



May 24, 2011

Mr. Scott Miller
Remedial Project Manager
U.S. Environmental Protection Agency
Region IV, Superfund North Florida Section
61 Forsyth Street, SW
Atlanta, GA 30303-3104

Subject: Transmittal of the “*Former Process Area In-Situ Geochemical Stabilization Remediation Demonstration Project Workplan for Hawthorn Group Deposits, Former Koppers Inc. Site, Gainesville, Florida*”

Dear Mr. Miller:

On behalf of Beazer East, Inc., attached is a copy of the workplan entitled “*Former Process Area In-Situ Geochemical Stabilization Remediation Demonstration Project Workplan for Hawthorn Group Deposits, Former Koppers Inc. Site, Gainesville, Florida, March 24, 2011*”. This demonstration project is designed to test the implementation and performance of ISGS remediation in the Upper Hawthorn beneath the former Process Area. Beazer East, Inc. will implement this workplan upon approval from the U. S. Environmental Protection Agency (EPA).

Should you require additional information, please feel free to contact me at (303) 665-4390.

Sincerely,

A handwritten signature in black ink that reads 'James R. Erickson'.

James R. Erickson
Principal Hydrogeologist

A handwritten signature in black ink that reads 'James W. Mercer'.

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Enclosure

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**FORMER PROCESS AREA *IN-SITU* GEOCHEMICAL
STABILIZATION REMEDIATION DEMONSTRATION
PROJECT WORKPLAN FOR HAWTHORN GROUP
DEPOSITS**

**FORMER KOPPERS INC. SITE
GAINESVILLE, FLORIDA**

Prepared For:

Beazer East, Inc.

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May 24, 2011

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1.0 INTRODUCTION

This workplan describes the process of design, field evaluation and implementation for *in-situ* geochemical stabilization (ISGS) in the Upper Hawthorn unit of the former Process area of the Koppers portion of the Cabot Carbon/Koppers Superfund Site (the Site¹) in Gainesville, Florida. ISGS entails the injection of an enhanced permanganate reagent to oxidize, contain and isolate subsurface dense non-aqueous phase liquids (DNAPLs). ISGS treatment for the former Process Area is part of the remedial plan for the Site, as described in the February 2011 Record of Decision (ROD) published by the United States Environmental Protection Agency (USEPA). The ISGS technology has been shown to be effective at rendering DNAPL immobile.

The ISGS remediation technology consists of a permanganate-based reagent (RemOx® EC) that is injected into DNAPL impacted zones for the purposes of DNAPL treatment, containment/stabilization and solute flux reduction. A manganese dioxide (MnO₂) precipitate with associated silicate minerals and other ISGS reagents is quickly deposited around DNAPL ganglia and droplets following reagent injection. The precipitate that forms around the DNAPL effectively isolates the free-phase DNAPL from future migration and groundwater dissolution reactions. In addition to containing the free-phase DNAPL, oxidation of dissolved-phase constituents results in a “hardening” or “chemical weathering” of the DNAPL as it loses its more labile semi-volatile organic compounds (SVOCs). The deposition of the MnO₂ mineral shell also reduces the overall formation permeability in the treated area, thereby reducing the volumetric flux of upgradient groundwater into and through the impacted area. The ISGS processes reduce organic constituent loading to the groundwater and allow natural attenuation mechanisms to more effectively degrade organic constituents downgradient of the treated area. Thus, the remedy will reduce contaminant toxicity, mobility and volume through *in-situ* treatment.

Full-scale implementation of the ISGS technology was successfully demonstrated in a phased implementation approach at an active wood-treating site in Denver, Colorado (Adventus, 2003 and GeoTrans, 2004c). In addition, a pilot test for the implementation of the ISGS technology in the Surficial Aquifer was demonstrated at the Site’s former North Lagoon in 2008 (Adventus, 2009).

1.1 SITE BACKGROUND

The Site is located in the City of Gainesville, in Alachua County, Florida (**Figure 1**). The Site encompasses approximately 86 acres and was used continuously as an active wood-treating facility from 1916 to 2009. Adjacent properties include the former Cabot Carbon portion of the Superfund Site to the east, private residences to the west and northwest, and commercial facilities and private residences to the north and south.

¹ In this document “Site” refers to the Koppers portion of the Cabot-Carbon/Koppers Superfund Site, unless otherwise noted. The Site property is now owned by Beazer East, Inc.

Creosote DNAPLs were released to the subsurface during the historical operation of the former wood-treating Site. Wood-treating operations at this Site were performed from 1916 until 2009. Creosote-treatment operations at the Site ceased in the early 1990s. The majority of DNAPL releases are believed to have occurred before 1980 when creosote usage was greater. In the later years of operation (1990 to 2009), other wood preservatives were used in place of creosote at this facility.

Creosote DNAPL impacts have been found within and beneath four former operational areas: 1) Process Area; 2) Drip Track; 3) North Lagoon; and 4) South Lagoon. Creosote DNAPL impacts have been detected in the Surficial Aquifer and underlying Hawthorn Group (HG) deposits beneath these former operational areas. DNAPL impacts have not been detected in the deeper Upper Floridan Aquifer and appear to be vertically contained by a clay unit (30-35 feet thick) at the base of the HG deposits. Field investigations reveal that DNAPL impacts decrease with depth with the more significant impacts present in the Surficial Aquifer. The majority of the HG deposits beneath the former source areas do not contain free-phase or residual DNAPL impacts. DNAPL impacts within the HG deposits are restricted to thin higher permeability sand seams, 1-to 12-inches thick, with thick sequences (2 to 10 feet) of non-impacted deposits separating them. The majority of these HG impacts are within the Upper Hawthorn; a low-permeability clay unit limits vertical migration of DNAPL impacts to the underlying Lower Hawthorn where only relatively thin zones of residual DNAPL impacts have been observed.

The former Process Area is located in the southeast corner of the Site. Over the approximately 93 years of operations at this Site a number of buildings and structures associated with former Process Area were demolished and above-ground structures removed; however, in most cases the below-ground concrete pads and foundations were left in place. One of the challenges with implementation of remediation activities in the former Process Area is working around these buried structures.

Detailed descriptions of the Site historical source areas are provided in a 2004 report on subsurface investigations in these areas (GeoTrans, 2004a). Additional information on subsurface DNAPL impacts along the eastern property boundary is included in a later investigation report (GeoTrans, 2009). The Site hydrogeologic conceptual model is provided in a groundwater flow and transport modeling report (GeoTrans, 2004b) and a conceptual depiction of the Site conceptual model is provided in **Figure 2**.

1.2 OBJECTIVES

The primary objective of this project is to demonstrate and measure the effectiveness of full-scale ISGS implementation in the Upper Hawthorn beneath the former Process Area.

A primary concern of the USEPA and other groups and persons interested in Site remediation is the potential for vertical migration of free-phase DNAPL into the Upper Floridan Aquifer. Consequently, a primary short-term objective of the proposed ISGS demonstration program is to contain and stabilize free-phase DNAPLs in the Upper Hawthorn beneath the Site's former Process Area. This objective will be achieved through the injection of an ISGS

reagent at select depths within the Upper Hawthorn. The principal short-term (<1 year) performance criteria for the achievement of this objective will be a significant reduction in DNAPL recovery volumes for Upper Hawthorn monitoring wells completed in the former Process Area.

A longer-term secondary objective of ISGS implementation will be a reduction in dissolved-phase concentrations of groundwater downgradient of the treatment area. As part of the Site-wide remedial design process, a longer-term performance monitoring program will be developed for the Site that will include an evaluation of dissolved-phase concentrations, DNAPL crust formation, and permeability reduction for this remedy.

Because equipment will be mobilized to perform the demonstration on the Upper Hawthorn, ISGS treatment of the Surficial Aquifer may also be performed as a complementary activity. Pilot testing of ISGS in the Surficial Aquifer previously demonstrated the efficacy of ISGS for DNAPL treatment in this unit (Adventus, 2009). A separate project workplan for the Surficial Aquifer in the former Process Area will be submitted at a later date.

2.0 STRUCTURES, HYDROGEOLOGY AND DNAPL DISTRIBUTION

Much of the work described in this workplan involves intrusive subsurface investigation and injections. To effectively and safely perform this work, additional knowledge of surface and subsurface features in the former Process Area is needed. Numerous upgrades to the wood-treating operations over the past 100 years have resulted in subsurface structures that may impact implementation of remedies in the former Process Area. DNAPL investigations have been performed in the former Process Area; however, the level of detail resulting from these investigations is not sufficient to implement ISGS without additional data. A summary of the current understanding and potential challenges associated with ISGS implementation are provided below.

2.1 PROCESS AREA STRUCTURES

The wood-treatment operations at this Site have evolved over the years resulting in changes to former buildings, conveyance systems and treatment processes. As a result of these changes, a number of buildings and structures have moved or been replaced over the years. In most cases the aboveground structures were removed, but belowground structures, such as building footers, slabs and basements, were most likely left in place. For some of the more recent buildings, concrete footers and slabs are shown in **Figure 3**; however, locations of structures that predate this 1990s basemap are unknown. Therefore, one of the first tasks associated with implementation of the ISGS technology in the former Process Area will be to locate these structures.

Wood-treating operations at the Site ceased in 2009 and the property was sold to Beazer East, Inc. (Beazer) in March 2010. Beazer conducted demolition activities of Site structures and buildings from December 2010 through February 2011. This included demolition and disposal of all aboveground structures in the Process Area in January 2011 including the Boiler House, a wood-chip silo, a wood-chip loading dock and conveyance system, and several tanks and tank-containment systems. Subsurface structures and utilities remain in place at the Process Area including concrete slabs/footings and underground piping.

2.2 HYDROGEOLOGY

The hydrogeology of the Site has been thoroughly investigated and analyzed over the past 25 years by numerous investigations (TRC, 2003; GeoTrans, 2004a, 2004b, 2005 and 2009; Adventus, 2009). Over 200 wells have been installed at this Site where geologic cores have been collected to characterize deposits. A simplified hydrostratigraphic model of the local geology consists of approximately 20 feet of unconsolidated surficial deposits, which overlie approximately 120 feet of unconsolidated HG deposits, which overlie greater than 300 feet of the Ocala Limestone and Avon Park Formations (**Figure 4**).

Surficial Aquifer

The Surficial Aquifer consists of approximately 16 to 22 feet of marine terrace deposits, primarily consisting of unconsolidated, fine- to medium-grained sand with thin layers of interbedded silt and clay deposits. Groundwater flow in the Surficial Aquifer is primarily

controlled by surface topography and localized discharge points such as wetlands, creeks and drainage ditches. The Surficial Aquifer is not a source of potable groundwater on or around the Site; however, in other parts of the State, wells have been installed in this aquifer for residential irrigation purposes.

The local groundwater flow direction for the Surficial Aquifer at the Site is from southwest to northeast. A hydraulic-containment system was installed in the Surficial Aquifer system at the Site in 1995 to capture impacted groundwater prior to it flowing off Site. Groundwater extraction is occurring from a series of shallow downgradient extraction wells along the eastern and northern property boundary. In addition, four approximately 250 to 300-foot long horizontal drains (wells) were installed in 2009 adjacent to each of the former source area to recover impacted groundwater in close proximity to the sources. Total groundwater extraction from the wells and horizontal drains average approximately 60 gallon per minute (gpm).

Hawthorn Group Deposits

The HG deposits underlie the Surficial Aquifer and consist of a thick sequence of low permeability, unconsolidated sedimentary deposits. The HG deposits are approximately 115 to 125 feet thick at the Site consisting of low-permeability clay, clayey sand and silt deposits interbedded with moderate-permeability sand, silty sand and carbonate deposits. Three major clay units are present in the HG deposits termed the upper clay, middle clay and lower clay units. The upper clay unit is approximately 3 to 5 feet thick, the middle clay unit is approximately 10 to 15 feet thick and the lower clay unit is approximately 30 to 35 feet thick at the Site. Moderately permeable sedimentary deposits that lie between the HG upper and lower clay units have been termed the Upper Hawthorn and moderately permeable sedimentary and carbonate deposits that lie between the HG middle and lower clay units have been termed the Lower Hawthorn (**Figure 4**).

The HG deposits effectively separate the overlying Surficial Aquifer from the underlying Floridan Aquifer as indicated by the approximately 120 feet of hydraulic-head difference between these two aquifers. The majority of the hydraulic-head loss is across the lower clay unit, with a hydraulic-head difference of approximately 90 feet. Hydraulic-head difference across the upper clay unit is about 2 feet and the head difference across the middle clay unit is about 30 feet. Hence, each of the clay units provides some level of protection, with the upper clay unit acting as the first of three hydraulic traps mitigating vertical DNAPL migration.

Lateral groundwater flow within the Upper Hawthorn is generally to the northeast at the Site mirroring the groundwater flow direction in the Surficial Aquifer. Lateral groundwater flow in the Lower Hawthorn changes from east to west across the Site. A groundwater divide is present in the Lower Hawthorn, which is oriented southeast to northwest. Groundwater flow in the Lower Hawthorn on the eastern half of the Site is to the north-northeast and groundwater flow on the western half of the Site is to the north-northwest.

The HG deposits are not locally used for potable water due to the low permeability of the formation in this area; however, this unit has reportedly been used as a limited source of potable water in other parts of Florida.

Upper Floridan Aquifer

The Floridan Aquifer underlies the HG deposits and is subdivided into two aquifers, the Upper Floridan and the Lower Floridan Aquifers. The Upper Floridan Aquifer is the most widely used aquifer in this area and locally consists of the Ocala Limestone and Avon Park Formations. The Lower Floridan Aquifer is typically not utilized in this area due to its greater depth.

The Upper Floridan Aquifer is at a depth of approximately 140 to 150 feet at the Site. Regional groundwater flow within this aquifer is to the northeast towards the Murphree wellfield. The cone of depression resulting from the Murphree wellfield encompasses the Site resulting in the northeastern flow direction. The groundwater flow direction at the Site generally mimics the regional flow direction toward the wellfield; however, secondary permeability features in this aquifer result in some localized variations from the northeastern flow direction.

2.3 DNAPL DISTRIBUTION

Presently, the only accumulation of free-phase (i.e. mobile) DNAPL detected in wells at the Site is within monitoring wells installed in the Upper Hawthorn. No significant free-phase/mobile DNAPL has been detected in any of the monitoring wells installed in the overlying Surficial Aquifer, or the underlying Lower Hawthorn. However, residual DNAPL impacts (*i.e.*, non-mobile) have been previously noted in cores collected from the Surficial, and to a lesser degree, Lower Hawthorn deposits; however, once DNAPL reaches residual saturation it is immobile. Mobile and/or residual DNAPL impacts have never been observed in the Floridan Aquifer at this Site, indicating that the vertical extent of historical and present day DNAPL migration is limited to HG deposits. The majority of the free-phase DNAPL impacts detected at the Site are restricted to deposits above the HG middle clay unit (*i.e.* the Upper Hawthorn).

In 2004, a comprehensive effort was undertaken by Beazer to characterize the lateral and vertical extent of DNAPL-impacts in the surficial and HG deposits at the site, including delineation of dissolved-phase impacts in the former Process Area. As a result of this study, the approximate lateral and vertical extent of DNAPL impacts at the source areas were defined. The results of this study are documented in GeoTrans (2004a). Site features and the approximate extent of DNAPL occurrence in the former Process Area resulting from this study are depicted in **Figure 3**.

A number of additional groundwater investigations have been performed at the Site since the GeoTrans (2004a) investigation. Some of the investigations include the installation of monitoring wells and boring in the vicinity of source areas. A study performed by GeoTrans (2009) investigated the lateral extent of DNAPL migration along the eastern Site property boundary. One of the primary objectives of this study was to evaluate potential DNAPL migration from the former Process Area to properties located immediately to the east of the Site. A series of borings installed along the eastern property boundary documented the hydrostratigraphic contacts, lithologies and DNAPL-impacted zones. This investigation indicated that there were minimal DNAPL impacts in the Upper Hawthorn along the eastern property boundary. Three borings located to the east of the former Process Area had thin zones

(1- to 6-inches thick) of residual DNAPL impacts resulting from historic DNAPL migration in this area; however, no free-phase DNAPL impacts were detected along the property boundary. In general, this 2009 investigation along with borings/wells installed adjacent to the other source areas support the 2004 source-area delineations. Based on the 2004 investigation, the areal extent of potential DNAPL impacts to be targeted in the former Process Area occurs in an irregularly shaped footprint approximately 340 feet by 330 feet, covering about 91,000 square feet (approximately 2.1 acres).

As part of the GeoTrans (2004a) investigation, two Upper Hawthorn monitoring wells (HG-15S and HG-11S) were installed in the central area of the former Process Area. The locations for these wells were selected based on their ability to collect free-phase DNAPL. DNAPL was manually bailed from these well on a bimonthly basis from 2004 until 2009. Starting in August 2009, the manual bailing of DNAPL for these wells was replaced by DNAPL recovery via a peristaltic pump, in an effort to improve DNAPL recovery and product thickness measurements. The combined total DNAPL recovered from the two wells is averaging about 1 to 1.5 gallons every 2 weeks, with a total of about 220 gallons recovered since June of 2004. The DNAPL recovered from well HG-15S appears to be entering the well from three thin DNAPL ganglia zones located approximately 2 feet above the HG middle clay unit (approximately 66 to 68 feet below ground surface (bgs)), within a fairly uniform silty-sand deposit. Conversely, the DNAPL being recovered in HG-11S is originating from a clayey-sand deposit located approximately 17 to 13 feet above the HG middle clay unit (approximately 51 to 57 feet bgs). Similar to HG-15S, the DNAPL source for this well appears to be restricted to thin DNAPL ganglia emanating from coarser-grained sand lenses within an otherwise fairly uniform clayey-sand deposit. As evidenced from these two wells, the depth of free-phase DNAPL within the Upper Hawthorn is variable and dependent on the location of coarser-grained sand lenses within an otherwise fairly uniform clayey-sand deposit. It is useful to note that the ISGS technology as proposed will strategically target these (and other) zones of residual DNAPL impacts.

DNAPL recovery has been on-going since 2004 at three other Upper Hawthorn monitoring wells, which are located in the former Drip Track Area (HG-12S) and the former North Lagoon (HG-10S and HG-16S). The recovered DNAPL volumes at these two former source areas are less than half of what is being recovered in the former Process Area. The occurrence and recovery of DNAPL at these source areas are similar to observations at the former Process Area, in that it appears to be restricted to thin DNAPL-impacted ganglia zones. One conclusion that can be established from these investigations and historical DNAPL recovery is that free-phase DNAPL impacts within the Upper Hawthorn appear to be restricted to thin, discrete and potentially discontinuous sand lenses. Potential recovered volumes tend to be relatively low because the DNAPL saturations are close to residual levels, combined with the fact that the thin impacted DNAPL zones restrict flow rates to wells.

Based on these data, one of the first tasks associated with implementing ISGS within the former Process Area is to more accurately identify zones of free-phase DNAPL impacts so they can be targeted for treatment. Additional DNAPL recovery wells will be installed to document recovery both pre- and post-ISGS treatment for some of the more highly-impacted zones. Details of these pre-implementation tasks are described in Section 3.1.1.

3.0 PROJECT IMPLEMENTATION

The primary objective of this field-scale demonstration project is to validate the ability of the ISGS technology to successfully contain and stabilize potentially mobile DNAPL within the Upper Hawthorn. Accordingly, the field-scale demonstration will involve: 1) Additional characterization of the former Process Area; 2) Installation of additional DNAPL recovery wells so that a pre- and post-measure of DNAPL mobility (recovery rate) can be established across the former Process Area; 3) Testing and implementation of the ISGS technology; and 4) Monitoring the post-treatment effects of the ISGS remedy.

The project has been divided into four phases consisting of the following: 1) Phase I – Process Area Characterization; 2) Phase II - ISGS Reagent Injection; 3) Phase III - Performance Evaluation; and 4) Phase IV - Spot Treatment. Each of these phases is discussed below.

3.1 PHASE I – PROCESS AREA CHARACTERIZATION

The Phase I Process Area Characterization will include a detailed evaluation of free-phase DNAPL distribution, DNAPL recovery well installation, and laboratory testing of DNAPL impacted cores. A discussion of the individual characterization tasks are included below.

3.1.1 Subsurface DNAPL and Geologic Characterization

The Phase I subsurface characterization will be performed to better define the spatial distribution of DNAPL impacts in the former Process Area. Emphasis will be placed on defining zones of free-phase (potentially mobile) DNAPL so they can be targeted during remediation implementation. Investigation data will be gathered to better design the remediation program, including chemical and physical core analysis, injection methods and equipment testing. Specific tasks to be performed under Phase I are the following:

- Identification of subsurface buried structures in treatment area;
- Free-phase/residual DNAPL, vertical and lateral distributions;
- Environmental Visualization System (EVS[®]) model development for DNAPLs;
- DNAPL recovery wells and ZOD well installations; and
- Pre-treatment assessment of core samples for permanganate Soil Oxidant Demand (pSOD) and permeability reduction.

A discussion of each of these investigation efforts is provided below.

3.1.1.1 Locating Subsurface Structures

The former Process Area is known to contain subsurface structures, sumps, relict utilities, foundations and other features that might require an adjustment of drilling method and/or injection locations (**Figure 3**). Attempts will be made to identify subsurface structures prior to mobilizing injection equipment to the Site. Historical basemaps, aerial photos and field reconnaissance will be utilized in an attempt to locate subsurface structures. It is not the intent

of this field- demonstration project to physically remove buried obstructions in the former Process Area. Larger structures, such as concrete slabs and building footers, may require coring and the installation of temporary casings for injection equipment access. If possible, the injection-point locations will be adjusting slightly in order to avoid structures. The locations of subsurface structures will be surveyed and plotted on a Site basemap for future reference.

3.1.1.2 DNAPL Distribution Characterization

The current understanding of DNAPL impacts within the Upper Hawthorn beneath the former Process Area is limited to a few wells and borings installed in this area over the past 20 years. In order to strategically target free-phase DNALP impacts, a more detailed characterization of subsurface impacts is needed. This investigation will provide the level of detail needed to successfully target DNAPL impacts for remediation.

Core samples will be collected in surficial and HG deposits using a mini-rotasonic rig to provide detailed information on DNAPL distribution and potential correlation with sedimentary deposits. The rotasonic drilling method is efficient at drilling through unconsolidated deposits at this Site and has previously demonstrated its success at collecting intact, continuous geologic cores for visual identification of DNAPL impacts. Select DNAPL-impacted cores will also be collected for laboratory testing.

Investigative boring locations will be on an approximate 40-foot triangular grid (**Figure 5**), with the final sample locations to be adjusted slightly based on the presence of Site features such as foundations and subsurface utilities. Preliminary boring locations will be surveyed and located with Global Positioning System (GPS) survey equipment prior to mobilization of the drilling equipment. Any significant modifications to these locations will be resurveyed at the completion of the investigation.

Soil samples will be collected continuously from land surface to the top of the HG middle clay unit at approximately depth of 65 to 70 feet bgs. The samples will be logged for the presence of DNAPL by a hydrogeologist with site-specific experience in the hydrostratigraphy and identification of DNAPLs. The cores will be categorized as follows:

- 1) “DNAPL not observed” – no evidence, such as staining or liquid DNAPL, is observed in the core;
- 2) “DNAPL Staining observed” – the sediments are discolored consistent with contact with DNAPL; staining is often accompanied by creosote-like odors;
- 3) “DNAPL present below residual saturation” – when the core is disaggregated and sprayed with water, droplets of DNAPL form on the surface of the core material; and
- 4) “DNAPL present above residual saturation” – DNAPL flows freely from the core material.

The cores will also be logged to characterize lithology and photoionization detector (PID) screening results. The geologist will examine the core carefully for layers of silts and or clay which would promote development of higher DNAPL saturations in overlying sediments. The core will be photographed before disposal with the drill cuttings. Select cores will be retained for pre-treatment testing as described in Section 3.1.3.

To prevent potential future ISGS reagent day-lighting (i.e. flowing vertically upward through the formation and/or borehole, and discharging at land surface), the borings will be abandoned by backfilling with cement-bentonite grout mixture (6.5 gallons per 94 lb sack of cement with 3 to 5 percent bentonite). The grout mixture will be placed starting at the bottom of the boring using a tremie pipe or equivalent.

3.1.1.3 EVS[®] Model Development

Utilizing data and observations collected from the DNAPL investigation, the three-dimensional distribution of DNAPL in both the Surficial Aquifer and the Upper Hawthorn deposits will be evaluated using the Environmental Visualization System (EVS[®]) software (C Tech, 2010). DNAPL observations will be entered into the software in classifications to include: 1) "DNAPL not observed"; 2) "DNAPL staining observed"; 3) "DNAPL present below residual saturation"; and 4) "DNAPL present above residual saturation". EVS[®] will then be used to display the classification on the basis of color-coding of boreholes, displayed in three-dimensions (**Figure 6**). Borehole lithology data will also be entered into the EVS[®] model to help in the identification of potential "geologic traps" for DNAPL accumulation. The inclusion of geologic data allows the visual interpretation of DNAPL-in-core results to be placed in the context of the lithologies present at the site. These data will assist in the identification of laterally continuous lithologic units where free-phase (potentially mobile) DNAPL is likely to be present and ISGS treatment is needed.

3.1.2 DNAPL Recovery and ZOD Well Installations

Part of Phase I will include the installation of three DNAPL recovery wells in the former Process Area to supplement the two existing DNAPL recovery wells (HG-11S and HG-15S). The primary objective of the five DNAPL recovery wells is to provide baseline and post-injection DNAPL recovery rate data as a metric for DNAPL mobility reduction assessment. In addition, the wells will help to reduce easily recoverable DNAPL mass prior to the demonstration program implementation. The wells will be located to optimize the volume of product recovered and will be based on the results of the characterization described in Section 3.1.1. DNAPL recovery well installation procedures are described in **Appendix A** of this workplan.

DNAPL will be removed from the recovery wells on a bi-weekly basis using the DNAPL recovery procedures detailed in the CGMSAP (FTS and GeoTrans, 2010). All pre and post removal depths to water and DNAPL will be recorded. In addition, total volumes of DNAPL and water removed from the wells will be monitored over the duration of this demonstration project. Similar to the two existing DNAPL recovery wells, it is anticipated that DNAPL will be removed via a peristaltic pump to minimize disturbance of the DNAPL/water column. If the

depth to water/DNAPL in the three new recovery wells is too great for the use of a peristaltic pump, disposable bailers will be used to remove DNAPL from the wells. DNAPL recovery activities will commence immediately after well completion and will continue through the demonstration project performance assessment phase.

The FDEP Permit Variance for the use of the *in-situ* chemical oxidation using RemOx® EC specifies a ZOD to be within 150 feet of the ISGS reagent injection. A preliminary review of monitoring well locations indicate that downgradient Upper Hawthorn monitoring wells are located beyond of the 150 foot ZOD; hence, one or two additional Upper Hawthorn wells will be installed to meet this Variance requirement. Surficial Aquifer monitoring wells (M-25A, M-25B, PZ-17A and EW-17) are located approximately 60 to 70 feet downgradient of the former Process Area. Beazer will work with the FDEP to determine if Surficial Aquifer monitoring is required given the continual operation of the hydraulic-containment system and the close proximity of this system to the treated area. Preliminary Upper Hawthorn ZOD monitoring well locations are shown in **Figure 7**. Procedures to be used in well installation are provided in **Appendix B** of this workplan.

3.1.3 Pre-Treatment Assessment Core Samples

The reaction of RemOx® EC with reduced materials causes the precipitation of MnO_2 , which interacts with other ISGS reagents forming a silicate-based precipitate. The deposition of the enhanced MnO_2 precipitate results in an overall reduction in the permeability the treated zone and a corresponding reduction in groundwater flux through this area. The primary source of reduced material is likely to be the DNAPL that occurs in a small volumetric percentage of the Upper Hawthorn. Thus, the expectation is that injection of RemOx® EC into “DNAPL-rich” areas will result in moderately rapid decrease in permeability within the injection zone, potentially limiting the volume of ISGS reagent that can be injected over time.

The following laboratory tests on cores will be performed to determine the degree of permeability reduction in the “DNAPL-poor” deposits:

Step 1: Measure the permanganate Soil Oxidation Demand (pSOD) (see **Appendix D**) on five samples of “DNAPL-rich” Upper Hawthorn material and five samples of “DNAPL-poor” Upper Hawthorn material.

Step 2: Perform laboratory-permeability tests to evaluate effects of short-term ISGS reagent exposure on Upper Hawthorn cores:

- a) Measure the permeability to water for three samples of “DNAPL-rich” Upper Hawthorn material and three samples of “DNAPL-poor” material.
- b) React the samples with a measured volume of 4.5% permanganate ISGS reagent for 24 hours. Measure the concentration of permanganate in the solution, for calculation of the mass of permanganate consumed.

- c) Re-measure the permeability to water on the samples. The water flowing through the core will be collected for measurement of the permanganate concentration, as described in step 2b.

Step 3: Perform laboratory-permeability tests to evaluate effects of long-term ISGS reagent exposure:

- a) Measure the permeability to water for three samples of “DNAPL-rich” Upper Hawthorn material and three samples of “DNAPL-poor” material.
- b) React the samples with a measured volume of 4.5% permanganate ISGS solution for 4 weeks. Measure the concentration of permanganate in the solution, for calculation of the mass of permanganate consumed.
- c) Re-measure the permeability to water on the samples. The water flowing through the core will be collected for measurement of the permanganate concentration, as described in step 3b.

Step 2 testing will provide information pertinent to short-term geoprobe injections and step 3 testing will provide information pertinent to longer-term injections via temporary points (wells).

These data will be used, in conjunction with information provided by the field testing described below, to determine the optimal strategy for injection of the ISGS reagent.

3.2 PHASE II – ISGS REAGENT INJECTION

Two methods for injection the ISGS reagent are anticipated for the Upper Hawthorn. The first is the use of geoprobe tools to inject the reagent into 1 to 2-foot targeted DNAPL-impacted zones. It is anticipated that these targeted injections will require 100s of gallons of reagent injected into each target zone over a time period of 1-2 hour. This approach allows more controlled injection, but requires high-injection rates, and thus higher-injection pressures. The second approach is to inject the reagent into laterally and vertically extensive DNAPL-impacted zones (10s of feet) via temporary injection points. It is anticipated that these vertically extensive injections will require 1000s of gallons of reagent per injection point. The reagent will be injected via temporary injection wells, with screen intervals ranging from 10 to 20 foot in length. The injection will be done using gravity feed from elevated tanks, with longer injection periods (days to weeks) and reduced injection pressures.

3.2.1 Injection Pressures and Fluid Flow Considerations

Fluids can be injected into a formation under different modes, which will have an impact on the overall distribution of the injected fluid. The three modes of injection flow include: 1) Darcian flow; 2) Non-Darcian flow hydrofractures; and 3) Non-Darcian flow liquefaction. Each of these modes is dependent on injection pressures and material properties. The following is a discussion of the three modes of fluid flow, injection pressures and reagent distribution:

- 1) Darcian flow – Under low-injection pressures and potentially lower flow rates, the permeability of the formation does not change during the injection process. Injected

permanganate will tend to move radially out from the injection point, with dispersion occurring because of small-scale differences in the permeability of the sediments near the point of injection. As a result of differences in velocity of the water and reagent movement, there will generally be a decrease in reagent concentrations away from the injection point. As the permanganate reacts with organic compounds, MnO_2 will precipitate, decreasing the formation permeability. The greatest reduction is expected adjacent to the borehole in “NAPL-rich” sediments. If the sediments are sufficiently permeable, then low-injection pressures can be used to inject the ISGS reagent, and the distribution of the reagent will be determined primarily by the distribution of permeability around the injection point. The “NAPL-rich” sediments are expected to experience a rapid reduction in permeability (days), while “NAPL-poor” sediments will experience less permeability reduction over a longer period of time (months to year).

- 2) Non-Darcian flow through hydrofractures – If the permeability is sufficiently low, fluid pressures can be increased to a point where the sediments may fracture, and a fracture will propagate from the injection point as long as fluid pressures at the end of the fracture remain high enough to cause the sediments/rock at the end of the fracture to separate/break. In shallow materials, hydraulic fractures tend to be horizontal, in part because the land surface can freely be displaced upward. Because the lithostatic load decreases with decreasing depth, the fractures would tend to propagate in a manner that they become shallower with increasing distance from the injection point. In practice, however, the heterogeneity of the materials affect the propagation of the fractures, and fractures can grow in different directions. If a hydrofracture encounters a permeable layer or pre-existing fracture, the more permeable material will intercept the flow of injected fluid, and growth of the fracture may cease.

When fluid is being injected into low-permeability material, the injection pressure will quickly rise to a peak value without a significant increase in injection flow rate, then decrease to a lower value (accompanied by an increase in flow rate) for as long as fluid is being injected. This behavior is indicative of hydraulic fracturing (fracking), with the fracture initiation occurring when the pressure drops off after reaching the peak value. Fractures will form when the subsurface material is cohesive.

A similar pressure response could be observed for subsurface materials that are not cohesive; however, distinct fractures will not form under these conditions. Rather, the grains will be pushed apart by the increased fluid pressure, increasing the materials porosity and permeability. The ISGS reagent will flow outward via the separation of matrix grains.

The advantage of hydraulic fracturing is that the permeability of the material is increased to allow injection of the solution. Because the volume of the fracture is small, the

fracture can grow to cover a large area. However, when the injection pressure is decreased, the fracture will close unless proppant solids are injected into the fracture.

Because the orientations of the fractures are determined by properties outside the control of the injection contractor, efforts to generate closely-space fractures are likely to create fractures that short-circuit through previously created fractures.

- 3) Non-Darcian flow through liquefaction – The third mode of injection is one in which the permeability is increased by decreasing the grain-to-grain contact (creating a quick condition) and increasing the pore dimensions within the sediments. This is done through increasing the pore pressure as in hydraulic fracturing, but the pressure buildup is accompanied by an increase in injection rate in a non-linear fashion, and no distinct breakdown occurs. Rather than having a distinct fracture along which the reagent will move, the reagent will be injected into a larger zone of unknown size and shape. The zone of liquefaction may grow upwards, in much the same manner as sand boils are developed following earthquake-induced liquefaction. In addition, there is the potential for liquefied sediments to flow back into the geoprobe injection casing string after the injection pressure is reduced.

3.2.2 Pre-Demonstration ISGS Injection Testing

Prior to performing the full-scale demonstration ISGS injection, the geoprobe and temporary injection point approaches will be tested and evaluate. Two pre-injection test locations are planned. Both test locations will be performed in areas known to contain free-phase DNAPL impacts. Test locations will be selected after the Phase I – Process Area Characterization data have been collected and analyzed for the Upper Hawthorn.

The goals of this pre-demonstration injection testing are to obtain the following information for both the geoprobe and temporary injection point approach, so that scale-up from these tests can be achieved:

- 1) Develop information on achievable injection rates and volumes at multiple injection pressures;
- 2) Establish the affected radius (radius of influence) and optimal mode of permanganate injection; and
- 3) Evaluate whether changes in depth of injection affect the injection method and distribution of permanganate.

A discussion of the pre-demonstration injection testing procedures is provided below.

3.2.2.1 Geoprobe-Injection Tests

Injection of the ISGS reagent using a geoprobe rig may be constrained by the relatively low permeability of the Upper Hawthorn and the corresponding time it will take to inject the specified reagent volumes. In addition, the reaction of the permanganate with organic materials will cause the precipitation of MnO_2 in the pore space, further reducing the permeability of the sediments. Testing will be performed to provide information with which to optimize the injection program. Briefly, this evaluation entails the following steps:

- 1) Select locations within the former Process Area to perform injection testing, based on the results of the DNAPL Distribution Characterization (see Section 3.1.1). The primary selection criteria for the test locations are that it is representative of deposits and DNAPL impacts within the former Process Area. The optimum test location will contain: a) Free-phase DNAPL impacts, and b) A range of low to moderate permeability deposits.
- 2) Based on the results of the DNAPL Distribution Characterization (see Section 3.1.1), select three depths within the Upper Hawthorn for injection testing. Initially, the injection testing is planned for 1 to 2-foot intervals approximately 5 feet below the bottom of the HG deposit upper clay unit (approximate depth below land surface of 20 to 30 feet), in the middle of the Upper Hawthorn (approximate depth below land surface of 40 to 50 feet), and 5 feet above the top of the middle clay (approximate depth below land surface of 60 to 70 feet). Final selection of test intervals will be dependent on the results of the DNAPL Distribution Characterization, discussed in Section 3.1.1).
- 3) Using a geoprobe rig, inject the ISGS reagent at three depths at two separate locations (**Figure 8**). Injection will occur from shallow to deep at the test locations. The total volume of reagent injected at each 2-foot interval depth will be 750 gallons (the 750 gallons of reagent is equivalent to the volume required to displace all fluid in a 2-feet long by 10-foot radius cylinder of porous media, with a 15-percent porosity). It is difficult to predict the final reagent distribution prior to injecting; however, it is expected that the injected reagent will follow the path of least resistance and exceed a 10-foot radius in some directions and will be less than 10 foot radius in other directions.
- 4) During the injection process at each depth, step-injection tests will be performed, monitoring the injection pressure and injection rate using a data logger. Based on previous experience at wood-treating Sites, the minimum pressure required for injecting the reagent is approximately 20 psi and the maximum sustainable pressure for the injection equipment is approximately 100 psi. Therefore, pressure step sizes of 20, 40, 60, 80, 100 psi gauge (as measured at land surface) will be evaluated, with each step lasting approximately 30 minutes. An approximate equal volume (150 gallons) of reagent will be injected at each of the five injection pressures discussed above. Injection will continue based on the incremental pressure steps until a maximum of 750 gallons has been injected. In some cases, it may be necessary to hydraulically fracture the formation with pressures exceeding 100 psi to achieve reasonable injection rates. If pressure breakdown occurs (indicating hydraulic fracturing), injection will continue at the stabilized pressure until a total of 750 gallons has been injected.

- 5) Following completion of the geoprobe injections at three depths and two locations, collect continuous core from land surface to the top of the middle clay at six locations at a distance of 5 and 10 feet from the injection point (**Figure 9**). If the reagent is observed at a distance of 10 feet, additional cores will be collected at 5 foot distance increments (15, 20, etc. feet) until the reagent is no longer observed. Additional cores will only be collected in the directions where reagent was observed to exceed a distance of 10 feet; no additional cores will be collected in directions where the reagent was not observed at 10 feet. The cores will be photographed, and logged for presence of nonreacted permanganate, MnO_2 , and DNAPL. Detailed lithologic descriptions will be developed for all cores.

3.2.2.2 Temporary Injection Point (Well) Tests

Injection of the ISGS reagent using temporary injection points will allow for slower injection of reagent at lower pressures (i.e. gravity drainage). However, the longer injection time may result in an increased reduction of permeability in the deposits surrounding the temporary injection point due to the precipitation of MnO_2 in the pore space. Therefore, one of the primary objectives of the temporary injection point test is to evaluate the injection rate under gravity drainage and the potential reduction in rate with time. Temporary injection point test evaluation entails the following steps:

- 1) Two temporary injection points (wells) will be installed, using standard monitoring well techniques (**Figure 9**). Temporary isolation casing will be installed through the Surficial Aquifer to prevent downward movement of contamination during well construction (see **Appendix C**). The wells will be constructed with a 10-foot screen, and appropriate filter pack material. The annular space above the filter pack will be sealed with bentonite. The temporary casing will be removed contemporaneously with the placement of the bentonite seal.
- 2) Injection testing will be performed in each well under a gravity-feed system from elevated mixing tanks. Pressure transducers installed in the tanks will be used to monitor injection rates and injection pressures. The same volume of reagent injected per 2-foot interval (750 gallons) for the geoprobe testing will also be injected for the temporary injection points. A well screen 10 feet in length will result in a total injected reagent volume of 3,750 gallons of reagent. After 3,750 gallons of reagent have been injected at each of the temporary injection points, the injection will be stopped.
- 3) Soil cores will be collected around each of the temporary injection points. At each injection point, six continuous cores will be collected at equally spaced intervals at a distance of 5 and 10 feet from the injection points, from the water table to the top of the HG middle clay unit (**Figure 9**). Additional cores will be collected at 5-foot incremental distances out from the injection point (i.e. 15 and 20 foot distances), if reagent is observed in cores collected at 10 feet. The cores collected beyond 10 feet will only be collected in directions where reagent was observed at a distance of 10 feet and not in the directions where reagent was absent at the 10-foot distance. The cores will be

photographed, and logged for presence of non-reacted permanganate, MnO₂, and DNAPL. Detailed lithologic descriptions will be developed for all cores.

3.2.2.3 ISGS Reagent Injection Approach

Based on the results of the preliminary injection testing, the optimal approach to ISGS reagent injection will be developed. More than one technique may be used depending on Site conditions. For example, temporary-injection points may be used to build a permanganate zone on the exterior of the treated area to limit movement of DNAPL away from interior zones that will likely be targeted by higher-pressure geoprobe injections. In addition, temporary injection points may be used in areas of laterally and vertically extensive DNAPL impacts, where it may be more efficient to inject over longer intervals for extended periods of time.

Direct Push Geoprobe Injection

Advantages

Vertical direct-push drilling using geoprobe (or other, equivalent methods) does not require drilling fluids and provides relatively rapid borehole advancement with minimal investigation derived waste (IDW) generation. The borehole is approximately the same size as the direct-push casing, providing a relatively effective seal against fluid “blow-by”, when compared to other drilling methods. The annular seal can be further improved using bentonite-based products in a pilot hole installed in the surficial deposits, prior to advancing the tool into the Upper Hawthorn.

A short injection interval (approximately 1 to 2 feet) allows better control for subsurface delivery of the ISGS reagent at targeted depths. Side- injection tools are typically 0.5 to 1 foot in length. The procedure for injecting reagent is to advance the tool to the target depth and pull the tool and drill string up 1 to 2 feet, resulting in an open borehole beneath the injection tool. The injection fluid pressure pushes the injection head out of the protective sleeve to expose the ports and allow fluid to flow into the formation. Hence, the majority of the reagent will be injected within the open borehole interval opposite the injection ports and immediately below it. Because side-injection tool are relatively short, attempts to inject into zones greater than 2 feet would be difficult to control where reagent actually flowed into the formation. In addition, longer injection intervals would increase the likelihood that higher permeability sections absorb the great majority of the reagent, where it will slowly migrate into less permeability zones.

A pressure-pulse injection tool can potentially overcome some injection challenges by generating a fluid-pressure pulse. In theory, the pulse causes momentary elastic flexure of the pore structure which allows fluid movement into an increased system of pore networks, allowing a more uniform injection front and potentially reducing the “blow-by” effect. Both side-injection uniform pressure and side-injection pressure-pulse tools will be evaluated during the pre-injection investigation process. It is anticipated that one test location will be used to evaluate a constant pressure side-injection tool and a second location will be used to evaluate the pressure-pulse tool.

Disadvantages

One of the potential disadvantages of direct-push injections is that it may be necessary to hydraulically fracture the formation in order to inject the reagent. Fracking the formation will make it more difficult to control where the reagent flows and may require shorter (1 foot) injection intervals to obtain targeted distribution of reagent. The use of high injection pressures increases the likelihood of reagent day-lighting, especially at shallow injection depths. In addition, because of the large number of injection points and the relatively short injection intervals (approximately 1 to 2 feet), it will be necessary to achieve injection rates of 5 gpm or greater in order to complete the injection phase within a reasonable timeframe. Because of the large number of injection points and intervals, it is likely that multiple geoprobe rigs will be utilized to install multiple injection strings that will be manifolded together during a single injection event. The use of multiple rigs and injection strings will allow simultaneous injections at four to six locations, thereby, reducing the total time to complete the ISGS injection treatment.

Temporary Injection Point Injection

Advantages

Because the temporary injection points can be left installed over a period of several months, it may be possible to inject the ISGS reagent over a longer period of time, and thus at a much slower rate than needed for direct-push tools. Therefore, high-injection pressures (greater than 60 psi) would not be required.

The lower pressures used with this technique would not cause hydrofracturing or liquefaction. Thus, the distribution of the reagent will be primarily determined by the distribution of permeability within the sediments. Similarly, free-phase DNAPL is likely to be present in the higher permeability deposits. Therefore, the reagent is more likely to follow the DNAPL impacts located in high permeability deposits with this method, versus injection via a geoprobe hydrofracturing process.

The individual temporary injection points may be reused to inject additional ISGS reagent at a later date. Reuse of the temporary injection points will require that the majority of the screen interval for these points remain unplugged.

Disadvantages

The slower injection via temporary injection points can only be successful if the permanganate reacts slowly in the “NAPL-poor” sediments. If MnO₂ precipitation occurs in all parts of the injection interval, the resultant reduction in permeability may make this technique infeasible. Temporary injection points were successfully used at a wood-treating site in Colorado, where clogging of the screen interval was not a major issue during a 1 to 2-week injection period.

Because the ISGS reagent will preferentially flow through the more permeable sediments, DNAPL that may be present in lower permeability materials is less likely to be treated. Cores collected at the Site indicate that the majority of the DNAPL impacts are primarily restricted to the high-permeability deposits, with less DNAPL impacts present in the lower-permeability, fine-grained material. Therefore, the potential for significant DNAPL impacts in lower-permeability deposits is not expected at this Site.

Comparison of Delivery Options

After completion of the preliminary assessment data collection, each of the methods described above will be analyzed for pros and cons for use in Phase II ISGS field-scale demonstration project. Primary evaluation criteria include the following:

- Proven history of use at similar sites;
- Robustness and reliability of system equipment;
- Length of time required for implementation; and
- Potential for injection-related failures, such as “blow-by” (reagent bypassing the injection string seal against the borehole and flowing up the borehole) and/or day-lighting.

Each of these selection criteria will be considered and the final selection process will be documented in a brief memorandum, prior to full-scale demonstration implementation.

3.2.3 Demonstration ISGS Reagent Injections

The Phase II ISGS implementation will be performed based on data obtained during the Phase I testing. This testing will provide critical information on: 1) Optimal injection delivery method; 2) Injection point spacing; 3) Injection pressures; 4) ISGS reagent concentrations; and 5) Borehole sealing approach to mitigate blow-by and day-lighting during injection. Although a number of the specific details for the implementation of the ISGS will be established during Phase I, assumptions concerning implementation have been made for the purposes of this workplan.

Injection-Point Locations, Spacing and Sequencing

Based on previous studies at the site (Adventus, 2008 and 2009), the estimated conservative radius of influence that can be attained through careful injection pressure and volume control may be approximately 10 to 15 feet; however, the average injection radius will be confirmed during Phase I testing. For this workplan it is assumed that the radius of influence will be 10 feet and that the injection points will be located on a 20-foot triangular grid. Preliminary injection-point locations are shown in **Figure 10**.

It is anticipated that ISGS reagent injection will start on the outer limits of the targeted treatment area, in order to establish a zone of ISGS reagent material in the event of DNAPL displacement during injections into the central area of the DNAPL mass. Depending on the Phase I investigations and DNAPL distribution, specific injection sequencing and locations will be developed at the completion of this investigation.

Chemical-Mixing Systems

The final reagent mixing will be performed at the Site immediately before injection. Specific details of the proprietary formulation will not be provided in this document; however, the generic formulation and procedure will be discussed below and were confirmed to be effective during testing in the Surficial Aquifer. Description of ISGS reagents including MSDS

and related materials were previously submitted, reviewed and approved by FDEP for use at the Site.

Chemicals required to prepare the ISGS solution include sodium permanganate (40 % solution) and other liquid and solid chemical reagents as part of the proprietary formulation. To ensure the highest quality, ISGS is generally mixed in the field using high-speed mixing equipment and appropriate means of safe chemical measuring and transfer. The permanganate and other reagents are used along with a local supply of water to produce a 4.5 wt% ISGS solution. Permanganate and other ISGS reagents may be shipped in drums, totes, or tankers, in accordance with site-specific product quantity and storage requirements.

Prior to beginning the mixing process, it is important to verify that all injection equipment is operational. Most of these checks can be made using potable water. Location of the mixing tanks will be as close as possible to the injection points to minimize the length of the injection hose from the pump to the injection point.

Geoprobe-Injection Procedure

Geoprobe manufactures various sizes of downhole tooling and specially-designed injection equipment for *in-situ* applications. Typically, 1.0- to 1.5-inch diameter rods are used with Geoprobe GS-series grout pumps.

For better control of ISGS reagent placement, injection from ground surface downward is recommended. Injection from the bottom of the boring upward can result in unwanted reagent injection through open intervals of the borehole. The injection tooling and procedures will be optimized during Phase I injection testing. These procedures may be modified to accommodate tools or methods that may be more effective in delivering the ISGS reagent to the formation. The following general procedures are to be used during the injections (Note that the procedures described below are for one injection point):

- 1) Drive the injection rods to the desired depth, using either a retractable screen, a pressure-activated probe or other device at the lead end of the geoprobe drill string.
- 2) Blend the reagents in a mixing and transfer tank.
- 3) Pump the pre-determined quantity of ISGS reagent into the formation while monitoring and recording pump pressures, flow rates and volumes to ensure the formation is accepting the reagent. In the event of refusal or unacceptably high pressures, modify the reagent concentration or adjust injection-point spacing.
- 4) In some tool designs a high-pressure hose, connected to the injection point, is used to inject the reagent. The high-pressure hose runs down the inside of the injection rods and isolates the rods from the reagent fluid. Other systems do not utilize a separate hose and the reagent is delivered inside of the injection rods. In cases where reagent is in contact with the rods, allow system pressures to dissipate before removing tooling to minimize reagent splattering when rod joints are disconnected.

- 5) Move to next injection depth interval and repeat steps 3 through 5.
- 6) After completing the injection, remove the tooling from the probe hole and seal the open borehole with bentonite or cement grout to prevent blow-by/day-lighting during injection in adjacent locations.

Temporary-Injection Point Procedure

Injection via the temporary injection points will be performed with a gravity-feed system. An approximately 21,000 gallon Baker tank, specifically developed for these types of applications, will be utilized for mixing and injecting the reagent. The Baker tank will be equipped with four 10-horsepower, double paddle mixers to keep the solution thoroughly mixed during the injection. The mixing tank may be elevated to increase the hydraulic head during injection.

The delivery system to the injection-point well head will consist of HDPE piping. A manifold system will be installed at the end of the HDPE pipe, which allowed simultaneous injection into multiple injection points (up to 10 points). Each of the manifold lines connecting to an injection-point well head will be equipped with a brass control valve and a flow meter to record the total volume of ISGS reagent injected.

The reagent will be injected under low pressure (10 to 20 psi) through a gravity-delivery system, described above. An approximately constant flow rate of between 1 and 10 gallons per minute (gpm) will be maintained during the injection process. Experience indicates that the accuracy of the flow meters will decline as the injection rates decline. In cases where inaccuracies in the flow meter are noted, the injection contractor will be instructed to reconcile the difference based on the mixed batch volumes of permanganate solution.

3.3 PHASE III – PERFORMANCE EVALUATION

The performance goals of the field-scale demonstration project will include a complete evaluation of the performance goals detailed in the February 2011 ROD. The performance goals summarized in the ROD (Page 122) are the following:

- 1) *Consistent and controlled delivery and distribution of ISGS injectate throughout the designated treatment area with corresponding reduction in permeability and encapsulation of DNAPL;*
- 2) *Pronounced reduction in groundwater contaminant concentrations/DNAPL and reduction in mass flux both laterally and vertically; and*
- 3) *Demonstrated longevity and stability of stabilized matrix, with no rebound.*

Achievement of goals #1 and #3 will have a direct impact on the performance of the ISGS remedy; however, the ultimate success of the ISGS remedy will be demonstrated by performance goal #2, a “*pronounced reduction in groundwater contaminant concentrations/DNAPL*”. The other goals will have a direct impact on goal #2, but the real determination of success is did the ISGS remedy reduce DNAPL mobility and the mass flux of constituent concentrations originating from the source areas.

The short-term evaluation of this field-scale demonstration project will concentrate on the reduction in DNAPL mobility. The long-term evaluation will concentrate on the both the longevity of the stabilized DNAPL and the reduction in mass flux of constituents. A discussion of the short-term and long-term performance evaluation is provided below.

3.3.1 Short-Term Performance Evaluation

The short-term objective of the field-scale demonstration project is to contain and immobilize DNAPLs in the Upper Hawthorn in the former Process Area. The primary method for evaluating the effectiveness of the ISGS remedy toward meeting this goal will be through monitoring the rate of DNAPL recovery in the two existing DNAPL recovery wells (HG-11S and HG-15S), and three new DNAPL recovery wells installed as part of the Phase I investigation. During the pre-injection and post-injection periods, CGMSAP SOP #116 Depth to Groundwater and NAPL Measurements (FTS and GeoTrans, 2010) will be followed to ensure consistency between the two sets of measurements.

The short-term determination of the effectiveness will be based on temporal plots of DNAPL thickness and DNAPL recovery. Plots of these parameters for HG-11S and HG-15S over the last 12 to 18 months are characterized by low- to moderate-levels of noise with occasional obvious outliers; however, there has been a general downward trend in thicknesses and recovered volumes over this time period. Shortly after the injection phase, perturbations in the plots may occur, as water, and perhaps DNAPL saturations are redistributed. However, after a relatively short period (months), a dramatic decrease in the DNAPL recovery rate is expected, based on experience at other creosote sites where ISGS has been used. While immobilization of all free-phase DNAPL should not be expected, the majority of the DNAPL mass within the former Process Area should be immobilized and contained, with a corresponding decrease in the recovery rate in wells.

One of the goals of the ISGS evaluation is “a reduction in permeability” of the treated areas. This reduction in permeability is expected to be fairly rapid and will occur within the first few months to a year following treatment. The ROD specifies (Page 122):

“Pre- and post-treatment slug tests and monitoring of water levels/hydraulic gradients in monitoring wells/piezometers and downgradient recovery wells to document attainment of anticipated changes in hydraulic conductivity/permeability in treatment areas and downgradient.”

Although the reduction in formation permeability is expected to occur in the ISGS treatment zones, it is possible that in-situ measurements of hydraulic conductivity via single well tests (i.e. “slug tests”) will not reflect this reduction. The current conceptual model for the DNAPL impacts in the Upper Hawthorn is that the majority of the deposits are not impacted and that DNAPL is primarily restricted to discrete zones. As such the ISGS implementation will target these discrete zones, but not the entire thickness of Upper Hawthorn deposits where DNAPL impacts are not present. Therefore, the average permeability reduction for the entire Upper Hawthorn (both treated and untreated zones) is expected to be small as a result of the ISGS

treatment. Slug tests performed in monitoring wells with 10-foot screens may not be sensitive to a permeability reduction in a 1 to 2 foot DNAPL treated zone within this screen interval. In addition, it should be recognized that the presences of DNAPL in an aquifer matrix, as a separate-phase liquid reduces the overall permeability of the formation to water. Encapsulating the DNAPL will further reduce the permeability; however the degree of permeability reduction will be dependent on the DNAPL saturations within the zone. Lower DNAPL saturations will result in less permeability reduction.

Pre- and post-treatment slug tests will be performed in Upper Hawthorn monitoring/recovery wells, as required by the ROD. An analysis of the tests may not show a significant reduction in permeability, depending on the extent of the treated zone; however, the lack of permeability reduction is not a good measure of ISGS treatment success or failure, as discuss above. Rather, the success of the ISGS remedy will be a demonstrated reduction in DNAPL mobility as indicated by a significant reduction in DNAPL recovery in wells in the former Process Area.

3.3.2 Long-Term Performance Evaluation

Long-term performance evaluation (5 to 10 years) is not proposed as part of this field-demonstration project and will be incorporated into a comprehensive performance evaluation of the final remedy. However, long-term performance criteria that will be evaluated under a more comprehensive long-term monitoring program include:

- 1) On-going containment and stabilization of free-phase DNAPLs;
- 2) Evaluation of the long-term geochemical stability of silixcate-MnO₂ shells;
- 3) Reductions in downgradient dissolved-phase PAHs concentrations;
- 4) Evaluation of permeability reduction in treatment zones; and
- 5) Evaluation of reduced groundwater flux through treatment zones.

In addition, other techniques could be used to collect information on the distribution of the ISGS reagent, and may be proposed to develop a better understanding of the injection processes, if the DNAPL recovery rate is not significantly decreased. This additional information would be useful in developing better approaches for injection of reagents in the Upper Hawthorn and similar lithologies, and to develop a program for additional treatment of the former Process Area. These techniques include:

- Downhole electrical-conductivity logging (using a geoprobe conductivity probe, or equivalent) could be used to evaluate the distribution of the ISGS reagent around the injection points;
- *In-situ* groundwater flow sensors and/or passive flux meters (PDF) could be used to evaluate groundwater flux reduction; and/or
- Coring to map distribution of DNAPL, reacted ISGS reagent, and non-reacted ISGS reagent around the injection points.

Although these additional post-injection characterizations are not currently proposed as part of this demonstration project; one or more of these investigations may be proposed after

preliminary performance monitoring data are evaluated. These data may be used to support the spot ISGS treatments discussed in Section 3.4.

3.4 PHASE IV – ISGS SPOT TREATMENTS

Additional ISGS treatment may be proposed after completion of the initial ISGS implementation and performance evaluation. Given the inherent difficulty in injecting ISGS reagent into low-permeability material, it may be necessary to address hot-spot zones that were not fully treated during the initial injection. Depending on the performance-monitoring data and post-ISGS DNAPL thickness/recovery rate at individual wells, it may be necessary to reevaluate the initial ISGS reagent subsurface distributions. Potential additional investigations that may be proposed are described in Section 3.3.2 and consist of electrical-conductivity logging and/or core collection. These additional investigations may help to explain performance monitoring results and provide additional information needed to target untreated DNAPL zones. The need to perform a second spot treatment of DNAPL zones will be decided after 4 to 5 months of performance monitoring.

3.5 EQUIPMENT DECONTAMINATION AND IDW

3.5.1 Equipment Decontamination

A thorough decontamination of downhole equipment between each geoprobe investigative borehole is not critical given that the investigation will be performed in the former source area. Concern with cross-contamination between boreholes is not a major issue since the entire source area will ultimately be treated. All downhole drilling equipment will be thoroughly decontaminated prior to the equipment arriving on Site and following the investigative boring program. Decontamination between investigative boreholes will be on an as needed basis at the discretion of the on-Site geologist. Gross DNAPL contamination on downhole equipment will be removed; however, a thorough decontamination is not planned or needed during this investigation.

Decontamination will be performed prior to installing each of the new DNAPL recovery wells. Decontamination will be performed by steam/pressure washing all downhole equipment. An isolation casing will be set in the HG upper clay unit, prior to drilling into the Upper Hawthorn. All drilling equipment and tools will be decontaminated prior to drilling the open hole beneath the lowermost casing and prior to starting a new DNAPL recovery wells.

3.5.2 Investigative Derived Waste

All wastewater and soil generated during the activities described in this workplan will be containerized in drums or bulk tanks. The aqueous fractions from drums or bulk tank(s) will be mixed with influent water from the on-going groundwater extraction system and treated on-Site, prior to discharging to the permitted POTW. Soils and rock cuttings will be staged in sealed roll-off containers or drums for characterization and off-Site disposal.

4.0 PERMIT REQUIREMENTS

All necessary permits will be obtained prior to the implementation of this field-scale demonstration project. State permits required for this work include: 1) DNAPL recovery well construction permits; and 2) Temporary injection-point permits. It is Beazer's understanding that an Underground Injection Control (UIC) permit is not required for this Site, since this Site is under Superfund and the direction of the U. S. EPA. Further, Beazer assumes that the Carus Corporation, Inc. March 28, 2008 State-wide Petition for Variance for RemOx® EC Stabilizing Reagent usage, approved by FDEP on July 24, 2008, is still in effect and that modifications to this variance are not required for this demonstration project.

Well and Temporary-Injection Point Permits

St. Johns River Water Management District (SJRWMD) is responsible for the issuance of permits for well construction at the Site. All forms and associated fees associated with obtaining well permits from SJRWMD will be completed prior to well-installation activities.

The use of temporary-injection points (wells) will be evaluated as part of the Phase I investigations and testing. Two temporary injection points will be evaluated during initial testing under Phase I. Beazer will work with the SJRWMD to determine if a permit is required for use of temporary injection points.

UIC Permit

A Class V UIC permit application is not required, if the work is performed in accordance with a U.S. EPA corrective action plan or remedial action plan (Telephone communication with FDEP, December 10, 2010). Therefore, based on guidance from FDEP, it is anticipated that no UIC permit application will be required for this pilot project.

Permit for Variance

On July 24, 2008, the State of Florida Department of Environmental Protection granted Carus Corporation a Final Order Granting Petition for Variance from Rule 62-522.300(3) of the Florida Administrative Code. The petition was for a variance under section 120.542 of the Florida Statutes, from Rule 62-522.300(3), which prohibits a zone of discharge through wells as part of an *in-situ* remediation process. The process described in the variance involves the use of temporary Class V underground injection control wells or borings at the site of contamination. The variance applies specifically to Carus' RemOx® EC Stabilizing Reagent. The variance is subject to the following conditions:

- 1) Use of this product must be through a Department approved remedial action plan, or other Department-enforceable document, for an aquifer remediation project and such approval shall not be solely by a delegated local program.
- 2) The discharge to the groundwater must be through a Class V, Group 4 underground injection control well which meets all of the applicable construction, operating, and monitoring requirements of chapter 62-528 of the Florida Administrative Code.

- 3) The extent of the zone of discharge for antimony, arsenic, chromium, mercury, beryllium, cadmium, lead, thallium, selenium, and molybdenum shall be within a 150 foot radius from the point of injection and the duration of the zone of discharge shall be 1 year. This will allow ample time for the temporarily exceeded parameters to return to the drinking water standards or applicable levels set forth in chapters 62-550 and 62-777 of the Florida 5 Administrative Code, or their naturally occurring background levels at the site, whichever is less stringent.
- 4) The injection of the product shall be at such a rate and volume (no greater than 4.5-percent sodium permanganate solution {the concentration of sodium permanganate in RemOx® EC}) that no undesirable migration occurs of the product, it's by-products, or the contaminants already present in the aquifer.
- 5) The Department-approved remedial action plan shall address appropriate groundwater monitoring requirements associated with the use of the *in-situ* chemical oxidation using RemOx® EC for remediation based on site-specific hydrogeology and conditions. These shall include the sampling of groundwater at monitoring wells located outside the contamination plume, before use of RemOx® EC Stabilization Reagent, to determine the naturally occurring background levels of antimony, arsenic, chromium, mercury, beryllium, cadmium, lead, thallium, selenium, molybdenum, sodium, chloride, aluminum, manganese, TDS, pH, iron, and color which are the parameters pertinent to this variance. Monitoring of these parameters in groundwater should also be included downgradient from the injection points for at least 1 year after active remediation. (Sodium, chloride, aluminum, manganese, TDS, pH, iron, and color are included herein solely because of the recent rules amendments discussed in paragraph 3 above, which require any parameter that will not meet its standard, and for which a variance is no longer needed, to be included in the remedial action plan for monitoring and zone of discharge purposes).
- 6) The sodium permanganate which is used in the RemOx® EC Stabilization Reagent shall be derived from manganese ore as specified in the petition.

The Variance specifies a zone of discharge to be within 150 feet of the ISGS reagent injection. As required by the 2008 Variance discussed above, baseline groundwater samples will be collected from both Surficial Aquifer and Upper Hawthorn monitoring wells to evaluate metals, inorganic constituents and field parameters associated with RemOx® EC. Preliminary ZOD monitoring well locations are shown in **Figure 7**.

Two rounds of groundwater samples will be collected using conventional methods from each of the ZOD monitoring wells to establish baseline constituent concentrations prior to ISGS reagent injection. Quarterly samples will be collected from these monitoring wells for 1 year following the ISGS reagent treatment.

5.0 PROJECT MANAGEMENT PLANS

The project management plans that will be utilized to guide the work outlined in this section will include the following documents:

- 1) Health and Safety Plan (HASP);
- 2) Quality Assurance Project Plan (QAPP); and
- 3) Comprehensive Groundwater Management and Sampling Analysis Plan (CGMSAP).

A HASP and QAPP were previously prepared (TRC, 2002b; TRC, 2002c) and incorporated the items listed below:

Health and Safety Plan

A project-specific HASP (TRC, 2002b) has been prepared to define the health and safety requirements for this project. This HASP establishes the procedures and requirements used to minimize health and safety risks to persons working on the project. The HASP meets the requirements of the Occupational Safety and Health Administration (OSHA) Standard, 29 CFR 1910.120 and 29 CFR 1926.65, "Hazardous Waste Operations and Emergency Response".

In addition to the plan prepared or amended under this workplan, subcontractors will be required to prepare Health and Safety Plans that are specifically focused on their specialized activities. These plans will include Job Hazard Analyses and MSDS forms for any materials that may be required to complete the specified task.

Quality Assurance Project Plan

Quality assurance/quality control activities and requirements, including project quality objectives, field data reduction, data validation, and quality assurance objectives for measurements for all groundwater samples collected under this workplan, will be performed as specified in Quality Assurance Project Plan (TRC, 2002c) and CGMSAP (FTS and GeoTrans, 2010).

Comprehensive Groundwater Management and Sampling Analysis Plan

The CGMSAP will be used for monitoring data collection and handling. This plan will be amended, if necessary, to accommodate any new procedures needed for this fieldwork.

6.0 REPORTING, SCHEDULE AND COMMUNITY RELATIONS

6.1 REPORTING

A final report documenting the results of activities described in this workplan will be submitted for Agency review after the performance evaluation is completed. The report will include a description of all field activities, boring logs, as-built drawings for well installations, and documentation of ISGS reagent injection (description of the solution, solution strength, injection locations, volumes, pressures and duration). The final report will include documentation of the performance evaluation criteria, DNAPL collection, and analytical results from ZOD monitoring wells.

6.2 SCHEDULE

The schedule for completion of this field-scale demonstration project is subdivided into four phases: Phase I: Process Area Characterization; Phase II: ISGS Reagent Injection; Phase III: Performance Evaluation; and Phase IV: Spot Treatment. The total time required to implement the four phases of this project is approximately 1.5 years; however, the actual time required to perform the initial subsurface boring characterization and to complete the ISGS reagent injections is approximately 6 months. The approximately 1.5 years required to complete this demonstration project is due to the extended time required to collect pre- and post DNAPL recovery data. It is estimated that approximately a 6-month time period is required to establish the pre-injection DNAPL recover rates in the new wells and a 6- to 9-month time period is required to evaluate ISGS treatment performance. Therefore, overall project schedule is dependent on initiating Phase I of this demonstration project as soon as possible to allow sufficient time to establish DNAPL recovery baseline conditions.

The schedule for this ISGS demonstration project is provided in **Figure 11**. The schedule is based on the assumption that Phase I will begin in July 2011. Phase I will require approximately 8 months to complete. Phase II will require approximately 3 months to complete and the Phase III will require approximately 6 to 9 months. Phase IV Spot Treatment may not be required; however, if needed, these injections are anticipated to take 1 to 2 weeks to complete. A detailed description of time required to complete subtasks under each of these four phases is provided in **Figure 11**.

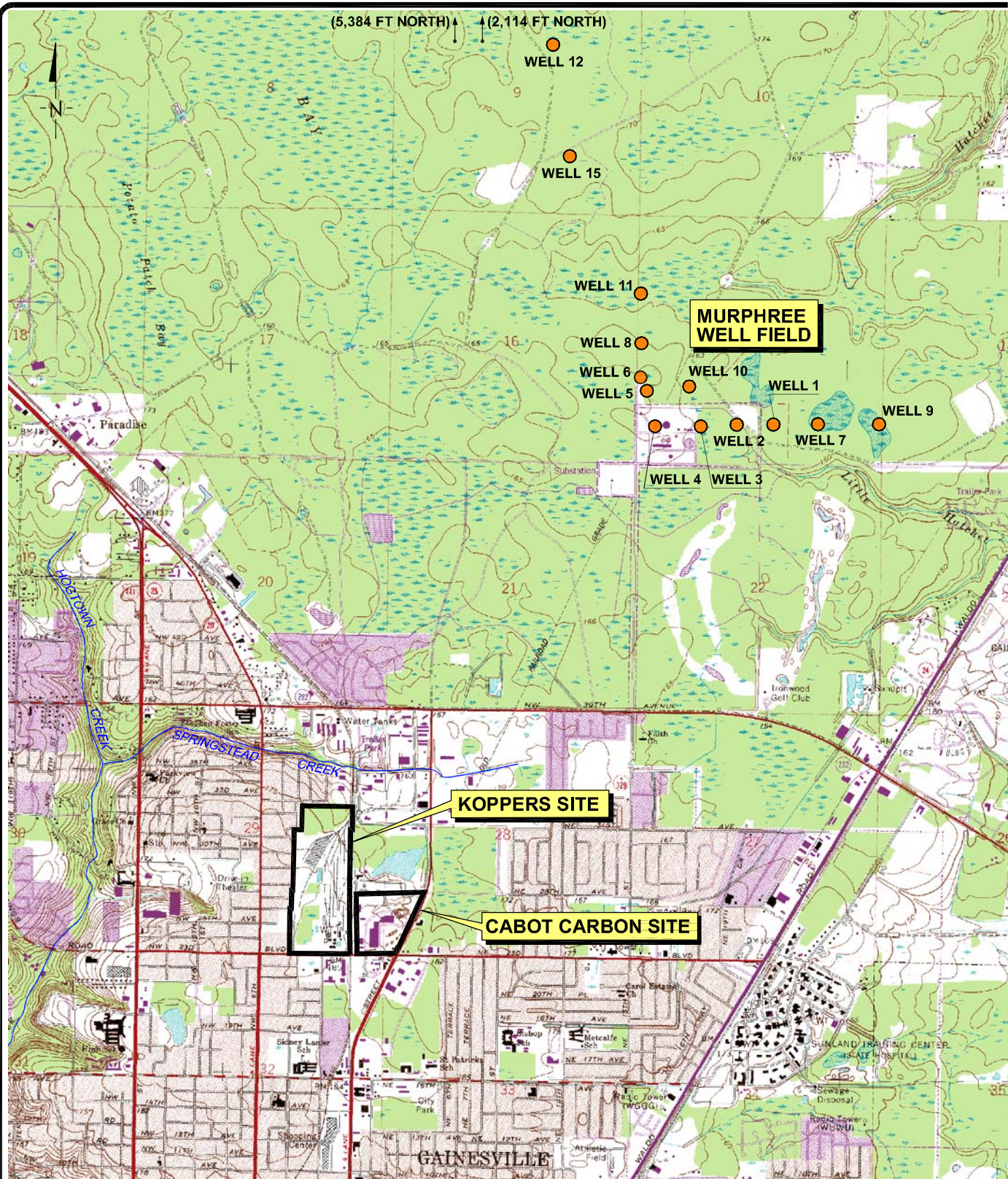
The schedule for implementation of this work plan will be dependent on regulatory approval and subcontractor availability.

6.2 COMMUNITY RELATIONS

A Fact Sheet will be developed and distributed to interested parties prior to the initiation of the ISGS reagent treatment. The demonstration project will be performed on Site within the former Process Area and will have little to no visible impact on the community.

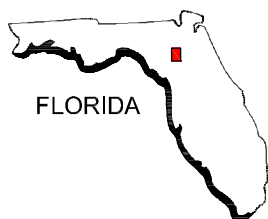
7.0 REFERENCES

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- GeoTrans, 2004a, Data Report for Additional Investigation of Hawthorn Group DNAPL Source Evaluation for the Koppers Industries Property, Cabot Carbon/Koppers Superfund Site, Gainesville, Florida, September, 2004.
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- GeoTrans 2004c, Phase 2 Potassium Permanganate Injection Field Documentation Report, Koppers Inc. Denver Colorado, August 6, 2004.
- GeoTrans, 2005, Addendum to the Floridan Aquifer Monitoring Program, Supplemental Upper Floridan Aquifer Monitoring Well Installation, Koppers, Inc. Site, Gainesville, Florida, February 28, 2005.
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- TRC, 2002a. Soil and Ground Water Sampling Plan. Cabot Carbon/Koppers Superfund Site, Gainesville, Florida. January 2002.
- TRC, 2002b. Health and Safety Plan. Cabot Carbon/Koppers Superfund Site, Gainesville, Florida. January 2002.
- TRC, 2002c. Quality Assurance Project Plan for the Additional Characterization of the Hawthorn Group Formation Workplan. Cabot Carbon/Koppers Superfund Site, Gainesville, Florida. January 2002.
- TRC, 2003. TRC Environmental Solutions, Inc., Addendum Hawthorn Group Field Investigation Report, Cabot Carbon/Koppers Superfund Site, Gainesville, FL, August 2003.
- TRC, 2004, Floridan Aquifer Monitoring Plan, Cabot Carbon/Koppers Superfund Site, Gainesville, Florida, June 2004.



SOURCE: U.S.G.S. QUADRANGLE GAINESVILLE
EAST, FLA 1966 (PHOTOREVISED 1988)

0 3000 6000
SCALE IN FEET



FLORIDA

TITLE:

SITE LOCATION MAP

LOCATION:

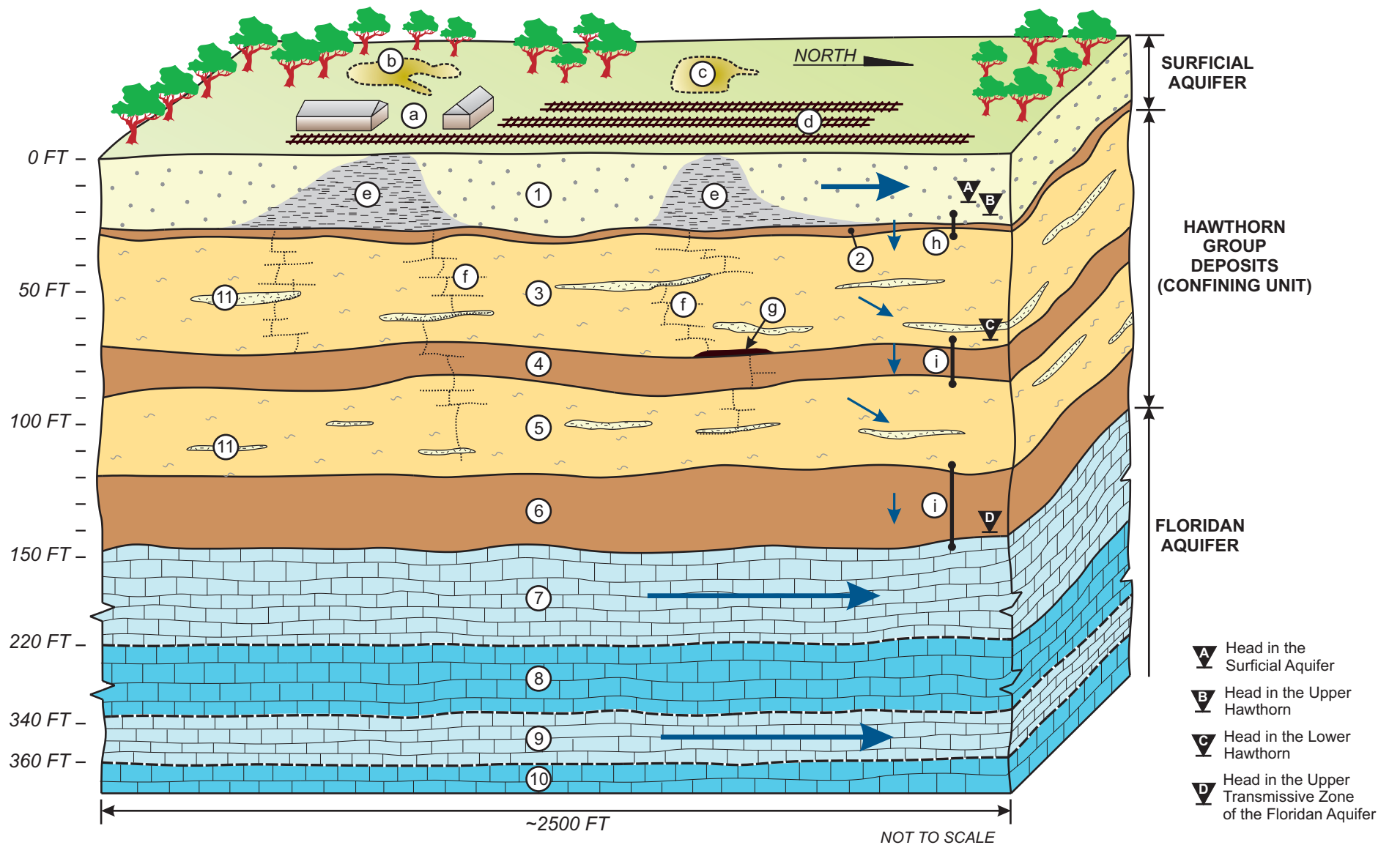
Cabot Carbon/Koppers Superfund Site
Gainesville, Florida



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DRAFTED	CP
FILE	2201128025A.DWG
DATE	6-19-08

FIGURE:

1



- 1) Surficial Aquifer
- 2) Hawthorn Group - Upper Clay
- 3) Hawthorn Group - Upper Hawthorn
- 4) Hawthorn Group - Middle Clay
- 5) Hawthorn Group - Lower Hawthorn
- 6) Hawthorn Group - Lower Clay
- 7) Floridan Aquifer - Upper Transmissive Zone
- 8) Floridan Aquifer - Semi-Confining Zone
- 9) Floridan Aquifer - Lower Transmissive Zone
- 10) Floridan Aquifer - Semi-Confining Zone
- 11) Discontinuous Sandy Interbeds

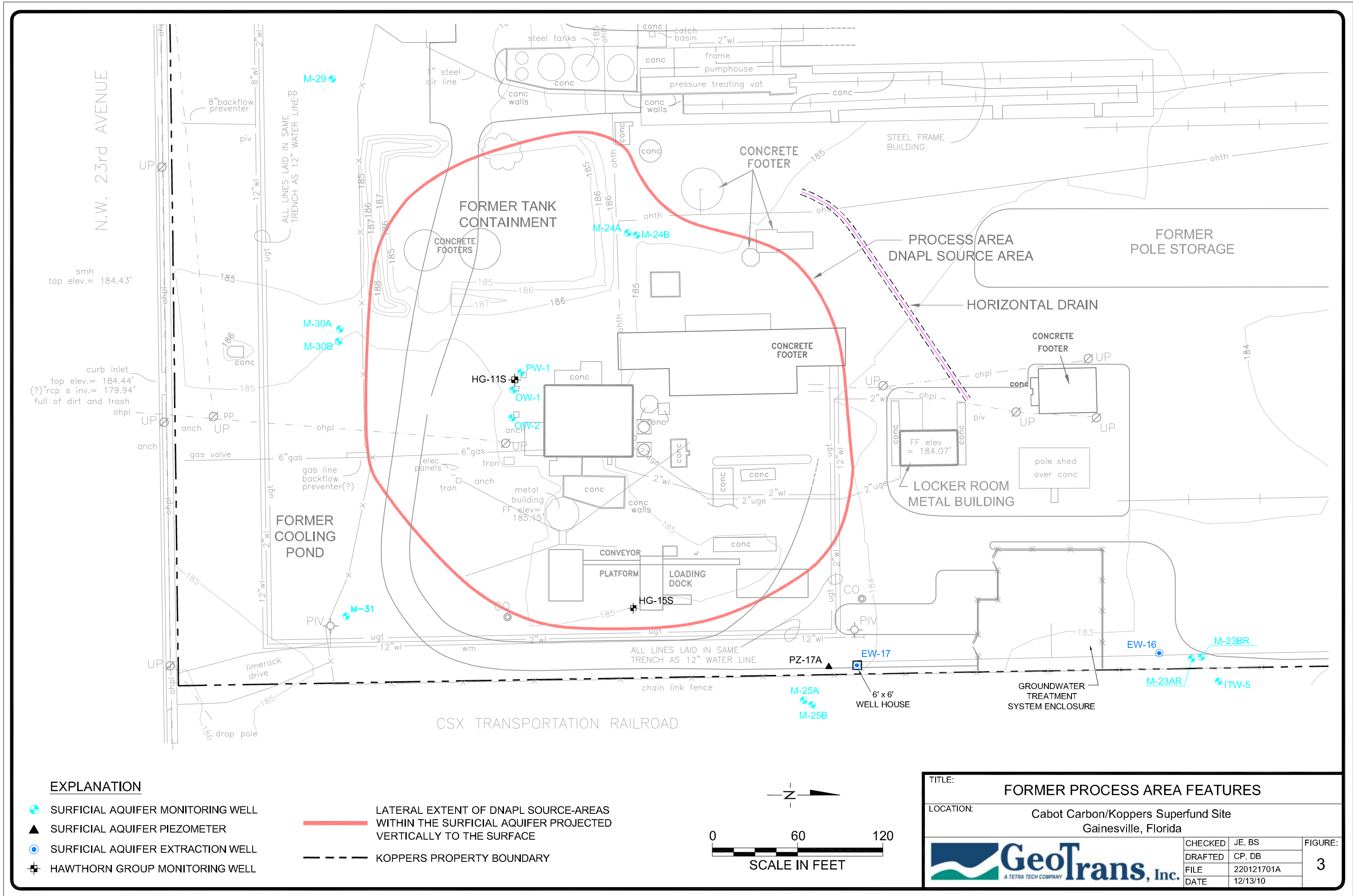
- a) Former Process Area
- b) Former South Lagoon
- c) Former North Lagoon
- d) Former Drip Track
- e) Soils with Residual DNAPL
- f) Sparse Seams of Residual DNAPL
- g) Sparse Seams of Locally Continuous DNAPL
- h) Moderate Vertical Hydraulic Gradient (~1 ft/ft)
- i) Large Vertical Hydraulic Gradient (~3 ft/ft)

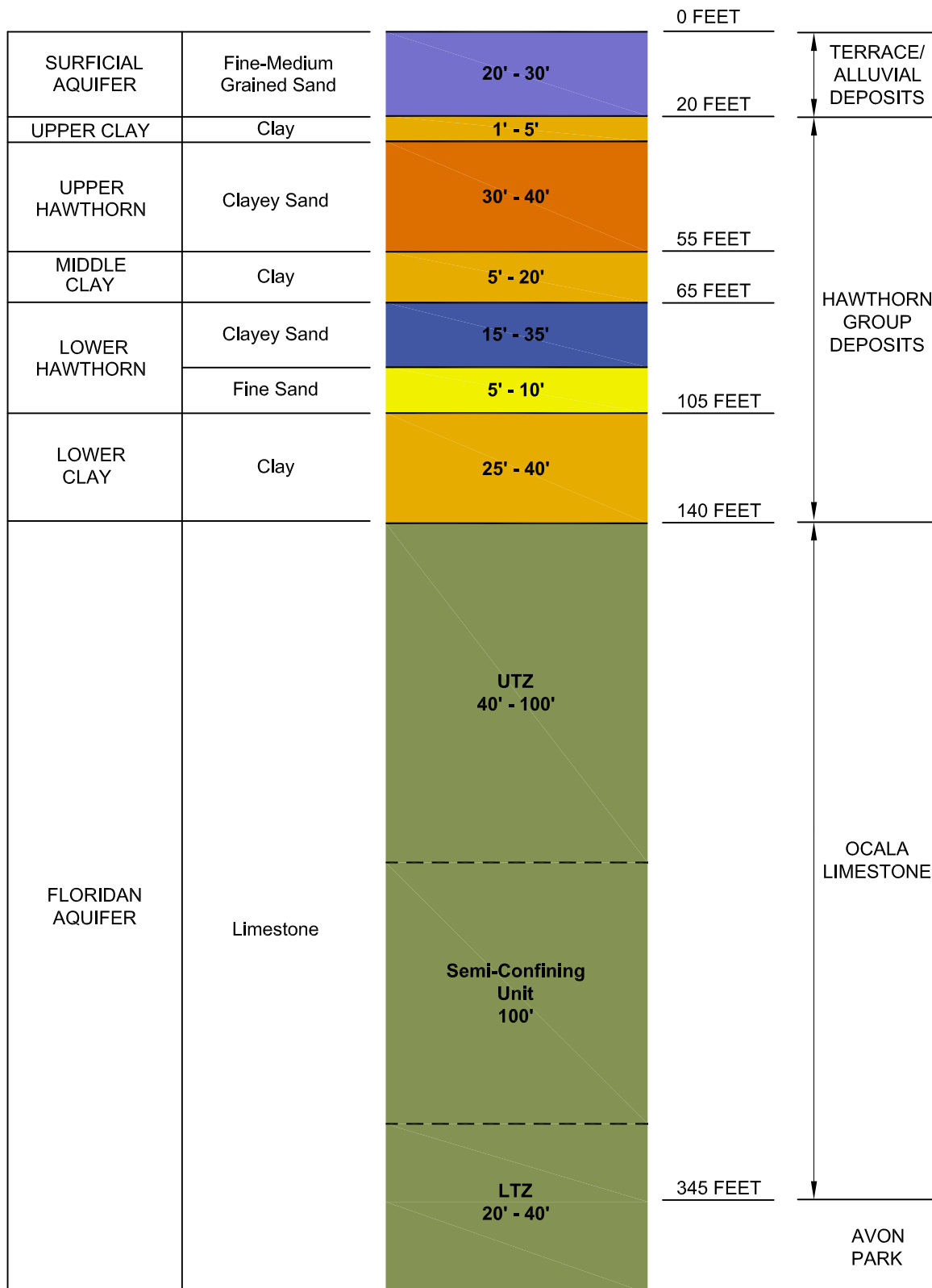
Note:
There are uncertainties
associated with the
conceptual understanding
presented in this figure.

Figure 2.

Conceptual Block Diagram

Cabot Carbon/Koppers Superfund Site, Gainesville, Florida





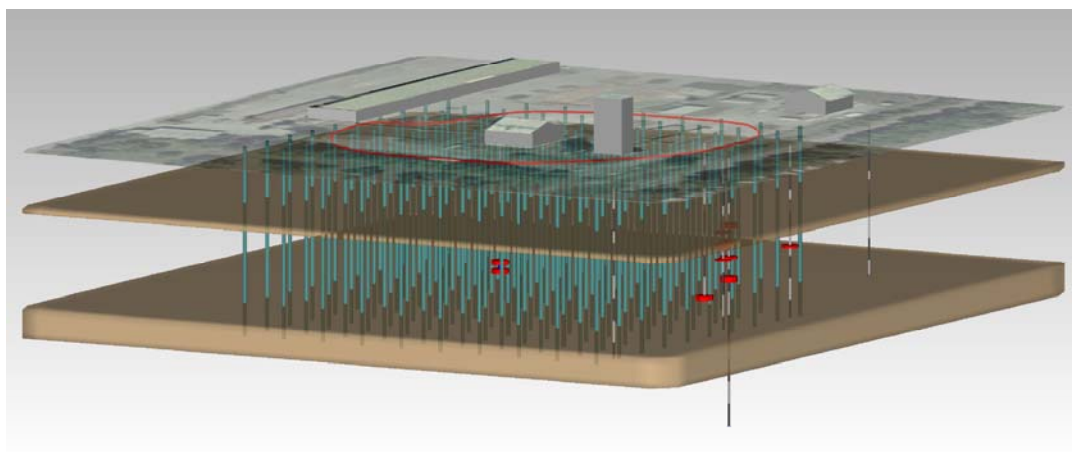
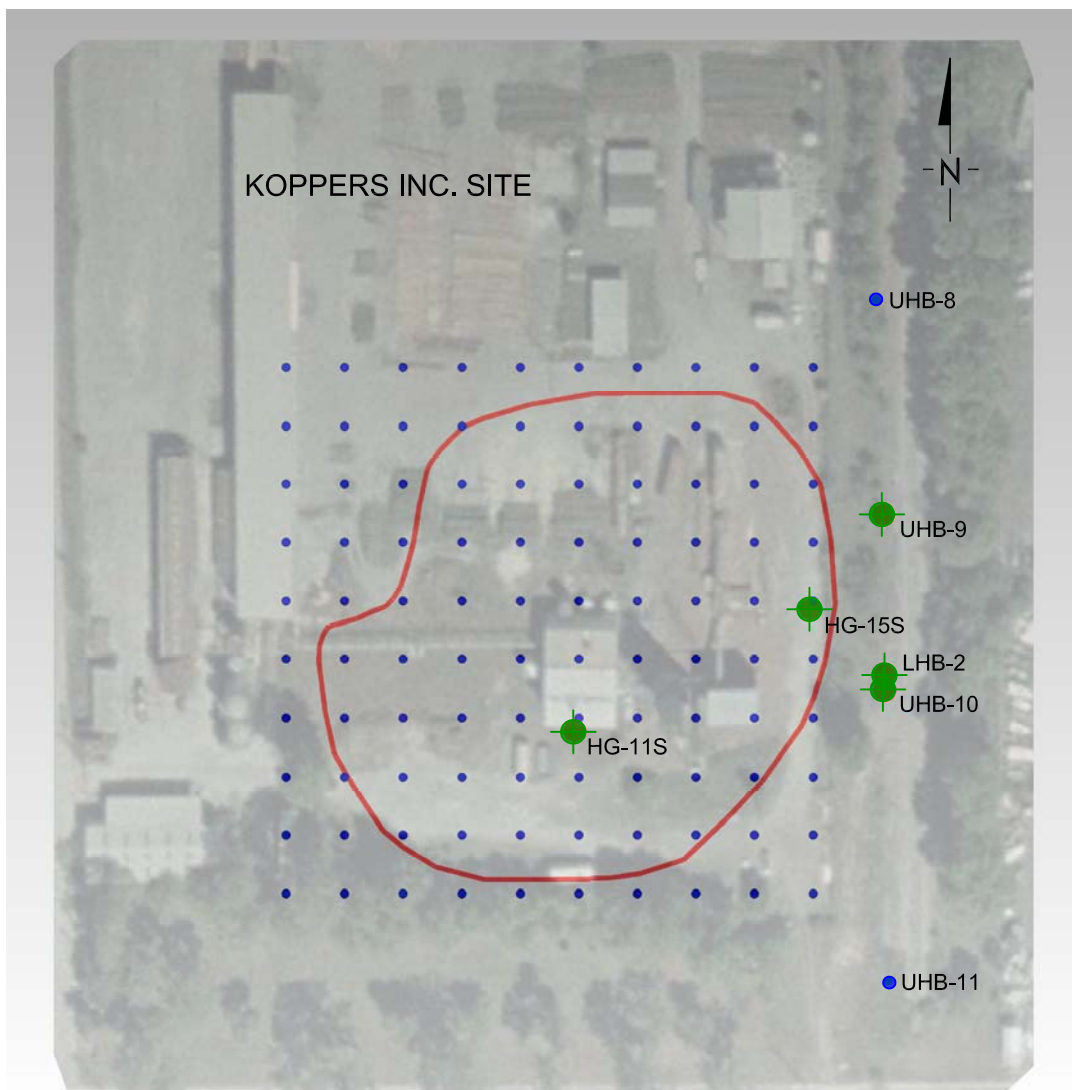
TITLE: HYDROSTRATIGRAPHY OF DEPOSITS BENEATH SITE

LOCATION: Cabot Carbon/Koppers Superfund Site, Gainesville, Florida



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DRAFTED	DJB
FILE	hydrostat column
DATE	06/30/10

FIGURE:
4



Explanation

- Presence of NAPL in existing borehole

TITLE:

EVS 3D VISUALIZATION OF
DNAPL INVESTIGATION BORINGS

LOCATION:

Cabot Carbon/Koppers Superfund Site
Gainesville, Florida






GeoTrans, Inc.
A TETRA TECH COMPANY

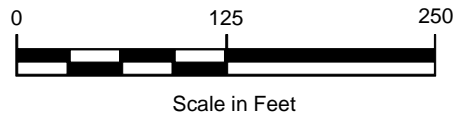
CHECKED	JE
DRAFTED	CG, DB
FILE	MVS Figures
DATE	12/13/10

FIGURE:

6

Explanation

-  **HG-6D** HG Monitoring Well
-  **HG-ZOD1** Preliminary ZOD Well
-  Former Potential Source Area



**Koppers, Inc.
Site**

Former
South
Lagoon

Former
Process
Area

 **HG-11S**


 **HG-15S**

 **HG-ZOD1**

150 ft

 **HG-ZOD2**

150 ft

 **HG-6S
HG-6D**

NW 23rd Ave.

**Cabot Carbon
Site**

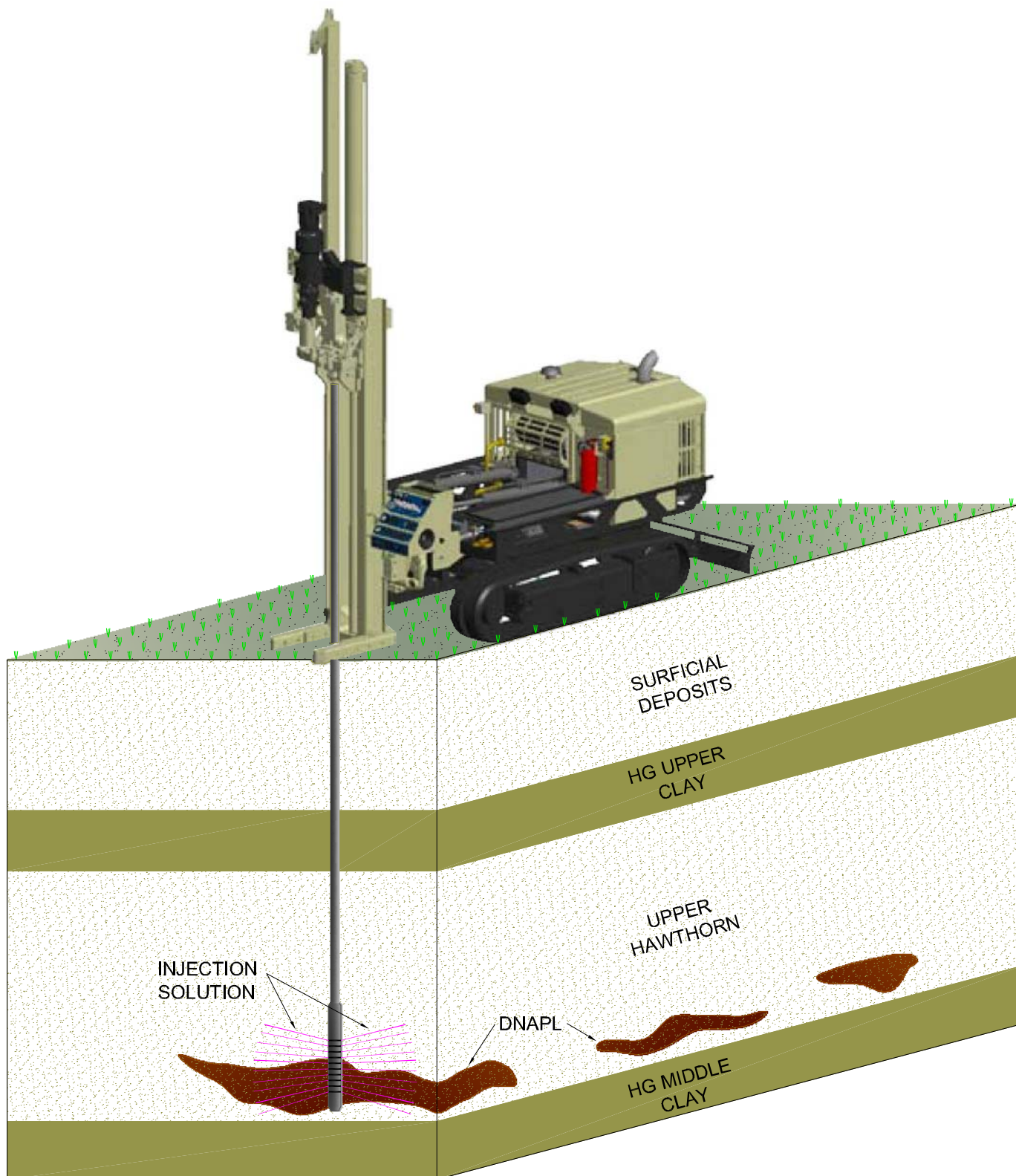
TITLE: Preliminary location of Zone of Discharge (ZOD) monitoring wells.

LOCATION: Cabot Carbon/Koppers Superfund Site, Gainesville, Florida



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DRAFTED	LAD
FILE	SAP_HG_well_locs_122010
DATE	5/17/2011

FIGURE:
7



TITLE: SCHEMATIC INJECTION POINT DESIGN WITH
CONCEPTUAL HORIZONTAL INJECTION PATTERN

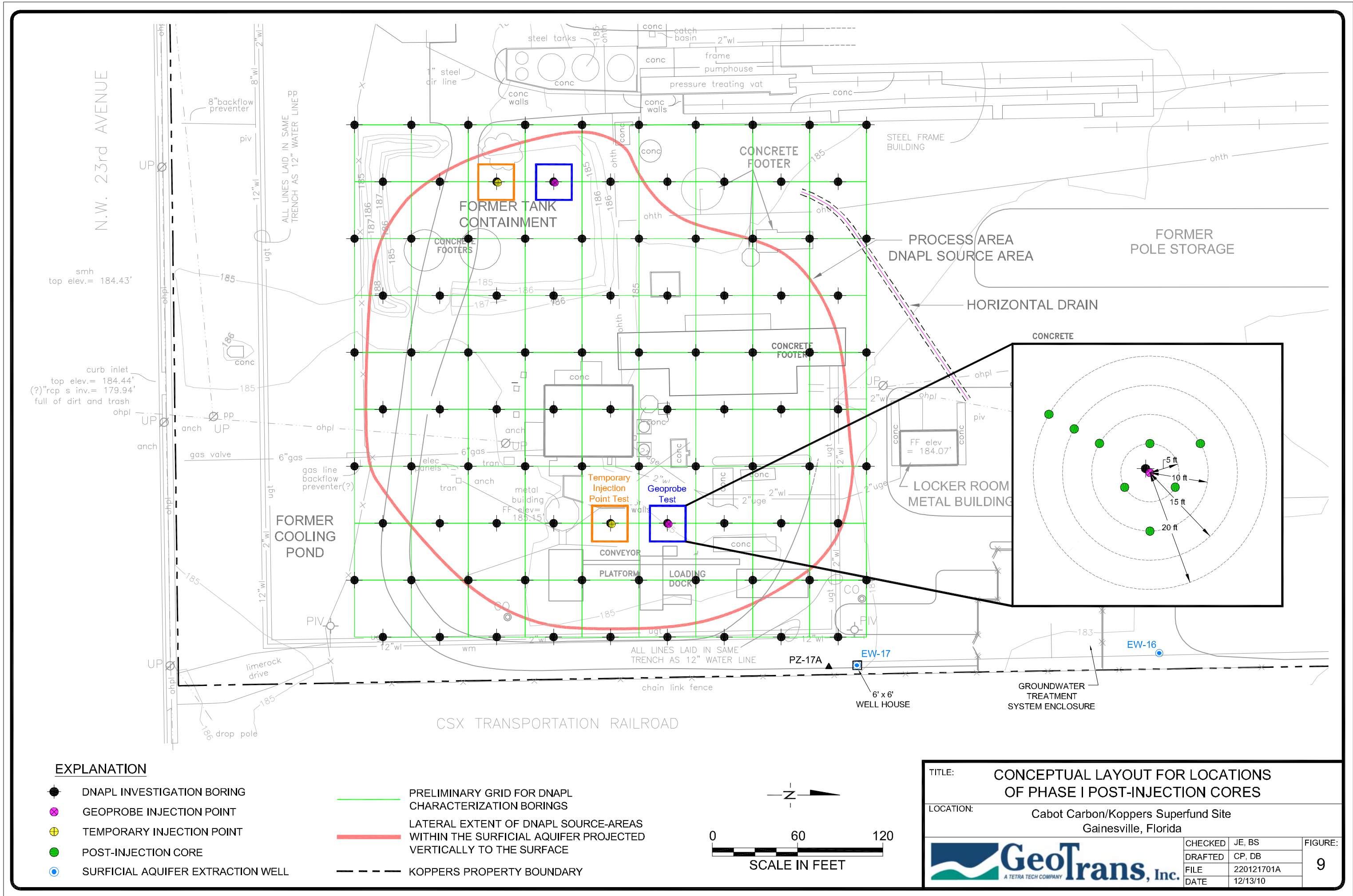
LOCATION: Cabot Carbon/Koppers Superfund Site
Gainesville, Florida



CHECKED	JE, BS
DRAFTED	DB
FILE	220121701A
DATE	12/13/10

FIGURE:

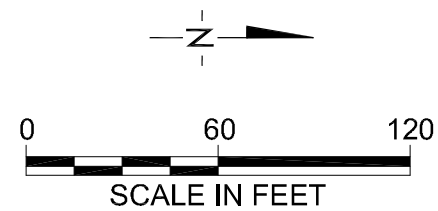
8



EXPLANATION

- DNAPL INVESTIGATION BORING
- ⊗ GEOPROBE INJECTION POINT
- ⊕ TEMPORARY INJECTION POINT
- POST-INJECTION CORE
- SURFICIAL AQUIFER EXTRACTION WELL

- PRELIMINARY GRID FOR DNAPL CHARACTERIZATION BORINGS
- LATERAL EXTENT OF DNAPL SOURCE-AREAS WITHIN THE SURFICIAL AQUIFER PROJECTED VERTICALLY TO THE SURFACE
- - - KOPPERS PROPERTY BOUNDARY




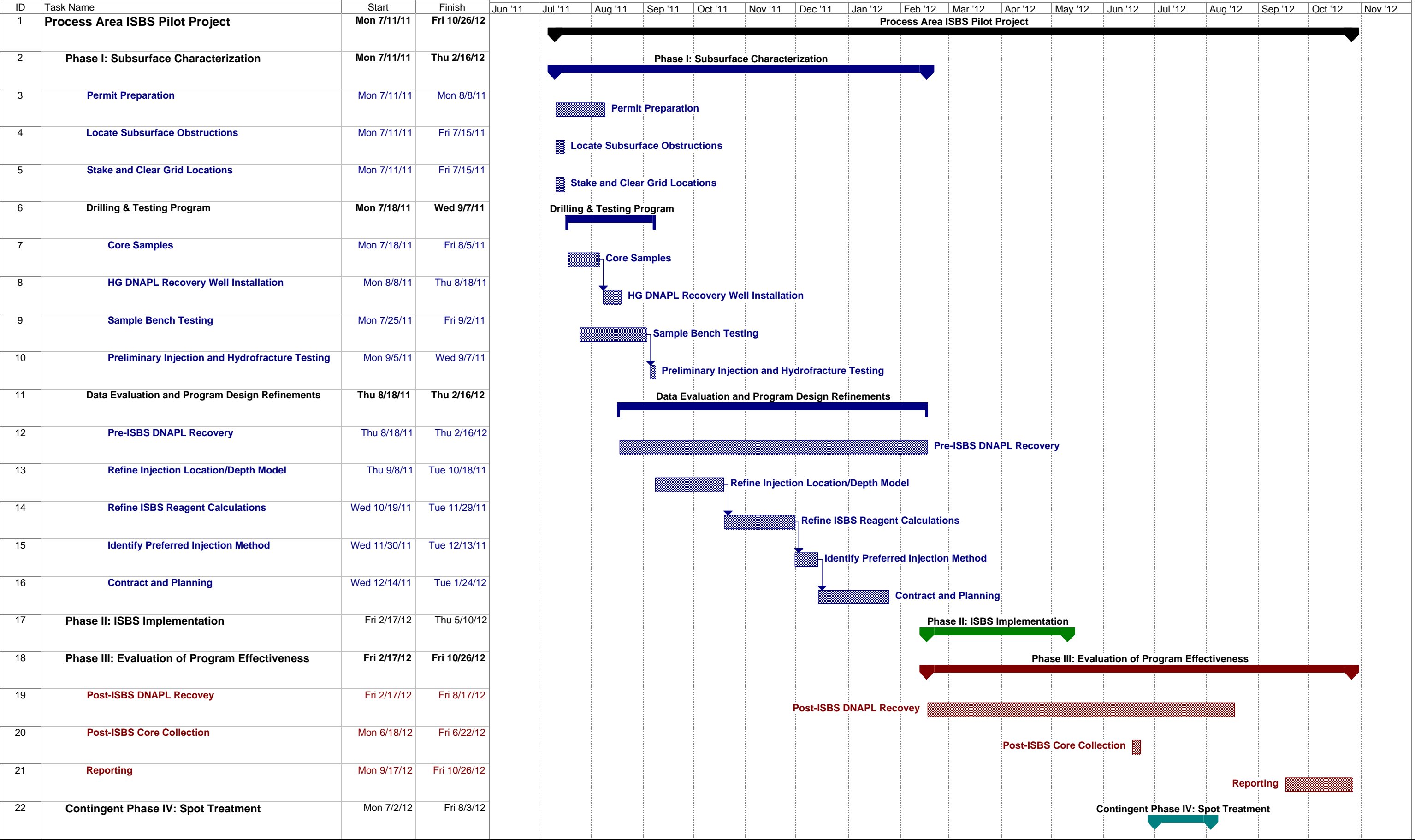
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LOCATION:		Cabot Carbon/Koppers Superfund Site Gainesville, Florida	
		CHECKED	JE, BS
		DRAFTED	CP, DB
		FILE	220121701A
		DATE	12/13/10
			FIGURE:
			9

Figure 11. Schedule for former Process Area ISBS remediation pilot project.



APPENDIX A: DNAPL RECOVERY WELL INSTALLATION PROCEDURES

APPENDIX A

DNAPL RECOVERY WELL INSTALLATION PROCEDUES

FORMER KOPPERS INC. SITE GAINESVILLE, FLORIDA

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2.1	DRILLING AND WELL COMPLETION	3
2.2	CASING GROUT	4
2.3	EQUIPMENT DECONTAMINATION	4
2.4	WELL SURFACE COMPLETION AND DEVELOPMENT	4

LIST OF FIGURES

Figure A-1. Typical Upper Hawthorn recovery well construction.

1.0 INTRODUCTION

This document provides procedures for the installation of Upper Hawthorn Dense Nonaqueous Phase Liquid (DNAPL) recovery wells for the former Koppers Inc. portion of the Cabot Carbon/Koppers Superfund Site in Gainesville, Florida (the Site).

The objective of the DNAPL recovery wells is to: 1) Provide pre- and post-ISGS injection product recovery rate information to be used as a basis for evaluation of system effectiveness; and 2) Facilitate recovery DNAPL to reduce contaminant mass in the former process area.

2.0 RECOVERY WELL CONSTRUCTION

Because the HG wells will be completed at locations that contain free-phase DNAPLs, they will be constructed using stainless-steel casing and screen. The recovery wells will use 4-inch diameter casing and will have 20-slot screen openings to maximize DNAPL recovery and to minimize the production of fine-grained sediments. The screened intervals for the wells will be installed across DNAPL-impacted lithologic deposits most likely to contain free-phase DNAPLs. A permanent isolation casing will not be installed into the HG upper clay unit to isolate the Surficial Aquifer impacts from the Upper Hawthorn, since drag down during well installation is not a concern. Rather, a temporary isolation casing will be installed into the HG upper clay unit and removed during the final installation of the recovery wells.

2.1 DRILLING AND WELL COMPLETION

Prior to drilling, the proposed well sites will be staked and the necessary permits will be obtained from the Saint Johns River Water Management District (SJRWMD). Sunshine State One Call (SSOC) will be contacted (as required by law) for utility clearance of the site. The borings will be advanced by hand auger or vacuum drilling to a depth of 4 feet.

Continuous 4-inch diameter soil core will be collected from rotasonic borings and logged by the oversight geologist/engineer to characterize lithology and observable DNAPL impacts in the Surficial Aquifer and in the HG Deposits. Core will be described, photographed, scanned with a photo ionization detector (PID) and carefully evaluated for the presence of DNAPLs. The core samples will be disaggregated to facilitate the identification of residual DNAPLs, if present. In addition, potable water will be sprayed on the disaggregated core to facilitate the identification and logging of residual DNAPL that may be present. DNAPL will occur in the disaggregated cores as small “blebs” or droplets on the surface of the wet core. These observations will be recorded in the lithologic log. Core samples will be preserved in labeled, wooden core boxes for potential subsequent analysis. The well completion depth and screened intervals will be based on the depths to these geologic contacts and on the presence and apparent mobility of DNAPL in the core samples. The core also will be used to identify and describe major lithologic unit tops and bottoms.

A temporary 10-inch isolation casing will be advanced approximately 2 feet into the HG upper clay unit, prior to drilling into the Upper Hawthorn. The temporary isolation casing will be sealed with approximately 1 foot of bentonite at the base of the casing. The boring will be reamed to 8 inches inside of the 10-inch temporary casing to accommodate permanent 4-inch wells.

The recovery wells will be completed in accordance with the State of Florida requirements and will be constructed with 4-inch 304 stainless steel well casing to be constructed inside of the rotasonic override casing (Figure A-1). The well screen depth will be determined based on conditions observed during coring, but are anticipated to be 10- to 20-feet in length. Grain-size analysis of the upper HG deposits indicate the use of 20/30 mesh silica sand filter pack with 0.020-inch opening (20-slot) screen. The filter pack material (sand) will be poured into the borehole through the override casing and will extend to approximately 2 feet above the

top of the well screen. A 2-foot thick bentonite plug will be placed above the filter pack. The bentonite will be allowed to hydrate for approximately 2 hours prior to grouting the remainder of the borehole to land surface. All grout will be tremied into the borehole. If subsurface conditions indicate that it is necessary to separate the well screens with blank casing to improve placement of the screens adjacent to DNAPL-bearing strata, the filter pack will be continuous and only one bentonite seal will be place in the well.

2.2 CASING GROUT

The grout slurry to be used in extraction well construction will be in accordance with SJRWMD requirements and with ASTM D-5092. The mixture will consist of ASTM Type I Portland cement, powdered bentonite, and potable city water. The cement will first be mixed into a smooth slurry using 6 to 7 gallons of fresh water for each 94-pound bag of cement; 5 pounds of powdered bentonite will be added to the cement mixture to minimize cement shrinkage during the curing process. The annular space outside of the well casings will be filled from the bottom up via a tremmie pipe or equivalent, positive displacement method. Where required, casing centralizers will be installed at appropriate distances on the outside of all casings to help minimize grout channeling and to help ensure a complete grout seal. The grout will be allowed to cure a minimum of 12 hours prior to additional work being performed inside of the casing.

2.3 EQUIPMENT DECONTAMINATION

All drilling equipment, rods, bits, tools, and rotasonic casing that enter the borehole during the drilling will be decontaminated by thorough pressure washing prior to advancing the borehole. Because of the presence of product at the well locations, all downhole equipment will be thoroughly inspected before use and after each decontamination process for visual indications of residual product. If necessary, additional decontamination will be performed using steam and/or trisodium phosphate detergent (such as Alconox) to ensure that all product has been removed.

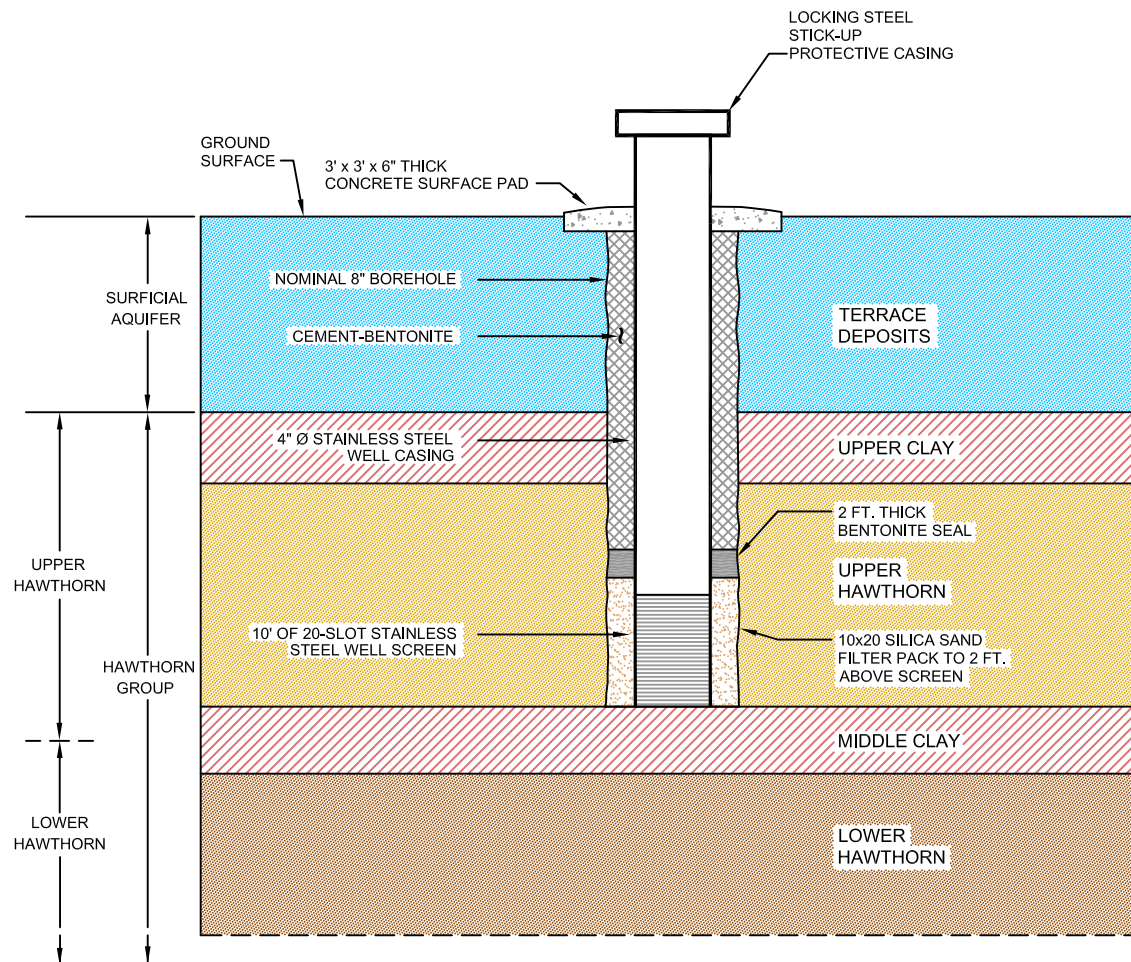
2.4 WELL SURFACE COMPLETION AND DEVELOPMENT

Each 4-inch diameter well casing will be completed within a locking, steel, stickup protective casing. Each protective casing will be painted safety yellow with the well ID stenciled with black paint with locks to be keyed alike and match existing Site locks. The protective casings will be encased in a 3-foot by 3-foot by 6-inch thick concrete pad. Each pad will be completed 3 inches above existing grade with the apron tapered 2 inches lower such that precipitation runoff will flow away from the well.

After installation, the ground surface and the top of each inner well casing will be surveyed to within 0.01-foot vertical accuracy. As-built well diagrams will be constructed for each of the wells.

The wells will be developed no sooner than 24 hours after installation to remove fine-grained material from the sand packs of each well. Wells will be developed by bailing and/or by

pumping, as determined by the field geologist, in consultation with the drilling firm. Well development shall consist of over-pumping or bailing the well until the discharge water appears to be visibly clear and free of sediment. Care will be taken to minimize excessive development to help ensure that DNAPL impacted zones are not adversely impacted. With the potential risk of damage to field instruments from DNAPL immersion, field parameters will not be measured, rather, purge water will be monitored for visual clarity and the lack of visible sediments. Wells will be developed up to a maximum of 4 hours or until the purge water is visibly free of sediments, as documented by the field geologist. An attempt will be made to contain all DNAPL removed during the development phase to document recovered DNAPL volumes.



NOT TO SCALE

TITLE: TYPICAL UPPER HAWTHORN RECOVERY WELL CONSTRUCTION		
LOCATION: Cabot Carbon/Koppers Superfund Site, Gainesville, Florida		
	CHECKED	JRE
	DRAFTED	DJB
	PROJECT	ISGS
	DATE	05-23-11
		FIGURE: A-1

APPENDIX B: MONITORING WELL INSTALLATION PROCEDURES

APPENDIX B

UPPER HAWTHORN MONITORING WELL INSTALLATION PROCEDURES

**FORMER KOPPERS INC. SITE
GAINESVILLE, FLORIDA**

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2.3	EQUIPMENT DECONTAMINATION	3
2.4	WELL SURFACE COMPLETION AND DEVELOPMENT	3
2.5	GROUNDWATER SAMPLING.....	4
2.6	INVESTIGATIVE DERIVED WASTE.....	4

LIST OF FIGURES

Figure B-1. Proposed Upper Hawthorn monitoring well construction.

1.0 INTRODUCTION

This document provides procedures for the installation of Upper Hawthorn monitoring wells for the former Koppers Inc. portion of the Cabot Carbon/Koppers Superfund Site in Gainesville, Florida (the Site).

The objective of the Upper Hawthorn monitoring wells is to provide post-ISBS injection water quality information to monitor the effects of the ISBS reagent on water quality.

2.0 WELL CONSTRUCTION

The Upper Hawthorn wells will be completed as 2-inch diameter schedule 40 polyvinyl chloride (PVC) monitoring wells. PVC well casing and screens will be utilized for the construction of the monitoring wells, since the wells are located outside of residual creosote DNAPL impacts; as such, degradation of PVC materials would not be anticipated. The screen intervals for the wells will be approximately 10-feet in length and will have a 10-slot screen opening.

2.1 DRILLING AND WELL COMPLETION

Prior to drilling, the proposed well sites will be staked and the necessary permits will be obtained from the Saint Johns River Water Management District (SJRWMD). Sunshine State One Call (SSOC) will be contacted (as required by law) for utility clearance of the site. Because historic subsurface structures are known to exist in the former Process Area (these subsurface structures will not be located by the SSOC service), the well locations will be cleared as described in the workplan, to which this document is appended. Additionally, the borings will be advanced by hand auger or vacuum drilling to a depth of four feet.

Continuous 4-inch diameter soil/rock core will be collected from all rotasonic borings and logged by the oversight geologist/engineer to characterize lithology. Core will be described and photographed before disposing of the core with the drill cuttings. Core samples will not be saved and stored, since sufficient on-Site core currently exists for the HG deposits. The well completion depth and screened intervals will be based on ISBS injection depths, but will not exceed the depth to the top of the Middle HG clay.

Because the Upper Hawthorn monitoring wells will be installed immediately downgradient of an impacted area, they will be constructed with a single telescopic isolation casing by drilling a nominal 10-inch diameter hole from land surface to approximately 1-2 feet into the HG upper clay unit with a rotasonic override casing. A 6-inch ID mild-steel (or equivalent) isolation casing will be set in the upper clay unit and grouted to land surface. After an appropriate grout set-up period of at least 12 hours, a nominal 6-inch hole will be advanced through the center of the 6-inch ID casing into the Upper Hawthorn using a nominal 6-inch OD rotasonic override casing. A permanent 2-inch ID PVC well casing and screen will be constructed inside of the override casing (Figure B-1).

Each monitoring well will be completed as per the State of Florida requirements for monitoring wells. The wells will be constructed with 2-inch ID schedule 40 PVC screen and casing. The well screens will be 10-feet in length with a 10-slot screen opening. A PVC casing with borehole centralizers will extend to land surface. The filter pack will consist of 10 x 20 silica sand and will be placed through the override casing. The filter pack will extend approximately 2 feet above the top of the well screen and a 1 to 2-foot thick bentonite plug will be placed above the filter pack. The bentonite will be allowed to hydrate for approximately 2 hours prior to grouting the remainder of the borehole to land surface. All grout will be tremied into the borehole.

2.2 BOREHOLE AND CASING GROUT

The grout slurry to be used in monitoring well and telescoping casing installation will consist of ASTM Type I Portland cement, powdered bentonite, and potable city water. The cement will first be mixed into a smooth slurry using 6 to 7 (per ASTM) gallons of water for each 94-pound bag of cement; 5 pounds of powdered bentonite will be added to the cement mixture to minimize cement shrinkage during the curing process. The annular spacing outside of all telescoping casings will be filled from the bottom up via a tremmie pipe. Where required, casing centralizers will be installed at appropriate distances on the outside of all casings to help minimize grout channeling and to help ensure a complete grout seal. The grout will be allowed to cure a minimum of 12 hours prior to additional work being performed inside of the casing.

2.3 EQUIPMENT DECONTAMINATION

All drilling equipment, rods, bits, tools, and rotasonic casing that enter the borehole during the drilling and installation of each of the telescoping casings will be decontaminated by steam/pressure washing prior to advancing the borehole to the next surface/well casing completion depth. Similarly, all drilling equipment and tools will be decontaminated prior to drilling the open hole beneath the lowermost casing and prior to starting a new borehole. The same procedure will be used for the investigative borings.

2.4 WELL SURFACE COMPLETION AND DEVELOPMENT

The 2-inch diameter PVC well casings will use a stick-up protective casing. Each stickup will be spray painted safety yellow with the well ID stenciled with black paint. A 3-foot by 3-foot by 6-inch thick concrete pad will be constructed around each stickup, where appropriate. Each pad will be completed 3 inches above existing grade with the apron tapered 2 inches lower such that precipitation runoff will flow away from the well. Bollard poles will be located around all casings with stickup for surface protection, as needed. All locks for the wells will be keyed alike and match existing Site locks. After installation, the ground surface and the top of each inner well casing will be surveyed to within 0.01-foot vertical accuracy. As-built well diagrams will be constructed for each of the wells.

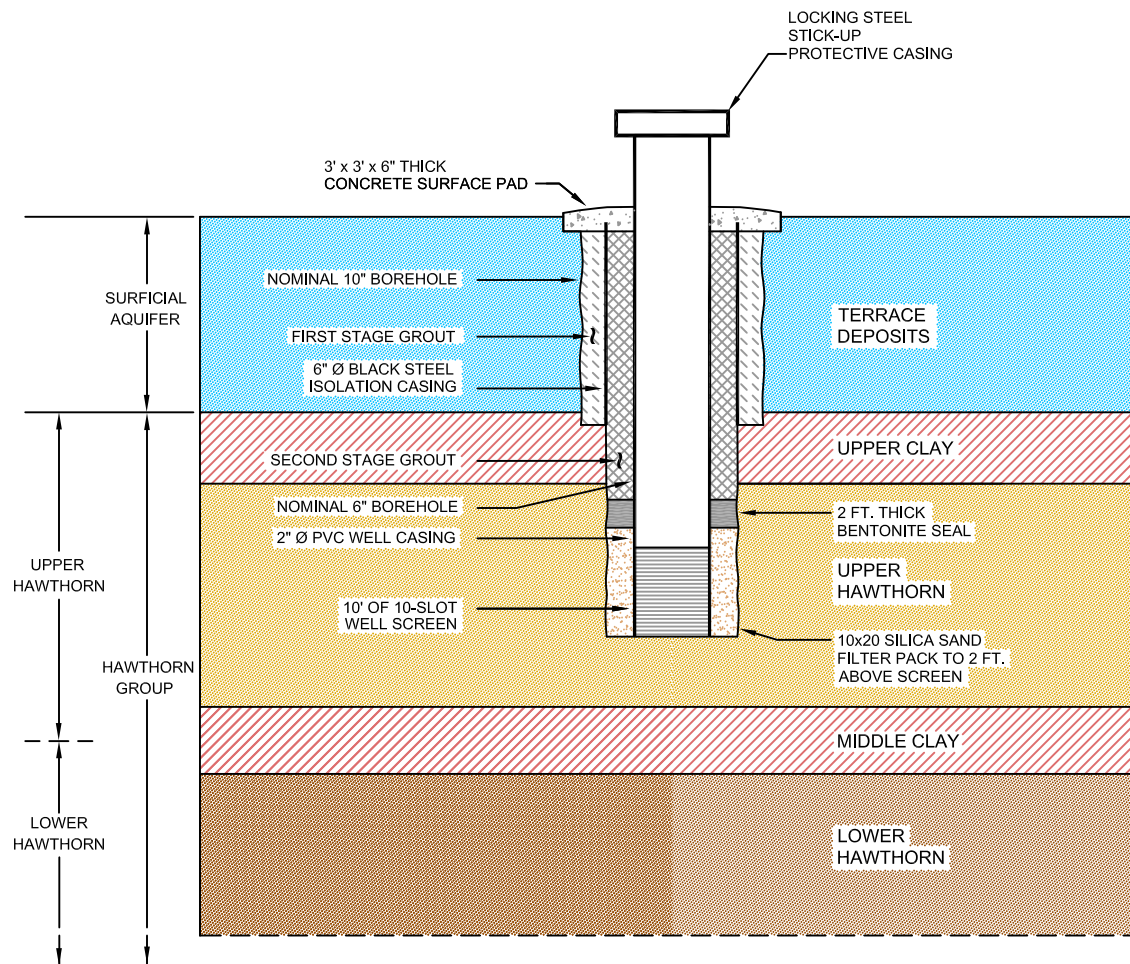
The wells will be developed no sooner than 24 hours after installation to remove fine material from around the monitored interval of each well. Wells will be developed by bailing or by pumping, as determined by the field geologist, in consultation with the drilling firm. Well development shall consist of over-pumping of the well until the discharge water appears to be visibly clear. The purge water will be monitored for pH, temperature, specific-conductance and turbidity. Wells will be developed up to a maximum of 4 hours or until the water-quality field measurements become stable and the purge water is visibly free of sand, as documented by the field geologist. Data collection and recording will follow procedures used in previous fieldwork at the Site.

2.5 GROUNDWATER SAMPLING


Following the development of the wells, a groundwater sample will be collected from each of the wells and analyzed for potential Site constituents and associated ISGS reagent constituents. Sample collection procedure and collection criteria will be similar to the existing monitoring program at the Site described in the Comprehensive Groundwater Monitoring and Sampling Analysis Plan (CGMSAP) for the Site.

2.6 INVESTIGATIVE DERIVED WASTE

All wastewater and soil generated during the activities described in this workplan, including wastewater generated from drilling, development, and sampling will be containerized in drums or bulk tanks. The aqueous fractions from drums or bulk tank(s) will be mixed with influent water to the on-Site treatment system, prior to discharging to the permitted POTW. Soils and rock cuttings will be staged in sealed drums for characterization and off-Site disposal.



NOT TO SCALE

TITLE:			PROPOSED UPPER HAWTHORN MONITORING WELL CONSTRUCTION	
LOCATION:			Cabot Carbon/Koppers Superfund Site, Gainesville, Florida	
 GeoTrans, Inc. <small>A TETRA TECH COMPANY</small>	CHECKED	JRE	FIGURE: B-1	
	DRAFTED	DJB		
	PROJECT	ISGS		
	DATE	05-23-11		

APPENDIX C: TEMPORARY INJECTION WELL INSTALLATION PROCEDURES

APPENDIX C

TEMPORARY INJECTION POINT INSTALLATION PROCEDURES

**FORMER KOPPERS INC. SITE
GAINESVILLE, FLORIDA**

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Figure C-1. Temporary injection point conceptual design.

1.0 INTRODUCTION

This document provides procedures for the installation of the Upper Hawthorn temporary injection points (TIPs) for ISGS reagent injection at the former Koppers Inc. portion of the Cabot Carbon/Koppers Superfund Site in Gainesville, Florida (the Site).

The objective of the TIP installation is to facilitate injection of the ISGS reagent during pilot testing and potentially during demonstration implementation of the ISGS program. These wells will allow longer-term injections and/or recurring injections. The use of these points will be fully explored during Phase I site characterization when injection tests will be used to determine whether formation characteristics are suited to the use of these points or other methods of injection. Upon program completion they will be abandoned by grouting.

2.0 TEMPORARY INJECTION POINT CONSTRUCTION

2.1 DRILLING AND TIP COMPLETION

Prior to drilling, the TIP sites will be staked and the necessary permits will be obtained. Sunshine State One Call (SSOC) will be contacted (as required by law) for utility clearance of the site. Because historic subsurface structures are known to exist in the former Process Area (these subsurface structures will not be located by the SSOC service), TIP locations will be cleared as described in the workplan, to which this document is appended. Additionally, the borings will be advanced by hand auger or vacuum drilling to a depth of 4 feet.

Continuous approximate 3-inch diameter soil/rock core will be collected from all TIP borings and logged by the oversight geologist/engineer to characterize lithology. Core will be described and photographed before disposing of the core with the drill cuttings. Core samples will not be saved and stored, since sufficient on-Site core currently exists for the HG deposits. The well completion depth and screened intervals will be based on required ISGS injection depths (corresponding to DNAPL depth) but will not exceed the depth to the top of the HG middle clay. Because these wells will be installed as part of a program to immobilize DNAPLs, they will not be constructed using isolation casings.

TIPs will be completed using 2-inch, schedule-40 PVC screen and casing. Screen length and depth will vary depending on the depth to the DNAPL to be injected. Where multiple DNAPL zones are identified, multiple screens may be installed, depending on formation characteristics. Screens will have 30-slot screen openings. The filter pack will consist of 8 x 16 silica sand and will be placed by pouring. The filter pack will extend approximately 2 feet above the top of the well screen. To prevent “blow-by” during injection, the remainder of the borehole will be cement grouted to land surface either by tremie or by other positive displacement methods to ensure a good seal.

2.2 CASING GROUT

The grout slurry to be used in monitoring well and telescoping casing installation will consist of ASTM Type I Portland cement, powdered bentonite, and potable city water. The cement will first be mixed into a smooth slurry using 6 to 7 (per ASTM) gallons of water for each 94-pound bag of cement; 5 pounds of powdered bentonite will be added to the cement mixture to minimize cement shrinkage during the curing process. The grout will be allowed to cure a minimum of 12 hours prior to additional work being performed inside of the casing.

2.3 EQUIPMENT DECONTAMINATION

All drilling equipment, rods, bits, tools, and casing that enter the borehole during drilling and TIP installation will be decontaminated by steam/pressure washing prior to advancing the borehole to the next surface/ completion depth.

2.4 TIP SURFACE COMPLETION AND DEVELOPMENT

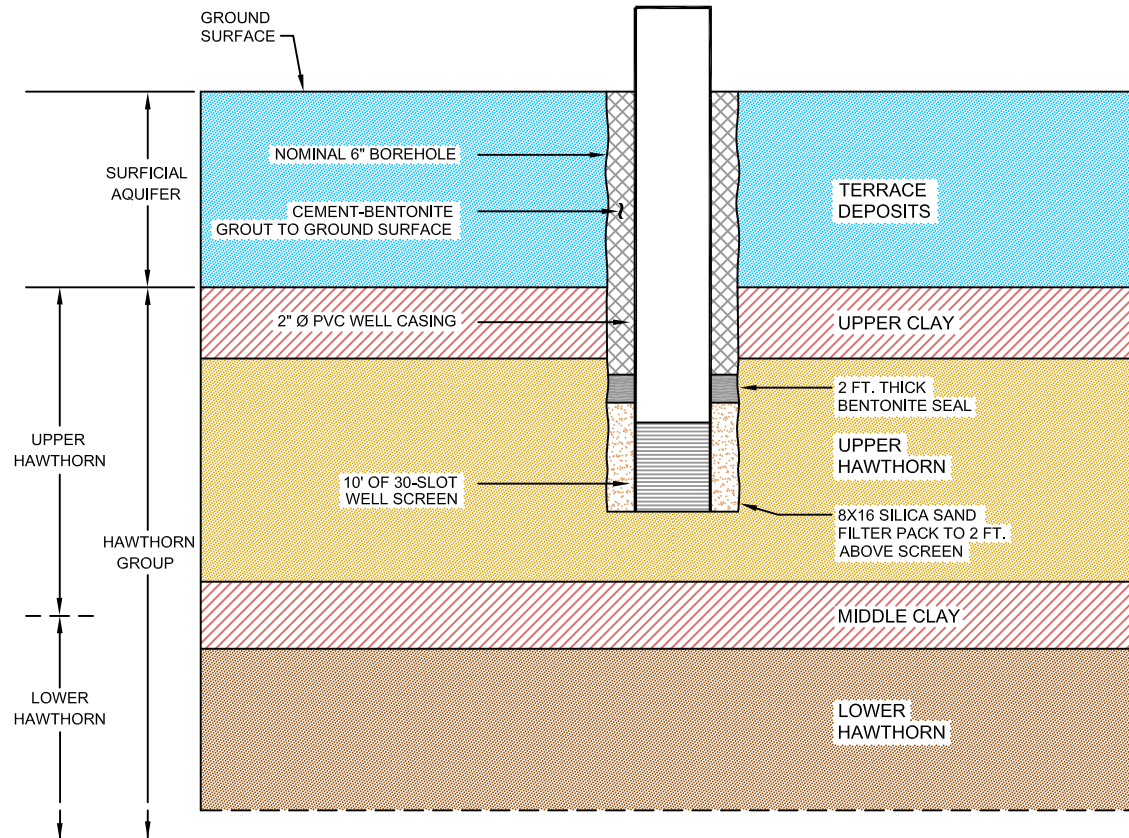
The 2-inch diameter well casings will be completed by allowing the casing to stick up approximate 1 foot above grade. The top of the casing will be either threaded or neatly cut and fitted with either a blank cap or a fitting suitable for connection to injection equipment. As-built diagrams will be constructed for each of the TIPS.

2.5 TIP ABANDONMENT

After it has been determined that the TIPS are no longer of use to the program, they will be abandoned by backfilling with grout mixed to the specifications described above. The grout will be placed by pouring it down the inside of the 2-inch casing. All TIP materials, wastewater and soil generated will be disposed as Investigative Derived Waste (IDW).

2.6 INVESTIGATIVE DERIVED WASTE

All wastewater and soil generated during the activities described in this workplan, including wastewater generated from drilling, development, and sampling will be containerized in drums or bulk tanks. The aqueous fractions from drums or bulk tank(s) will be mixed with influent water to the on-Site system, prior to discharging to the permitted POTW. Soils and rock cuttings will be staged in sealed drums for characterization and off-Site disposal.



NOTE: SCREEN LENGTH WILL VARY BASED ON INJECTION REQUIREMENTS

NOT TO SCALE

TITLE: TEMPORARY INJECTION POINT CONCEPTUAL DESIGN		
LOCATION: Cabot Carbon/Koppers Superfund Site, Gainesville, Florida		
	CHECKED	JRE
	DRAFTED	DJB
	PROJECT	ISGS
	DATE	05-23-11
		FIGURE: C-1

**APPENDIX D:
BENCH-SCALE LABORATORY COLUMN TESTING ISGS REAGENT**

APPENDIX D

BENCH-SCALE LABORATORY COLUMN TESTING OF ISGS REAGENT

**KOPPERS INC. SITE
GAINESVILLE, FLORIDA**

Adventus Laboratory Testing Scope in Support of UHG ISGS Pilot Testing

This work is intended to supplement existing site data and enable appropriate data collection during upcoming pilot testing of the ISGS technology in the geologic unit known as the Upper Hawthorne Group (UHG) at the subject site.

The results from these tests will:

- i) validate the ability of the ISGS™ technology to treat the site-specific constituents of interest (COI) by reducing NAPL solubility and decreasing permeability of the impacted soil matrix; and
- ii) identify the most cost efficient and effective treatment protocol.

Task 1 – Bench Testing

Bench Testing Objectives

At the conclusion of the bench study we will identify the most effective ISGS treatment regime for the Site as determined by:

- Chemical characteristics of the Site soil;
- The permanganate Soil Oxidant Demand (pSOD) of the soil;
- COI removal; and
- Leachable COI post-ISGS treatment

Scope of Work

The scope of work for this bench scale treatability study will consist of:

- Baseline Sampling
- Column Studies
- Reporting/Project management

The work will be conducted at Adventus' laboratory near Toronto, Ontario, Canada.

Baseline Sampling

Immediately upon receipt of the Site soil at our laboratory, a composite soil sample will be sent for baseline analysis. The sample will be tested for semi volatile organic compounds (sVOC) which will detect PAHs. In addition, tests for total organic carbon (TOC), pH, ORP, heavy metals and inorganic ions will be conducted. All analyses will be conducted by Test America, Inc.

(Chicago). At GeoTrans' request, additional parameters may be added to the baseline and test analyses outlined herein, as required.

The pSOD will be determined using a procedure described in **Appendix A**. This testing will be performed on up to ten soil samples, to be selected by GeoTrans. It is our understanding that GeoTrans' intent is to collect five samples from relatively 'NAPL-rich' areas, and five from relatively 'NAPL-poor' areas.

Column Study Setup

Glass columns 15 cm long and 4.8 cm in ID will be used for the ISGS tests. Three "flow-through" columns will be packed with Site soil (about 500 g) (**Photograph 1**). Reactive columns will be amended with two ISGS solution dosages (**Table 1**) and left stagnant for 14 days. A control column will be packed with Site soil and saturated with distilled water.

Table 1. Proposed ISGS Treatments for Bench Testing

Column	Lab Treatment Solution	Surrogate for (Field Scale)
1	Distilled Water	Control
2	0.225% ISGS Solution at 100% Pore Volume	4.5% ISGS solution at 5% Pore volume
3	0.45% ISGS Solution at 100% Pore Volume	4.5% ISGS solution at 10% Pore volume

Following the 14-day treatment period, the solutions in the columns will be allowed to drain by gravity and fresh distilled water will be pumped through the column at a rate of about 1,000 ml/day in a bottom-up direction for 2 days (i.e. about 30 column pore volumes of flow). The cumulative post-treatment leachate will be collected, homogenized and sampled in duplicate for analysis of COIs and ORP/pH. Once the leachate has been collected, soil from each column will be homogenized and a single, composite soil sample from each column will be submitted for analysis of COIs, heavy metals and pH.

All organic analyses will be conducted by Test America, Inc. (Chicago) using US EPA standard methods. Samples will be shipped on ice via overnight courier under standard chain of custody.

Photograph 1. Flow-Through Columns Studies



Material Requirements

GeoTrans will collect representative soil samples and them to the Adventus Facility at the following address:

Ms. Sandra Owen

Adventus Remediation Technologies

1345 Fewster Drive

Mississauga, Ontario, CANADA L4W 2A5

Phone (905) 273-5374

Schedule

The study will be initiated immediately upon receipt of samples. We anticipate project completion within 8 weeks. A Draft Bench Scale Treatability Study Report will be submitted within seven working days of completing the study. A preliminary project schedule is provided in **Table 2**.

Table 2. Preliminary Project Bench Test Schedule

WEEKS	0	1	2	3	4	5	6	7	8
Sample Acquisition	X								
Baseline Sampling	X	X							
Column Set-Up			X						
pSOD tests		X	X						
Column Study				X	X	X			
Sampling						X			
Data interpretation			X					X	
Receipt of Final Analytical Data								X	
Draft Report									X

Task 2 – Injection Hydraulic Conductivity Testing

The purpose of this testing is to assess the apparent rate at which permeability reductions in site soil cores may be observed during a simulated one-dimensional, flow-through injection process. The general procedure for hydraulic conductivity testing is identified in **Appendix B**.

This procedure will be modified to utilize pressure transducers and data loggers to monitor the head (i.e., pressure) differential across the column for up to one week. Up to three 'NAPL-rich' and 3 'NAPL-poor' cores may be tested. To the extent practical in our lab, a variety of flow rates may be tested. At the least, a 'steady-state' head would be established, prior to any possible adjustments in flow rate. Initially, site groundwater collected from adjacent wells that are screened in the same geologic unit will be used as the fluid in the conductivity test.

A number of factors limit the potential ability of the ISGS reagent to migrate through a one-dimensional column. The one-dimensional nature of the test does not allow for the formation of

alternate injectate migration pathways that are likely to occur under actual field conditions. In our lab, we have generally observed plugging of soil pores at the influent ends of such columns, especially at higher ISGS concentrations. Thus, a 10% ISGS solution is expected to plug more quickly than a 4.5% ISGS solution than a 1% ISGS solution. In addition, the acrylic column and peristaltic pump used in our lab are seemingly unlikely to develop the pressures that may be required to force the ISGS reagent through the soil column.

Accordingly, we have considered the above observations in the testing protocol. Following the first test on each column (site water permeability), a more dilute ISGS solution (starting at 0.45%) will be pumped through each column. If flow is successfully attained at this dosage, pressure differentials will be monitored for up to one week. Following this, ISGS concentrations will be ramped up for one week injection conductivity tests until no flow is observed using our equipment. After the first week of injections at 0.45 wt%, 1 wt%, 2.5 wt%, and, ultimately 4.5 wt% will be used as long as flow is maintained.

Following up to four weeks of such ISGS reagent injection testing, the columns will then be re-tested with the site water if flow is still occurring at that time. Thus, a total of six weeks of testing may be conducted on each core. At GeoTrans discretion, or if site soils are found to plug, a range of coarser geologic media (e.g., medium to coarse sands) may be used to conduct the tests.

Material Requirements

GeoTrans will collect representative soil samples and them to the Adventus Facility at the following address:

Ms. Sandra Owen

Adventus Remediation Technologies

1345 Fewster Drive

Mississauga, Ontario, CANADA L4W 2A5

Phone (905) 273-5374

Schedule

The study will be initiated immediately upon receipt of samples. We anticipate project completion within 11 weeks. A Draft Bench Scale Treatability Study Report will be submitted within seven working days of completing the study. A preliminary project schedule is provided in **Table 3**.

Table 3. Preliminary Project Bench Test Schedule

[illegible]

OXIDANT DEMAND TEST USING POTASSIUM PERMANGANATE (KMnO₄)

INTRODUCTION

Potassium permanganate has been shown to be effective for oxidizing a variety of organic contaminants in the subsurface. However, potassium permanganate may react with or be consumed by other oxidizable compounds within the soil matrix. The permanganate Soil Oxidant Demand Test (pSOD) is conducted to evaluate the amount of potassium permanganate that will be consumed by these oxidizable species in the soil matrix. Each pSOD test uses a representative sample of soil from the site where permanganate has been proposed as a remediation technology.

OBJECTIVE

Determine the dosage of potassium permanganate required to meet the pSOD of the soil sample.

METHOD

1. Conduct the entire test under the fume hood.
2. Contact lenses may not be worn when working with chemicals. Throughout the experiment, rubber gloves, safety goggles and a lab coat must be worn.
3. Inspect soil and remove any large particles or foreign matter that is not representative of the soil type. Particles should be discarded in the appropriate waste soil 5-gallon bucket, depending on the place of origin (e.g. Europe, United States, Canada etc). The inspection should be conducted quickly to minimize moisture and volatile contaminant loss from the sample.
4. Homogenize soil samples using a stainless steel pastry cutter or spoon until the sample appears to be visually homogeneous. Homogenization should be conducted as quickly as possible to minimize loss of moisture and volatile components from the sample. Record the soil description in the lab book.
5. Label the soil samples with the date and store the soil samples with minimal headspace at 4°C until it is time to begin the experiment. The maximum holding time for homogenized soil samples should be used as soon as possible.
6. Based on the soil type select the range of concentrations of permanganate solution that are expected to meet the matrix oxidant demand of the soil being investigated.

For most soils (excluding very organic rich soils) the following concentrations of 1N potassium permanganate solution (equivalence: 31.61-mg/mL) will be used:

Jar Number	Volume 1N KMnO ₄ (mL)	Volume Water (mL)	Dosage (mg KMnO ₄ /g soil)	Concentration (mg/L)
1	0.0	75.0	0.00	-
2	0.5	74.5	0.32	211
3	1.5	73.5	0.95	632
4	5.0	70.0	3.16	2,107
5	15.0	60.0	9.50	6,323
6	50.0	25.0	31.61	21,073
7	75.0	0.0	47.42	31,610

CAUTION: Any spills of potassium permanganate should be rinsed with water. Paper towel should not be used.

7. Label seven 125-mL glass jars with the date, project number, source of soil, amount and concentration of potassium permanganate and sequence number.

8. Using the scale weigh out approximately 50 grams of soil and transfer into one of the labeled jars. Repeat until there are a total of 7 prepared jars. Record weights in the lab book. Place the remaining soil into a Ziploc bag or a mason jar.

9. Pipette the appropriate volume of 1N potassium permanganate solution into each of six graduated cylinders. The first cylinder in each sequence is reserved as a control and will not receive any potassium permanganate solution. Top up each graduated cylinder (except for number 7) with deionized water so that it contains a total volume of 75-mL of liquid (volumes shown in table above).

10. Add the contents of one graduated cylinder to the corresponding jar. Seal each jar and shake gently to evenly distribute the liquid and solid fractions. Loosen the lid once the jar is mixed. Store the jars together on a tray within the fume hood at room temperature. Record the start date and time of the experiment and room temperature in the lab book.

11. Gently turn each jar several times and allow the liquid and soil to mix twice a day for the duration of the experiment, (typically 48 hours or 7 days depending on the project specifics). In the lab book, record the time, date and room temperature each time the jars are mixed.

12. Each time the jar is turned examine the septum to ensure that no excess gas is being generated. If gas is being generated, the septum will bulge upwards. To degas the sample, open the lid of the jar. Samples over 10,000-ppm KMnO_4 represent the largest risk of excess gas generation.

CAUTION: If gas is allowed to build up within the jar, there is a possibility that the jar could crack or explode.

13. After 48 hours, some jars will be purple and some will be clear. Without disturbing the samples, record the colour of the samples in the lab book. Note that the intensity of the purple colour will vary and may be affected by suspended solids within the water.

14. Extract 10-mL of the supernatant from the purple jar with the lowest potassium permanganate concentration (lightest purple colour) and the jar with the next lowest concentration using a 10-milliliter disposable plastic syringe.

15. Inject the supernatant into the sampling vessel for the spectrophotometer. Record the colour of the filtered liquid. Analyze the concentration of potassium permanganate using the spectrophotometer. Record the concentration in the lab book.

16. Measure and record the pH of the supernatant using pH paper.

17. Remove excess liquid from the control sample and the least purple (i.e. treated soil).

18. Collect residual soil submit to commercial laboratory for analysis total organic carbon (TOC), chemical oxygen demand (COD), ICP metals and pH testing. Submit the samples to commercial laboratory along with the appropriate chain of custody and clear sample identifiers. Record the date samples were submitted in the lab book.

19. Neutralize the remaining samples containing potassium permanganate by adding several drops of low molarity concentration of sodium thiosulphate (0.1N), only until the solution is no longer purple.

CAUTION: The container may feel warm since the neutralization reaction is exothermic. Higher molarity solutions of sodium thiosulphate should not be used because explosion could occur.

20. Dispose of all leftover soil in the appropriate waste soil 5-gallon buckets. Ensure that the soil is disposed of in the correct bucket for its country of origin.

21. The pSOD for the soil will be reported as the range of dosages that correspond with the concentrations of the two jars for which concentrations were measured.

CALCULATIONS FOR OXIDANT DEMAND

$$\text{Initial KMnO}_4 \text{ concentration} = \frac{\text{amount of KMnO}_4 \text{ (ml)} \times \text{equivalence}^*}{\text{Amount of solution (ml)}}$$

$$\text{Final KMnO}_4 \text{ concentration} = \frac{(\text{Amount of supernatant} + \text{dilution amount}) \times \text{spectrophotometer reading}^*}{\text{Amount of solution in spectrometer (ml)}}$$

$$\text{Mass KMnO}_4 \text{ used} = \text{Vol. of H}_2\text{O (l)} \times (\text{Initial KMnO}_4 \text{ conc.} - \text{Final KMnO}_4 \text{ conc.})$$

$$\text{pSOD (mg KMnO}_4\text{/g soil)} = \frac{\text{Mass KMnO}_4 \text{ used (mg)}}{\text{Mass of soil in jar (g)}}$$

$$\text{pSOD (kg KMnO}_4\text{/tonne soil)} = \text{pSOD (g KMnO}_4\text{/kg soil)} = \text{pSOD (mg KMnO}_4\text{/g soil)}$$

$$\text{pSOD (kg/ m}^3\text{)} = \text{pSOD (g/kg)} \times 1.8 \text{ tonnes}^{**}/\text{m}^3$$

$$\text{pSOD (lbs/ yd}^3\text{)} = \text{pSOD (kg/m}^3\text{)} \times 2.2046 \text{ lbs/kg} \times \text{m}^3/1.308 \text{ yd}^3 = \text{pSOD (kg/m}^3\text{)} \times 1.69$$

* Concentration is in mg/L

** tonne is a metric ton and is = 1,000 kg

Hydraulic conductivity measurement Procedure

The method involves measurement of water levels in two manometers (i.e.; plastic tubing) connected to the influent and effluent end of the column (Figure A1). In this setting, water flows to both the column and to manometers. With a known flow rate (column pumping rate), the head difference between the two manometers represents the head difference (ΔH) at that flow rate. The hydraulic gradient (i) across the column is calculated from the head difference divided by the length of the column. Hydraulic conductivity (K) is then calculated from the hydraulic gradient and the pumping rate, using the Darcy equation:

$$K = \frac{q}{iA}$$

where: q is column flow rate

i is the hydraulic gradient across the column bed

A is column x-section surface area.

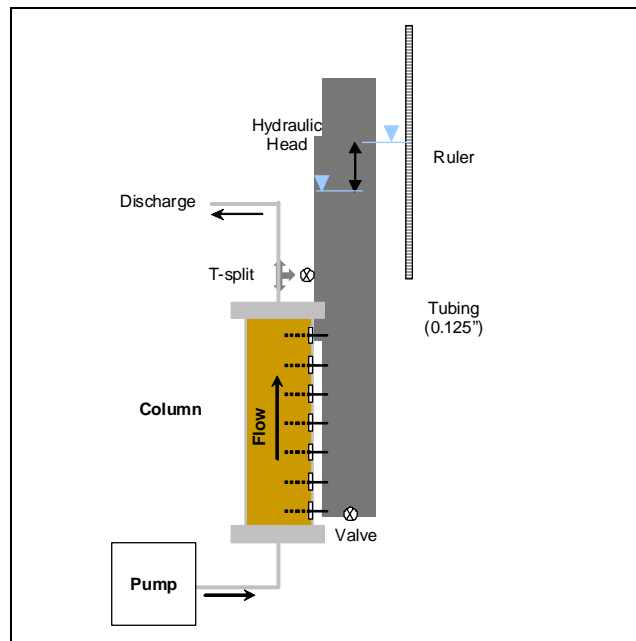


Figure A1. Manometer setup for hydraulic conductivity measurement.