | SAMPLER(S) SIGNATURES: | SAMPLING INITIATED AT: | SAMPLING ENDED AT: |
|---|---|---|---|
| PUMP OR TUBING DEPTH IN WELL (feet): | SAMPLE PUMP FLOW RATE (mL per minute): | TUBING MATERIAL CODE: | |
| FIELD DECONTAMINATION: Y N | FIELD-FILTERED: Y N FILTER SIZE: ____ µm<br>Filtration Equipment Type: _____ | DUPLICATE: Y N | |

| SAMPLE CONTAINER SPECIFICATION | | | | SAMPLE PRESERVATION | | | INTENDED ANALYSIS AND/OR METHOD | SAMPLING EQUIPMENT CODE |
|---|---|---|---|---|---|---|---|---|
| SAMPLE ID CODE | # CONTAINERS | MATERIAL CODE | VOLUME | PRESERVATIVE USED | TOTAL VOL ADDED IN FIELD (mL) | FINAL pH | | |
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REMARKS:

**MATERIAL CODES:** **AG** = Amber Glass; **CG** = Clear Glass; **PE** = Polyethylene; **PP** = Polypropylene; **S** = Silicone; **T** = Teflon; **O** = Other (Specify)

**SAMPLING/PURGING EQUIPMENT CODES:** **APP** = After Peristaltic Pump; **B** = Bailer; **BP** = Bladder Pump; **ESP** = Electric Submersible Pump; **PP** = Peristaltic Pump; **RFPP** = Reverse Flow Peristaltic Pump; **SM** = Straw Method (Tubing Gravity Drain); **VT** = Vacuum Trap; **O** = Other (Specify)

**NOTES: 1. The above do not constitute all of the information required by Chapter 62-160, F.A.C.**

2. STABILIZATION CRITERIA FOR RANGE OF VARIATION OF LAST THREE CONSECUTIVE READINGS (SEE FS 2212, SECTION 3)

**pH:** ± 0.2 units **Temperature:** ± 0.2 °C **Specific Conductance:** ± 5% **Dissolved Oxygen:** all readings ≤ 20% saturation (see Table FS 2200-2); optionally, ± 0.2 mg/L or ± 10% (whichever is greater) **Turbidity:** all readings ≤ 20 NTU; optionally ± 5 NTU or ± 10% (whichever is greater)