ARCADIS BBL

Infrastructure, environment, facilities

Imagine the result

Chevron Environmental Management Company

Pre-Design Groundwater Investigation Work Plan

Former Tappan Terminal Site
Hastings-on-Hudson, New York

November 2007

Figures

Appendices

Acronyms

COC	constituent of concern
COD	chemical oxygen demand
CSIA	Compound-Specific Stable Isotope Analysis
DNAPL	dense nonaqueous-phase liquid
DO	dissolved oxygen
ISCO	in-situ chemical oxidation
µg/L	micrograms per liter
mg/L	milligrams per liter
mL/min	milliliters per minute
MNA	monitored natural attenuation
MPS	Multiprobe System
NOD	natural oxygen demand
NYSDEC	New York State Department of Environmental Conservation
ORP	oxidation-reduction potential
Panther	Panther Technologies, Inc.
PDI	Predesign Investigation
ppm	parts per million
QAPP	Quality Assurance Project Plan

RAWP	Remedial Action Work Plan
RDWP	Remedial Design Work Plan
ROD	Record of Decision
SIP	Stable Isotope Probing
site	Tappan Terminal Site (3-60-015), Hastings-on-Hudson, Westchester County, New York
SOP	Standard Operating Procedure
SVOC	semivolatile organic compound
TIC	tentatively identified compound
TOD	total oxygen demand
VOC	volatile organic compound
work plan	*Predesign Groundwater Investigation Work Plan*
12C	carbon 12
13C	carbon 13

1. Introduction

1.1 General

This *Predesign Groundwater Investigation Work Plan* (work plan) has been developed for the Tappan Terminal Site (3-60-015) located in the village of Hastings-on-Hudson, Westchester County, New York (site).

1.2 Purpose and Scope

The purpose of this work plan is to detail the predesign investigations (PDIs) and remedial technology assessment activities that will support the development of a Remedial Design Work Plan (RDWP). The RDWP will present the selected remedy that is capable of meeting the remedial objectives for site-wide groundwater consistent with the Record of Decision (ROD) issued for this site by the New York State Department of Environmental Conservation (NYSDEC) (NYSDEC, 2006).

1.3 Report Organization

- *Section 1* — The remaining subsections of Section 1 describe the site, the Site Conceptual Model and objectives of the remedial design for the site.
- *Section 2* — Describes Phase I of the PDI, including the monitoring well program and dense nonaqueous phase liquid (DNAPL) assessment, and characterizing the source area.
- *Section 3* — Describes Phase II of the PDI, which includes evaluating in-situ chemical oxidation for treatment of the source area, enhanced bioremediation technologies for treatment of the source area and/or downgradient plume, monitored natural attenuation (MNA) and phytoremediation.
- *Section 4* — Identifies how the results of Phase I and Phase II of the PDI will be reported.
- *Section 5* — Provides the schedule for conducting Phase I and Phase II of the PDI activities.
- *Section 6* — Lists the references.

1.4 Site Description

The site is located on 7.7 acres along the Hudson River waterfront in the village of Hastings-on-Hudson, Westchester County, New York. The former Tappan Terminal is located adjacent to the Hudson River; the Uhlich Color Company (which is located along the railroad tracks) defines the eastern boundary of the site. A small portion of the southern end of the property is leased to the Pioneer Boat Club for use as a marina. Figure 1 shows the location of the site. Limited access to the site is from Railroad Avenue at the southeast corner of the site and over the Zinsser Bridge that crosses the railroad tracks. Both the former Tappan Terminal and Uhlich Color Company Site are surrounded by a chain-link fence. This bridge has fallen into disrepair and is no longer open to vehicular traffic.

In 1961, the Tappan Tanker Terminal purchased the western section of the property and began operating a petroleum distribution facility. In 1975, Mobil Oil Company purchased the terminal and continued operations until 1985. The Uhlich Color Company was recently acquired by Magruder Color Company, and has discontinued operations at the Hastings-on-Hudson property.

The site is adjacent to the Harbor-at-Hastings Site, a Class 2 inactive hazardous waste disposal site that is contaminated with polychlorinated biphenyls, metals and polycyclic aromatic hydrocarbons.

1.4.1 Source Area

The source of chlorobenzene was a former storage tank located near monitoring well MW-D1. Releases from the chlorobenzene tank migrated through the subsurface and along the former sanitary sewer link backfill material. The dissolved-phase chlorobenzene plume extends along the sanitary sewer line to the northwest and from the source area toward the Hudson River. Several semivolatile organic compounds (SVOCs) have also been detected within the chlorobenzene plume; the source of the SVOCs has not been identified.

1.4.1.1 Constituents of Concern

1.4.1.1.1 Volatile Organic Compounds

In October 2006, chlorobenzene was detected at concentrations ranging from approximately 2 micrograms per liter (µg/L) in monitoring well OW-27A to 8,100 µg/L in monitoring well OW-12. Benzene was detected at concentrations ranging from 1.4 µg/L

in monitoring well MW-13 to 130 µg/L in monitoring well MW-15. The NYSDEC Ambient Water Quality Standard and Guidance Values for chlorobenzene and benzene are 5 µg/L and 1 µg/L, respectively (NYSDEC, 1998).

1.4.1.1.2 SVOCs

Several SVOCs, including naphthalene, chlorophenol, 4-chloroaniline and 1-4 dichlorobenzene have been detected in groundwater above the Ambient Water Quality Standard and Guidance Values (NYSDEC, 1998). Naphthalene was detected at concentrations ranging from 1 µg/L in MW-10, GW-2 and GW-4 to 70 µg/L in MW-13 (Ambient Water Quality Standard and Guidance Value is 10 µg/L). 2-Chlorophenol was detected at concentrations ranging from 1.9 µg/L in MW-10 to 61 µg/L in LMS-2 (Ambient Water Quality Standard and Guidance Value is 1 µg/L). 4-Chloroaniline was detected at concentrations ranging from 2 µg/L in OW-17 to 25 µg/L in MW-9A (Ambient Water Quality Standard and Guidance Value is 5 µg/L). 1-4 Dichlorobenzene was detected at concentrations of 1.1 µg/L in MW-12 to 170 µg/L in MW-15.

1.5 Remedial Objectives

The remedial objectives for groundwater as defined in the ROD (NYSDEC, 2006) are to:

- prevent ingestion of and direct contact with contaminated soil.
- prevent ingestion of groundwater with contaminant levels exceeding drinking water standards.
- prevent inhalation of volatile organic compounds (VOCs) from contaminated soil and groundwater.
- treat the source of groundwater contamination.
- prevent the discharge of contaminants to the Hudson River.
- to the extent practicable, attain NYSDEC Class Ambient Water Quality Standard and Guidance Values for constituents of concern (COCs) in groundwater and soil cleanup guidelines that are protective of human health and groundwater quality.

2. Phase I Predesign Investigation

2.1 General

Phase I PDI activities will include further characterizing the source area, augmenting the existing monitoring well network, developing additional water quality data required to support the remedial technology assessment program and conducting DNAPL assessments. Information collected during the Phase I PDI will be used to support Phase II of the PDI. However, to the extent practicable, Phase II activities will be initiated as early as possible to minimize the overall PDI schedule. Field activities will be completed in accordance with the *Health and Safety Plan* provided in Appendix A.

2.2 Source Characterization

The source of the chlorobenzene plume observed in groundwater at this site appears to have resulted from the release of chlorobenzene from a former aboveground storage tank. The location and orientation of the observed chlorobenzene plume suggest that the elongated source area is a result of chlorobenzene migration through the subsurface from the former AST to the north along the bedding of a sanitary sewer line (which acted as a preferential pathway).

To further characterize the chlorobenzene source area, a series of test pits and soil borings will be advanced in the source area along the sanitary sewer line that runs along the boundary between the Uhlich and ExxonMobil properties. The test pit and soil boring investigations are discussed in this subsection.

Approximately six test pits will be installed along the sanitary sewer line (Figure 2) to determine if any of the sanitary sewer is remaining, to visually characterize the soils in the source area and to collect soil samples for the treatability studies. The test pits will be excavated using a backhoe and will measure a minimum of 10 feet long, extending to the base of the sanitary sewer fill or up to 8 feet below ground surface. Up to five soil samples will be collected from each of the test pits and submitted for analysis of VOCs, ferrous iron and total organic carbon. The Standard Operating Procedure (SOP) for excavating test pits is provided in Appendix B.

Approximately six soil borings will be drilling along the sanitary sewer line (Figure 3) to vertically delineate the chlorobenzene source area. Soil samples will be collected continuously for visual classification and NAPL screening from the ground surface to the bottom of each boring. The soil borings will be advanced to the top of the marine

silt confining unit. Groundwater samples will be collected every 5 feet below the water table and at the base of the fill unit through a stainless steel well screen. Groundwater samples will be collected using a peristaltic pump after purging the well screen for a minimum of 15 minutes at a flow rate of 100 milliliters per minute (mL/min). Field parameters include pH, dissolved oxygen (DO) and oxidation-reduction potential (ORP), and will be measured using a flow-through cell prior to collecting groundwater samples. Groundwater samples will be submitted for VOC analysis according to the *Quality Assurance Project Plan* (QAPP) (Appendix D). The SOPs for groundwater sampling and drilling of soil borings are provided in Appendix B.

2.3 Additional Monitoring Wells

Seventeen additional monitoring wells will be installed as part of the PDI. These wells will be used to augment the existing monitoring network and to facilitate the pilot testing programs to be implemented during Phase II of the PDI. The monitoring wells will be constructed using 2-inch-diameter, Schedule 40, machine-slotted polyvinyl chloride; the well screen length will vary depending on the purpose of the monitoring well. If evidence of DNAPL is observed during installation, a 2-foot sump will be added to the monitoring well construction and the well construction material may be changed to stainless steel.

During monitoring well installation, soil samples will be collected continuously for visual classification using split-spoon sampling methods or Geoprobe® methods from ground surface to the bottom of each boring. A photo ionization detector will be used to obtain headspace readings of each sample interval, and to provide health and safety monitoring for field personnel during the drilling program. After installation of the monitoring well is complete, the monitoring well will be developed. The SOPs for monitoring well installation and monitoring well development are provided in Appendix B. The purpose, location and additional monitoring well construction details are provided in Sections 2.3.1, 2.3.2 and 2.3.3.

2.3.1 Downgradient Monitoring Wells

Three additional water-table monitoring wells will be installed to define the extent of the dissolved-phase chlorobenzene plume. The monitoring wells will be constructed with a 10-foot-long well screen, with approximately 3 feet of well screen above the water table in the following locations:

- One water-table monitoring well will be installed downgradient of LMS-2 as a replacement to grab groundwater sample GW-2.
- One water-table monitoring well will be installed downgradient of OW-27A to define the extent of the chlorobenzene plume.
- One replacement monitoring well will be installed in the area of OW-16.

2.3.2 DNAPL Assessment Monitoring Wells

Two monitoring wells will be installed at the base of the overburden unit, above the marine silt confining unit for DNAPL monitoring. The monitoring wells will be installed in the source area near OW-12 and will be constructed using a 10-foot-long well screen with 2-foot sump. DNAPL assessment monitoring wells may be constructed using stainless steel based on field observations. In addition, one soil boring will be advanced to the base of the fill unit at the location of the chlorobenzene tank. The DNAPL assessment wells will be installed after the test pits have been excavated, the vertical profiling of groundwater has been completed, and the pilot test monitoring wells have been installed. The location of the DNAPL assessment monitoring wells may be changed based on observations during the subsurface investigations.

2.3.3 Pilot Test Monitoring Wells

Twelve monitoring wells will be installed to facilitate the pilot testing as discussed in Section 3.3.3. The monitoring wells will be constructed using 20-foot-long well screens and will be installed at the base of the overburden unit.

2.4 Groundwater Sampling

Groundwater samples will be collected from the proposed and pilot test monitoring wells, in addition to select existing monitoring wells. Groundwater samples will be collected to define the chlorobenzene and SVOC plumes, and to provide information for evaluation of MNA. Groundwater sampling locations are provided in Table 1 and on Figure 3.

Groundwater samples will be collected using low-flow sampling procedures until the field parameters (pH, DO, conductivity, temperature, turbidity, salinity and ORP) have stabilized. The SOP for groundwater sampling is provided in Appendix B.

2.5 DNAPL Assessment

During the subsurface investigation, soils encountered during the subsurface investigation will be screened for DNAPL using a black light and/or soil-water shake test using Oil Red O or Sudan IV powder. If DNAPL is observed during drilling of a soil boring, the soil boring will be converted into a monitoring well with a 2-foot sump. If DNAPL is observed during installation of a monitoring well, a 2-foot DNAPL sump will be installed and the well construction materials will be reviewed and well may be constructed using stainless steel. If DNAPL is observed during excavation of the test pits, one monitoring well will be installed near the test pit and will screen the interval where DNAPL was observed. Additional monitoring wells may be installed downgradient of the observed DNAPL, if practical. One soil boring will be drilling to the base of the fill unit at the location of the former chlorobenzene storage tank. The DNAPL Contingency Plan is included in Appendix C.

2.6 Waste Management

Waste generated during the source characterization will include drill cuttings, purge water and decontamination water. Drill cuttings that are grossly contaminated will be drummed at and transported to an approved off-site disposal facility. Drill cuttings that are not grossly contaminated will be returned to ground surface in the area of the monitoring well or soil boring, or returned to the test pits. Purge and decontamination water will be transported to an approved off-site disposal facility.

3. Phase II Predesign Investigation

3.1 General

Phase II PDI activities will include assessment of remedial technologies, including air sparging/soil vapor extraction (AS/SVE), in-situ chemical oxidation (ISCO), enhanced in-situ bioremediation, MNA and phytoremediation. Results of these assessments will be used to select the groundwater remedy demonstrated to be technically appropriate and capable of achieving the remedial objectives. The selected remedy will then be proposed, along with a demonstration of its potential effectiveness, in the Remedial Action Work Plan (RAWP) for NYSDEC approval.

3.2 Air Sparging/Soil Vapor Extraction (AS/SVE)

AS/SVE was identified in the ROD as part of the NYSDEC's selected remedy for the site. The AS/SVE was expected to effectively remove VOCs from soil and groundwater beneath the site. The SVE component was also anticipated to promote biodegradation of some SVOCs by introducing oxygen into the subsurface. However, subsurface site conditions and the results of the feasibility study conducted at the site indicate that AS/SVE may not be as effective a remedy as other technologies. Therefore, other treatment technologies (i.e., ISCO, enhanced in-situ bioremediation, MNA, and phytoremediation) are also being evaluated during the pre-design investigation. Information obtained from the evaluation of these other treatment technologies (described below) will also be used to further evaluate the potential application of AS/SVE at the site to treat groundwater and soil. The information used for evaluation purposes may include, but is not limited to, the subsurface physical and chemical properties and the existing microbial population.

The evaluation will consider the potential use of AS/SVE as a remedial treatment of the source area and/or the downgradient plume.

3.3 In-Situ Chemical Oxidation Technology

Chemical oxidation uses highly reactive chemicals, including hydrogen peroxide, sodium persulfate and ozone or sodium/potassium permanganate to chemically mineralize COCs upon contact. COCs are broken down upon contact with oxidants to innocuous byproducts, including carbon dioxide, water and salts. In the process of selecting the most appropriate oxidant and developing an approach and design for implementation, it is necessary to confirm several technical aspects of the ISCO

approach. These technical aspects are best evaluated in bench-scale testing during which natural oxygen demand (NOD) and total (natural and chemical) oxygen demand (TOD) of different chemistries and dosages are completed. Panther Technologies, Inc. (Panther) will conduct bench-scale testing to evaluate the potential use of ISCO technology as a remedial alternative for the source area.

Sodium persulfate will be the oxidant evaluated in the ISCO bench-scale test due to the historical concentrations of chlorobenzene at the site. Based on Panther's field experience and oxidation chemistry, sodium persulfate is anticipated to be the most effective oxidant for the treatment of chlorobenzene (the primary COC at the site). Permanganates are not appropriate for chlorobenzene, as they are not capable of mineralizing benzene. Fenton's or "Fenton's-like" chemistry would be effective; however, the reaction of kinetics make it a poor choice in terms of efficiency (i.e., quantity of oxidant required), as it is typically consumed by natural oxidant demand factors, as well as COCs, before it can migrate very far from the introduction point. Hydrogen peroxide itself can produce exothermic reactions, off-gassing, and potential ground heaving. All of which can be a problem from a health and safety standpoint, as well as general site safety.

If bench-scale test results indicate that chemical oxidation is the most effective technology for remediation of the chlorobenzene source area, any pilot testing required to refine the full-scale application will be incorporated into the overall remedial plan proposed in the RAWP and implemented during full-scale implementation of the ISCO approach.

Depending on the oxidant recipe, there could be a number of mechanisms that mineralize chlorobenzene, but generally it is an aggressive oxidation reaction that completely mineralizes chlorobenzene to carbon dioxide and water. As part of the bench scale test, the pre-and post-treatment VOCs will be reviewed to determine if there are any intermediates remaining.

3.3.1 Collection of Representative Source Materials

Soil and groundwater samples will be collected from the source area for use in the bench-scale study. Soil cores will be collected from soil borings near existing well OW-12 in accordance with the soil boring installation SOP (Appendix B). These soil cores will be collected during the Phase I activities discussed in Section 2 of this work plan. Three 4-foot macrocores (or equivalent) will be sealed with beeswax at both ends, kept cold and delivered to the Panther Facility located in Medford, New Jersey. Three

gallons of groundwater from existing well OW-12 will also be sent to Panther for testing in 1-gallon glass containers with no headspace.

3.3.2 Bench-Scale Testing Procedures

As part of any chemical oxidation project, one of the first elements and often a driver from a cost, timing and chemical usage perspective is the determination of NOD. The NOD must be overcome during implementation for the ISCO approach to effectively destroy the COCs. NOD testing will be performed on site soils so natural oxidation "sinks" present in native soil from a given site are quantified and accounted for. These sinks exist in the form of natural organic matter and/or transitional metals that may be oxidized before the COCs. Inaccurate assessment of NOD often results in under dosing, which in turn results in desired results not being realized. NOD will be evaluated prior to commencing the bench-scale test in development of the calculated TOD required to achieve the goals of mass reduction. Initially, NOD testing will be completed on one homogenized soil sample and one groundwater sample.

After completing baseline VOC and SVOC analysis of site soils and groundwater from the Phase I PDI, and upon determining the NOD, the oxidant sodium persulfate will be tested in the site soil/water matrix. Generally, for environmental applications sodium persulfate needs to be activated to be an effective oxidant. Sodium persulfate can be activated in alkaline conditions (i.e., low pH); with chelated metal catalysts (e.g., Fe (III)- EDTA) [Iron]); and in a dual oxidant system (e.g., hydrogen peroxide). Therefore, the bench-scale testing will include evaluating the activation of sodium persulfate using these different methods (i.e., pH, iron, and hydrogen peroxide). The sodium persulfate and activation combinations will be referred to as recipes in the following discussion of the bench-scale test.

The control will be used to quantify any loss of volatiles through sample handling. Two dosages (low-high dose) of up to three different oxidant recipes will be evaluated as part of the bench-scale testing. Each recipe will be tested for effectiveness by analyzing the treated soil and groundwater for VOCs and SVOCs after 10 days of reaction time. As a measure of the efficacy of the various mixtures tested, samples will be analyzed for VOCs and SVOCs, and compared to the baseline and control VOC and SVOC results. All VOC and SVOC samples will be analyzed by TestAmerica.

The table below summarizes the tests that will be run as part of the bench-scale study.

Tests	Matrix	Persulfate NOD	Day 0 VOCs	Day 10 VOCs
1. Baseline	Soil/GW	X	X	-
2. Control	Soil/GW	-	X	X
2a. pH activation (low)	Soil/GW	-	-	X
2b. pH activation(high)	Soil/GW	-	-	X
3a. H_2O_2 activation (low)	Soil/GW	-	-	X
3b. H_2O_2 activation (high)	Soil/GW	-	-	X
4a. Iron activation (low)	Soil/GW	-	-	X
4b. Iron activation (high)	Soil/GW	-	-	X

3.3.3 Evaluation

Results of the bench-scale study will be evaluated by comparing the baseline and post-treatment analytical results. The results will be used to select the remedial measure and ISCO recipe, and to provide supporting data for full-scale implementation. In addition, the bench-scale study results will be used for evaluating each oxidant recipe's potential to affect NAPL mobilization.

3.4 Enhanced In-Situ Bioremediation Technologies

In-situ groundwater bioremediation processes rely on naturally occurring microorganisms that are stimulated through the control of environmental factors to reduce COC concentrations in groundwater. These soil bacteria use COCs as a source of carbon for biomass production and energy. Enhanced aerobic processes typically involve supplementing terminal electron acceptors such as DO and, where necessary, other essential nutrients in groundwater to enhance natural attenuation of the COCs. The following diagram illustrates the aerobic degradation pathway of chlorobenzene (Nishino Et Al, 1992).

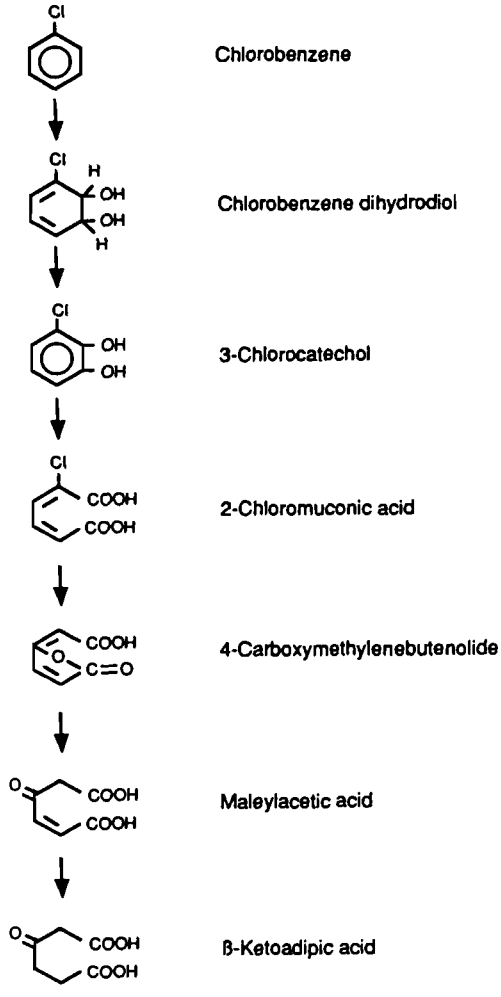


FIG. 3. Modified *ortho* pathway.

Because chlorobenzene is known to be amenable to aerobic biodegradation, enhanced in-situ bioremediation technologies will be evaluated as a source area remedy and/or as a downgradient plume remedy for this site. Three variations of the enhanced in-situ bioremediation technologies will be evaluated as part of this work plan:

- nutrient amendment
- nutrient and oxygen gas amendment
- nutrient and hydrogen peroxide amendment

Bench-scale studies will be conducted to evaluate the potential effectiveness of nutrients with and without an oxygen source to enhance biodegradation of VOCs and SVOCs in groundwater. Pilot studies will be conducted subsequent to the bench-scale studies to determine the potential effectiveness of nutrients with and without an oxygen source (in the form of oxygen gas and hydrogen peroxide) as an in-situ remedial alternative for treatment of VOCs and SVOCs in site groundwater.

3.4.1 Background

The source area and groundwater plume will be defined based on site historical data, as well as additional data that will be obtained as part of this work plan. The locations selected for the bench-scale material and pilot studies have been tentatively identified based on historical data for the site; however, these locations may be modified based on new data obtained during site investigation activities.

3.4.2 Bench-Scale Study

3.4.2.1 Sample Collection

For the bench-scale study, groundwater and soil will be collected from the aquifer at the site during soil and groundwater investigation activities conducted under Phase I of this PDI.

Groundwater will be collected from existing well OW-12 (Figure 2). Approximately 20 gallons of groundwater will be collected and placed into sterile containers, and delivered to the ARCADIS treatability laboratory located in North Carolina. Prior to sample collection, three volumes of groundwater will be purged from OW-12. During and following purging, field parameter measurements (DO, ORP, pH, temperature and specific conductance) will be recorded.

Approximately 7 pounds of soil will be collected from the site, from soil cuttings collected during Phase I soil investigation activities. Soil will be collected at the site

from the test pit near existing well OW-12. Soil will be collected into buckets and delivered to the ARCADIS treatability laboratory located in North Carolina.

3.4.2.2 Reactor Construction

Reactors will consist of three 500-mL serum bottles. Each serum bottle will be prepared by mixing 20 grams of site soil with site groundwater to fill each bottle to zero headspace. A small liquid volume will be used for amendments to achieve the treatments discussed below.

The site soil and groundwater will be used to produce a complete set of reactors under the following experimental conditions:

- sterile control
- nutrients (nitrogen and phosphorous)
- 100 milligrams per liter (mg/L) oxygen (dosed as hydrogen peroxide) plus nitrogen and phosphorous

For the reactors (three serum bottles each) being amended with nitrogen and phosphorous, nutrients will be added at a carbon:nitrogen:phosphorous ratio of 50:25:10. Oxygen will be dosed as hydrogen peroxide (30 percent). To monitor reactor conditions during the experimental period, additional reactors will be prepared similar to each reactor condition, with the exception that only one flask will be used. The reactors will be monitored for pH, nutrient levels and DO, and subsequently to amend the experimental reactors, if necessary. All reactors will be shaken weekly during the bench-scale study. Reactors will be sacrificed weekly to measure pH, nutrient levels and DO. All reactors will be kept in a dark room with the temperature maintained at approximately 70 degrees Fahrenheit.

3.4.2.3 Analyses

The nutrient and nutrient-plus oxygen reactors will be sacrificed (i.e., removed from the experiment and sent to Test America, Inc.'s Buffalo Laboratory for analysis) five times during the initial month of the experiment. Duplicate reactors will be removed at Day 0, 3, 7, 14 and 30. Three of the 500-mL bottles will be combined and sampled as one reactor at each sampling time. Two additional sets of duplicate reactors for each environmental condition will continue to be mixed. In the event that additional analysis

is determined to be needed after Day 30, these reactors will be sacrificed on Days 60 and 90.

Samples from the sacrificed reactors will be submitted to Test America, Inc.'s Buffalo laboratory for VOCs, SVOCs and chemical oxygen demand (COD) analyses. The laboratory analyses will be conducted in accordance with the site-specific QAPP (Appendix D).

Samples from the sacrificed reactors will also be used for microbial population plate counts (i.e., heterotrophs, chlorobenzene-specific degraders and chloroaniline-specific degraders). Plate counts will be conducted by ARCADIS's North Carolina treatability lab in accordance with the site-specific QAPP.

The following table presents the analyses to be run and volume of water required for each analysis.

Analysis	Volume Required
VOCs	80 mL
SVOCs	1,000 mL
COD	100 mL
Heterotrophs plate count	10 grams
Chlorobenzene-specific degraders plate count	10 grams
Chloroaniline-specific degraders plate count	10 grams

One hundred forty-two bottles will be prepared with varying amendments as described in Section 3.4.2.2. This number of bottles includes the additional quantity needed to monitor and amend the experimental reactors throughout the experiment.

3.4.2.4 Evaluation

The enhanced bioremediation bench-scale study will yield data to support the selection of the most successful amendment combination and provide supporting data to develop pilot studies to be conducted following completion of the bench-scale study.

3.4.3 Pilot Studies

Based on the results of the enhanced bioremediation bench-scale study, the specific details of the pilot studies summarized below will be further refined. The objective of these pilot studies are to evaluate whether enhanced bioremediation should be used

as a component of the final groundwater remedy for this site. These pilot studies will evaluate three enhanced biodegradation technologies in determining the optimal method of biodegradation as a remedial alternative. The three enhanced biodegradation technologies include nutrient amendment and two technologies introducing an oxygen source (i.e., oxygen gas diffusion system and hydrogen peroxide amendment). As an initial analysis, the nutrient and oxygen technologies will be evaluated using direct injection methods.

For each of the three studies, an existing well was selected for application of each biodegradation enhancement technology. Locations were selected based upon the uniformity of subsurface conditions between the three selected wells and proximity to the chlorobenzene source area. The application wells are located within the impacted areas of the aquifer, southwest of Tank Pad 1 (Figure 4). As described in Section 2.3.3, new monitoring wells will be installed around the application well to monitor the effect of the three remedial technologies on site groundwater. The application and monitoring wells for each technology study are listed in the table below.

Enhanced Biodegradation Technology	Application Well	Area Monitoring Wells
Nutrient amendment	MW-1/TW4	4 new monitoring wells installed around existing application well
Oxygen gas diffusion system	MW-T3	4 new monitoring wells installed near existing application well
Hydrogen peroxide amendment	OW-12	4 new wells installed around new existing application well
Control	MW-9A	1 existing monitoring well

A description of each pilot study is provided in the following discussion. The pilot studies will be modified as needed based on the results of the bench-scale studies.

Pursuant to the USEPA Underground Injection Control (UIC) Program, the USEPA has been provided notification of the proposed pilot testing.

3.4.3.1 Description of Enhancement Alternatives

3.4.3.1.1 Nutrient Amendment

The purpose of the nutrient amendment study is to evaluate enhancement of in-situ biodegradation of VOCs and SVOCs using nutrient addition. Macronutrients (including nitrogen and phosphorous) in the form of a Miracle-Gro® aqueous solution, will be

introduced to existing well MW-1/TW4. The material safety data sheet for Miracle-Gro® water soluble all-purpose plant food is provided as Appendix J.

Figure 4 identifies the locations of four new monitoring wells to be installed to monitor the effect of the nutrient amendment on groundwater conditions around MW-1/TW4. The wells will be constructed as described in Section 2.3.3.

The nutrient amendment solution was designed for optimal growth of naturally occurring microorganisms that biodegrade VOCs and SVOCs. For this study, subsurface chlorobenzene concentrations were used to determine the appropriate proportions of Miracle-Gro® to be added to the amendment solution. A carbon: nitrogen:phosphorous ratio of 50:25:10 is required for optimal biodegradation conditions. This ratio equates to a Miracle-Gro™ concentration of 545 mg/L in solution.

The amendment solution will be mixed in 55-gallon batches immediately prior to application. The amendment solution will be prepared according to the following procedures:

- Fill a clean 55-gallon drum (steel or plastic) with approximately 20 gallons of site groundwater obtained from a monitoring well with COC concentrations less than the NYSDEC Ambient Water Quality Standards and Guidance Values (NYSDEC, 1998).
- Add approximately 4 ounces of Miracle-Gro®.
- While mixing, continue adding water to a total volume of 55 gallons.
- Continue mixing if necessary.

The proportions of Miracle-Gro® to be added to the amendment solution may change during the pilot study based on field observations or other information.

After the nutrient solution is mixed, it will be applied to each well using a hand pump or by pouring through a funnel into clean plastic tubing that leads to the bottom of the well. The application rate will be adjusted so that the water-level increase in the well is minimized to confirm that no water is forced out of the top of the well. In the event that biofouling occurs at the application well, steps, such as pulsing the nutrient amendments as they are introduced, will be taken. When addition of the nutrient solution is complete, the wells will be capped and locked. The amount of solution

applied to each well may vary depending on each well's ability to accept the nutrient solution.

The nutrient solution will be applied regularly for 60 days. The nutrient solution will be applied twice per week for 2 weeks, once weekly for the following 2 weeks, and then once monthly for the remaining duration of the 60-day pilot study. Application frequency may change during the pilot study based on field observations or other information. Once the optimum application frequency of nutrients is determined, an evaluation will be done to confirm that none of the ingredients in Miracle-Gro® will exceed appropriate MCLs at the intended dose. Nutrient solution application frequency will be consistent between all three enhanced biodegradation technology pilot studies.

3.4.3.1.2 Oxygen Diffusion System

The purpose of the oxygen diffusion system pilot study is to evaluate aerobic biodegradation of VOCs and SVOCs by introducing nutrients and an oxygen source. Nutrients and oxygen gas will be introduced to the groundwater at existing well MW-T3.

Figure 4 identifies the locations of the four new monitoring wells to be installed to monitor the effect of nutrients and oxygen on groundwater conditions around MW-T3. The wells will be constructed as described in Section 2.3.3.

An oxygen diffusion system will be used to provide a controlled release of oxygen gas to the site groundwater for the duration of the pilot study. The oxygen gas in combination with nutrients is anticipated to enhance the growth of naturally occurring microorganisms that aerobically biodegrade VOCs and SVOCs. The oxygen gas is anticipated to be supplied at a rate of approximately 19.5 mL per minute; however, this rate may be adjusted based on results obtained from the bench-scale study discussed in Section 3.4.2. Appendix E includes an installation protocol for the oxygen diffusion system.

The oxygen diffusion system will be operated and maintained using the checklist provided in Appendix F. In addition, following startup of the oxygen diffusion system, groundwater DO concentrations in the application well will be monitored with a YSI 556 Multiprobe System (MPS) to determine that target DO levels (i.e., greater than 2 parts per million [ppm]) are reached. DO in the application well should reach equilibrium within the first 24 hours. DO monitoring will then be performed in accordance with Section 3.4.3.2. The DO concentration increases with immersion depth of the

dispersion unit below the water table; therefore, the unit should always sit as close to the bottom of the well as practical.

The oxygen dispersion unit is anticipated to use approximately 1 cubic foot of oxygen per day. However, cylinders are not always 100 percent full, and flow may vary slightly. Pressure settings on the regulator will be set per the manufacturer's specifications.

If DO concentrations are not attained, it may be due to higher than expected groundwater flow or a large oxygen demand. The regulator pressure can be increased to increase DO concentrations. The gas usage will then increase and should be assessed for expected usage and tank change out scheduling.

During each site visit, the remaining cylinder pressure will be recorded, along with the regulator pressure setting. The estimated number of days to cylinder replacement will be calculated based on gas consumption using the worksheet provided in Appendix G.

Water filters will be inspected monthly, at a minimum, and drained of accumulated water as necessary.

Similar to the nutrient amendment pilot study, macronutrients (including nitrogen and phosphorous) in the form of a Miracle-Gro® aqueous solution will be introduced to the groundwater. The nutrient solution will be introduced to groundwater at MW-T3 using the same method described above for the nutrient amendment pilot study. In the event that biofouling occurs at the application well, steps, such as pulsing the nutrient amendments as they are introduced, will be taken. As previously noted, the nutrient solution will be applied twice per week for 2 weeks, once weekly for the following 2 weeks and then once monthly for the remaining duration of the 60-day pilot study. Application frequency may change during the pilot study based on field observations or other information obtained during the predesign activities. As discussed in Section 3.3.3.1.1, the optimum dose of Miracle-Gro® will be evaluated to confirm that none of the ingredients will exceed appropriate MCLs at the intended dose. Nutrient amendment solution application frequency will be consistent between all three enhanced biodegradation technology pilot studies.

3.4.3.1.3 Hydrogen Peroxide Amendment

The hydrogen peroxide treatment study will evaluate the effects of amending site groundwater with nutrients and diluting the hydrogen peroxide solution on the in-situ aerobic biodegradation of VOCs and SVOCs. The use of hydrogen peroxide as an

oxygen source for groundwater is well established, with 1 mole of hydrogen peroxide producing ½ mole of oxygen, as shown below.

$$H_2O_2 \xrightarrow{\text{catalase}} \tfrac{1}{2} O_2 + H_2O$$

Based on this relationship, 200 mg/L of hydrogen peroxide will produce 100 mg/L of oxygen. It is anticipated that hydrogen peroxide will be initially added to groundwater at a concentration 200 mg/L; however, this concentration may be adjusted based on results obtained from the bench-scale study discussed in Section 3.3.2. Therefore, to create a 200 mg/L hydrogen peroxide solution, approximately 1.5 liters of 3 percent hydrogen peroxide (available at any local grocery store or pharmacy) will be added to 55 gallons of site groundwater obtained from a monitoring well with COC concentrations less than the NYSDEC Groundwater Quality Criteria. At this concentration, the indigenous bacteria will not be lysed.

Figure 4 identifies the locations of the four new monitoring wells to be installed to monitor the effect of nutrients and hydrogen peroxide on groundwater conditions around OW-12. The wells will be constructed as described in Section 2.3.3.

Consistent with the process described above for the nutrient amendment and the oxygen diffusion system pilot studies, nutrients (in the form of Miracle-Gro®) will be added to dilute the hydrogen peroxide solution at a carbon:nitrogen:phosphorous ratio of 50:25:10. The nutrients and diluted hydrogen peroxide solution will be introduced to site groundwater at OW-12 using the same method described above for the nutrient amendment pilot study. In the event that biofouling occurs at the application well, steps, such as pulsing the nutrients and diluted hydrogen peroxide amendments as they are introduced, will be taken. As previously noted, the nutrient solution will be applied twice per week for 2 weeks, once weekly for the following 2 weeks and then once monthly for the remaining duration of the 60-day pilot study. The proportions of hydrogen peroxide and Miracle-Gro® to be added to the hydrogen peroxide/nutrient solution may change during the pilot study based on field observations or other information obtained during the predesign activities. As previously discussed, the optimum dose of Miracle-Gro® will be evaluated to confirm that none of the ingredients will exceed appropriate MCLs at the intended dose. Nutrient amendment solution application frequency will be consistent between all three enhanced biodegradation technology pilot studies.

3.4.3.2 Monitoring and Evaluation

Prior to each application and at the time of each sampling event, the following parameters will be measured at the four application wells (MW-1/TW-4, MW-3 and OW-12), the 12 monitoring wells and the control well MW-9A:

- temperature
- pH
- ORP
- conductivity
- turbidity

These measurements will be made using a YSI 556 MPS water quality sensor (or equivalent). The groundwater will be pumped to the surface and through the YSI 556 MPS, with flow-through cell measurements recorded every minute until the measurements have stabilized. In addition to measuring in-situ parameters, groundwater samples will be collected for laboratory analysis at each of the 12 monitoring wells and the control well MW-9A on Days 0, 30 and 60. Groundwater sampling will be conducted in accordance with the groundwater sampling SOP in Appendix B. Groundwater samples will be submitted to Test America, Inc.'s Buffalo Laboratory and analyzed for VOCs, SVOCs and in accordance with the site-specific QAPP (Appendix D).

Data obtained from the 12 monitoring wells and the control well during this pilot study will be evaluated to determine if the nutrient amendment and/or oxygen sources enhance the in-situ biodegradation of site-specific VOCs and SVOCs. The VOC and SVOC concentrations will be evaluated between Day 0 and Day 30 to determine if the enhanced bioremediation is resulting in surfactant-like effects that may be of concern for full-scale application. The evaluation will consider the potential use of each amendment as a remedial treatment of the source area and/or the downgradient plume.

3.4.3.3 Comparison of Enhanced Bioremediation Technologies

Results of the laboratory analyses obtained from the three enhanced biodegradation technology pilot studies will be used to determine if there is a treatment technology that

is effective in enhancing the biodegradation of VOCs and SVOCs. The technology selection will be based on the effectiveness of contaminant removal. Analytical results will be evaluated relative to the NYSDEC Groundwater Quality Criteria. If contaminant removal is adequate and consistent between more than one technology, other factors (such as time and costs) will be considered. Results of these enhanced bioremediation technology studies will be used to facilitate development of the RDWP for site groundwater.

3.5 Monitored Natural Attenuation

MNA includes natural subsurface processes, such as dilution, volatilization, biodegradation, adsorption and chemical reactions with subsurface materials that reduce contaminant concentrations through time. Long-term monitoring must be conducted throughout the process to confirm that degradation is proceeding at rates consistent with meeting cleanup objectives.

This remedial alternative will be evaluated for its potential application at the site. The evaluation will include the following steps:

- Review VOC, SVOC and TIC analytical data for the site and identify potential zones of MNA applications.
- Conduct groundwater sampling to analyze for MNA parameters.
- Conduct MNA isotopic analyses to determine if there is evidence to support the potential application of MNA for select areas of the site.

These steps are discussed in Section 3.4.1.

3.5.1 Description

3.5.1.1 Data Review

The initial step for evaluating MNA as a remedial alternative is to review VOC and SVOC analytical data for the site. The analytical data to be reviewed includes the historical/existing VOC and SVOC analytical data previously collected at the site, as well as the supplemental data that will be collected during Phase I of the PDI (Section 2).

3.5.1.2 Groundwater Sampling

Based on the data review, potential zones of MNA applications will be identified. In addition, groundwater samples will be collected from the locations selected within these potential MNA application zones. As shown on Figure 3, groundwater samples are anticipated to be collected from approximately 15 locations across the site. These select locations are anticipated to be located in areas upgradient and downgradient of the source area, as well as in two locations within the source area (i.e., one area being treated with an enhanced bioremediation technology and one area without treatment).

Samples will be collected in accordance with the groundwater sampling SOP located in Appendix B. The samples will be submitted to Test America, Inc.'s Buffalo Laboratory for analysis of select MNA parameters in accordance with the site-specific QAPP (Appendix D). The following MNA parameters will be analyzed:

- nitrogen as ammonia
- nitrate
- sulfate
- sulfide
- phosphorous as orthophosphate
- total dissolved organic carbon
- alkalinity-bicarbonate
- carbon dioxide
- iron (filtered and unfiltered)
- manganese (filtered and unfiltered)

In addition, the following MNA parameters will be measured in the field at each sampling location while collecting groundwater samples:

- pH
- ORP
- DO
- alkalinity

3.5.1.3 Isotopic Analyses

A large component of MNA is demonstrating that a specific biodegradation process is truly occurring at a given site. MNA isotopic analysis will be conducted using two methods to determine if there is evidence to support MNA as a viable remedial alternative. The first method is Stable Isotope Probing (SIP), which will be conducted by Microbial Insights, Inc. The second method is carbon Compound-Specific Stable Isotope Analysis (CSIA), which will be conducted by the University of Oklahoma.

3.5.1.3.1 Stable Isotope Probing

SIP is a technique that couples the use of stable isotopic compounds (as surrogates), as well as with molecular-based biological tools to prove that biological degradation of a specific contaminant (i.e., chlorobenzene) is occurring. Microbial Insights, Inc. has developed a direct in-situ technique for performing SIP in conjunction with Bio-Trap® samplers. Using this approach, the Bio-Trap® samplers will be "baited" with a known concentration of a carbon 13- (13C-) enriched compound (i.e., chlorobenzene) and analyzed to determine the concentration of biomass that shows use of the 13C-enriched compound (which proves biodegradation occurred). In addition, this technique will determine the percentage loss and estimate the relative rate of chlorobenzene degradation. Results from this analysis will be determined using a modified version of the phospholipid fatty acid analysis in which uptake of the 13C-enriched compound is determined for each fatty acid.

Microbial Insights, Inc.'s Bio-Traps® will be installed at the locations provided in Table 1 and on Figure 3 to collect microbes through time to better understand the biodegradation potential at the site for chlorobenzene. Chlorobenzene was chosen for this evaluation based on historical concentrations detected at the site.

The Bio-Traps® will be installed in accordance with the installation protocol included in Appendix H. The Bio-Traps® will be installed in select wells approximately 30 days before the groundwater sampling event and then collected and submitted to Microbial Insights, Inc. for analysis, which will be conducted in accordance with the site-specific QAPP (Appendix D).

The results obtained from the Bio-Traps® installed at the select wells, excluding AB-MW-2 and OW-27A, will be used to evaluate the potential effectiveness of MNA at current site conditions as well as the potential effectiveness of MNA applied in combination with an active remedy (i.e., enhanced bioremediation and ISCO).

3.5.1.3.2 Compound-Specific Stable Isotope Analysis

The CSIA method will also be used to provide evidence of the occurrence of biodegradation of chlorobenzene. CSIA is used to determine the isotopic ratios of individual COCs. Chemical reactions (including bio- and inorganic degradation) tend to favor molecules with the lighter isotopic species (e.g., carbon 12 [12C]). The resulting enrichment of the unreacted substrate in heavier isotopic species (e.g., 13C), referred to as kinetic isotopic fractionation, allows the extent of fractionation to be used as a proxy for biodegradation. Processes including, but not limited to, volatilization and sorption result in minimal degrees of fractionation and do not interfere with the isotopic signal due to biodegradation.

Groundwater samples will be collected at the locations provided in Table 1 and shown on Figure 3, and then submitted to Dr. Philp's Laboratory at the University of Oklahoma for CSIA of chlorobenzene. Chlorobenzene was chosen for this evaluation based on historical concentrations detected at the site. Groundwater samples will be collected in accordance with the sample collection protocol included in Appendix I. CSIA will be conducted in accordance with the site-specific QAPP (Appendix D).

3.5.2 Evaluation

Strong evidence for intrinsic biodegradation activities can be learned from site chemical monitoring. The data obtained during the predesign groundwater investigation activities will be used to support the decision to apply or not to apply MNA at the site.

Nitrate (as ammonia) and o-phosphate are limiting nutrients required for microbial growth and activity. The ammonia and o-phosphate data obtained may suggest whether the rate of biodegradation activities is nutrient-limited.

Aerobic conditions may be suggested by a DO concentration above 1 ppm and/or by a highly positive ORP value.

COC biodegradation is largely based on microbial respiration. In respiration, microbes gain energy from the consumption (oxidation) of electron donors coupled to the use (reduction) of electron acceptors. The electron acceptors' presence, or absence, in comparison to background levels can therefore be used to infer biodegradative processes. During aerobic metabolism of COCs, oxygen is the electron acceptor, while the COC is the electron donor. In general, rates of biodegradation follow an order of favorable electron acceptor availability [i.e., O_2>MnIV>NO_3^->Fe(III)>SO_4^{2-}>CO_2] (Weidemeier et al., 1999).

A decrease in nitrate concentrations or the presence of nitrite in groundwater may indicate nitrate reduction. Similarly, a decrease in sulfate concentrations or the presence of sulfide in groundwater may indicate sulfate reduction. Elevated levels of Fe(II) may indicate the microbial reduction of iron. Increased chloride concentrations may indirectly indicate reductive dechlorination (Weidemeier et al., 1999).

Complete degradation of COCs may be indicated by elevated carbon dioxide or methane concentrations. The formation of alkalinity may also indicate the occurrence of biodegradation activities (Weidemeier et al, 1999).

Results of this evaluation will be used to determine if MNA should be selected as a remedial alternative to address site-specific VOCs and SVOCs. MNA's potential to meet the approved cleanup objectives for the site within a time frame that is reasonable will be compared to the other remedial alternatives being considered for this site.

3.6 Phytoremediation

Based on a preliminary review of available literature, phytoremediation could be a viable remedial alternative for this site. Studies have shown that chlorobenzene is metabolized by plants and degradation is enhanced in the rhizosphere. Therefore, phytoremediation may be considered as a contingency remedial action if the other proposed remedial actions evaluated in the PDI do not appear to be viable remedial measures. If phytoremediation is further pursued as a component of the selected remedy for groundwater at this site, a detailed work plan for additional bench-scale and/or pilot studies would be presented for agency consideration.

3.7 Evaluation

The process by which the most appropriate groundwater remedial technology will be selected for incorporation into RDWP will include, but is not limited to, the following steps:

- *Further Characterization of Extent of Groundwater to be Remediated* — The mass of VOCs (principally chlorobenzene) present within impacted source soil and dissolved in groundwater to be remediated will be estimated based on existing and supplemental remedial investigation site data.

- *Evaluation of Remedial Technologies* — Evaluation of the remedial technologies will consider results of the bench and pilot studies, practical application for the site (e.g., ability to implement, demonstrated capability to achieve remedial objectives established in the ROD, cost effectiveness) and potential future reuse of the site.

A remedial technology other than that presented within the ROD (NYSDEC, 2006) (i.e., air sparging/soil vapor extraction) may be selected to address groundwater at this site. If this occurs, appropriate documentation of the basis for selection of this alternative remedial technology and a demonstration that this alternative is a technically appropriate and cost-effective approach by which to achieve the remedial objectives established within the ROD, will be submitted to the NYSDEC prior to initiating the RDWP development.

4. Remedial Design Work Plan

Upon completion of the PDI, an RDWP will be prepared that documents the PDI activities completed, presents results of the remedial alternatives evaluation, and demonstrates adequate support for selection of the most appropriate remedial technologies to achieve the established remedial objectives at this site.

The RDWP will include data summary tables, soil boring logs, well construction logs and figures showing the horizontal extent of the source area. The RDWP will include the location and a description of the selected remedial actions, monitoring procedures to be implemented during remedial activities, confirmation sampling plan, and schedule. The RDWP will be submitted to the NYSDEC for review and approval prior to implementation.

5. Schedule

Phase I and Phase II PDI activities are anticipated to be conducted concurrently to the extent practicable. Therefore, information obtained and evaluations conducted during these activities will be used, as they become available, to support the decision making process of this work plan.

The overall schedule to complete Phase I of the PDI is anticipated to extend for a period of 65 days and Phase II of the PDI is anticipated to extend for a period of 180 days. This assumes that mobilization of the field activities will be initiated within 2 weeks after receiving NYSDEC approval of this work plan. The duration of Phase I and II of the PDI is detailing in the table below.

Upon completing the data evaluation and remedy selection activities, results of the Phase I and Phase II investigation will be incorporated into an RDWP to be submitted to the NYSDEC within 180 days of initiating this work plan.

	Duration (days)	Comments
Phase I Activities		
Mobilization/clearing Utilities	30	
Excavation of test trenches	7	
Installation and development of monitoring wells	21	DNAPL assessment wells will be installed last.
Vertical profiling of groundwater	7	
Phase II Activities		
Bench Scale Testing	60	
Evaluation of bench scale testing results and refinement of pilot test program	30	
Pilot Test Program	60	
Bio-Traps® installation and groundwater sampling	30	Groundwater sampling will be completed after the removal of the Bio-Traps®.

6. References

New York State Department of Environmental Conservation. 1998. *Technical and Operational Guidance Series 1.1.1. Ambient Water Quality Standards and Guidance Values and Groundwater Effluent Limitations.* June 1998.

New York State Department of Environmental Conservation. 2006. *Record of Decision Tappan Terminal Site Village of Hastings-on- Hudson, Westchester County, New York*, 3-60-015. September 2006.

Nishino, S.F., J.C. Spain, L.A. Belcher, and C.D. Litchfield, 1992. Chlorobenzene Degradation by Bacteria Isolated from Contaminated Groundwater, *Applied and Environmental Microbiology*, May 1992, p. 1719-1726.

Weidemeier, Todd H., John T. Wilson, Donald H. Kampbell, Ross N. Miller and Jerry E. Hansen. 1999. *Technical Protocol for Implementing Intrinsic Remediation With Long-Term Monitoring for Natural Attenuation of Fuel Contamination Dissolved in Groundwater.* Air Force Center for Environmental Excellence. March 8, 1999.

ARCADIS BBL

TABLE

Table 1. Groundwater Sampling Summary, Former Tappen Terminal Site, Hastings on the Hudson, New York

Sample ID	VOCs	SVOCs + TICs*	MNA**	Biotraps	CSIA***
AB-MW-1	X	X	X	X	X
AB-MW-2	X	X	X	X	X
AB-MW-3	X	X	X	X	X
LMS-1	X				
LMS-2	X	X			
LMS-7	X		X		
LMS-5	X		X		
MW-1A	X	X	X	X	X
MW-1/TW4	X				
MW2/TW5	X				
MW-6	X		X	X	X
MW-7A	X		X		
MW-9A	X	X	X	X	X
MW-10	X	X	X	X	X
MW-12	X	X			
MW-13	X	X			
MW-14	X	X			
MW-15	X	X			
MW-D1	X				
MW-S1	X				
MW-T1	X				
MW-T2	X				
MW-T3	X				
MW-T6	X				
OW-5A	X				
OW-8	X	X	X	X	X
OW-7	X	X			
OW-9A	X		X	X	X
OW-12	X	X			
OW-1S				X	X
OW-15	X		X	X	X
OW-27A	X	X	X	X	X

*Tentatively Identified Compounds (TICs) are as follows: 0-chloraniline, 2-methyl-benzenamine, p-aminotoluene, 9,10-anthracenedione, 1,4-dihydroxy-9,10-anthracenedione, 1-hydroxy-9,10-anthracenedione, (z)-9-octadecenamine.

**Monitored Natural Attenuation (MNA) parameters are as follows: methane, chloride, nitrogen as ammonia, nitrate, sulfate, sulfide, phosphorous as orthophosphate, total dissolved organic carbon, pH, oxidation-reduction potential, alkalinity, alkalinity-bicarbonate, carbon-dioxide, iron (filtered and unfiltered).

***Carbon Compound-Specific Stable Isotope Analysis (CSIA).

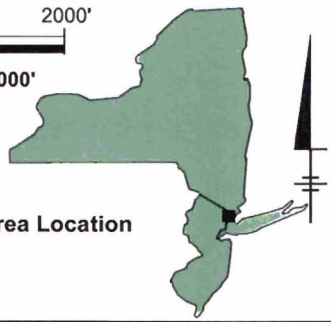
"X" - Groundwater sample location.

FIGURES

REFERENCE: BASE MAP USGS 7.5 MIN. QUAD., YONKERS, N.Y. - N.J., 1966, PHOTOREVISED 1979.

2000' 0 2000'

Approximate Scale: 1" = 2000'



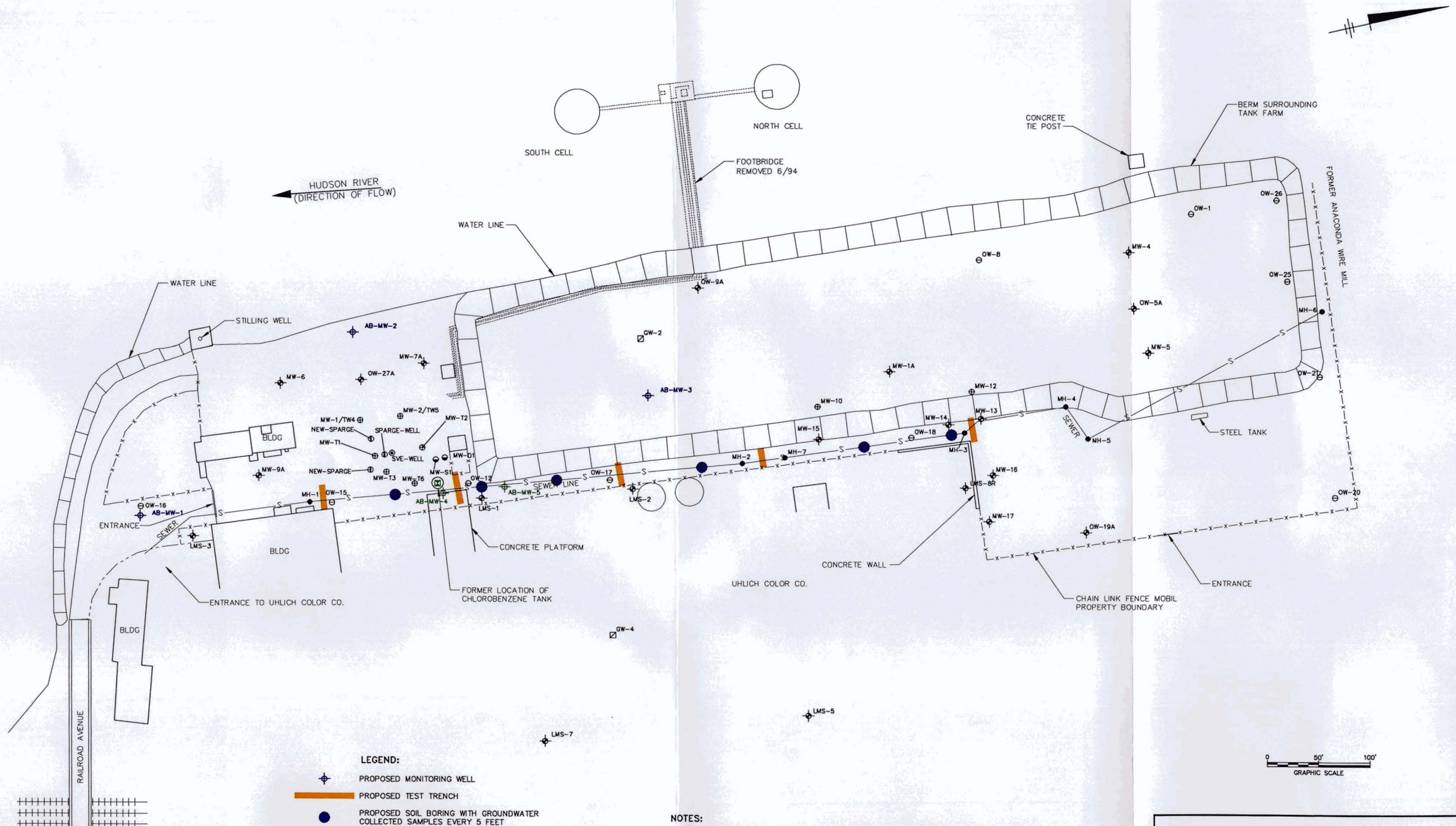
TAPPAN TERMINAL SITE
HASTINGS-ON-HUDSON, NEW YORK

SITE LOCATION MAP

ARCADIS BBL
Infrastructure, environment, facilities

FIGURE
1

8/09/07-SYR-KLS
45347001/45347N01.CDR



NOTES:

1. BASEMAP PROVIDED BY WOODARD & CURRAN, FIGURE 1, TITLED "GROUNDWATER CONTOUR PLAN" DATED JAN 2002.

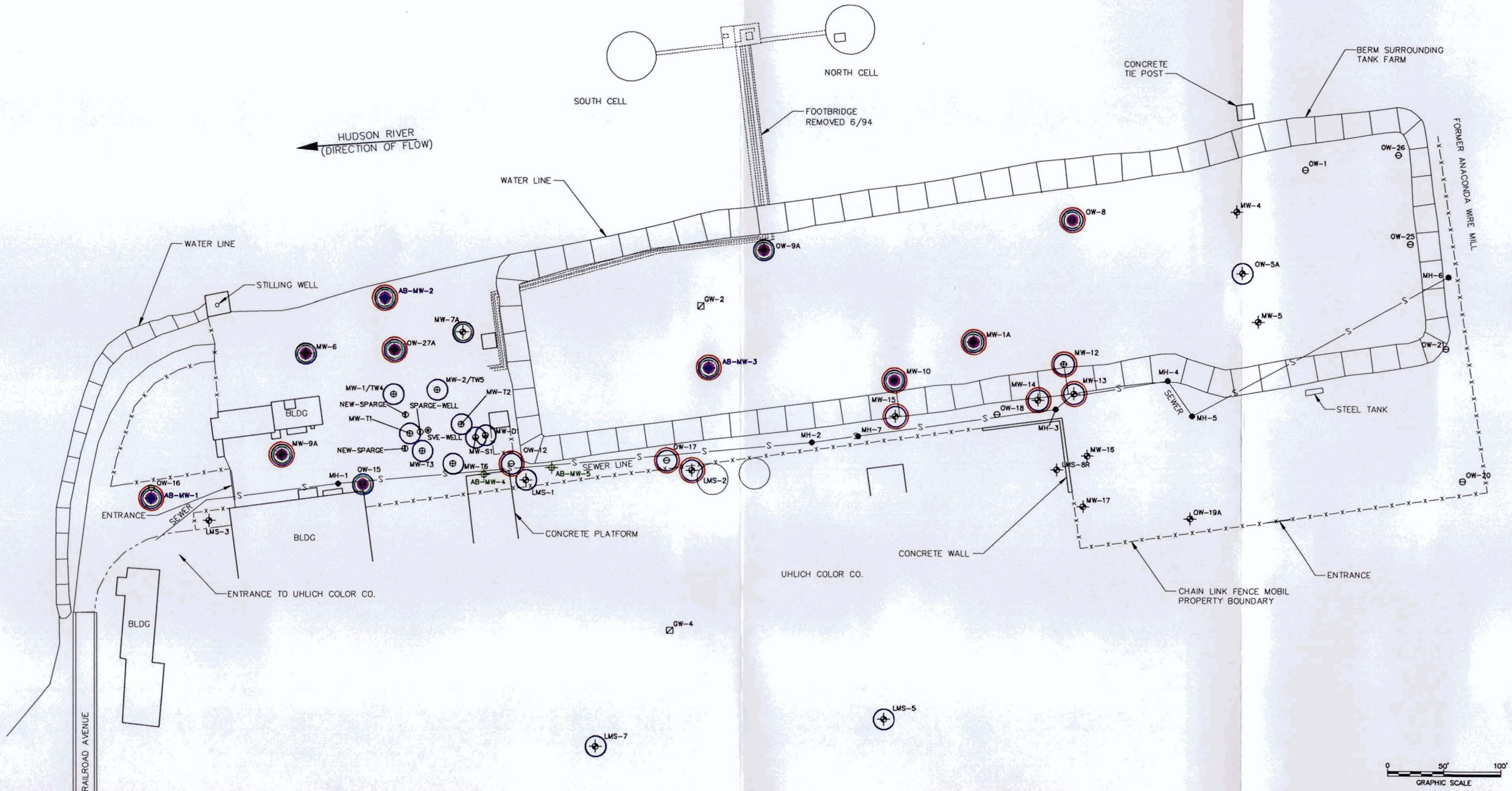
FORMER TAPPAN TERMINAL SITE
HASTING ON THE HUDSON, NEW YORK

PROPOSED TEST PIT, MONITORING WELL, AND SOIL BORING LOCATIONS

ARCADIS BBL
Infrastructure, environment, facilities

FIGURE
2

SYR-BS-GWS LAF LAYER: ON='*', OFF='REF*
G:\CAD\ACTIVE\-DWG\ACT\45866001\45866P01.DWG SAVED:11/21/2007 8:33 AM LAYOUT:2 PAGESETUP:DL2B-PDF PENTABLE:PLTFULLCTB PRINTED:11/21/2007 9:33 AM BY:LFORAKER
PROJECTNAME:----
XREFS: IMAGES:



LEGEND:

- PROPOSED MONITORING WELL
- DNAPL MONITORING WELL
- MW-10 — 4-INCH DIAMETER NEW MONITOR WELL
- MW-6 — 4-INCH DIAMETER MONITORING WELL
- OW-1 — 2-INCH DIAMETER OBSERVATION WELL
- MW-D1 — 6-INCH DIAMETER TEST WELL
- GW-4 — GROUNDWATER SAMPLE
- MH-7 — SANITARY SEWER MANHOLE
- S — SANITARY SEWER

- BIOTRAP AND CARBON COMPOUND-SPECIFIC STABLE ISCOTOPE ANALYSIS SAMPLE LOCATION
- MNA GROUNDWATER SAMPLE LOCATION
- VOC GROUNDWATER SAMPLE LOCATION
- SVOC GROUNDWATER SAMPLE LOCATION

NOTES:

1. BASEMAP PROVIDED BY WOODARD & CURRAN, FIGURE 1, TITLED "GROUNDWATER CONTOUR PLAN" DATED JAN 2002.

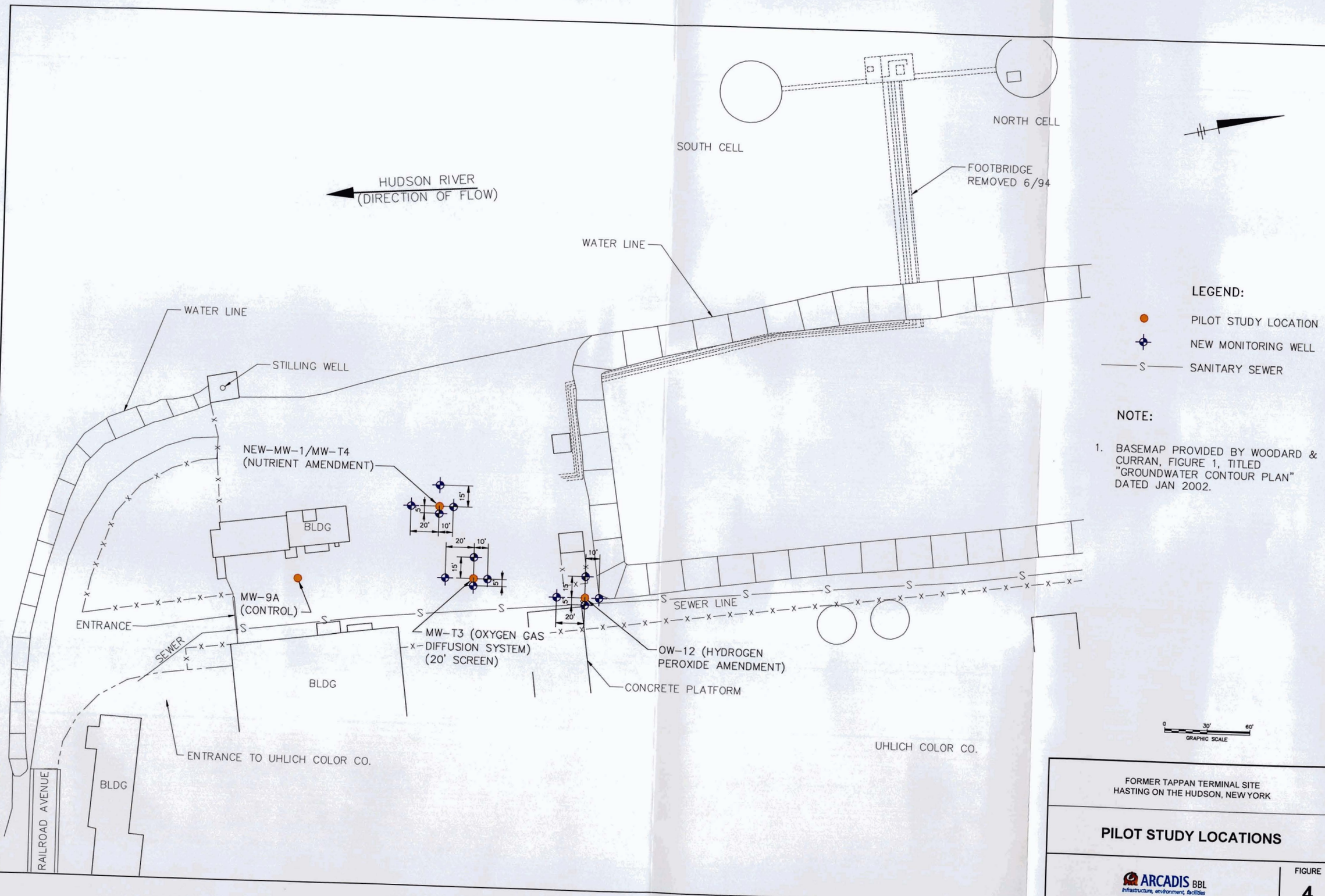
FORMER TAPPAN TERMINAL SITE
HASTING ON THE HUDSON, NEW YORK

GROUNDWATER MONITORING LOCATIONS

ARCADIS BBL
Infrastructure, environment, facilities

FIGURE
3

SYR-05-GNS LAF LAYER: GN=* OFF=REF*
G:\CAD\ACTIVE\-DWG\ACT\435660\435660P02.DWG SAVED:11/21/2007 9:35 AM LAYOUT:3 PAGESETUP:DLZB-PDF PENTABLE:PLTFULL.CTB PRINTED:11/21/2007 9:35 AM BY:LFORAKER
PROJECTNAME: -----
XREFS: IMAGES:



FORMER TAPPAN TERMINAL SITE
HASTING ON THE HUDSON, NEW YORK

PILOT STUDY LOCATIONS

ARCADIS BBL
Infrastructure, environment, facilities

FIGURE
4

ARCADIS BBL

Appendix B

ARCADIS BBL SOPs

Standard Operating Procedure: Monitoring Well Installation

I. Scope and Application

Monitoring well boreholes are typically drilled using the hollow-stem auger drilling method. Other drilling methods that are also suitable for installing overburden monitoring wells, and are sometimes necessary due to site-specific geologic conditions, include: drive-and-wash, spun casing, Rotasonic, dual-rotary (Barber Rig), and fluid/mud rotary. Direct-push techniques (e.g., Geoprobe or cone penetrometer) and driven well points may also be used in some cases. The drilling method to be used at a given site will be selected based on site-specific consideration of anticipated drilling/well depths, site or regional geologic knowledge, type of monitoring to be conducted using the installed well, and cost.

No oils or grease will be used on equipment introduced into the boring (e.g., drill rod, casing, or sampling tools). No coated bentonite pellets will be used in the well drilling or construction process. Material safety data sheets (MSDS) and specifications of materials to be installed in the well will be obtained prior to mobilizing onsite, including:

- well casing;
- bentonite;
- sand; and
- grout.

Well materials will be inspected and, if needed, cleaned prior to installation.

II. Personnel Qualifications

Monitoring well installation activities will be performed by persons who have been trained in proper well installation procedures under the guidance of an experienced field geologist, engineer, or technician. Where field sampling is performed for soil characterization, field personnel will have undergone in-field training in terms of soil classification.

III. Equipment List

The following materials will be available during soil boring and monitoring well installation activities, as required:

- Site Plan with proposed soil boring/well locations;
- Work Plan or *Field Sampling Plan* (FSP), and site *Health and Safety Plan* (HASP);
- personal protective equipment (PPE), as required by the HASP;
- drilling equipment required by the American Society of Testing and Materials (ASTM) D 1586, when performing split-spoon sampling;
- disposable plastic liners, when drilling with direct-push equipment;
- appropriate soil sampling equipment (e.g., stainless steel spatulas, knife);
- equipment cleaning materials;
- appropriate sample containers and labels;
- chain-of-custody forms;
- insulated coolers with ice, when collecting samples requiring preservation by chilling;
- photoionization detector (PID) or flame ionization detector (FID);
- keys to wells;

- well construction materials; and
- field notebook.

IV. Cautions

Prior to beginning field work, underground utilities in the vicinity of the drilling areas will be delineated by the drilling contractor or an independent underground utility locator service. See separate SOP for utility clearance.

No coated bentonite pellets will be used in monitoring well construction, as the coating could contaminate the well. Overburden monitoring wells may be installed with Schedule 40 polyvinyl chloride (PVC) to a maximum depth of 200 feet below ground surface (bgs). PVC monitoring wells between 200 and 400 feet total depth will be constructed using Schedule 80 PVC. Monitoring wells deeper than 400 feet will be constructed using steel.

V. Health and Safety Considerations

Field activities associated with monitoring well installation will be performed in accordance with a site-specific HASP, a copy of which will be present on site during such activities.

VI. Procedures

The procedures for installing groundwater monitoring wells in soil are presented below:

Hollow-Stem Auger, Drive-and-Wash, Spun Casing, Fluid/Mud Rotary, Rotasonic, and Dual-Rotary Drilling Methods

1. Locate boring/well location, establish work zone, and set up sampling equipment cleaning area.

2. Advance soil boring to depth. Collect soil samples at appropriate interval as specified in the Work Plan and/or FSP. Collect, document, and store samples for laboratory analysis as specified in the Work Plan and/or FSP. A common sampling method that produces high-quality samples with relatively little soil disturbance is the ASTM D 1586 - *Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils.* Split-spoon samples are obtained during drilling using hollow-stem auger, drive-and-wash, spun casing, and fluid/mud rotary. Rotasonic drilling produces large-diameter soil cores that tend to be more disturbed than split-spoon samples due to the vibratory action of the drill casing. Dual-rotary removes cuttings by compressed air and allows only a general assessment of geology.

3. Describe each soil sample, including soil type; color; percent recovery; relative moisture content; soil texture; grain-size and shape; consistency; presence of any staining, sheen, or odor; and any other pertinent observations. Record descriptions in the field notebook. During soil boring advancement, document all drilling events in field notebook, including blow counts (number of blows required to advance split-spoon sampler in 6-inch increments) and work stoppages. Blow counts will not be available if Rotasonic, dual-rotary, or direct-push methods are used.

4. Upon completing the borehole to the desired depth, install the monitoring well by lowering the screen and casing assembly with sump through the augers or drill casing. Monitoring wells typically will be constructed of 2-inch-diameter, flush-threaded PVC slotted well screen and blank riser casing. Smaller diameters may be used if wells are installed using direct-push methodology or if multiple wells are to be installed in a single borehole. The screen length will be specified in the Work Plan or FSP based on regulatory requirements and specific monitoring objectives. Monitoring well screens are usually 5 to 10 feet long, but may be up to 25 feet long in very low permeability, thick geologic formations. The screen length will depend on the purpose for the well and the objectives of the groundwater investigation. Typically, the slot size will be 0.010 inch and the sand pack will be Morie No. 0 or equivalent. In very fine-grained formations where

sample turbidity needs to be minimized, it may be preferred to use a 0.006-inch slot size and Morie No. 00 or equivalent sand pack. Alternatively, where monitoring wells are installed in coarse-grained deposits and higher well yield is required, a 0.020-inch slot size and Morie No. 1 or equivalent sand pack may be preferred. To the extent practicable, the slot size and sand pack gradation will be predetermined in the Work Plan or FSP based on site-specific grain-size analysis or other geologic considerations or monitoring objectives. A blank sump may be attached below the well screen if the well is being installed for dense non-aqueous phase liquid (DNAPL) recovery/monitoring purposes. If so, the annular space around the sump will be backfilled with neat cement grout to the bottom of the well screen prior to placing the sand pack around the screen. This grout will be allowed to harden for a minimum 12 hour, and preferably 24 hour, period before placing sand pack. A blank riser will extend from the top of the screen to approximately 2.5 feet above grade or, if necessary, just below grade where conditions warrant a flush-mounted monitoring well.

5. When the monitoring well assembly has been set in place and the grout has been placed around the sump (if any), place a washed silica sand pack in the annular space from the bottom of the boring to a height of 1 to 2 feet above the top of the well screen. The sand pack is placed and drilling equipment extracted in increments until the top of the sand pack is at the appropriate depth. The sand pack will be consistent with the screen slot size and the soil particle size in the screened interval, as specified in the Work Plan or FSP. A hydrated bentonite seal (a minimum of 2 feet thick) will then be placed in the annular space above the sand pack. If non-hydrated bentonite is used, the bentonite should be permitted to hydrate in place for a minimum of 30 minutes before proceeding. No coated bentonite pellets will be used in monitoring well drilling or construction. Potable water may be added to hydrate the bentonite if the seal is above the water table. Monitor the placement of the sand pack and bentonite with a weighted tape measure. During the extraction of the augers or casing, a cement/bentonite grout will be placed in the annular space from the bentonite seal to a depth approximately 2 feet bgs.

6. Place a locking, steel protective casing (extended at least 1.5 feet below grade and 2 feet above grade) over the riser casing and secure with a neat Portland Cement seal. Alternatively, for flush-mount completions, place a steel curb box with a bolt-down lid over the riser casing and secure with a neat Portland Cement seal. In either case, the cement seal will extend approximately 1.5 to 2.0 feet below grade and laterally at least 1 foot in all directions from the protective casing, and should slope gently away to promote drainage away from the well. Monitoring wells will be labeled with the appropriate designation on both the inner and outer well casings or inside of the curb box lid.

   When an above-grade completion is used, the PVC riser will be sealed using an expandable locking plug and the top of the well will be vented by drilling a small-diameter (1/8 inch) hole near the top of the well casing or through the locking plug, or by cutting a vertical slot in the top of the well casing. When a flush-mount installation is used, the PVC riser will be sealed using an unvented, expandable locking plug.

7. During well installation, record construction details and actual measurements relayed by the drilling contractor and tabulate materials used (e.g., screen and riser footages; bags of bentonite, cement, and sand) in the field notebook.

8. After completing the well installation, lock the well, clean the area, and dispose of materials in accordance with the procedures outlined in Section VII below.

Direct-Push Method

The direct-push drilling method may also be used to complete soil borings and monitoring wells. Examples of this technique include the Diedrich ESP vibratory probe system or AMS Power Probe® dual-tube system. Environmental probe systems typically use a hydraulically operated percussion hammer. Depending on the equipment used, the hammer delivers 140- to 350-foot pounds of energy with each blow. The hammer provides the force needed to penetrate very stiff/medium dense soil formations. The hammer simultaneously advances

an outer steel casing that contains a dual-tube liner for sampling soil. The outside diameter (OD) of the outer casing ranges from 1.75 to 2.4 inches and the OD of the inner sampling tube ranges from 1.1 to 1.8 inches. The outer casing isolates shallow layers and permits the unit to continue to probe at depth. The double-rod system provides a borehole that may be tremie-grouted from the bottom up. Alternatively, the inside diameter (ID) of the steel casing provides clearance for the installation of small-diameter (e.g., 0.75- to 1-inch ID) micro-wells. The procedures for installing monitoring wells in soil using the direct-push method are described below.

1. Locate boring/well location, establish work zone, and set up sample equipment cleaning area.

2. Advance soil boring to designated depth, collecting samples at intervals specified in the Work Plan. Samples will be collected using dedicated, disposable, plastic liners. Describe samples in accordance with the procedures outlined in Step 2 above. Collect samples for laboratory analysis as specified in the Work Plan and/or FSP.

3. Upon advancing the borehole to the desired depth, install the micro-well through the inner drill casing. The micro-well will consist of approximately 1-inch ID PVC slotted screen and blank riser. The sand pack, bentonite seal, and cement/bentonite grout will be installed as described, where applicable, in Step 4 above.

4. Install protective steel casing or flush-mount, as appropriate, as described in Step 5 above. During well installation, record construction details and tabulate materials used.

5. After completing the well installation, lock the well, clean the area, and dispose of materials in accordance with the procedures outlined in Section VII below.

Driven Well Point Installation

Well points will be installed by pushing or driving using a drilling rig or direct-push rig, or hand-driven where possible. The well point construction materials will consist of a 1- to 2-inch-diameter threaded steel casing with either 0.010- or 0.020-inch slotted stainless steel screen. The screen length will vary depending on the hydrogeologic conditions of the site. The casings will be joined together with threaded couplings and the terminal end will consist of a steel well point. Because they are driven or pushed to the desired depth, well points do not have annular backfill materials such as sand pack or grout.

VII. Waste Management

Investigation-derived wastes, including soil cuttings and excess drilling fluids (if used), decontamination liquids, and disposable materials (well material packages, PPE, etc.), will be placed in clearly labeled, appropriate containers, or managed as otherwise specified in the Work Plan or FSP.

VIII. Data Recording and Management

Drilling activities will be documented in a proper field notebook. Pertinent information will include personnel present on site, times of arrival and departure, significant weather conditions, timing of well installation activities, soil descriptions, well construction specifications (screen and riser material and diameter, sump length, screen length and slot size, riser length, sand pack type), and quantities of materials used.

A field survey control program will be conducted using standard instrument survey techniques to document well or piezometer location, ground, and inner and outer casing elevations. Generally, a local baseline control will be set up. This local baseline control can then be tied into the appropriate vertical and horizontal datum, such as the National Geodetic Vertical Datum of 1929 and the State Plane Coordinate System. At a minimum, the elevation of the top of the inner casing used for water-level measurements should be measured to the nearest

0.01 foot. Elevations will be established in relation to the National Geodetic Vertical Datum of 1929. A permanent mark will be placed on top of the inner casing to mark the point for water-level measurements.

IX. Quality Assurance

All drilling equipment and associated tools (including augers, drill rods, sampling equipment, wrenches, and any other equipment or tools) that may have come in contact with soil will be cleaned in accordance with the procedures outlined in the Field Equipment Cleaning-Decontamination SOP. Well materials will also be cleaned prior to well installation.

X. References

American Society of Testing and Materials (ASTM) D 1586 - *Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils.*

Standard Operating Procedure: Monitoring Well Development

I. Scope and Application

Monitoring wells (or piezometers, well points, or micro-wells) will be developed to clear them of fine-grained sediment and any drilling fluids that may have been used during well installation, and enhance the hydraulic connection between the well and the surrounding geologic formation. Development will be accomplished by evacuating well water by either pumping or bailing. Prior to pumping or bailing, the screened interval will be gently surged using a surge block, bailer, or inertial pump with surge-block fitting. In addition, sediment accumulated in the bottom of the well will be removed by bailing with a bottom-loading bailer.

Pumping methods will be selected based on site-specific geologic conditions, anticipated well yield, water table depth, and groundwater monitoring objectives, and may include one or more of the following:

- submersible pump;
- inertial pump (Waterra™ pump);
- bladder pump;
- peristaltic pump; and
- centrifugal pump.

When developing a well using the pumping method, the pump (or, with inertial pumps, the tubing) is lowered to the screened portion of the well. During purging, the pump or tubing will be moved up and down the screened interval until the well yields relatively clear water.

Submersible pumps have a motor-driven impeller that pushes the water discharge tubing to the ground surface. Inertial pumps have a check valve at the bottom of stiff tubing which, when operated up and down, lifts water to the ground surface. Bladder pumps have a bottom check valve and a flexible internal bladder that fills from below and is then compressed using pressurized air to force water out the top of the bladder through the discharge tubing to the ground surface. These three types of pumps have a wide range of applicability in terms of well depth and water depth. Centrifugal and peristaltic pumps use atmospheric pressure to lift water from the well, and therefore can only be practically used where the depth to water is less than 25 feet.

II. Personnel Qualifications

Monitoring well development activities will be performed by persons who have been trained in proper well development procedures under the guidance of an experienced field geologist, engineer, or technician.

III. Equipment List

Materials for monitoring well development using a pump include:

- health and safety equipment, as required by the site Health and Safety Plan (HASP);
- cleaning equipment;
- photoionization detector (PID) to measure headspace vapors;
- pump;
- polyethylene pump discharge tubing;
- plastic sheeting;
- power source (generator or battery);
- field notebook;
- graduated pails;

- appropriate containers; and
- monitoring well keys.

Materials for monitoring well development using a bailer include:

- personal protective equipment (PPE) as required by the HASP;
- cleaning equipment;
- PID to measure headspace vapors;
- bottom-loading bailer, sand bailer;
- polypropylene or nylon rope;
- plastic sheeting;
- graduated pails;
- appropriate containers; and
- keys to wells.

IV. Cautions

Where surging is performed to assist in removing fine-grained material from the sand pack, surging must be performed in a gentle manner. Excessive suction could promote fine-grained sediment entry into the outside of the sand pack from the formation.

V. Health and Safety Considerations

Field activities associated with monitoring well development will be performed in accordance with a site-specific HASP, a copy of which will be present on site during such activities.

VI. Procedure

1. The procedures for monitoring well development are described below. (Note: Steps 6, 7, and 9 can be performed contemporaneously using an inertial pump with a surge-block fitting.)

2. Don appropriate PPE (as required by the HASP).

3. Place plastic sheeting around the well.

4. Clean all equipment entering each monitoring well, except for new, disposable materials that have not been previously used.

5. Open the well cover while standing upwind of the well, remove well cap. Insert PID probe approximately 4 to 6 inches into the casing or the well headspace and cover with gloved hand. Record the PID reading in the field notebook. If the well headspace reading is less than 5 PID units, proceed; if the headspace reading is greater than 5 PID units, screen the air within the breathing zone. If the PID reading in the breathing zone is below 5 PID units, proceed. If the PID reading is above 5 PID units, move upwind from well for 5 minutes to allow the volatiles to dissipate. Repeat the breathing zone test. If the reading is still above 5 PID units, don the appropriate respiratory protection in accordance with the requirements of the HASP. Record all PID readings.

6. Obtain an initial measurement of the depth-to-water and the total well depth from the reference point at the top of the well casing.

7. Lower a surge block or bailer into the screened portion of the well. Gently raise and lower the surge block or bailer within the screened interval of the well to force water in and out of the screen slots and sand pack.

Continue surging for 15 to 30 minutes. Note that this step is optional but recommended for all new wells/piezometers, particularly in formations with a relatively high content of fine-grained material.

8. Lower a bottom-loading bailer to the bottom of the well and gently bounce the bailer on the bottom of the well to collect accumulated sediment, if any. Remove and empty the bailer. Repeat until the bailed water is free of excessive sediment and the bottom of the well feels solid.

9. After surging the well and removing excess accumulated sediment from the bottom of the well, re-measure the depth-to-water and the total well depth from the reference point at the top of the well casing.

10. Remove formation water by pumping or bailing. Where pumping is used, measure and record the pre-pumping water level. Operate the pump at a relatively constant rate. Measure the pumping rate using a calibrated container and stop watch. Measure and record the water level in the well at least once every 5 minutes during pumping. Note any relevant observations in terms of water color, visual level of turbidity, sheen, odors, etc. Pump or bail for 30 to 60 minutes or until termination criteria specified in the Work Plan or Field Sampling Plan (FSP) are reached. Record the total volume of water purged from the well.

11. If the well goes dry, stop pumping or bailing and allow well to recover. Resume pumping or bailing when sufficient water has recharged the well.

12. Contain all water in appropriate containers.

13. When complete, secure the lid back on the well.

14. Place disposable materials in plastic bags for appropriate disposal and decontaminate reusable, downhole pump components and/or bailer.

VII. Waste Management

Materials generated during monitoring well installation and development will be placed in appropriate containers. Containerized waste will be disposed of by the client.

VIII. Data Recording and Management

Well development activities will be documented in a proper field notebook. Pertinent information will include personnel present on site; times of arrival and departure; significant weather conditions; timing of well development activities; development method(s); observations of purge water color, turbidity, odor, sheen, etc.; purge rate; and water levels before and during pumping.

IX. Quality Assurance

All reused, non-disposable, downhole well development equipment will be cleaned in accordance with the procedures outlined in the Field Equipment Cleaning-Decontamination SOP.

X. References

Not Applicable.

Standard Operating Procedure: Low-Flow Groundwater Purging and Sampling Procedures for Monitoring Wells

I. Scope and Application

Groundwater samples will be collected from monitoring wells to evaluate groundwater quality. The protocol presented in this standard operating procedure (SOP) describes the procedures to be used to purge monitoring wells and collect groundwater samples. This protocol has been developed in accordance with the United States Environmental Protection Agency (USEPA) Region I Low Stress (Low Flow) Purging and Sampling Procedures for the Collection of Groundwater Samples from Monitoring Wells (USEPA SOP No. GW0001; July 30, 1996). Both filtered and unfiltered groundwater samples may be collected using this low-flow sampling method. Filtered samples will be obtained using a 0.45-micron disposable filter. No wells will be sampled until well development has been performed in accordance with the procedures presented in the SOP titled Monitoring Well Development, unless that well has been sampled or developed within the prior 1-year time period. Groundwater samples will not be collected within 1 week following well development.

II. Personnel Qualifications

Low-flow groundwater purging and sampling activities will be performed by persons who have been trained in proper well sampling procedures under the guidance of an experienced field geologist, engineer, or technician. Field personnel will have undergone in-field training in terms of sampling procedures.

III. Equipment List

Specific to this activity, the following materials (or equivalent) will be available:

- Health and safety equipment (as required in the site Health and Safety Plan [HASP]).
- Site Plan, well construction records, prior groundwater sampling records (if available).
- Sampling pump, which may consist of one or more of the following:
  - submersible pump (e.g., Grundfos Redi-Flo 2);
  - peristaltic pump (e.g., ISCO Model 150); and/or
  - bladder pump (e.g., Marschalk System 1).
- Teflon® tubing or polyethylene tubing of an appropriate size for the pump being used. For peristaltic pumps, dedicated Tygon® tubing (or other type as specified by the manufacturer) will also be used through the pump apparatus.
- Water-level probe (e.g., Solinst Model 101).
- Water-quality (temperature/pH/specific conductivity/ORP/turbidity/dissolved oxygen) meter and flow-through measurement cell. Several brands may be used, including:
  - YSI 6-Series Multi-Parameter Instrument;
  - Hydrolab Series 3 or Series 4a Multiprobe and Display; and/or

- Supplemental turbidity meter (e.g., Horiba U-10 or Hach 2100P). Turbidity measurements collected with multi-parameter meters have been shown to sometimes be unreliable due to fouling of the optic lens of the turbidity meter within the flow-through cell. A supplemental turbidity meter will be used to verify turbidity data during purging if such fouling is suspected. Note that industry improvements may eliminate the need for these supplemental measurements in the future.
- Appropriate water sample containers (supplied by the laboratory).
- Appropriate blanks (trip blank supplied by the laboratory).
- 0.45-micron disposable filters.
- Large glass mixing container.
- Teflon® stirring rod.
- Cleaning equipment.
- Groundwater sampling log (attached) or bound field logbook.

Note that in the future, the client may acquire different makes/models of some of this equipment if the listed makes/models are no longer available, or as a result of general upgrades or additional equipment acquisitions. In the event that the client uses a different make/model of the equipment listed, the client will use an equivalent type of equipment (e.g., pumps, flow-through analytical cells) and note the specific make/model of the equipment used during a sampling event on the groundwater sampling log. In addition, should the client desire to change to a markedly different sampling methodology (e.g., discrete interval samplers, passive diffusion bags, or a yet to be developed technique), the client will submit a proposed SOP for the new methodology for USEPA approval prior to implementing such a change.

The maintenance requirements for the above equipment generally involve decontamination or periodic cleaning, battery charging, and proper storage, as specified by the manufacturer. For operational difficulties, the equipment will be serviced by a qualified technician.

IV. Cautions

If heavy precipitation occurs and no cover over the sampling area and monitoring well can be erected, sampling must be discontinued until adequate cover is provided. Rain water could contaminate groundwater samples.

Do not use permanent marker or felt-tip pens for labels on sample container or sample coolers – use indelible ink. The permanent markers could introduce volatile constituents into the samples.

It may be necessary to field filter some parameters (e.g., metals) prior to collection, depending on preservation, analytical method, and project quality objectives.

Check monitoring well logs for use of bentonite pellets. Make note of potential use of bentonite pellets on the groundwater sampling log. Coated bentonite pellets have been found to contaminate monitoring wells.

Store and/or stage empty and full sample containers and coolers out of direct sunlight.

To mitigate potential cross-contamination, groundwater samples are to be collected in a pre-determined order from least impacted to impacted based on previous analytical data. If no analytical data are available, samples are collected in order of upgradient, then furthest downgradient to source area locations.

Be careful not to over-tighten lids with Teflon liners or septa (e.g., 40 mL vials). Over-tightening can impair the integrity of the seal.

V. Health and Safety Considerations

Field activities associated with groundwater purging and sampling will be performed in accordance with a site-specific HASP, a copy of which will be present on site during such activities. If thunder or lighting is present, discontinue sampling until 30 minutes have passed after the last occurrence of thunder or lighting.

VI. Procedure

Groundwater will be purged from the wells using an appropriate pump. Peristaltic pumps will initially be used to purge and sample all wells. If the depth to water is below the sampling range of a peristaltic pump (approximately 25 feet), submersible pumps or bladder pumps will be used provided the well is constructed with a casing diameter greater than or equal to 2 inches (the minimum well diameter capable of accommodating such pumps). For smaller diameter wells where the depth to water is below the sampling range of a peristaltic pump, alternative sampling methods (i.e., bailing) will be used to purge and sample the groundwater. Purge water will be collected and containerized.

1. Calibrate field instruments according to procedures for calibration.

2. Measure initial depth to groundwater prior to placement of pumps. If a submersible or bladder pump is being used, slowly lower pump, safety cable, tubing, and electrical lines into the well to a depth corresponding to the approximate center of the saturated screen section of the well. If a peristaltic pump is being used, slowly lower the sampling tubing into the well to a depth corresponding to the approximate center of the saturated screen section of the well. The pump intake or sampling tube must be kept at least 2 feet above the bottom of the well to prevent mobilization of any sediment present in the bottom of the well.

3. Measure the water level again with the pump in the well before starting the pump. Start pumping the well at 200 to 500 milliliters (mL) per minute. The pump rate should be adjusted to cause little or no water level drawdown in the well (less than 0.3 feet below the initial static depth to water measurement) and the water level should stabilize. The water level should be monitored every 3 to 5 minutes (or as appropriate) during pumping if the well diameter is of sufficient size to allow such monitoring. Care should be taken not to break pump suction or cause entrainment of air in the sample. Record pumping rate adjustments and depths to water. If necessary, pumping rates should be reduced to the minimum capabilities of the pump to avoid pumping the well dry and/or to stabilize indicator parameters. A steady flow rate should be maintained to the extent practicable. Groundwater sampling records from previous sampling events (if available) should be examined to estimate the optimum pumping rate and anticipated drawdown for the well in order to more efficiently reach a stabilized pumping condition.

   If the recharge rate of the well is very low, alternative purging techniques should be used, which will vary based on the well construction and screen position. For wells screened across the water table, the well should be pumped dry and sampling should commence as soon as the volume in the well has recovered sufficiently to permit collection of samples. For wells screened entirely below the water table, the well should be pumped until a stabilized level (which may be below the maximum displacement goal of 0.3 feet) can be maintained and monitoring for stabilization of field indicator parameters can commence. If a lower stabilization level cannot be maintained, the well should be pumped until the drawdown is at a level

slightly higher than the bentonite seal above the well screen. Sampling should commence after one well volume has been removed and the well has recovered sufficiently to permit collection of samples.

During purging, monitor the field indicator parameters (e.g., turbidity, temperature, specific conductance, pH, etc.) every 3 to 5 minutes (or as appropriate). Field indicator parameters will be measured using a flow-through analytical cell or a clean container such as a glass beaker. Record field indicator parameters on the groundwater sampling log. The well is considered stabilized and ready for sample collection when turbidity values remain within 10% (or within 1 NTU if the turbidity reading is less than 10 NTU), the specific conductance and temperature values remain within 3%, and pH remains within 0.1 units for three consecutive readings collected at 3- to 5-minute intervals. If the field indicator parameters do not stabilize within 1 hour of the start of purging, but the groundwater turbidity is below the goal of 50 NTU and the values for all other parameters are within 10%, the well can be sampled. If the parameters have stabilized but the turbidity is not in the range of the 50 NTU goal, the pump flow rate should be decreased to a minimum rate of 100 mL/min to reduce turbidity levels as low as possible. If dissolved oxygen values are not within acceptable range for the temperature of groundwater (Attachment 1), then check for and remove air bubbles on probe or in tubing.

During extreme weather conditions, stabilization of field indicator parameters may be difficult to obtain. Modifications to the sampling procedures to alleviate these conditions (e.g., measuring the water temperature in the well adjacent to the pump intake) will be documented in the field notes. If other field conditions exist that preclude stabilization of certain parameters, an explanation of why the parameters did not stabilize will also be documented in the field logbook.

4. Complete the sample label and cover the label with clear packing tape to secure the label onto the container.

5. After the indicator parameters have stabilized, collect groundwater samples by diverting flow out of the unfiltered discharge tubing into the appropriate labeled sample container. If a flow-through analytical cell is being used to measure field parameters, the flow-through cell should be disconnected after stabilization of the field indicator parameters and prior to groundwater sample collection. Under no circumstances should analytical samples be collected from the discharge of the flow-through cell. When the container is full, tightly screw on the cap. Samples should be collected in the following order: VOCs, TOC, SVOCs, metals and cyanide, and others.

6. If sampling for total and filtered metals and/or PCBs, a filtered and unfiltered sample will be collected. Install an in-line, disposable 0.45-micron particle filter on the discharge tubing after the appropriate unfiltered groundwater sample has been collected. Continue to run the pump until an initial volume of "flush" water has been run through the filter in accordance with the manufacturer's directions (generally 100 to 300 mL). Collect filtered groundwater sample by diverting flow out of the filter into the appropriately labeled sample container. When the container is full, tightly screw on the cap.

7. Secure with packing material and store at 4°C in an insulated transport container provided by the laboratory.

8. Record on the groundwater sampling log or bound field logbook the time sampling procedures were completed, any pertinent observations of the sample (e.g., physical appearance, and the presence or lack of odors or sheens), and the values of the stabilized field indicator parameters as measured during the final reading during purging.

9. Remove pump and tubing from well, secure well, properly dispose of personal protective equipment (PPE) and disposable equipment.

10. If tubing is to be dedicated to a well, it should be folded to a length that will allow the well to be capped and also facilitate retrieval of the tubing during later sampling events. A length of rope or string should be used to tie the tubing to the well cap.

11. Complete the procedures for packaging, shipping, and handling with associated chain-of-custody.

12. Complete cleaning procedures for flow-through analytical cell and submersible pump, as appropriate.

13. At the end of the day, perform calibration check of field instruments.

If it is not technically feasible to use the low-flow sampling method, purging and sampling of monitoring wells may be conducted using the bailer method as outlined below:

1. Don appropriate PPE (as required by the HASP).

2. Place plastic sheeting around the well.

3. Clean sampling equipment.

4. Open the well cover while standing upwind of the well. Remove well cap and place on the plastic sheeting. Insert PID probe approximately 4 to 6 inches into the casing or the well headspace and cover with gloved hand. Record the PID reading in the field log. If the well headspace reading is less than 5 PID units, proceed; if the headspace reading is greater than 5 PID units, screen the air within the breathing zone. If the breathing zone reading is less than 5 PID units, proceed. If the PID reading in the breathing zone is above 5 PID units, move upwind from well for 5 minutes to allow the volatiles to dissipate. Repeat the breathing zone test. If the reading is still above 5 PID units, don appropriate respiratory protection in accordance with the requirements of the HASP. Record all PID readings. For wells that are part of the regular weekly monitoring program and prior PID measurements have not resulted in a breathing zone reading above 5 PID units, PID measurements will be taken monthly.

5. Measure the depth to water and determine depth of well by examining drilling log data or by direct measurement. Calculate the volume of water in the well (in gallons) by using the length of the water column (in feet), multiplying by 0.163 for a 2-inch well or by 0.653 for a 4-inch well. For other well diameters, use the formula:

   Volume (in gallons) = π TIMES **well radius** (in feet) **squared** TIMES **length of water column** (in feet) TIMES **7.481** (gallons per cubic foot)

6. Measure a length of rope at least 10 feet greater than the total depth of the well. Secure one end of the rope to the well casing and secure the other end to the bailer. Test the knots and make sure the rope will not loosen. Check bailers so that all parts are intact and will not be lost in the well.

7. Lower bailer, submersible pump, or peristaltic pump tubing (whichever is applicable) into well and remove one well volume of water. Contain all water in appropriate containers.

8. Monitor the field indicator parameters (e.g., turbidity, temperature, specific conductance, and pH). Measure field indicator parameters using a clean container such as a glass beaker or sampling cups provided with the instrument. Record field indicator parameters on the groundwater sampling log.

9. Repeat Steps 7 and 8 until three or four well volumes have been removed. Examine the field indicator parameter data to determine if the parameters have stabilized. The well is considered stabilized and ready for sample collection when turbidity values remain within 10% (or within 1 NTU if the turbidity reading is

less than 10 NTU), the specific conductance and temperature values remain within 3%, and pH remains within 0.1 units for three consecutive readings collected once per well volume removed.

10. If the field indicator parameters have not stabilized, remove a maximum of five well volumes prior to sample collection. Alternatively, five well volumes may be removed without measuring the field indicator parameters.

11. If the recharge rate of the well is very low, wells screened across the water table may be bailed dry and sampling should commence as soon as the volume in the well has recovered sufficiently to permit collection of samples. For wells screened entirely below the water table, the well should only be bailed down to a level slightly higher than the bentonite seal above the well screen. The well should not be bailed completely dry, to maintain the integrity of the seal. Sampling should commence as soon as the well volume has recovered sufficiently to permit sample collection.

12. Following purging, allow water level in well to recharge to a sufficient level to permit sample collection.

13. Complete the sample label and cover the label with clear packing tape to secure the label onto the container.

14. Slowly lower the bailer into the screened portion of the well and carefully retrieve a filled bailer from the well causing minimal disturbance to the water and any sediment in the well.

15. The sample collection order (as appropriate) will be as follows:

    a. VOCs;
    b TOC;
    c. SVOCs;
    d. metals and cyanide; and
    e. others.

16. When sampling for volatiles, collect water samples directly from the bailer into 40-mL vials with Teflon®-lined septa.

17. For other analytical samples, remove the cap from the large glass mixing container and slowly empty the bailer into the large glass mixing container. The sample for dissolved metals and/or filtered PCBs should either be placed directly from the bailer into a pressure filter apparatus or pumped directly from the bailer with a peristaltic pump, through an in-line filter, into the pre-preserved sample bottle.

18. Continue collecting samples until the mixing container contains a sufficient volume for all laboratory samples.

19. Mix the entire sample volume with the Teflon® stirring rod and transfer the appropriate volume into the laboratory jar(s). Secure the sample jar cap(s) tightly.

20. If sampling for total and filtered metals and/or PCBs, a filtered and unfiltered sample will be collected. Sample filtration for the filtered sample will be performed in the field using a peristaltic pump prior to preservation. Install new medical-grade silicone tubing in the pump head. Place new Teflon® tubing into the sample mixing container and attach to the intake side of pump tubing. Attach (clamp) a new 0.45-micron filter (note the filter flow direction). Turn the pump on and dispense the filtered liquid directly into the laboratory sample bottles.

21. Secure with packing material and store at 4°C in an insulated transport container provided by the laboratory.

22. After sample containers have been filled, remove one additional volume of groundwater. Measure the pH, temperature, turbidity, and conductivity. Record on the groundwater sampling log or bound field logbook the time sampling procedures were completed, any pertinent observations of the sample (e.g., physical appearance, and the presence or lack of odors or sheens), and the values of the field indicator parameters.

23. Remove bailer from well, secure well, and properly dispose of PPE and disposable equipment.

24. If a bailer is to be dedicated to a well, it should be secured inside the well above the water table, if possible. Dedicated bailers should be tied to the well cap so that inadvertent loss of the bailer will not occur when the well is opened.

25. Complete the procedures for packaging, shipping, and handling with associated chain-of-custody.

VII. Waste Management

Materials generated during groundwater sampling activities, including disposable equipment, will be placed in appropriate containers. Containerized waste will be disposed of by the client consistent with the procedures identified in the HASP.

VIII. Data Recording and Management

Sampling activities will be documented in a proper field notebook. Pertinent information will include personnel present on site; times of arrival and departure; significant weather conditions; timing of well sampling activities; observations of purge water color, turbidity, odor, sheen, etc.; purge rate; water levels before and during pumping; field parameters measured; sampling method used and analytical samples collected. Initial field logs and chain-of-custody records will be transmitted to the ARCADIS BBL PM at the end of each day unless otherwise directed by the PM. The groundwater team leader retains copies of the groundwater sampling logs.

IX. Quality Assurance

In addition to the quality control samples to be collected in accordance with this SOP, the following quality control procedures should be observed in the field:

- Collect samples from monitoring wells in order of increasing concentration, to the extent known.
- Equipment blanks should include the pump and tubing (if using disposable tubing) or the pump only (if using tubing dedicated to each well).
- Collect equipment blanks after wells with higher concentrations (if known) have been sampled.
- Operate all monitoring instrumentation in accordance with manufacturer's instructions and calibration procedures. Calibrate instruments at the beginning of each day and verify the calibration at the end of each day.
- Clean all groundwater sampling equipment prior to use in the first well and after each subsequent well using procedures for equipment decontamination.

X. References

United States Environmental Protection Agency (USEPA) Region I Low Stress (Low Flow) Purging and Sampling Procedures for the Collection of Groundwater Samples from Monitoring Wells (USEPA SOP No. GW0001; July 30, 1996).

USEPA. 1986. RCRA Groundwater Monitoring Technical Enforcement Guidance Document (September 1986).

USEPA. 1991. Handbook Groundwater, Volume ii Methodology, Office of Research and Development, Washington, DC. USEPN62S, /6-90/016b (July, 1991).

U.S. Geological Survey (USGS). 1977. National Handbook of Recommended Methods for Water-Data Acquisition: USGS Office of Water Data Coordination. Reston, Virginia.

Standard Operating Procedure: Test Pit Excavation

I. Scope and Application

Test pits will be excavated using a decontaminated, rubber-tired backhoe. Test pits may be performed based on the need to identify subsurface structures, facilitate the collection of soil samples that cannot be collected by soil borings, and areas requiring subsurface characterization for design or implementation. Personnel should stand upwind of the excavation area to the extent possible. Continuous air monitoring will be conducted as indicated in the site Health and Safety Plan (HASP). Excavating will be conducted at the selected locations that have been cleared for utilities until significant source materials, groundwater, or bedrock is encountered, or to within the physical limits of the backhoe. Test pit materials will be visually observed and described with respect to depth. Photographs of the soil will be taken for future reference.

II. Personnel Qualifications

Test pit excavation activities will be overseen by a person or persons who have been trained in excavation and competent person training. Where field sampling is performed for soil characterization, field personnel will have undergone in-field training in terms of soil classification.

III. Equipment List

The following equipment will be available, as required, during GPR surveys:

- rubber-tired backhoe;
- stainless steel shovel, scoop, hand auger, or trowel;
- polyethylene sheeting; and
- ground stakes.

IV. Cautions

Prior to beginning field work, underground utilities in the vicinity of the drilling areas will be delineated by the drilling contractor or an independent underground utility locator service. See separate SOP for utility clearance.

V. Health and Safety Considerations

Field activities associated with test pit excavation will be performed in accordance with a site-specific HASP, a copy of which will be present on site during such activities.

VI. Procedures

Where necessary to characterize soil conditions, soil will be collected in one of two manners:

1. If the excavation is less than 3 feet deep, the sample may be collected directly from the sidewall of the test pit with a decontaminated stainless steel shovel, scoop, or hand auger.

2. If the test pit is deeper than 3 feet, the soil sample will be collected from the backhoe bucket, either directly or with a decontaminated stainless steel scoop or trowel.

Samples should be homogenized, if appropriate.

Material removed from the test pit during excavation will be placed on polyethylene sheeting. Visually clean soils (i.e., cap materials) will be segregated from soils that may contain source materials. Upon completion, the materials from the test pits will be placed back into the excavation. The visually clean soils, if any, will be used to cover the source materials in the excavation. To facilitate surveying, the location of the pit will be marked with stakes after it has been backfilled. Stakes should be placed at the ends of the test pit and at any significant bend or corner, as appropriate.

VII. Data Recording and Management

Test pit activities will be documented in a proper field notebook. Pertinent information will include personnel present on site, times of arrival and departure, significant weather conditions, timing of excavation activities, soil descriptions, and equipment used.

A field survey control program will be conducted using standard instrument survey techniques to document the edges of the excavation. Generally, a local baseline control will be set up. This local baseline control can then be tied into the appropriate vertical and horizontal datum, such as the National Geodetic Vertical Datum of 1929 and the State Plane Coordinate System. Elevations will be established in relation to the National Geodetic Vertical Datum of 1929. Stakes or other appropriate markers will be placed on the ends of the test pit and/or a paint mark will be used to identify the limits of excavation.

VIII. Quality Assurance

All excavation equipment and associated tools (including hand tools) that may have come in contact with soil will be cleaned in accordance with the procedures outlined in the Field Equipment Cleaning-Decontamination SOP.

IX. References

Not Applicable.

Standard Operating Procedure: Chain-of-Custody, Handling, Packing, and Shipping

I. Scope and Application

This Standard Operating Procedure (SOP) describes the chain-of-custody, handling, packing, and shipping procedures for the delivery of samples that are protected from cross-contamination, tampering, mis-identification, and breakage, and are maintained in a controlled environment from the time of collection until receipt by the analytical laboratory.

II. Personnel Qualifications

BBL field sampling personnel will have current health and safety training, including 40-hour HAZWOPER training, site supervisor training, and site-specific training, as needed. In addition, BBL field sampling personnel will be versed in the relevant SOPs and possess the skills and experience necessary to successfully complete the desired field work.

III. Equipment List

The following materials, as required, will be available during chain-of-custody, handling, packing, and shipping procedures:

- indelible ink pens;
- polyethylene bags (resealable-type);
- clear packing tape, strapping tape, duct tape;
- custody seal evidence tape;
- appropriate sample containers, labels, and chain-of-custody forms;
- large (30 to 40 gallon) insulated coolers;
- ice;
- cushioning and absorbent material (i.e., vermiculite);
- thermometer; and
- field notebook.

IV. Cautions

If methanol preservation is used in soil samples, shipping containers must not exceed 500 mL total volume of methanol and must be labeled **"This package conforms to 49 CFR 173.4."**

V. Health and Safety Considerations

Follow health and safety procedures outlined in the site Health and Safety Plan (HASP).

VI. Procedures

Chain-of-Custody Procedures

1. Prior to collecting samples, complete the chain-of-custody record (Attachment 1 or laboratory equivalent) header information by filling in the project number, project name, and the name(s) of the sampling technician(s). Please note it is important that chain-of-custody information is printed legibly using indelible ink.

2. After sample collection, enter the individual sample information by filling in the following chain-of-custody fields:

   a. **STA. NO.** Indicates the station number or location that the sample was collected from. Appropriate values for this field include well locations, grid points, or soil boring identification numbers (e.g., MW-3, X-20, SB-30).

   b. **Date.** Indicates the date the sample was collected. The date format to be followed should be mm/dd/yyyy (e.g., 03/07/2005).

   c. **Time.** Indicates the time the sample was collected. The time value should be presented using military format. For example, 3:15 P.M. should be entered as 15:15.

   d. **Comp.** This field should be marked with an "X" if the sample was collected as a composite.

   e. **Grab.** This field should be marked with an "X" if the sample was collected as an individual grab sample.

   f. **Station Location.** This field should represent the complete sample name; although in some instances, it may be similar to the "STA. NO." field. An example of a complete sample name is "SB-3 (0.5-1.0)," where the 0.5-1.0 represents the depth interval in feet from where the sample was collected. Please note it is very important that the use of hyphens in sample names and depth units (i.e., feet or inches) remain consistent for all samples entered on the chain-of-custody form. Sample names may also use the abbreviations "MS/MSD," "FB," "TB," and "DUP" as prefixes or suffixes to indicate that the sample is a matrix spike/matrix spike duplicate, field blank, trip blank, or field duplicate, respectively.

   g. **Number of Containers.** This field represents the number of containers collected at the sampling location to be submitted for analysis.

   h. **Analytical Parameters.** The analytical parameters that the samples are being analyzed for should be written legibly on the diagonal lines to the right of the "number of containers" column. As much detail as possible should be presented to allow the analytical laboratory to properly analyze the samples. For example, polychlorinated biphenyl (PCB) analyses may be represented by entering "PCBs" or "Method 8082." Multiple methods and/or analytical parameters may be combined for each column (e.g., PCBs/VOCs/SVOCs or 8082/8260/8270). These columns should also be used to present project-specific parameter lists (e.g., Appendix IX+3 target analyte list or MADEP SW-846). Quality assurance/quality control (QA/QC) information may also be entered in a separate column for each parameter (e.g., PCBs - MS/MSD) to identify a sample that the laboratory is to use for a specific QA/QC requirement. Each sample that requires a particular parameter analysis will be identified by placing an "X" in the appropriate analytical parameter column.

   i. **Remarks.** The remarks field should be used to communicate special analytical requirements to the laboratory. These requirements may be on a per sample basis such as "extract and hold sample until

notified," or may be used to inform the laboratory of special reporting requirements for the entire sample delivery group (SDG). Reporting requirements that should be specified in the remarks column include: 1) turnaround time; 2) contact and address where data reports should be sent; 3) name of laboratory project manager; and 4) type of sample preservation used.

j. **Relinquished By.** This field should contain the signature of the sampling technician who relinquished custody of the samples to the shipping courier or the analytical laboratory.

k. **Date.** Indicates the date the samples were relinquished. The date format should be mm/dd/yyyy (e.g., 03/07/2005).

l. **Time.** Indicates the time the samples were relinquished. The time value should be presented using military format. For example, 3:15 P.M. should be entered as 15:15.

m. **Received By.** This field should contain the signature of the sample courier or laboratory representative who received the samples from the sampling technician.

3. Complete as many chain-of-custody forms as necessary to properly document the collection and transfer of the samples to the analytical laboratory.

4. Upon completing the chain-of-custody forms, forward two copies to the analytical laboratory and retain one copy for the field records.

Handling Procedures

1. After completing the sample collection procedures, record the following information in the field notebook with indelible ink:

   - project number and site name;
   - sample identification code and other sample identification information, if appropriate;
   - sampling method;
   - date;
   - name of sampler(s);
   - time;
   - location (project reference); and
   - any comments.

2. Fill in sample label with the following information in indelible ink:

   - sample type (e.g., surface water);
   - project number and site name;
   - sample identification code and other sample identification information, if applicable;
   - analysis required;
   - date;
   - time sampled;
   - initials of sampling personnel;
   - sample type (composite or discrete);
   - tissue preparation procedure (biota; e.g., fillets, whole body), if applicable; and
   - preservative added, if applicable.

3. Cover the label with clear packing tape to secure the label onto the container.

4. Check the caps on the sample containers to seal them tightly.

5. Wrap the sample container cap with clear packing tape to prevent it from becoming loose.

6. Place a signed custody seal label over the cap such that the cap cannot be removed without breaking the custody seal. Alternatively, if shipping several containers in a cooler, custody seal evidence tape may be placed on the shipping container as described below.

Packing Procedures

1. Using duct tape, secure the outside and inside of the drain plug at the bottom of the cooler being used for sample transport.

2. Place each container or package in individual polyethylene bags (resealable-type) and seal. If a cooler temperature blank is supplied by the laboratory, it should be packaged following the same procedures as the samples. If the laboratory did not include a temperature blank, do not add one since the sample temperature will be determined by the laboratory using a calibrated infrared thermometer.

3. Place 1 to 2 inches of cushioning material (i.e., vermiculite) at the bottom of the cooler.

4. Place the sealed sample containers upright in the cooler.

5. Package ice or blue ice in small resealable-type plastic bags and place loosely in the cooler. Do not pack ice so tightly that it may prevent the addition of sufficient cushioning material. Samples placed on ice will be cooled to and maintained at a temperature of approximately 4°C.

6. Fill the remaining space in the cooler with cushioning/absorbent material. The cooler must be securely packed and cushioned in an upright position and be surrounded by a sorbent material capable of absorbing spills from leaks or breakage of sample containers. (Note: to comply with 49 CFR 173.4, filled cooler must not exceed 64 pounds).

7. Place the completed chain-of-custody record(s) in a large resealable-type bag and tape the bag to the inside of the cooler lid.

8. Close the lid of the cooler and fasten with packing tape.

9. Wrap strapping tape around both ends of the cooler.

10. Mark the cooler on the outside with the following information: shipping address, return address, "Fragile, Handle with Care" labels on the top and on one side, and arrows indicating "This Side Up" on two adjacent sides.

11. Place custody seal evidence tape over front right and back left of the cooler lid and cover with clear plastic tape.

Note: Procedure numbers 2, 3, 5, and 6 may be modified in cases where laboratories provide customized shipping coolers. These coolers are designed so the sample bottles and ice packs fit snugly within preformed styrofoam cushioning and insulating packing material.

Shipping Procedures

1. All samples will be delivered by an express carrier within 48 hours of sample collection. Alternatively, a laboratory courier may be used for sample pickup. If parameters with short holding times are being analyzed (e.g., VOCs [EnCore™ Sampler], nitrate, ortho-phosphate [dissolved], and BOD), sampling personnel will take precautions so that the maximum holding times for these parameters will not be exceeded.

2. The following chain-of-custody procedures will apply to sample shipping:

   - Relinquish the sample containers to the laboratory via express carrier or laboratory courier. The signed and dated forms should be included in the cooler. The express carrier will not be required to sign the chain-of-custody forms.

   - When the samples are received by the laboratory, laboratory personnel will complete the chain-of-custody by recording the date and time of receipt of samples, measuring and recording the internal temperature of the shipping container, and checking the sample identification numbers on the containers to ensure they correspond with the chain-of-custody forms.

VII. Waste Management

Not applicable.

VIII. Data Recording and Management

Copies of chain-of-custody forms will be maintained in the project file.

IX. Quality Assurance

Chain-of-custody forms will be filled out in accordance with the Quality Assurance Project Plan (QAPP). A copy of the completed chain-of-custody form forwarded with the samples to the laboratory will be sent to the Project Manager for review. Subsequent chain-of-custody form submissions to the Project Manager will be at the Project Manager's discretion.

X. References

Not applicable.

ATTACHMENT 1

ARCADIS
Infrastructure, environment, facilities

ID#:

CHAIN OF CUSTODY & LABORATORY ANALYSIS REQUEST FORM

Page ___ of ___

Lab Work Order #

Send Results to:

Contact & Company Name:
Telephone:
Address:
Fax:
City State Zip
E-mail Address:
Project Name/Location (City, State):
Project #:
Sampler's Printed Name:
Sampler's Signature:

Preservation
Filtered (Y)
# of Containers
Container Description

PARAMETER ANALYSIS & METHOD

Keys
Preservation Key: A - H2SO4, B - HCl, C - HNO3, D - NaOH, E - None, F - Other, G - Other, H - Other
Container Description Key: 1 - 40 ml Vial, 2 - 1 L Amber, 3 - 250 ml Plastic, 4 - 500 ml Plastic, 5 - Encore, 6 - 2 oz. Glass, 7 - 4 oz. Glass, 8 - 8 oz. Glass, 9 - Other
Matrix Key: SO - Soil, W - Water, T - Tissue, SD - Sediment, A - Air, NL - NAPL/Oil, SW - Sample Wipe, Other

Sample ID	Collection Date	Collection Time	Type (✓) Comp	Type (✓) Grab	Matrix	REMARKS

Special Instructions/Comments:

☐ Special QA/QC Instructions(✓):

Laboratory Information and Receipt		Relinquished By	Received By	Relinquished By	Laboratory Received By
Lab Name:	Cooler Custody Seal (✓)	Printed Name:	Printed Name:	Printed Name:	Printed Name:
☐ Cooler packed with ice (✓)	☐ Intact ☐ Not Intact	Signature:	Signature:	Signature:	Signature:
Specify Turnaround Requirements:	Sample Receipt (✓)	Firm:	Firm/Courier:	Firm/Courier:	Firm:
Shipping Tracking #:	Condition/Cooler Temp:	Date/Time:	Date/Time:	Date/Time:	Date/Time:

2073668M CoC AR Form 01.12.2007

Distribution: WHITE – Laboratory returns with results YELLOW – Lab copy PINK – Retained by BBL

ARCADIS BBL

Appendix C

DNAPL Contingency Plan

Standard Operating Procedure: DNAPL Contingency Plan

I. Scope and Application

This document has been prepared to guide drilling activities at sites where there is a reasonable expectation that dense, non-aqueous phase liquid (DNAPL) may be present, and provide procedures to be implemented in the event that DNAPL is encountered during subsurface investigations. These procedures are proposed to limit the potential of remobilizing DNAPL, if any, in response to drilling and sampling activities. In addition, the procedures are designed to optimize the recovery of encountered DNAPL (if any) in a safe and efficient manner. This DNAPL Contingency Plan was developed based on a similar document prepared by DNAPL expert Bernard H. Kueper, Ph.D., P.Eng., of Queens University, for an EPA Region 1 Superfund Site (Kueper, May 1995).

Downward DNAPL mobilization from overburden into the bedrock may occur in response to drilling activities (short-circuiting along drill stem and/or completed well screen) and groundwater extraction (creation of downward hydraulic gradient in excess of previously measured downward gradients). This DNAPL Contingency Plan addresses drilling-related issues.

II. Personnel Qualifications

DNAPL contingency field activities will be performed by persons who have been trained in proper drilling and well installation procedures under the guidance of an experienced field geologist, engineer, or technician.

III. Equipment List

The following materials will be available during soil boring and monitoring well installation activities, as required:

- Work Plan, Field Sampling Plan (FSP), and site Health and Safety Plan (HASP);
- personal protective equipment (PPE), as required by the HASP;
- equipment specified under drilling and well installation SOPs;
- hydrophobic dye (Oil Red O or Sudan IV), pertinent at chlorinated solvent sites;
- disposable polyethylene pans for performing soil-water pan tests; and
- clean, empty jars for performing soil-water shake tests.

IV. Cautions

The presence or absence of DNAPL at a site can have significant implications in terms of site management, health and safety, and the feasibility of potential remedial alternatives. Therefore, field personnel must be attentive to the potential for DNAPL, recognize when DNAPL is encountered during drilling, and accurately document field observations indicating the presence of DNAPL and interpreted DNAPL depth. In addition, opportunities to characterize DNAPL, when present, may be rare. When practicable, DNAPL samples should be collected and analyzed for physical and chemical characteristics.

V. Health and Safety Considerations

Field activities associated with this DNAPL Contingency Plan will be performed in accordance with the site HASP, a copy of which will be present on site during such activities.

VI. Procedure

DNAPL Screening During Overburden Drilling

To screen for the potential presence of DNAPL in soil, drilling procedures must allow for high-quality porous media samples to be taken. Split-spoon samples or direct-push samplers should be taken continuously in 2-foot intervals ahead of the auger or drill casing. Upon opening each split-spoon sampler or direct-push plastic liner sleeve, the soil will immediately be screened for the presence of organic vapors using a portable photoionization detector (PID) or organic vapor analyzer (OVA). During screening, the soil will be split open using a clean spatula or knife and the PID or OVA probe will be placed in the opening and covered with a gloved hand. Such readings will be obtained along the entire length of the sample.

If the PID or OVA examination reveals the presence of organic vapors above 100 parts per million (ppm), the sample will undergo further detailed evaluation for visible non-aqueous phase liquid (NAPL). The assessment for NAPL will include a combination of the following tests/observations:

- Evaluation for Visible NAPL Sheen or Free-Phase NAPL in Soil Sampler – The NAPL sheen will be a colorful iridescent appearance on the soil sample. NAPL may also appear as droplets or continuous accumulations of liquid with a color typically ranging from yellow to brown to black, depending on the type of NAPL. Creosote DNAPL (associated with wood-treating sites) and coal-tar DNAPL (associated with manufactured gas plant [MGP] sites) are typically black and have a characteristic, pungent odor. Pure chlorinated solvents may be colorless in the absence of hydrophobic dye. Solvents mixed with oils may appear brown.

- Soil-Water Pan Test – A portion of the selected soil interval with the highest PID or OVA reading > 100 ppm will be placed in a disposable polyethylene dish along with a small volume of potable or distilled water. The dish will be gently tilted back and forth to mix the soil and water, and the surface of the water will be viewed in natural light to observe the development of a sheen, if any. A small quantity of Oil Red O or Sudan IV hydrophobic dye powder will be added and the soil and dye will be manually mixed for approximately 30 to 60 seconds and smeared in the dish to create a paste-like consistency using a new nitrile glove-covered hand. A positive test result will be indicated by a sheen on the surface of the water and/or a bright red color imparted to the soil following mixing with dye.

- Soil-Water Shake Test – A small quantity of soil (up to 15 cc) will be placed in a clear, colorless, 40-mL vial containing an equal volume of potable or distilled water. After the soil settles into the water, the surface of the water will be evaluated for a visible sheen. The jar will be closed and gently shaken for approximately 10 to 20 seconds. Again, the surface of the water will be evaluated for a visible sheen or a temporary layer of foam. A small quantity (approximately 0.5 to 1 cc) of Oil Red O or Sudan IV powder will be placed in the jar. The sheen layer will be evaluated for a reaction to the dye (change to bright red color). The jar will be closed and gently shaken for approximately 10 to 20 seconds. The contents in the closed jar will be examined for visible bright red dyed liquid inside the jar. A positive test result will be indicated by the presence of a visible sheen and foam on the surface of water, a reaction between the dye and the sheen layer upon first addition of the dye powder, a bright red coating the inside of the vial (particularly above the water line), or red-dyed droplets within the soil.

- Estimation of Relative Degree of NAPL Saturation – When NAPL is interpreted as present in a particular portion of soil, the field geologist will attempt to estimate the relative degree of NAPL saturation in the soil. Specifically, based on the apparent, visible continuity of NAPL within the soil, an interpretation will be made as to whether the observed NAPL is pooled (continuous section of soil across entire diameter of soil sample in which the pore spaces are filled with a mixture of NAPL and water) or residual (isolated droplets or blebs of NAPL, surrounded by pore spaces containing only water).

If NAPL is obviously present upon opening the soil sampler or evaluating the soil sample within the split-spoon sampler or direct-push liner sleeve, it is not necessary to perform a soil-water pan test or soil-water shake test. In addition, it is not necessary to perform both a soil-water pan test and a soil-water shake test. Either test method is acceptable. The pan test may be preferred in some circumstances because the presence of sheen may be easier to see on a wider surface.

The results of each test or observation will be recorded in the field notebook.

DNAPL Screening During Bedrock Drilling

To screen for the potential presence of DNAPL in bedrock, drilling fluids, rock cuttings, and/or core samples are monitored for the presence of sheens. During drilling using rotary methods (coring or roller bit drilling with water or drilling mud), the return fluid will be screened with a PID or OVA and evaluated continuously for the presence of a sheen in the recirculation tub. Where core samples are obtained, they will be carefully evaluated for the presence of sheen on fracture surfaces. During drilling using air-rotary methods, rock cuttings will be continuously screened using a PID or OVA and evaluated for the presence of sheen. During drilling with rotary methods, the positive head level at the borehole will reduce the potential for DNAPL short-circuiting via the borehole.

If a sheen is observed with any of these methods, drilling will be temporarily discontinued and an evaluation will be undertaken to determine whether pooled DNAPL is present. The drill stem will be retracted to a few feet above the apparent depth where the sheen was first encountered. Groundwater will be extracted from the borehole to produce a drawdown of 5 to 10 feet below the approximate static, non-pumping water level for a period of 20 minutes to test for the presence of pooled, mobilizable DNAPL in the fractures surrounding the open borehole. The bottom of the borehole will then be evaluated for the presence of DNAPL using an interface probe or bottom-loading bailer. If no DNAPL is observed, the interpretation will be made that the sheen was not produced by pooled DNAPL. In this case, if drilling by the rotary method, the recirculation water will be replaced by clean water and drilling will continue. Replacing the recirculation water reduces the potential for cross-contamination and facilitates observation of a newly created sheen, if any, at a deeper interval. Accumulation of DNAPL in the bottom of the borehole, however, indicates that the boring has encountered pooled DNAPL. If DNAPL has accumulated, it will be removed using a bottom-loading bailer or pump.

Data Collection Below Zone Containing Pooled DNAPL

If pooled DNAPL is encountered in a borehole and deeper drilling is required to collect data below a zone containing pooled DNAPL, one of the following actions will be taken.

1. Adjustment of Drilling Location - The boring where pooled DNAPL was encountered will be abandoned by tremie grouting using neat cement grout and a replacement boring will be re-attempted at a nearby location.

2. DNAPL Sump Installation - A DNAPL collection well will be installed with a blank sump properly grouted in place below the screen and the boring will be re-attempted at a nearby location. In this case, after removing the DNAPL in the borehole, the boring may be advanced an additional 2 to 3 feet to accommodate a blank sump below the interval with apparent pooled DNAPL.

3. Casing Off DNAPL Layers - If pooled DNAPL is found to be present throughout an area where deeper drilling is essential, a permanent, grouted casing should be installed. The bottom of the pooled DNAPL likely coincides with the top of a relatively fine-grained, low permeability, stratum (capillary barrier). Permanent casing will be installed to the bottom of the borehole and grouted in place using the displacement method prior to advancing the borehole any further. In this case, after removing any DNAPL that may have accumulated in the borehole, the boring may be advanced a few feet into the top of the underlying confining layer or up to 5 feet in bedrock prior to grouting the casing to assist in isolating the zone containing apparently pooled DNAPL. When the casing is grouted in place and the grout has set, the drilling recirculation water will be replaced with clean water to prevent cross-contamination and facilitate observation of a newly created sheen (if any) at a deeper interval, and drilling will continue.

DNAPL Monitoring

New wells installed in borings where DNAPL was encountered during drilling will be monitored for DNAPL accumulation in the DNAPL sump using an oil-water interface probe or bottom-loading bailer within approximately one day following initial installation. If DNAPL is encountered, a bottom-loading bailer or pump will be used to remove the DNAPL, the final DNAPL thickness will be recorded, and the DNAPL thickness will be reassessed after another day of accumulation (if any). This process will be repeated until DNAPL no longer accumulates overnight, at which point the accumulation monitoring and removal period will extend to one-week intervals. If no DNAPL accumulation is observed over a period of one week, further DNAPL monitoring may be continued with a longer period between monitoring events.

Any DNAPL recovered during drilling and monitoring activities should be analyzed for chemical composition, DNAPL-water interfacial tension, density, and viscosity. The physical tests should be performed at the approximate groundwater temperature at the site where the DNAPL sample was obtained, typically between 10°C and 20°C. These parameters will allow for correlation of groundwater chemistry with suspected DNAPL locations and will allow an estimate to be made of the volume and potential mobility of DNAPL, if any, in the formation.

VII. Waste Management

DNAPL removed from wells will be temporarily stored on-site in metal drums for subsequent appropriate off-site disposal. The locations and volumes of recovered DNAPL will be noted.

VIII. Data Recording and Management

Any occurrence of DNAPL encountered during subsurface investigations will be documented in an appropriate field notebook in terms of the drilling location (boring or well identification), depth below surface, type of geologic material DNAPL was observed within, field screening and testing results, and apparent degree of DNAPL saturation (pooled or residual). DNAPL locations and depths will be recorded on subsurface log forms, as appropriate.

IX. Quality Assurance

DNAPL can be mobilized downward as a result of drilling operations. It is very difficult to drill through DNAPL without bringing about vertical DNAPL mobilization. This opinion is stated by USEPA (1992): "In DNAPL zones, drilling should generally be minimized and should be suspended when a potential trapping layer is first encountered. Drilling through DNAPL zones into deeper stratigraphic units should be avoided." The DNAPL screening procedure outlined in this plan should, therefore, be implemented while drilling at all locations and depths within overburden or bedrock where potential DNAPL presence is suspected. If data collection is

required below a zone containing DNAPL, the interval containing DNAPL will be cased off prior to drilling deeper.

X. References

Kueper, B.H., May 11, 1995. DNAPL Contingency Plan. [Prepared at the request of *de maximis, inc.*].

United States Environmental Protection Agency (USEPA), 1992. Memorandum from D. Clay: Considerations in Ground-Water Remediation at Superfund Sites and RCRA Facilities – Update. OSWER Directive No. 9283.1-06.

Appendix D

Quality Assurance Project Plan

(refer to CD at Appendix C)

ARCADIS BBL

Appendix E

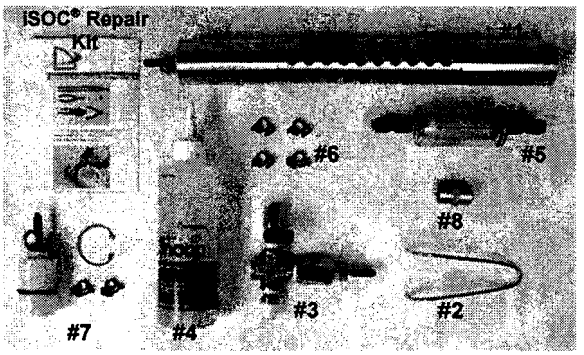
iSOC® System Installation

iSOC® Technology

iSOC® Installation Specification Sheet

ITEMS SUPPLIED PER iSOC® WITH iSOC® SYSTEM:

1. iSOC® unit.
2. iSOC® tool for use when opening drain plug (1 per distribution header).
3. Distribution header complete with regulator connector, bleed valve and iSOC® valve connections.
4. Snoop Liquid Leak Detector (1 per distribution header).
5. 1 filter (default type 'A' for ¼" OD tubing).
6. 4 black hose clamps: 2 used at distribution header barb connection (install hose clamps opposing each other), 1 used at iSOC® barb connection (1 spare).
7. 1 iSOC® repair kit: 1 iSOC® flow-control valve, 1 stainless steel snap ring, 2 plastic hose clamps, 1 direction sheet.
8. Optional ¼" FPT connector for distribution header



NOTE: Part descriptions can be found at www.isocinfo.com.

ITEMS NEEDED TO BE ACQUIRED FOR iSOC® SYSTEM INSTALLATION:

- Two-stage low flow regulator with ¼" NPT female outlet or ¼" NPT male outlet.
- Gas cylinder.
- CLEAN ¼" Polyurethane tubing (0.250" OD x 0.167" ID - SMC part # TIUB07). If tubing is 6mm OD x 4mm ID (SMC part# TU0604 or equal), filter type 'B' will be necessary. SMC Corp can be found at www.smcworld.com.

INSTALLATION STEPS:

1. **Place tape over ends of on site Polyurethane tubing before installation.** The iSOC®, iSOC® flow-control valve and distribution header barb connections are supplied with vinyl caps covering the openings. Tape ends of polyurethane tubing before installing. Keep caps and tape on all fittings and tubing until final connections are made. Caps and tape help to prevent dirt and water from entering the system internally. Note: iSOC® system failure may occur if dirt or water enters the system via on site tubing, iSOC®, iSOC® distribution header or filter.

2. **Make sure all on site tubing is installed correctly.** It should be well protected from being crushed or severed. There should be no tight bends or kinks – see tubing specification for minimum bend radius.

3. **Install gas bottle, regulator and iSOC® distribution header in a clean, dry, well protected area** sheltered from the elements and safe from vandalism.

4. **Crack open new gas cylinder BEFORE attaching regulator** to purge out any debris such as sand and paint chips. Be sure to do so while wearing proper eye protection and making sure there are no open flames or combustibles in the area. Observe OSHA safety guidelines for handling and securing gas cylinders. *Note: Follow same procedure for routine changing of gas cylinders.* ***Failure to perform this procedure may cause iSOC® system failure.***

5. **Attach two-stage low flow regulator to gas cylinder**.

6. **Attach iSOC® distribution header to the two-stage low flow regulator.**

7. **Close all barbed valves on the iSOC® distribution header.** *Note: Open/close Directions on each valve lever.*

8. **Attach polyurethane tubing to iSOC® distribution header barb (see note #1).** Secure distribution header barb connection with 2 black plastic hose clamps placed so that they are opposite each other. Pinch hose clamp teeth together using pliers until tight and free of any movement.

9. **Turn the regulator counterclockwise to make sure the pressure of the regulator is at zero**. At zero pressure there is no gas flow.

10. **Open gas cylinder valve completely, then back off a slight amount making sure pressure remains at zero**.

KEEP ON SITE WITH DISTRIBUTION HEADER

11. **Drill two holes in well cap** - one for the iSOC® tubing and the other for the eyebolt used to secure the plastic coated iSOC® lifting wire.

12. **Set regulator on gas cylinder to 50 psi for immersion depths less than 60 ft (18.3 m) of water.** This will result in 15 - 20 standard cc/min of oxygen delivered to the groundwater by iSOC®. NOTE: Pressure settings below 50 psi will result in system failure. At 50 psi, gas usage will be approximately 1.25 cubic foot / iSOC® / day. **For immersion depths greater than 60 ft (18.3 m) of water, it is recommended that the gas cylinder be set at 60 psi.** Increasing of pressure does not necessarily optimize system. NOTE: Pressure settings exceeding 70 psi may result in system failure.

13. VERY IMPORTANT – Open and then close each barbed valve on the iSOC® distribution header one at a time for a minimum of 15 seconds to purge the regulator, the iSOC® distribution header and each piece of on site tubing of any water or debris following safety guidelines outlined in step 4. ***Failure to perform this procedure may cause iSOC® system failure.***

14. **Attach reusable iSOC® filter to on site polyurethane tubing. Ensure tubing attached to filter is cut squarely and placed fully into filter unions** (see warning #4 below). Location of filter is **6" above iSOC®** down well. Note: Removal of unions from filter will destroy filter. **Secure plastic coated line to lifting eye on iSOC®.**

15. **Attach a 6" long piece of polyurethane tubing between end of filter and iSOC®.** Secure iSOC® barb connection with black plastic hose clamp and ensure tubing attached to filter is cut squarely and placed fully into filter union.

16. **Open valve on iSOC® distribution header and start gas flow to the iSOC® unit.**

17. **Submerge iSOC® unit in a bucket of water.** In 1-2 minutes you should observe one bubble every second coming from the topside of the iSOC®. NOTE: *The single bubble release is normal and is designed to mix D.O. throughout the full vertical extent of the well and release nitrogen, assuring good mass transfer.*

18. While iSOC® is in the bucket of water, **use Snoop to test for leaks on all exposed fittings**. Key objective: if any leaks are found, repair before continuing.

19. **Slowly lower the iSOC® into the well at intervals of approximately 20 ft every 5 minutes**. Note: Do not allow plastic coated lifting wire and Polyurethane tubing to wrap around each other. This can cause kinking, cutting, loss of gas flow and possible flooding of the iSOC®.

20. Once the iSOC® is at desired depth in well, **monitor the iSOC® bubble rate and regulator pressure gauge for the next 20-30 minutes.** NOTE: *If you are in need of assistance, please call your iTi representative* **while on site** *so that they can help in any of the steps above or any problem you may have encountered. Your iSOC® representative contact information can be found at www.isocinfo.com.*

NOTES:

1. **Attaching polyurethane tubing to barb fittings –** Start tubing onto barb at an angle and wiggle or 'walk' it down until entire barb is covered. Avoid kinking the tubing when doing so.

2. **Removing polyurethane tubing from barb fitting –** Pinch side of tubing at hose barb with pliers only, than pull tubing off barb with fingers. DO NOT score the barb when doing so. DO NOT cut tubing off barb using a knife or damage to the barb may occur resulting in a leak.

WARNINGS:

1. **DO NOT ALLOW GAS CYLINDER TO RUN OUT BETWEEN SITE VISITS. REFER TO GAS USAGE GUIDE IN DESIGN & INSTALLATION OR OPERATIONS & MAINTENANCE SECTIONS OF WWW.ISOCINFO.COM. UPON FAILURE TO MAINTAIN GAS FLOW REFER TO "RESTORING iSOC® UNIT AFTER INTERNAL FLOODING".**

2. **STORE THE ISOC® UNIT IN A CLEAN, COOL, DRY PLACE.** **NOTE: iSOC® failure may occur if the iSOC® unit is exposed to temperatures in excess of 60° C (140° F).*

3. **DO NOT USE ISOC® IN FREE PHASE CHLORINATED ALIPHATIC HYDROCARBON PRODUCT.**

4. **DURING ROUTINE SITE VISITS, ENSURE THE ISOC® FILTER HAS NOT FILLED WITH WATER.** If iSOC® filter has filled with water: 1) Cut tubing squarely 1 inch on either side of filter. 2) Remove remaining tubing pieces from filter by a) Pressing tubing towards union b) Pressing down on union collar c) Pulling tubing out while pressing down on collar. 3) Turn filter upside down and shake out all water. 4) Repeat step #13 by purging lines and equipment of any water or debris. 5) Reattach filter inline with iSOC®. 6) Test filter connections for leaks.

ARCADIS BBL

Appendix F

iSOC® System O&M Checklist

iSOC® Technology

iSOC® System O & M Checklist

Step	Task	Corrective Action
1	**Check pressure setting on regulator.** Pressure should be set at 50 psi (3.4 bar)for water depths of less than 60 feet or 25 psi above the head of water for greater depths (33 feet of water = 14.7 psi and 10 m of water = 1 bar).	Turn gas regulator knob clockwise to increase desired pressure. Turn regulator knob counter clockwise and momentarily open purge valve on distribution header to reduce pressure.
2	**Check Gas Supply in Cylinder** Is the cylinder empty? Why? Is there a leak?	Use Snoop to test for gas leaks. Check all fittings; Repair gas leaks;
3	**How To Replace The Gas Cylinder**	Close iSOC® connection valves to trap gas; Quickly exchange cylinders. Re-open valves after changing gas bottle.
4	**Check iSOC® for flooding** (1) Submerge iSOC® in a bucket of water (2) Make sure tubing is ok. (3) Remove drain plug; (4) Is water in the tube above the iSOC®? (5) Follow installation procedures and place iSOC® in bucket of water	(1) Should see 1-2 bubbles every 1-2 seconds coming from side of iSOC®. (2) Un-kink; check for damage/leak. (3) Should see bubbles in (1) above.
5	**Re-install the iSOC** (1) Connect tubing iSOC® Distribution Header and iSOC® (2) Close Two Stage regulator (3) Pressurize the system. (4) Open regulator (5) Submerge iSOC® in a bucket of water. (6) Place iSOC® in well.	(1) Set regulator at 50 psi (3.4) or compute head for water depths over 60 feet (18.3 m) (2) Look for 1-2 bubbles every few seconds.
6	**Check For Safety**	Secure gas cylinders and check for gas leaks.
7	**Do You Still Need Assistance?** Call iSOC® Representative	Discuss over the phone; Or iSOC® Rep may need to do site visit.

ARCADIS BBL

Appendix G

Oxygen Cylinder Life and Production Rates Worksheet

Oxygen Cylinder Life and Production Rates

***input your data and specification in green highlighted cell**

Depth of H2O to Unit (ft)	**20**	**ft**
Number of of iSOCs	**1**	
Oxygen Regulator Setting (should be between 50 - 70 psi)	**50**	**psi**

Your Water Pressure (psig)	9	
Total Pressure (atm)	1.6	
Oxygen Flow per iSOC	**19.7**	standard cc/min

Oxygen Cylinder Volume (ft^3)	**Oxygen (pounds)**	**Actual Cylinder Life for Y iSOCs**
40	3	**37**
80	7	**73**
125	10	**115**

Max Dissolved Oxygen @ Y depth (ppm)	**65**
Oxygen Production Rate (Grams / Day)	**34.2**
(mg / Day)	**34.2×10^3**
(ug / Day)	**34.2×10^6**

***caution: pressure guages are often inaccurate after a period of use, particularly at low pressures**
***temperature variations can effect the pressure reading by as much as 15%**

ARCADIS BBL

Appendix H

Bio-Trap® Sampler Protocol

microbialinsights

2340 Stock Creek Blvd.
Rockford TN 37853-3044
Phone (865) 573-8188
Fax: (865) 573-8133
Email: info@microbe.com

Bio-Trap Sampler Protocol — Stable Isotope Probing

Handling:

Bio-Trap samplers used for Stable Isotope Probing (SIP) are baited with ^{13}C-labeled contaminant of interest (e.g. benzene, MTBE, chlorobenzene) which is adsorbed onto the powder activated carbon (PAC). Controlled laboratory conditions have shown only minimal loss of contaminant due to volatilization. However, special considerations must be taken into account when handling SIP Bio-Trap samplers in order to reduce risk of volatilization in the field. SIP Bio-Trap samplers are shipped out chilled on blue ice and it is essential that they should be kept cool until deployment. When retrieving the Bio-Trap samplers, they should immediately be placed on ice and they should be shipped on ice for next day delivery. These steps will ensure the most accurate results.

Although the contaminant is absorbed onto the beads, caution should be used in handling these Bio-Trap samplers because the contaminant compounds are associated with possible health and safety risks. We provide the appropriate MSDS when shipping SIP Bio-Trap samplers, which can be consulted as needed.

Note: Clean sterile gloves should be used at all times when handling Bio-Trap Samplers.

Storage:

It is important to minimize the amount of time that Bio-Trap Samplers are stored prior to being installed in the field. The physical properties of the Bio-Trap Samplers that make them an ideal medium for collecting microbes also increase the chances of microbial or chemical contamination. Bio-Trap Samplers need to remain sealed and refrigerated (not frozen) until they can be installed in the field. If the Bio-Trap Samplers are stored for an extended time (more than two weeks), drying could occur, which may then require a longer incubation time in the well.

Installing Bio-Trap Samplers:

- Prior to installing the Bio-Trap Samplers, the monitoring well may need to be purged if it has not been sampled in a while. If purging is necessary, MI recommends that three well volumes be removed to ensure contact with formation water and reduce well bore effect.
- Remove the Bio-Trap Sampler from the zippered bag and attach the nylon attachment loop (provided) to a nylon line (not provided) and suspend the Bio-Trap Sampler at a depth where significant contaminant concentrations exist. If no data are available on the vertical distribution of contaminants, then suspend the Bio-Trap Sampler in the middle of the saturated screened interval for chlorinated hydrocarbons. For petroleum hydrocarbons, suspend the Bio-Trap Sampler about 1-1.5 ft below the top of the water table. If large fluctuations in the water level are anticipated during the period of incubation, the Bio-Trap Sampler should be suspended from a float (contact MI for further details).
- Once installed, incubation times can vary depending upon the project.

Removing Bio-Trap Samplers after incubation:

- Open the monitoring well and pull up the Bio-Trap Samplers. Cut and remove the nylon line used to suspend the Bio-Trap Samplers.
- Transfer the recovered Bio-Trap Samplers to labeled (well number and date) zippered bags, seal, then double bag in a larger (one-gallon) zippered bag, and immediately place on blue ice in a cooler.
- Repeat the above for all Bio-Trap Samplers from the site. Individual zippered bags containing the Bio-Trap Samplers can be placed in the same one-gallon zippered bag (if there is enough space).
- A chain of custody (COC) form must be included with each shipment of samples. Access our COC at www.microbe.com/Chain_of_Custody.pdf

Shipment:

Bio-Trap Samplers need to be shipped on ice (or blue ice) for next day delivery (please call to confirm Saturday delivery). If regular ice is used, the ice should be double bagged.

Samples should be shipped to:

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

Saturday Delivery:

Due to the short hold time associated with RNA it is not recommended to send samples for Q-Expression (RNA) for Saturday delivery.

ARCADIS BBL

Appendix I

Chevron Standard Procedure Sample
Collection for VOC Isotopic Analysis
Univ. of Oklahoma

Chevron

Standard Procedure

Sample Collection for VOC Isotopic Analysis

Univ. of Oklahoma

June 27, 2006

Sample Collection for Chlorinated Ethenes Isotopic Analysis

Summary: The samples will be analyzed by GC-IRMS. Use standard VOC sample collection methods. Use care to prevent volatile losses.

Note: Acquisition of isotope ratios of the full range of the analytes requires two separate analyses: 1) ethene, ethane and vinyl chloride; 2) 1,1-dichloroethene up to tetrachloroethene (see below for sample volume requirements).

- Use standard methods for collecting VOC samples.
- Collect six 40 ml VOA vials from each well for full analyte range.
- Use HCl (standard VOA approach) as the preservative.
- Place in cooler with ice or ice packs.
- CoC – request:

  Carbon CSIA (compound-specific isotope analysis) and list target analytes

- Ship overnight to:

  Dr. Tomasz Kuder
  Dr. Philp's Laboratory
  Dept. of Geology / Geophysics, OU
  SEC #810
  100 E Boyd
  Norman, OK, 73019

  tkuder@ou.edu (email the VOC analytical results to Tomasz Kuder)
  405-325-4453

- Due to delays in the University Receiving Dept, ship only between Mon – Wed. If samples are collected at the end of the week, store in refrigerator and ship on Monday.

- Leave a message at 405-325-4453 that the samples have been sent.

June 27, 2006

SOP Procedures for GCIRMS Analyses of VOC and SVOC Compounds in Ground Water Samples.

The following is a somewhat generic description of the methods used for the isotopic characterization of VOC and SVOCs in groundwater samples. It is my understanding that the compounds of interest in the current project are chlorobenzene and chloroaniline. If this is not correct please advise and this can be corrected appropriately. However prior to running any samples, the first step of the method development will be to evaluate the generic method described below for these particular compounds. Standards of these compounds will be determined using a direct inlet isotope ratio mass spectrometer. Once these values are known then when we develop the purge and trap methods, we will know the isotope values expected for the standards after they have been isolated by purge and trap. As indicated below, once the method has been developed with the appropriate standards, the samples will be analyzed and after approximately 10 runs the standards will be run again to check combustion conditions.

Generally if the compounds of interest cannot be extracted and require solvent extraction, we generally require the client to arrange for the samples to be extracted and then send us the extracts. Again prior to running any extracts appropriate standards would be analyzed.

VOCs are extracted from the water by an OI 4560 purge and trap (Vocarb 3000 or Tenax-silica gel-charcoal trap) with the PT transfer line interfaced to either a Finnigan MAT 252 IRMS for the carbon analyses or a Finnigan Delta XL for hydrogen isotope analyses. A thermal conversion reactor installed as part of the GC–IRMS interface converts the analytes to carbon dioxide or hydrogen without affecting chromatographic resolution. A Nafion membrane installed prior to the IRMS removes water transferred from PT and water resulting from combustion. For the determination of $\delta^{13}C$ and δD values for the individual compounds, a modified VOC analysis protocol will be used. A 25ml sample will be purged for 12 min at 25°C with purge flow of 40 ml/min., sample temperature 60°C and desorbed for 5 min. P&T is baked 15 min after each run. P&T transfer line connects to a precolumn used to separate water prior to cryofocussing. Analytes eluting from the precolumn are focused on liquid nitrogen trap and then the analytes are separated on a second GC column. The two columns are interfaced through a 6-port switching valve resulting with splitless refocusing of the P & T effluent. The final separation column is DB1 column 60 m x 0.32 mm i.d. GC is held isothermal at 35°C. After data acquisition the GC oven is ramped to final temperature and held for 15 minutes to clean the column. The combustion reactor for the carbon determination is a ceramic tube packed with oxidized nickel and platinum catalyst wires held at 980°C and exposed to an auxiliary oxygen trickle. The pyrolysis reactor used for the δD determination is an empty ceramic tube with carbon deposit, held at 1440°C. This setup permits determination of the carbon isotopic composition for VOCs at single ppb's concentrations and hydrogen isotope ratios at lower tens of ppb concentrations.

Quantification of isotope ratios in individual compounds by GCIRMS

Raw output of GC-IRMS consists of three (carbon mode) or two (hydrogen mode) simultaneously acquired signal channels, corresponding to target analyte (CO_2 or H_2, respectively) with variable C H O isotope substitution. Rather than measuring the absolute ratios of isotope species, IRMS technique relies on data normalization relative to internal standard of known isotopic composition. A number of pulses of standard gas (CO_2 or hydrogen, respectively) and/or coinjected standard are introduced into the IRMS's source during each run to provide a reference for sample-derived signal. GC separation of the analyte permits integration of individual chromatographic peaks, positioned over a uniform background noise. An automatic software routine detects peaks and assigns their background value. Integration of the individual channel outputs over the peak's retention time window provides a ratio of isotope species (D/H or $^{13}C/^{12}C$), which in turn is automatically normalized relative to the standard of known isotopic

composition. The final output of the automatic integrator has to be reviewed manually, in particular to eliminate errors upon the background determination. The data are reported in delta notation.

$$\delta^{13}C = (R_{sample}/R_{standard} - 1) * 1000$$

R_{sample} and $R_{standard}$ represent $^{13}C/^{12}C$ ratios of the sample and the international standard (VPDB), respectively.

Precision and accuracy of the P&T-GCIRMS system are periodically checked by external or coinjected standard. Depending on the specific method used, numbers obtained by GCIRMS may differ from true isotopic composition of a compound (method bias). The factors affecting the raw isotope ratios in P&T extraction and direct injection GCIRMS analysis are:

1) The presence of excessive level of contaminants in the carrier gas – especially H_2O and O_2.
2) P&T temperature and time program – defines how much analyte is recovered from aq. sample, and thus defines the scale of isotope effect upon sample-vapor partitioning.
3) The specific batch (lot #) and age of P&T trap used.
4) Split ratio if split-splitless injection is used.
5) Temperature and condition of the thermal conversion reactor.

Water and oxygen may fluctuate during the run and affect IRMS performance by interfering with ion formation and possibly with the collector cup responses. The bias cause by the background O_2 and H_2O may be neutralized by application of standard gas pulses allowing raw output normalization, where both analyte and standard are subject to the same bias. With properly maintained instrument, factors 2-5 remain relatively stable over the period of weeks, resulting with highly reproducible net isotope effect. An exception is hydrogen isotope fractionation caused upon thermal conversion step, which may drift significantly faster and may need to be checked for each consecutive sample if the drift becomes apparent based on external standard data. In the case of carbon isotope analysis, the bias tends to be at the level of decimal parts of a $\delta^{13}C$ permil unit, remaining stable in the period of weeks, while much larger fluctuations are normal for hydrogen isotope analysis. In the latter case, drift of the instrument may be significant in the time range of hours. Accordingly, each sample analyzed for hydrogen CSIA is bracketed by standard runs or has at least one standard run immediately before or after the run. Moreover, while only select samples are analyzed in duplicate for carbon CSIA, all hydrogen samples are treated in this way. Current deviation of the hydrogen GCIRMS method is determined from the standard injections and the final analyte results are updated accordingly.

Typical routine for carbon CSIA, example taken from P&T-GCIRMS analysis:

1) CO_2 standard gas pulses introduced adjacent (within 1 minute before and after the MTBE peak).
2) Appropriate standard run by P&T-GCIRMS daily, repeated after 10 samples.
3) Isotope ratio of compounds normalized relative to one of the CO_2 pulses.
4) Results from external standard run over the period of a specific sample series provide a correction (if any) to eliminate isotope ratio bias due to sample extraction, combustion etc.
5) Selected samples analyzed in duplicate (25-30 %) and the set of standard runs allow determining method precision.

To date a bias of 0.5 permil $\delta^{13}C$ or less was observed. The discussed quality control measures allow fast detection of malfunctions affecting isotope ratios. The corrective actions are taken to pinpoint the location of the problem and fix it. Three most common problems are: 1) failure of P & T sorbent trap; 2) failure of combustion reactor tube on GC-IRMS interface; 3) malfunction of GCIRMS backflush valve or operator error resulting with large excess of water background. The corrective action in the former two examples is replacing the element, while in the latter case the backflush valve performance has to be checked, possibly a valve program modified or the valve has to be rebuilt.

Appendix J

Miracle-Gro® Material Safety Data Sheet

MATERIAL SAFETY DATA SHEET

Date-Issued: 09/24/2003
MSDS Ref. No: 100113
Date-Revised: 09/24/2003
Revision No: New MSDS

Miracle-Gro® All Purpose Plant Food 15-30-15

1. PRODUCT AND COMPANY IDENTIFICATION

PRODUCT NAME: Miracle-Gro® All Purpose Plant Food 15-30-15

MANUFACTURER

The Scotts Company
Earthgro-Hyponex-Miracle Gro
Scotts-Scotts Lawn Service-Scotts Sierra-Swiss Farms
14111 Scottslawn Road
Marysville, OH 43041

PN: S9958

24 HR. EMERGENCY TELEPHONE NUMBERS

CHEMTREC (U.S.): (800) 424-9300
International: 1-703-527-3887
Emergency Phone: 1-937-644-0011

2. COMPOSITION / INFORMATION ON INGREDIENTS

Chemical Name	CAS#	OSHA PEL	ACGIH TLV
Urea	57-13-6	None	None
Ammonium Phosphate	7722-76-1	None	None
Urea Phosphate	4861-19-2	None	None
Potassium Chloride	7447-40-7	None	None
Boric Acid	10043-35-3	None	None
Copper Sulfate	7758-98-7	None	1 mg (Cu)/m3
Iron EDTA	15708-41-5	None	None
Manganese EDTA	15375-84-5	None	None
Sodium Molybdate	7631-95-0	5 mg/m3	5 mg/m3
Zinc Sulfate	7733-02-0	None	None

Nuisance Dust	15 mg/m3	3 mg/m3

COMMENTS: The ACGIH Threshold Limit Values (TLV) for nuisance (inert) dusts containing < 1% crystalline silica and no asbestos are: 10 mg/m3 inhalable particulates and 3 mg/m3 respirable particulate. The OSHA TLV is 15 mg/m3 total dust, 5 mg/m3 respirable fraction. Material exposure limits are for airborne 8-hour time-weighted averages and apply only to occupational exposures.

3. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

IMMEDIATE CONCERNS: Follow precautionary product label information.
General Considerations: Avoid breathing dusts or mists by using adequate ventilation. Reduce material contact by wearing gloves when handling material for extended periods or by washing hands after use. Minimize material contact during application of lawn/garden products by wearing long pants, shoes, and socks. Avoid eye contact with any foreign body and do not ingest product. Keep out of reach of children.

POTENTIAL HEALTH EFFECTS

EYES: May cause slight, temporary irritation as a foreign body in the eye.

SKIN: Repeated skin contact may dry skin resulting in skin irritation in sensitive individuals.

INGESTION: May result in temporary nausea or diarrhea.

INHALATION: Inhalation of dusts or aerosols may aggravate asthma.

MEDICAL CONDITIONS AGGRAVATED: Skin abrasions, sores, or other pre-existing skin conditions. Inhalation of dust may aggravate asthma.

4. FIRST AID MEASURES

EYES: Hold eye open and rinse slowly and gently with water for 15 to 20 minutes. Remove contact lenses, if present, after the first 5 minutes, then continue rinsing eyes. Call a poison control center or doctor for treatment advice.

SKIN: If on skin or clothing, take off contaminated clothing. Rinse skin immediately with plenty of water for 15-20 minutes. Call a poison control center or doctor for treatment advice.

INGESTION: If swallowed, call a poison control center or doctor immediately for treatment advice. Have person sip glass of water if able to swallow. Do not induce vomiting unless told to by a poison control center or doctor. Never give anything by mouth to an unconscious person.

INHALATION: Move person to fresh air. If person is not breathing, call 911 or an ambulance, then give artificial respiration, preferably mouth-to-mouth, if possible. Call a poison control center or doctor for further treatment advice.

COMMENTS: See product label for specific First Aid Measures. The above measures are the most conservative and would apply in the event a product label is not immediately available.

5. FIRE FIGHTING MEASURES

EXTINGUISHING MEDIA: Water fog or spray.

EXPLOSION HAZARDS: Explosive conditions may exist when a high airborne concentration of fertilizer or organic material occurs in an enclosed area.

FIRE FIGHTING PROCEDURES: Use self-contained air supply.

HAZARDOUS DECOMPOSITION PRODUCTS: In a fire, fertilizer products may produce ammonia and toxic oxides of carbon, nitrogen, potassium, phosphorous, and/or sulfur.

---

6. ACCIDENTAL RELEASE MEASURES

GENERAL PROCEDURES: Use good housekeeping practices. Sweep up spills. As a general practice, avoid contact with skin, eyes, or clothing. Wash thoroughly with soap and water after handling. Remove to approved landfill. See label for specific disposal procedures.

---

7. HANDLING AND STORAGE

HANDLING: See label. Wash hands with soap and water after handling product. Avoid container breakage. Avoid inhalation or contact with skin, eyes, or clothing. Keep out of lakes, streams or ponds, KEEP OUT OF REACH OF CHILDREN.

STORAGE: See label. KEEP OUT OF REACH OF CHILDREN. Avoid container breakage. Store in cool, dry area in closed container or package. Keep away from feed or foodstuffs.

---

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

ENGINEERING CONTROLS: Use adequate ventilation to keep the airborne concentrations of this material below the recommended exposure standard.

PERSONAL PROTECTIVE EQUIPMENT

EYES AND FACE: See label. Protective eye wear is typically not required for normal product use.

SKIN: See label. No special protective clothing is necessary under normal use conditions. Gardening gloves are suggested for repeated handling of lawn care products. Applicators should wear long-sleeved shirt, long pants, shoes, and socks.

RESPIRATORY: See label. No special respiratory protection is required under normal use conditions. However, if operating conditions create high airborne concentrations of product, a dust mask, or other appropriate respiratory protection is recommended.

---

9. PHYSICAL AND CHEMICAL PROPERTIES

PHYSICAL STATE: Solid
APPEARANCE: Granular

COLOR: Blue

10. STABILITY AND REACTIVITY

STABLE: YES

HAZARDOUS POLYMERIZATION: NO

CONDITIONS TO AVOID: Protect from moisture and heat.

HAZARDOUS DECOMPOSITION PRODUCTS: Urea and methylene urea nitrogen sources can generate ammonia in a fire. Also toxic oxides of nitrogen, phosphorus, chlorine, carbon, and potassium may form.

INCOMPATIBLE MATERIALS: None known.

11. TOXICOLOGICAL INFORMATION

ACUTE

EYES: Not an eye irritant (rabbit) for a similar formulation.

DERMAL LD_{50}: >2,000 mg/kg (rabbit) for a similar formulation.

ORAL LD_{50}: >5,000 mg/kg (rat) for a similar formulation.

SKIN EFFECTS: Primary Dermal Irritation (rabbit): Non-irritating and non-staining for a similar formulation.

CARCINOGENICITY:

CARCINOGENICITY COMMENTS: IARC: No; NTP: No; OSHA: No

GENERAL COMMENTS: Results of acute toxicity studies conducted on a comparable formulaton accorrding to Consumer Product Safety Commission testing methods (Oral; 15003.(i), Dermal (1500.41), Eye Irritation (1500.42), and Primary Skin Irritation (1500.41) indicate this product is "Non-Hazardous" as defined by 29 CFR, Part 1910.1200.

12. ECOLOGICAL INFORMATION

ECOTOXICOLOGICAL INFORMATION: See label. Keep out of lakes, streams, or ponds.

13. DISPOSAL CONSIDERATIONS

DISPOSAL METHOD: Dispose in normal waste disposal. Do not reuse empty container. See label for specific product disposal recommendations.

14. TRANSPORT INFORMATION

DOT (DEPARTMENT OF TRANSPORTATION)
PROPER SHIPPING NAME: Not DOT regulated.

SPECIAL SHIPPING NOTES: The description shown may not apply to all shipping situations. Consult 49CFR, or appropriate Dangerous Goods Regulations, for additional description requirements (e.g., technical name) and mode-specific or quantity-specific shipping requirements.

15. REGULATORY INFORMATION

GENERAL COMMENTS: Contact local authorities for proper disposal of large quantities of unused product.

16. OTHER INFORMATION

REVISION SUMMARY New MSDS

NFPA CODES

HEALTH: 1 **FIRE:** 0 **REACTIVITY:** 0

MANUFACTURER DISCLAIMER: The information contained herein is, to the best of the Manufacturer's (see Section 1) knowledge and belief, accurate and reliable as of the date of preparation of this document. However, no warranty or guarantee, express or implied, is made as to the accuracy or reliability, and the Manufacturer shall not be liable for any loss or damage arising out of the use thereof. No authorization is given or implied to use any patented invention without a license. In addition, the Manufacturer shall not be liable for any damage or injury resulting from abnormal use, from any failure to adhere to recommended practices or from any hazards inherent in the nature of the product.

ADDITIONAL MSDS INFORMATION: NFPA Hazard Rating: 0=Least; 1=Slight; 2=Moderate; 3=High; 4=Severe.

GENERAL STATEMENTS: This document contains health, safety, and environmental information useful to emergency response agencies, health care providers, manufacturers, and workers/employees. It does not replace the precautionary language, use directions, or the storage and disposal information found on the product label.