# WORK PLAN - ENHANCED IN SITU BIOCHEMICAL DEGRADATION PILOT TESTING

**IBM Gun Club – Former Burn Pit Area**
**Union, New York**

**Copied by SHPC-Maine**

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# WORK PLAN - ENHANCED IN SITU BIOCHEMICAL DEGRADATION PILOT TESTING

**IBM Gun Club – Former Burn Pit Area**
**Union, New York**

*Prepared for*
**IBM Corporate Environmental Affairs**

*Prepared by*
**Sanborn Head Engineering, P.C. with assistance from Sanborn, Head & Associates, Inc.**

File 3025.00
April, 2010

IBM

*8976 Wellington Road*
*Manassas, VA 20109*

April 9, 2010

Mr. Jonathan Greco
NYSDEC
625 Broadway
Albany, NY 12233-7016

Re: Work Plan - Enhanced In Situ Biochemical Degradation Pilot Testing
IBM Gun Club – Former Burn Pit Area
Union, New York

Dear Mr. Greco,

Enclosed is the Work Plan prepared by Sanborn, Head Engineering, PC. with the assistance of Sanborn, Head & Associates, Inc. that will guide work associated with proposed field scale pilot testing of enhanced biochemical degradation, including permitting, concepts regarding data reduction, schedule and reporting.

The work will be performed under the Brownfield Cleanup Program (BCP), administered by the NYSDEC under the BCP Agreement #C704044 between IBM and NYSDEC, dated August 22, 2005, and is to be conducted as a part of Remedial Alternatives Analysis.

If you have any questions regarding the enclosed Work Plan, please contact me at 703-257-2582.

Very truly yours,

K Whalen

Kevin Whalen
IBM Program Manager

Enclosures: Work Plan - Enhanced In Situ Biochemical Degradation Pilot Testing

cc: Justin Deming (NYSDOH), Desiree Gillerman (IBM Corp.), and Kevin O'Hara (Binghamton Country Club).

SHPC
ENGINEERS

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April 9, 2010
File No. 3025.00

Mr. Kevin Whalen
IBM Corporation Environmental Affairs
8976 Wellington Road
Manassas, VA 20109

Re: Work Plan - Enhanced In Situ Biochemical Degradation Pilot Testing
IBM Gun Club – Former Burn Pit Area
BCP Agreement #C704044
Union, New York

Dear Mr. Whalen:

We have enclosed the above referenced Work Plan for pilot testing of enhanced in situ biochemical degradation at the IBM Gun Club – Former Burn Pit Area. The work is being conducted as part of the Remedial Alternatives Analysis under the New York State Brownfield Cleanup Program (BCP).

Thank you for the opportunity to serve IBM on this important project.

Very truly yours,
Sanborn, Head Engineering, PC

Allan H. Horneman, Dr.Eng.Sci.
Senior Project Manager (SHA)

Daniel B. Carr, P.E., P.G
Principal and Vice President

AHH/DBC:ahh

Encl. Work Plan - Enhanced In Situ Biochemical Degradation Pilot Testing

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## 1.0 INTRODUCTION

Sanborn, Head Engineering, P.C. (SHPC), with the assistance of Sanborn, Head & Associates, Inc. (SHA), has prepared this Work Plan for field pilot testing of enhancing in situ biochemical degradation at the IBM Gun Club site, Former Burn Pit Area (BPA). This work is to be conducted as a part of Remedial Alternatives Analysis under the New York State Brownfield Cleanup Program (BCP). The Work Plan is intended to communicate and guide work associated with proposed field scale pilot testing of enhanced biochemical degradation, including permitting, concepts regarding data reduction, schedule and reporting. We understand that IBM will forward this Work Plan to New York State Department of Environmental Conservation (NYSDEC).

The primary focus of the remedial alternatives analysis is the on-going presence of chlorinated volatile organic compounds (CVOCs), principally trichloroethene (TCE) and its biochemical breakdown products in the bedrock matrix and groundwater flowing in fractures. As outlined in the background discussion, field pilot testing of enhanced in situ biochemical degradation is the next logical step following an initial screening of remedial alternatives and the positive findings of a program of in situ Biotrap testing. This pilot testing program is intended to collect data to aid in further assessing the viability of enhancing existing biological processes as needed to more fully consider this remedial alternative. The findings of this work will support completion of a detailed analysis of remedial alternatives as expected under the BCP and could be used to support full scale design. A separate effort is being conducted to assess in situ thermal treatment as a remedial alternative. Our work and this document are subject to the Limitations provided in Appendix A.

## 2.0 BACKGROUND AND OBJECTIVES

Enhanced biochemical degradation was one of five technologies identified in the August 5, 2009 Remedial Investigation Report of Findings[1] (RI report) to be carried forward for detailed Alternatives Analysis. We believe that biostimulation by adding nutrients to the subsurface, has the potential to enhance biological processes already active at the site.

Our initial screening of alternatives following submittal of the RI report was communicated in a memorandum of July 21, 2009[2], concluding that enhanced biochemical degradation offers potential for relatively low capital cost, low energy usage, and less concern for workers safety, along with the potential to permanently destroy CVOC mass inside and outside of the 1.6 acre area that constitutes the primary source of on-going VOC presence in groundwater (primary source rock). The technology is the only alternative under consideration with a potential to directly address CVOCs in groundwater within and downgradient of the primary source rock.

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[1] Sanborn, Head & Associates, Inc., Report of Findings, Brownfield Cleanup Program Remedial Investigation, IBM Gun Club – Former Burn Pit Area, Union, New York, August 5, 2009.

[2] Sanborn, Head Engineering, P.C, Memorandum Report: Initial Screening of Remedial Alternatives, Brownfield Cleanup Program Alternative Analysis, IBM Gun Club Property, Former Burn Pit Area, July 21, 2009.

Enhanced biochemical degradation should be considered both as a standalone alternative and as used in conjunction with other remedial alternatives.

As outlined in our memorandum report dated September 8, 2009[3], a program of in situ testing conducted concurrent with finalizing the RI report verified that dechlorinating bacteria associated with biochemical degradation of CVOCs are present and active in the subsurface. The observed degradation rates were within range of those reported in other field studies where in situ biological degradation is active. However, the data indicated that biochemical degradation rates for locations outside the primary source rock are likely limited by less favorable geochemical conditions and availability of organic carbon. Providing a carbon source and creating more chemically reducing conditions downgradient of the primary source rock is intended to enhance the biochemical degradation of CVOCs and further limit their migration in groundwater.

Reducing the downgradient VOC mass flux from the primary source rock was identified as the first of three preliminary remedial goals established in the RI report. The measure of success identified in the RI was a material reduction in VOC concentrations in groundwater outside the source rock and in water reaching seeps and springs.

## 2.1 Pilot Test Area Characteristics

The pilot test is intended to influence an area generally limited to the treatment and monitoring zone extending from the former BPA to the edge of hole number 9 on Binghamton Country Club property as depicted on Figure 1. The area shown on Figure 1 is intended to encompass the area of subsurface in the primary downgradient direction from the BPA as indicated by water level and water quality data.

The uppermost 15 to 20 feet of highly fractured rock, where most of the VOC mass is found, is the intended target of the pilot test. The goal is to establish geochemical conditions more conducive to reductive dehalogenation within a subset of this area depicted on Figure 1 by introducing an organic carbon amendment. The aim is to add sufficient mass of organic carbon to maintain these conditions for an approximate 6 months period. A program of more intensive monitoring is being proposed for at least another 3 months period to supplement the on-going biannual groundwater monitoring program.

As shown on Figure 1, the vicinity of monitoring well BP-4A has been identified as the proposed amendment injection area. Well BP-4A is located approximately 100 feet (ft) southwest of the Burn Pit within primary source rock. The total CVOC concentration found in sampling of BP-4A is within the same order of magnitude as that observed in wells immediately adjacent to the Burn Pit at hundreds of micrograms per liter (µg/L), under similar sulfate reducing/methanogenic biochemical conditions, but with total organic carbon (TOC) concentrations an order of magnitude lower. Whereas TCE constitutes only about 10 to 40% of the CVOCs at monitoring

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[3] Sanborn, Head Engineering, P.C., September 8, 2009, Summary of BioTrap Results, Inference and Recommendations, Brownfield Cleanup Program Alternatives Analysis, Former Burn Pit Area.

locations proximate to the Burn Pit, it constitutes almost 90% of the VOC mass in groundwater from BP-4A and from monitoring locations further downgradient.

The sulfate/methanogenic conditions appear to extend several hundred feet downgradient from BP-4A to near monitoring well BP-9A where TOC concentrations are lower still, at about 2 milligrams per liter (mg/L). Groundwater from monitoring well BP-31A, located approximately 300 ft downgradient of BP-4A, exhibits nitrate, manganese or iron-reducing conditions with dissolved TOC at less than 1 mg/L. Geochemical conditions and TOC observed in sampling of BP-31A and locations further downgradient, (e.g. BP-30A) are not particularly conducive to TCE biochemical degradation, which is reflected in the relatively high proportion of TCE as compared to its breakdown products (>90% TCE).

The uppermost highly fractured rock is characterized by more than 10 fractures per vertical meter above the first inferred aquitard interval encountered at depths of 15 to 20 ft below ground. The first inferred aquitard is readily distinguished by a marked reduction in fracture density and fewer high angle fractures. The saturated thickness of the uppermost highly fractured rock averages about 3 ft near the Burn Pit and about 7 ft further downgradient on Binghamton Country Club property. The hydraulic gradients range from 0.02 to 0.15 feet per foot (ft/ft) and are steepest beneath the hillslope extending from BP-9A to the edge of the golf course on Binghamton Country Club property as depicted on Figure 1.

Assuming the geometric mean fracture porosity ($\Phi_{frac}$) of 0.0005 expressed as a fraction of the bulk rock mass and a nominal saturated thickness of about 5 ft, about 0.4 gallons of water would be contained in the fractures beneath 100 $ft^2$ of land area. As shown on Figures 1 and 2, on the order of 3,000 gallons of water would reside in the saturated fracture volume beneath the area gross area shown on Figures 1 and 2 with about 20, 880 and 2,100 gallons beneath the injection zone and two “treatment/monitoring zones” shown on the figures.

Based on the advective groundwater seepage velocities estimated in the RI report, the advective transport time downslope through the three zones may be on the order of about 20 days using median values of transport properties, and range from about a week to 3 months at the reasonable upper and lower bound seepage velocities. At the median estimate of seepage velocity, groundwater flow would pass through this area on the order of about 10 times in the 6 to 9 months pilot test period. At the estimated groundwater volume flux per foot of flow, the areas identified as the injection and Primary Treatment Zone would exchange saturated fracture volumes about every week with a reasonable upper bound of about a month.

The actual advective transport times across the test area will vary considerably according to the actual subsurface conditions, including heterogeneities affecting the lengths of the actual flow paths, hydraulic conductivity, fracture porosity, and spatially and time varying saturated thickness. Groundwater flow from the injection area will also include components of flow to the west and northwest of the injection area.

Whereas we can estimate the advective transport in advance, the downgradient propagation of carbon amendment and geochemical conditions more conducive to biological degradation will also be influenced by the combined effects of processes that are more difficult to estimate such as molecular diffusion of amendment into the matrix, biological utilization, seasonally variable dilution with infiltration, and other factors. The pilot testing, however, provides an opportunity to further understand field scale transport as needed to rationally design a possible future full scale remedial application. Amendment injection coupled with application of one or more conservative tracers is intended to further refine our understanding of fracture porosity, seepage velocity, transport velocity, matrix diffusion, and amendment retardation at the field scale.

We have developed estimates of design amendment loading using generally accepted design protocols but the actual performance in the field will vary. Given the relatively rapid advective travel times, we are biased toward using a nonaqueous amendment that is released through dissolution; this should be a longer lived approach under these conditions, however, the rate of actual dissolution of such amendments in the fractured rock setting is not readily predictable. The monitoring program is designed based on our present knowledge of site conditions and is intended to allow for collection of data to refine our understanding of the transport conditions and allow for adjustment in the injection and monitoring program based on actual conditions.

### 2.2 Objectives

The objectives of the pilot study include:

- Testing carbon source amendment for the fractured bedrock setting;

- Refining concepts of amendment emplacement and delivery, including assessing how much is lost to the bedrock matrix and the duration an amendment stimulates CVOC degradation in the subsurface;

- Field observation of actual reduction in downgradient concentrations given larger scale degradation rates and the range of transport velocities;

- Verifying rates of biochemical degradation at the field scale under biostimulated conditions; and

- Assessing for potential negative outcomes of enhanced biochemical degradation and the clogging of fractures.

The pilot study is intended to provide additional site-specific information on the application of enhanced biochemical degradation as a remedial technology for the ongoing alternatives analysis and aid in assessing whether enhanced biochemical degradation can address one or both of the remedial goals, by reducing downgradient VOC concentrations, and/or reducing VOC concentrations within the primary source rock. A positive outcome would include:

- A significant decrease in groundwater TCE concentrations in the vicinity of BP-4A located in the area with primary source rock (>1 order of magnitude) and accompanied by an increase in the presence of terminal breakdown products.

- A material reduction in TCE concentrations by about an order of magnitude concurrent with an increase in the presence of terminal breakdown products in monitoring wells and temporary monitoring points downgradient from BP-4A.

- A shift from nitrogen and manganese/iron reducing towards sulfate/methanogenic geochemical conditions in the area located between BP-9A and BP-31A. This would indicate conditions more conducive to biochemical degradation of TCE and its breakdown products.

## 3.0 PILOT TEST DESIGN BASIS

Based on our present concept, amendments would be injected into the subsurface through drilled bedrock boreholes as depicted on Figure 2. Assuming a 5 ft thick saturated interval for an approximately 20 ft by 60 ft area with a $\Phi_{frac}$ of 0.0005, the fracture volume between the water table and the first aquitard interval would be on the order of approximately 20 gallons for an Injection Zone 1. The actual shape and size of the effective injection zone will differ from that depicted on Figure 2. Hydrogeologic testing and water quality monitoring will be used for characterizing the initial distribution of the amendment and overall pilot test performance.

The proposed treatment and monitoring zones consists of the Injection Zone 1 and an area in the primary downgradient direction from the injection zone where the amendment is expected to migrate. For discussion purposes, the area downgradient of the proposed Injection Zone 1 is subdivided into Treatment Zone 2, located in the area with primary source rock; and treatment/monitoring Zone 3, outside the primary source rock. The monitoring program, including the location and frequency of monitoring, is designed in consideration of the estimated advective travel velocities and biochemical degradation rates inferred from past in situ testing.

We have designed the amendment loading with the goal to provide a supplemental source of organic carbon for approximately 6 months at utilization rates that were estimated from prior field testing. While actual substrate utilization and migration rates are likely to differ from estimated rates, the amended organic carbon concentrations are intended to be largely depleted after the 6 months period. The amendment injection will be performed in two stages, with results, observations, and inference from the first injection (Stage 1) informing the second injection (Stage 2). Stage 1 will include tracer testing to develop field estimates of advective seepage velocities, fracture porosity, effective diffusion coefficient, and amendment retardation. Stage 1 is also expected to be informative regarding amendment injection efficiency and substrate utilization based on the monitoring of geochemical parameters. The Stage 2 amendment injection is intended to inject sufficient amendment to support degradation of CVOC mass in the fractures beneath Zones 1 and 2 for the remaining pilot testing period. The staged approach will also provide the opportunity to adjust the concentration and solubility of the amendment. Sections 3.1 and 3.2 describe the Staged approach in more detail.

### 3.1 Stage 1 Injection

The Stage 1 tracer testing and amendment injection will be performed following the drilling and completion of the injection borehole gallery and temporary monitoring wells and the pre-injection water quality monitoring event. In chronological order, Stage 1 injection includes:

- Tracer testing zone using a conductivity tracer that can be monitored in the field without requiring laboratory analysis. As discussed in Section 4.3, the testing is intended to refine estimates of effective fracture porosity, advective seepage velocity and transport velocity.

- Concurrent amendment and tracer injection followed by monitoring of field parameters, including specific conductance (conductivity), pH, dissolved oxygen (DO), oxidation-reduction potential (ORP), and temperature, along with sampling and laboratory analysis for TOC. The lag time between tracer arrival and carbon arrival will be taken as an indicator of the retardation of the amendment. The duration of monitoring following Stage 1 injection is anticipated to be about 1 month.

As described in Section 3.3 and Appendix C, the amendment dose injected during Stage 1 is measured out based on organic carbon demand from CVOCs in water flowing through fractures within an assumed 1,200 $ft^2$ Injection Zone 1. The amendment injection will initially replace, dilute, and mix with groundwater. Enhanced biochemical degradation of TCE and its breakdown products will be monitored through a program of water quality monitoring using existing and new temporary monitoring wells.

### 3.2 Stage 2 Injection

The details of Stage 2 amendment injection may be refined on the basis of data and observations recorded in the Stage 1. Parameters that may be revised for the Stage 2 injection include, but are not limited to, the type of amendment, nutrient addition, pH buffer, amendment dilution and solubility, and injection method.

It is our intention that the amendment be designed to address CVOC dissolved phase mass in fractures beneath Zones 1 and 2 (approximately 1.1 acres) for an additional 5 months. Although sulfate/methanogenic conditions already are present within Zone 2, the additional organic carbon is expected to improve rates of biochemical degradation beneath this area monitoring well BP-9A (situated about 100 ft downgradient of the injection zone) along with an array of temporary monitoring wells will be used to monitor water quality conditions within Zone 2.

The dissolved TOC concentrations are expected to decrease with distance downgradient from the injection zone as a result of biological processes as well as dilution, dispersion, matrix diffusion, and retardation. A measure of success would be increased TOC concentrations and more chemically-reducing conditions extending to Zone 3 outside the primary source rock. The conditions will be monitored using existing monitoring wells BP-30A and BP-31A and proposed temporary monitoring points.

We are not targeting significant increases in TOC concentrations outside of the identified pilot test zones. However, monitoring wells BP-20A, BP-25A, BP-27A, and a proposed temporary monitoring point (TM-8), as well as downgradient seeps and springs will be observed for changes in geochemical conditions, and the concentrations of TOC and VOCs.

### 3.3 Design Basis

As discussed in Sections 3.1 and 3.2, Stage 1 is intended to address CVOC mass in groundwater beneath Zone 1, whereas design dosing for Stage 2 testing is intended to address CVOC mass in groundwater below a larger 1.1 acre area below Zones 1 and 2. The aim is to provide an organic carbon source to enhance biochemical degradation of CVOCs in water below Zones 1 and 2 for a total of 6 months, though beneficiary changes to geochemistry are also expected within Monitoring Zone 3.

Concentrations of TCE in water samples from this area range from 100s to 1,000s of µg/L and constitutes more than 90% of the total CVOCs present in groundwater within Zones 1 and 2, however, inorganic electron receptors, mainly sulfate, are also dissolved in groundwater. The design estimates of organic carbon dosing were developed considering:

- Volume of water beneath the water table in fracture spaces beneath Zone 1 and Zone 2;
- Estimated seepage velocities and the associated fracture volume exchanges over a 6 months period;
- Organic carbon required by about 1,000 µg/L TCE and breakdown products over a 6 months period; and
- Reduction of sulfate to sulfide, assuming sulfate concentrations of 70 mg/L.

Four major screening criteria were considered in the initial screening of amendments:

1. Amendment solubility- less soluble amendments offer better potential for remaining in the subsurface over a longer period, whereas more soluble amendments would be expected to dissipate more rapidly in the fracture system;
2. The amendment should be able to penetrate the fracture pores space. Our estimates of fracture aperture range from 1s to 100s of microns, typically in the 10s of microns averaging about 50 x $10^{-6}$ m (50 microns).
3. Commercial availability of product and the compatibility with pH buffer additions to maintain geochemical conditions conducive to biochemical degradation of CVOCs and/or other nutrients.

4. Sufficiently high organic carbon content in amendment to be serving as a source of carbon substrate for up to 6 months.

As discussed in more detail in Appendix C and in Section 4.2, we believe that edible oil meets the amendment screening criteria. However, based on observations and inference during the Stage 1 testing, the amendment choice will be re-evaluated prior to the second Stage of injection.

The cis-1,2-dichloroethene (cDCE) half-lives inferred from past in situ testing using Biotrap samplers deployed with and without amendment within the primary source rock ranged from about 80 to 140 days. It is unlikely that measurable degradation of TCE will be observed in the approximately 1 month period following the Stage 1 injection assuming that a half-life of 80 days represents the upper bound TCE degradation rate in the field. However, the Stage 1 injection represents an opportunity to better understand field conditions and refine the second stage of amendment injection accordingly.

Design considerations we intend to address during Stage 1 include:

- Performance testing of the injection of oils with relative high viscosity and surface tension compared to water to determine if it can be successfully injected into fractures using relatively low injection pressures;

- Observe retardation of the amendment relative to water flowing through fractures. This will be explored using a sodium bromide (NaBr) conservative tracer;

- Observe the rate of geochemical change within the Injection Zone 1 as the increased levels of organic carbon create more reducing conditions; and

- Assess possible amendment injection affects on the permeability of the injection zone, and re-evaluate seepage velocities and fracture volume exchanges after amendment injection.

Although the pilot study is designed for a period of 6 months, the actual carbon utilization and downgradient transport will likely differ from what can be approximated. In situ biological processes tend to self-perpetuate. As such, groundwater quality monitoring related to the pilot test has been assumed to continue for about a 9 months period.

## 4.0 SCOPE OF WORK

The text to follow details the proposed scope of field and laboratory programs. The main components of the work in chronological order include:

- Submittal of an Underground Injection Control (UIC) permit application for the selected amendment. A UIC permit application is included as Appendix E;

- Drilling and construction of the injection borehole gallery and temporary monitoring well installations. The drilling and well construction is anticipated to require about 10 working days to complete including programs of well development, and slug testing;

- A program of pre-injection groundwater monitoring and laboratory analysis;

- Stage 1 tracer testing and amendment injection. Post injection monitoring including sampling and field screening and lab analysis for geochemical parameters, VOCs, TOC, and light gasses. The duration of Stage 1 monitoring will be approximately 6 to 8 weeks;

- Stage 2 amendment injection informed by Stage 1 data, observations, and inference. The scope of the Stage 2 injection may vary as the Stage 1 observations are reviewed and the design is refined accordingly. The second amend injection is intended to address VOC mass sourced to and transported through fracture pore spaces beneath Zones 1 and 2 for an additional 5 months. A program of performance similar to Stage 1 will be conducted; and

- Data analysis and reporting.

Refer to Section 3.0 for the objectives, rationale, sequence of the various activities described below.

## 4.1 Bedrock Drilling, Well Construction and Field Testing

SHA will retain a drilling subcontractor (see Table 1) for drilling and completing the injection gallery and temporary monitoring wells. After the well installation, SHA will retain the services of a survey subcontractor to survey the horizontal and vertical position of the injection and temporary monitoring well locations. The boring and monitoring point installations, development, and testing will be performed in general accordance with methodologies consistent with those employed in the RI Work Plan, and as described in more detail below. An addendum to the Site Specific Health and Safety Plan is provided in Appendix B and field procedures and forms are provided in Appendix D.

### *4.1.1 Amendment Injection Boreholes*

The purpose of the injection boreholes is to create a route for delivering amendments into the saturated portion of the uppermost highly fractured rock above the first inferred aquitard where the CVOC mass predominantly resides.

A total of 9 proposed injection borings (well ID IB-1 through IB-9) will be drilled at the locations indicated on Figure 2. The proposed borings are to be arranged in two parallel east to west oriented transects spaced 10 ft apart in an off-set pattern. The borehole diameter and spacing was selected as outlined in Table C.4 in Appendix C. The spacing allows for an approximate 2/3 radius of influence overlap between boreholes during an injection of about 6 gallons of amendment in each of the 9 injection wells.

Four inch boreholes will be drilled with to a depth of 18 to 20 ft below ground surface (bgs) using Rotosonic drilling techniques. The proposed borehole completions are shown on Figure 3A.

### *4.1.2 Temporary Monitoring Wells*

The temporary monitoring wells are intended to supplement the current monitoring network by providing a means for monitoring amendment and tracer migration, changes to water chemistry, and evidence of enhanced biochemical degradation within the three Zones. A total of 8 temporary monitoring wells (designated TM-1 through TM-8) are proposed for installation at the approximate locations shown on Figure 2.

The locations of the temporary monitoring points within the three Zones were selected based on the estimated advective travel times, and are expected to monitor transport from the injection wells within 3 to 5 day(s), 1 to 2 week(s), and 1 to 2 month(s), respectively. Additional monitoring wells would be positioned upgradient (approximately 50 ft northeast of Injection Zone 1) and to monitor potential westerly transport of amendment (approximately 50 ft to the west of Injection Zone 1).

Temporary wells will be installed to depths of about 20 ft bgs area using Rotosonic drilling techniques. Well construction diagrams are provided as Figure 3B.

### *4.1.3 Injection Well and Temporary Monitoring Point Development*

The injection boreholes and temporary monitoring wells will be developed after installation until water quality parameters, including specific conductance and pH stabilize within 10% of original values, and the turbidity is less than 10 Nephelometric Turbidity Units (NTU). The development will be completed with bailers or a peristaltic pump. Well development field forms can be found in Appendix D.2.

### *4.1.4 Hydraulic Testing*

Borehole slug tests will be performed on newly installed injection borings and temporary monitoring points to provide “pre-injection” hydraulic property estimates for the injection and temporary monitoring wells. Estimates of hydraulic conductivity (K) may be used for assessing potential decreases in hydraulic conductivity due to the injected amendment or from bio-film. Please see Appendix D.3 for an example rising head slug test.

## 4.2 Amendment Selection

The amendment selection included a review of technical guidance documents, case studies, literature search, and communication with potential amendment vendors. In order to achieve a successful enhancement of biochemical degradation processes in the fractured rock setting, the screening included the four criteria discussed in Section 3.3 and Appendix C.

Appendix C summarizes the screening of potential amendments and the dosing design. The amendment selected for at least Stage 1 of the pilot test is an "edible oil", or a soybean oil emulsion product. Commercially available edible oil emulsion products, (EOS® Remediation's *598,* JRW Bioremediation's *Lactoil*™ or similar) can be injected as a non-aqueous phase liquid (NAPL) (approximately 45-60% edible oil by weight), or as a dilute emulsion (diluted to as much as 2 to 6% by weight). Emulsions are reported to be retarded in sediments/rock through sorption and matrix diffusion, and are characterized as longer-lasting amendments that are typically effective for months to years. The average oil globule size in emulsion form is reportedly 1 µm, which is smaller than the estimated mean fracture aperture of 30 to 50 microns. Commercial grade products are also available with nutrient amendments and pH buffers (EOS *B42* or *Aquabuf*).

We estimate that approximately 22 gallons of diluted emulsion product will be injected during Stage 1. The aim is to provide a volume equivalent to about one fracture space volume of Zone 1 and a dose corresponding to the theoretical 6 months organic carbon demand within this Zone. The injection volume during Stage 2 is based on the fracture space exchanges within Zone 2 over an additional 5 months period.

These diluted emulsion volume estimates were derived by estimating the stoichiometric demand of electron acceptors and for biochemical degradation of CVOCs in groundwater, assuming 27 and 2 complete fracture pore volume exchanges per month for Zone 1 and Zone 2, respectively. The stoichiometrically derived estimate was multiplied by a scaling factor of five reflecting uncertainties that include microbial efficiency, electron acceptor efficiency, safety factor, and a dilution of the concentrated oil emulsion product. Design loading for the Stage 2 injection will be informed by estimated transport velocities, and amendment retardation estimated from tracer testing conducted during the Stage 1 injection. Details of the Stage 1 injection calculations as well as the amendment product material safety data sheets (MSDS) are also included in Appendix C.

Our estimates are based on certain simplifying equations and approximations that may or may not represent actual field conditions. It is possible that the amendment will be utilized at a much slower or quicker rate than anticipated, or that the amendment becomes more or less mobile in the subsurface than estimated from its chemical properties. If during the performance monitoring period, we identify that insufficient carbon is available for stimulating biochemical degradation, we may recommend an additional injection of a similar or alternate amendment. Additional injection(s) could occur within the original injection area (Zone 1) or locations downgradient where it is anticipated that amendment would travel via groundwater flow (Zone 2).

The NYSDEC Draft DER-10 Guidance (DER-10)[4] indicates that remedial actions involving groundwater injection would require an injection permit, as regulated through 40 CFR Part 144. Injection permitting will be provided by UIC Program, which is administrated by the U.S. EPA, Region 2. Injection of a carbon amendment and tracer (sodium bromide or similar) would

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[4] New York Department of Environmental Conservation, Division of Environmental Remediation, Draft DER-10 Technical Guidance for Site Investigation and Remediation. December 2002, pgs 99-103.

require a Class V-5B permit, "to be used for beneficial use in subsurface environmental remediation," for underground injection that does not endanger underground sources of drinking water.

## 4.3 Tracer Testing and Amendment Injection

### *4.3.1 Stage 1 Tracer Testing and Amendment Injection*

The amendment injection constitutes an opportunity to conduct tracer testing to measure pilot-scale transport, including average seepage and transport velocities, effective fracture porosity, matrix diffusion, and amendment retardation factor. The transport velocity differs from average seepage velocity in that a sparse interconnected network of a few larger fractures may be responsible for the majority of mass transport, whereas the average seepage velocity is influenced by the whole fracture network, including fractures only responsible for a fraction of the CVOC (or amendment) mass transport. Similarly, the effective fracture porosity may differ from the values reported in the RI Report, in that the effective porosity only takes into account the fractures responsible for transporting the majority of mass during the tracer tests. The tracer testing and Stage 1 injection are discussed in more detail in Appendix D.4. We propose conducting three "sets" of tracer tests using a subset of the injection borings and monitoring wells depicted on Figure 2:

1. Pulse Tracer Test: Upon completing the injection wells and prior to the actual injection of amendment, a "pulse" tracer test will be conducted by mixing a NaBr salt into a small volume of water, and placing it into one injection borehole, and observing the specific conductance response in nearby "response wells" to estimate peak transport velocities and average seepage velocities within the Injection Zone 1.

2. Dose Response Tracer Test: A dose response tracer test will be conducted by injecting a concentrated slug of tracer mixed with water into one borehole, and monitoring the specific conductance "dose response" in 4 of the injection borehole locations until "steady state" concentrations are reached in "dose response" locations. This tracer test is intended to estimate effective fracture porosity within Zone 1.

3. Retardation and matrix diffusion Test: Stage 1 amendment injection will consist of a pressurized release of an emulsified organic carbon substrate mixed with the dissolved NaBr tracer at the 9 borehole locations. Coupled monitoring of specific conductance, bromide concentrations, and laboratory analysis of TOC will be conducted in selected dose response locations. This testing is intended to estimate the retardation factor for the organic carbon amendment, and support modeling of matrix diffusion.

The amendment injection will be performed at a maximum pressure applied at the groundwater table to limit potential for fracturing and uplift of the formation using a packer assembly as discussed in Appendix D.4. About 22 gallons of mixed emulsion will be injected divided between the 9 injection borings. The amendment injection will be followed by injection of a static borehole volume of water from the on-site water supply well in each of the wells to displace the amendment from the injection boreholes into the fracture pore space.

### *4.3.2 Stage 2 Amendment Injection*

The Stage 2 amendment injection will be performed approximately 6 to 8 weeks following the Stage 1 injection, tracer testing and groundwater quality monitoring, and is intended, as discussed in Sections 3.2 and 4.2 of this Work Plan, to alter geochemical conditions within Zones 1 and 2 for an additional 5 months period. The Stage 2 injection will be performed using all nine injections wells using a packer system to target fractures below the static groundwater table.

## 4.4 Monitoring Program

The purpose of the pre- and post-injection monitoring program is to collect information on the performance of the pilot test including geochemical conditions, CVOC degradation, and migration, utilization, and retardation of injected amendments. As described below, and discussed in Section 3.0, we are proposing a staged approach to monitoring. The groundwater quality monitoring program includes pre- and post-injection sampling of selected monitoring wells, and seeps and springs as well as assessment of temperature, conductivity, ORP, and DO in four monitoring wells (BP-4A, TM-1, TM-2, and BP-9A) measured by YSI 556 Multi-Probe Meters (YSI probe). The YSI probe data is accessed by telemetry and computer modem to continually monitor for changes in geochemistry after the injection and to assess when initial performance monitoring rounds should occur.

Subsequent water quality monitoring events will be conducted based on field indicators, tracer concentrations, and geochemical parameters observed during post-injection sampling. Details are described below.

### *4.4.1 Pre-Injection Water Quality Monitoring*

Prior to the Stage 1 amendment injection, YSI probes will be installed in the four downgradient monitoring locations shown on Figure 2 and in a background location outside the tested area (BP-1A). Data collected from YSI probes, including pH, temperature, conductivity, oxidation-reduction potential, and DO, will be wirelessly transmitted in to a computer located in the B665 Former IBM Testing Facility. SHA personnel will have access to review and assess this information through an ethernet connection. The field YSI probe water quality parameters will be used during the Stage 1 monitoring period to aid in assessing for changes to water quality that would warrant conducting performance monitoring as well as to gather information to be used in the design of the Stage 2 injection.

Pre-injection water quality monitoring parameters will be recorded at 19 locations[5] using the low flow sampling technique and include the 8 temporary water table monitoring wells; 8 existing water table monitoring wells, and 3 seeps and springs monitoring locations summarized in Table 2. At all 19 locations, field geochemical parameters will be screened using the YSI probe and Hach Turbidity Meter, as well as geochemical field testing. Samples for laboratory analysis will be collected at each of the 19 locations for TOC, VOCs, and light gasses. Additionally, analysis of alkalinity and volatile fatty acids (VFAs) will be conducted on samples from selected locations as detailed in Table 2.

### *4.4.2 Post-Injection Water Quality Monitoring*

We anticipate conducting five post-injection water quality monitoring rounds during the pilot test. The initial schedule for water quality monitoring is shown in Figure 4, however, additional rounds may be warranted if findings suggest that significant residual amendment remains 5 months after the Stage 2 injection. The timing of post-injection sampling events may be adjusted based on the observations and inference during the pilot test. The first 3 rounds of water quality monitoring will be performed using the low flow sampling technique; however, pending field testing, the last two sampling rounds may be conducted using passive diffusion bag (PDB) devices. Regenerated cellulose dialysis membranes PDB samplers may be installed following the third groundwater quality monitoring event and will be maintained in monitoring wells until pilot testing is completed. We anticipate the use of PDB samplers will significantly reduce sampling time, yet provide data of similar quality to low-flow sampling techniques for both organic and inorganic parameters; however, the PDBs will be field tested at the site. Manufacturers' specification sheets for regenerated cellulose dialysis membranes PDB specifications are included in Appendix D.6.

Following the Stage 1 injection, the timing of the water quality monitoring will be indicated by changes in water quality parameters as indicated by the YSI probe data. Parameters indicating changes to geochemistry as a result of enhanced biochemical degradation include decreases in pH, ORP, and DO, as well as increased conductivity and bromide concentrations indicating the presence of NaBr tracer discussed in Section 4.3.

Field parameters, including ORP, conductivity, and geochemical assessment of DO and iron concentrations will be used as a screening tool for choosing when samples for organics (VOCs, light gasses, or VFAs) should be collected at the monitoring wells. As a consequence, the monitoring locations furthest downgradient may only be sampled for organics during the pre-injection monitoring and 5 months after the Stage 2 amendment injection at the termination of the pilot testing.

### *4.4.3 Laboratory Analysis and QA/QC Requirements*

Laboratory analysis of selected analytes will be conducted by Lancaster Laboratories of Lancaster, PA, and Microseeps Laboratory of Pittsburgh, PA, and in-field geochemical analysis

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[5] Groundwater quality monitoring of one or more of the injection borings will also be performed.

will be conducted by SHA personnel as summarized on Table 2. The Quality Assurance and Quality Control (QA/QC) plan for the Pilot Test will be consistent with the QA/QC elements described in the RI Work Plan. Table 2 from the approved 2006 RI Work Plan include details on QA/QC procedures and is included as Appendix F. The procedures outlined in the Appendix are for samples collected for VOC analysis. For VOCs, one trip blank should be submitted with each cooler. In addition, one matrix spike, and matrix spike duplicate (MS/MSD) should be collected for every 20 groundwater samples. Furthermore a VOC field blank should be collected daily. Duplicate samples should at a minimum be collected daily or at a 10% frequency.

For the remaining analytes shown in Table 3, the field QA/QC procedure will consist of duplicates. One duplicate field sample should be collected for every 10 groundwater samples or at a minimum at a daily basis.

## 5.0 DATA ANALYSIS AND REPORTING

SHPC with the assistance of SHA will compile, reduce and analyze data generated as part of the Pilot Study and prepare a Report of Findings upon completing the study and receiving all the related laboratory data. The report will include: a summary of the work completed; an overview of the findings including, but not limited to, a discussion of the usability of the field and analytical laboratory data; a discussion of the tracer testing results, including refined estimates of average seepage velocity, transport velocity, and effective fracture porosity; a discussion of injection approach, amendment migration and retardation, and changes in TOC concentrations over time; a discussion of amendment effect on geochemical conditions, and evidence and extent of enhanced biochemical degradation of CVOCs; and conclusions and recommendations summarizing the outcome of the pilot study, identifying potential data gaps to be filled, and providing recommendations to be included in the remedial alternatives analysis.

The report will provide an assessment of enhanced biochemical degradation, and in particular review it in the light of the remedial goals to permanently destroy CVOC mass inside and outside of the 1.6 acre area that constitutes the primary source of on-going VOC presence in groundwater. Elements of the Report of Findings will include, but not be limited to:

- Plan view maps depicting the extent of enhanced organic carbon concentrations observed in groundwater, changes to geochemical conditions, and apparent enhanced degradation of CVOCs;
- Time series plots depicting geochemistry and biochemical degradation over time;
- Tabular summaries of field and laboratory geochemical data;
- Attachments summarizing the data analysis of the tracer tests;
- Attachment summarizing limitations to our inference and conclusions; and
- Attachments on disk compiling laboratory reports as well as data validation reports and/or data usability reviews performed by an independent chemist or SHA personnel, respectively.

SHPC will provide IBM with preliminary data summary reports after each enhanced biochemical degradation pilot milestone, including: after completing the Stage 1 drilling, tracer testing, and amendment injection; following the Stage 2 amendment injection; and after receiving laboratory data from each of the five planed groundwater quality monitoring events. The agencies will be informed of pilot study progress and preliminary field observations and inference and laboratory data through monthly reporting and routine communication with IBM CEA representatives.

## 6.0 SCHEDULE

Figure 4 presents a schedule of planning, implementation, monitoring, and reporting activities associated with the Enhanced Bio Pilot Test. The schedule is provided to depict estimated timeframes associated with major Pilot Test tasks and is based on anticipated length for Agency review, our current understanding of the site, and the proposed Pilot Test design.

As indicated on Figure 4, the expected duration of the Pilot Test is approximately 6 to 9 months. A Pilot Test Report of Findings is expected to be delivered to the agencies within about 3 months of completing the final round of performance monitoring. Based on the current projected schedule, important milestones include:

- Submittal of Draft Work Plan to IBM by mid March;
- Submittal of Work Plan to Agencies and concurrent submittal of UIC permit by early April approximately 1 month prior to scheduled Stage 1 injection;
- Field Preparation by late April, including drilling and tracer testing;
- Stage 1 Amendment Injection by mid May 2010;
- Stage 2 Amendment Injection by early July 2010;
- Ongoing performance monitoring between May and December 2010; and
- Submittal of Pilot Test Report to the Agencies in the first quarter of 2011.

The scope of work includes five performance monitoring rounds, expected to take place 2 weeks, 4 weeks, 2 months, 4 months, and 6 months after the initial amendment injection. Depending upon observed transport velocities of the tracer/amendment and utilization of the amendment within the treatment area, the timeline of sampling may be adjusted. Please note that the projected schedule shown on Figure 4 is subject to possible delays beyond IBM's control including but not limited to agency approval, subcontractor availability, field conditions, and actual performance monitoring results.

# TABLES

## Table 1
## Project Contact List

Work Plan – Enhanced Bio Pilot Testing
IBM Gun Club – Former Burn Pit Area
Union, New York

| Name | Title | Company | Cell Phone | Office Phone |
|---|---|---|---|---|
| Daniel Carr | Principal In Charge | SHA | | 207-347-4714 |
| Allan Horneman | Senior Project Manager | SHA | 207-415-1551 | 207-347-4713 |
| Patrick Malone | Site Supervisor/Safety Officer/Project Engineer | SHA | 508-397-4089 | 978-577-1034 |
| Kevin Whalen | Program Manager | IBM CEA | | 703-257-2582 |
| Jonathan Greco | Project Manager | NYSDEC | | 518-402-9774 |
| Justin Deming | | NYSDOH | | 518-402-7870 |
| Robert Danckert | Drilling Services | Boart Longyear Company | 978-495-6808 | 508-936-1050 |
| Nicole Maljovec | Client Services | Lancaster Laboratories | N/A | 707-656-2300 x1537 |
| Scott Williams | Project manager | Butler Land Surveying | | 570-623-2909 |
| Debbie Hallo | Client Services | Microseeps Laboratories | N/A | 412-826-5245 |

**Notes:**

The table summarizes key contacts, including subcontractors and Sanborn, Head & Associates, Inc. personnel, for the Enhanced Bio Pilot Testing at the IBM Gun Club – Former Burn Pit area.

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# Table 2
## Projected Schedule - Monitoring Frequency
## Work Plan - Enhanced Bio Pilot Testing
## IBM Gun Club - Former Burn Pit Area
## Union, New York

| Monitoring Location | Zone/Location | Pre-Injection Monitoring | | | | | | | Performance Monitoring Rounds 1-5 Approx 2 weeks to 8 months | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Field Probe | TOC | VOCs | Light Gasses | Alkalinity | VFAs | Field Testing | Field Probe | TOC | VOCs | Light Gasses | Alkalinity | VFAs | Field Testing |
| BP-4A | Zone 1 - Injection Zone | x | x | x | x | x | x | x | x | x | x | x | x | *P2* | x |
| TM-1 | Zone 2 - Treatment Zone | x | x | x | x | x | x | x | x | x | x | x | x | *P2* | x |
| TM-2 | Zone 2 - Treatment Zone | x | x | x | x | x | x | x | x | x | x | x | x | *P2* | x |
| BP-9A | Zone 2 - Treatment Zone | x | x | x | x | x | x | x | x | x | x | x | x | *P2* | x |
| TM-3 | Zone 2 - Treatment Zone | x | x | x | x | x | x | x | x | x | x | x | x | *P2* | x |
| TM-4 | Zone 3 - Monitoring Zone | x | x | x | x | x | x | x | x | x | x | x | *P1* | *P2* | x |
| TM-5 | Zone 3 - Monitoring Zone | x | x | x | x | x | | x | x | x | x | x | *P1* | | x |
| TM-6 | Zone 3 - Monitoring Zone | x | x | x | x | x | | x | x | x | x | x | *P1* | | x |
| BP-30A | Zone 3 - Monitoring Zone | x | x | x | x | x | | x | x | x | x | x | *P1* | | x |
| BP-31A | Zone 3 - Monitoring Zone | x | x | x | x | | | x | x | *P1* | *P2* | *P2* | | | *P1* |
| BP-23A | Zone 3 - Monitoring Zone | x | x | x | x | | | x | x | *P1* | *P2* | *P2* | | | *P1* |
| BP-24A | Zone 3 - Monitoring Zone | x | x | x | x | | | x | x | *P1* | *P2* | *P2* | | | *P1* |
| TM-7 | Sidegradient from Zone 1 | x | x | x | x | | | x | x | *P1* | *P2* | *P2* | | | *x* |
| TM-8 | Upgradient from Zone 1 | x | x | x | x | | | x | x | *P1* | *P2* | *P2* | | | *x* |
| Seep 1 | Zone 2 - Treatment Zone | x | x | x | x | | | x | x | *P1* | *P2* | *P2* | | | *P1* |
| Seep 2 | Zone 2 - Treatment Zone | x | x | x | x | | | x | x | *P1* | *P2* | *P2* | | | *P1* |
| SWA | Zone 2 - Treatment Zone | x | x | x | x | | | x | x | *P1* | *P2* | *P2* | | | *P1* |
| BP-20A | Binghamton Country Club | x | x | x | x | | | x | x | x | x | x | | | x |
| BP-27A | Binghamton Country Club | x | x | x | x | | | x | x | x | x | x | | | x |
| Total Samples | | 19 | 19 | 19 | 19 | 9 | 6 | 19 | 19 | 11 | 11 | 11 | 5 | 0 | 13 |

Notes:

1. The table is intended to summarize the number of groundwater monitoring events and testing parameters related to the enhance bio pilot testing .

2. Additional Field Testing and water quality monitoring of injection boreholes may occur during pre- and post-injection performance monitoring rounds.

3. Field Probe testing includes estimates of bromide, pH, conductivity, and temperature by electrometric water quality indicating devices and data loggers.

4. Laboratory analysis of total organic carbon (TOC), volatile organic carbon (VOCs), and alkalinity will be conducted by Lancaster Laboratories of Lancaster, Pennsylvania. Analysis of light gasses and volatile fatty acids (VFAs) will be conducted by Microseeps, Inc. of Pittsburgh, Pennsylvania.

5. Field Testing will be used for selected geochemical analytes, including dissolved oxygen (DO), nitrate, Iron, sulfate, sulfide, and chloride, using kits and a DR800/DR2800 spectrophotometer manufactured by Hach®.

6. "x" denotes locations where samples should be collected. Where denoted "P1" or "P2" samples will be collected based on the following criteria:
"P1" If bromide > initial, TOC sample and/or alkalinity should be collected, and "Field Testing" geochemical analysis should be performed where denoted.
"P2" If "Field Testing" geochemical analysis indicates DO < 3 milligram per liter (mg/l) or Iron > 2 mg/l, sample for VOCs, Lt Gasses, and/or VFAs should be collected where denoted.

7. Refer to Work Plan text and appendices for further discussion.

# Table 3
# Analyte List, Sample Containers and Preservation

Work Plan – Enhanced Bio Pilot Testing
IBM Gun Club – Former Burn Pit Area
Union, New York

| Analyte | Laboratory/ Method | Sample Containers | QA/QC Elements | Hold Time |
|---|---|---|---|---|
| Volatile Organic Compounds (VOCs) | Lancaster<br>SW 846 8260B | 4- 40 ml VOA glass<br>HCl preserved | As specified in Section 4.4.3 | 14 days |
| Total Organic Carbon (TOC) | Lancaster<br>SM20 5310C | 1-125 ml amber glass<br>$H_2SO_4$ preserved | 5% Duplicates (or daily) | 28 days |
| Light Gasses (methane, ethene, ethane) | Microseeps<br>AM20GAX | 2-40 ml VOA glass<br>$Na_3PO_4$ preserved | | 14 days |
| Volatile Fatty Acids (acetate, lactate, proponiate, pyruvic, butyrate) | Microseeps<br>AM23G | 2-40 ml VOA glass<br>Benzalkonium Chloride preserved | | 14 days |
| Alkalinity | SM20 2320B | 1 - 200 ml glass | | 14 days |
| Bromide,<br>pH, Cond., Temp. | Field Testing<br>YSI and Bromide Probes | N/A | | N/A |
| Dissolved Oxygen | Field Testing<br>Hach Kits & Spectrophotometer | 1-250 ml Nalgene | | 1 minute |
| Nitrate | | | | 10 minutes |
| Total Iron/Fe(II) | | | | 5 minutes |
| Sulfate | | | | 10 minutes |
| Sulfide | | | | 1 minute |
| Chloride | | | | 10 minutes |

**Notes:**

1. The table is intended to summarize the analyte list, sample containers, preservation, and field QA/QC elements included in the performance monitoring program.
2. The QA/QC elements for volatile organic compounds are summarized in Section 4.4.3 of the Work Plan Text.
3. The field parameters will be estimated by SHA personnel using electrometric water quality devices and data loggers, Hach Kits, and Spectrophotometer.
4. Refer to Work Plan text for further discussion.

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# FIGURES

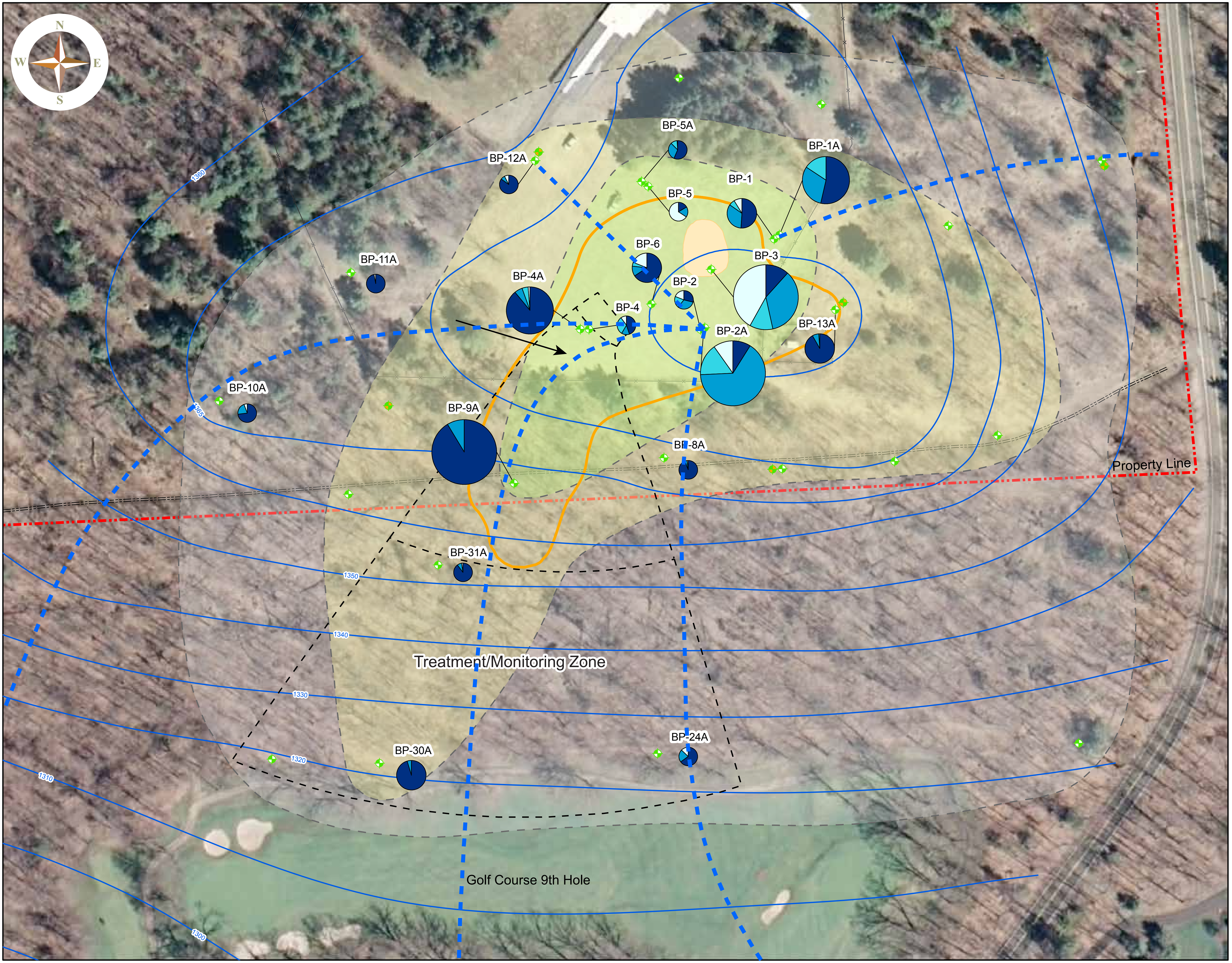

Figure 1

# Concepts of Enhanced Biochemical Pilot Testing

Work Plan - Enhanced Bio Pilot Testing

IBM Gun Club - Union, New York

Drawn By: J. Prellwitz/J. Pierce
Designed By: A. Horneman
Reviewed By: D. Carr
Date: April 2010

Figure Narrative:
This figure is intended to summarize enhanced biochemical degradation pilot study concepts and related geochemical and hydrologic inference also summarize in the August 5, 2009, Remedial Investigation Report. The relative proportion of parent and daughter product VOCs are depicted on a micromolar basis (pie charts) with the primary terminal electron accepting processes (TEAPs) (isopleths) for selected monitoring wells in the uppermost highly fractured rock and intermediate depths.

The TEAPs were inferred from geochemical information for the following oxidized and reduced chemical species: oxygen, nitrate, nitrite, Fe(III), Fe(II), sulfate, sulfide, and methane, where available, or from oxidation-reduction potentials observed during low-flow sampling. Please refer to the Work Plan text for further discussion.

## Legend

- Burn Pit
- Monitoring Well
- Multi Level Monitoring Well
- Groundwater Contours (June 2008)
- Inferred Area with Primary Source Rock

Primary TEAP

- Suboxic
- Nitrate/Manganese/Iron Reducing
- Sulfate Reducing/Methanogenesis

- Parent VOC (Trichloroethene)
- Primary Daughter Product (*cis*-1,2DCE)
- Secondary Daughter Product (Vinyl Chloride)
- Terminal Breakdown Products (Ethane, Ethene)

Total Chlorinated Ethanes & Ethenes in Groundwater (μmol/L)

0.01 to 0.1
>0.1 to 1
>1 to 10
>10 to 100

50 25 0 50 100 150 Feet

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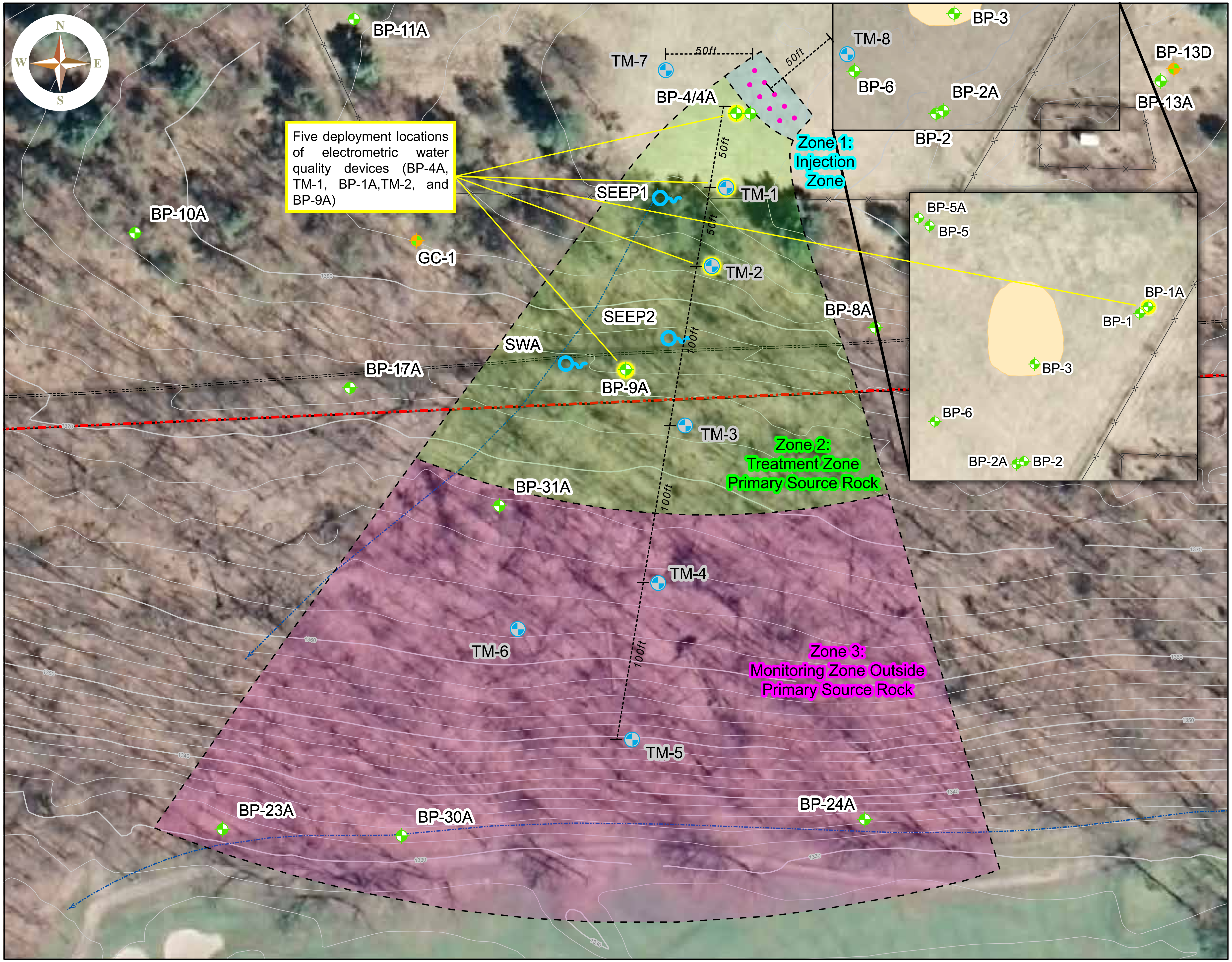

Five deployment locations of electrometric water quality devices (BP-4A, TM-1, BP-1A,TM-2, and BP-9A)

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Figure 2

# Proposed Injection Boring and Temporary Monitoring Point Locations

Work Plan - Enhanced Bio Pilot Testing

IBM Gun Club - Union, New York

Drawn By: S. Warner
Designed By: A. Horneman
Reviewed By: D. Carr
Date: April 2010

Notes:

1. The figure is intended to depict proposed injection boring and temporary monitoring point locations associated with enhanced biochemical degradation pilot testing.

2. The 2 foot photogrammetric topography is based on an Auto CAD deliverable from Butler Land Surveying, LLC. of Little Meadows, Pennsylvania (Butler) dated 8/11/08.

3. Site features including monitoring wells, seeps, and springs were surveyed by Butler.

4. Inset represents a 180 x 180 feet view of the site located northeast of the injection zone where a background electrometric water quality device will initially be deployed.

5. Refer to Figure 1 and Workplan text for further discussion.

**Legend**

1320 2ft Topographic Contour (AMSL)

Proposed Locations

IB-1 ● Injection Boring (IB-1 through IB-9)

TM-1 Temporary Monitoring Point

Existing Groundwater and Surface Water Sample Locations

Seep1 Seep or Spring Sampling Location if labeled

BP-2A Monitoring Well

BP-14D Multi Level Monitoring Installation

30 15 0 30 60 90 Feet

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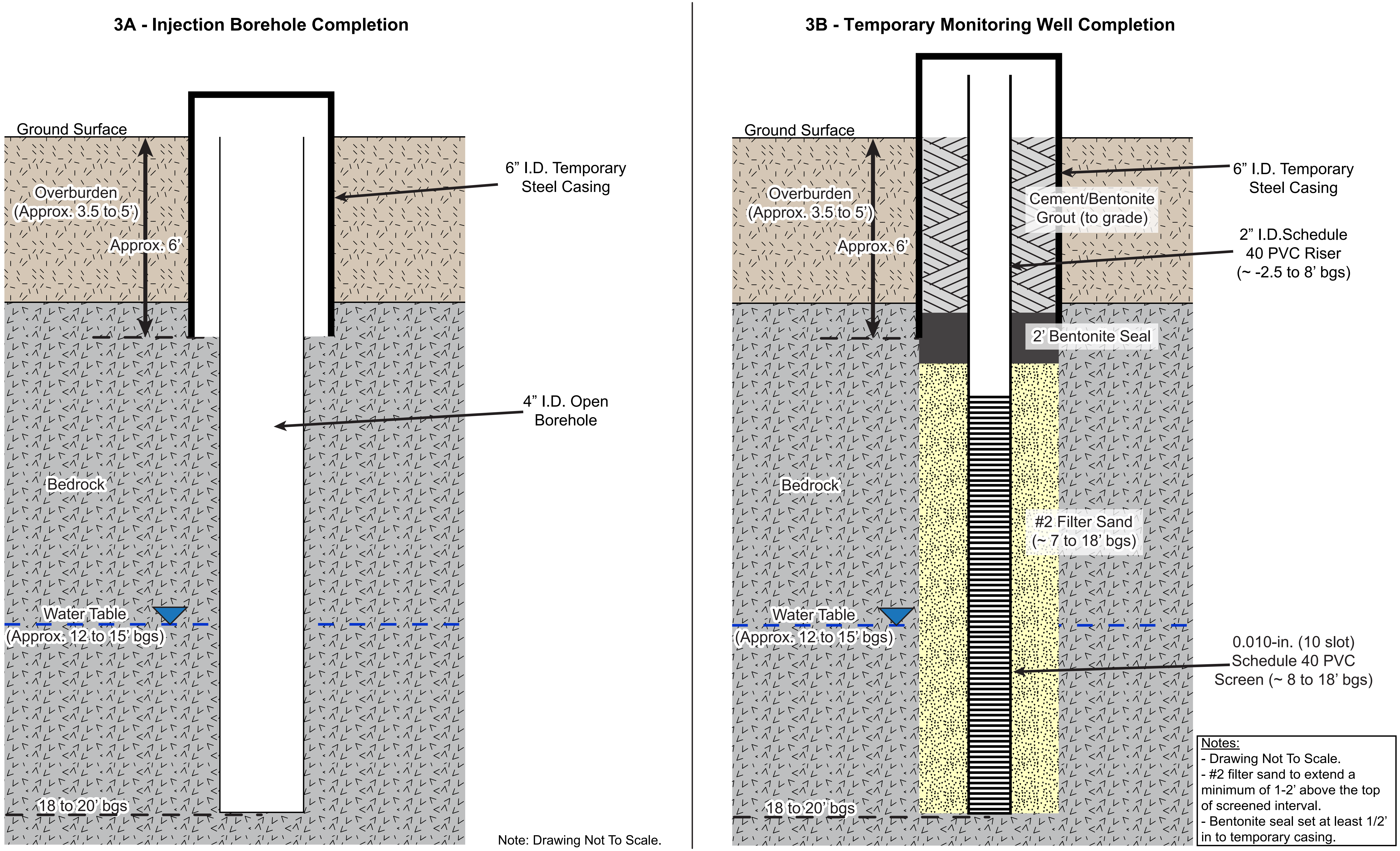

Note: Drawing Not To Scale.

Notes:
- Drawing Not To Scale.
- #2 filter sand to extend a minimum of 1-2' above the top of screened interval.
- Bentonite seal set at least 1/2' in to temporary casing.

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## Figure 3

## Injection Boring and Temporary Monitoring Well Completion
## Work Plan - Enhanced Bio Pilot Testing

**IBM Gun Club - Union, New York**

| | |
|---|---|
| Drawn By: | J. Prellwitz |
| Designed By: | P. Mouser / A. Horneman |
| Reviewed By: | D. Carr |
| Date: | March 2010 |

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ENGINEERS

## Figure 4

## Projected Schedule

Enhanced Biodegradation Pilot Test
IBM Gun Club - Former Burn Pit Area
Union, New York

| Description of Task | 2010 | | | | | | | | | | | 2011 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feb | Mar | April | May | June | July | Aug | Sept | Oct | Nov | Dec | Jan | Feb | Mar |
| Task 1 - Work Plan | | | | | | | | | | | | | | |
| Development of Work Plan | ▨ | ▨ 12-Mar to IBM | | | | | | | | | | | | |
| IBM Review of Work Plan | | ▨ | 29-Mar IBM Review Complete | | | | | | | | | | | |
| SHA Address IBM Comments | | ▨ | 9-Apr Submit to Agencies | | | | | | | | | | | |
| Submittal to Agencies | | | ▨ | 3-May Agency Review Complete | | | | | | | | | | |
| Task 2 - Construction | | | | | | | | | | | | | | |
| Boring Installation & Development | | | ▨ | 26-Apr Construction Begins | | | | | | | | | | |
| Hydraulic & Tracer Testing | | | ▨ | 3-May Testing Continues | | | | | | | | | | |
| Initial Sampling | | | ▨ | 3-May Sampling Continues | | | | | | | | | | |
| Task 3 - Stage 1 Injection & Initial Monitoring | | | | | | | | | | | | | | |
| Amendment Injection | | | | ▨ 10-May Injection Begins | | | | | | | | | | |
| Performance Monitoring (1) | | | | ▨ | | | | | | | | | | |
| Performance Monitoring (2) | | | | | ▨ | | | | | | | | | |
| Task 4 - Stage 2 Injection | | | | | | | | | | | | | | |
| Stage 2 Amendment Injection | | | | | | ▨ | | | | | | | | |
| Task 5 - Ongoing Monitoring | | | | | | | | | | | | | | |
| Performance Monitoring (3) | | | | | | ▨ | | | | | | | | |
| Performance Monitoring (4) | | | | | | | | ▨ | | | | | | |
| Performance Monitoring (5) | | | | | | | | | | | ▨ | | | |
| Task 6 - Documentation and Reporting | | | | | | | | | | | | | | |
| Final Report Preparation | | | | | | | | | | | ▨ | ▨ | ▨ | |
| IBM Review of Report | | | | | | | | | | | | | ▨ | |
| Submittal to Agencies | | | | | | | | | | | | | | ▨ |

Notes:

1. The Figure is intended to outline the timeline for the enhanced bio pilot testing. The timeline for performance monitoring and final reporting may be adjusted based on field observations during the initial and ongoing pilot test.

2. Refer to Work Plan text for further discussion.

# APPENDIX A

# LIMITATIONS

# APPENDIX A
# LIMITATIONS

1. The conclusions, design basis and recommendations described in this work plan are based in part on the data obtained from widely spaced subsurface explorations. The nature and extent of variations between these explorations may not become evident until further investigation, pilot testing, or remediation is initiated. If variations or other latent conditions then appear evident, it will be necessary to re-evaluate the design basis and recommendations of this work plan.

2. The generalized lithologic profiles depicted on figures and described in the text are intended to convey trends in subsurface conditions. The lithologic boundaries between strata are interpretations that are approximate and idealized and have been developed based on data and observations from of widely spaced explorations and samples. The actual transitions are probably more gradual. For specific information, refer to the exploration logs.

3. The conclusions, design basis and recommendations contained in this work plan are based in part upon various types of chemical data as well as historical and hydrogeologic information. While SHA has reviewed that data and information as stated in this report, any of SHA's interpretations, conclusions, and recommendations that have relied on that information will be contingent on its validity. Should additional chemical data, historical information, or hydrogeologic information become available in the future, such information should be reviewed by SHA and the interpretations, conclusions and recommendations presented herein should be modified accordingly.

4. This Work Plan has been prepared for the exclusive use of the International Business Machines Corporation for specific application for the Remedial Investigation of the IBM Gun Club – Former Burn Pit Area, in Union, NY, in accordance with generally accepted hydrogeologic and engineering practices. No other warranty, express or implied, is made.

5. The analyses, conclusions and recommendations contained in this Work Plan are based on the data obtained from the referenced subsurface explorations. The explorations indicate subsurface conditions only at the specific locations and times, and only to the depths penetrated. They do not necessarily reflect strata variations that may exist between such locations. The validity of the recommendations is based in part on assumptions SHA has made about conditions at the site. Such assumptions may be confirmed only during remediation. If subsurface conditions different from those described become evident, the conclusions, design basis and recommendations in this work plan must be re-evaluated. It is advised that SHA be retained to monitor the remediation in order to help confirm that our assumptions and recommendations are valid or to modify them accordingly.

6. In the event that any changes in the nature, design, or location of the facilities are planned, the conclusions, design basis and recommendations contained in this work plan should not be considered valid unless the changes are reviewed and conclusions of this work plan modified or verified in writing by SHA. SHA is not responsible for any claims, damages, or liability

associated with interpretation of subsurface data or re-use of the subsurface data or engineering analyses without the express written authorization of SHA.

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# APPENDIX B

# ADDENDUM TO SITE SPECIFIC HEALTH AND SAFETY PLAN

# APPENDIX B
# ADDENDUM TO SITE SPECIFIC HEALTH AND SAFETY PLAN

This Addendum to the Site Specific Health and Safety Plan (HASP) has been developed for use by Sanborn, Head & Associates, Inc. (SHA) employees who will be working on the IBM Gun Club former Burn Pit Area (the Site) during Enhanced Bio Pilot Testing. This Addendum supplements the Health and Safety Plan developed for the Gun Club Remedial Investigation[1] and outlines additional safety and health procedures and requirements for the scope of work described in the Enhanced Bio Work Plan.

## Boring Investigations and Temporary Well Installation

Boring investigations and temporary well installations for the Bio Pilot Test will be conducted using rotosonic drilling methods. Rotosonic methods use high-frequency, resonate energy to advance a core barrel/casing into subsurface formations. SHA employees will be working around heavy equipment with moving parts, and should adhere to appropriate personal protective equipment (PPE), designated as Modified Level D, while working at the site. This includes at a minimum, a hard hat, safety glasses, hearing protection, work clothing, gloves, and other PPE as appropriate.

Drilling in bedrock using sonic methods may require the addition of fluids (*i.e.* municipal water) that lubricate and cool the drill bit during advancement. Under certain conditions, heat created during sonic drilling may increase the temperature of drilling fluids, soil, and rock cores. As a result, SHA employees should avoid all unnecessary contact with fluids and samples until directed by the drilling foreman that the samples are safe to handle. SHA employees should use specified safety equipment and PPE when handling environmental media as described in the HASP.

## Amendment Emulsification and Injection

SHA employees will oversee the mixing of amendments to be injected into the subsurface by drilling subcontractor. Amendments will include a liquid/non aqueous phase liquid organic substrate compound, EOS 598 B42, and a salt sodium bromide (NaBr) to be mixed with water and used as a conservative tracer,. The material safety data sheets (MSDS) for these compounds are included as attachments to this Work Plan.

The organic substrate and tracer amendments will be emulsified into water using a commercial grade mixer. Amendment mixture will be injected under pressure into the subsurface. SHA employees will oversee the emulsification and injection of amendments by the drilling subcontractor. SHA employees should use specified safety equipment and PPE when handling amendments, including hearing protection, safety glasses, safety gloves, and other appropriate equipment and PPE as described in the HASP.

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[1] Sanborn, Head & Associates, January 2008. “Site Specific Health and Safety Plan, IBM Gun Club Site, Union, New York”.

The following zones will be established during injection:

**Injection Zone (IZ):** Maintain an injection zone radius of ten feet from the borehole or large enough to encompass all injection equipment or materials. The IZ will be marked using at traffic cones or other high visibility markers such as fiberglass reflective poles with flagging.

**Exclusion Zone (EZ):** Outside the IZ, SHA employees should maintain a work zone radius large enough to encompass all equipment and materials used by SHA to monitor the injection process and large enough to encompass all drilling equipment and decontamination materials needed by the drilling subcontractor.

**Contamination Reduction Zone (CRZ):** Removal of PPE as well as equipment decontamination should occur at the perimeter of the EZ.

**Support Zone (SZ):** All areas external to the EZ and CRZ are considered the support zone.

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# APPENDIX C

# SCREENING OF POTENTIAL AMENDMENTS AND DOSING DESIGN

# APPENDIX C
# SCREENING OF POTENTIAL AMENDMENTS, DESIGN OF AMENDMENT DOSING AND INJECTION GALLERY

## C. 1 Introduction

This Appendix summarizes the screening of potential carbon source amendments, selection of an amendment and development of a rational design for proposed injection dosing for two stages of pilot testing. For additional details regarding the overall pilot test work plan, please refer to the Work Plan text.

The screening of potential amendments described in this appendix was conducted considering and applying generally accepted hydrogeologic principles and our understanding of site-specific conditions, physical and chemical properties of potential carbon source amendments or "substrates", and relevant contaminant fate and transport concepts.

The following are terminological definitions are applicable and used throughout this appendix:

- *Substrate demand* – This describes the stoichiometrically estimated total substrate mass or volume that may be required for the duration and goals of the test.

- *Attenuation rate* – This describes the rate at which carbon amendment is lost through the combined process of dilution, diffusion, sorption, chemical reactions, and biological respiration processes occurring in the subsurface.

- *Seepage velocity* or *advective velocity* – This term describes the average macrosopic rate of movement of a water particle in the subsurface. The seepage velocity can be estimated based on a form of darcy's equation.

Using generally accepted procedures and considering site-specific conditions, we developed estimates of potential substrate demand for a proposed 6-month pilot test period and assessed potential fate and transport mechanisms for the proposed carbon substrate in the subsurface. As outlined in more detail below, we expect that the actual attenuation rates, including substrate utilization rates and transport processes, will differ perhaps markedly from these estimates.

Pilot testing is designed to be conducted in two steps or stages, as discussed in more detail in Section 3.0 of the Work Plan. The first stage of injection is to include a smaller amendment dosing along with a non-bioreactive tracer and will be observed to aid in better understanding actual transport conditions at the field scale. Based on observations and inference from the Stage 1 testing, a more substantial amendment injection will be conducted in the second stage.

## C.2 Screening of Potential Amendments

The amendment selection process included a review of technical guidance, case studies, literature search, and communication with commercial amendment vendors with the goal of identifying amendments that may be more suitable to application in the fractured sedimentary rock environment. The four major screening criteria or considerations included:

1. Amendment solubility- less soluble amendments offer better potential for remaining in the subsurface over a longer period, whereas more soluble amendments would be expected to dissipate more rapidly in the fracture system;

2. The amendment should be able to penetrate the fracture pores space. Our estimates of fracture aperture range from 1s to hundreds of microns, typically in the tens of microns averaging about $50 \times 10^{-6}$ m (50 microns).

3. Commercial availability of product and the compatibility with pH buffer additions to maintain geochemical conditions conducive to biochemical degradation of chlorinated volatile organic compounds (CVOCs) and/or other nutrients.

4. Sufficiently high organic carbon content in amendment to be serving as a source of carbon substrate for up to 6 months.

Table C.1 summarizes information gathered on the eight major groups of amendments discussed in the literature, and provides an overall rating for site-specific application, with 1 being most positive overall rating and 5 being least positive rating. The rating is somewhat subjective in nature and represents our professional judgment as to the relative suitability of candidate amendments for application to this site in consideration of our stated pilot test objectives. The rating should not be considered a judgment regarding possible application to other sites. As noted in Table C.1, the soybean oil/vegetable oil amendments appear to better meet the screening criteria for the fractured rock setting. As such, we recommend the injection of an edible oil such as soybean oil in a non aqueous phase liquid (NAPL) form or as a concentrated emulsion for the carbon amendment to be used in the pilot test. The MSDS sheets for EOS emulsion products are included as Attachment C.1.

### C.3 Amendment Dosing Design

The proposed amendment dosing was developed using an analytical approach modified from the U. S. Air Force Center for Environmental Excellence (AFCEE) guidance, 2004[1]. Consistent with the AFCEE guidance, the amendment dosing was estimated considering the additive potential substrate demand from CVOC mass and other major potential electron acceptors. Our dosing design was adapted for the fractured rock setting from the AFCEE methodologies which were developed for a soil setting, in consideration of lower fracture porosity, and the resultant relatively rapid fracture pore volume exchanges.

In this case, for the purposes of relatively short-term pilot testing, we considered the potential substrate demand that may result from CVOCs and electron acceptors present in groundwater migrating through the fracture pore space without accounting for loss of substrate to the

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[1] Air Force Center for Environmental Excellence (AFCEE), 2004. “Principals and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents”. Prepared by Parsons Corporation, August, 2004.

unfractured rock matrix or potential substrate demand associated with CVOCs and electron acceptors within the rock matrix. We believe that during the short duration pilot test, the substrate demand associated with the rock matrix will not be fully manifested. Tables C.2 and C.3 summarize the assumptions and the substrate demand estimated for the Stage 1 and Stage 2 injections based on site-specific estimates of fracture porosity, seepage velocities, and water quality data consistent with those reported in the RI Report.

As shown in Table C.2, the estimated stoichiometric-based substrate demand for the Injection Zone 1 for the test period is 10 lbs, equivalent to approximately 2 gallons of undiluted commercially available edible oil amendment (assuming 60% soybean oil by weight). Diluting the amendment by about 11 times would result in a total liquid volume equivalent to the estimated fracture volume in the injection zone as depicted on Figure C.3. The manufacturer recommends dilution of the amendment by about 4 to 19 times to reduce the dynamic viscosity of the injection fluid.

Extending this dosing demand to the Treatment Zone 2 area, approximately 24 lbs substrate demand, or 5 gallons of undiluted commercially available edible oil amendment is estimated for the second phase of injection (Table C.3). Diluted according to the manufacturers recommendations would result in about 20 to 95 gallons of injection volume. The tracer testing during the Stage 1 injection is intended to provide more information about potential amendment migration and retardation. The amendment mass estimate for the Stage 2 testing may be revised based on Stage 1 injection, tracer testing observations, and water quality monitoring.

Injection of an oil water emulsion will emplace globules of oil into the formation that will not immediately result in dissolved organic carbon, but will dissolve over time serving as a longer term source of carbon. The proportion that will remain physically immobile in globule form and the short-term organic carbon loading in dissolved phase is uncertain. Based on published information for applications in more highly permeable granular soils indicate that on the order 10% of oil mass is expected to be retained in oil globule form whereas for less permeable soils or with injection of oil in a NAPL form, on the order of 40% to 90% maybe retained in oil globule form within the injection area[2].

One goal of Stage 1 injection will therefore be to observe the increase in dissolved organic carbon as an indication of how much of the emulsion may be retained within the Injection Zone. As discussed further below, the emplacement of oil globules into fracture pore space will decrease the effective hydraulic conductivity in the subsurface to some degree.

## C.4 Design of Borehole Injection Gallery

The number, diameter, and spacing of boreholes to be used in injection was designed in consideration of the horizontal radius (R) extending out from the center of the boring that is expected to be influenced during amendment injection assuming mean fracture porosity values

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[2] Environmental Security Technology Certification Program (ESTCP), 2006. “Protocol for Enhanced In Situ Bioremediation Using Emulsified Edible Oil”. Prepared by Solutions – IES, May 2006.

derived from RI testing, and allowing for 2/3 overlap in injection volume. Table C.4 summarizes the rationale for the number and spacing of the injection boring, yielding 9, 4" diameter boreholes spaced at equal distances across a 60' x 20' Injection Zone. The borings will be arranged in two lines spaced about 10 ft apart perpendicular to the anticipated primary direction of groundwater flow and a spacing of approximately 10 ft between boreholes as depicted on Figure C.4 and on Figure 2 of the Work Plan.

### C.5 Theoretical Amendment Utilization and Attenuation

The effect of hypothetical substrate attenuation were reviewed for attenuation rate constants between 0.001 and 0.1 day$^{-1}$. As defined above, attenuation could include biological utilization of substrate along with chemical utilization, dilution, diffusion, or sorption processes acting to disperse the amendment. For comparison, biochemical degradation rates for chlorinated ethenes derived from in situ testing at the site were estimated to be as high as 0.01 day$^{-1}$.

Arbitrarily assuming that a TOC concentration of 100 mg/l is achieved within the Injection Zone and attenuation rates are 0.01 day$^{-1}$, TOC concentrations are shown to drop by about an order of magnitude after about 240 days, or 8 months as shown in Exhibit 1 below.

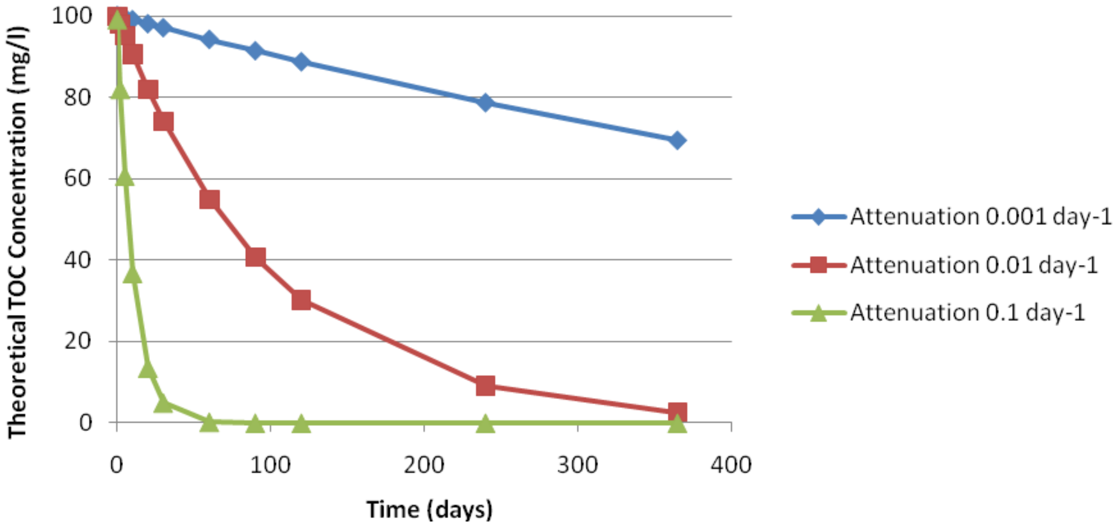

**Exhibit 1. Theoretical TOC concentration versus Time in the Injection Zone during the Pilot Test.**

Exhibit 2 depicts hypothetical TOC concentration profiles assuming downgradient transport by advection alone for hypothetical attenuation rate constants between 0.001 and 0.1 day$^{-1}$. Given a high attenuation rate (0.1 day$^{-1}$) at the low end of advective transport velocity of 5 feet per day (ft/d), the estimated distance for which theoretical substantial increases in TOC may be observed downgradient would be less than 100 feet. Assuming an attenuation rate similar to the high end degradation rates derived from in situ testing at the site (0.01 day$^{-1}$) and a moderate advective velocity of 18 ft/d, the TOC would approach background concentrations (around 2 mg/l) within a distance of 2,000 ft downgradient. At the low end of theoretical substrate attenuation (0.001 day$^{-1}$) and high end of advective transport rate (80 ft/d), increased TOC could be observed at distances greater than 10,000 ft downgradient. However, this last scenario is inconsistent with sorption and matrix diffusion concepts and included to provide a limited sensitivity analysis. At other field sites where edible oils have been injected into granular soils, substantial increases in TOC concentrations are generally not observed more than 50 feet downgradient[3].

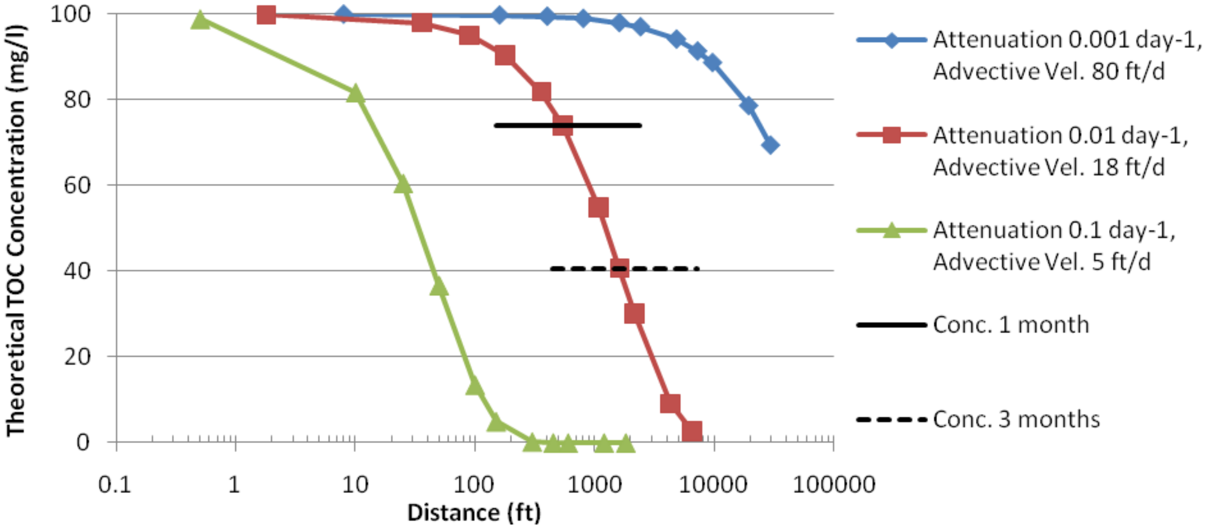

**Exhibit 2. Theoretical TOC concentrations versus distance from the Injection Zone for a range of advective transport rates and attenuation rates.**

The actual downgradient transport in the field will also be influenced by physical/chemical sorption and diffusion of the dissolved phase substrate into the matrix, both of which would reduce downgradient transport. Although we have not completed specific modeling of dissolved oil transport with sorption and diffusion as mechanisms under the time frame contemplated for this pilot testing, we can extrapolate from stylistic modeling conducted to simulate downgradient transport of TCE as completed by representative of the University of Guelph.

Simulations of TCE transport for a 10-year transport period, neglecting biological degradation indicate retardation ratios ranging from about $3x10^{-3}$ to $6.8x10^{-3}$ expressed as the ratio of model-estimated transport distance to the distance implied by advective seepage velocities alone. Assuming that these retardation ratios would be similar for dissolved oil/TOC, the resulting transport distances would be on the order of tens of feet over a nine month period at concentrations one to three orders of magnitude below the source concentrations in the injection zone. Recognizing that retardation ratios increase with time scale, arbitrarily assuming one order of magnitude lower retardation over a nine month time frame, would result in transport distances of up to about 30, 400, and 600 feet at one month, 6 months, and 9 months, respectively for concentrations about 3 orders of magnitude lower than source concentrations. More simply put,

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[3] Environmental Security Technology Certification Program (ESTCP), 2006, pp 5,. "Protocol for Enhanced In Situ Bioremediation Using Emulsified Edible Oil". Prepared by Solutions – IES, May 2006

assuming source concentrations of 100 mg/L and neglecting substrate utilization as outlined above, 1 mg/L TOC would be transported up to 600 feet downgradient over nine months.

We conclude on the basis of the assessment outlined above, that the treatment/monitoring zones outlined in the Work Plan are appropriate for the anticipated scale of transport. The actual downgradient transport distances for substrate amendment are likely to be on the order of tens of feet to a few hundred feet or less. Downgradient changes in geochemistry and VOC concentrations may differ. The actual transport conditions will be evaluated in two phases of monitoring.

### C.6 Other Amendment Injection Effects

Injection of oil is expected to at least temporary alter hydrogeology and geochemistry in the injection zone. These changes may include:

- partitioning of the CVOCs into the amendment oil phase which would act to reduce dissolved phase concentrations;
- reduction in the effective hydraulic conductivity within the Injection Zone due to amendment occupying the fracture pore space and perhaps due to build up of biological mass.

As a result of these two factors, we would expect reduced groundwater flow through the injection zone and increased retardation of CVOC transport. Basic back of an envelope calculations indicate that the retardation factor of CVOCs in groundwater might increase by a factor of 10 to 200 times under emplacement of a pure NAPL oil, and perhaps 2 to 10 times with a 2% emulsion. In other words, mass flux of CVOCs from the injection zone would be expected to decrease with sufficient contact between groundwater and edible oils. Whether this decreased mass flux would be realized in downgradient concentrations is uncertain and would be the subject of the monitoring program.

Previous field studies using edible oils have cited order of magnitude decreases in aquifer hydraulic conductivity resulting from the presence of oil and increased biological activity[2]. Reduced hydraulic conductivity of the injection Zone will be assessed by conducting slug tests in injection borings prior to amendment addition and after the Pilot Test.

Encl.

| | |
|---|---|
| Table C.1 | Summary of Enhanced Biochemical Degradation Amendments |
| Table C.2 | Preliminary Stoichiometric-Based Substrate Demand Calculation – Stage 1 |
| Table C.3 | Preliminary Stoichiometric-Based Substrate Demand Calculation – Stage 2 |
| Table C.4 | Borehole Spacing Design |
| Attachment C.1 | MSDS sheets for EOS emulsion products |

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# Table C.1
# Summary of Enhanced Biochemical Degradation Amendments
## Enhanced Bio Work Plan
## IBM Gun Club – Former Burn Pit Area
## Union, New York

| Amendment | Form/ Lifespan | Comment | Overall Rating (1=positive, 5=negative) |
|---|---|---|---|
| Sodium Lactate/Acetate | Soluble<br>Weeks to months | Would require multiple injections for pilot test. Biotrap results indicated lactate may require pH buffer. Commercially available and have been applied at numerous sites. | 4 |
| Ethanol/Methanol | Miscible<br>Days to weeks | Would require multiple injections for pilot test. Available for purchase through commercial laboratories. Applications have mostly included laboratory scale testing. | 5 |
| Refined/Complex Sugars (Corn Syrup/Molasses) | NAPL<br>Weeks to months | Available for purchase as a food-grade product. Reviewed applications have only included NAPL injections and included both laboratory and field studies. | 4 |
| Soybean/Vegetable Oil (EOSOil/Lactoil) | NAPL(months to years) or emulsion (Months) | Can be emulsified to particles smaller than avg. fracture size. High sorption/retardation potential. Commercial products available that are combined with vitamins and pH buffers. Slightly less dense than water (~0.95-0.99). Applications include both laboratory and field studies. | 1 |
| Hydrogen Release Compound (HRC) | NAPL<br>Months to years | High sorption/retardation potential. No dilution or emulsification allowed by manufacturer. Commercial products available that are combined with vitamins and pH buffers. More dense than water (~1.3). Applications include both laboratory and field studies. | 2 |
| Whey | Slurry to soluble<br>Months to years | Lower overall sorption/retardation potential. Variable product source (i.e. not commercially available). Generally contains natural vitamins and buffers. Applications include both laboratory and field studies. | 2 |
| Chitin Compound | Slurry to solid<br>Years | Low overall sorption/retardation potential. Slurry product larger than avg. fracture size. Commercially available product available that generally contain vitamins and buffers. Applications include both laboratory and field studies. | 2 |
| Organic Materials (Mulch/Compost) | Solid<br>Years | Injection of solids difficult. Could be placed in large diameter well casings. Applications include both laboratory and field studies. | 4 |

Notes:

1. The table is intended to summarize the screening of potential amendments, and provides an overall rating for site-specific application, with 1 being most positive overall rating and 5 being least positive rating. The rating is somewhat subjective in nature and represents our professional judgment as to the relative suitability of candidate amendments for application to this site in consideration of our stated pilot test objectives. The rating should not be considered a judgment regarding possible application to other sites. The ranking may change based on additional information provided by vendors and observations during the Stage 1 and Stage 2 pilot testing.

2. The Form and Lifespan information is based on data provided by vendors and review of laboratory and field testing described in the literature. The comments include information pertinent to and specific to the IBM Gun Club former Burn Pit Area.

3. Please refer to Appendix C and Work Plan text for further discussion.

# Table C.2
## Preliminary Stoichiometric-Based Substrate Demand Calculation
## Stage 1 Enhanced Bio Pilot Test
## IBM Gun Club - Former BPA

| LEGEND | |
|---|---|
| ▨ | =User Input |
| ⬜ | =Calculated |
| 🟦 | =Subtotal |
| 🟪 | =Total |
| 🟧 | Final Demands |

| **Injection Zone 1 Dimensions** | Value | Units | |
|---|---|---|---|
| Width (perpendicular to GW flow) | 60 | feet | |
| Length (parallel to GW flow) | 20 | feet | |
| Saturated Thickness | 5 | feet | |
| Treatment Zone Surface Area | 1,200 | ft2 | |
| Treatment Zone Volume | 6,000 | ft3 | |
| Treatment Zone Pore Volume (volume x total porosity) | 2,244 | gallons | Pore space due to matrix porosity |
| Treatment Zone Effective GW Volume (volume x effective porosity) | 22 | gallons | Pore space due to fracture porosity |

| **Injection Zone 1 Hydrogeologic Properties** | Value | Units | |
|---|---|---|---|
| Total Porosity, n | 0.05 | unitless | Matrix porosity of bedrock |
| Effective Porosity, ne | 0.0005 | unitless | Fracture porosity of bedrock |
| Avg. Hydraulic Conductivity, K | 0.11 | ft/day | |
| Avg. Hydraulic Gradient, i | 0.08 | ft/ft | |
| Avg. Seepage Velocity Ki/$n_e$ | 18 | ft/day | |
| Avg. Seepage Velocity Ki/$n_e$ | 6,424 | ft/yr | |
| Avg GW Flux = KiA | 7,208 | gal/year | |
| Bulk Density | 2.67 | g/cm3 | |
| Saturated fracture volume exchanges per month | 27 | | |

**Electron Acceptor Flux Demand (six months)**

| *Aqueous Phase* | Concentration mg/l | Mass lbs | Stoichiometric demand wt/wt H2 | Hydrogen demand lbs |
|---|---|---|---|---|
| Oxygen | 3 | 0.2 | 7.9 | 0.02 |
| Nitrate/Nitrite | 2 | 0.1 | 10.2 | 0.01 |
| Sulfate | 70 | 4.2 | 10.6 | 0.40 |
| Carbon Dioxide (estimated as amount of methane produced) | 0.1 | 0.0 | 5.5 | 0.00 |
| | | | Total Competing e- Acceptor Demand Flux (lbs/yr) | 0.4 |
| | | | Total for a 6-month period | 0.2 |

See note below on calculation.

| *Contaminant Mass, Dissolved* | Concentration mg/l | Mass lbs | Stoichiometric demand wt/wt H2 | Hydrogen demand lbs |
|---|---|---|---|---|
| PCE | 0 | 0.000 | 20.6 | 0.00 |
| TCE | 1 | 0.060 | 21.7 | 0.00 |
| cDCE | 0.1 | 0.006 | 24 | 0.00 |
| VC | 0.02 | 0.001 | 31 | 0.00 |
| CT | 0.001 | 0.000 | 25.4 | 0.00 |
| CF | 0.001 | 0.000 | 12.3 | 0.00 |
| | | | Total Soluble e- Acceptor Demand Flux (lbs/yr) | 0.0031 |
| | | | Total for a 6-month period | 0.0015 |

Flux demand is calculated assuming average electron acceptor and VOC concentrations in fractures flowing into the treatment cell. Demand calculation multiplies concentration by

Conversion factors: 1 gal = 3.785 Liters
1 kg = 2.2 lbs.
$10^6$ mg = 1 kg
1 $ft^3$ = 7.48 gallons

| Overall Hydrogen Demand (lb/yr) | 0.2 |
|---|---|

| **Design Factors and Total Hydrogen Demand** | |
|---|---|
| Microbial Efficiency Utilization Uncertainty | 2X - 5X |
| Methane and Solid-Phase Electron Acceptor Uncertainty | 2X - 5X |
| Remedial Design Safety Factor (e.g. Substrate Leaving Reaction Zone) | 1X - 2X |
| Total Hydrogen Demand (lb. $H_2$, assuming 5X Design Factor) | 1.1 |

| Substrate | Ratio H2 Produced to Substrate (g/g) | Substrate to Fulfill Demand (lbs) |
|---|---|---|
| Pure Form Edible Oil Product (soybean oil, corn oil, cotton oil) | 0.115 | 9.5 |

| Product Specifications for EOS 598 B42 | | |
|---|---|---|
| Percent Soybean Oil | 60% | vol/vol |
| Volume Substrate to Inject (assuming pure NAPL form) | 2 | gals |
| Volume Substrate to Inject (assuming 11:1 dilution with water) | 21 | gals |

Notes:

1. The table is intended to summarize the Stage 1 stiochiometric-based estimated substrate demand for a commercially-available edible oil product (EOS 598 B42). The estimates are based on assumptions of the hydrogen demand of oxidized electron acceptors in the bedrock fractures, including chlorinated ethenes and inorganics that could potentially react with a carbon substrate in a subsurface environment during a 6-month testing period. Demands are derived from oxidation reduction reactions and theoretical stoichiometric relationships reported in AFCEE guidance materials for granular soils, and adapted to the fractured rock setting for estimation purposes only. Actual site conditions and demands may differ, perhaps markedly, from these estimates.

2. A 5 x design safety factor for hydrogen demand is included. The calculation assumes EOS 598B42 makes up 60% of the undiluted edible oil product and has a specific gravity of 0.95.

3. Please see Appendix C and work plan text for further details and discussion.

# Table C.3
# Preliminary Stiochiometric-Based Substrate Demand Calculation
## Stage 2 Enhanced Bio Pilot Test
## IBM Gun Club - Former BPA

| LEGEND | |
|---|---|
| ▨ | =User Input |
| ⬜ | =Calculated |
| 🟦 | =Subtotal |
| 🟪 | =Total |
| 🟧 | Final Demands |

| **Injection Zone 1 Dimensions** | Value | Units | |
|---|---|---|---|
| Width (perpendicular to GW flow) | 180 | feet | |
| Length (parallel to GW flow) | 280 | feet | |
| Saturated Thickness | 5 | feet | |
| Treatment Zone Surface Area | 50,400 | ft2 | |
| Treatment Zone Volume | 252,000 | ft3 | |
| Treatment Zone Pore Volume (volume x total porosity) | 94,248 | gallons | Pore space due to matrix porosity |
| Treatment Zone Effective GW Volume (volume x effective porosity) | 942 | gallons | Pore space due to fracture porosity |

| **Injection Zone 1 Hydrogeologic Properties** | Value | Units | |
|---|---|---|---|
| Total Porosity, n | 0.05 | unitless | Matrix porosity of bedrock |
| Effective Porosity, ne | 0.0005 | unitless | Fracture porosity of bedrock |
| Avg. Hydraulic Conductivity, K | 0.11 | ft/day | |
| Avg. Hydraulic Gradient, i | 0.08 | ft/ft | |
| Avg. Seepage Velocity $Ki/n_e$ | 18 | ft/day | |
| Avg. Seepage Velocity $Ki/n_e$ | 6,424 | ft/yr | |
| Avg GW Flux = KiA | 21,623 | gal/year | |
| Bulk Density | 2.67 | g/cm3 | |
| Fraction Organic Carbon (foc) | 0.0018 | unitless | |
| Pore volume exchanges per month | 2 | | |

**Electron Acceptor Flux Demand (five months)**

See note below on calculation.

| *Aqueous Phase* | Concentration mg/l | Mass lbs | Stoichiometric demand wt/wt H2 | Hydrogen demand lbs |
|---|---|---|---|---|
| Oxygen | 3 | 0.5 | 7.9 | 0.07 |
| Nitrate/Nitrite | 2 | 0.4 | 10.2 | 0.04 |
| Sulfate | 70 | 12.6 | 10.6 | 1.19 |
| Carbon Dioxide (estimated as amount of methane produced) | 0.1 | 0.0 | 5.5 | 0.00 |
| | Total Competing e- Acceptor Demand Flux (lbs/yr) | | | 1.3 |
| | Total for a 5-month period | | | 0.5 |

Flux demand is calculated assuming average electron acceptor and VOC concentrations in fractures flowing into the treatment cell. Demand calculation multiplies concentration by Avg GW

| *Contaminant Mass, Dissolved* | Concentration mg/l | Mass lbs | Stoichiometric demand wt/wt H2 | Hydrogen demand lbs |
|---|---|---|---|---|
| PCE | 0 | 0.000 | 20.6 | 0.00 |
| TCE | 1 | 0.180 | 21.7 | 0.01 |
| cDCE | 0.1 | 0.018 | 24 | 0.00 |
| VC | 0.02 | 0.004 | 31 | 0.00 |
| CT | 0.001 | 0.000 | 25.4 | 0.00 |
| CF | 0.001 | 0.000 | 12.3 | 0.00 |
| | Total Soluble e- Acceptor Demand Flux (lbs/yr) | | | 0.0092 |
| | Total for a 5-month period | | | 0.0038 |
| | Overall Hydrogen Demand (lb/yr) | | | 0.5 |

Conversion factors: 1 gal = 3.785 Liters
1 kg = 2.2 lbs.

| **Design Factors and Total Hydrogen Demand** | |
|---|---|
| Microbial Efficiency Utilization Uncertainty | 2X - 5X |
| Methane and Solid-Phase Electron Acceptor Uncertainty | 2X - 5X |
| Remedial Design Safety Factor (e.g. Substrate Leaving Reaction Zone) | 1X - 2X |
| Total Hydrogen Demand (lb. $H_2$, assuming 5X Design Factor) | 2.7 |

| Substrate | Ratio H2 Produced to Substrate (g/g) | Substrate to Fulfill Demand (lbs) |
|---|---|---|
| Pure Form Edible Oil Product (soybean oil, corn oil, cotton oil) | 0.115 | 23.6 |

| Product Specifications for EOS 598 B42 | | |
|---|---|---|
| Percent Soybean Oil | 60% | vol/vol |
| Volume Substrate to Inject (assuming pure NAPL form) | 5 | gals |
| Volume Substrate to Inject (assuming 11:1 dilution with water) | 53 | gals |

Notes:

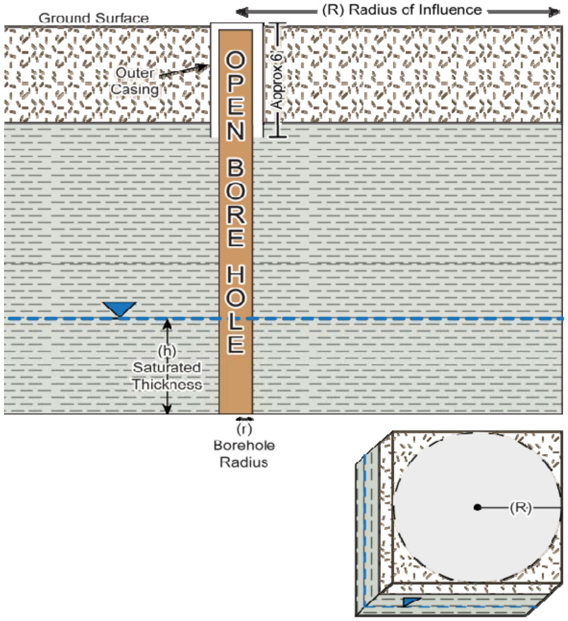
1. The table is intended to summarize the Stage 2 stiochiometric-based estimated substrate demand for a commercially-available edible oil product (EOS 598 B42). The estimates are based on assumptions of the hydrogen demand of oxidized electron acceptors in the bedrock fractures, including chlorinated ethenes and inorganics that could potentially react with a carbon substrate in a subsurface environment during a 6-month testing period. Demands are derived from oxidation reduction reactions and theoretical stoichiometric relationships reported in AFCEE guidance materials for granular soils, and adapted to the fractured rock setting for estimation purposes only. Actual site conditions and demands may differ, perhaps markedly, from these estimates.

2. A 5 x design safety factor for hydrogen demand is included. The calculation assumes EOS 598B42 makes up 60% of the undiluted edible oil product and has a specific gravity of 0.95.

3. Please see Appendix C and work plan text for further details and discussion.

# Table C.4
## Borehole Spacing Design
## IBM Gun Club - Former Burn Pit Area Enhanced Bio Pilot Test

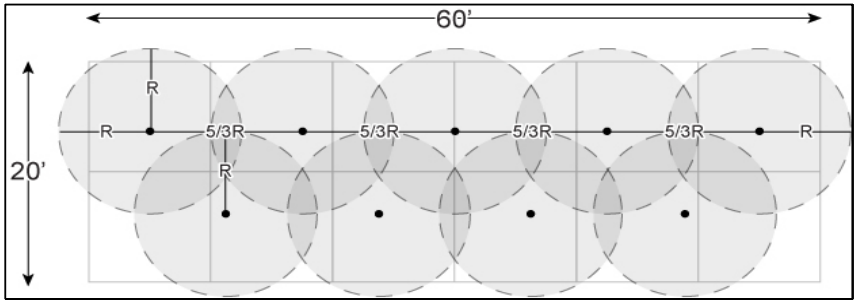
| Variable | Value | Units | Value | Units |
|---|---|---|---|---|
| ($\pi$) Pi | 3.1415927 | | | |
| (h) Saturated Thickness | 5 | ft | | |
| ($\gamma$ rock) Rock Bulk Density | 2.67 | $g/cm^3$ | 166.68 | $lb/ft^3$ |
| ($\Phi f$) Fracture Porosity | 0.0005 | unitless | | |
| (r) Borehole Radius* | 2 | in. | 0.17 | ft |
| V(saturated space) | 0.44 | $ft^3$ | 3.26 | gallons |
| V(ammendment) | 0.44 | $ft^3$ | 3.26 | gallons |
| (R) Radius of Influence | 7.45 | ft | | |
| 4/3R | 9.94 | ft | | |
| Area of Influence ($\pi R^2$) | 174.53 | $ft^2$ | | |
| (X) Test Zone Distance in X Direction | 60 | feet | | |
| (Y) Test Zone Distance in Y Direction | 18 | feet | | |
| Area of Test Zone (X * Y) | 1080 | $ft^2$ | | |
| # of Borings Needed in X Direction | 4.5 | rounded to nearest whole | | |
| # of Borings Needed in Y Direction | 2.4 | rounded to nearest whole | | |
| Total # of Borings Needed for Test Zone Area | 10 | rounded to nearest whole | | |

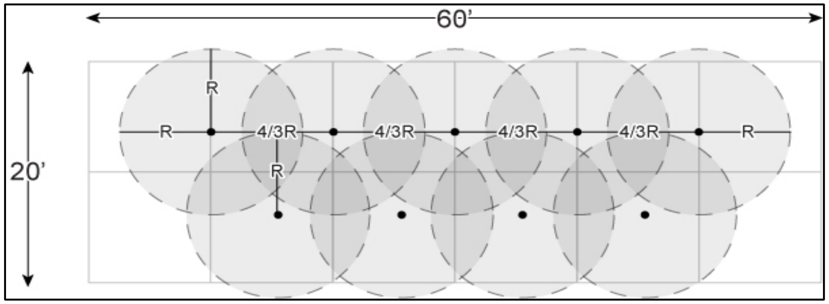


Notes:

*Edit the borehole radius (r ) to view changes in the Radius of Influence (R )

*Edit the X and Y distances to *view changes in # of borings needed*





For borings with 2" radius, 60' x 20' injection area (# of borings approx. = 9):

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# Formulations

## EOS® Family of Proven Products

EOS Remediation's family of soybean oil emulsions / emulsified vegetable oil (EVO™) includes several product formulations. Selecting the appropriate product for your project is important. The comparison chart below provides information needed to compare and understand each product offering.

| **Ingredients / Composition** | **EOS® 450**<br>**(% by Weight)** | **EOS® 598**<br>**(% by Weight)** | **EOS® 598B42**<br>**(% by Weight)** |
|---|---|---|---|
| Soybean Oil (food grade) | 49.9 ± 2% | 59.8 ± 2% | 59.8 ± 2% |
| Long Chain Fatty Acids | 0.9 ± 0.2% | 0 | 0 |
| Fast Release Soluble Substrate | 4 ± 0.2% | 4 ± 0.2% | 4 ± 0.2% |
| Food Additives / Emulsifiers / Preservatives | 10.1 ± 0.2% | 10.1 ± 0.2% | 10.1 ± 0.2% |
| Extracts | No | No | 2 ± 0.2% |
| Water | Balance | Balance | Balance |
| Percent Organic, by weight | 63 ± 2% | 72 ± 2% | 74 ± 2% |
| EOS® Vitamin $B_{12}$ Supplement | No | No | Yes |

*EOS Remediation reserves the right to change Product specifications and formulations without notice and without liability for such changes.

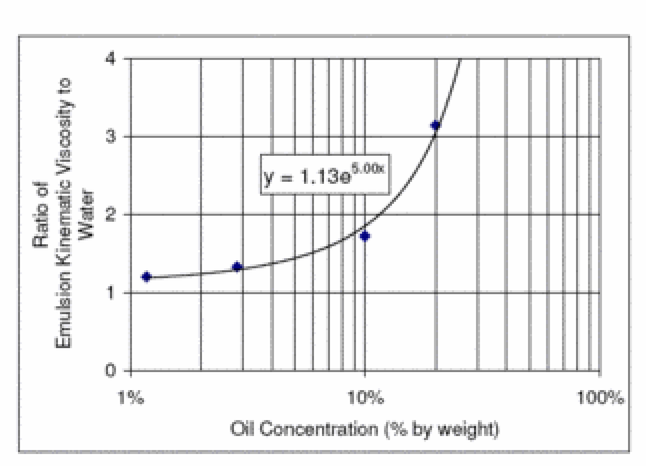
EOS Remediation, LLC

# Visvosity

## Viscosity

For EOS® 598B42, we typically suggest that the concentrate be diluted 19:1 to 4:1 with water prior to injection (3 to 12% final oil concentration). This ensures the injected emulsion will be between 1.3 and 2.1 times as viscous as water.

Concentrated emulsions can be highly viscous. EOS Remediation's oil-in-water emulsions are much less viscous than NAPL oils and do not require any special handling equipment. Viscosity in the figure below is presented as the ratio of emulsion viscosity to water viscosity at 20 °C.



Ratio of emulsion kinematic viscosity to water for EOS® 598B42 emulsion diluted with varying amounts of water

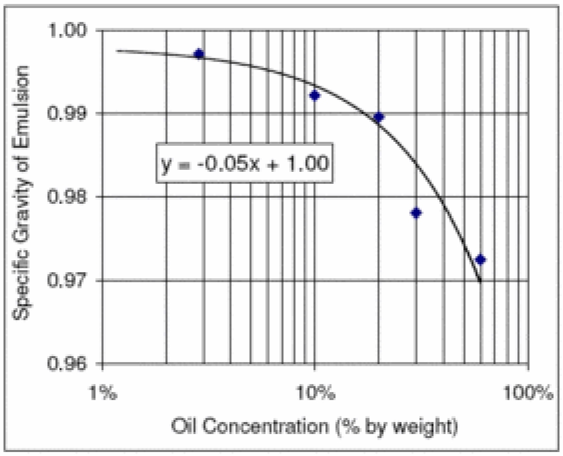
For EOS® 598B42, we typically suggest that the concentrate be diluted 19:1 to 4:1 with water prior to injection (3 to 12% final oil concentration). This ensures the injected emulsion will be between 1.3 and 2.1 times as viscous as water.

EOS Remediation, LLC

# Density

## Density

The density of concentrated oil emulsions is between 0.96 and 1.00 g/ml and varies as a function of oil content. The figure below shows the specific gravity of EOS® 598B42.



Specific gravity of EOS® 598B42 emulsion diluted with varying amounts of water

# MATERIAL SAFETY DATA SHEET

**EMULSIFIED EDIBLE OIL SUBSTRATE**

D.O.T. HAZARD CLASSIFICATION: NONE

| ----HMIS---- | |
|---|---|
| HEALTH | 1 |
| FLAMMABILITY | 0 |
| REACTIVITY | 0 |
| PERSONAL PROTECTION | B |

MANUFACTURER'S NAME

**EOS Remediation, Inc**
**1101 Nowell Road**
**Raleigh, NC 27607**
**www.EOSRemediation.com**

DATE OF PREPARATION
01-24-03, Rev. 04-19-05

INFORMATION TELEPHONE NO.
**919-873-2204**

## SECTION I - PRODUCT IDENTIFICATION

| | |
|---|---|
| PRODUCT NAME | **EOS®CONCENTRATE 598B 42** |
| PRODUCT CLASS | **VEGETABLE OIL BASED EMULSION** |
| CAS NUMBER | **MIXTURE** |

## SECTION II - HAZARDOUS INGREDIENTS

| COMPONENT(S) | EXPOSURE LIMIT |
|---|---|

**THIS PRODUCT IS A MIXTURE OF EDIBLE FOOD GRADE ADDITIVES AND CONTAINS NO HAZARDOUS INGREDIENTS.**

## SECTION III - PHYSICAL DATA

| | |
|---|---|
| BOILING POINT: | **212°F** |
| SPECIFIC GRAVITY: | **0.97; .92 (pure oil phase)** |
| VAPOR PRESSURE: | **NOT ESTABLISHED** |
| PERCENT VOLATILE BY VOLUME (%): | **24 (AS WATER)** |
| VAPOR DENSITY: | **HEAVIER THAN AIR** |
| EVAPORATION RATE: | **NOT ESTABLISHED** |
| SOLUBILITY IN WATER: | **SOLUBLE** |
| APPEARANCE AND ODOR: | **OFF WHITE LIQUID WITH VEGETABLE OIL ODOR** |

## SECTION IV - FIRE AND EXPLOSION HAZARD DATA

| | |
|---|---|
| FLASH POINT: | **>300°F** |
| FLAMMABLE LIMITS: | **NOT ESTABLISHED** |
| EXTINGUISHING MEDIA: | **$CO_2$, FOAM, DRY CHEMICAL**<br>**NOTE: WATER, FOG, AND FOAM MAY CAUSE FROTHING AND SPATTERING.** |
| UNUSUAL FIRE AND EXPLOSION HAZARDS: | **BURNING WILL CAUSE OXIDES OF CARBON.** |
| SPECIAL FIRE FIGHTING PROCEDURES: | **WEAR SELF CONTAINED BREATHING APPARATUS AND CHEMICAL RESISTANT CLOTHING. USE WATER SPRAY TO COOL FIRE EXPOSED CONTAINERS.** |

## SECTION V - PHYSICAL HAZARDS

| | |
|---|---|
| STABILITY: | **STABLE** |
| CONDITIONS TO AVOID: | **NONE** |
| INCOMPATIBILITY: | **STRONG ACIDS AND OXIDIZERS.** |
| HAZARDOUS DECOMPOSITION PRODUCTS: | **THERMAL DECOMPOSITION MAY PRODUCT OXIDES OF CARBON.** |
| HAZARDOUS POLYMERIZATION: | **WILL NOT OCCUR** |

## SECTION VI - HEALTH HAZARDS

SIGNS AND SYMPTOMS OF EXPOSURE:

| | |
|---|---|
| 1. Acute Overexposure - | **NONE** |
| 2. Chronic Overexposure - | **NONE** |

| | |
|---|---|
| MEDICAL CONDITIONS GENERALLY AGGRAVATED BY EXPOSURE: | **NONE KNOWN** |

CHEMICAL LISTED AS CARCINOGEN OR POTENTIAL CARCINOGEN:

N.T.P. - **NO** I.A.R.C. - **NO** OSHA - **NO**

EMERGENCY AND FIRST AID PROCEDURES:

| | |
|---|---|
| 1.) Inhalation- | **REMOVE TO FRESH AIR.** |
| 2.) Eyes- | **FLUSH WITH WATER FOR 15 MINUTES, IF IRRITATION PERSISTS SEE PHYSICIAN.** |
| 3.) Skin- | **WASH WITH MILD SOAP AND WATER.** |
| 4.) Ingestion- | **PRODUCT IS NON-TOXIC. IF NAUSEA OCCURS, INDUCE VOMITING AND SEEK MEDICAL ATTENTION.** |

## SECTION VII - SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION: **NOT NORMALLY REQUIRED**
VENTILATION: **LOCAL EXHAUST**
PROTECTIVE GLOVES: **NOT NORMALLY REQUIRED**
EYE PROTECTION: **NOT NORMALLY REQUIRED**
OTHER PROTECTIVE CLOTHING OR EQUIPMENT: **NONE**

## SECTION VIII - SPECIAL PRECAUTIONS AND SPILL/LEAK PROCEDURES

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: **DO NOT STORE NEAR EXCESSIVE HEAT OR OXIDIZERS.**

OTHER PRECAUTIONS: **NONE**

STEPS TO BE TAKEN IN CASE MATERIAL IS SPILLED: **SOAK UP WITH DRY ABSORBENT AND FLUSH AREA WITH LARGE AMOUNTS OF WATER.**

WASTE DISPOSAL METHODS: **DISPOSE OF ACCORDING TO FEDERAL, STATE, AND LOCAL REGULATIONS.**

## SECTION IX - ADDITIONAL REGULATORY INFORMATION

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**

THIS PRODUCT DOES **NOT** CONTAIN SECTION 313 REPORTABLE INGREDIENTS.

---

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.

EOS

EOS Remediation, LLC

# Injection Equipment

## Injection Equipment

Proper handling and injecting EOS Remediation products is a critical, cost-sensitive step in the overall remediation process. That's why EOS Remediation offers continuous mixing equipment for purchase or rent.

Regardless of the number of injection points, equipment and systems that simplify and facilitate this process provide time and cost saving advantages over more labor-intensive on-site mixing and blending approaches. In association with Dosatron International, S.A. (http://www.dosatronusa.com/) , EOS Remediation has developed a metering system based on Dosatron® DI520.

The EOS® DI520 Metering System installs directly to any available water supply line. It operates without electricity, using water pressure as the power source. Inside the DI520, any EOS® concentrate can be pulled directly from the drum, tote or tank and is mixed with water at a determined dilution rate. The water pressure forces the diluted emulsion downstream to the injection well. The amount of EOS concentrate is directly proportional to the volume of water entering the system so variations in water pressure or flow rate have no effect on the dilution. EOS® Metering Systems are available for rental or purchase.

# APPENDIX D

# FIELD PROCEDURES AND FORMS

# Appendix D.1

## Test Boring/Well Installation Log

**Project: Gun Club**
**Location: Union, NY**
**SHA Project No.: 2400.00**

# Log of Boring

**Ground Elevation:**

**Drilling Method:**

**Datum:**

**Sampling Method:**

**Groundwater Readings**

| Date | Time | Depth to Water | Ref. Pt. | Depth of Casing | Depth of Hole | Stab. Time |
|---|---|---|---|---|---|---|

**Drilling Company:**
**Foreman:**
**Date Started:** **Date Finished:**
**Logged By:** **Checked By:**

| Depth (ft) | Sample No. | Drill Rate (min/ft) | Sample Information | | | | Stratum | | | Geologic Description | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Depth (ft) | Pen/ Rec (ft) (%) | RQD (%) | Field Testing Data | Log | Frac- tures | Description | | |
| 0 | | | | | | | | | -----0'----- | | |
| 2 | | | | | | | | | | | |
| 4 | | | | | | | | | | | |

**Fracture Symbols** ∽ Crack ▭ Joint ▨ Extremely Fractured Zone

**Sheet: 1 of 10**

**Project: Gun Club**
**Location: Union, NY**
**SHA Project No.: 2400.00**

# Log of Boring

**Ground Elevation:**

**Drilling Method:**

**Datum:**

**Sampling Method:**

**Groundwater Readings**

| Date | Time | Depth to Water | Ref. Pt. | Depth of Casing | Depth of Hole | Stab. Time |
|---|---|---|---|---|---|---|

**Drilling Company:**
**Foreman:**
**Date Started:** **Date Finished:**
**Logged By:** **Checked By:**

| Depth (ft) | Sample No. | Drill Rate (min/ft) | Sample Information | | | | Stratum | | | Geologic Description | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Depth (ft) | Pen/ Rec (ft) (%) | RQD (%) | Field Testing Data | Log | Frac- tures | Description | | |
| 6 | | | | | | | | | | | |
| 8 | | | | | | | | | | | |
| 10 | | | | | | | | | | | |

**Fracture Symbols** ∿ Crack ⊟ Joint ▨ Extremely Fractured Zone

**Sheet: 2 of 10**

SHA
IMPROVING EARTH

**Project: Gun Club**
**Location: Union, NY**
**SHA Project No.: 2400.00**

# Log of Boring

**Ground Elevation:**

**Drilling Method:**

**Datum:**

**Sampling Method:**

**Groundwater Readings**

| Date | Time | Depth to Water | Ref. Pt. | Depth of Casing | Depth of Hole | Stab. Time |
|---|---|---|---|---|---|---|

**Drilling Company:**
**Foreman:**
**Date Started:** **Date Finished:**
**Logged By:** **Checked By:**

| Depth (ft) | Sample No. | Drill Rate (min/ft) | Sample Information | | | | Stratum | | | Geologic Description | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Depth (ft) | Pen/ Rec (ft) (%) | RQD (%) | Field Testing Data | Log | Frac- tures | Description | | |
| 10 | | | | | | | | | | | |
| 12 | | | | | | | | | | | |
| 14 | | | | | | | | | | | |

CORING LOG S:\PORDATA\2400S\2400\WORK\GINT LOGS\ROCK GINT LOGS\FINAL 2400 ROCK LOGS.GPJ 2008 SHA V1.GLB 2008 SHA V1.GDT 04/18/08

**Fracture Symbols** ▭ Crack ▭ Joint ▨ Extremely Fractured Zone

**Sheet: 3 of 10**

**Project: Gun Club**
**Location: Union, NY**
**SHA Project No.: 2400.00**

# Log of Boring

**Ground Elevation:**

**Drilling Method:**

**Datum:**

**Sampling Method:**

**Groundwater Readings**

| Date | Time | Depth to Water | Ref. Pt. | Depth of Casing | Depth of Hole | Stab. Time |
|---|---|---|---|---|---|---|

**Drilling Company:**
**Foreman:**
**Date Started:** **Date Finished:**
**Logged By:** **Checked By:**

| Depth (ft) | Sample No. | Drill Rate (min/ft) | Sample Information | | | | Stratum | | | Geologic Description | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Depth (ft) | Pen/ Rec (ft) (%) | RQD (%) | Field Testing Data | Log | Frac- tures | Description | | |
| 16 | | | | | | | | | | | |
| 18 | | | | | | | | | | | |
| 20 | | | | | | | | | | | |

**Fracture Symbols** Crack Joint Extremely Fractured Zone

# Appendix D.2

# Well Development Field Form

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# Summary of Monitoring Well Development

| Well | Water Volume Added During Drilling (gal) | Date Development Performed | Development Water Level (ft) | Pumping Data | Approximate Pumping Rate (gal/min) | Pumping Duration (min) | Approximate Volume Purged (gal) | Silt @ Bottom of Well | Visual Indicators | | | pH Pre- & Post-Development (s.u.) | | Specific Conductance Pre- & Post-Development (µS/cm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Turbid | Cloudy | Clear | Pre- | Post- | Pre- | Post- |
| | | | | | | | | | | | | | | | |
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**Approximate Total Volume of Water Purged (gallons):**

**Comments**

1.
2.
3.

# Appendix D.3

# Rising Head Slug Test Field Procedure

SHPC
ENGINEERS

# Appendix D.3
# Rising Head Slug Test Procedure
# Enhanced Bio Pilot Test

Rising head slug tests will be performed during pilot testing on boreholes/wells that are screened across the groundwater table. The following procedures will be used during slug testing:

- The depth to water table will be measured;

- An In-situ Level Troll pressure transducer/data logger (or similar) and a slug consisting of PVC filled with sand will be lowered into the borehole/well. The lowering of equipment into the borehole/well will instantaneously raise the water level; therefore, the water table will be allowed time to return to its static level prior to slug testing;

- During testing, the slug will be rapidly pulled out of the well, which instantaneously lowers the water level in the borehole/well. The transducer/data logger will record the re-equilibration of the water by making a measurement every 0.5 to 10 seconds;

- The test data will be downloaded to a laptop computer.

The slug test field data will be analyzed using the method of Bouwer and Rice[1] with the software package Aquifer Test, version 4.2. Slug test analysis results will be summarized in tabular and graphical format, as shown before.

**Test Name:** BP-18A Rising (Example)
**Analysis Method:** Bouwer & Rice

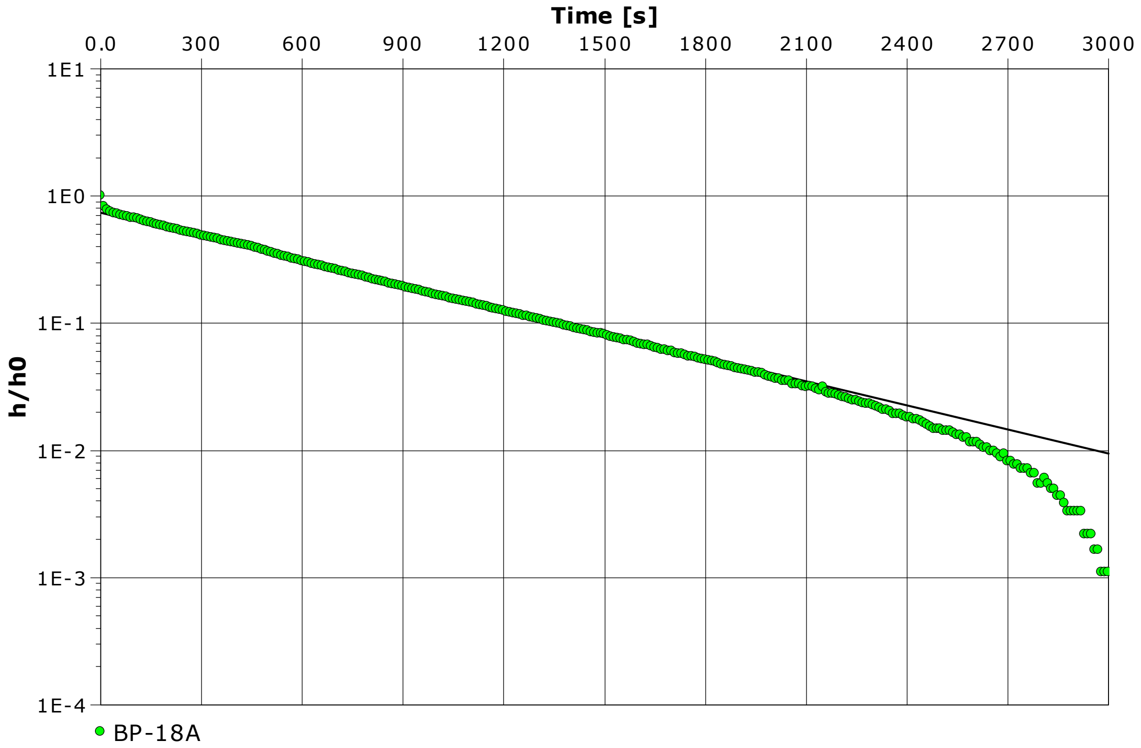
**Analysis Result:** Conductivity (K)= 1.72E-6 ft/s (5.24E-5cm/s)

**Test Parameters**
Test Well: BP-18A
PVC Well Radius (r): 1" (0.08 ft)
Boring Radius (R): 2" (0.17 ft)
Casing Radius (B): 2" (0.17 ft)*
Boring Penetration: Fully
Type Bedrock: Fractured
Screen Length (L): 8.0 ft
Static water table level (b): (1372.33' AMSL)
Aquifer Thickness: 8.0 ft
Pre-Test Depth to water (top of PVC): 14.12' below TPVC (1372.33' AMSL)
Depth to water (from TPVC) at $t_0$: 15.97' below TPVC (1370.50' AMSL)
Depth to bottom of screen (from TPVC): 22.45 ft

**Comments:** Test conducted by P. Mouser on May 8, 2008. A porosity of 0.3 was assumed for the well filter pack. The length of the saturated screen was used as the aquifer thickness.
*According to Aquifer Test Memo by O'Donnell (08/11/07)

---

[1] Bouwer, H. and R.C. Rice, 1976. A slug test method for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells. Water Resources Research, vol. 12, no. 3, pp. 423-428.



Time [s]
0.0
300
600
900
1200
1500
1800
2100
2400
2700
3000
1E1
1E0
1E-1
1E-2
1E-3
1E-4
h/h0
● BP-18A

# Appendix D.4

# Tracer Testing – Field Procedures and Data Reduction

# APPENDIX D.4
# TRACER TESTING – FIELD PROCEDURE AND DATA REDUCTION

## INTRODUCTION AND SCOPE

The amendment injection constitutes an opportunity to conduct tracer testing to measure pilot-scale transport, including average seepage and transport velocities, effective fracture porosity, effective diffusion coefficient, and amendment retardation factor. The bulk advective transport velocity differs from average seepage velocity in that a sparse interconnected network of few larger fractures may be responsible for the majority of mass transport, whereas the average seepage velocity is influenced by the whole fracture network, including fractures only responsible for a fraction of the CVOC (or amendment) mass transport. Similarly, the effective fracture porosity may differ from the values reported in the RI Report, in that the effective porosity only takes into account the fractures responsible for transporting the majority of mass during the tracer tests. We propose conducting three "sets" of tracer tests using a subset of the injection borings and monitoring wells depicted on Figure 2 of the Work Plan and Attachment D.4.1 of this Appendix:

1. <u>Pulse Tracer Test:</u> Upon completing the injection wells and prior to the actual injection of amendment, a "pulse" tracer test will be conducted by adding a sodium bromide salt (NaBr, MSDS included in Attachment D.4.2) to a small volume of water, and mixing it into one injection borehole, and observing the specific conductance response in nearby "response wells." Results from the pulse testing will be used to estimate peak transport velocities and average seepage velocities within the injection Zone 1.

2. <u>Dose Response Tracer Test</u>: A dose response tracer test will be conducted by injecting a concentrated slug of tracer mixed with water into one borehole, and monitoring the specific conductance "dose response" in 4 of the injection borehole locations until "steady state" concentrations are reached in "dose response" locations. This tracer test is intended to estimate effective fracture porosity within Zone 1.

3. <u>Retardation Test and Matrix Diffusion Estimate</u>: Stage 1 amendment injection will consist of a pressurized release of a diluted emulsified organic carbon substrate mixed with the dissolved NaBr tracer at nine borehole locations. Coupled monitoring of specific conductance, bromide, and laboratory analysis of total organic carbon (TOC) will be conducted in selected dose response locations. This testing is intended to estimate the retardation factor and matrix diffusion for the organic carbon amendment.

The tracer tests assume that NaBr behaves as a conservative tracer. The Stage 1 injection and tracer testing observations and inference will be used in the design of the Stage 2 injection. Additional monitoring that will conducted after the Stage 1 and 2 injections will be used to further assess transport conditions at a larger scale. This Appendix outlines the field approach and data reduction for each of the three tracer tests summarized above.

## TRACER TESTING APPROACH AND DATA REDUCTION

### Pulse Tracer Test

After the drilling and completion of the injection boreholes, a small volume of high specific conductance water is added to IB-3 by dissolving NaBr salt in approximately 0.5 gallons of water from the on-site water supply to produce a solution with a specific conductance of $10^4$ micro Siemens per centimeter (µS/cm). The solution will be actively mixed within the open borehole to produce a specific conductance of about $10^3$ µS/cm within the borehole. YSI 556 Multi-Probe Meters (YSI probes) temporary installed in injection wells IB-2, IB-4, IB-7 and IB-8 (response wells) will record specific conductance at a frequency of one reading per minute. The data will be uploaded directly from the probes to a computer. At each of the four “dose response” locations, we intend to record a) the initial arrival time of the tracer; b) the time when specific conductance peaks; and c) the reduction in specific conductance following the peak.

The recorded data will be used to estimate the average seepage velocities and the peak transport velocities between IB-3 and the 4 response wells. Based on prior estimates of seepage velocity, the YSI probes will record the specific conductance at 30 second intervals. The specific conductance response is expected to pass by the response wells within about 24 hours. Exhibit D.4.1 below depicts idealized theoretical observations in a Response Well situated a distance of 10 feet (ft) from the Pulse Test Borehole (IB-3).

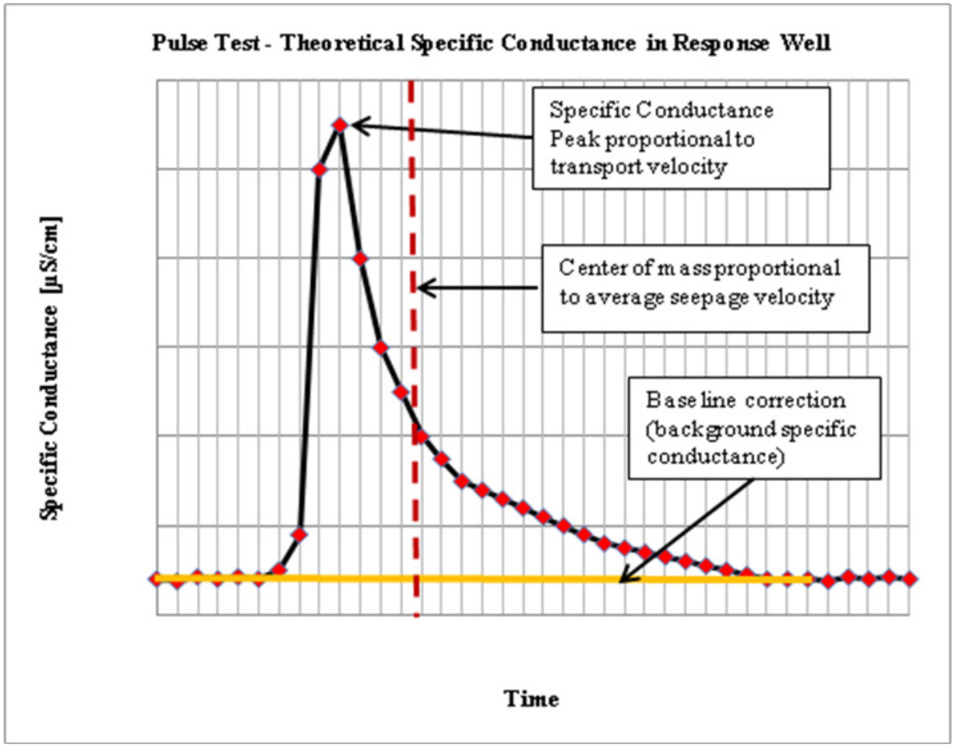


**Exhibit D.4.1:** Idealized theoretical specific conductivity profile in Response Well during a pulse tracer test.

As indicated on Exhibit D.4.1 the transport velocity ($v_T$) and average seepage velocity ($v_{seepage}$) will be estimated as follows:

$$v_{seepage} = t_{center}/x$$

$$v_T = t_{peak}/x$$

Where, $t_{center}$ and $t_{peak}$ are the arrival time of the center of mass and the specific conductance peak, respectively, and x is the distance between the test well and response well.

### Dose Response Tracer Test

A second dose response tracer test will be performed using IB-3 as the test borehole, and IB-2, -4, -7, and -8 as the dose response boreholes equipped with YSI probes monitoring specific conductance at 10 second intervals. Water from the on-site water supply well will be mixed with NaBr to achieve a specific conductance of $10^4$ µS/cm and subsequently injected into IB-3 at a steady rate of about 0.5 gallons per minute. The injection will be performed using a packer system to focus the tracer delivery within the saturated zone and limit tracer injection above the static water table. Based on estimated uplift pressure and a 25% safety factor we believe that the injection pressure should be no greater than about 8 psi or the equivalent of about 18 feet of water applied below the packer at the water table the actual gauge injection pressure should account for the distance of the gauge above the water table. As an example the injection pressure measured via a gauge at the groundsurface should be about 3 psi to account for the elevation head above the groundwater table during the injection. The actual injection pressure will vary somewhat in the field on the basis of the actual depth to water and rock, respectively. The basis for the injection pressure is summarized in Attachment D.4.3.

The YSI probes in the four dose response boreholes will continually monitor the specific conductance at a measurement frequency of one reading every ten seconds, while pressure transducers measure changes in groundwater elevation and increased saturated thickness during the dose response tracer test. The specific conductance measurements in the dose response boreholes should enable us to estimate the effective fracture porosity within Zone 1. Based on fracture porosity estimates provided in the RI report, we estimate that it will require about 5.5 gallons of water to replace the water present in the 5 ft thick saturated interval within a 10 ft radius (equivalent to the distance between the injection wells). The tracer test is concluded when steady specific conductance estimates are observed in the four dose response boreholes. We expect to inject less than 10 gallons of water with NaBr to conduct the dose response tracer test. Exhibit D.4.2 below depicts idealized theoretical observations in a Dose Response Borehole situated a distance of 10 ft from the Test Borehole (IB-3).

As indicated on Exhibit D.4.2 the effective fracture porosity ($\Phi_{eff}$) will be estimated by a graphical approximation as follows:

$$C_{½max} \sim \Phi_{eff}$$

Where, $C_{½max}$ is half the maximum specific conductance observed in the dose response well (corrected for background specific conductance).

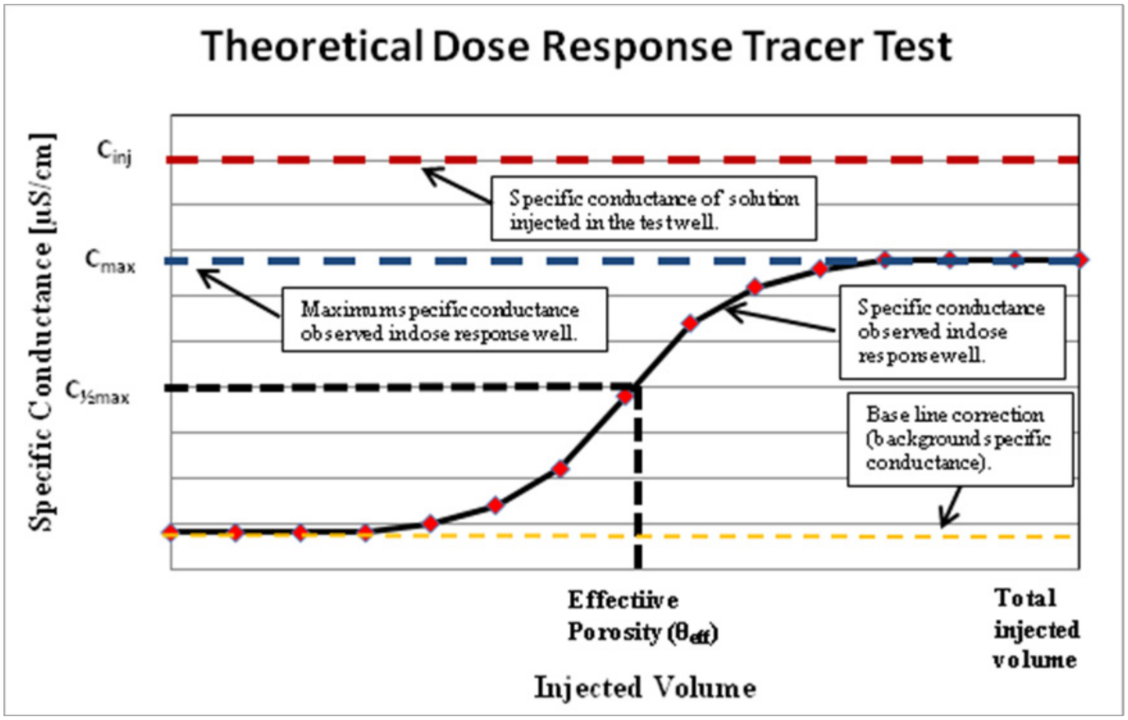


**Exhibit D.4.2:** Idealized theoretical specific conductance profile in Dose Response Borehole during a dose response tracer test. Specific conductance measured in the dose response well is plotted on the Y-axis and the injected volume of water with NaBr in the test well is plotted on the X-axis.

## Retardation Test and Matrix Diffusion Estimate

### *Stage 1 Injection Retardation Test*

The Retardation Testing will be performed concurrent with Stage 1 amendment injection. Dissolved NaBr tracer will be mixed with the diluted emulsified oil amendment until the bromium concentration of the amendment reaches a concentration about two orders of magnitude above background levels as determined by pre-injection water quality monitoring[1]. The amendment injection will be performed at a pressure similar to the dose response trace test discussed in the section above and using a packer assembly. Approximately 2.5 gallons of emulsified diluted amendment mixed with NaBr tracer will be injected in each of the nine injection borings. The amendment injection will be followed by injection of a volume of water equivalent to the saturated section of the borehole to displace the amendment from the injection boreholes into the fracture pore space. The water will be from the on-site water supply or from the borings themselves.

---

[1] About 490 milligram NaBr salt per gallon of diluted emulsified amendment corresponds to 100 milligram per liter (mg/L) bromide.

After completing the Stage 1 injection, we intend to monitor the bromide concentrations and specific conductance in downgradient monitoring wells BP-4A and TM-1[2] as part of the tracer testing to estimate the amendment retardation factor and matrix diffusion. The bromide and specific conductance, as well as temperature, ORP, and dissolved oxygen will be measured by electrometric water quality devices and data loggers at a frequency of one recording per hour, and accessed by telemetry and computer modem. Upon observing bromide and/or specific conductance about two times the initial background levels in BP-4 and TM-1, samples for TOC laboratory analysis will be collected. The intended TOC sample frequency will be about one sample per 24 hours; however, this sample frequency may be modified based on the initial laboratory results, field observations and inference. Based on seepage velocities discussed in the RI Report, expected advective travel times from the injection borings to BP-4A and TM-1 are on the order of days to a week, respectively. Exhibit D.4.3 depicts idealized results from a theoretical tracer test for assessing retardation factor using a conservative tracer.

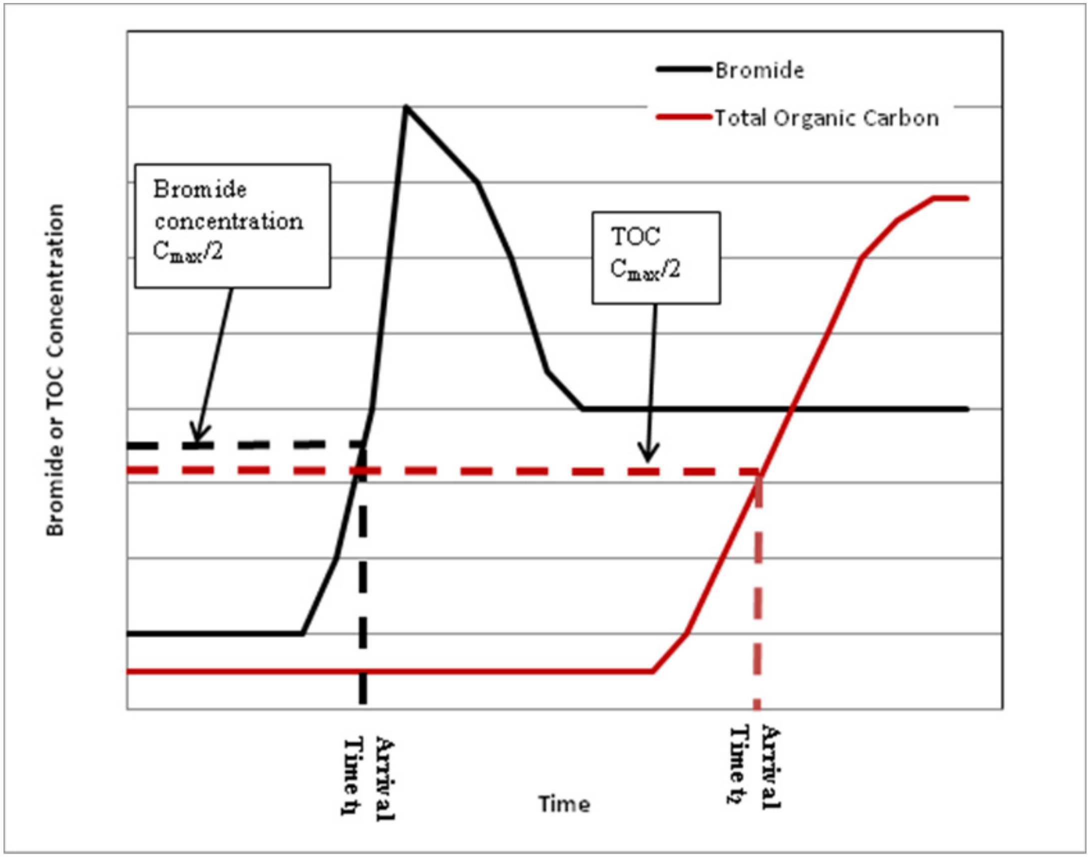


**Exhibit D.4.3:** Idealized theoretical bromide and TOC concentrations in down-gradient monitoring wells. The arrival time difference between the conservative NaBr tracer ($t_1$) and reactive TOC ($t_2$) is proportional to the retardation of the injected amendment.

---

[2] Electrometric water quality devices and data logger monitoring will also be performed in TM-2 and BP-9A, however, not as part of the Stage 1 tracer testing.

If a reactive and a conservative tracer are injected simultaneously into the same velocity field, the retardation factor is simply the ratio of the time of arrival of the reactive solute ($t_2$) to the time of arrival of the nonreactive solute ($t_1$). That is:

$$R = t_2/t_1$$

### *Matrix Diffusion Estimate*

The diffusion of NaBr into the matrix will be estimated by the Maloszewski & Zuber (1985) approximation. The field estimates will be complementary to laboratory estimates discussed in the RI Report. Comparison of laboratory and field scale estimates of matrix diffusion indicates that field scale estimates typically are order of magnitude higher than the small scale laboratory tests. Attachment D.4.4 includes a paper[3] with an example application of field scale matrix diffusion testing in a fractured rock setting. As discussed in the paper the solution to the transport equation for a fixed short distance is:

$$C_f(t) = \frac{aM}{2\pi Q}\int_0^t \sqrt{\frac{t_0}{P_D}} \exp\left[-\frac{(t_0-u)^2}{4uP_D t_0} - \frac{a^2u^2}{t-u}\right] \frac{du}{\sqrt{u(t-u)^3}}$$

Where,

**$C_f$** is the flux-averaged tracer concentrations observed in the observation well;
**M** is the injected mass of the amendment;
**Q** is the volumetric flow rate through the system and equals Vv/x (V is fracture porosity, v is seepage velocity and x is travel distance) and is estimated by pulse test and dose response test;
**$t_0$** is the mean transit time of water and equals x/v and is estimated by the pulse tracer test;
**$P_D$** is the dispersion parameter;
**a** is the diffusion parameter describing the matrix diffusion process; and
**u** is the integration variable (varies between 0 and t).

This particular tracer test will have the two fitting parameters $P_D$ and $a$ (as v and V are defined by the pulse test and the dose response tests, respectively):

$$P_D = D/(vx) = \alpha_L/x \text{ and } a = \Phi_{eff}\,(D_p)^{0.5}/(e)$$

Where, D is the dispersion coefficient; $\alpha_L$ is the dispersivity; $\Phi_{eff}$ is the effective fracture porosity (approximated by the dose response test and estimated in the RI report); e is the fracture

---

[3] Ensiedl & Maloszewski, 2005, Tracer Tests in Fractured Rocks with a new Fluorescent Dye – Pyrene-1,3,6,8-Tetra Sulphonic Acidt (PTS), *Hydrological Sciences Journal*, 50(3), 2005.

aperture (geometric mean estimated as 30 to 50 microns); and $D_p$ is the effective diffusion coefficient of the tracer in water within the matrix.

The test includes the concept of relative mass recovery allowing us to fit concentrations and recovery curves simultaneously. The relative mass recovery rate (RR) is calculated from the experimental theoretical concentration curves as a function of time:

$$RR(t) = Q\int_0^t C_f(t)dt/M$$

The matrix diffusion will be modeled with the assistance of University of Guelph.
Exhibit D.4.4 depicts theoretical fitting of $C_f(t)$ and RR(t).

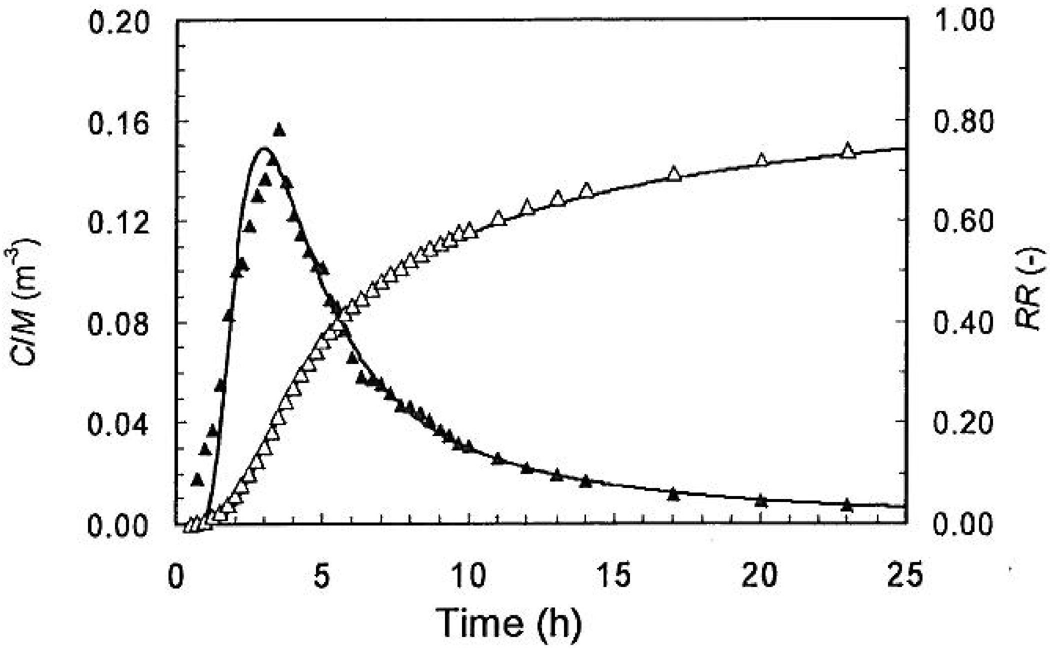


**Exhibit D.4.4:** Depiction of modeled cureves (solid lines) obtained as a best-fit to observed “tracer” concentrations (▲ ) and relative recoveries (△ ) (from Einsiedl & Maloszewski, 2005).

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**Attachments:**

| | |
|---|---|
| Attachment D.4.1 | Injection Boring Location Plan |
| Attachment D.4.2 | Sodium Bromide MSDS |
| Attachment D.4.3 | Estimate of Injection Pressure |
| Attachment D.4.4 | Background Information – Ensiedl & Maloszewski, 2005 |

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Attachment D.4.1

# Injection Boring Location Plan

## Work Plan - Enhanced Bio Pilot Testing

IBM Gun Club - Union, New York

Drawn By: S. Warner
Designed By: P. Mouser
Reviewed By: A. Horneman
Date: April 2010

Notes:

1. The figure is intended to depict proposed injection boring and temporary monitoring point locations associated with enhanced biochemical degradation pilot testing and tracer testing.

2. Please refer to Appendix D.4 text and Work Plan text and figures for further discussion.

**Legend**

| | | |
|---|---|---|
| 1320 | | 2ft Topographic Contour (AMSL) |
| Proposed Loctions | | |
| IB-5 | ● | Injection Well Location (IW-1 through IW-9) |
| TM-2 | ⊕ | Temporary Monitoring Point |
| IB-2 | ◉ | Tracer Testing Dose Response Boreholes |
| Existing Groundwater and Surface Water Sample Locations | | |
| Seep1 | ○~ | Seep or Spring Sampling Location if labeled |
| BP-2A | ⊕ | Monitoring Well |

25 12.5 0 25 Feet

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# Material Safety Data Sheet
## Sodium Bromide, Anhydrous, 99+%

ACC# 96487

## Section 1 - Chemical Product and Company Identification

**MSDS Name:** Sodium Bromide, Anhydrous, 99+%
**Catalog Numbers:** AC205130000, AC205130010, AC205131000, AC2051325
**Synonyms:** None.
**Company Identification:**
Acros Organics N.V.
One Reagent Lane
Fair Lawn, NJ 07410
**For information in North America, call:** 800-ACROS-01
**For emergencies in the US, call CHEMTREC:** 800-424-9300

## Section 2 - Composition, Information on Ingredients

| CAS# | Chemical Name | Percent | EINECS/ELINCS |
|---|---|---|---|
| 7647-15-6 | SODIUM BROMIDE | >99 | 231-599-9 |

**Hazard Symbols:** None listed.
**Risk Phrases:** None listed.

## Section 3 - Hazards Identification

### EMERGENCY OVERVIEW

Appearance: white solid. **Caution!** May cause eye and skin irritation. May cause respiratory and digestive tract irritation. May cause central nervous system depression. May cause fetal effects based upon animal studies. Hygroscopic.
**Target Organs:** Central nervous system.

**Potential Health Effects**
**Eye:** May cause eye irritation.
**Skin:** May cause skin irritation.
**Ingestion:** May cause central nervous system depression, characterized by excitement, followed by headache, dizziness, drowsiness, and nausea. Advanced stages may cause collapse, unconsciousness, coma and possible death due to respiratory failure. Advanced stages may cause collapse, unconsciousness, coma and possible death due to respiratory failure.��������������������������������������
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**Inhalation:** May cause respiratory tract irritation. May cause effects similar to those described for ingestion.
**Chronic:** May cause fetal effects. Chronic ingestion may cause bromism characterized by disturbances of the central nervous system, skin and digestive tract. May cause incoordination and mental disturbances.

## Section 4 - First Aid Measures

**Eyes:** Immediately flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids. Get medical aid.
**Skin:** Get medical aid. Flush skin with plenty of soap and water for at least 15 minutes while removing contaminated clothing and shoes. Wash clothing before reuse.
**Ingestion:** If victim is conscious and alert, give 2-4 cupfuls of milk or water. Never give anything by mouth to an unconscious person. Get medical aid immediately.
**Inhalation:** Remove from exposure to fresh air immediately. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical aid.
**Notes to Physician:** Treatment includes hydration, mild diuresis, and possible hemodialysis. Consider the use of ammonium chloride in divided doses with a diuretic.

## Section 5 - Fire Fighting Measures

**General Information:** As in any fire, wear a self-contained breathing apparatus in pressure-demand, MSHA/NIOSH (approved or equivalent), and full protective gear. During a fire, irritating and highly toxic gases may be generated by thermal decomposition or combustion.

**Extinguishing Media:** Use extinguishing media most appropriate for the surrounding fire. Use water spray, dry chemical, carbon dioxide, or appropriate foam.
**Flash Point:** Not applicable.
**Autoignition Temperature:** Not available.
**Explosion Limits, Lower:**N/A
**Upper:** N/A
**NFPA Rating:** Not published.

## Section 6 - Accidental Release Measures

**General Information:** Use proper personal protective equipment as indicated in Section 8.
**Spills/Leaks:** Sweep up, then place into a suitable container for disposal. Avoid generating dusty conditions. Provide ventilation.

## Section 7 - Handling and Storage

**Handling:** Wash thoroughly after handling. Remove contaminated clothing and wash before reuse. Use with adequate ventilation. Avoid contact with eyes. Do not ingest or inhale.
**Storage:** Store in a cool, dry place. Store in a tightly closed container. Store protected from moisture.

## Section 8 - Exposure Controls, Personal Protection

**Engineering Controls:** Use adequate general or local exhaust ventilation to keep airborne concentrations below the permissible exposure limits.
**Exposure Limits**

| Chemical Name | ACGIH | NIOSH | OSHA - Final PELs |
|---|---|---|---|
| SODIUM BROMIDE | none listed | none listed | none listed |

**OSHA Vacated PELs:** SODIUM BROMIDE: No OSHA Vacated PELs are listed for this chemical.
**Personal Protective Equipment**
**Eyes:** Wear appropriate protective eyeglasses or chemical safety goggles as described by OSHA's eye and face protection regulations in 29 CFR 1910.133 or European Standard EN166.
**Skin:** Wear appropriate gloves to prevent skin exposure.
**Clothing:** Wear appropriate protective clothing to minimize contact with skin.
**Respirators:** Follow the OSHA respirator regulations found in 29 CFR 1910.134 or European Standard EN 149. Always use a NIOSH or European Standard EN 149 approved respirator when necessary.

## Section 9 - Physical and Chemical Properties

**Physical State:** Solid
**Appearance:** white
**Odor:** not available
**pH:** Not available.
**Vapor Pressure:** Not applicable.
**Vapor Density:** Not available.
**Evaporation Rate:**Not applicable.
**Viscosity:** Not available.
**Boiling Point:** 1390 deg C @ 760.00mm Hg
**Freezing/Melting Point:**755 deg C
**Decomposition Temperature:**800 deg C
**Solubility:** 95g/100 ml water (25 c)
**Specific Gravity/Density:**3.208
**Molecular Formula:**BrNa
**Molecular Weight:**102.89

## Section 10 - Stability and Reactivity

**Chemical Stability:** Stable under normal temperatures and pressures.
**Conditions to Avoid:** Incompatible materials, moisture.
**Incompatibilities with Other Materials:** Strong oxidizing agents, strong acids.
**Hazardous Decomposition Products:** Irritating and toxic fumes and gases, hydrogen bromide.
**Hazardous Polymerization:** Has not been reported.

## Section 11 - Toxicological Information

**RTECS#:**
**CAS#** 7647-15-6: VZ3150000
**LD50/LC50:**
Not available.

**Carcinogenicity:**
CAS# 7647-15-6: Not listed by ACGIH, IARC, NIOSH, NTP, or OSHA.
**Epidemiology:** No information available.
**Teratogenicity:** No information available.
**Reproductive Effects:** No information available.
**Neurotoxicity:** No information available.
**Mutagenicity:** No information available.
**Other Studies:** No data available.

## Section 12 - Ecological Information

No information available.

## Section 13 - Disposal Considerations

Chemical waste generators must determine whether a discarded chemical is classified as a hazardous waste. US EPA guidelines for the classification determination are listed in 40 CFR Parts 261.3. Additionally, waste generators must consult state and local hazardous waste regulations to ensure complete and accurate classification.
**RCRA P-Series:** None listed.
**RCRA U-Series:** None listed.

## Section 14 - Transport Information

| | US DOT | IATA | RID/ADR | IMO | Canada TDG |
|---|---|---|---|---|---|
| **Shipping Name:** | No information available. | | | | No information available. |
| **Hazard Class:** | | | | | |
| **UN Number:** | | | | | |
| **Packing Group:** | | | | | |

## Section 15 - Regulatory Information

### US FEDERAL

**TSCA**
CAS# 7647-15-6 is listed on the TSCA inventory.
**Health & Safety Reporting List**
None of the chemicals are on the Health & Safety Reporting List.
**Chemical Test Rules**
None of the chemicals in this product are under a Chemical Test Rule.
**Section 12b**
None of the chemicals are listed under TSCA Section 12b.
**TSCA Significant New Use Rule**
None of the chemicals in this material have a SNUR under TSCA.
**SARA**

**CERCLA Hazardous Substances and corresponding RQs**
None of the chemicals in this material have an RQ.
**SARA Section 302 Extremely Hazardous Substances**
None of the chemicals in this product have a TPQ.
**Section 313**
No chemicals are reportable under Section 313.
**Clean Air Act:**
This material does not contain any hazardous air pollutants. This material does not contain any Class 1 Ozone depletors. This material does not contain any Class 2 Ozone depletors.
**Clean Water Act:**
None of the chemicals in this product are listed as Hazardous Substances under the CWA. None of the chemicals in this product are listed as Priority Pollutants under the CWA. None of the chemicals in this product are listed as Toxic Pollutants under the CWA.
**OSHA:**

None of the chemicals in this product are considered highly hazardous by OSHA.

**STATE**

CAS# 7647-15-6 is not present on state lists from CA, PA, MN, MA, FL, or NJ.

California No Significant Risk Level: None of the chemicals in this product are listed.

### European/International Regulations

**European Labeling in Accordance with EC Directives**

**Hazard Symbols:**

Not available.

**Risk Phrases:**

**Safety Phrases:**

S 24/25 Avoid contact with skin and eyes.

**WGK (Water Danger/Protection)**

CAS# 7647-15-6: 1

**Canada - DSL/NDSL**

CAS# 7647-15-6 is listed on Canada's DSL List.

**Canada - WHMIS**

WHMIS: Not available.

**Canadian Ingredient Disclosure List**

CAS# 7647-15-6 is listed on the Canadian Ingredient Disclosure List.

**Exposure Limits**

## Section 16 - Additional Information

**MSDS Creation Date:** 3/06/1998

**Revision #1 Date:** 8/02/2000

*The information above is believed to be accurate and represents the best information currently available to us. However, we make no warranty of merchantability or any other warranty, express or implied, with respect to such information, and we assume no liability resulting from its use. Users should make their own investigations to determine the suitability of the information for their particular purposes. In no event shall Fisher be liable for any claims, losses, or damages of any third party or for lost profits or any special, indirect, incidental, consequential or exemplary damages, howsoever arising, even if Fisher has been advised of the possibility of such damages.*

# Attachment D.4.3
# Estimate of Injection Pressure
# Enhanced Biodegradation Pilot Test
# IBM Gun Club - Former Burn Pit Area

| Parameter | Value | Unit | Comment |
|---|---|---|---|
| Depth of static water level (bgs) [L] | 10 | ft | From RI Report |
| Density of rock [$\rho_r$] | 2.67 | $g/cm^3$ | |
| Density of soil [$\rho_s$] | 1.85 | $g/cm^3$ | |
| Thickness of soil [$L_s$] | 5 | ft | |
| Total overburden mass [M] | 690 | $g/cm^2$ | $M = 30.5 (L_s \times \rho_s + (L-L_s) \times \rho_r)$ |
| Over burden pressure at water table depth [P] | 10 | psi | $P = M/70.4$ |
| Design $P_{max}$ to limit potential for uplift of rock and soil column. | 7.5 | psi | Given the highly fractured nature of the top 5 feet of rock, we apply a safety factor of 25%. |

Notes:

1. The table summarizes the estimate of maximum injection pressure [Pmax] during amendment injection, and include parameters included in the estimate, values, units, and comments .

2. ft = foot, $g/cm^3$ = gram per cubic centimeter, $g/cm^2$ = gram per square centimeter, and psi = pounds per square inch.

3. The factor of 30.5 for Total overburden mass estimates are used to convert from foot to centimeter. A factor of 1/70.4 converts from $g/cm^2$ to psi.

4. The Pmax safety factor of 25% for highly fractured rock was obtained from The Massachusetts Department of environmental Protection Standard references for Monitoring Wells, Part I, Section 5.4, January 1991.

5. Refer to Work Plan and Appendix D.4 text for further discussion.

**Hydrological Sciences Journal**
Publication details, including instructions for authors and subscription information:
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# Tracer tests in fractured rocks with a new fluorescent dye—pyrene-1,3,6,8-tetra sulphonic acid (PTS) / Tests de traçage en roches fracturées avec un nouveau produit fluorescent—l'acide pyrène 1.3.6.8 tétra sulfonique (PTS)

Florian Einsiedl [a];Piotr Maloszewski [b]
[a] 1. GSF - Institute of Groundwater Ecology, D-85764 Neuherberg, Germany.. [b] 2. GSF - Institute of Groundwater Ecology, D-85764 Neuherberg, Germany..

**To cite this Article** Einsiedl, Florian andMaloszewski, Piotr(2005) 'Tracer tests in fractured rocks with a new fluorescent dye—pyrene-1,3,6,8-tetra sulphonic acid (PTS) / Tests de traçage en roches fracturées avec un nouveau produit fluorescent—l'acide pyrène 1.3.6.8 tétra sulfonique (PTS)', Hydrological Sciences Journal, 50: 3, 543 — 554
**To link to this Article: DOI:** 10.1623/hysj.50.3.543.65026
**URL:** http://dx.doi.org/10.1623/hysj.50.3.543.65026

*Hydrological Sciences–Journal–des Sciences Hydrologiques,* **50**(3) June 2005

# Tracer tests in fractured rocks with a new fluorescent dye—pyrene-1,3,6,8-tetra sulphonic acid (PTS)

**FLORIAN EINSIEDL & PIOTR MALOSZEWSKI**
*GSF – Institute of Groundwater Ecology, D-85764 Neuherberg, Germany*
einsiedl@gsf.de

**Abstract** Two multi-tracer tests were performed in fissured rocks accessible in underground laboratories to examine a new fluorescent dye: pyrene-1,3,6,8-tetra sulphonic acid (PTS). The first test was carried out at the Lindau Rock Laboratory (LRL), Germany, in a highly permeable ore dike, and the second, at the Grimsel Test Site (GTS), Switzerland, in a heterogeneous granite fault zone (AU 126). At the LRL new tracer was injected together with uranine in a convergent flow field (monopole test), and slightly different tracer breakthrough curves were observed according to different diffusion coefficients of both tracers. The matrix porosity calculated with the aid of the one-dimensional (1-D) single-fissure dispersion model (SFDM) agrees well with that found in earlier tracer tests and with measurements performed on core samples. At the GTS, the PTS tracer was applied together with pyranine in two-well injection–withdrawal (dipole) tests. Both tracers yielded identical tracer concentration curves, which confirm their conservative behaviour. Mathematical simulations performed with the aid of a 3-D numerical model (FRAC3DVS) yielded equally good fits for different sets of parameters, independent of whether matrix porosity was included or neglected. That lack of unique solution and the difficulty in observing the influence of matrix diffusion result from a wide distribution of the transit times of particular streamlines, which is characteristic for injection–withdrawal tests. However, both tracer tests clearly indicated that the new tracer (PTS) behaves conservatively at high pH values and can be successfully used for groundwater labelling.

**Key words** fractured rock; monopole and dipole tracer tests; new fluorescent dye; transport modelling; matrix diffusion

## Tests de traçage en roches fracturées avec un nouveau produit fluorescent—l’acide pyrène 1.3.6.8 tétra sulfonique (PTS)

**Résumé** Deux tests multi-traceurs ont été effectués en milieux de roches fracturées, dans le but de tester un nouveau produit fluorescent: l’acide pyrène 1.3.6.8 tétra sulfonique (PTS). Le premier test a été opéré au laboratoire Lindau Rock (LRL), en Allemagne, dans un filon minéralisé très perméable, tandis que le deuxième test a été effectué sur le site de Grimsel (STS), en Suisse, dans une zone de failles de granites hétérogènes (AU 126). Au LRL, le nouveau traceur a été injecté, mélangé à de l’uranine, dans les conditions d’un régime d’écoulement convergent (test monopôle), et des courbes d’arrivée légèrement différentes ont été identifiées, en fonction des différents coefficients de diffusion des deux traceurs. La porosité de matrice calculée à l’aide d’un modèle 1D de dispersion à travers une seule fracture (SFDM) est en conformité avec les résultats obtenus par des tests de traçage préalables et par des mesures réalisées sur des carottes. Au GTS, le traceur PTS a été injecté, mélangé à de la pyranine, au niveau de deux forages avec injection et pompage (tests dipôles). Les deux traceurs révèlent des courbes de concentrations identiques, confirmant ainsi leur comportement conservatif. Les simulations mathématiques réalisées avec un modèle numérique 3D (FRAC3DVS) donnent des résultats de qualités égales avec différents jeux de paramètres, indépendamment de la prise en compte ou non de la porosité de matrice. Cette non-unicité de la solution et la difficulté d’observer l’influence de la matrice de diffusion proviennent d’une grande distribution des temps de transit selon des directions d’écoulement particulières, ce qui est caractéristique des tests par injection-pompage. Cependant les deux tests de traçage indiquent clairement que le nouveau traceur (PTS) se comporte de manière conservative pour de fortes valeurs de pH et peut être utilisé avec succès pour la caractérisation des eaux souterraines.

**Mots clefs** roches fracturées; tests monopôle et dipôle de traçage; nouveau produit fluorescent; modélisation de transport; matrice de diffusion

## INTRODUCTION

A number of fluorescent tracers, such as uranine, eosine, pyranine and rhodamines, have been used to estimate transport parameters (velocity, dispersivity, water storage capacity, etc.) in porous media and karst channels (e.g. Seiler *et al.*, 1989; Abelin *et al.*, 1991; Behrens *et al.*, 1997; Ptak, 1997), or in fissured rocks (e.g. Neretnieks *et al.*, 1982; Novakowski *et al.*, 1985; Maloszewski & Zuber, 1993; Himmelsbach *et al.*, 1998; Hoehn *et al.*, 1998; Reimus *et al.*, 1999; Meigs *et al.*, 2001; Sanford *et al.*, 2002, Witthüser *et al.*, 2003, Mazurek *et al.*, 2003).

For the application of fluorescent tracers, several conditions should be satisfied: low detection limit and high solubility of the tracer, no toxicity, a simple analysis method, no or low sorption behaviour under different pH values, no microbial degradation, and different wavelength spectra (EMW) for multi-tracer experiments. These conditions cannot be well satisfied simultaneously for known tracers. Therefore, it is always of interest to search for new tracers, which could better satisfy the above requirements. In particular, there is a need for a tracer, which could be applied under different pH conditions and which has different fluorescence emission spectra from those of other commonly used dye tracers (e.g. uranine, eosine, pyranine), so that more dye tracers can be detected simultaneously. For instance, Leibundgut & Wernli (1988) proposed naphthionate for groundwater studies while Hadi *et al.* (1996) have tested succinyluranine disodium salt and 5(6)-carboxyuranine trisodium salt. In the present study the pyrene-1,3,6,8-tetra sulphonic acid (PTS) was tested as a new groundwater tracer. In comparison to pyranine, PTS has four sulphonic acid functional groups (Fig. 1) and is not toxic. Its fluorescence spectrum is stable for pH values between 2 and 11, and can be detected online in the presence of pyranine or uranine without pH separation ($\mathrm{EMW}_{\mathrm{PTS}}$: 403 [nm], $\mathrm{EMW}_{\mathrm{uranine}}$: 512 [nm], $\mathrm{EMW}_{\mathrm{pyranine}}$: 512 [nm]). In comparison to the commonly used uranine, the PTS tracer has a very low degradation in the presence of light and in column experiments in tertiary sand and quaternary gravel it shows significantly lower sorption at lower pH values (<pH 7) than uranine (Einsiedl *et al.*, 1999). Generally, fluorescent tracers show different transport behaviour depending on the pH value (Smart & Laidlaw, 1977; Einsiedl, 1999). However, at pH values above 9, all used fluorescent dyes should have an anionic character and in consequence low or non-reacting transport behaviour. At the Lindau Rock Laboratory (LRL), the fracture water shows a high pH solution of 10.2 and at the Grimsel Test Site (GTS) in a heterogeneous granite fault zone (AU126), pH values of 8.5–9.3 were measured.

The detection limit for PTS is 0.05 $\mu g\ l^{-1}$ under laboratory conditions and about 1 $\mu g\ l^{-1}$ for an online system in the field. After successful tests of PTS in flow-through laboratory columns (Einsiedl, 1999), the present study focuses on the examination of PTS transport behaviour at the field scale at two test sites. The first study was performed at the Lindau Rock Laboratory (LRL), southern Black Forest, Germany, where a 600-m long observation tunnel was excavated to investigate the hydraulic effect of a highly permeable fault zone (ore dike) at a planned dam site (Himmelsbach *et al.*, 1998). The second test was carried out at the Grimsel Test Site (GTS), which is the NAGRA (National Cooperative for the Disposal of Radioactive Waste) underground rock laboratory in the Swiss Alps (Haslital, Berner Oberland). NAGRA has been operating the GTS laboratory over the last 20 years to develop concepts of secure radioactive waste disposal (Frick *et al.*, 1992; Smith *et al.*, 2001).

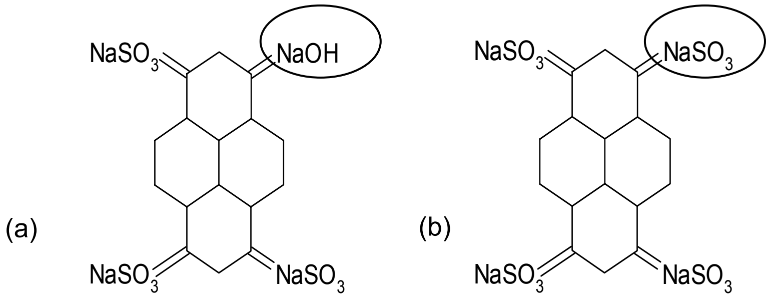

**Fig. 1** Chemical structure of (a) pyranine and (b) the new fluorescent tracer pyrene-1,3,6,8-tetra sulphonic acid (PTS).

The field tests had two main goals: (a) the examination of the PTS-transport behaviour in the fissured aquifers in comparison to pyranine and uranine, which are regarded by Smart & Laidlaw (1977) as non-reacting dyes under favourable conditions in porous aquifers; and (b) the estimation of rock parameters at the LRL ore dike and the fault-zone AU 126 of the GTS. Rock parameters found at the LRL were compared to those previously obtained by Himmelsbach *et al.* (1998) who used deuterium, pyranine and uranine.

## Experimental site and test design at the LRL

The Lindau Rock Laboratory (LRL) is situated in the Albtal granite pluton with a transmissivity of $2.5 \times 10^{-5}$ $m^2$ $s^{-1}$ and matrix porosity of more than 6%, which represents a dense fracture system. The ore dike is nearly vertical with a thickness of 0.3–3.0 m. The tunnel system of the rock laboratory is about 90 m below the ground surface. Details on the test site and the experimental set up for the LRL can be found in Himmelsbach *et al.* (1998). In the LRL a tracer experiment was performed under a radial convergent flow field (monopole test). The distance between the injection (BL8) and detection boreholes (BL10) is 11.2 m. An instantaneous injection of the tracer cocktail containing uranine and PTS was performed. According to the results of Himmelsbach *et al.* (1998), the thickness of the ore dike is approximately 2 m, while the hydraulic conductivity is $2.4 \times 10^{-5}$ m $s^{-1}$ (2.07 m $day^{-1}$). A constant hydraulic head was adjusted by opening borehole BL10, which led to a constant flow rate of 0.23 l $s^{-1}$. In comparison to previous tracer tests, the flow rate was two times larger than that of the monopole tests (0.1 l $s^{-1}$) but close to the dipole experiments (0.2–0.25 l $s^{-1}$) of Himmelsbach *et al.* (1998). A pH value of approximately 10.2 and an electrical conductivity of 77 $\mu$S $cm^{-1}$ were observed during the present tracer test. It is unclear if the dissolution of concrete at the tunnel wall, and/or mineral reactions, led to that high pH value. For such a pH value, uranine has an anionic character (Behrens, 1988), and should exhibit a non-reactive transport behaviour.

## Experimental site and test design at the GTS

The GTS is located at a depth of 450 m in the crystalline rock of the Aare Massif. The rock massif consists mainly of pre-Hercynian gneisses and Hercynian granites. The Hyperalkaline Plume in Fractured Rocks (HPF) experiment site is set up in a conducting

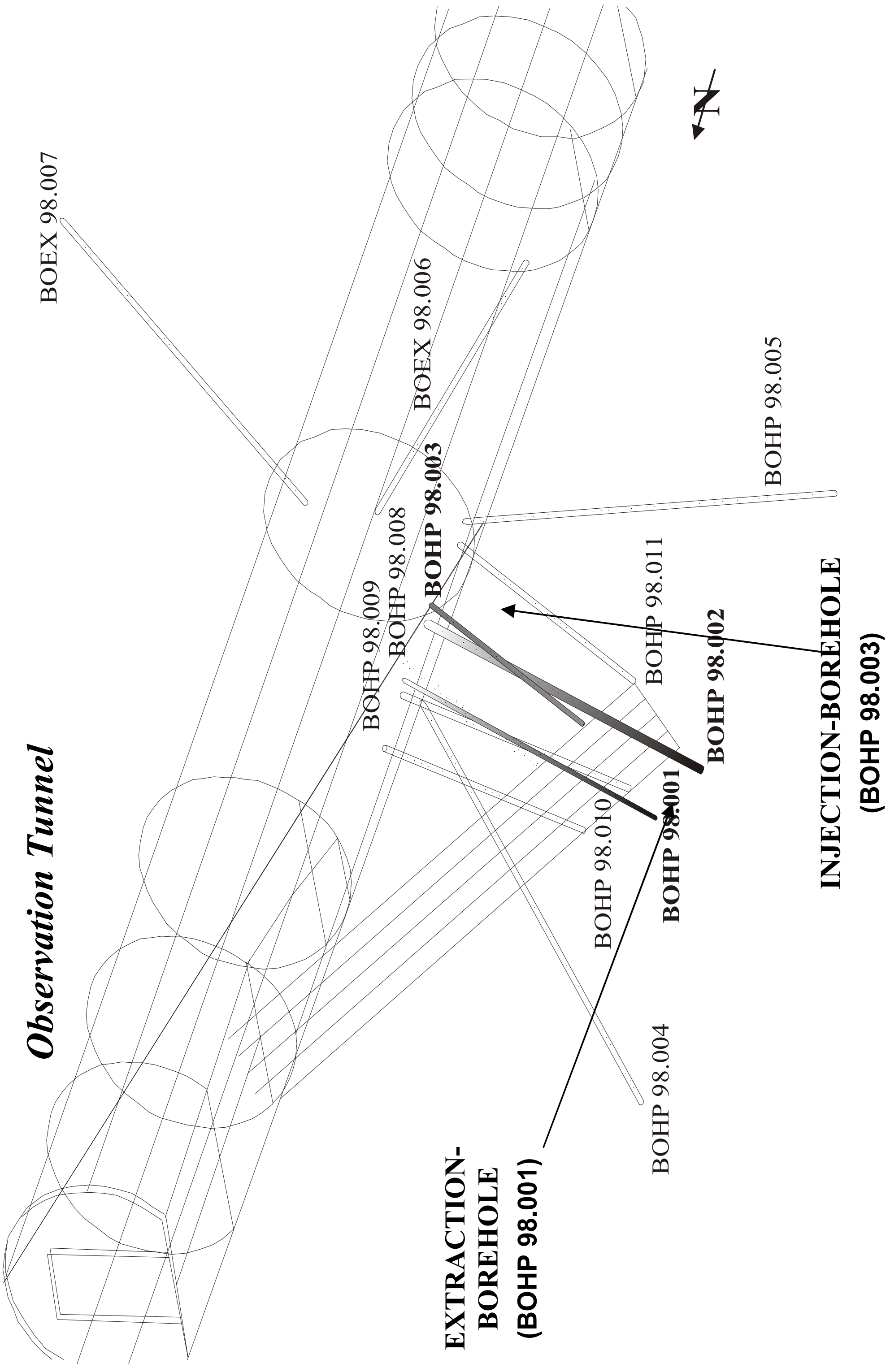

**Fig. 2** Observation tunnel at the GTS test site (adapted from NAGRA).

conducting shear zone (AU 126) of the granodiorite of the Aare Massive. The major fault zones (AU 96, AU 126) have a regional dip of 70–90° and a principal NE–SW strike (Frick *et al*., 1992). Ten boreholes were drilled into the HPF shear zone AU 126 and the granite rock to investigate their hydraulic properties (Bossart *et al*., 1991; Meyer *et al*., 1989). Figure 2 presents the GTS tunnel with all observation wells. Due to the low permeability in the HPF shear zone, a withdrawal experiment could not be performed by pumping, but only by free outflow (Pfingsten & Soler, 2003) or by water injection–withdrawal test with the same flow rates (about 60 ml $h^{-1}$). In such a case a symmetrical dipole flow field can be assumed in a homogeneous flow system when the natural gradient is close to zero. Generally, dipole tracer tests should not be recommended for double-porosity systems because they yield wide distributions of streamlines with flow times going theoretically to infinity. Then, even for an instantaneous injection of tracer, the resulting breakthrough curve is characterized by a strong tailing effect ("hydraulic tail") and significantly lower tracer recovery (Himmelsbach *et al*., 1998). In addition, other studies, for example by Kunstmann *et al*. (1997) or Becker & Shapiro (2000), have shown that the hydrodynamic dispersion in a single fracture and/or the transverse dispersivity may also generate strong tailing effects. As a consequence, both the "hydraulic tail" and "dispersive tail", may mask the tailing effect resulting from the matrix diffusion and make the interpretation of tracer curves very ambiguous.

A triple packer system, recommended by Novakowski (1992) and Bäumle *et al*. (2001) was used for the injection (BOHP 98.003)–extraction (BOHP 98.001) system. At the test site, the fault zone has a thickness of 0.45–0.55 m, a fracture permeability of about $1.5 \times 10^{-8}$ m $s^{-1}$ and a hydraulic conductivity of the rock matrix of about $9.7 \times 10^{-11}$ m $s^{-1}$ (Fisch, 1999). The matrix porosity of the granite and mylonite has an average value of about 0.1–2%, whereas the dominant openings (filled with fault gouge, i.e. coarse rock components) have porosities even larger than 20% (Pfingsten & Soler 2003). Borehole imaging performed in the shear zone AU 126 showed fractures with apertures of 1 mm or more (Pfingsten & Soler, 2003).

The tracer test was performed over a distance of 0.77 m. The groundwater from the fault zone AU 126 is relatively poorly mineralised with an ionic strength of about 1 mM. During the present experiment the pH value ranged from 8.5 to 9.3. More details on pH values in the shear zone AU 126 can be found in Pfingsten & Soler (2003).

The injection system consisted of two tanks, one with the tracer cocktail and the second with local fault-zone water from AU 96 having identical chemical composition to water in the shear zone AU 126. To obtain steady-state hydraulic conditions, local freshwater was injected for four days into the injection borehole with a constant flow rate ($Q_{inj}$) of 66 ml $h^{-1}$. The withdrawal was obtained by opening the borehole BOHP 98.001 and adjusting a free outflow ($Q_{out}$) of 58 ml $h^{-1}$. After reaching steady-state flow conditions, the tracer cocktail, consisting of pyranine and PTS was injected as a step-pulse (top hat) during 27 h with the same injection flow rate. After the end of tracer injection, the local groundwater was injected further with the same $Q_{inj}$ to keep hydraulic conditions at a steady state. During the tracer test, quasi-constant pressure of about 195 kPa and 98 kPa were observed at the injection and observation boreholes, respectively.

## RESULTS AND DISCUSSION

### LRL experiment

The tracer experiment performed at the LRL in a radial–convergent flow field was interpreted using the Single Fissure Dispersion Model (SFDM). This model, developed by Maloszewski & Zuber (1985), combines the convective–dispersive equation for tracer flow in a single fracture with diffusion processes of the tracer into an adjacent infinitely extended rock matrix. The assumption of the infinite matrix is well satisfied for short-term tests in densely fractured media because then the diffusion of tracer is not influenced by the presence of adjacent fractures. Then, the solution to the transport equation for a fixed distance reads (Maloszewski & Zuber, 1985, 1990):

$$C_f(t) = \frac{aM}{2\pi Q}\int_0^t \sqrt{\frac{t_0}{P_D}} \exp\left[-\frac{(t_0-u)^2}{4uP_D t_0} - \frac{a^2u^2}{t-u}\right]\frac{\mathrm{d}u}{\sqrt{u(t-u)^3}} \tag{1}$$

where $C_f$ is the flux-averaged tracer concentration observed in the outflow; $M$ is the injected mass of the tracer; $Q$ is the volumetric flow rate through the system (pumping rate); $t_0$ is the mean transit time of water; $P_D$ is the dispersion parameter; $a$ is the diffusion parameter describing the matrix diffusion process; and $u$ is the integration variable (varies between 0 and $t$).

This model has three fitting parameters:

$$t_0 = x/v \text{ or } V/Q \tag{2a}$$

$$P_D = D/(vx) = \alpha_L/x \tag{2b}$$

$$a = n_p(D_p)^{1/2}/(2b) \tag{2c}$$

where $x$ is the distance between the wells; $v$ is the average water velocity; $V$ is the volume of mobile water in the system; $D$ is the dispersion coefficient; $\alpha_L$ is the dispersivity ($\alpha_L = D/v$); $n_p$ is the matrix porosity; $2b$ is the fracture aperture; and $D_p$ is the effective diffusion coefficient of the tracer in water in the matrix ($D_p = D_m/\tau_p$), where $D_m$ is the molecular diffusion coefficient of the tracer in water and $\tau_p$ is the tortuosity factor of the matrix (assumed as equal to 1.5).

In the case of monopole or dipole tests, it is important to include in the calibration procedure the concept of a relative mass recovery and to fit tracer concentration and recovery curves simultaneously (Klotz *et al.*, 1988; Maloszewski & Zuber, 1990). The relative tracer recovery rate (*RR*) is calculated from the experimental and theoretical tracer concentration curves as a function of time:

$$RR(t) = Q\int_0^t C_f(t)\mathrm{d}t/M \tag{3}$$

The experimental data and the best-fit curves for both concentration and the recovery of uranine and PTS are shown in Fig. 3. The shape of both curves clearly suggests the existence of tracer diffusion into porous rock matrix. The concentration curve of PTS has a slightly lower peak with $(C/M)_{\max} = 0.125/0.155$ (1 m$^{-3}$), and a slightly longer tail in comparison to uranine, due to a higher molecular diffusion coefficient than that of uranine. Therefore, it diffuses faster and deeper into the porous rock matrix than

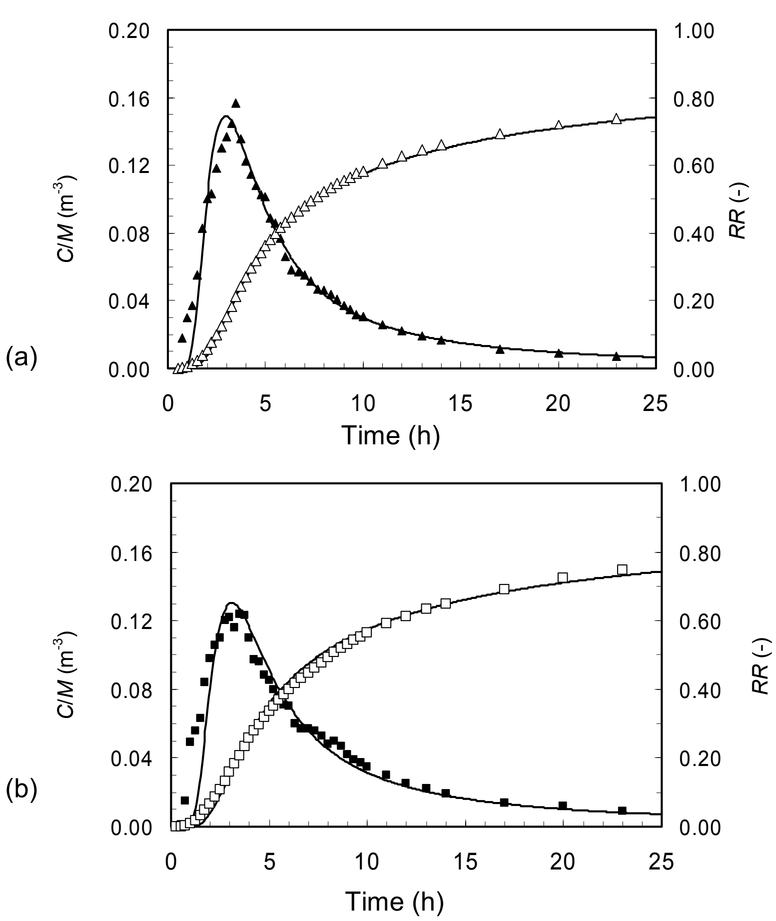

**Fig. 3** Modelled curves (solid lines) obtained as a best-fit to (a) observed uranine normalized concentrations (▲) and relative recoveries (Δ) and (b) PTS normalized concentrations (■) and relative recoveries (□).

uranine. The values of fitting parameters support the existence of matrix diffusion. Both tracers yield the same values of transit time and dispersivity: $t_0 = 2.4$ h and $\alpha_L = 0.56$ m, while the values of $a$ parameter are $7.6 \times 10^{-3}$ $s^{-1/2}$ and $8.5 \times 10^{-3}$ $s^{-1/2}$ for uranine and PTS, respectively.

For a radial–convergent flow field, the fracture porosity (defined as $n_f = 2b/L$, where $L$ is the fissure spacing) can be calculated from (e.g. Zuber, 1974):

$$n_f = (Q \cdot t_0)/(\pi \cdot m \cdot x^2) \tag{4}$$

where $m$ is here the thickness of the ore dike, whereas the fracture aperture, $2b$ (μm) based on the cubic law is:

$$2b = 4.29\tau_f (K/n_f)^{0.5} \tag{5}$$

where $K$ is the hydraulic conductivity expressed in m day$^{-1}$ and $\tau_f$ is the fracture tortuosity.

Using a thickness of the ore dike of 2 m, the fracture porosity of 0.24% was obtained from equation (4). The obtained value of $n_f$, together with the hydraulic conductivity of 2.07 m day$^{-1}$, and the fracture tortuosity of 1.5, were used in equation (5) to calculate the fracture aperture of 188 μm. The molecular diffusion coefficient for uranine is equal to $4.5 \times 10^{-10}$ m$^2$ s$^{-1}$ (Skagius & Neretnieks, 1986). For PTS, the

**Table 1** Model and rock parameters found from the tracer test performed at the LRL.

| Tracer | Model parameters: | | | Rock parameters: | | | |
|---|---|---|---|---|---|---|---|
| | $t_0$ (h) | $P_D$ (-) | $a$ ($s^{-0.5}$) | $\alpha_L$ (m) | $2b$ (μm) | $n_p$ (%) | $n_f$ (%) |
| Uranine | 2.4 | 0.05 | $7.6 \times 10^{-3}$ | 0.56 | 188 | 8.1 | 0.24 |
| PTS | 2.4 | 0.05 | $8.5 \times 10^{-3}$ | 0.56 | 188 | 5.0 | 0.24 |

$t_0$: mean transit time of water; $P_D$: dispersion parameter; $a$: diffusion parameter;
$\alpha_L$: longitudinal dispersivity; $2b$: fracture aperture; $n_p$: matrix porosity; $n_f$: fracture porosity

molecular diffusion coefficient of pyranine $D_m = 1.5 \times 10^{-9}$ m$^2$ s$^{-1}$ (Himmelsbach *et al.*, 1998) was assumed, because both tracers have nearly the same chemical structure (see Fig. 1). Finally, using the values of $a$, fracture aperture ($2b$) and diffusion coefficients ($D_p = D_m/1.5$), the matrix porosity ($n_p$) was calculated by applying equation (2c). The matrix porosity found from the PTS and uranine data was equal to 5.0 and 8.1%, respectively. The modelling results of LRL test are summarized in Table 1.

The present values of fracture porosity (0.24%) and dispersivity (0.56 m) are approximately two times larger than those obtained in previous monopole experiments performed between the wells (Himmelsbach *et al.*, 1998), whereas the fracture aperture shows a similar value. The pumping rate ($Q$) applied in the recent study was two times higher than that in the previous monopole tests. The higher pumping rate mobilized the larger water volume (more fractures with mobile water are activated) which perhaps results in greater fracture porosity and dispersivity. This finding is supported by similarly higher fracture porosity obtained by Himmelsbach *et al.* (1998) in dipole tests which were carried out with flow rates close to those used in the present test.

The matrix porosity found from the present test with PTS agrees with the results obtained earlier using eosine, uranine, pyranine and deuterium, and with the mercury porosimetry data (less than 3% for the granitic to more than 6% for the hydrothermally altered rocks) reported for the LRL test site (Himmelsbach *et al.*, 1998). However, matrix porosity obtained from the uranine breakthrough curve within this study is about 1.5 times higher than that measured on the core samples. Uranine seems to be reactive in the micro-porous matrix, which leads to a larger value of $a$ parameter and to the overestimation of the matrix porosity, if the matrix sorption is not taken into account (see e.g. Maloszewski *et al.*, 1999).

## GTS experiment

The concentrations of pyranine and PTS were measured online in the injection (BOHP 98.003) and extraction (BOHP 98.001) boreholes as a result of a step-pulse injection (see Fig. 4). The largest concentrations of 0.46 and 4.6 mg l$^{-1}$ for pyranine and PTS, respectively, were reached in the injection borehole after 1.5 h, and next the fluorescence signal was constant for the injection period of 24 h. After that, the tracer injection was stopped, and the original background fluorescence in the injection borehole was reached after 1.5 h. The complete duration of tracer injection was approximately 27 h (Fig. 4). The injected masses ($M$) of pyranine and PTS were calculated from:

$$M = Q_{\text{inj}} \int_0^{t_{\text{inj}}} C_{\text{inj}}(t)\,\mathrm{d}t \tag{6}$$

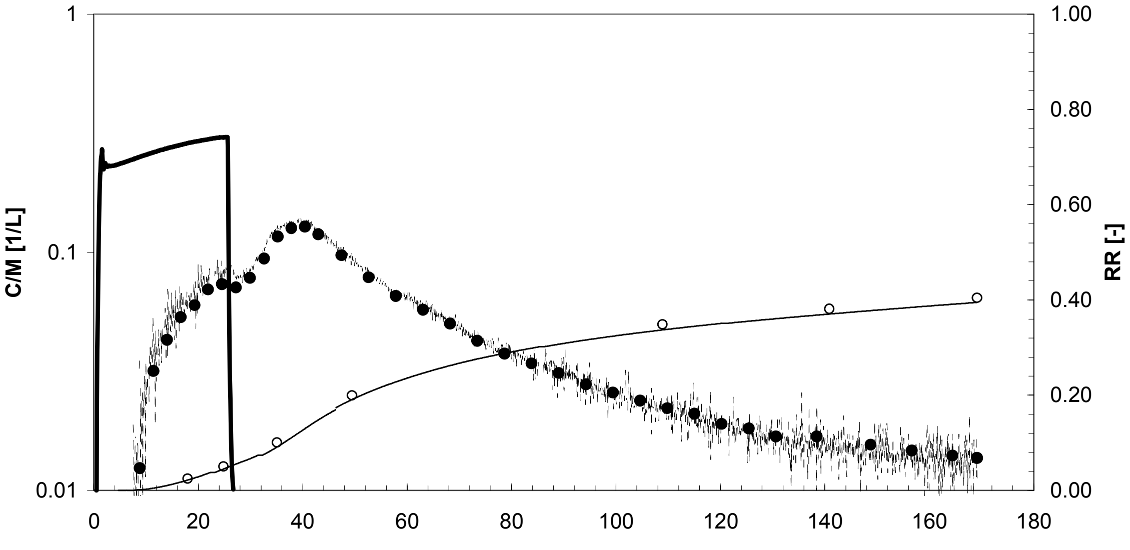

**Fig. 4** Normalized tracer concentration curves (*C*/*M*) for pyranine (●) and PTS (dashed line), recovery rates *RR* for pyranine (○) and PTS (line) observed in withdrawal well and the injection function of both tracers (heavy line).

where $Q_{\text{inj}}$ is the flow rate (66 ml $h^{-1}$) and $C_{\text{inj}}(t)$ is the input tracer concentration (see Fig. 4) in the injection borehole. The injected masses of pyranine and PTS were equal to 0.65 and 6.5 mg, respectively. PTS is detectable at higher concentration and therefore a larger injected mass of that tracer was required.

The concentrations of pyranine and PTS observed in the withdrawal borehole (BOHP 98.001) normalized to the total injected mass (*C*/*M*) are shown in Fig. 4. Both tracers show nearly the same concentration (*C*/*M*) and recovery (*RR*) curves. Taking into account that pyranine and PTS have the same molecular diffusion coefficients, the same shape of those curves clearly demonstrates the conservative behaviour of PTS at the GTS.

The existence of two peaks in the observed tracer breakthrough curve (Fig. 4) results either from a depth stratification (e.g. Zuber, 1974) or from channelling (Moreno *et al.*, 1993; Smith *et al.*, 2001). Within the present study too few data exist to perform a quantitative interpretation of two flow paths.

Under an assumption of a single flow path, a quantitative interpretation of the breakthrough curves was performed using the FRAC3DVS numerical model developed by Therrien & Sudicky (1995), which considers the 3-D tracer transport in discretely-fractured, saturated–unsaturated media. It includes advection, longitudinal and transverse dispersion and the tracer diffusion into the rock matrix. For the numerical calculations, the following dimensions of the fracture plane were used: $x$ = 3.0 m (horizontal) and $z$ = 3.0 m (vertical), while in the direction perpendicular to the plane a matrix domain with $y$ = 0.01 m was assumed. Variable spacing was used for discretization with a finer nodal spacing being equal to 0.01 m near the injection and extraction boreholes in the $x$- and $z$-directions, and to 0.0001 m in the rock matrix ($y$-direction). The flow distance was 0.77 m, while the volumetric flow rates in the injection and withdrawal wells were 66 and 58 ml $h^{-1}$, respectively. Some additional rock parameters required for the numerical calculation (matrix density of 2.67 g $cm^{-3}$, matrix hydraulic conductivity of $9.65 \times 10^{-11}$ m $s^{-1}$, and the fracture conductivity of

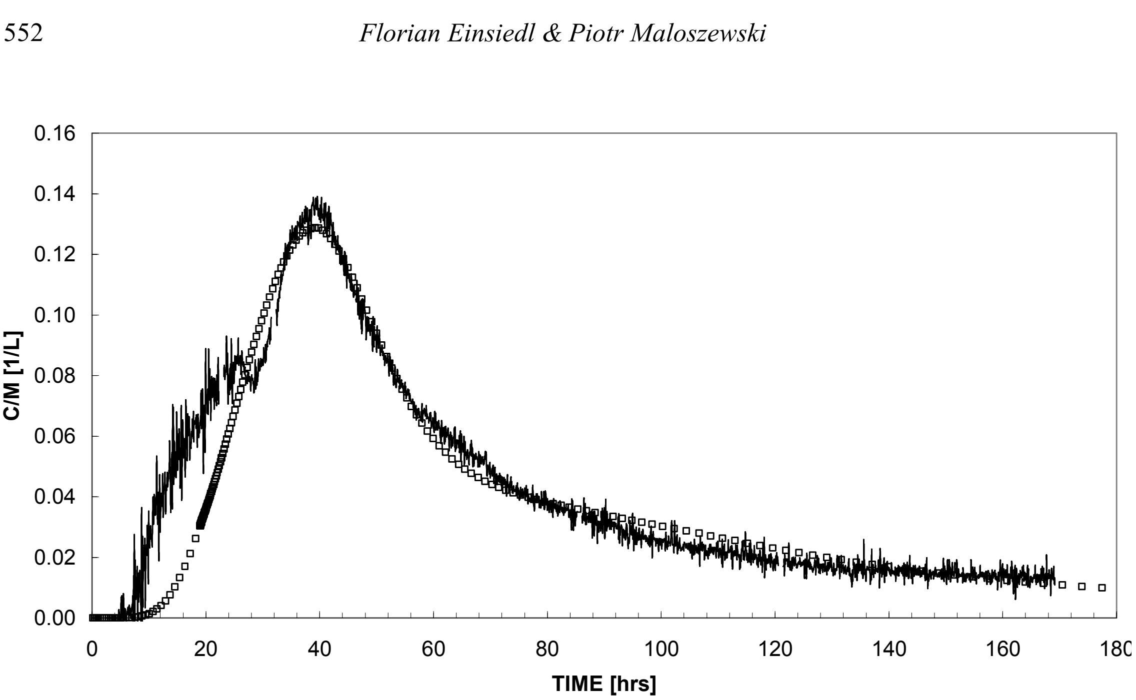

**Fig. 5** Best fit obtained with the FRAC3DVS model (□) to the experimental tracer curve of PTS (line).

**Table 2** Model parameters chosen for the simulation of the tracer test performed at the GTS with the aid of the FRAC3DVS program.

| Tracer | $\alpha_L$ (m) | $\alpha_T$ (m) | $2b$ (μm) | $n_p$ (%) |
|---|---|---|---|---|
| Pyranine | $2 \times 10^{-2}$ | $5 \times 10^{-5}$ | 900 | 1.5 |
| PTS | $2 \times 10^{-2}$ | $5 \times 10^{-5}$ | 900 | 1.5 |

$1.5 \times 10^{-8}$ m s$^{-1}$), were taken from Fisch (1999). The diffusion coefficient in the matrix ($D_p = D_m/\tau_p = 1.0 \times 10^{-9}$ m$^2$ s$^{-1}$) was also taken as being known for both tracers. Under these assumptions four parameters were sought in FRAC3DVS: longitudinal and transverse dispersivities ($\alpha_L$ and $\alpha_T$, respectively), matrix porosity ($n_p$) and fracture aperture ($2b$). Performed simulations showed that a number of different parameter sets yielded nearly the same good fit shown in Fig. 5. The set of the finally selected parameters based on the results of earlier investigations is shown in Table 2. The borehole imaging performed in the shear zone AU126 has shown fracture apertures of 1000 μm. The Peclet number (Pe = $1/P_D$) of Pe = 35 agrees reasonably well with the values of 20 and 30 found within the shear zones AU 96 and AU 126, respectively by Heer & Hadermann (1996) and Pfingsten & Soler (2003). The matrix porosity at the location of the packer intervals of the boreholes reported by Pfingsten & Soler (2003) vary from less than 0.1% to more than 20%, with the result of the present study being within that range.

## CONCLUSIONS

Two tracer tests were performed in radial–convergent and injection–withdrawal flow fields at the Lindau (LRL) and Grimsel (GTS) underground rock laboratories. The results of both tests clearly document the conservative behaviour of a new fluorescent tracer (PTS) and its applicability for groundwater investigations.

In the test performed at the LRL, the fitted and resulting rock parameters found using the PTS concentration and recovery curves (fracture aperture, matrix and fracture porosities) are in a very good agreement with earlier findings of Himmelsbach *et al*. (1998).

The dipole tracer test performed in the GTS using PTS and pyranine (tracers of equal diffusion coefficients) showed identical transport behaviour confirming a conservative behaviour of the PTS in these bedrock environments. The modelling of tracer curves has shown that the unique inverse solution is not available. An acceptable set of fit parameters was selected on the basis of knowledge obtained in earlier studies. The present experiment has shown that the influence of the matrix porosity to radionuclide transport for the shear zone AU 126 cannot be well determined by applying injection–withdrawal tests. Practically, all tracer experiments performed until the present at the shear zone AU 126 (Pfingsten & Soler, 2003) have shown that the dipole tests in fissured rocks supply little information.

**Acknowledgements** Financial support for this work was provided by the German Research Foundation (DFG). The authors wish to thank B. Frieg (NAGRA), P. Steffen (Geotec AG, Switzerland), P. Schnegg (University of Neuchatel, Switzerland) and the National Cooperative of Radioactive Waste Deposit for Radioactive Waste (NAGRA) for technical support. The authors acknowledge E. Sudicky (University of Waterloo, Canada) for providing the FRAC3DVS program. Thanks are also due to the University of Karlsruhe, especially K. Witthüser for his support during field experiments. The authors want to express special acknowledgements to both reviewers: A. Zuber and M. Becker, for their valuable comments and remarks which helped to improve the manuscript.

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**Received 30 March 2004; accepted 10 February 2005**

# Appendix D.5

# Groundwater Sampling Field Form

SHPC
ENGINEERS

# Appendix D.5
# Groundwater Sample Field Form
# Enhanced Bio Pilot Testing
# IBM Gun Club - Former BPA, Union, NY

| | | | | |
|---|---|---|---|---|
| SHA<br>IMPROVING EARTH | Project No.: | Well Diameter: | Water Level: | Well No.: |
| | Location: | Reference Point: | Total Depth: | Date: |
| | SHA Rep.: | Intake Depth: | Screen Interval: | Weather: |

| **Instrumentation** | **Sampling Equipment and Materials** | |
|---|---|---|
| DO, Conductivity, Temperature, pH, ORP: YSI 556/600 XLM Hanna Probe | Low Flow Peristaltic Pump Bailer Diffusion Bag (PDS) | |
| Geochemistry: Hach 2800 Other: | Bladder/Peristaltic Pump S/N: | Bailer/PDS Diameter: 1/2" 1" 2" |
| Turbidity: Hach 2100P Other: | Tubing Specifications: Poly Teflon | Replace PDS Membrane? Yes No |
| Bromide: Br Probe Other: | Tubing Diameter: 1/4" 3/8" 1/2" | |

| Time (min.) | Pump Rate | | | Water Level (ft) | Flow (ml/min) | Temperature (°C) | Specific Conductance (μS/cm) | DO (mg/l) | pH (s.u.) | ORP (mV) | Turbidity (NTU) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Compressor Pressure (psi) | Recharge (sec) | Discharge (sec) | | | | | | | | | |
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| | | | | | | | | | | | | |
| **Equilibrium Goals**<br>**(3 consecutive readings 3-5 min apart)** | | | | **<0.3 ft total drawdown** | **100 - 400 ml/min** | **± 3%**<br>**(may not equilibrate)** | **± 3%** | **± 10%** | **± 0.1** | **± 10 mV** | **± 10%**<br>**(for > 1 NTU)** | **Purge Volume (gal):** |

# Appendix D.5
# Groundwater Sample Field Form
# Enhanced Bio Pilot Testing
# IBM Gun Club - Former BPA, Union, NY

| | | | | |
|---|---|---|---|---|
| SHA<br>IMPROVING EARTH | Project No.: | Well Diameter: | Water Level: | Well No.: |
| | Location: | Reference Point: | Total Depth: | Date: |
| | SHA Rep.: | Intake Depth: | Screen Interval: | Weather: |

| | | | |
|---|---|---|---|
| **In Field Geochemical Analysis** | Sample ID: | Collection Time: | Analysis Time |

| Analyses | Sample | Duplicate | Dilution Factor | Conc (mg/l) | Start | Read | Comments |
|---|---|---|---|---|---|---|---|
| Bromide | | | | | | | |
| Sulfide | | | | | | | |
| DO (LR) | | | | | | | |
| DO (HR) | | | | | | | |
| Ferrous Iron, Fe(II) | | | | | | | |
| Iron, Total | | | | | | | |
| Nitrate | | | | | | | |
| Sulfate | | | | | | | |
| Chloride | | | | | | | |
| Other | | | | | | | |

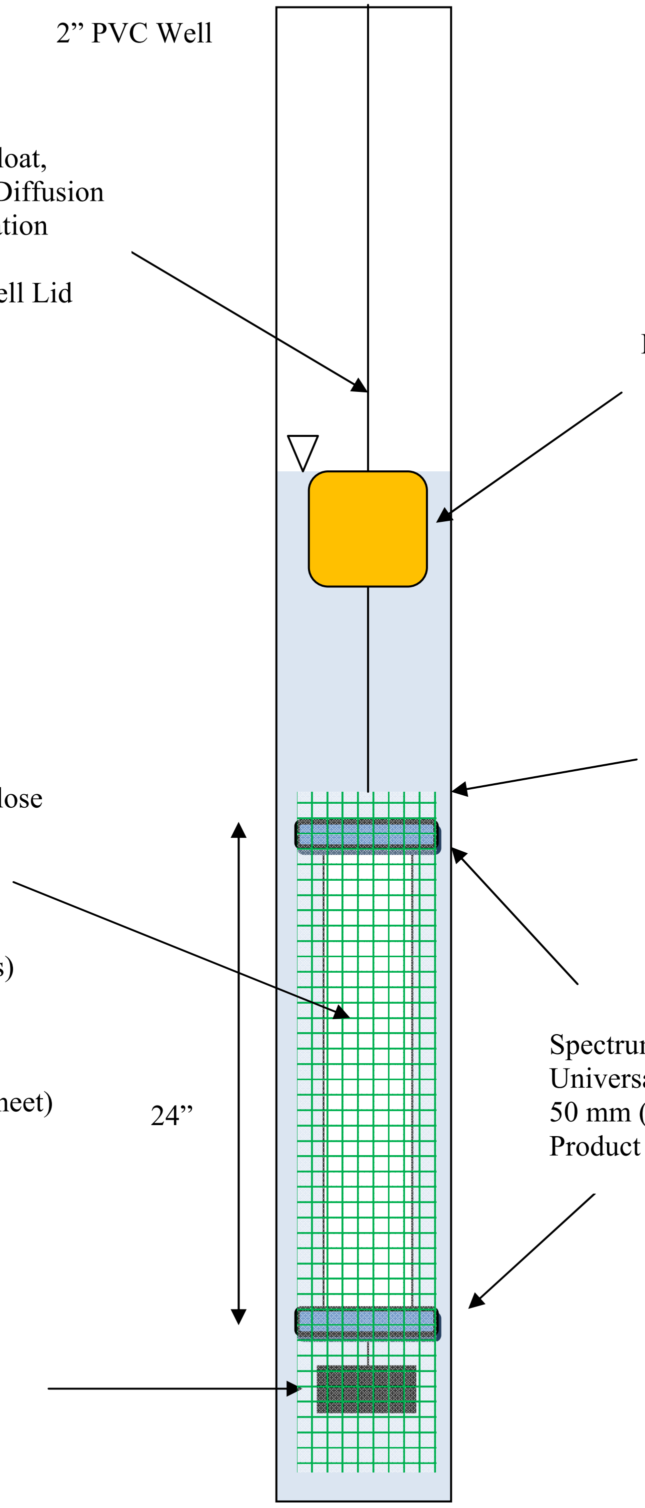
| | | | |
|---|---|---|---|
| **Laboratory Samples** | Sample ID: | Collection Time: | |

| Analyses | # Sample Vials | # Duplicate Vials | # Matrix Spike (MS) Vials | # MS Dup (MSD) Vials | Total No. Vials | Laboratory/Comments |
|---|---|---|---|---|---|---|
| VOCs | | | | | | |
| Light Gasses | | | | | | |
| TOC | | | | | | |
| Volatile Fatty Acids | | | | | | |
| Alkalinity | | | | | | |
| Other | | | | | | |

# Appendix D.6

## Passive Diffusion Bag Setup and Specifications

# APPENDIX D.6
# PASSIVE DIFFUSION BAG SETUP AND SPECIFICATIONS



Rope tied to Float,
Poly-Net and Diffusion
Bag Configuration

Secured on Well Lid

Buoyancy Float

Cole Parmer Poly-Net
Protective Netting
1-2” Diameter
Product #R-09405-25

Spectrum Labs Specta/Por7
Standard Regenerated Cellulose
(RC) Dialysis Tubing
Pre-wetted and Pre-treated

Specifications:
8,000 Daltons (kD, MWCOs)
50 mm (1.9”) flat width
32 mm (1.25”) diameter
Product # 132131
(see attached specification sheet)

Spectrum Labs
Universal Closure for RC Membranes
50 mm (1.9”) closure width
Product #142154

Steel Weight

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**Spectra/Por®**

# Spectra/Por®
# 1, 2, 3, 4, 5, 6 and 7
# Regenerated Cellulose (RC) Dialysis Membranes

SPECTRUMLABS.COM
*Leading the Way in Bioseparation*

## Table of Contents

## Introduction

The Spectra/Por® Regenerated Cellulose (RC) membrane has proven to be the most useful membrane available for laboratory dialysis. It carries no fixed charge and does not adsorb most solutes.

Unlike native cellulose which is highly crystalline and rigid, regenerated cellulose is largely amorphous and highly swollen by water. However, it still contains small regions of crystallinity, that lock (cross-link) the chains in place so that they maintain their integrity. Depending on the conditions of manufacture, these regions are more or less numerous. The areas between cross-links, swollen with water, act like pores permitting sufficiently small solute molecules to pass through the membrane.

Because of the amorphous gel-like nature of regenerated cellulose, mechanical strain will alter the porosity of the membrane.

## Membrane Composition and Specifications

Spectra/Por 1, 2, 3, 4, 5, 6 and 7 dialysis membranes are manufactured from natural cellulose reconstituted from cotton linters. These RC membranes carry no fixed charge and do not adsorb most solutes. The standard RC dialysis membranes are used for general laboratory dialysis functions, ie. desalting, buffer exchange, or molecular separation.

These flexible, transparent membranes feature good chemical and pH resistance and high temperature tolerance without significant changes in the MWCO rating.

Spectra/Por 1 through 6 contain trace levels of heavy metals and sulfides. Spectra/Por 7 membranes have been chemically treated to minimize the heavy metal and sulfur content, eliminating the need for special cleaning treatments.

In the manufacturing process Spectra/Por 5 membrane is reinforced with a layer of porous paper to increase its wet strength for use in high shear or torque environments, resulting in a lower permeation rate compare to the other membranes.

## Membrane Specifications

### Specifications

| | |
|---|---|
| **Membrane Type:** | Symmetric Regenerated Cellulose Tubing |
| **Physical Properties:** | Transparent, flexible (Spectra/Por® 5 reinforced with porous paper layer) |
| **PH limits:** | 2-12 |
| **Suggested temperature:** | 60° C |
| **Organic Solvent Tolerance:** | Good |

### Specifications

| | Spectra/Por® 1-5 | Spectra/Por® 6 & 7 |
|---|---|---|
| **Packaged:** | Dry | Wet |
| **Preservative:** | Glycerin | 0.05% sodium azide |
| **Disc/Flat sheet:** | Yes | No |

## Metal Content in Spectra/Por® 1-6 dialysis membranes

The following are approximate concentration of heavy metal and sulfur found in the Spectra/Por 1 through 6 membranes.

| Element | Concentration | Element | Concentration |
|---|---|---|---|
| Cd | <1 ppm | Ni | 1-2 ppm |
| Cr | <1 ppm | Pb | 2-6 ppm |
| Cu | <1 ppm | Zn | 5-10 ppm |
| Fe | 20-60 ppm | S | 0.1% |
| Mg | 50-100 ppm | | |

## Criteria for Selecting the Membrane for use

### Membrane Selection of MWCO

| Spectra/Por® | MWCO Daltons | Spectra/Por® | MWCO Daltons |
|---|---|---|---|
| 1 | 6000-8000 | 6 | 1k, 2k, 3.5k, 8k, 10k, 15k, 25k, and 50k |
| 2 | 12,000-14,000 | | |
| 3 | 3,500 | | |
| 4 | 12,000-14,000 | 7 | 1k, 2k, 3.5k, 8k 10k, 15k, 25k, and 50k |
| 5 | 12,000-14,000 | | |

## Membrane Permeability Characterization

The widely used method to characterize dialysis membranes is the molecular weight cut off (MWCO). Spectrum determines the MWCO of a membrane by conducting a 17 hour dialysis test with a set of solutes of known molecular weight. The MWCO of the membrane is then said to be the molecular weight of the smallest solute which is at least 90% retained during this test (the smallest solute for which the permeation is 10% or less).

Dialysis membrane may also be characterized by the rate at which a permeable species passes through the membrane. A rate test may be carried out by placing a solution of a permeable species on one side of a membrane and pure solvent on the other. If both the solution and the solvent are well stirred and the pure solvent is constantly changed (so that it never contains an appreciable concentration of solute), a first-order rate will be observed.

A very important variable in the rate of dialysis is the molecular weight of the solute. As the molecular weight of a permeable solute increases, the rate of dialysis decreases. At molecular weights far from the MWCO, the rate decrease is caused by the decrease of the diffusion rate with the increasing molecular weight. As the solute's molecular weight nears the MWCO, the rate will slow dramatically with further increases in molecular weight until finally, the molecules become too large to pass through the membrane.

## MWCO Selection

The effective size of many solute molecules will be affected by the pH and ionic strength of the solution in which they are dissolved.

Therefore, the listed MWCO values should be used merely as typical and not absolute values. To establish the optimal MWCO for any application, it may be necessary to test several membranes. To maximize the rate of dialysis, the membrane with the largest MWCO which will not cause excess loss of the desired species should be used.

The selecting of MWCO is based on the Molecular Weight (MW) of the macro molecules that are going to be retained inside the membrane and the MW of the micromolecule contaminants to be removed. For reasonably efficient separation by means of dialysis with Spectra/Por membranes, the ratio of the molecular weights of the two compounds to be separated should be at least 25. A rule of thumb is to choose a MWCO by selecting an MWCO value about half of the MW of the macromolecules to be retained in order to achieve a minimum 90% retention.

## Chemical Compatibility

Spectra/Por® RC membranes have a good chemical resistance. Variables in temperature, concentrations, durations of exposure and other factors may affect the use of the membrane. You may wish to test under your conditions first. These membranes are resistant to the following groups: halogenated hydrocarbons, alcohols, ketones, esters, oxides and solvents containing nitrogen. They are not recommended for use with >25% hydrochloric, nitric and perchloric acids; 96% sulfuric acid; 1N potassium hydroxide and 10% phenol. Please see chemical compatibility table on **page 20**.

### Membrane Tubing “Flat Width” Selection

The selection of the flat width membrane tubing depends on the size of the sample volume and the dialysis reservoir. The smaller tubing (which has a higher surface area to volume ratio) will dialyze more quickly and larger tubing will dialyze more slowly due to the longer diffusion distances involved. For easy handling of the membrane tubing, the suggested total length including closures and head space should be approximately 10 to 15 cm. The “Volume/Length” ratio (ml/cm) is provided in the catalog and packaging label.

### Closure Selection

It is recommended to select a closure width of 4 to 10 mm longer than the flat width of the membrane tubing. This will allow the closure to seal the tubing securely when the sample solution is being filled inside.

Closures are available in two types of material: polypropylene (Spectra/Por) or nylon (Universal).

#### Polypropylene closures (Spectra/Por®)

These closures are autoclavable and commonly used for

RC membranes. There are 3 types of polypropylene closure:

- **Standard Closures:** float on their own. The standard closures seal at the top of the membrane tubing.
- **Weighted Closures:** contain a stainless steel bar which is embedded in the standard closures. The weighted closures are applied at the bottom of the membrane tubing to keep a vertical floating position.
- **Magnetic Weighted Closures**: contain a magnetic stir bar. There is no need for a magnetic stir bar when the magnetic weighted closure is used at the bottom of the membrane tubing.

#### Nylon Closures (Universal)

*Nylon closures can be used for all types of membrane tubing*. These Universal closures sink on their own and allow the membrane tubing to float vertically with a head space. They are not autoclavable.

## Membrane Preparation

### Spectra/Por® 1-6

For most applications, the membrane can be soaked in distilled water at room temperature for 30 minutes to remove the preservative (glycerine or sodium azide). Then, rinse the membrane thoroughly in distilled water.

If the presence of heavy metals and sulfides is anticipated to cause interferences, the membranes can be treated with Spectrum Sulfide Removal solutions and Spectrum Heavy Metals Cleaning Solution. The Sulfide Removal kit contains two separate wash solutions and instructions for their use. This cleaning process takes less than 10 minutes to complete. The Heavy Metals Cleaning solution is a chelating rinse which strips the heavy metals from the membrane.

### Spectra/Por® 7

Spectra/Por 7 membrane has been chemically treated to minimize the content of heavy metals and sulfide contaminants; therefore, it is only necessary to soak the membrane in a large volume of deionized or distilled water for 30 minutes to remove the sodium azide preservant agent. Then, rinse thoroughly with running deionized or distilled water.

## Membrane Handling and Use

The following dialysis procedure is a general protocol for basic dialysis. There are many variables that should be taken into consideration before starting the dialysis of your sample. Some of the variables that will affect the rate of dialysis are sample solvent, membrane compatibility, membrane MWCO, dialysate solvent, dialysate volume, temperature, etc. Therefore, some application specific changes to the following dialysis procedure may be necessary.

1. Fill a Spectra/Por Dialysis Reservoir with a large volume of appropriate dialysate (buffer). The dialysate volume should be equal 100X of sample volume. (Example: dialyze 10 ml of sample in a Liter of dialysate.)

2. Cut dialysis tubing into appropriate lengths. Allow extra tubing length (about 10% of total sample volume) for a small head space. This insures that the sack will float and not be damaged by the rotating stir bar. Prepare the tubing according to the directions for use. **(see page 7-8)**
3. Open the Closure by releasing the security lock. Insert dialysis tubing into the opened Closure and reclamp with approximately 3 to 5 mm of tubing extending from the Closure.
4. Load the sample into dialysis tubing through the open end. Adjust the length for a head space and clamp the tubing closed.
5. Place the Dialysis sample in appropriate dialysis buffer.
6. Drop a clean magnetic stir bar into the dialysis reservoir. Make sure that the stir bar is large enough to stir the entire dialysate volume but not too large that it can not freely rotate. Place the dialysis reservoir on a stirrer. Adjust the control for the maximum speed that does not pull down the sample by the vortex.

## Sample Recovery

Grasp the tubing extending from Closure and unclamp Closure. Decant the dialyzed sample or remove it with a Pasteur Pipette or syringe. Very small samples may also be recovered by carefully puncturing the tubing and drawing the sample into a syringe using a 24-gauge hypodermic needle.

Typically, dialysis is allowed to run overnight. During the duration of dialysis, the entire dialysate volume can be changed for fresh dialysate solution. Dialysis should be allowed to continue for at least 2 to 4 hours after the last dialysate change. Note: For highly concentrated contaminants, sample may need to dialyze for a longer duration with more frequent changes of dialysate solution.

## Membrane Storage and Shelf Life

Store dry membrane at room temperature or at 4° C in a polyethylene bag. Store unopened wet membrane at 4° C. Once wet, membranes should be immersed in a solution of one of the following: 0.05% sodium azide, 1% sodium benzoate or 1% formaldehyde.

**Note:** Once wet, do not allow membrane to dry. Drying causes unrecoverable collapse of the pore structure.

Shelf life is two years depending on storage conditions. For maximum shelf life of wet membranes, the preservative solution should be changed periodically.

## Membrane Sterilization

The common method of membrane sterilization is exposure to ethylene oxide (EtO) gas. Alternative sterilization methods are either gamma irradiation or steam autoclaving.

Spectrum does not recommend boiling or steam autoclaving Regenerated Cellulose membranes. Temperatures greater than 60° C will change the structure of membrane by decreasing the permeability after sterilization. It is essential that steam autoclaved RC membranes should be recharacterized to compensate for any change in permeation characteristics or MWCO. Membranes may be autoclaved at 121° C for no more than 15 minutes (cycle should be kept as short as possible) immersed in distilled water.

## Ordering Information

### Spectra/Por® 1-5 Dialysis Membranes

- Packaged dry with glycerine
- Rolls of 15 and 30 meters

### Spectra/Por® 1 6,000-8,000 Dalton MWCO

| Product No. | Flat Width (mm) | Diameter (mm) | Vol/Length (ml/cm) | Length (m/ft) |
|---|---|---|---|---|
| 132645 | 10 | 6.4 | 0.32 | 15/50 |
| 132650 | 23 | 14.6 | 1.7 | 30/100 |
| 132655 | 32 | 20.4 | 3.3 | 30/100 |
| 132660 | 40 | 25.5 | 5.1 | 30/100 |
| 132665 | 50 | 32 | 8.0 | 30/100 |
| 132670 | 100 | 64 | 32 | 15/50 |
| 132675 | 120 | 76 | 46 | 15/50 |

## Spectra/Por® 2 12,000-14,000 Dalton MWCO

| Product No. | Flat Width (mm) | Diameter (mm) | Vol/Length (ml/cm) | Length (m/ft) |
|---|---|---|---|---|
| 132685 | 6 | 3.8 | 0.1 | 15/50 |
| 132676 | 10 | 6.4 | 0.32 | 15/50 |
| 132678 | 25 | 16.0 | 2.0 | 15/50 |
| 132680 | 45 | 29.0 | 6.4 | 15/50 |
| 132682 | 105 | 67.0 | 34.0 | 15/50 |
| 132684 | 120 | 76.0 | 46.0 | 15/50 |

## Spectra/Por® 3 3,5000 Dalton MWCO

| Product No. | Flat Width (mm) | Diameter (mm) | Vol/Length (ml/cm) | Length (m/ft) |
|---|---|---|---|---|
| 132720 | 18 | 11.5 | 1.0 | 15/50 |
| 132724 | 45 | 29 | 6.4 | 15/50 |
| 132725 | 54 | 34 | 9.3 | 15/50 |

## Spectra/Por® 4 12,000-14,000 Dalton MWCO

| Product No. | Flat Width (mm) | Dia (mm) | Vol/Length (ml/cm) | Length (m/ft) |
|---|---|---|---|---|
| 132697 | 10 | 6.4 | 0.32 | 30/100 |
| 132700 | 25 | 16 | 2.0 | 30/100 |
| 132703 | 32 | 20.4 | 3.3 | 30/100 |
| 132706 | 45 | 29 | 6.4 | 30/100 |
| 132709 | 75 | 48 | 18 | 15/50 |

## Spectra/Por® 5 High Wet Strength
## 12,000-14,000 Dalton MWCO

Spectra/Por 5 is reinforced with a layer of porous paper to increase its wet strength for use in high shear or torque environments. Spectra/Por 5 has a relatively low permeation rate for solutes compared to other membranes.

| Product No. | Flat Width (mm) | Diameter (mm) | Vol/Length (ml/cm) | Length (m/ft) |
|---|---|---|---|---|
| 132754 | 65 | 41 | 13 | 15/50 |
| 132757 | 140 | 89 | 62 | 15/50 |

## Spectra/Por® 6

- Regenerated Cellulose membrane tubing
- Supplied wet in 0.05% sodium azide preservant solution
- Chemical pretreatment may be required for removing traces of heavy metal contaminants.
- Package of 10 meter/33 feet length

| Product No. | Flat Width (mm) | Dia (mm) | Vol/Length (ml/cm) |
|---|---|---|---|
| **MWCO 1,000** | | | |
| 132636 | 18 | 11.5 | 1.0 |
| 132638 | 38 | 24 | 4.6 |
| 132640 | 45 | 29 | 6.4 |

## Spectra/Por® 6 (cont.)

| Product No. | Flat Width (mm) | Dia (mm) | Vol/Length (ml/cm) |
|---|---|---|---|
| **MWCO 2,000** | | | |
| 132620 | 18 | 11.5 | 1.0 |
| 132625 | 38 | 24 | 4.6 |
| 132633 | 45 | 29 | 6.4 |
| **MWCO 3,500** | | | |
| 132590 | 18 | 11.5 | 1.0 |
| 132592 | 45 | 29 | 6.4 |
| 132594 | 54 | 34 | 9.3 |
| **MWCO 8,000** | | | |
| 128056 | 6 | 3.8 | 0.1 |
| 132579 | 12 | 7.5 | 0.45 |
| 128058 | 18 | 11.5 | 1.0 |
| 132580 | 24 | 15 | 1.8 |
| 132582 | 32 | 20.4 | 3.3 |
| 132584 | 40 | 25.5 | 5.1 |
| 132586 | 50 | 32 | 8.0 |
| **MWCO 10,000** | | | |
| 128106 | 6 | 3.8 | 0.1 |
| 132570 | 12 | 7.5 | 0.45 |
| 128118 | 18 | 11.5 | 1.0 |
| 132572 | 24 | 15 | 1.8 |
| 132574 | 32 | 20.4 | 3.3 |
| 132576 | 45 | 29 | 6.4 |
| **MWCO 15,000** | | | |
| 128156 | 6 | 3.8 | 0.1 |
| 132560 | 12 | 7.5 | 0.45 |
| 128158 | 18 | 11.5 | 1.0 |
| 132562 | 24 | 15 | 1.8 |

| Product No. | Flat Width (mm) | Dia (mm) | Vol/Length (ml/cm) |
|---|---|---|---|
| **MWCO 15,000 (cont.)** | | | |
| 132564 | 32 | 20.4 | 3.3 |
| 132566 | 45 | 29 | 6.4 |
| **MWCO 25,000** | | | |
| 128206 | 6 | 3.8 | 0.1 |
| 132550 | 12 | 7.5 | 0.45 |
| 128218 | 18 | 11.5 | 1.0 |
| 128224 | 24 | 15 | 1.8 |
| 132552 | 28 | 18 | 2.5 |
| 132554 | 34 | 22 | 3.7 |
| **MWCO 50,000** | | | |
| 132539 | 10 | 6.4 | 0.3 |
| 132540 | 12 | 7.5 | 0.45 |
| 132542 | 28 | 18 | 2.5 |
| 132544 | 34 | 22 | 3.7 |

## Spectra/Por® 7

- Regenerated Cellulose Membrane Tubing
- Minimum sulfur and heavy metal contamination
- Supplied wet in 0.05% sodium azide
- Package of 5 meter/16 feet length

| Product No. | Flat Width (mm) | Dia (mm) | Vol/Length (ml/cm) |
|---|---|---|---|
| **MWCO 1,000** | | | |
| 132103 | 18 | 11.5 | 1.0 |
| 132104 | 38 | 24 | 4.6 |
| 132105 | 45 | 29 | 6.4 |

## Spectra/Por® 7 (cont.)

| Product No. | Flat Width (mm) | Dia (mm) | Vol/Length (ml/cm) |
|---|---|---|---|
| **MWCO 2,000** | | | |
| 132107 | 18 | 11.5 | 1.0 |
| 132108 | 38 | 24 | 4.6 |
| 132109 | 45 | 29 | 6.4 |
| **MWCO 3,500** | | | |
| 132110 | 18 | 11.5 | 1.0 |
| 132111 | 45 | 29 | 6.4 |
| 132112 | 54 | 34 | 9.3 |
| **MWCO 8,000** | | | |
| 128356 | 6 | 3.8 | 0.1 |
| 132113 | 12 | 7.5 | 0.45 |
| 128358 | 18 | 11.5 | 1.0 |
| 132114 | 24 | 15 | 1.8 |
| 132115 | 32 | 20.4 | 3.3 |
| 132116 | 40 | 25.5 | 5.1 |
| 132131 | 50 | 32 | 8.0 |
| **MWCO 10,000** | | | |
| 128406 | 6 | 3.8 | 0.1 |
| 132117 | 12 | 7.5 | 0.45 |
| 128418 | 18 | 11.5 | 1.0 |
| 132118 | 24 | 15 | 1.8 |
| 132119 | 32 | 20.4 | 3.3 |
| 132120 | 45 | 29 | 6.4 |
| **MWCO 15,000** | | | |
| 128456 | 6 | 3.8 | 0.1 |
| 132121 | 12 | 7.5 | 0.45 |

| Product No. | Flat Width (mm) | Dia (mm) | Vol/Length (ml/cm) |
|---|---|---|---|
| **MWCO 15,000 (cont.)** | | | |
| 128458 | 18 | 11.5 | 1.0 |
| 132122 | 24 | 15 | 1.8 |
| 132123 | 32 | 20.4 | 3.3 |
| 132124 | 45 | 29 | 6.4 |
| **MWCO 25,000** | | | |
| 128506 | 6 | 3.8 | 0.1 |
| 132125 | 12 | 7.5 | 0.45 |
| 128518 | 18 | 11.5 | 1.0 |
| 128524 | 24 | 15 | 1.8 |
| 132126 | 28 | 18 | 2.5 |
| 132127 | 34 | 22 | 3.7 |
| **MWCO 50,000** | | | |
| 132128 | 12 | 7.5 | 0.45 |
| 132129 | 28 | 18 | 2.5 |
| 132130 | 34 | 22 | 3.7 |

## Spectra/Por® RC Membrane Discs and Flat Sheet

- Precut membrane discs are packaged 50 per pack
- Flat sheet membranes are packaged 25 per pack
- Membrane supplied dry with glycerol as a humectant

| Spectra/Por® | MWCO (Daltons) | Product No. for Dia. Discs 33 mm | 47 mm | 100 mm |
|---|---|---|---|---|
| Spectra/Por® 1 | 6,000-8,000 | 132478 | 132476 | 132474 |
| Spectra/Por® 2 | 12,000-14,000 | 132482 | 132480 | 132477 |
| Spectra/Por® 3 | 3,500 | 132488 | 132486 | 132484 |
| Spectra/Por® 4 | 12,000-14,000 | 132498 | 132496 | 132494 |

## Spectra/Por® RC Membrane Flat Sheet (cont)

| Spectra/Por® | MWCO (D) | Sheets (mm) | Product No. |
|---|---|---|---|
| Spectra/Por® 1 | 6,000-8,000 | 240 x 240 | 132677 |
| Spectra/Por® 2 | 12,000-14,000 | 200 x 200 | 132686 |
| Spectra/Por® 3 | 3,500 | 108 x 108 | 132723 |
| Spectra/Por® 4 | 12,000-14,000 | 150 x 150 | 132712 |
| Spectra/Por® 5 | 12,000-14,000 | 275 x 275 | 132759 |

## Spectra/Por® Ready-to-Use Dialysis Sacks

Spectra/Por Ready-to-Use Dialysis Sacks feature regenerated cellulose tubing sealed at one end with a closure and open at the other. These sacks have a funnel attached to the top for easy sample filling. Supplied in a 0.05% sodium azide preservant, sacks should be rinsed prior to use. Each Dialysis Sack is 60 cm in length for volumes of 1 to 40 ml or 50 to 400 ml. Supplied 10/package in three MWCO choices.

| Product No. | Description | MWCO (Daltons) | Flat Width (mm) |
|---|---|---|---|
| **1 to 40 ml** | | | |
| 132651 | Spectra/Por® 1 | 6,000-8,000 | 23 |
| 132679 | Spectra/Por® 2 | 12,000-14,000 | 25 |
| 132721 | Spectra/Por® 3 | 3,500 | 18 |
| 132701 | Spectra/Por® 4 | 12,000-14,000 | 25 |
| **50 to 400 ml** | | | |
| 132666 | Spectra/Por® 1 | 6,000-8,000 | 50 |
| 132681 | Spectra/Por® 2 | 12,000-14,000 | 45 |
| 132726 | Spectra/Por® 3 | 3,500 | 54 |
| 132707 | Spectra/Por® 4 | 12,000-14,000 | 45 |

---

## Heavy Metals Cleaning Solution

Spectra/Por 1, 2, 3, 4, 5, and 6 membranes contain traces of heavy metals. For ultracritical work, chelate wash the membranes with Heavy Metals Cleaning solution before use.

| Product No. | Description |
|---|---|
| 132908 | Heavy Metals Cleaning Kit, 8 oz. |

## Sulfide Removal Solution

Spectra/Por 1, 2, 3, 4, 5 and 6 membranes have 0.1% sulfur present from the manufacturing process which requires removal only if the presence might interfere with the subsequent analysis of the dialysate or retentate.

| Product No. | Description |
|---|---|
| 132906 | Sulfide Removal Kit<br>Solution A, 8 oz.<br>Solution B, 8 oz. |

## Spectra/Por® Openers

Solve the problem of opening dry dialysis tubing with Spectra/Por Openers. They have a strong adhesive that grips dry tubing for easy membrane separation for filling with sample solution.

| Product No. | Description | Qty |
|---|---|---|
| 132730 | Spectra/Por® Openers | 100 |

## Membrane Compatibility Table

This chemical resistance chart is intended for use as a guide, not as a guarantee of chemical compatibility. Variables in temperature, concentrations, durations of exposure and other factors may affect the use of the product. It is recommended to test under your own conditions.

The following codes are used to rate chemical resistance:

| | |
|---|---|
| **R** | Recommended |
| **L** | Limited Exposure |
| **NR** | Not Recommended |
| **U** | Unknown |

| Regenerated Cellulose (RC) | | Regenerated Cellulose (RC) | |
|---|---|---|---|
| Acetic acid (diluted-5%) | R | Chloracetic acid | R |
| Acetic acid (med conc-25%) | R | Chloroform | R |
| Acetic acid (glacial) | R | Chromic acid | NR |
| Acetone | R | Cresol | R |
| Acetonitrile | R | Cyclohexane | R |
| Ammonium hydroxide (diluted) | R | Cyclohexanone | R |
| Ammonium hydroxide (med conc) | L | Diacetone alcohol | R |
| Amyl acetate | R | Dichloromethane | R |
| Amyl alcohol | R | Dimethyl formamide | L |
| Aniline | R | Dimethylsulfoxide | R |
| Benzene | R | 1,4 Dioxane | L |
| Benzyl alcohol | R | Ethers | R |
| Boric acid | R | Ethyl acetate | R |
| Brine | R | Ethyl Alcohol | R |
| Bromoform | R | Ethyl alcohol (15%) | R |
| Butyl acetate | R | Ethyl alcohol (95%) | R |
| Butyl alcohol | R | Ethylene dichloride | R |
| Butyl cellosolve | L | Ethylene glycol | R |
| Butylraldehyde | R | Ethylene oxide | L |
| Carbon tetrachloride | R | Formaldehyde (2%) | R |
| Cellosolve | L | Formaldehyde (30%) | R |

| Regenerated Cellulose (RC) | | Regenerated Cellulose (RC) | |
|---|---|---|---|
| Formic acid (25%) | R | Nitrobenzene | L |
| Formic Acid (50%) | R | Nitropropane | L |
| Freon® | R | Oils, mineral | R |
| Gasoline | R | Pentane | R |
| Glycerine | R | Perchloric acid (25%) | L |
| Glycerol | R | Perchloroethylene | R |
| Hexane | R | Petroleum based oils | R |
| Hexanol | R | Petroleum ether | R |
| Hydrochloric acid (diluted-5%) | R | Phenol (0.5%) | R |
| Hydrochloric acid (med conc-25%) | NR | Phenol (10%) | R |
| Hydrochloric acid (con-37%) | NR | Phosphoric acid (25%) | L |
| Hydrofluoric acid (25%) | L | Potassium hydroxide (1N) | L |
| Hydrogen peroxide (30%) | NR | Potassium hydroxide (25%) | R |
| Iodine solutions | NR | Potassium hydroxide (50%) | NR |
| Isobutyl alcohol | R | Propanol | R |
| Isopropanol | R | Pyridine | R |
| Isopropyl acetate | R | Silicone oil | R |
| Isopropyl alcohol | R | Sodium hydroxide (0.1N) | R |
| Isopropyl ether | R | Sodium hydroxide (diluted-5%) | L |
| Jet Fuel 640A | R | Sodium hydroxide (25%) | L |
| Kerosene | R | Sodium hydroxide (conc-50%) | NR |
| Lactic acid | R | Sodium Hydroxide (Concentrated) | NR |
| Methyl acetate | R | Sodium Hypochlorite | R |
| Methyl alcohol | R | Sulfuric acid (diluted-5%) | R |
| Methyl alcohol (98%) | R | Sulfuric acid (med conc-25%) | L |
| Methyl cellosolve | L | Sulfuric acid (6N) | L |
| Methyl Chloride | R | Sulfuric Acid (concentrated) | NR |
| Methyl ethyl ketone | R | Tetrahydrofuran | R |
| Methyl formate | L | Toluene | R |
| Methyl isobutyl ketone | R | Trichloroacetic acid (25%) | NR |
| Methylene chloride | R | Trichlorobenzene | R |
| N-Methyl-2-Pyrrolidone | R | Trichloroethane | R |
| Mineral spirits | R | Trichloroethylene | R |
| Monochlorobenzene | R | Triethylamine | R |
| Nitric acid (diluted-5%) | R | Turpentine | R |
| Nitric acid (med conc-25%) | NR | Urea | R |
| Nitric acid (6N) | NR | Urea (6N) | R |
| Nitric acid (conc-70%) | NR | Water | R |
| Nitric acid (concentrated) | NR | Xylene | R |

**To place an order go to www.spectrumlabs.com or:**

## THE AMERICAS

**Spectrum Laboratories Inc.**
18617 South Broadwick Street
Rancho Dominguez, CA  90220-6435, USA

| | |
|---|---|
| **voice** | (800) 634-3300 (US & Canada)<br>(310) 885-4600 (world-wide) |
| **fax** | (800) 445-7330 (US & Canada)<br>(310) 885-4666 (worldwide) |
| **e-mail** | customerservice@spectrumlabs.com |

## EUROPE

**Spectrum Europe B.V.**
P.O. Box 3262
4800 DG Breda, The Netherlands

| | |
|---|---|
| **voice** | 00 31 (0)76 5719 419 |
| **fax** | 00 31 (0)76 5719 772 |
| **e-mail** | info@spectrumeurope.nl |

## JAPAN

**Spectrum Japan**
3-12-18, Shimosakamoto
Otsu-City, Shiga
520-0105, Japan

| | |
|---|---|
| **phone/fax** | 00 81 (0)77 578 0166 |
| **e-mail** | spectrum.j@gol.com |

# Appendix D.7

# YSI Calibration Form

# Low Flow Sampling Equipment Calibration Data Sheet

Project Number:
Date:
Project Name:
Project Location:
SHA Representative:
Weather:

## Instrument

☐ YSI 650 MDS (S/N 00K0804 AA) with 600XLM Probe Module (S/N 00K0681) (SH-1)
☐ YSI 556 MPS (S/N 04M126 AO) with 5563 Probe Module (S/N 655168) (SH-2)
☐ YSI 650 MDS (S/N 02F0014 AA) with 600XLM Probe Module (S/N 02F0415 AB) (SH-3)
Barometric Pressure: ________________________________________
Hach 2100P Turbidity Meter: ☐ SH-1 (S/N 990100020323) ☐ SH-2 (S/N 010800023156)
☐ Other:________________________________________________________

## Calibration Solutions Used

| Parameter | Solution Concentration | Manuafacturer | Lot # | Exp. Date |
|---|---|---|---|---|
| DO | mg/l | | | |
| Specific Conductance | µS/cm | | | |
| ORP | mV | | | |
| pH | s.u. | | | |
| pH | s.u. | | | |
| pH | s.u. | | | |
| Turbidity | <0.1, 20, 100, 800 NTU | | | |

## Calibration Data

| Parameter | Calibration Reading | Inst. Temp. Reading (ºC) | Meet Cal. Guidelines? | End of Day Instrument Reading | Inst. Temp. Reading (ºC) |
|---|---|---|---|---|---|
| DO | mg/l | | Y N | | |
| Specific Conductance | µS/cm | | Y N | | |
| ORP | mV | | Y N | | |
| pH ________ | s.u. | | Y N | | |
| pH ________ | s.u. | | Y N | | |
| pH ________ | s.u. | | Y N | | |
| Turbidity <0.1 NTU | NTU | | Y N | | |
| Turbidity 20 NTU | NTU | | Y N | | |
| Turbidity 100 NTU | NTU | | Y N | | |
| Turbidity 800 NTU | NTU | | Y N | | |

## Calibration Guidelines

| | |
|---|---|
| DO | ≤ 0.5 mg/l |
| Specific Conductance | ± 10% |
| ORP | ± 10 mV |
| pH | ± 0.2 s.u. |
| Turbidity | ± 10% |

Notes:
1. As a rule, when conducting the pH calibration, a 3 point calibration should be performed and the middle value buffer solution should be the first calibration solution used.
2. The YSI 556 MPS requires temperature dependent buffer solution values to be input during calibration. Therefore, during pH calibration for the YSI 556 MPS, enter the temperature adjusted pH value of the solution at the current temperature. pH vs. temperature tables are often printed on the labels of the pH buffer solution bottles. The YSI 600 XLM does not require temperature adjusted buffer solution values to be input.

# APPENDIX E

# US EPA REGION 2 UIC INVENTORY PERMIT FORM

SHA
IMPROVING EARTH

SANBORN, HEAD & ASSOCIATES, INC.
95 High Street ▪ Portland, ME 04101
P (207) 761-9300 ▪ F (207) 761-9339
www.sanbornhead.com

# MEMORANDUM

**To:** Kevin Whalen, IBM Corporate Environmental Affairs

**From:** Allan Horneman, Dr.Eng.Sci.
Senior Project Manager

**File:** 3025.00

**Date:** April 9, 2010

**Re:** Injection Permit Procedure
Pilot Testing of Enhanced Biochemical Degradation
IBM Gun Club – Former Burn Pit Area

**cc:** Daniel Carr, P.G., P.E.

---

Sanborn, Head, & Associates, Inc. (SHA), has prepared this memorandum to provide a summary of the New York State permitting processes related to enhanced in situ biochemical degradation pilot testing at the IBM Gun Club – Former Burn Pit area (BPA). This work is to be conducted as a part of Remedial Alternatives Analysis under the New York State Brownfield Cleanup Program (BCP). We understand that IBM will transmit this memorandum and the attached permit application form to the U.S. Environmental Protection Agency Region 2 to support the work.

The work includes the injection of a commercially available carbon amendment (EOS 598 B42) and a sodium bromide (NaBr) tracer into the shallow subsurface (<30 feet) using nine injection wells located within a 60 feet by 20 feet area as discussed in the Work Plan text. The MSDS for the EOS amendment and the NaBr salt are attached and both are classified as non-hazardous. Furthermore, organic carbon and NaBr salt are not regulated by primary or secondary New York State groundwater standards. We are presently proposing to inject about 2 pounds of NaBr salt and 35 pounds of EOS amendment. The NaBr salt and EOS amendment dosages may be adjusted based on the observed subsurface response but will not exceed 10 and 350 pounds, respectively.

The New York State Department of Environmental Conservation (NYDEC) has provided guidance on the regulatory permits associated with soil and groundwater remediation activities in their Draft DER-10 Guidance (DER-10)[1]. The DER-10 indicates that remedial actions involving groundwater injection would require an underground injection permit, and that the standards,

---

[1] New York Department of Environmental Conservation, Division of Environmental Remediation, Draft DER-10 Technical Guidance for Site Investigation and Remediation. December 2002, pgs 99-103.

criteria and guidance for groundwater injection are promulgated through the 40 CFR Part 144 - Underground Injection Control (UIC) Program. In New York, this program is administrated by the U.S. EPA, Region 2 office.

We understand based on our review of the UIC guidance materials that an injection of a non-hazardous fluid into the shallow subsurface and groundwater, as proposed in the Pilot Test, would fall under the Class V - 5B category, "to be used for beneficial use in subsurface environmental remediation"[2]. The agency contact for Class V wells in New York is Robert Ferri, who is available at (212)-637-4227; ferri.robert@epa.gov; 290 Broadway, New York, NY 10007-1866.

The UIC guidance indicates that Class V wells are "authorized by rule". Therefore, class V wells may inject to the groundwater as long as:

- They do not endanger underground sources of drinking water; and

- Well owners or operators submit basic inventory information to the EPA.

The necessary steps to receive authorization by rule for injection to a Class V well would be to submit an inventory form (attached) to U.S. EPA Region 2 office. Included with the inventory form, we are providing specifications of the amendment(s) to be used in the Pilot Test to support that the injection media will not cause a violation of drinking water standards or adversely affect public health.

PJM/AHH:pjm

Encl.
Attachment 1 Injection Permit Inventory Form
Attachment 2 Injection Boring Construction Detail
Attachment 3 Carbon Amendment MSDS
Attachment 4 Sodium Bromide MSDS

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[2] http://www.epa.gov/safewater/uic/wells_drawings.html and 40CFR 144, page 40597.

**Type or print all information. See reverse for instructions.** **OMB No. 2040-0042** **Approval Expires 4/30/07**

# INVENTORY OF INJECTION WELLS

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF GROUND WATER AND DRINKING WATER

**(This information is collected under the authority of the Safe Drinking Water Act)**

**1. DATE PREPARED** *(Year, Month, Day)*
03-11-10

**2. FACILITY ID NUMBER**
NYSC704044

**PAPERWORK REDUCTION ACT NOTICE**

The public reporting burden for this collection of information is estimated at about 0.5 hour per response, including time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding the burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Chief, Information Policy Branch, 2136, U.S. Environmental Protection Agency, 401 M Street, SW, Washington, DC 20460, and to the Office of Management and Budget, Paperwork Reduction Project, Washington, DC 20503.

**3. TRANSACTION TYPE** *(Please mark one of the following)*

☐ Deletion ☑ First Time Entry
☐ Entry Change ☐ Replacement

## 4. FACILITY NAME AND LOCATION

**A. NAME** *(last, first, and middle initial*
IBM Gun Club - Former Burn Pit Area

**B. STREET ADDRESS/ROUTE NUMBER**
1395 Robinson Hill Road

**C. LATITUDE**

| DEG | MIN | SEC |
|---|---|---|
| 42 | 7 | 58.2744 |

**D. LONGITUDE**

| DEG | MIN | SEC |
|---|---|---|
| -76 | 0 | 21.3732 |

**E. TOWNSHIP/RANGE**

| TOWNSHIP | RANGE | SECT | 1/4 SECT |
|---|---|---|---|
| 126 | 18 | 1 | 20 |

**F. CITY/TOWN**
Union

**G. STATE**
NY

**H. ZIP CODE**
13760

**I. NUMERIC COUNTY CODE**
007

**J. INDIAN LAND** *(mark "x")* ☐ Yes ☒ No

## 5. LEGAL CONTACT:

**A. TYPE** *(mark "x")* ☒ Owner ☐ Operator

**B. NAME** *(last, first, and middle initial*
Mr. Kevin Whalen, IBM Coprporate Environmental Affairs

**C. PHONE** *(area code and number)*
(703) 257-2582

**D. ORGANIZATION**
IBM Corporate Environmental Affairs

**E. STREET/P.O. BOX**
8976 Wellington Road

**F. CITY/TOWN**
Manassas

**G. STATE**
VA

**H. ZIP CODE**
20109

**I. OWNERSHIP** *(mark "x")*

☒ PRIVATE ☐ PUBLIC ☐ SPECIFY OTHER
☐ STATE ☐ FEDERAL

## 6. WELL INFORMATION:

| A. CLASS AND TYPE | | B. NUMBER OF WELLS | | C. TOTAL NUMBER OF WELLS | D. WELL OPERATION STATUS | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | COMM | NON-COMM | | UC | AC | TA | PA | AN |
| V | B | | 9 | 9 | 9 | | | | |
| | | | | 0 | | | | | |
| | | | | 0 | | | | | |
| | | | | 0 | | | | | |
| | | | | 0 | | | | | |
| | | | | 0 | | | | | |
| | | | | 0 | | | | | |

**COMMENTS** *(Optional):*
Planned injection of a commercial edible soybean oil based amendment and a sodium bromide salt tracer. Please see attached injection amendment Material Safety Data Sheets (MSDS) and injection boring construction detail.

**KEY:**

DEG = Degree
MIN = Minute
SEC = Second

SECT = Section
1/4 SECT = Quarter Section

COMM = Commercial
NON-COMM = Non-Commercial

AC = Active
UC = Under Construction
TA = Temporarily Abandoned
PA = Permanently Abandoned and Approved by State
AN = Permanently Abandoned and not Approved by State

**EPA Form 7520-16 (Rev. 8-01)**

**SECTION 1. DATE PREPARED:** Enter date in order of year, month, and day.

**SECTION 2. FACILITY ID NUMBER:** In the first two spaces, insert the appropriate U.S. Postal Service State Code. In the third space, insert one of the following one letter alphabetic identifiers:

D - DUNS Number,
G - GSA Number, or
S - State Facility Number.

In the remaining spaces, insert the appropriate nine digit DUNS, GSA, or State Facility Number. For example, A Federal facility (GSA - 123456789) located in Virginia would be entered as : VAG123456789.

**SECTION 3. TRANSACTION TYPE:** Place an “x” in the applicable box. See below for further instructions.

**Deletion.** Fill in the Facility ID Number.
**First Time Entry.** Fill in all the appropriate information.
**Entry Change.** Fill in the Facility ID Number and the information that has changed.
**Replacement.**

**SECTION 4. FACILITY NAME AND LOCATION:**

**A.** **Name.** Fill in the facility’s official or legal name.
**B.** **Street Address.** Self Explanatory.
**C.** **Latitude.** Enter the facility’s latitude (all latitudes assume North Except for American Samoa).
**D.** **Longitude.** Enter the facility’s longitude (all longitudes assume West except Guam).
**E.** **Township/Range.** Fill in the complete township and range. The first 3 spaces are numerical and the fourth is a letter (N,S,E,W) specifying a compass direction. A township is North or South of the baseline, and a range is East or West of the principal meridian (e.g., 132N, 343W).
**F.** **City/Town.** Self Explanatory.
**G.** **State.** Insert the U.S. Postal Service State abbreviation.
**H.** **Zip Code.** Insert the five digit zip code plus any extension.

**SECTION 4. FACILITY NAME & LOCATION (CONT’D.):**

**I.** **Numeric County Code.** Insert the numeric county code from the Federal Information Processing Standards Publication (FIPS Pub 6-1) June 15, 1970, U.S. Department of Commerce, National Bureau of Standards. For Alaska, use the Census Division Code developed by the U.S. Census Bureau.
**J.** **Indian Land.** Mark an “x” in the appropriate box (Yes or No) to indicate if the facility is located on Indian land.

**SECTION 5. LEGAL CONTACT:**

**A.** **Type.** Mark an “x” in the appropriate box to indicate the type of legal contact (Owner or Operator). For wells operated by lease, the operator is the legal contact.
**B.** **Name.** Self Explanatory.
**C.** **Phone.** Self Explanatory.
**D.** **Organization.** If the legal contact is an individual, give the name of the business organization to expedite mail distribution.
**E.** **Street/P.O. Box.** Self Explanatory.
**F.** **City/Town.** Self Explanatory.
**G.** **State.** Insert the U.S. Postal Service State abbreviation.
**H.** **Zip Code.** Insert the five digit zip code plus any extension.
**I.** **Ownership.** Place an “x” in the appropriate box to indicate ownership status.

**SECTION 6. WELL INFORMATION:**

**A.** **Class and Type.** Fill in the Class and Type of injection wells located at the listed facility. Use the most pertinent code (specified below) to accurately describe each type of injection well. For example, 2R for a Class II Enhanced Recovery Well, or 3M for a Class III Solution Mining Well, etc.
**B.** **Number of Commercial and Non-Commercial Wells.** Enter the total number of commercial and non-commercial wells for each Class/Type, as applicable.
**C.** **Total Number of Wells.** Enter the total number of injection wells for each specified Class/Type.
**D.** **Well Operation Status.** Enter the number of wells for each Class/Type under each operation status (see key on other side).

---

**CLASS I** Industrial, Municipal, and Radioactive Waste Disposal Wells used to inject waste below the lowermost Underground Source of Drinking Water (USDW).

**TYPE** **1I** Non-Hazardous Industrial Disposal Well.
**1M** Non-Hazardous Municipal Disposal Well.
**1H** Hazardous Waste Disposal Well injecting below the lowermost USDW.
**1R** Radioactive Waste Disposal Well.
**1X** Other Class I Wells.

**CLASS II** Oil and Gas Production and Storage Related Injection Wells.

**TYPE** **2A** Annular Disposal Well.
**2D** Produced Fluid Disposal Well.
**2H** Hydrocarbon Storage Well.
**2R** Enhanced Recovery Well.
**2X** Other Class II Wells.

**CLASS III** Special Process Injection Wells.

**TYPE** **3G** *In Situ* Gassification Well
**3M** Solution Mining Well.

**CLASS III (CONT’D.)**

**TYPE** **3S** Sulfur Mining Well by Frasch Process.
**3T** Geothermal Well.
**3U** Uranium Mining Well.
**3X** Other Class III Wells.

**CLASS IV** Wells that inject hazardous waste into/above USDWs.

**TYPE** **4H** Hazardous Facility Injection Well.
**4R** Remediation Well at RCRA or CERCLA site.

**CLASS V** Any Underground Injection Well not included in Classes I through IV.

**TYPE** **5A** Industrial Well.
**5B** Beneficial Use Well.
**5C** Fluid Return Well.
**5D** Sewage Treatment Effluent Well.
**5E** Cesspools (non-domestic).
**5F** Septic Systems.
**5G** Experimental Technology Well.
**5H** Drainage Well.
**5I** Mine Backfill Well.
**5J** Waste Discharge Well.

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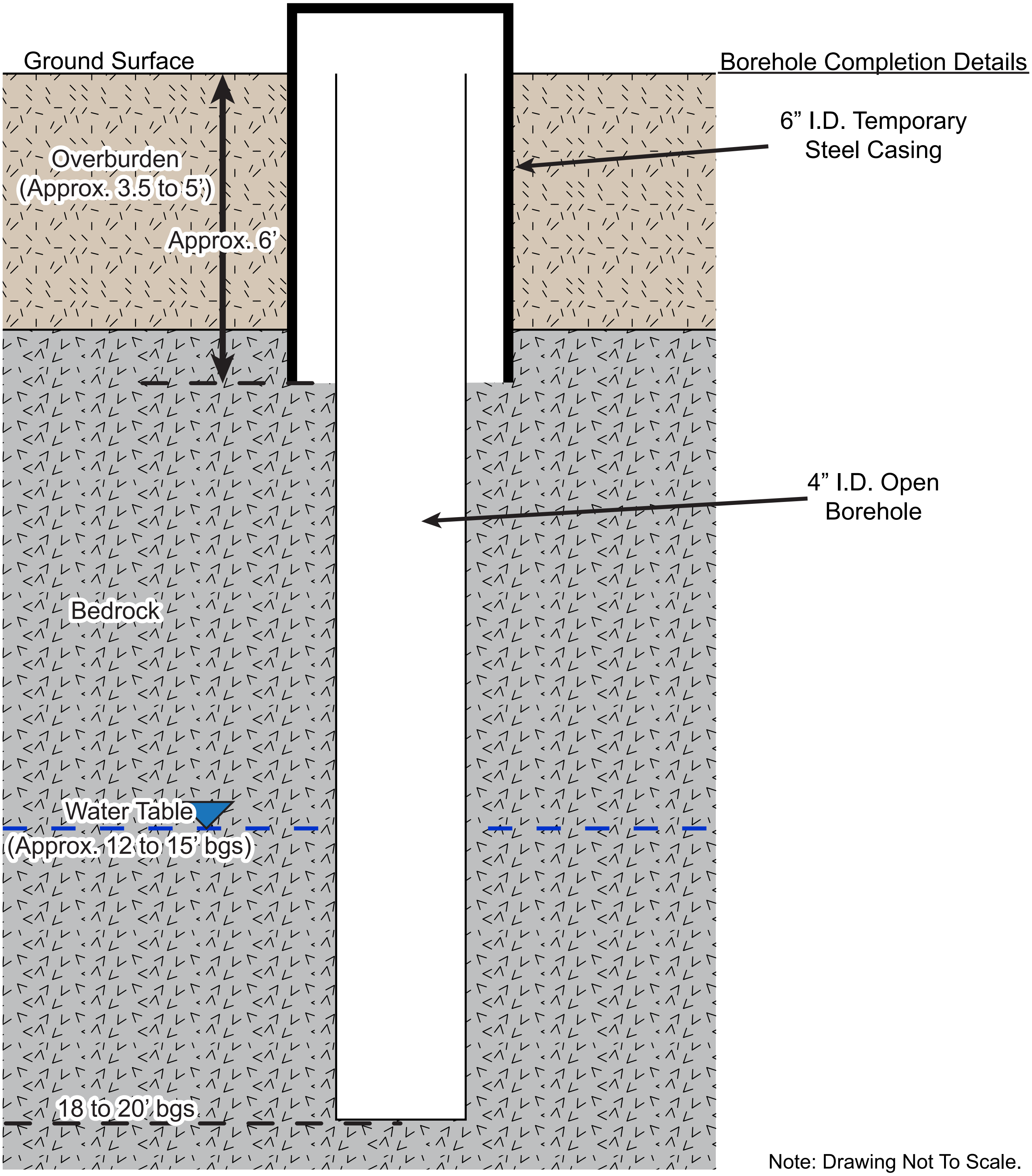

Note: Drawing Not To Scale.

S:\PORDATA\3000s\3025.00\Figures\February 2010\20100402_Fig3A_Injection_Boring_Completion.ai

SHPC
ENGINEERS

Drawn By: J. Prellwitz
Designed By: P. Mouser
Reviewed By: D. Carr
Date: April 2010

**Attachment 2**

## Injection Boring Completion
## Work Plan - Enhanced Bio Pilot Testing

**IBM Gun Club**
Union, New York

# MATERIAL SAFETY DATA SHEET

**EMULSIFIED EDIBLE OIL SUBSTRATE**

D.O.T. HAZARD CLASSIFICATION: NONE

| ----HMIS---- | |
|---|---|
| HEALTH | 1 |
| FLAMMABILITY | 0 |
| REACTIVITY | 0 |
| PERSONAL PROTECTION | B |

MANUFACTURER'S NAME

**EOS Remediation, Inc**
**1101 Nowell Road**
**Raleigh, NC 27607**
**www.EOSRemediation.com**

DATE OF PREPARATION
01-24-03, Rev. 04-19-05

INFORMATION TELEPHONE NO.
**919-873-2204**

## SECTION I - PRODUCT IDENTIFICATION

| | |
|---|---|
| PRODUCT NAME | **EOS®CONCENTRATE 598B 42** |
| PRODUCT CLASS | **VEGETABLE OIL BASED EMULSION** |
| CAS NUMBER | **MIXTURE** |

## SECTION II - HAZARDOUS INGREDIENTS

| COMPONENT(S) | EXPOSURE LIMIT |
|---|---|

**THIS PRODUCT IS A MIXTURE OF EDIBLE FOOD GRADE ADDITIVES AND CONTAINS NO HAZARDOUS INGREDIENTS.**

## SECTION III - PHYSICAL DATA

| | |
|---|---|
| BOILING POINT: | **212°F** |
| SPECIFIC GRAVITY: | **0.97; .92 (pure oil phase)** |
| VAPOR PRESSURE: | **NOT ESTABLISHED** |
| PERCENT VOLATILE BY VOLUME (%): | **24 (AS WATER)** |
| VAPOR DENSITY: | **HEAVIER THAN AIR** |
| EVAPORATION RATE: | **NOT ESTABLISHED** |
| SOLUBILITY IN WATER: | **SOLUBLE** |
| APPEARANCE AND ODOR: | **OFF WHITE LIQUID WITH VEGETABLE OIL ODOR** |

## SECTION IV - FIRE AND EXPLOSION HAZARD DATA

| | |
|---|---|
| FLASH POINT: | **>300°F** |
| FLAMMABLE LIMITS: | **NOT ESTABLISHED** |
| EXTINGUISHING MEDIA: | **$CO_2$, FOAM, DRY CHEMICAL**<br>**NOTE: WATER, FOG, AND FOAM MAY CAUSE FROTHING AND SPATTERING.** |
| UNUSUAL FIRE AND EXPLOSION HAZARDS: | **BURNING WILL CAUSE OXIDES OF CARBON.** |
| SPECIAL FIRE FIGHTING PROCEDURES: | **WEAR SELF CONTAINED BREATHING APPARATUS AND CHEMICAL RESISTANT CLOTHING. USE WATER SPRAY TO COOL FIRE EXPOSED CONTAINERS.** |

## SECTION V - PHYSICAL HAZARDS

| | |
|---|---|
| STABILITY: | **STABLE** |
| CONDITIONS TO AVOID: | **NONE** |
| INCOMPATIBILITY: | **STRONG ACIDS AND OXIDIZERS.** |
| HAZARDOUS DECOMPOSITION PRODUCTS: | **THERMAL DECOMPOSITION MAY PRODUCT OXIDES OF CARBON.** |
| HAZARDOUS POLYMERIZATION: | **WILL NOT OCCUR** |

## SECTION VI - HEALTH HAZARDS

SIGNS AND SYMPTOMS OF EXPOSURE:

1. Acute Overexposure - **NONE**
2. Chronic Overexposure - **NONE**

MEDICAL CONDITIONS GENERALLY AGGRAVATED BY EXPOSURE: **NONE KNOWN**

CHEMICAL LISTED AS CARCINOGEN OR POTENTIAL CARCINOGEN:
N.T.P. - **NO** I.A.R.C. - **NO** OSHA - **NO**

EMERGENCY AND FIRST AID PROCEDURES:

| | |
|---|---|
| 1.) Inhalation- | **REMOVE TO FRESH AIR.** |
| 2.) Eyes- | **FLUSH WITH WATER FOR 15 MINUTES, IF IRRITATION PERSISTS SEE PHYSICIAN.** |
| 3.) Skin- | **WASH WITH MILD SOAP AND WATER.** |
| 4.) Ingestion- | **PRODUCT IS NON-TOXIC. IF NAUSEA OCCURS, INDUCE VOMITING AND SEEK MEDICAL ATTENTION.** |

## SECTION VII - SPECIAL PROTECTION INFORMATION

| | |
|---|---|
| RESPIRATORY PROTECTION: | **NOT NORMALLY REQUIRED** |
| VENTILATION: | **LOCAL EXHAUST** |
| PROTECTIVE GLOVES: | **NOT NORMALLY REQUIRED** |
| EYE PROTECTION: | **NOT NORMALLY REQUIRED** |
| OTHER PROTECTIVE CLOTHING OR EQUIPMENT: | **NONE** |

## SECTION VIII - SPECIAL PRECAUTIONS AND SPILL/LEAK PROCEDURES

| | |
|---|---|
| PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: | **DO NOT STORE NEAR EXCESSIVE HEAT OR OXIDIZERS.** |
| OTHER PRECAUTIONS: | **NONE** |
| STEPS TO BE TAKEN IN CASE MATERIAL IS SPILLED: | **SOAK UP WITH DRY ABSORBENT AND FLUSH AREA WITH LARGE AMOUNTS OF WATER.** |
| WASTE DISPOSAL METHODS: | **DISPOSE OF ACCORDING TO FEDERAL, STATE, AND LOCAL REGULATIONS.** |

## SECTION IX - ADDITIONAL REGULATORY INFORMATION

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**

THIS PRODUCT DOES **NOT** CONTAIN SECTION 313 REPORTABLE INGREDIENTS.

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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.

# Material Safety Data Sheet
Sodium Bromide, Anhydrous, 99+%

ACC# 96487

## Section 1 - Chemical Product and Company Identification

**MSDS Name:** Sodium Bromide, Anhydrous, 99+%
**Catalog Numbers:** AC205130000, AC205130010, AC205131000, AC2051325
**Synonyms:** None.
**Company Identification:**

Acros Organics N.V.
One Reagent Lane
Fair Lawn, NJ 07410

**For information in North America, call:** 800-ACROS-01
**For emergencies in the US, call CHEMTREC:** 800-424-9300

## Section 2 - Composition, Information on Ingredients

| CAS# | Chemical Name | Percent | EINECS/ELINCS |
|---|---|---|---|
| 7647-15-6 | SODIUM BROMIDE | >99 | 231-599-9 |

**Hazard Symbols:** None listed.
**Risk Phrases:** None listed.

## Section 3 - Hazards Identification

### EMERGENCY OVERVIEW

Appearance: white solid. **Caution!** May cause eye and skin irritation. May cause respiratory and digestive tract irritation. May cause central nervous system depression. May cause fetal effects based upon animal studies. Hygroscopic.
**Target Organs:** Central nervous system.

**Potential Health Effects**
**Eye:** May cause eye irritation.
**Skin:** May cause skin irritation.
**Ingestion:** May cause central nervous system depression, characterized by excitement, followed by headache, dizziness, drowsiness, and nausea. Advanced stages may cause collapse, unconsciousness, coma and possible death due to respiratory failure. Advanced stages may cause collapse, unconsciousness, coma and possible death due to respiratory failure.�������������������������������������
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**Inhalation:** May cause respiratory tract irritation. May cause effects similar to those described for ingestion.
**Chronic:** May cause fetal effects. Chronic ingestion may cause bromism characterized by disturbances of the central nervous system, skin and digestive tract. May cause incoordination and mental disturbances.

## Section 4 - First Aid Measures

**Eyes:** Immediately flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids. Get medical aid.
**Skin:** Get medical aid. Flush skin with plenty of soap and water for at least 15 minutes while removing contaminated clothing and shoes. Wash clothing before reuse.
**Ingestion:** If victim is conscious and alert, give 2-4 cupfuls of milk or water. Never give anything by mouth to an unconscious person. Get medical aid immediately.
**Inhalation:** Remove from exposure to fresh air immediately. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical aid.
**Notes to Physician:** Treatment includes hydration, mild diuresis, and possible hemodialysis. Consider the use of ammonium chloride in divided doses with a diuretic.

## Section 5 - Fire Fighting Measures

**General Information:** As in any fire, wear a self-contained breathing apparatus in pressure-demand, MSHA/NIOSH (approved or equivalent), and full protective gear. During a fire, irritating and highly toxic gases may be generated by thermal decomposition or combustion.

**Extinguishing Media:** Use extinguishing media most appropriate for the surrounding fire. Use water spray, dry chemical, carbon dioxide, or appropriate foam.
**Flash Point:** Not applicable.
**Autoignition Temperature:** Not available.
**Explosion Limits, Lower:**N/A
**Upper:** N/A
**NFPA Rating:** Not published.

## Section 6 - Accidental Release Measures

**General Information:** Use proper personal protective equipment as indicated in Section 8.
**Spills/Leaks:** Sweep up, then place into a suitable container for disposal. Avoid generating dusty conditions. Provide ventilation.

## Section 7 - Handling and Storage

**Handling:** Wash thoroughly after handling. Remove contaminated clothing and wash before reuse. Use with adequate ventilation. Avoid contact with eyes. Do not ingest or inhale.
**Storage:** Store in a cool, dry place. Store in a tightly closed container. Store protected from moisture.

## Section 8 - Exposure Controls, Personal Protection

**Engineering Controls:** Use adequate general or local exhaust ventilation to keep airborne concentrations below the permissible exposure limits.
**Exposure Limits**

| Chemical Name | ACGIH | NIOSH | OSHA - Final PELs |
|---|---|---|---|
| SODIUM BROMIDE | none listed | none listed | none listed |

**OSHA Vacated PELs:** SODIUM BROMIDE: No OSHA Vacated PELs are listed for this chemical.
**Personal Protective Equipment**
**Eyes:** Wear appropriate protective eyeglasses or chemical safety goggles as described by OSHA's eye and face protection regulations in 29 CFR 1910.133 or European Standard EN166.
**Skin:** Wear appropriate gloves to prevent skin exposure.
**Clothing:** Wear appropriate protective clothing to minimize contact with skin.
**Respirators:** Follow the OSHA respirator regulations found in 29 CFR 1910.134 or European Standard EN 149. Always use a NIOSH or European Standard EN 149 approved respirator when necessary.

## Section 9 - Physical and Chemical Properties

**Physical State:** Solid
**Appearance:** white
**Odor:** not available
**pH:** Not available.
**Vapor Pressure:** Not applicable.
**Vapor Density:** Not available.
**Evaporation Rate:**Not applicable.
**Viscosity:** Not available.
**Boiling Point:** 1390 deg C @ 760.00mm Hg
**Freezing/Melting Point:**755 deg C
**Decomposition Temperature:**800 deg C
**Solubility:** 95g/100 ml water (25 c)
**Specific Gravity/Density:**3.208
**Molecular Formula:**BrNa
**Molecular Weight:**102.89

## Section 10 - Stability and Reactivity

**Chemical Stability:** Stable under normal temperatures and pressures.
**Conditions to Avoid:** Incompatible materials, moisture.
**Incompatibilities with Other Materials:** Strong oxidizing agents, strong acids.
**Hazardous Decomposition Products:** Irritating and toxic fumes and gases, hydrogen bromide.
**Hazardous Polymerization:** Has not been reported.

## Section 11 - Toxicological Information

**RTECS#:**
**CAS#** 7647-15-6: VZ3150000
**LD50/LC50:**
Not available.

**Carcinogenicity:**
CAS# 7647-15-6: Not listed by ACGIH, IARC, NIOSH, NTP, or OSHA.
**Epidemiology:** No information available.
**Teratogenicity:** No information available.
**Reproductive Effects:** No information available.
**Neurotoxicity:** No information available.
**Mutagenicity:** No information available.
**Other Studies:** No data available.

## Section 12 - Ecological Information

No information available.

## Section 13 - Disposal Considerations

Chemical waste generators must determine whether a discarded chemical is classified as a hazardous waste. US EPA guidelines for the classification determination are listed in 40 CFR Parts 261.3. Additionally, waste generators must consult state and local hazardous waste regulations to ensure complete and accurate classification.
**RCRA P-Series:** None listed.
**RCRA U-Series:** None listed.

## Section 14 - Transport Information

| | US DOT | IATA | RID/ADR | IMO | Canada TDG |
|---|---|---|---|---|---|
| **Shipping Name:** | No information available. | | | | No information available. |
| **Hazard Class:** | | | | | |
| **UN Number:** | | | | | |
| **Packing Group:** | | | | | |

## Section 15 - Regulatory Information

### US FEDERAL

**TSCA**
CAS# 7647-15-6 is listed on the TSCA inventory.
**Health & Safety Reporting List**
None of the chemicals are on the Health & Safety Reporting List.
**Chemical Test Rules**
None of the chemicals in this product are under a Chemical Test Rule.
**Section 12b**
None of the chemicals are listed under TSCA Section 12b.
**TSCA Significant New Use Rule**
None of the chemicals in this material have a SNUR under TSCA.
**SARA**

**CERCLA Hazardous Substances and corresponding RQs**
None of the chemicals in this material have an RQ.
**SARA Section 302 Extremely Hazardous Substances**
None of the chemicals in this product have a TPQ.
**Section 313**
No chemicals are reportable under Section 313.
**Clean Air Act:**
This material does not contain any hazardous air pollutants. This material does not contain any Class 1 Ozone depletors. This material does not contain any Class 2 Ozone depletors.
**Clean Water Act:**
None of the chemicals in this product are listed as Hazardous Substances under the CWA. None of the chemicals in this product are listed as Priority Pollutants under the CWA. None of the chemicals in this product are listed as Toxic Pollutants under the CWA.
**OSHA:**

None of the chemicals in this product are considered highly hazardous by OSHA.

**STATE**

CAS# 7647-15-6 is not present on state lists from CA, PA, MN, MA, FL, or NJ.
California No Significant Risk Level: None of the chemicals in this product are listed.

### European/International Regulations

**European Labeling in Accordance with EC Directives**

**Hazard Symbols:**

Not available.

**Risk Phrases:**

**Safety Phrases:**

S 24/25 Avoid contact with skin and eyes.

**WGK (Water Danger/Protection)**

CAS# 7647-15-6: 1

**Canada - DSL/NDSL**

CAS# 7647-15-6 is listed on Canada's DSL List.

**Canada - WHMIS**

WHMIS: Not available.

**Canadian Ingredient Disclosure List**

CAS# 7647-15-6 is listed on the Canadian Ingredient Disclosure List.

**Exposure Limits**

## Section 16 - Additional Information

**MSDS Creation Date:** 3/06/1998
**Revision #1 Date:** 8/02/2000

*The information above is believed to be accurate and represents the best information currently available to us. However, we make no warranty of merchantability or any other warranty, express or implied, with respect to such information, and we assume no liability resulting from its use. Users should make their own investigations to determine the suitability of the information for their particular purposes. In no event shall Fisher be liable for any claims, losses, or damages of any third party or for lost profits or any special, indirect, incidental, consequential or exemplary damages, howsoever arising, even if Fisher has been advised of the possibility of such damages.*

# APPENDIX F

# RI WORK PLAN – PROPOSED SCHEDULE OF QUALITY CONTROL ELEMENTS

SHPC ENGINEERS

# Attachment F
# Proposed Schedule of Quality Control Elements

RI Work Plan – Former Burn Pit Area
IBM Gun Club, Union, New York

| Quality Control Element | Description | Frequency | Purpose | Synonyms |
|---|---|---|---|---|
| **Sampling:** | | | | |
| Duplicate Samples | Two or more co-located samples collected simultaneously. | At least one set of duplicate samples per day of sampling or a minimum of one duplicate per ten samples (10 % frequency). | To improve confidence in measured concentrations and to evaluate representativeness. | Collocated samples<br>Parallel samples |
| Trip Blank | Unused laboratory certified clean VOA vial containing VOA-free water or methanol (depending on how samples are collected) that accompanies VOA containers to field and samples back to laboratory. | One trip blank per sample cooler for VOA analysis – only. | To assess for the presence of target compounds that could be due to ambient field conditions, or sample container transportation to and from the field. | Field Blank<br>Blank |
| Atmospheric Blank | Unused laboratory certified clean sampling container (i.e. VOA vial) that is opened in the field and then closed. | One atmospheric blank per day. | To assess for the presence of target compounds that could be due to ambient field conditions. | Field Blank |
| Equipment Blank | Metals: Distilled deionized water applied to non-dedicated equipment in the field following field decontamination procedures. VOA: VOA-free water applied to decontaminated field equipment. | At least one equipment blank per day, or one per 20 samples. Separate VOA and metals equipment blanks needed. | To assess for the presence of target compounds that could be due to carry over from non-dedicated sampling equipment. | Field Equipment Blank<br>Rinseate Blank |
| **Analysis:** | | | | |
| Method Blank | Analyte-free matrix analyzed like samples. | One per analytical batch, up to 20 field samples of same matrix. | To assess contamination from sample recovery. | Blank |
| Surrogates | Compounds similar to compounds of interest, but not normally found in nature. | Every sample including QC for organic analyses. | To assess accuracy of preparation and analysis. | Recovery Standards |
| Lab Control Sample (LCS) | Aliquot of analyte-free matrix spiked with compounds of interest and analyzed like samples. | One LCS per analytical batch. | To assess accuracy and precision of analyses in the absence of the site matrix. | Laboratory Fortified Blank (LFB) or Blank Spike (BS/BSD) |
| Matrix Spike (MS) and Matrix Spike Duplicate (MSD) | Aliquots of field samples spiked with compounds of interest and analyzed like samples. | One MS/MSD pair per analytical batch for organic analyses. | To assess accuracy and precision of analyses relative to matrix. | Laboratory Fortified Matrix (LFM) |
| Matrix Spike (MS) and Matrix Duplicate (MD) | Aliquots of field samples. One sample is spiked with compounds of interest and analyzed while the other aliquot is only analyzed like samples. | One MS/MD pair per analytical batch for inorganic analyses. | To assess accuracy and precision of analyses relative to matrix. | Laboratory Fortified Matrix (LFM),<br>Duplicate (Dup) |

Note: This table is intended to specify the type and minimum frequency of quality control elements proposed for soil, weathered bedrock, and groundwater sampling to be performed as part of Remedial Investigation activities in the former Burn Pit area of the IBM Gun Club site in Union, New York. As outlined in Section 5.3, the frequency of quality control samples such as duplicates and field blanks may be increased if warranted based on the observed results of initial testing.