Geosyntec consultants

1111 Broadway, 6th Floor
Oakland, California 94607
PH 510.836.3034
FAX 510.836.3036
www.geosyntec.com

13 August 2013

Ms. Penny Wilson Reddy
USEPA Region IX
75 Hawthorne Street
San Francisco, California 94105

Subject: Work Plan for Pilot Study Data Collection
401 National Avenue
Mountain View, California

Dear Ms. Reddy:

On behalf of Schlumberger Technology Corporation (STC), Geosyntec Consultants, Inc. (Geosyntec) is planning a pilot study to evaluate alternative methods for treatment of chlorinated volatile organic compounds (cVOCs), primarily trichloroethene (TCE) and its breakdown products (cis-1,2-dichloroethene [cDCE] and vinyl chloride), at the former Fairchild Semiconductor Corporation (Fairchild) Building 9 facility located at 401 National Avenue in Mountain View, California (Site, Figures 1 and 2). A preliminary scope for the pilot study was presented to the United States Environmental Protection Agency (EPA) in a meeting on 2 July 2013 and includes:

- Shut down and decommissioning of the existing groundwater extraction wells;
- Targeted in-situ bioremediation (ISB) injections in the areas containing relatively high cVOC concentrations; and
- Breaching of the existing Building 9 slurry wall to promote groundwater flow in the A-zone across the Site, with installation of a zero-valent iron (ZVI) permeable reactive barrier (PRB) in the slurry wall breach (on the downgradient side) to treat groundwater as it migrates off-site.

This work plan presents a scope of work for collection of field data that will be used to support the pilot study design.

BACKGROUND

Building 9 operated as a facility for receiving, mixing, and delivering chemicals for Fairchild from 1966 to 1987. During the Remedial Investigation/Feasibility Study (RI/FS) completed in 1988 for the Middlefield-Ellis-Whisman (MEW) Study Area (HLA, 1987; Canonie, 1988)[1], two potential source areas (LS28 and LS29) were identified at the Site. LS28 was located on the north side of Building 9 and consisted of four solvent storage tanks and a spill collections sump. LS29 was a pH neutralization system located inside Building 9 that consisted of three treatment sumps. The proposed pilot study encompasses an area in the north east portion of the Site where relatively high concentrations of cVOCs are detected in groundwater, east of LS28, and northeast of LS29.

The 401 National Avenue property was purchased by 401 National Avenue Partners, LLC in 2013 and is slated for redevelopment in conjunction with three properties to the north. Planned redevelopment activities include the demolition of Building 9 and the construction of a two-story parking garage over most of the 401 National Avenue property. The ISB injections and construction of the PRB/slurry wall breach will take place following building demolition and prior to parking garage construction. Therefore, timing of the pilot study will be dependent on the development schedule.

Local Hydrogeology

Cross-sections for the Site have been developed using historical information (Canonie, 1986;[2] MEW project database) and are included as Figure 3. The cross-sections are focused on the A-zone, where the pilot study will be implemented.

The local Site geology consists of alluvial deposits that are primarily fine-grained (i.e., silt and clay) inter-bedded with thin layers of coarser-grained materials (i.e., sand and gravelly sand). The A-zone at the Site is heterogeneous laterally and vertically but is generally encountered between 17 and 40 feet below ground surface (bgs). Two zones of coarse-grained material are present within the planned pilot study area: the shallower coarse zone is generally encountered

---

[1] Canonie Environmental (Canonie), 1988. Draft Feasibility Study, Middlefield-Ellis-Whisman Area, Mountain View, California, November 1988.
Harding Lawson Associates (HLA), 1987. Remedial Investigation Report, Remedial Investigation/Feasibility Study, Middlefield-Ellis-Whisman Area, Mountain View, California, Vol. 1-8, July 1987 (revised in 1988).

[2] Canonie, 1986. Pumping Test Interim Remedial Program, Mountain View Facility, Prepared for Fairchild Semiconductor Corporation, January.

between 18 and 24 feet bgs and the deeper coarse zone is generally encountered between 35 and 37 feet bgs.

The potentiometric surface of the A-zone at the Site generally occurs under confined conditions at approximately 18 feet bgs. Under pumping conditions, the groundwater gradient inside the Site slurry wall is relatively flat, with groundwater elevations measured between 25.5 and 25.8 feet Mean Sea Level (MSL) in Site monitoring wells during the September 2012 annual gauging event (Geosyntec, 2013).[3] Inward horizontal gradients are observed along most of the slurry wall, with the periodic exception of some locations along the northern sections (Geosyntec, 2008).[4]

cVOCs in Groundwater

cVOC concentrations (TCE, cDCE, and VC) within the proposed pilot study area are shown on Figures 2 and 3 for wells sampled in 2012. Over the last 5 years, the maximum concentration of TCE detected in Site groundwater was 8,300 micrograms per liter (µg/L), measured in AE/RW-9-2 in 2011 (Geosyntec, 2013).

Previous Remedial Actions

A number of remedial actions have been and are being conducted at the Site, including (in chronological order):

- 1986: installation of a slurry wall (Figure 2) in the A-zone to a depth of approximately 40 feet;
- Ongoing since 1986: operation of a groundwater extraction and treatment system. Extraction wells AE/RW-9-1, AE/RW-9-2, RW-20A, and RW-21A are currently operating within the Building 9 slurry wall; groundwater from these wells is conveyed to the Fairchild Treatment System No. 1, where it is treated and discharged;

[3] Geosyntec Consultants, Inc (Geosyntec), 2013. 2012 Annual Progress Report for Former Fairchild Buildings 1-4,9, and 18 Groundwater Remediation Programs, Mountain View, California, April 15.

[4] Geosyntec, Northgate Environmental Management, Inc., Schlumberger Water Services, and Weiss Associates. (Geosyntec, et al), 2008. Optimization Evaluation, Fairchild Sites, Middlefield-Ellis-Whisman Area, Mountain View, California, September 3.

- 1995: 3,000 cubic yards of soil were excavated to a depth of 6 feet bgs and aerated at the Site (Smith, 1995; EPA, 2004);[5] and
- 1996 through 1997: soil vapor extraction (SVE) in shallow soil at depths from 6 feet bgs to 18 inches above the water table (Locus, 1997; Smith, 1997a; and Smith, 1997b). [6]

SCOPE OF WORK

The purpose of the data collection described herein is to collect data for use in designing the Pilot Study, including the distribution of cVOC concentrations and the local hydrogeologic conditions.

The pilot study data collection field work will include the following components:

- Excavate test pits at two locations along the slurry wall to evaluate the slurry wall width and to visually inspect the nature of the contact between the slurry wall and native formation;
- Advance soil borings using direct-push (DP) technology to further delineate the potential treatment zone for ISB injections (i.e., coarse-grained depth intervals with elevated TCE concentrations located within the slurry wall) (Figure 2);
- Collect groundwater samples from AE/RW-9-2 and 137A to evaluate baseline pilot study conditions and for use in bench-scale treatability testing for the ZVI PRB;
- Measure water level response to a temporary shutdown of Site extraction wells to evaluate expected hydraulic conditions within the slurry wall prior to breaching; and

---

[5] Smith, 1995. Operation and Maintenance Plan, Fairchild Semiconductor Corporation, 401 National Avenue, Building 9, Mountain View, California, December, 1995.
EPA, 2004. Final First Five Year Review Report for the Middlefield-Ellis-Whisman Study Area, Mountain View, California, Region 9 San Francisco, California, September.

[6] Locus Technologies (Locus), 1997. Confirmatory Soil Sampling Report, Area 3, Fairchild Semiconductor Corporation, 401 National Avenue, Building 9, Mountain View, California, July 15, 1997.
Smith Technology Corporation (Smith), 1997a. Confirmatory Soil Sampling Report, Area 1, Fairchild Semiconductor Corporation, 401 National Avenue, Building 9, Mountain View, California, March 6, 1997.
Smith, 1997b. Confirmatory Soil Sampling Report, Area 2, Fairchild Semiconductor Corporation, 401 National Avenue, Building 9, Mountain View, California, April 24, 1997.

- Implement an injection test to assess achievable injection rates and pressures in preparation for ISB field work.

The following sections provide descriptions of the activities associated with each task in the pilot study data collection field effort.

Task 1: Pre-Field Activities

Before implementing the pilot study data collection field work, Geosyntec will perform the following:

- Develop a Site-specific health and safety plan (HASP);
- Coordinate with the owner of 401 National Avenue for access;
- Coordinate and subcontract with the drilling contractor and laboratories;
- Obtain a small project grading permit from Santa Clara County for the test pits;
- Mark proposed boring and test pit locations (actual boring locations will be determined in the field based on the results of real-time data obtained from the DP tools);
- Notify Underground Services Alert (USA) North in advance of subsurface work a minimum of 48 hours prior to conducting any intrusive subsurface work; and
- Retain a private utility locator to clear underground utilities in the area where field work is anticipated.

Task 2: Slurry Wall Test Pits

The existing slurry wall at the Site was constructed using a long-reach excavator and backfilled with soil-bentonite slurry. In order to determine the extent to which the slurry may have penetrated the surrounding native materials, two shallow test pits will be trenched across the slurry wall as shown on Figure 2. Observations from the test pits will be used to determine the excavator width needed during the slurry wall breach. Work at each test pit location will include:

- Saw cutting and removal of the pavement and concrete slab over the slurry wall;
- Excavation of a shallow test pit across the slurry wall using a backhoe. Test pits will be approximately 24 inches wide and less than 4 feet deep, with sloping or benching of sidewalls to allow entry and inspection of the slurry wall;

- Photo-logging of the test pit conditions;
- Backfilling of test pits and restoration of the ground surface as required by the property owner; and
- Profiling and disposal of test pit spoils off-site in accordance with STC's waste management procedures.

Task 3: Direct-Push Borings

Field work under this task will include developing depth profiles of relative cVOC concentrations using DP technology. High resolution, real-time data collection tools compatible with the DP technology such as the Soil Conductivity Probe (SCP) and the Membrane Interface Probe (MIP) will be used to provide supplemental high resolution information on the lithology of site soils and the distribution of cVOCs in the subsurface.

Membrane Interface Probe and Soil Conductivity Probe

The MIP is a tool equipped with a heated, semi-permeable membrane that volatilizes VOCs in the soil and groundwater adjacent to the tool as it is advanced through the soil using a DP drilling rig. The volatilized VOCs diffuse through the membrane and are delivered to the ground surface via a carrier gas, where VOCs in the carrier gas are detected using one or more of the following: a Flame Ionization Detector (FID), a Photoionization Detector (PID), and an Electron Capture Detector (ECD).[7]

The MIP provides a nearly continuous, real-time, depth-response profile with qualitative information on total cVOC readings. The resulting high resolution profiles of relative cVOC concentration with depth will provide useful real-time information on the potential extent of soil and groundwater impacts to facilitate decision making during the field effort as well as providing information to refine the potential application area for the planned ISB injections. Results obtained using the MIP can be used to approximate cVOC concentrations in the subsurface by comparison of the MIP data to the results of laboratory analysis of collocated depth-discrete groundwater samples.

[7] cVOCs, including TCE, cDCE, and vinyl chloride can be detected by the ECD because this detector responds to compounds containing chlorine atoms. These cVOCs can also be detected by the PID, which responds to compounds that can be ionized by a light source, and the FID, which responds to compounds that combust in a hydrogen flame. The ECD is more sensitive than the PID and FID to cVOCs such as TCE; and, therefore, will respond to lower concentrations of TCE. Non-chlorinated compounds, such as aromatics and ethene, can be detected by the PID and FID, but not the ECD.

The SCP is an electrical sensor attached to the MIP tool that continuously measures electrical conductivity, a physical property of the soil matrix that is primarily controlled by the clay mineral percentage and water content. Soils with relatively high clay mineral percentage are generally more electrically conductive than soils with low clay mineral percentage.

Direct-Push Borings

Approximately 6 to 11 DP borings will be advanced within the slurry wall to collect SCP and MIP data in the area identified in Figure 2. The total depth of each boring will be 40 feet bgs (bottom of the A-zone). Following boring completion, the DP rods will be extracted and the boring will be backfilled with neat cement grout.

After the first six DP borings are completed, additional step-out locations will be selected, if appropriate, based on the results of the previous borings. Initial and potential step-out locations are shown in Figure 2.

Soil Coring and Logging

Continuous soil cores will be collected at two locations with a dual-tube system advanced by a DP drilling rig for lithologic logging and comparison with the SCP results. The location of soil core borings will be determined in the field based on the results of the MIP investigation. Continuous core soil samples will be visually logged by Geosyntec field personnel for classification of soil type using the Unified Soil Classification System (USCS) as guidance and field screened for VOCs using a photo ionization detector (PID).

Quantification of cVOCs in Depth-Discrete Groundwater Samples

Depth-discrete groundwater samples will be collected from locations and depth intervals where MIP data indicate high concentrations of cVOCs are present and SCP data indicate the presence of relatively coarse-grained aquifer materials. Samples will be collected from a depth interval spanning four feet or less using a hydropunch-type sampling device advanced by a DP drilling rig, and will be analyzed for cVOCs by EPA Method 8260B (8010 analyte list). Three to ten groundwater samples will be collected to quantify cVOC concentrations at selected locations and depths based on the MIP profiles. Each sample will be collected in laboratory-supplied sample containers and labeled with project identification, sample location, analytical parameters, time and date of sampling, and any preservative added to the sample. Samples will be stored in an ice-cooled chest and maintained at approximately 4ºC for transport under chain-of-custody procedures to an EPA-certified laboratory for analysis. Results of the laboratory analysis will be compared with the results obtained with the MIP.

Quality assurance/quality control (QA/QC) samples will be collected for groundwater VOC samples. In accordance with the MEW quality assurance quality control plan (QAPP), one duplicate, one field blank, and one equipment blank will be collected for every 20 groundwater samples collected for VOC analysis.[8] In addition, a laboratory provided trip blank will be included with each cooler containing groundwater samples for VOC analysis that is sent to the laboratory.

Task 4: Groundwater Sample Collection from AE/RW-9-2 and 137A

Groundwater samples will be collected from AE/RW-9-2 and 137A to evaluate geochemical conditions within the pilot study area. Specific parameters selected for analysis are listed in Table 1 along with a general description of the purpose for each analysis. Geochemical parameters such as oxidation reduction potential (ORP), dissolved iron and manganese, and total organic carbon (TOC) can be used to evaluate whether existing Site conditions are favorable for ISB, to select the electron donor dose for the ISB injections, and to evaluate changes in redox conditions following injections. cVOC and geochemical data collected will also be used in the ZVI bench-scale treatability test to evaluate the performance under representative Site groundwater conditions. In addition, microbial analyses will be used to assess the presence of cVOC-reducing bacteria and inform the approach for bioaugmentation.

The groundwater sample from AE/RW-9-2 will be collected directly from the pump discharge line at the wellhead during normal operation. To measure field parameters (i.e. pH, dissolved oxygen, ORP, temperature, and electrical conductivity) at AE/RW-9-2, groundwater will be purged from the extraction well piezometer and pumped through a flow through cell. The groundwater sample from 137A will be collected using low flow sampling methods. Samples will be shipped to an EPA-certified laboratory for analysis of the parameters listed in Table 1. In addition, 4 gallons of water extracted from AE/RW-9-2 will be collected in 4-liter (1-gallon) amber sample bottles and shipped to SiREM Laboratory in Guelph, Ontario, Canada (SiREM) for use in the bench-scale ZVI treatability test.

In accordance with MEW QAPP, QA/QC samples consisting of one duplicate, one field blank, and one equipment blank will be collected for VOC analysis. In addition, a laboratory-provided trip blank will be included with each cooler containing groundwater samples for VOC analysis that is sent to the laboratory.

---

[8] Canonie, 1991. Quality Assurance Project Plan Middlefield-Ellis-Whisman Site, Mountain View, California, Rev. 1.0, 16 August.

Task 5: Bench-Scale ZVI Treatability Testing

A bench-scale ZVI treatability test will be performed by SiREM in a flow-through column using groundwater collected from AE/RW-9-2 and granular ZVI to establish site-specific degradation rates of cVOCs present in the site groundwater and their breakdown products under flowing conditions.[9] These rates will be used to determine the required cVOC residence time within the ZVI reactive material. Based on the residence time and the groundwater flow velocity, the flow-through width of the ZVI zone can be designed. Details of the ZVI treatability test are provided as Attachment A.

Task 6: Extraction Well Shutdown and Water Level Monitoring

Following sampling of AE/RW-9-2, Site extraction wells will be shut down to evaluate groundwater elevations within the slurry wall under non-pumping conditions. Prior to the extraction well shutdown, a pressure transducer will be installed in monitoring well 37A (Figure 2). The transducer will be used to collect real-time data on groundwater elevation changes inside the slurry wall following extraction well shutdown. In addition, a minimum of two rounds of groundwater level measurements (one before and one after extraction well shutdown) will be collected from Site wells located inside and outside the slurry wall. After deployment, the pressure transducer will be downloaded and the data will be analyzed to evaluate the hydraulic properties of the A-zone inside the slurry wall. It is anticipated that one or more of the Site groundwater extraction wells will remain off for up to four weeks during data collection.

Task 7: Injection Test

A one-day injection test will be performed at the Site using municipal water to evaluate achievable injection flow rates for use during design of the planned ISB injections. Extraction wells AERW-9-1 and RW-21A are expected to be operational during the ISB injections; therefore, these wells will be turned back on prior to the injection test. Additional details of the injection tests are provided as Attachment B.

---

[9] Gillham, R.W. and O'Hannesin, S.F., 1994. Enhanced Degradation of Halogenated Aliphatics by Zero-Valent Iron. Ground Water, Vol. 32, No. 1, pp. 958-967.

Task 8: Reporting

A report that describes the results of the pilot study data collection field activities (e.g., sample locations, laboratory reports, column and injection test results, and data QA/QC) will be submitted to EPA within 90 days of the completion of data collection.

SCHEDULE

In order to coordinate implementation of the pilot study with redevelopment activities planned for the Site, we have proposed an accelerated schedule for conducting the data collection effort. We have planned for field work to begin the first week of September 2013 and last 2 to 3 weeks, with bench-scale ZVI column testing starting one week after the start of field work and lasting seven weeks. This start date depends on driller availability and approval of this Work Plan by EPA. In order to meet the accelerated schedule, we request approval of this Work Plan by 30 August 2013. Please let us know if you have any questions regarding the proposed work.

Sincerely,

Deepa Gandhi, PE
Senior Engineer

John Gallinatti, CHg
Principal Hydrogeologist

Attachments: Table 1 – Groundwater Sampling Analyte List
Figure 1 – Site Location Map
Figure 2 – Proposed Data Collection Locations
Figure 3 – A-zone Cross-Sections in Proposed Pilot Study Area
Attachment A – Bench-Scale ZVI Column Test Scope of Work
Attachment B – Injection Test Scope of Work

Copies to: Virgilio Cocianni, Schlumberger Technology Corporation
Victor R. Fracaro, National Avenue Partners, LLC

TABLE

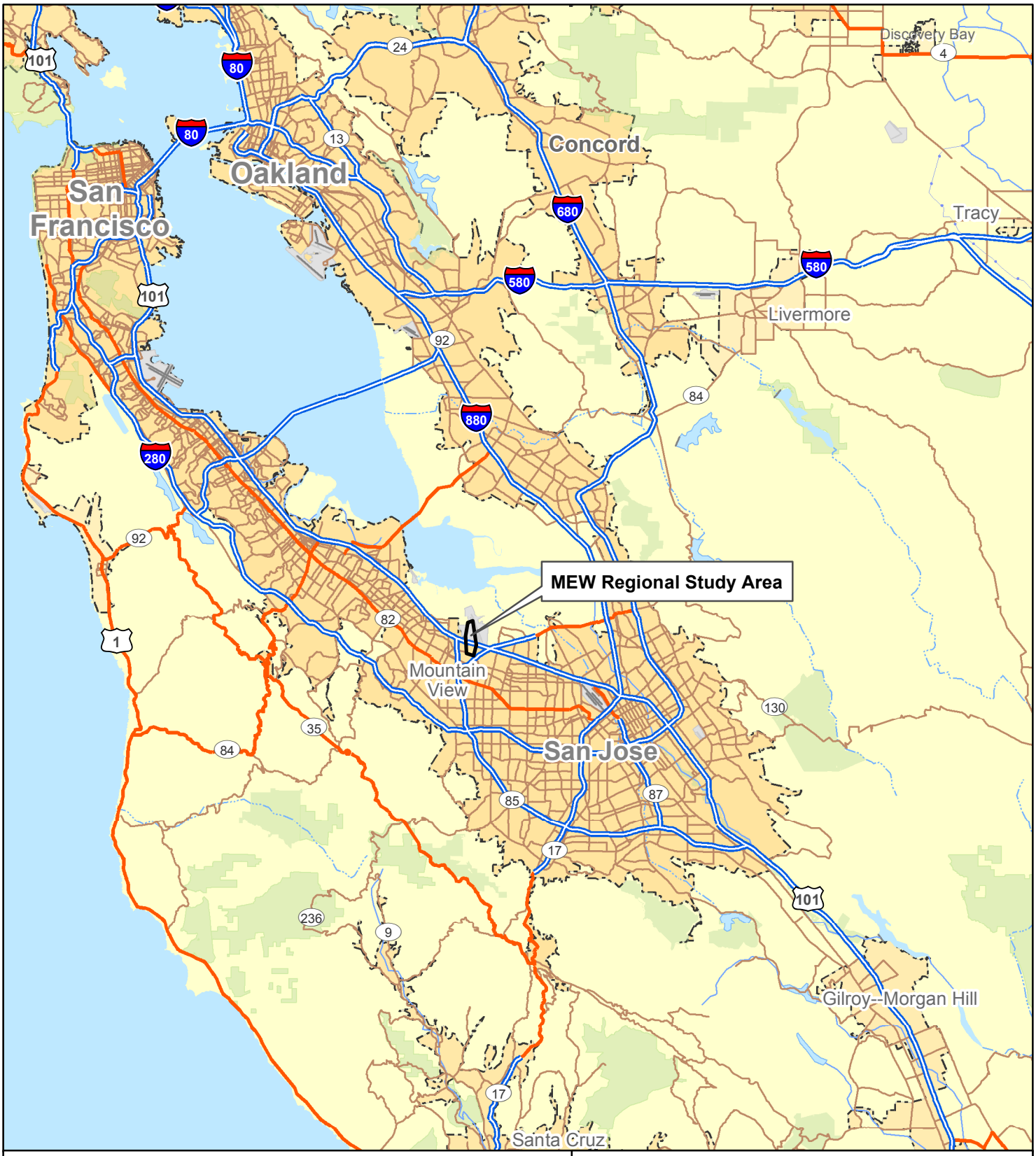
TABLE 1
GROUNDWATER SAMPLING - ANALYTE LIST
401 National Avenue Pilot Study
Mountain View, California

Analyte(s)	Analytical Method	Purpose	Assesses Performance of:	
			ISB	ZVI PRB
VOCs	EPA 8260B (8010 Analyte List)	baseline identification of site-related chemicals of interest, degradation products, and selection of potential electron donors	x	x
Sulfate, nitrate	EPA 300.0	identify concentration of dissolved non-target electron acceptors	x	x
Chloride, phosphate	EPA 300.0	evaluate ZVI reactivity towards VOCs		x
DO, ORP, pH, electrical conductivity, temperature	Field measurement	baseline conditions to evaluate changes in groundwater geochemistry from e-donor addition	x	x
Dissolved iron, manganese	EPA 6010B	baseline conditions to evaluate changes in groundwater geochemistry from e-donor addition	x	x
Dissolved calcium, sodium, magnesium, potassium, silica	EPA 6010B	evaluate ZVI reactivity towards VOCs		x
Ethene, ethane, acetylene, methane	RSK-175M	baseline conditions to evaluate degradation following e-donor addition	x	x
TOC	EPA 415.1	baseline conditions to evaluate changes in organic carbon due to e-donor addition and depletion	x	x
Dehalococcoides/ vcrA enumeration	Gene-Trac	measure existing population of reductively dechlorinating organisms and effectiveness of augmentation	x	
Alkalinity	SM 2320B	produced during microbial oxidation of organic e-donors; used evaluate ZVI reactivity towards VOCs	x	x
TDS	SM 2540C	evaluate ZVI reactivity towards VOCs		x

Note:
ZVI PRB data from an EPA-certified lab will be provided to SiREM Laboratories for column test baseline.

Abbreviations:
DO = dissolved oxygen
e-donor = electron donor
ISB = in-situ bioremediation
ORP = oxidation reduction potential
PRB = passive reactive barrier
TDS = total dissolved solids
TOC = total organic carbon
VOCs = volatile organic compounds
vcrA = vinyl chloride reductase
ZVI = zero-valent iron

FIGURES



N

0 10 Miles

Site Location Map

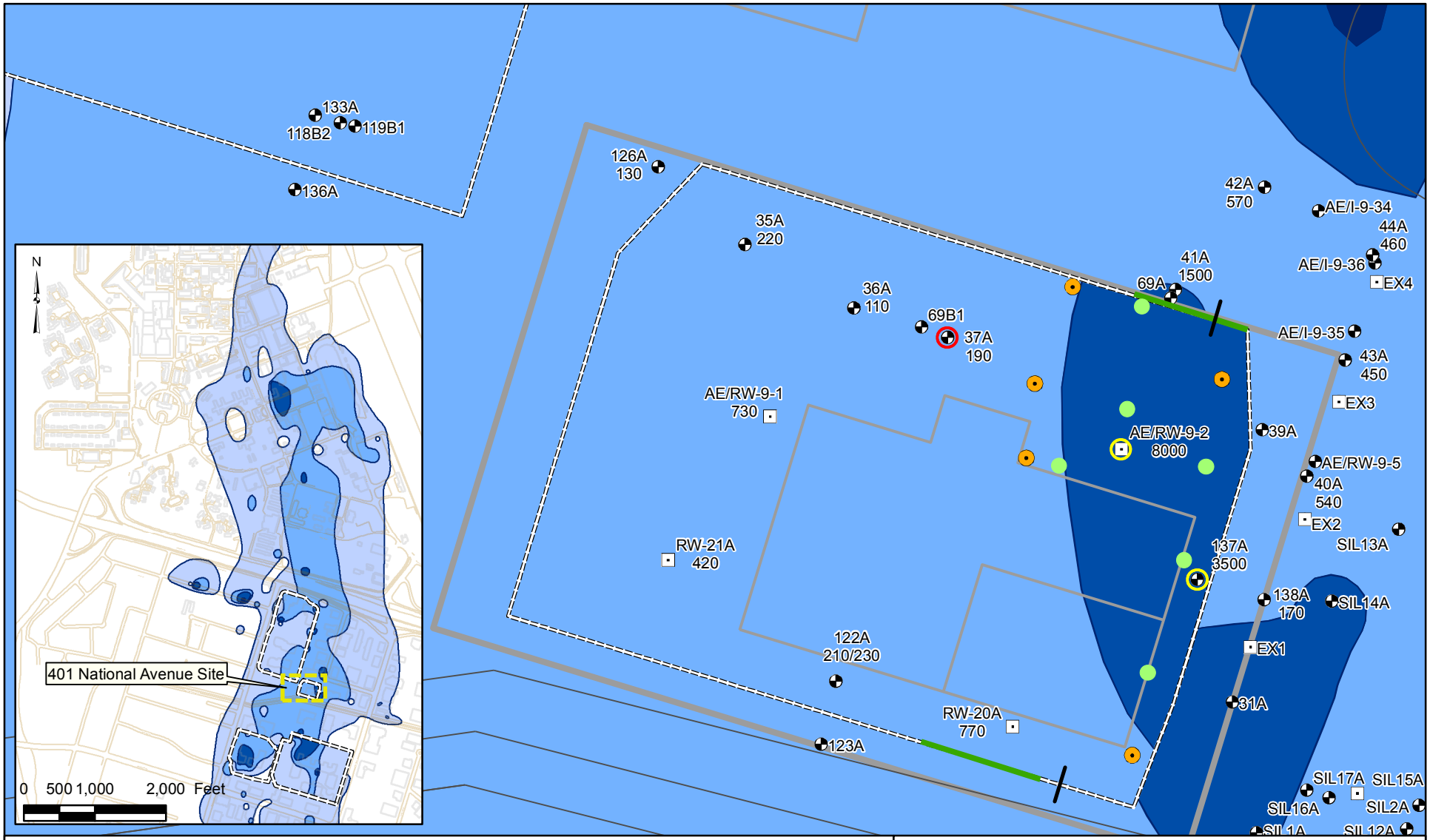
401 National Avenue Pilot Study
Mountain View, California

Geosyntec consultants

Oakland | August 2013

Figure 1

P:\GIS\MEW\Project\Fairchild\Building9\2013_401NationalOptimizationEvaluation\DataCollectionWorkplan\Fig01_Loc_Map.mxd



Legend

- Recovery Well On
- Recovery Well Off
- Monitoring Well
- 78A <0.50 — Well ID / TCE Concentration

A-Zone TCE Concentration

- 5 - 100 ug/L
- 100 - 1,000 ug/L
- 1,000 - 10,000 ug/L
- Greater than 10,000 ug/L

- Proposed MIP Location
- Proposed MIP Step-Out Location
- Proposed Transducer
- Conceptual Slurry Wall Breach Location
- Proposed Test Pit Location
- Proposed Groundwater Sample Location

- Slurry Wall
- Building
- Road

N

60 30 0 60 Feet

Notes:
TCE = Trichloroethene
ug/L = micrograms per liter
Figure shows results for only those wells sampled in 2012 for 401 National Avenue.
Final locations and lengths of test pits to be determined based on field conditions.

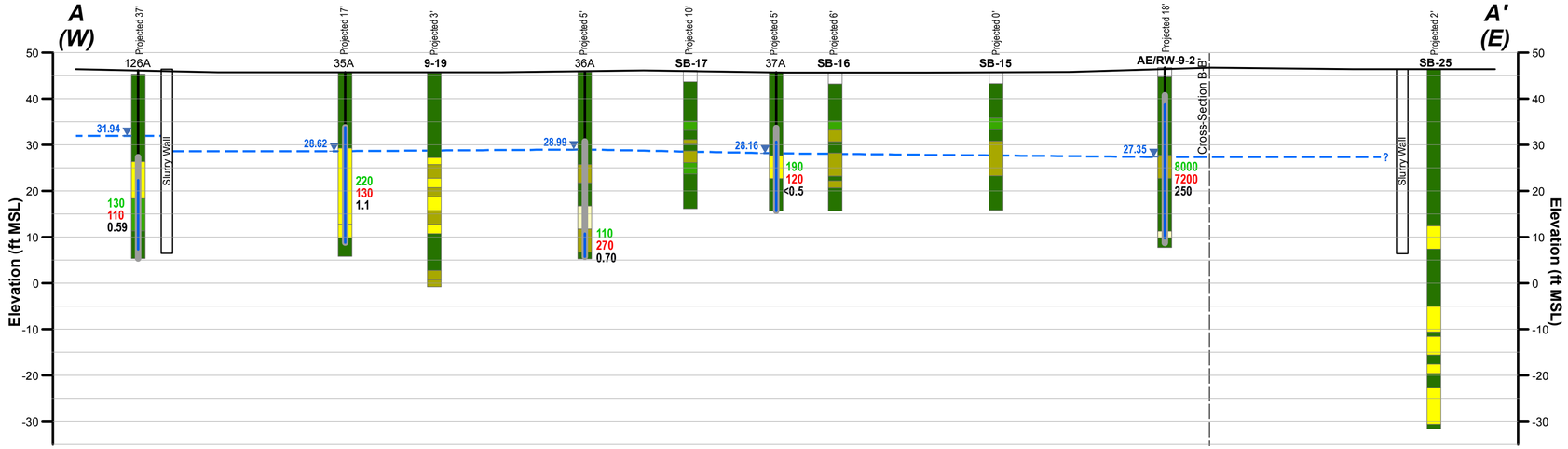
Proposed Data Collection Locations
401 National Avenue Pilot Study
Mountain View, California

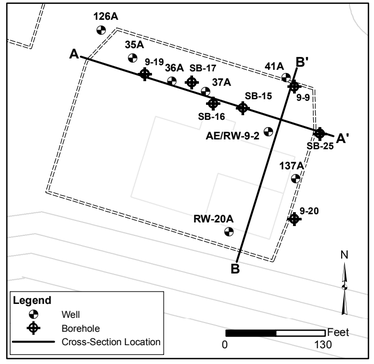
Geosyntec consultants

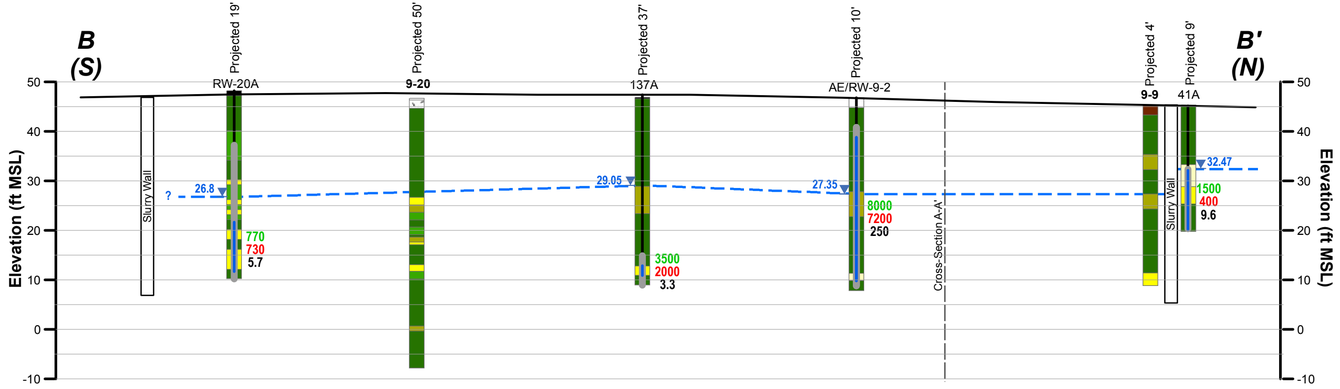
Oakland | August 2013

Figure 2

P:\GIS\MEW\Project\Fairchild\Building9\2013_401NationalOptimizationEvaluation\DataCollectionWorkplan\Fig02_ProposedDataCollectionLocations.mxd 8/12/2013 3:35:56 PM







LEGEND

41A

32.47 Groundwater Elevation (ft MSL) (20 September 2012)

Filter Pack

Well Screen

1500 / 400 / 9.6 September 2012 Sample Results
Trichloroethene Concentration [ug/L]
cis-1,2 Dichloroethene Concentration [ug/L]
Vinyl Chloride Concentration [ug/L]
ug/L - micrograms per liter

A Zone Potentiometric Surface

SB-25 Soil Boring

Boring Log

Soil Class

- No Recovery
- Asphalt; Fill
- Sand and Gravel Fill Material
- Topsoil
- CL Clay
- ML Silt
- SC-SM Clayey Sand to Silty Sand
- SP Poorly Graded Sand to Well Graded Sand
- SW-GW Well Graded Gravelly Sand to Well Graded Gravel

Notes:
ft MSL - Feet above Mean Sea Level
Slurry wall depth is approximate.
USGS digital elevation model used for surface elevation.

20 Feet
0 Feet 20

A-zone Cross-Sections in Proposed Pilot Study Area
401 National Avenue Pilot Study
Mountain View, California

Geosyntec consultants

Oakland | August 2013

Figure 3

P:\GIS\MEW\Project\Fairchild\Building9\2013_401NationalOptimizationEvaluation\DataCollection\Workplan\Fig03_AzoneCrossSections.mxd

ATTACHMENT A
Bench-Scale ZVI Column Test Scope of Work

ATTACHMENT A: BENCH-SCALE ZVI COLUMN TEST SCOPE OF WORK

Results of bench-scale treatability testing with groundwater from the site and commercial granular iron material will be used to predict system performance and provide data for field design. The bench-scale tests establish the site-specific degradation rates of the volatile organic compounds (VOCs) present in the site groundwater and their breakdown products under flowing conditions (Gillham and O'Hannesin, 1994). These rates are used to determine the required residence time in the reactive material. Using the residence time and the flow rate, the size of the treatment ZVI zone can be determined. The bench-scale test also includes inorganic sampling of column influent and effluent. This provides information concerning potential mineral precipitation in the reactive material caused by changing oxidation-reduction potential (ORP) and pH conditions. The potential for mineral precipitation must be considered in the field design as these processes will control treatment longevity.

SiREM Laboratory (Guelph, Ontario, Canada) will be contracted for the treatability test. The test procedure below is based on information provided by SiREM.

Bench-Scale Apparatus

The treatment column is constructed of Plexiglas® with a length of 1.6 feet (ft; 50 centimeter [cm]) and an internal diameter of 1.5 inches (3.8 cm). Seven sampling ports are positioned along the length of the column at distances of 0.08 (2.4 cm), 0.16 (4.9 cm), 0.33 (10.1 cm), 0.50 (15.2 cm), 0.66 (20.1 cm), 1.00 (30.5 cm) and 1.31 ft (39.9 cm) from the inlet end (Figure 1). Sampling ports are used to collect water samples for analysis. Each sampling port is constructed of a nylon Swagelok® fitting (0.063 in; 0.16 cm) secured into the side of the column. Within each fitting, a 16-gauge needle (Fischer Scientific) will be tightly secured to allow for sampling from the center axis of the column. To prevent solid materials from entering the needle, glass wool is placed in the needle. Each sample port is fitted with a Luer-Lok™ fitting, such that a glass syringe can be attached to the port to collect a sample. When not in operation, the ports are sealed by Luer-Lok™ plugs. Both the top and bottom of the column are sealed by rubber O-ring seals and contain fine (500 micron) mesh to inhibit solid material from entering the influent and effluent hose.

Commercial granular ZVI (8/50 US Mesh size) from Connelly GPM (Chicago, IL) will be tested. This type of ZVI has a high specific surface area, which tends to indicate high reactivity, and has been previously used in numerous previous permeable reactive barrier (PRB) applications. To assure a homogeneous mixture of reactive material while filling the column, aliquots of iron material are packed vertically in lift sections. Values of bulk density, porosity, and pore volume are determined gravimetrically. All column experiments are performed at room temperature (≈ 23°C / 73°F). During the design phase, degradation rates determined in the laboratory are adjusted for field groundwater temperature.

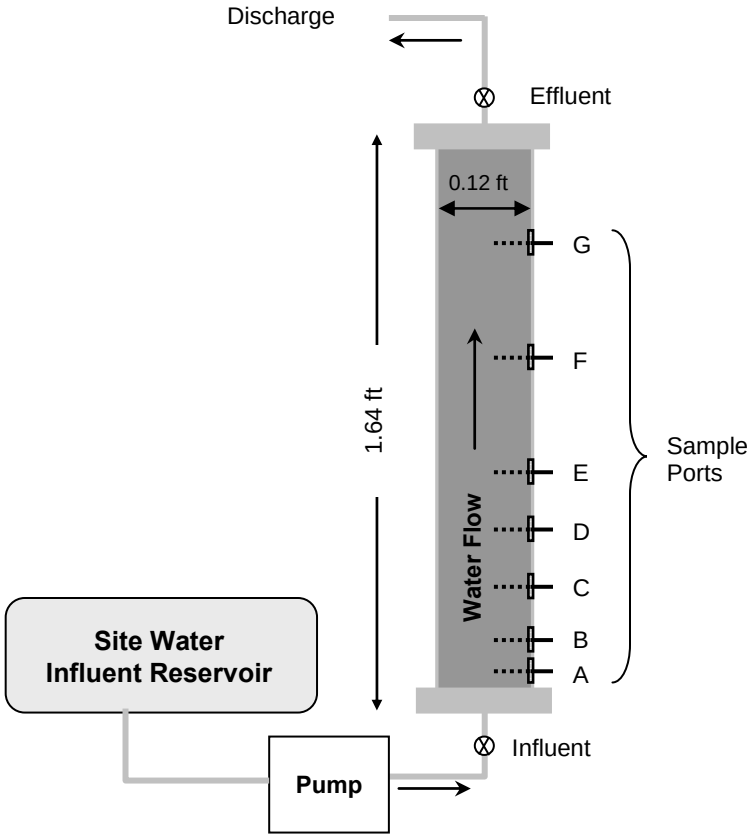


Figure 1: Schematic of the apparatus used in the treatability test.

Groundwater Shipment

Groundwater will be collected from a well in the vicinity of the proposed PRB such that the groundwater is representative of groundwater expected to enter the treatment zone. The groundwater will be shipped in 4-L (1-gallon) amber sample bottles with no headspace. When received, the site water will be stored at 4°C (39°F) until required, at which time it will be siphoned from the sample bottles into a collapsible Teflon® bag. The water will be analyzed immediately upon arrival for select VOCs. The water shipped to the laboratory from the site should have characteristics (VOC concentrations and inorganic chemistry) similar to the groundwater expected to enter a field-scale treatment system.

ZVI Column Operation

The ZVI column will operate for a period of seven weeks. The Site water will be supplied to the influent end of the column at a constant rate using a laboratory pump. The flow velocity through

the column will be equal to approximately one pore volume per day (i.e., approximately 1.6 ft/day for the column in Figure 1 above). At that flow rate, approximately 40 pore volumes of site water will be exchanged through the column. Previous studies have shown that contaminant half-lives in the presence of ZVI are independent of the flow rate for rates of up to several ft/day (Battelle, 2002), so the difference between Site groundwater velocity and the column flow velocity should not impact the results.

ZVI Column Sampling and Analysis

Water samples will be collected from the column, including influent, effluent, and individual ports for analysis of chlorinated VOCs (cVOCs), dissolved hydrocarbon gases (DHGs, e.g., ethene, ethane, or methane), ORP, and pH on a weekly basis. Split samples will also be collected from the influent and effluent at time zero (week 0), the mid-point (week 3) and the end point (week 6) for cVOC analysis by U.S. EPA method No. 8260B at a certified commercial laboratory.

Other analyses will include anions (chloride, nitrate, sulfate, and orthophosphate), cations (dissolved iron, Na, Mg, Ca, K, Mn, and Si), alkalinity (as milligrams $CaCO_3$/L) and total dissolved solids (TDS) on samples collected from the column influent and effluent to evaluate the potential for mineral precipitation. Anions will be sampled at time zero (week 0), the mid-point (week 3) and the end point (week 6). Cations, alkalinity, and TDS will be sampled at time zero (week 0) and end of the study only (week 6). Duplicate samples for all parameters will be collected from the groundwater as received to provide a baseline.

Aqueous sampling will be conducted using gas-tight Hamilton syringes. For cVOC analyses conducted at SiREM, samples will be collected from the column influent, effluent, or sampling port on the side of the column for analysis by GC. A 0.5-mL and 3-mL sample will also be collected for anion analysis, ORP/pH, and TDS analysis at SiREM, from the influent, effluent, or sampling ports. The SiREM cVOC, anion, and ORP/pH analysis methods including quality assurance/quality control measures are presented in Appendix 1.

Samples for the split cVOC analysis and inorganic parameters (cations, alkalinity, and total sulfide) will be sent to a commercial laboratory (TestAmerica). Samples for cation analysis will be collected in 100-mL plastic bottles. Cation analyses will be performed using inductively coupled plasma atomic emission spectroscopy (ICP-AES) (U.S. EPA Method No. 6010B). The unfiltered, 60-milliliter (mL) samples will be acidified to a pH of 2 with nitric acid and stored at 4°C until analyzed. Samples for alkalinity analysis will be collected in unpreserved 20-mL VOA vials. Alkalinity (as mg $CaCO_3$/L) in water will be determined by automated colorimetry (U.S. EPA Method No. 310.2). Samples for total sulfide analysis will be collected in 20-mL VOA vials and preserved with zinc acetate and sodium hydroxide and determined by UV-VIS (U.S. EPA Method No. 376.2).

Treatability Evaluation Report

A report providing the results and interpretations of the bench-scale study will be issued at the conclusion of the column testing. The report will contain:

- All chemical analyses completed on column samples;
- Calculated degradation rates of organic compounds;
- Summary tables of major results; and
- Graphs showing degradation behavior.

These results will be interpreted in the context of the Site hydrogeological data to provide basic conceptual residence time simulations for field-scale designs.

References

Battelle, 2002. Technical Report: Cost and Performance Report – Evaluating the Longevity and Hydraulic Performance of Permeable Reactive Barriers at Department of Defense Sites. Prepared for Naval Facilities Engineering Service Center, Port Hueneme, California. December.

Gillham, R.W. and O'Hannesin, S.F., 1994. Enhanced Degradation of Halogenated Aliphatics by Zero-Valent Iron. *Ground Water*, Vol. 32, No. 1, pp. 958-967.

Appendix 1: Quality Assurance/Quality Control Measures

Field Sampling Methods:

Groundwater samples will be collected from the effluent port at extraction well AE/RW-9-2. Samples will be collected in 1-gallon (4-Liter [L]) plastic bottles with no headspace and no preservative. The samples will be placed in a cooler with ice packs and shipped overnight under chain of custody to SiREM. In addition, groundwater will be purged from the piezometer for AE/RW-9-2 and pumped through a flow through cell to measure field parameters (i.e. pH, DO, ORP, temperature, and electrical conductivity).

Field Sampling Handling and Custody:

Upon receipt, the cooler will be opened and inspected including the condition of the sample containers. A sample reception record will be created and signed and dated by the receiving technician. A thermometer probe will be inserted into the cooler and activated to read the inside temperature of cooler. The temperature is recorded on the sample reception record along with any other observations during inspection. The shipment is given a unique Sample Reception # (S-____) for laboratory identification and the sample identification numbers are logged into a data management spreadsheet. The groundwater samples will be stored at 39°F (4°C) until required for column setup. There is no defined hold time for the groundwater as the water will be used for several weeks during the study. However, SiREM plans to start the column test within one week of receiving all of the materials for the study.

During column set-up and operation, precautions will be made to minimize exposure to the ambient air and cVOC losses during water handling, to the extent practicable. The influent groundwater bags will be covered (i.e., darkened) to avoid photodegradation of cVOCs over the course of the study.

Column Sampling Methods, Handling, and Custody

All samples collected from the column influent, effluent, and sampling ports will be collected using gas-tight Hamilton glass syringes. Syringes are cleaned with acidified water (pH ~2) and rinsed 10 times with deionized water between samples, to ensure that cross-contamination does not occur between different samples and sampling locations. For cVOC analyses performed by SiREM, the samples will be immediately acidified with hydrochloric acid to a pH of 2 to preserve and analyzed on the GC within 48 hours. Anion samples will be either analyzed immediately or frozen to preserve until time of analysis. If frozen, samples can be stored for up to one year. pH and ORP samples will be analyzed immediately after sample collection. Cations, total sulfides, TDS, and alkalinity samples will be collected at SiREM, but analyzed by an external analytical laboratory (TestAmerica). The samples will be collected and shipped on ice packs overnight to the laboratory. One duplicate sample for the analytes sampled at SiREM (cVOCs, anions, pH, and ORP) will be collected for every ten samples. Each sample will be

given a unique sample identification number (ID #) written on the sampling container and also recorded in the laboratory notebook.

SiREM Analytical Methods

SiREM uses custom methods for VOC/DHG and anion analysis. These methods were developed to use small sample volumes (up to 1 milliliter [mL]), as sample volumes are limited in laboratory studies. Standard United States Environmental Protection Agency (USEPA) methods for VOCs (e.g., EPA Method 8260B) typically require a minimum 40-mL sample volume, which is not practical for most laboratory studies. A small sample volume allows repetitive sampling from columns with Site-relevant flow rates. For this reason, SiREM does not employ the standard methods that typically require higher volume samples for analysis. The analytical methods employed by SiREM are described below.

SiREM VOC/DHG Analytical Method

SiREM quantifies cVOCs and DHGs using a gas chromatograph (GC) equipped with a flame ionization detector (FID). The analysis is performed on a Hewlett-Packard (Hewlett Packard 7890) GC equipped with an auto sampler (Hewlett Packard G1888) programmed to heat each sample vial to 75°C for 45 minutes prior to headspace injection into a GSQ Plot column (0.53 millimeters x 30 meters, J&W) and the FID. Sample vials are heated to ensure that all VOCs in the aqueous sample will partition into the headspace. The injector temperature is 200°C, and the detector temperature is 250°C. The oven temperature is programmed as follows: 35°C for 2 minutes, increased to 100°C at 50 degrees Celsius per minute (°C/min), then increased to 185°C at 25°C/minute and held at 185°C for 6.80 minutes. The carrier gas is helium at a flow rate of 11 milliliters per minute (mL/min).

After withdrawing a sample, the sample is injected into a 10-mL auto sampler vial containing 5.5 mL of acidified deionized water (pH ~2). The water is acidified to inhibit microbial activity between sampling and GC analysis. The vial is sealed with an inert Teflon®-coated septum and aluminum crimp cap for automated injection of 3 mL of headspace onto the GC. One VOC standard is analyzed with each set of samples to verify the instrument five-point calibration curve, and blanks are analyzed every 20 samples. Calibration is performed using external standard solutions (Sigma, St Louis, MO), where known volumes of standard solutions are added to acidified water in auto sampler vials and analyzed as described above for study samples. The calibration concentrations range from 10 micrograms per liter (µg/L) to 10,000 µg/L. Data are integrated using Chemstation Software (Agilent Technologies, Santa Clara, CA).

SiREM Anions Analytical Method

SiREM quantifies anions using an ion chromatograph (IC) with conductivity detector. The analysis is performed on a Dionex DX-600 IC equipped with a Dionex AS-40 auto sampler, 25-µL sample loop, AS18 column and conductivity detector. An isocratic separation is performed using 33 millimolar (mM) reagent grade sodium hydroxide (Fisher Scientific, Ottawa, ON) eluent for 13 minutes. One standard is analyzed with each set of samples tested in order to verify the seven-point calibration using external standards of known concentrations. External standards are prepared gravimetrically using chemicals of the highest purity available (Sigma, St Louis, MO, or Bioshop, Burlington, ON). The calibration concentrations range from 100 µg/L to 10,000 µg/L. Data are integrated using Peaknet Chromatography software (Dionex, Oakville, ON).

After withdrawing a sample from the column, the sample is immediately placed in a 1.5-mL micro-centrifuge tube. If it is not possible to analyze the samples immediately, the samples are stored frozen until time of analysis. The samples are centrifuged for five minutes at 13,000 revolutions per minute (rpm) to remove solids. The supernatant is removed, diluted 10-fold in deionized water, and placed in a Dionex auto sampler vial with a cap that filters the sample during automated injection onto the IC.

SiREM ORP/pH/TDS Analytical Method

Oxidation-reduction potential (ORP) will be determined using a combination Ag/AgCl reference electrode with a platinum button and a Corning 313 meter. An ORP standard (Thermo Electron Corporation) is used to verify that the electrode is reading accurately. Millivolt (mV) readings are converted to ORP, using the electrode reading and the standard potential of the Ag/AgCl electrode at a given temperature.

pH measurements will be made using a combination pH/reference electrode and an Oakton™ meter, standardized with the pH buffer 7 and the appropriate buffer of either 4 or 10.

TDS will be determined using a HACH Model 44600 conductivity meter. A salt standard is used to verify that the electrode is reading accurately. A 3.0-mL sample will be collected and analyzed immediately for ORP, pH, and TDS.

Quality Control

Quality control procedures are used to determine if analytical operations are working properly or if corrective actions are required. Calibration check standards, method blanks, and other quantifiable and qualitative indicators are monitored to evaluate the quality procedures. These measures are used to monitor the analytical program and to ensure that all data generated are suitable for their intended use.

Calibrations are performed in accordance with instrumentation-specific procedures and requirements. One check standard will be analyzed with each set of samples and percent recoveries will be recorded. Acceptable standard recoveries are +/- 20%. Method blanks are carried through the entire analytical procedure, and will be analyzed at a frequency of at least one method blank for every twenty samples. If peaks are detected in the method blanks above the method detection limit, the results for that run will be flagged, and the method blank data will be recorded in the data sheet. As discussed above, SiREM analytical methods are custom-designed for lab studies and as such, extensive quality control procedures associated with EPA Method 8260B are not routinely performed.

The reporting limits (RLs) are the lowest concentration standard in the calibration curve. The method detection limits (MDLs) have been set to be the same as the reporting limit as detailed MDL studies have not been performed for each compound. The RLs and MDLs for the compounds analyzed at SiREM for the study are listed in Table 1.

Table 1: SiREM Method Detection Limits (MDLs) and Reporting Limits (RLs)

Compound	MDL (µg/L)*	RL (µg/L)
Tetrachloroethene	10	10
Trichloroethene	10	10
cis-1,2-dichloroethene	10	10
trans-1,2-dichloroethene	10	10
1,1-dichloroethene	10	10
Vinyl chloride	10	10
Methane	50	50
Ethene	10	10
Ethane	10	10
Chloride	720	720
Nitrite-Nitrogen	120	120
Nitrate-Nitrogen	100	100
Sulfate	730	730
Phosphate	570	570
TDS	1,000	1,000

*Note the method detection limits have been set to be the same as the reporting limit. The reporting limit is the lowest concentration standard in the calibration curve.

Instrument/Equipment Testing, Inspection, and Maintenance

All instruments are visually inspected for damage prior to use. If damage is observed, corrective action is taken prior to instrument use. Testing and maintenance of equipment is performed in accordance with the specific instrument's maintenance manual.

Instrument/Equipment Calibration and Frequency

Instrument/equipment calibrations are performed in accordance with specific requirements to the particular instrumentation and procedures. GC and IC calibrations are conducted annually. One check standard will be analyzed with each set of samples, and percent recoveries will be recorded. pH meters are calibrated weekly with one standard being analyzed with each set of samples. For ORP, a known standard is tested with each set of samples to verify that the electrode is reading accurately (as per manufacturer's instructions). For TDS, a known salt solution is tested with each set of samples to verify that the instrument is reading accurately (as per manufacturer's instructions).

Inspection/Acceptance of Supplies and Consumables

The integrity of supplies and consumables are examined upon receipt. If acceptable, the products are logged into the supply management system and stored in the appropriate location in the laboratory. If deemed not acceptable, the products are returned to the supplier and new products are ordered. Prior to using a product, the technician will examine the product and check the shelf life (if applicable) and will not use the product if the product has expired or if the product is deemed not acceptable.

ATTACHMENT B
Injection Test Scope of Work

ATTACHMENT B: INJECTION TEST SCOPE OF WORK

Introduction

An injection test will be performed at the 401 National Avenue site to develop an injection approach for the site, including assessment of expected flow rates and pressures for the in-situ bioremediation pilot study implementation. The pilot study conceptual plan for injection of amendment includes the following components:

- Injection into coarse-grained intervals with elevated volatile organic compound (VOC) concentrations within the slurry wall using temporary injection points;
- Multiple depth-intervals, up to 5-feet thick, per injection location are anticipated. However, the number and thickness of injection depth intervals will be determined based on the lithologic and chemical information collected within the treatment area; and
- The design injection volume will be selected to be a large fraction of the calculated effective porosity of the treatment zone depending on, in part, the estimated capacity of the formation to accept the injection solution based on the results of the injection test.

This conceptual plan will be refined based on the results of the data collection effort, including the injection test. The methodology and field procedures that will be used in the injection test are described in the following sections.

Injection Test Methodology

Water will be injected into the same depth interval at multiple temporary locations simultaneously during the injection test. A direct push rig will be used to advance 1.5" outside diameter injection casing at each location to the desired injection zone. Municipal water will be distributed to each location via flexible tubing attached to an injection manifold instrumented to allow monitoring and adjustment of injection pressure and flow at each location during the test. The water will be injected into the desired injection zone through a 5-foot long injection screen at the bottom of the injection casing.

One of the injection points will be tested using a high resolution injection testing tool (HRIT) during injection. The HRIT is a direct push tool that has an integrated downhole pressure transducer and electrical conductivity sensors. While the tool is advanced through the subsurface, electrical conductivity (EC) readings are continuously collected, providing the operator with an indication of the type of lithology at a given depth. In a HRIT, the test fluid (water or an amendment) is pumped under pressure into the subsurface as a means of evaluating how the target interval will respond to fluid injection. Based upon the EC data, a target interval for injection testing is selected. Injection pressures will emulate those expected during injection of remediation compounds. Once injection commences, injection pressures and flow rates are continuously monitored (see Figure 1 below), and pressure and flow rate over time are measured for that target interval.

Field Procedures

Based on current site knowledge, the following scope of work is anticipated for the injection test:

- Injection tests points will be advanced using a direct push rig at four locations, one of which will be equipped with an HRIT.
- The injection points will be placed in a 30-foot square area to simulate the anticipated pilot test injection spacing.
- Injection points will be placed in proximity to a site monitoring well (e.g. 37A) to monitor the effects of injections on groundwater elevations.
- A minimum of one injection point will be placed within ten feet of the slurry wall.
- Injections will be performed at up to three coarse-grained zones (approximately 17 to 22 feet, 22 to 27 feet, and 32 to 37 feet below ground surface), starting with the shallowest zone.
- Water will be injected for a maximum of two hours per zone.
- Injection flow rates and pressures will be monitored continuously at the HRIT location and approximately every 5 minutes at the other three injection points.
- Injection flow rates will begin at 2 gallons per minute (gpm) and will be modified based on field observations.
- Injection pressures will not exceed 20 pounds per square inch (psi) at each injection point.

The actual injection point locations and depth intervals for the injection tests will be determined following MIP and direct-push sampling. While the exact total volume of water is dependent upon the amount of testing conducted, it is expected that less than 3,000 gallons will be used to complete all tests.

All field equipment will be removed from the injection points following injection and the boreholes will be backfilled with neat cement grout.

Boring:	HRIT5	Depth:	21 to 23

Company:		Date:	6/3/13
Project Name:		Start Time:	12:53:33
Project Address:		Stop Time:	13:13:20
		Total Gallons:	20.68

Notes:

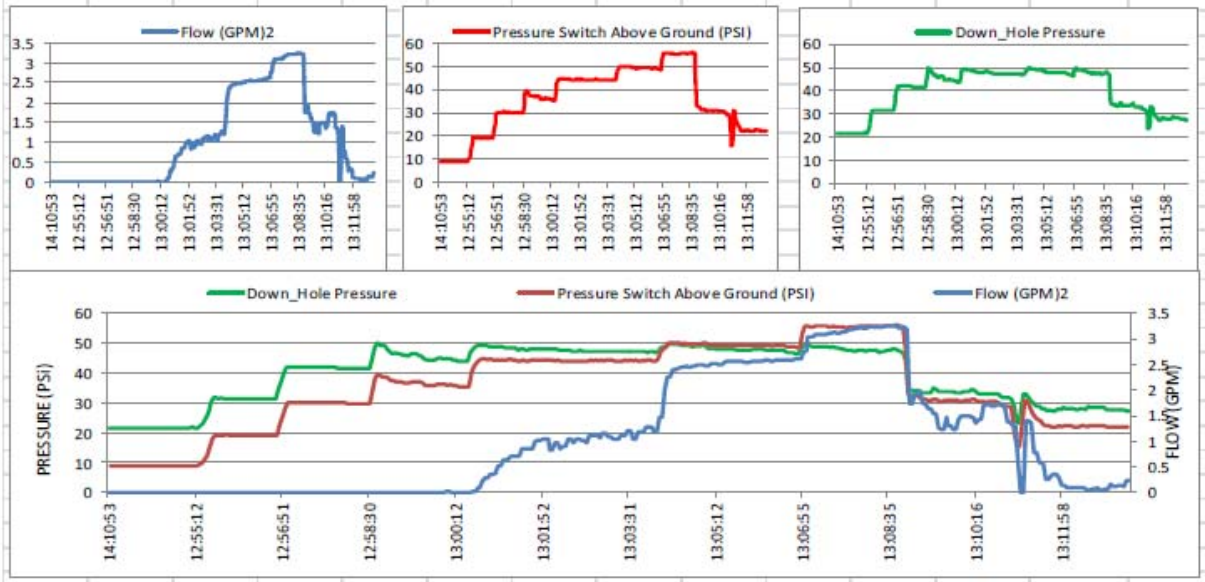


Figure 1 - HRIT Test Log from 21 to 23' BGS with 2' Injection Tool