Virgilio Cocianni
Remediation Manager

Schlumberger Technology Corporation
105 Industrial Boulevard
Sugar Land, Texas 77478
Tel: 281-285-4747
Fax: 281-285-7656

December 10, 2013

Penny Reddy
Groundwater Remediation Project Manager
Superfund Division SFD-7-3
EPA Region IX
75 Hawthorne Street
San Francisco, CA 94105

Subject: **Work Plan for In Situ Bioremediation Pilot Study: Phase 1**
401 National Avenue, Former Fairchild Building 9
Middlefield-Ellis-Whisman Area
Mountain View, California

Dear Ms. Reddy:

Enclosed with this letter is a work plan for phase 1 of an *in situ* bioremediation (ISB) pilot study at the former Fairchild Building 9, located at 401 National Avenue, Mountain View, California.

As indicated in the work plan, phase 1 of the ISB pilot study is scheduled to take place in February 2014, with project set-up and anoxic water preparation taking place the week of 3 February 2014, and injections beginning the week of 10 February 2014. We are therefore requesting approval of the work plan by 17 January 2014.

If you have any questions about the enclosed work plan, please feel free to contact me.

Very truly yours,

V. COCIANNI

Virgilio Cocianni
Remediation Manager

Attachment

CC: MEW Distribution List

Prepared for

Schlumberger Technology Corporation
105 Industrial Boulevard
Sugar Land, Texas 77478

WORK PLAN FOR IN SITU BIOREMEDIATION PILOT STUDY: PHASE 1

401 NATIONAL AVENUE
FORMER FAIRCHILD BUILDING 9
MIDDLEFIELD-ELLIS-WHISMAN AREA
MOUNTAIN VIEW, CALIFORNIA

Prepared by

Geosyntec consultants

engineers | scientists | innovators

1111 Broadway, 6th Floor
Oakland, California 94607

Project Number: WR1133A

10 December 2013

Work Plan for In Situ Bioremediation Pilot Study: Phase 1

401 National Avenue
Former Fairchild Building 9
Middlefield-Ellis-Whisman Area
Mountain View, California

Prepared by

Geosyntec Consultants, Inc.
1111 Broadway, 6th Floor
Oakland, California 94607

REGISTERED PROFESSIONAL ENGINEER
DEEPA H. GANDHI
No. C 67307
Exp. 9/30/14
CIVIL
STATE OF CALIFORNIA

Deepa Gandhi, P.E.
Senior Engineer

John D. Gallinatti, C.Hg.
Principal Hydrogeologist

Project Number: WR1133A
10 December 2013

TABLE OF CONTENTS

1. INTRODUCTION 1
   1.1 Background 1

2. SITE BACKGROUND 3
   2.1 Site Description and History 3
   2.2 Local Hydrogeology 4
   2.3 cVOCs in Groundwater Monitoring Wells 4

3. SEPTEMBER 2013 DATA COLLECTION RESULTS 5
   3.1 Hydrostratigraphy Inferred from Electrical Conductivity Results 5
   3.2 Vertical and Spatial Distribution of cVOCs based on MIP Profiles 6
   3.3 Hydropunch Sampling Results 7
   3.4 Injection Test Results 7
   3.5 Baseline Groundwater Sampling Results 8
   3.6 Implications of Data Collection Results for Phase 1 Activities 9

4. OBJECTIVES OF PHASE 1 WORK 11

5. OVERVIEW OF PHASE 1 COMPONENTS 12
   5.1 Selection of Amendment 12
   5.2 Amendment Dosing 13
   5.3 Bioaugmentation Approach 14
   5.4 Make-up Water Source for the Injection Solution 15
   5.5 Electron Donor Emplacement Methodology 16
   5.6 Performance Monitoring in Phase 1 Area 18
   5.7 Implementation Schedule 19

6. IMPLEMENTATION TASKS 20
   6.1 Pre-Field Activities 20
   6.2 Groundwater Extraction System 20
   6.3 Donor Amendment and Bioaugmentation 21
      6.3.1 Donor Material Handling and Mixing 21
      6.3.2 Anoxic Water Preparation 21
      6.3.3 ISB Borings and Injections 21

6.3.4 Surfacing and Preferential Pathways Monitoring 23
6.4 Phase 1 Performance Monitoring 23
6.4.1 Water Level Monitoring 23
6.4.2 Hydropunch Sampling 24
6.5 Investigation-Derived Waste (IDW) Management 24
6.6 Reporting 25

7. REFERENCES 26

LIST OF TABLES

Table 1: Hydropunch Groundwater Analytical Results: Detected cVOCs

Table 2: AE/RW-9-2 and 137A Groundwater Sample Results

Table 3: Field Parameter Results

Table 4: Phase 1 Performance Monitoring Parameters List

LIST OF FIGURES

Figure 1: Site Location Map

Figure 2: A-Zone TCE Concentrations in Groundwater – September/October 2012

Figure 3: Soil Conductivity and MIP Profiles

Figure 4: MIP/Hydropunch Results and Overview of Phase 1 Injections

Figure 5: Phase 1 Target Injection Intervals

LIST OF APPENDICES

Appendix A: A-Zone Chlorinated Ethenes in Groundwater

Appendix B: MSDS of Newman Zone® and Wilclear Plus

Appendix C: KB-1® Plus Specification Sheet

Appendix D: ESTCP Substrate Design Tool for Electron Donor Calculations

LIST OF ACRONYMS AND ABBREVIATIONS

AMEC	AMEC Environment and Infrastructure, Inc.
bgs	below ground surface
cDCE	cis-1,2-dichlorothene
cVOCs	chlorinated volatile organic compounds
Caltrans	California Department of Transportation
DNAPL	dense non-aqueous phase liquid
DO	dissolved oxygen
DP	direct-push
ECD	electron capture detector
EISB	enhanced in situ bioremediation
EPA	United States Environmental Protection Agency
ESD	Explanation of Significant Differences
ESTPC	Environmental Security Technology Certification Program
EVO	emulsified vegetable oil
Fairchild	Fairchild Semiconductor Corporation
FID	flame-ionization detector
FS	Feasibility Study
Geosyntec	Geosyntec Consultants, Inc.
gpm	gallons per minute
HASP	health and safety plan
HLA	Harding Lawson Associates
Hydropunch	Hydropunch™
IDW	investigation derived waste
ISB	in situ bioremediation

lbs	pounds
Locus	Locus Technologies
µg/L	micrograms per liter
MEW	Middlefield-Ellis-Whisman
MIP	membrane interface probe
mS/m	millisiemens per meter
MSDS	material safety data sheet
MSL	mean sea level
ORP	oxidation-reduction potential
PID	photo-ionization detector
PRB	permeable reactive barrier
psi	pounds per square inch
QA/QC	quality assurance/quality control
QAPP	quality assurance project plan
RI	Remedial Investigation
RNAS	Remediation and Natural Attenuation Systems, Inc.
ROD	Record of Decision
ROI	radius of influence
RWQCB	Regional Water Quality Control Board
Schlumberger	Schlumberger Technology Corporation
SCP	soil conductivity probe
Site	Former Fairchild Building 9 facility located at 401 National Avenue, Mountain View, California
Smith	Smith Technology Corporation
SVE	soil vapor extraction
TCE	trichloroethene
USA	Underground Services Alert

µV	microvolts
VC	vinyl chloride
vcrA	vinyl chloride reductase gene
XSD	halogen-specific detector
ZVI	zero valent iron

1. INTRODUCTION

This Work Plan (Work Plan), prepared on behalf of Schlumberger Technology Corporation (Schlumberger), describes the first phase of an *in situ* bioremediation (ISB) pilot study (Phase 1) for chlorinated volatile organic compounds (cVOC)[1] in groundwater at the former Fairchild Semiconductor Corporation (Fairchild) Building 9 facility located at 401 National Avenue[2] in Mountain View, California (Site, Figures 1 and 2). Geosyntec Consultants, Inc. (Geosyntec) has developed this Work Plan based on data available from previous characterization and remediation activities conducted at the Site since the mid-1980s and recent data collection field work conducted in September 2013.

The September 2013 field work successfully identified treatment areas for the ISB pilot study; however, data gaps remain beneath the existing building footprint. These data gaps will be addressed after demolition of the building as part of the Site redevelopment planned in 2014. The scope of work for the Phase 1 Work Plan covers pilot study activities that will be conducted prior to building demolition to address areas identified during the September 2013 data collection effort. A report documenting the findings of the September 2013 data collection effort and a Work Plan for the post-demolition activities (Phase 2) will be provided under separate covers. Limited discussion of these topics is included herein as needed.

Schlumberger would like to implement the Phase 1 work as soon as possible. Therefore, Schlumberger is requesting expedited review of this Work Plan to enable field implementation beginning in February of 2014.

1.1 Background

The Site is located within the Middlefield-Ellis-Whisman (MEW) Study Area. The groundwater remedy currently operating at the Site (groundwater extraction and treatment and slurry walls) was specified in the 1989 Record of Decision (ROD) for the MEW Study Area and two subsequent Explanations of Significant Differences (ESDs).

---

[1] Primarily trichloroethene (TCE) and its breakdown products (cis-1,2-dichloroethene [cDCE] and vinyl chloride [VC]).

[2] As part of redevelopment, 401 National Avenue and the properties located to the immediate north (620 through 640 National Avenue) have been consolidated into a single address: 600 National Avenue.

An optimization evaluation of the current remedy was conducted in response to a recommendation by United States Environmental Protection Agency (EPA) in its First Five-Year Review for the MEW Study Area (EPA, 2004), and a request from EPA in its 5 June 2008 letter, which required that an optimization evaluation be conducted prior to a potential site-wide feasibility study. As required, the optimization evaluation for the Fairchild sites was submitted on 3 September 2008.

The 2008 optimization evaluation for the Fairchild sites (Geosyntec, et al., 2008) included a recommendation to consider alternative technologies for groundwater treatment, which would enhance the individual site remedies. In 2013, EPA directed Schlumberger to increase mass removal for the existing remedies, pilot testing alternative technologies as needed. The former Building 9 was given a high priority among the Fairchild sites because of the planned redevelopment.

Between 28 August and 27 September 2013, fieldwork was performed to collect data to support the pilot study design in accordance with Geosyntec's 13 August 2013 *Work Plan for Pilot Study Data Collection* (Geosyntec, 2013a). The Data Collection Work Plan was approved by EPA on 20 September 2013, after receipt of and response to EPA comments (EPA, 2013; Geosyntec, 2013b).

The Phase 1 ISB injection program described in this work plan is a component of a larger pilot study to evaluate alternative technologies at the Site. Although a work plan for the full pilot study scope has not yet been submitted to EPA, a preliminary scope for the pilot study was presented to EPA in a meeting on 2 July 2013 and includes:

- Targeted ISB injections in the areas containing relatively high cVOC concentrations, to be implemented in a phased approach before and after building demolition for the redevelopment;
- Breaching of the existing Site slurry wall, 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; and,
- Shut down and decommissioning of the existing groundwater extraction wells.

2. SITE BACKGROUND

2.1 Site Description and History

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 MEW Study Area (HLA, 1987; Canonie, 1988), 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.

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;
- 1995: 3,000 cubic yards of soil were excavated to a depth of 6 feet below ground surface (bgs) and aerated at the Site (Smith, 1995; EPA, 2004); 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).

In 2013, the 401 National Avenue property was purchased by National Avenue Partners, LLC 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 current 401 National Avenue property.

2.2 Local Hydrogeology

As discussed in the Data Collection Work Plan (Geosyntec, 2013a), 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 14 and 40 feet bgs. Two zones of coarse-grained material are present within the planned pilot study area: the shallower coarse-grained zone is generally encountered between 17 and 23 feet bgs and the deeper coarse-grained zone is generally encountered between 32 and 37 feet bgs.

Under pumping conditions, the potentiometric surface of the A-zone at the Site generally occurs under confined conditions at approximately 18 feet bgs and 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, 2013c). When extraction wells are not operating, groundwater elevations within the slurry wall can be more than four feet higher compared to pumping conditions. Inward horizontal gradients are observed along most of the slurry wall, with the periodic exception of some locations along the northern sections (Geosyntec, et al., 2008).

2.3 cVOCs in Groundwater Monitoring Wells

TCE concentrations in groundwater from Site monitoring wells are shown on Figure 2 for wells sampled in 2012. cVOC concentrations (TCE, cDCE, and VC) versus time graphs for select A-zone monitoring wells are included as Appendix A. Over the last 5 years (2007 to 2012), the maximum concentration of TCE detected in Site groundwater monitoring wells was 8,300 micrograms per liter (µg/L), measured in AE/RW-9-2 in 2011 (Geosyntec, 2013c).

3. SEPTEMBER 2013 DATA COLLECTION RESULTS

The September 2013 data collection field work included the following tasks related to the ISB injection program design:

- Thirteen borings were advanced with a direct-push (DP) drill rig equipped with the soil conductivity probe (SCP) and the membrane interface probe (MIP) to provide supplemental high resolution information on the lithology of Site soils and the distribution of cVOCs in the subsurface. MIP detectors deployed during the field work included the electron capture detector (ECD), the photo-ionization detector (PID), the flame-ionization detector (FID), and the halogen-specific detector (XSD);
- Ten DP Hydropunch™ (Hydropunch) borings were advanced to collect grab groundwater samples for comparison with the MIP logs;
- Two DP continuous core soil borings were advanced to supplement the hydrostratigraphic information provided by the SCP profiles;
- Groundwater samples were collected from two wells, AE/RW-9-2 and 137A, to evaluate baseline conditions for the pilot study; and
- An injection test was performed at four depth intervals to assess achievable injection rates and pressures in preparation for ISB field work.

A report summarizing the field procedures and findings of the data collection field work will be submitted to EPA under a separate cover. The sections below summarize the results of the data collection fieldwork as they relate to the Phase 1 design.

3.1 Hydrostratigraphy Inferred from Electrical Conductivity Results

Electrical conductivity, a physical property of the soil matrix, is primarily controlled by the clay mineral percentage and water content. Soils with relatively high clay mineral percentage (i.e., finer-grained soils) are generally more electrically conductive than soils with low clay mineral percentage (i.e., coarse-grained soils). The plot labeled "Conductivity" on Figure 3 presents an overlay of soil conductivity profiles from the 13 borings. As shown in Figure 3, profiles were comparable across the 13 borings that

were advanced,[3] indicating two depth-intervals of relatively low SCP response (approximately 10 – 50 millisiemens per meter [mS/m]) at approximately 17 to 23 feet bgs and 32 to 37 feet bgs, separated by a depth interval of higher SCP response (approximately 50 – 125 mS/m). The areas of low SCP response recorded in the 13 MIP borings are generally consistent with coarse-grained soils observed in historical borings (Data Collection Work Plan, Figure 3) and in the two continuous core soil borings advanced during data collection activities.

3.2 Vertical and Spatial Distribution of cVOCs based on MIP Profiles

Response profiles for the ECD, PID, and XSD are plotted on Figure 3[4]. Each plot includes an overlay of the 13 MIP boring profiles.

The highest ECD, PID, and XSD responses were generally observed between 17 and 26 feet bgs[5]. High ECD responses were also observed between 32 and 36 feet bgs, with limited or no response for the other detectors. The zones of high detector response generally correspond with the coarse-grained intervals identified by the SCP. For the shallower coarse-grained interval (17 to 23 feet bgs), the highest detector response was observed just above and continued, to a limited extent, into the adjacent zone of fine-grained materials.

A summary of the highest response locations at the Site was developed by summing the PID detector responses (recorded every 0.05 feet during MIP advancement) at each MIP boring over the saturated zone, which is approximately 14 to 40 feet bgs under non-pumping conditions. The summed PID responses are displayed on Figure 4, represented by colored halos around each MIP location symbol. Larger halos with darker coloring correspond to larger values of summed PID response, whereas smaller halos and lighter coloring correspond to lower values of summed PID response. As

[3] The largest discrepancy in conductivity profiles is observed in the log for MIP-07. Data for MIP-07 is approximate due to a computer failure at 20 feet bgs. It is likely that no data was collected between 20 and 22 feet bgs.
[4] FID responses were limited and are not included on Figure 3.
[5] The ECD was the most responsive detector and reached its maximum value of 1.4×10^7 microvolts (uV) at most borings. In general, the PID and XSD responses were similar to each other but less responsive than the ECD, tending to respond only when the ECD response was sustained at the maximum value over a given depth interval.

shown on Figure 4, the highest detector responses are in the vicinity of MIP-2 and MIP-9/MIP-12.

3.3 Hydropunch Sampling Results

Groundwater sample results for the 10 Hydropunch samples collected to supplement MIP results are listed in Table 1. TCE and total VOC concentrations measured in the samples are also shown on Figure 4.

TCE concentrations in the Hydropunch samples ranged from 100 to 560,000 µg/L. Freon 113 was also detected at concentrations up to 7,000 µg/L, with the highest concentrations in samples collected from MIP-2 and MIP-12. Total VOCs concentrations ranged from 2,500 to 630,000 µg/L. The distribution of summed PID responses shown on Figure 4 correlates well with the distribution of groundwater cVOC concentrations detected in the Hydropunch samples, suggesting that the areas around MIP-2 and MIP-9/MIP-12 have the highest mass and also the highest concentrations of residual cVOCs in the investigation area.

Hydropunch samples collected in the 16- to 26-foot depth interval, where the highest MIP detector responses were observed, contained TCE and total VOC concentrations ranging from 2,100 to 560,000 µg/L and 2,500 to 630,000 µg/L, respectively (Figure 4). TCE and total VOC concentrations appear to increase with depth along this interval as indicated by sample results from MIP-12, where TCE concentrations at 18 to 22 feet bgs were two orders of magnitude lower than TCE concentrations measured at 22 to 26 feet bgs. TCE and total VOC concentrations measured in Hydropunch samples collected from the 32 to 36 foot depth interval were significantly lower than VOC concentrations in the shallow coarse grained interval, ranging from 100 to 1,200 µg/L and 3,200 to 5,600 µg/L, respectively. Total VOC values predominantly consist of TCE and cDCE, with other VOC concentrations one to two orders of magnitude lower in value (Table 1).

3.4 Injection Test Results

Injection rate tests using municipal water were conducted to facilitate the development of location-specific estimates for the achievable injection rates and pressures within the pilot study area. Extraction wells AE/RW-9-2 and RW-20A were shut down and wells AE/RW-9-1 and RW-21A were turned on during the injection tests. The injection tests were performed using DP technology at a location approximately 2 feet east of MIP-7

and approximately 11 feet west of the slurry wall (Figure 4). The tests were conducted at four depth intervals (20 to 22 feet bgs, 23 to 25 feet bgs, 26.5 to 28.5 feet bgs, and 33.5 to 35.5 feet bgs) and targeted a range of coarse- to fine-grained soils. Intervals with relatively high MIP detector response were selected for injection testing, as these intervals were under consideration for ISB injections. Once each of the target injection test intervals was reached, a step pressure test was performed to evaluate achievable injection flow rates and pressures.

The findings of the injection test include the following:

- Above-ground injection pressures required for flow varied between 19 and 30 pounds per square inch (psi), which correspond to pressures between 17 and 22 psi above the hydrostatic pressure between the water table and the injection depth;
- At the depth interval between 23 to 25 feet bgs, no flow was observed at aboveground injection pressure of up to 30 psi, and attempts were not made to induce flow using higher pressures;
- A stable injection rate of 2 gallons per minute (gpm) was achieved at the other three depth intervals at aboveground injection pressures between 20 and 30 psi; and,
- At two depth intervals (20 to 22 feet bgs and 26.5 to 28.5 feet bgs) it was possible to achieve stable higher injection rates (2.7 and 2.3 gpm, respectively) at aboveground injection pressures below 22 psi.

3.5 Baseline Groundwater Sampling Results

Baseline geochemical conditions were assessed at the Site by collecting groundwater samples from two wells located inside the proposed treatment area (137A and AE/RW-9A-2) and measuring field parameters in five wells located inside the slurry wall (35A, 137A, AE/RW-9A-2, RW-20A, and RW-21A). The results from this baseline geochemical conditions assessment are tabulated in Table 2 and Table 3. Review of these results indicates the following:

- cVOC concentrations measured in both wells were consistent with cVOC concentrations measured during the 2012 annual groundwater sampling event (Table 2 and Figure 2, Geosyntec, 2013c);

- With the exception of sulfate, competing electron acceptors are present at relatively low levels, and it is expected that replenishment of these compounds will be limited as long as confined flux conditions within the slurry wall are maintained;
- Field parameter measurements suggest favorable reducing conditions with relatively neutral pH, and low dissolved oxygen (DO) and oxidation-reduction potential (ORP);
- Microbial analysis showed that there is limited presence of cVOC-reducing bacteria (*Dehalococcoides)* and that the specific gene associated with TCE dechlorination to ethene (vinyl chloride reductase gene; [vcrA]) was not detected at wells AE/RW-9-2 and 137A; and,
- A low detection of ethene was measured at AE/RW-9-2, which suggests that some reductive dechlorination is already occurring at the Site.

3.6 Implications of Data Collection Results for Phase 1 Activities

The findings of the data collection results together with the Site historical information imply the following for the Phase 1 activities:

- Aquifer geochemistry is favorable for reductive dechlorination; however, bioaugmentation would likely reduce the time required to initiate reductive dechlorination reactions;
- Injection flow rates of approximately 2 gpm can be achieved at low pressures for most depth intervals (15 to 25 psi above hydrostatic pressure);
- The cVOC mass remaining within the investigation area inferred from MIP profiles is located to the greatest extent in two relatively limited areas in the vicinity of MIP-2 and MIP-9/MIP-12. The vertical extent is also constrained to just above and continues, to a limited extent, into the relatively fine-grained material below the 17 to 23 feet bgs coarse-grained depth interval. Hydropunch groundwater samples from these two locations of high MIP response contain total VOC concentrations above 100,000 µg/L. Phase 1 activities will be focused in these areas.
- Much lower MIP detector responses and cVOC concentrations were observed in the remainder of the investigation area, generally limited in extent to coarse-

grained intervals between approximately 17 to 23 feet bgs and 32 to 37 feet bgs. These zones will be addressed as part of the Phase 2 work.

4. OBJECTIVES OF PHASE 1 WORK

The Phase 1 work will address areas outside the existing building footprint where the highest cVOC mass and concentrations were identified during the September 2013 data collection field work. The objectives of Phase 1 of the ISB program include:

- Early treatment of high concentration areas prior to building demolition; and
- Collection of design information on the effectiveness of the Phase 1 injections in stimulating conditions favorable for ISB prior to implementation of Phase 2 of the ISB program.

5. OVERVIEW OF PHASE 1 COMPONENTS

The sections below provide an overview of the Phase 1 ISB program, including:

- Selection of amendment;
- Amendment dosing;
- Bioaugmentation approach;
- Make-up water source;
- Electron donor emplacement methodology;
- Performance monitoring program; and,
- Schedule.

5.1 Selection of Amendment

A variety of electron donors have been shown to stimulate bioremediation via the reductive dechlorination pathway and are commonly used for ISB implementation. The ultimate electron donor used in the reductive dechlorination reaction is hydrogen, which becomes available through the fermentation of electron donor under anaerobic conditions. Electron donors can be grouped into two general categories: soluble and non-soluble.

Soluble electron donors (e.g. dissolved sugars, acids, alcohols) are miscible in groundwater and are typically used in conjunction with groundwater circulation and/or short duration pulsed injections delivery methods to distribute the donor within a treatment zone. Soluble donors can reduce the timeframe required to create conditions favorable for reductive dechlorination compared to non-soluble donors, which is desirable for the Site. However, soluble donors are typically depleted relatively quickly compared to non-soluble donors.

Non-soluble electron donors are immiscible carbon-based compounds such as emulsified vegetable oil (soybean or canola oil) and are typically used in trenched barriers and/or one-time injections. Non-soluble donors can persist in the subsurface longer after injection than soluble donors, and are therefore more appropriate for the Site, given the lack of access for subsequent injections after redevelopment.

Because of the needs for rapid establishment of anaerobic conditions favorable to bacterial growth and a long-lasting electron donor, a mixture of soluble (fast-release electron donor) and non-soluble (slow-release electron donor) was chosen for the Site, such that 15% of the hydrogen produced will be provided by the fast-release donor. This ratio of donors was selected to allow for rapid establishment of anaerobic conditions via the fast-release donor, but also limit the potential for methane generation, thereby maximizing the amount of electron donor that is directed to promote reductive dechlorination. Most of the injected amendment will be in the form of the slow-release electron donor, which slowly produces low levels of hydrogen, allowing the bacteria responsible for reductive dechlorination to out-compete the bacteria responsible for methane generation (Yang and McCarty, 1998). Emulsified vegetable oil (EVO) and sodium lactate were selected as slow and fast-release electron donors, respectively.

Vegetable oil is a non-aqueous phase liquid (NAPL) that will slowly dissolve into the groundwater, thereby making it a slow-release carbon source. Because the fermentation of vegetable oil occurs slowly, it is able to provide electron donor for an extended period of time. In EVO, the vegetable oil is emulsified to form very small droplets in order to avoid permeability loss in the subsurface and optimize distribution of electron donor. Newman Zone® EVO from Remediation and Natural Attenuation Systems, Inc. (RNAS) was selected as the slow release electron donor for Phase 1. Newman Zone® consists of a mixture of 46% soybean oil by weight, 4% sodium lactate by weight, and food-grade stabilizing agents (material safety data sheet [MSDS] included in Appendix B).

Sodium lactate is a soluble substrate that will rapidly achieve reducing conditions in the treatment area. Once the lactate is injected, indigenous microorganisms will ferment it to lower molecular weight organic acids. Hydrogen becomes available through the subsequent fermentation of these lower molecular weight organic acids. Wilclear Plus® from JRW Bioremediation, LLC, consisting of a food-grade 60% sodium lactate solution, was selected as the fast release electron donor for Phase 1 (MSDS included in Appendix B).

5.2 Amendment Dosing

Amendment dosing for the higher and lower concentration depth intervals were selected based on professional judgment and experience at other sites with similar conditions. Doses were selected under the constraints of maximizing the amount of donor delivered to the subsurface during the Phase 1 injections while mitigating the generation of

methane to the extent practical. The dosing for the higher and lower concentration depth intervals are summarized below:

- For the higher concentration depth intervals, a dosing corresponding to 2.3% EVO (by weight) and 1% sodium lactate (by weight), was selected. This corresponds to hydrogen production of approximately 230 lbs per 10,000 gallons of injected solution; and,
- For other depth intervals, a dosing corresponding to 0.9% EVO (by weight) and 0.4% sodium lactate (by weight), was selected. This corresponds to hydrogen production of 90 lbs per 10,000 gallons of injected solution.

The selected doses were compared to the estimated amount of electron donor (hydrogen) required to meet Site-specific electron acceptor demand using the Substrate Design Tool (ESTCP, 2010). Results of the comparison are included in Appendix D. As shown in Appendix D, the selected doses greatly exceed the estimates of required electron donor demand, and as a result, the progress of the ISB pilot study is not expected to be limited by the availability of electron donor.

5.3 Bioaugmentation Approach

As discussed in Section 3.5, microbial analysis performed on Site groundwater as part of the data collection field work showed that there is limited presence of cVOC-reducing bacteria (*Dehalococcoides)* and that, while ethene was present at low concentrations, the specific gene associated with TCE dechlorination to ethene (vcrA) was not detected at wells AE/RW-9-2 and 137A. Therefore, bioaugmentation via the injection of KB-1® Plus, is recommended for Phase 1.

The KB-1® Plus consortia is a custom-blended microbial culture formulation provided by SiREM (specification sheet provided in Appendix C) that is capable of degrading a wide range of contaminants. KB-1® Plus contains bacteria of the *Dehalococcoides* genera capable of reductively dechlorinating TCE and cDCE, as well as organisms containing vcrA, which is required for conversion of vinyl chloride to ethene. KB-1® Plus also contains other microbial populations (including *Dehalobacter*), capable of

reducing compounds such as chlorinated ethanes and Freon 113, which have been detected at the Site (Section 3.2).[6]

Bioaugmentation and electron donor addition will be performed in one mobilization, with the injected donor solution being used to distribute the KB-1® Plus throughout the formation. KB-1® Plus requires an anaerobic environment for its survival. To limit the exposure of the anaerobic KB-1® Plus culture to oxygen and ensure that suitable conditions for bacterial growth are present in the subsurface, anoxic water amended with the electron donor will be the "make-up water" for the injection of KB-1® Plus. The electron donor/KB1®plus injections will be performed in a "doughnut" approach, so that the anoxic water is injected directly before and directly after the KB-1® Plus injections, effectively cushioning the KB-1® Plus with an anaerobic environment. A minimum of 20% of the injected solution will consist of the anoxic make-up water, with the remainder of the injected volume consisting of donor solution mixed with municipal water.

5.4 Make-up Water Source for the Injection Solution

As described in Section 4.3, anoxic water will be used as make-up water for the injection of KB-1® Plus. Anoxic conditions can develop in water where bacteria and electron donor are present. The time to create anoxic conditions depends on the initial redox state of the makeup water, with water that is initially aerobic and/or contains a limited microbial community requiring the most preparation for use in the injection program. Therefore, municipal water from a hydrant is not a desirable source of water for the production of anoxic conditions, and would require both reduction of oxygen and microbial inoculation.

The ideal source of makeup water is groundwater from the Site, which has low DO/ORP and relatively abundant bacteria. Groundwater is currently being extracted from four wells on-site (AE/RW-9-1, AE/RW-9-2, RW-20A, and RW-21A) as part of the Site remedy (Section 2.1). The effluent from these wells would meet the desired

[6] For this site, SiREM's chlorofluorocarbon (CFC) culture, from SiREM's KB-1® Plus line of cultures will be used. SiREM's CFC culture was enriched from a CFC/TCE contaminated site located in the south eastern US. The culture has demonstrated degradation of up to 20 mg/L Freon-113 in combination with TCE.

criteria for makeup water.[7] For preparation of anoxic water, effluent from the Site extraction wells will be diverted to an on-site storage tank until a sufficient volume of groundwater is extracted. Electron donor in the form of sodium lactate will be added to the tank to eliminate any residual oxygen. Once the oxygen is removed, the bioaugmentation culture KB-1® Plus will be added to the tank to reduce remaining cVOCs in the water.[8] Although complete treatment of cVOCs is not expected using this approach, resulting concentrations of cVOCs in the injection makeup water will likely be one to three orders of magnitude lower than groundwater concentrations in the treatment area.

5.5 Electron Donor Emplacement Methodology

As shown on Figure 4, the Phase 1 ISB injections will be performed at eight injection points, with four injection points in the MIP-9/MIP-12 area, and four injection points in MIP-2 area. The proposed injection locations are centered on the highest detected cVOC concentrations and were selected based on constraints on the available work locations (e.g., subsurface utility corridors and concrete slabs of unknown thickness). The injection point spacing is approximately 17 to 18 feet on center (Figure 4), with some variation due to constraints on available work locations. The target radius of influence (ROI) for the injections is approximately 10 feet, which would result in a 10 to 33 percent overlap between the injection points, depending on the effective injection interval.

Injection will be performed at three different 5-foot depth intervals (shallow: 16 to 21 feet bgs, middle: 21 to 26 feet bgs, and deep: 32 to 37 feet bgs) where SCP data indicate the presence of relatively coarse-grained aquifer materials and the MIP data indicate the presence of cVOCs (Figure 3 and Figure 5). The middle injection interval corresponds to the depths where MIP and Hydropunch sample data indicate the highest mass/concentrations of cVOCs (Figure 4). The top (16 to 21 feet bgs) and bottom (32

[7] Because the unit processes for the 401 National Avenue system includes ultraviolet treatment and air stripping, effluent water from the system would require removal of oxygen and microbial inoculation for use as injection makeup water, similar to hydrant water.

[8] TCE and total VOCs concentrations measured in groundwater samples collected from Site extraction wells located outside of the Phase 1 injection area during 2012 ranged from 420 to 770 µg/L and 820 to 1,600 µg/L, respectively (Geosyntec 2013c).

to 37 feet bgs) injection intervals are located in zones with relatively lower cVOC mass/concentrations.

Injection water will be pre-mixed with EVO and sodium lactate (donor solution) or dosed using an above ground amendment system, depending on the equipment provided by the licensed subcontractor. The dose of the donor solution that will be applied is depth dependent, with a higher dosing proposed for the middle depth interval corresponding to 2.3% EVO (by weight) and 1% sodium lactate (by weight). A lower dosing, corresponding to 0.9% EVO (by weight) and 0.4% sodium lactate (by weight) will be used for the shallow and deep injection intervals.

Assuming a total porosity of 25% and a 5-foot injection interval, a conservative estimate of the total pore volume at each injection point is 2,900 gallons given the target ROI of 10 feet. Because of the non-uniform distribution of coarse-grained material observed in the subsurface based on the SCP responses (Section 3.1), it is anticipated that the effective injection intervals will more likely be between 3 and 5 feet for the shallow and deep intervals and between 2 and 4 feet in the middle interval.

The effective porosity at the Site is assumed to be between 10 and 20%, accounting for small-scale heterogeneities. Therefore, the effective pore volume for each injection interval given the target ROI and anticipated effective injection interval is between 700 and 2,400 gallons for the shallow and deep intervals and between 500 and 1,900 gallons for the middle interval. Based on this information, the design target volume of injected solution is approximately 1,500 gallons per depth interval at each injection point (60 to 300% of the effective pore volume, depending on the assumptions described above). This equates to a total injection volume of approximately 35,000 gallons in the Phase 1 area.

At the low end of the estimated range of effective porosity and effective injection interval, the total effective pore volume over the three target intervals is calculated to be approximately 15,000 gallons. Although preparatory activities and material procurement will assume an injection volume of 35,000 gallons, if conditions in the field during implementation indicate that the lower range of the effective pore volume

estimate is more representative of field conditions, the donor target injection volume may be adjusted.[9]

KB-1® Plus will be injected a minimum of 3 times in each depth interval in order to ensure a good initial distribution of the bacterial culture in the subsurface. KB-1® Plus will be applied at a typical ratio of 1 liter per 9,200 gallons of pore volume in the shallow and deep intervals, and at a higher ratio of 3.5 liters per 9,200 gallons in the middle depth interval. A total of approximately 7 liters (1.8 gallons) of KB-1® Plus will be injected for Phase 1.

5.6 Performance Monitoring in Phase 1 Area

Performance monitoring for Phase 1 will involve a combination of water level and injection pressure monitoring during injection and Hydropunch groundwater sampling at two locations in the MIP-2 and MIP-12/MIP-9 areas as part of the Phase 2 activities (three to six months after injection). Monitoring while injections are in progress will provide information on the ROI of the injections. Water level monitoring will involve the installation of pressure transducers in three A-zone wells located within the slurry wall (37A, 137A, and AE/RW-9-2) to collect real-time data on groundwater elevation changes inside the slurry wall, supplemented with the collection of manual water level measurements in Site wells adjacent to the MIP-2 and MIP-9/MIP-12 areas (36A, 37A, 39A, 41A, 137A, 69B1, and AE/RW-9-2).

The two proposed Hydropunch groundwater sampling locations are shown on Figure 4. Hydropunch samples will be collected at the three injection depth-intervals (16 to 21, 21 to 26, and 32 to 37 feet bgs) to assess the progress of ISB within the treatment zone, including the distribution of electron donor and bioaugmentation culture (i.e., ROI), and redox conditions. Depending on the timing of the monitoring event, reductive dechlorination processes may not be sufficiently advanced to determine the overall response of cVOC concentrations to injections; however, preliminary data will be obtained. The list of monitoring parameters and the rationale for selection is provided in Table 4.

[9] EPA will be notified if there is a need to revise the donor target injection volume.

Geochemical parameters, such as dissolved iron, sulfate, and dissolved methane will be measured to assess the development of anaerobic conditions favorable to reductive dechlorination in the treatment zone. Redox conditions between sulfate reducing and methanogenic are favorable for reductive dechlorination (Stroo et al., 2010); however, high dissolved methane concentrations are not desired at the Site. The electron donor dosing recommended for Phase 1 is designed to minimize the processes that lead to methane production (methanogenesis) and favor the use of the injected electron donor by the dechlorination culture rather than competing methanogenic microbes (Section 5.2). The results of the Phase 1 monitoring will be used to modify the injection approach for Phase 2.

5.7 Implementation Schedule

Phase 1 is scheduled to take place in February 2014, with project set-up and anoxic water preparation taking place the week of 3 February 2014, and injections beginning the week of 10 February 2014, pending EPA approval of this work plan. Hydropunch sampling associated with initial Phase 1 performance monitoring will take place following building demolition, in conjunction with Phase 2 data collection activities. The timing of the performance monitoring will depend on the redevelopment schedule, but is anticipated to occur up to six months after injections. The long-term performance monitoring program for the pilot study (including the ISB program) will be described in subsequent work plans.

6. IMPLEMENTATION TASKS

Details regarding the methods and procedures that will be used for implementation of Phase 1 are provided in the sections below.

6.1 Pre-Field Activities

Before implementing fieldwork, Geosyntec will perform the following:

1. Assist Schlumberger in coordinating Site access with the property owner for the implementation of Phase 1;
2. Update the Site-specific health and safety plan (HASP);
3. Notify Underground Services Alert (USA) in advance of subsurface work in accordance with California law;
4. Coordinate and subcontract with the drilling contractor and laboratory;
5. Obtain concurrence from the San Francisco Bay Area Regional Water Quality Control Board (RWQCB) for the use of untreated water in the injection program;
6. Procure equipment and materials, including electron donor, bioaugmentation culture, and make-up water storage tanks; and,
7. Install transducers in three nearby monitoring/extraction wells to monitor the vertical and horizontal radius of influence of the injection test.

All field activities will be performed in accordance with the Site-specific HASP. A safety tailgate meeting will be held each day prior to the start of field activities and all on-site field personnel will sign the HASP acknowledging the discussion of potential hazards.

6.2 Groundwater Extraction System

At least three days prior to the ISB injections, extraction well AE/RW-9-2 will be turned off to reduce groundwater extraction adjacent to the injection areas, and limit the potential for the injected amendment to interact with the treatment system. AE/RW-9-1, RW-20A, and RW-21A will remain on at a reduced flow rate to minimize groundwater mounding within the slurry wall during injections.

6.3 Donor Amendment and Bioaugmentation

6.3.1 Donor Material Handling and Mixing

The Newman Zone® and Wilclear amendments will be delivered to the Site in 255 gallon totes or 55 gallon drums and stored in a materials staging area. The two solutions will be pre-mixed with injection water or dosed in the injection line using an aboveground dosing system to achieve the ratios discussed in Section 4.5.

6.3.2 Anoxic Water Preparation

A minimum of five days prior to use for injection, extracted groundwater will be temporarily diverted to an on-site storage tank, and made anoxic through the addition of sodium lactate. A field instrument capable of measuring DO, pH, and ORP, will be used to collect field geochemical parameter measurements prior to the addition of sodium lactate, and to confirm anoxic conditions before injections begin. After anoxic conditions have developed, 0.5 liters of the bioaugmentation culture KB-1® Plus will be added to each tank to reduce remaining cVOCs in the water (a minimum of two days before water is used for injection).

6.3.3 ISB Borings and Injections

Temporary borings for injections will be advanced by a C-57 licensed drilling contractor using DP technology. Prior to advancement of the direct-push rods, each borehole will be cleared for utilities to five feet bgs using hand driven auger. All down-hole equipment will be decontaminated prior to use.

At each of the eight injection locations, hollow steel direct-push rods will be first advanced to the shallow target injection interval. Injection solution will be emplaced in that depth interval concurrently at each of the eight locations. After the shallow interval is complete, the rods will be advanced to the next interval (top-down approach) and the process will be repeated until injections have been completed in all three target intervals (16 to 21 feet bgs, 21 to 26 feet bgs, and 32 to 37 feet bgs).

The injection event is anticipated to occur over five days, with one and one-half days of injection at each depth interval (approximately 1,500 gallons injected per location at an average flow rate of 2 gpm per point per interval). The primary injection line will be equipped with a mechanical flow totalizer, flow meter, pressure gauge, and flow control

valve to monitor the injection volume, rate, and pressure. Each injection point will be monitored with a flow meter, flow regulator, and pressure gauge. Prior to starting injections, the injection lines will be inspected for signs of damage or leaks, and connections will be checked.

Donor amendment will be performed by a licensed subcontractor under the supervision of Geosyntec personnel. Municipal water from a nearby hydrant, or anoxic water from an above ground storage tank will be pumped through flexible hosing, amended with the donor solution as discussed in Section 5.3.1, and injected into the target injection intervals. Bioaugmentation will be performed by adding KB-1® Plus to each injection point in 0.18 liter to 0.06 liter batches depending on the target depth interval (a larger amount will be added to the middle interval). It is anticipated that the KB-1® Plus will be added approximately three times at each depth interval to encourage even distribution of the amendment into the formation. The KB-1® Plus and donor injections will be performed using the following approach (doughnut approach):

- Donor solution mixed with municipal water
- Donor solution with anoxic make-up water
- KB1®plus
- Donor solution with anoxic make-up water
- Donor solution mixed with municipal water.

Design injection volumes are described in Section 5.4. During each injection, the rate and pressure will be slowly increased from conservatively low values at the start of injections to the design injection rate (2 gpm). The donor delivery rate and target injection volume may be adjusted during implementation based on observed field conditions.[10] The maximum operational pressure based on the results of the injection rate test (Section 3.4) will be 50 psi (aboveground pressure).

During injection, flow rates, injection pressures, and injection volumes will be recorded in the field documentation.

---

[10] EPA will be notified if there is a need to revise the donor delivery rate or target injection volume.

In order to limit the number of boreholes advanced in the pilot study areas and minimize the potential for preferential flow upward through abandoned boreholes, the injection tooling will be left in place while injections are ongoing. At the end of each working day, the injection tooling will be disconnected at the ground surface and each boring location will be covered and marked with a traffic cone. Gates to the Site will remain locked during non-working hours to protect the injection equipment.

Once injection at all three depth intervals is complete, the borings will be tremie grouted from total depth of the boring to ground surface using a liquid bentonite grout in accordance with Santa Clara Valley Water District (SCVWD) requirements. The ground surface will be completed to match the surrounding ground surface.

6.3.4 Surfacing and Preferential Pathways Monitoring

As donor solution is injected into the subsurface, it will move away from the injection point and can be influenced by natural heterogeneities in the subsurface, bedding and backfill materials associated with buried utilities, and compromised buried utility conduits (i.e., leaking storm sewers). A preferential pathway monitoring program will be implemented to expeditiously identify potential preferential pathways that could influence the movement of donor solution during injection activities. Prior to the start of injections, features where donor solution could surface (i.e., manholes, storm drains, etc.) will be identified and then monitored prior to and during ISB injections.

6.4 Phase 1 Performance Monitoring

6.4.1 Water Level Monitoring

Pressure transducers will be installed in three A-zone wells located within the slurry wall (37A, 137A, and AE/RW-9-2, Figure 4) prior to the start of injection. Pressure transducers will be downloaded daily during the injection program to collect real-time data on groundwater elevation changes inside the slurry wall. In addition, two rounds of groundwater level measurements (before and during injections) will be collected from Site wells located inside the slurry wall and adjacent to the MIP-2 and MIP-9/MIP-12 injection areas. The flow rate of operating extraction wells AE/RW-9-1, RW-20A, and RW-21A will be adjusted to reduce mounding during injection.

6.4.2 Hydropunch Sampling

Performance monitoring groundwater samples will be collected within the MIP-2 and MIP-9/MIP-12 treatment areas prior to the implementation of the Phase 2 injections. Actual timing of the performance monitoring will depend on the Site development schedule, but is anticipated that the monitoring will occur two to six months after injections. Groundwater samples will be collected using a Hydropunch type sampling technique to sample depth-discrete sample locations. At each location, hollow steel direct-push rods equipped with a retrievable stainless steel screen will be advanced to the sampling depth. Once the bottom of the sampling depth is reached, the rods will be retracted approximately 2 to 4 feet, exposing the stainless steel screen.

A minimum of 6 depth-discrete groundwater samples will be collected with a peristaltic pump into laboratory-supplied containers. New polyethylene tubing will be used for each groundwater sample. The samples will be labeled and placed in coolers with ice, and shipped to the analytical laboratory under chain-of-custody procedures. Specific parameters selected for analysis are listed in Table 3. Quality assurance/quality control (QA/QC) samples will be collected for cVOC samples in accordance with the MEW QAPP (one duplicate, one field blank, and one equipment blank). In addition, a laboratory provided trip blank will be included with each cooler containing groundwater samples for cVOC analysis that is sent to the laboratory.

Following advancement of each direct-push boring and Hydropunch sampling, the drill rods will be extracted then decontaminated before being driven at the next sampling location. The boreholes will be grouted to the surface in accordance with SCVWD requirements and completed to match the surrounding ground surface.

6.5 Investigation-Derived Waste (IDW) Management

Soil cuttings and solid investigation derived waste (IDW) will be containerized in 55-gallon drums or other California Department of Transportation (Caltrans)-approved containers and stored on-site pending analysis and off-site disposal at an appropriate facility in accordance with state and federal regulations and Schlumberger's internal procedures for handling solid waste streams.

Decontamination water and purge water will be transported to, treated, and disposed of using Fairchild System No. 1.

6.6 Reporting

A summary technical memorandum documenting Phase 1 ISB field activities will be submitted to EPA within 45 days following the completion of the Phase 1 work.

7. REFERENCES

Canonie, 1988. Draft Feasibility Study, Middlefield-Ellis-Whisman Area, Mountain View, California, November 1988.

EPA, 2004. Final First Five Year Review Report for the Middlefield-Ellis-Whisman Study Area, Mountain View, California, Region 9 San Francisco, California, September.

EPA, 2013. Email from Penny Reddy: RE: Response to Comments - Work Plan for Pilot Study Data Collection - 401 National Avenue, Mountain View. September 20.

Environmental Security Technology Certification Program (ESTCP), 2010. Loading Rates and Impacts of Substrate Delivery for Enhanced Anaerobic Bioremediation, ESTCP Project ER-0627, February.

Geosyntec Consultants, Inc. (Geosyntec), 2013a. Work Plan for Pilot Study Data Collection Former Fairchild Building 9, Groundwater Remediation Program 401 National Avenue, Mountain View, California, August 13.

Geosyntec, 2013b. Response to Comments, Work Plan for Pilot Study Data Collection, Former Fairchild Building 9 Groundwater Remediation Program 401 National Avenue, Mountain View, California, September 18.

Geosyntec, 2013c. 2012 Annual Progress Report for Former Fairchild Buildings 1-4,9, and 18 Groundwater Remediation Programs, Mountain View, California, April 15.

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.

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).

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), 1995. Operation and Maintenance Plan, Fairchild Semiconductor Corporation, 401 National Avenue, Building 9, Mountain View, California, December, 1995.

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.

Stroo HF, Major DW and Gossett JM (Stroo, et al.), 2010. Bioaugmentation for Anaerobic Bioremediation of Chlorinated Solvents, in Situ Remediation of Chlorinated Solvent Plumes, Stroo H.F. and Ward C.H. (eds.), © Springer Science+Business Media, LLC.

Yang Y and McCarty PL, 1998. *Competition for Hydrogen within a Chlorinated Solvent Dehalogenating Anaerobic Mixed Culture*. Environmental Science and Technology 32(22): 3591-3597.

TABLES

Table 1
Hydropunch Groundwater Analytical Results: Detected VOCs
401 National Avenue
Mountain View, California

Sample Location	Sample Depth (ft bgs)	Sample Date	Concentration in µg/L by EPA method 8260B									
			1,1-DCA	1,1-DCE	cis-1,2-DCE	trans-1,2-DCE	Freon 113	PCE	1,1,1-TCA	TCE	Vinyl Chloride	Total VOCs
MIP-02	21-25	9/9/2013	<1000	<1000	59,000	<1000	7,100	<1000	<1000	560,000	3,000	630,000
MIP-02	33-36	9/9/2013	<25	<25	5,300	71	<25	<25	<25	100	86	5,600
MIP-03	18-22	9/10/2013	<50	<50	15,000	200	<50	<50	<50	6,600	56	22,000
MIP-04	16-20	9/9/2013	<50	<50	11,000	79	<50	<50	<50	360	180	12,000
MIP-04	33-36	9/9/2013	<25/<25	<25/<25	2,700/2,700	<25/<25	<25/<25	<25/<25	<25/<25	1,200/1,200	25/25	3,900/3,900
MIP-08	18-22	9/10/2013	<50	<50	1,200	<50	64	<50	<50	2,100	<50	3,400
MIP-09	20-23	9/10/2013	210	140	45,000	480	410	<50	50	76,000	570	120,000
MIP-12	18-22	9/10/2013	<25	<25	180	<25	36	<25	<25	2,300	<25	2,500
MIP-12	22-26	9/10/2013	310	160	55,000	280	1,200	59	<50	120,000	520	180,000
MIP-12	33-35	9/10/2013	<50	<50	2,400	<50	<50	<50	<50	770	<50	3,200

Notes:
ft bgs = feet below ground surface
µg/L = micrograms per liter
1,1-DCA = 1,1-Dichloroethane
1,2-DCA = 1,2-Dichloroethane
1,1-DCE = 1,1-Dichloroethene
cis-1,2-DCE = cis-1,2-Dichloroethene
trans-1,2-DCE = trans-1,2-Dichloroethene
Freon 113 = Trichlorotrifluoroethane
PCE = Tetrachloroethene
1,1,1-TCA = 1,1,1-Trichloroethane
TCE = Trichloroethene
VOCs = volatile organic compounds
1,200/1,200 indicates primary and duplicate sample results
< indicates analyte not detected above the reported detection limit

Table 2
AE/RW-9-2 and 137A Groundwater Sample Results
401 National Avenue
Mountain View, California

Sample Location	**137A**	**AE/RW-9-2**
Date	**28-Aug-13**	**28-Aug-13**
Dissolved Gases by RSK-175 (µg/L)		
Methane	<5	16
Ethene	<5	25
Ethane	<5	<5
Acetylene	<5	<5
Metals by 6010B (mg/L)		
Dissolved Manganese	<0.02	0.52
Dissolved Iron	<0.04	<0.04
General Chemistry (mg/L)		
Nitrate as N (by 300.0)	1.5	0.77
Sulfate (by 300.0)	120	150
Alkalinity (by SM 2320B)	350	440
Bicarbonate Alkalinity as $CaCO_3$ (by SM 2320B)	350	440
TOC (by SM 5310C)	<1.0	1.1
Detected VOCs by 8260B (µg/L)		
1,1-DCA	5	86/110
1,1-DCE	13	23/50
cis-1,2-DCE	3000	7300/7300
trans-1,2- DCE	25	77/88
Freon 113	16	71/190
PCE	1.2	3.6/5
1,1,1-TCA	<0.5	35/65
TCE	3300	9800/8200
Vinyl Chloride	2.4	330/210
Microbial Data by Gene-Trac (copies/L)		
Dehalococcoides	$<3x10^3$	$3x10^3$
vcrA - Vinyl Chloride Reductase	--	$<3x10^3$

Notes:

mg/L = milligrams per liter
µg/L = micrograms per liter
1,1-DCA = 1,1-Dichloroethane
Freon 113 = Trichlorotrifluoroethane
1,1-DCE = 1,1-Dichloroethene
PCE = Tetrachloroethene
cis-1,2-DCE = cis-1,2-Dichloroethene
trans-1,2-DCE = trans-1,2-Dichloroethene
1,1,1-TCA = 1,1,1-Trichloroethane
TCE = Trichloroethene
VOCs = volative organic compounds
TOC = total organic carbon
7300/7300 - Primary and duplicate sample results
< indicates analyte not detected above the reported detection limit

Table 3
Field Parameter Results
401 National Avenue
Mountain View, California

Well	137A	AE/RW-9-2	35A	RW-20A	RW-21A
Date	4-Sep-13	4-Sep-13	4-Sep-13	5-Sep-13	5-Sep-13
DO (mg/L)	2.19	0.43	0.1	0.04	0.13
ORP (mV)	7	-30	-70	-200	-300
pH	7.33	7.28	7.23	7.24	7.88

Notes:

DO = dissolved oxygen

ORP = oxidation reduction potential

mg/L = milligrams per liter

mV = millivolts

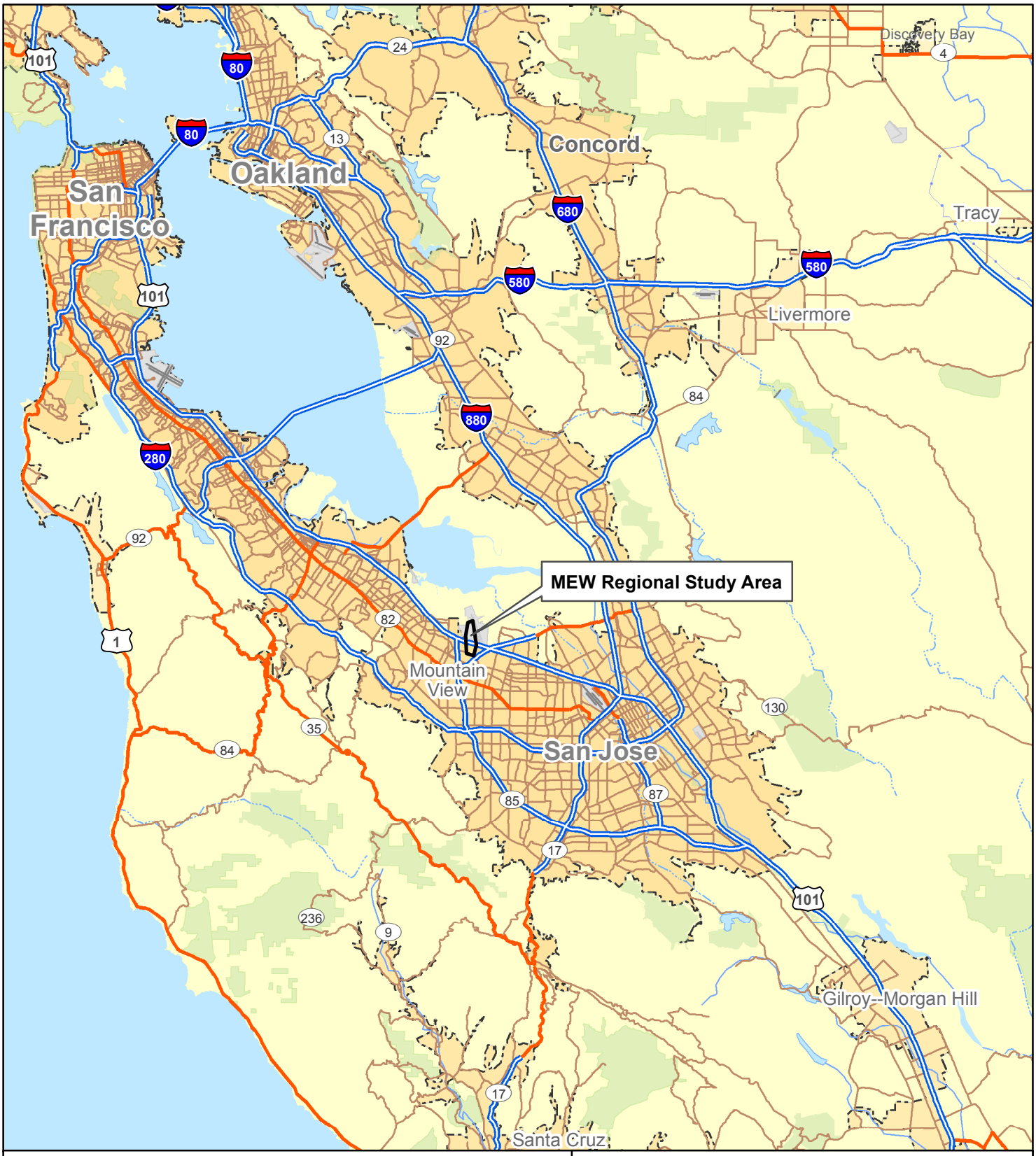
Field parameters were measured in each well using a YSI 600 XLM probe on a direct read cable lowered to a depth between 20 and 25 feet below ground surface. Measurements were recorded after stabilization between 25 minutes and 4 hours after deployment of the YSI meter.

Table 4
Phase 1 Performance Monitoring Parameters List
401 National Avenue
Mountain View, California

Analyte(s)	Analytical Method	Purpose
VOCs	EPA 8260B (8010 Analyte List)	Evaluate the in-situ destruction of TCE and related compounds, comparison with initial hydropunch sample results and evaluation of degradation
Sulfate, nitrate	EPA 300.0	Identify concentrations of dissolved non-target electron acceptors
DO, ORP, pH, electrical conductivity, temperature	Field measurement	Evaluate changes in groundwater geochemistry from e-donor addition
Dissolved iron, manganese	EPA 6010B	Evaluate changes in groundwater geochemistry from e-donor addition
Ethene, ethane, acetylene, methane	RSK-175M	Evaluate degradation following e-donor addition. Methane will be used to evaluate changes in groundwater geochemistry
TOC	EPA 415.1	Evaluate changes in organic carbon due to e-donor addition and depletion
Dehalococcoides/ vcrA enumeration	Gene-Trac	Measure population of organisms capable of reductive chlorination and effectiveness of bioaugmentation

Notes:
DO = dissolved oxygen
e-donor = electron donor
ORP = oxidation reduction potential
TOC = total organic carbon
VOCs = volatile organic compounds
vcrA = vinyl chloride reductase

FIGURES



N

0 10 Miles

Site Location Map

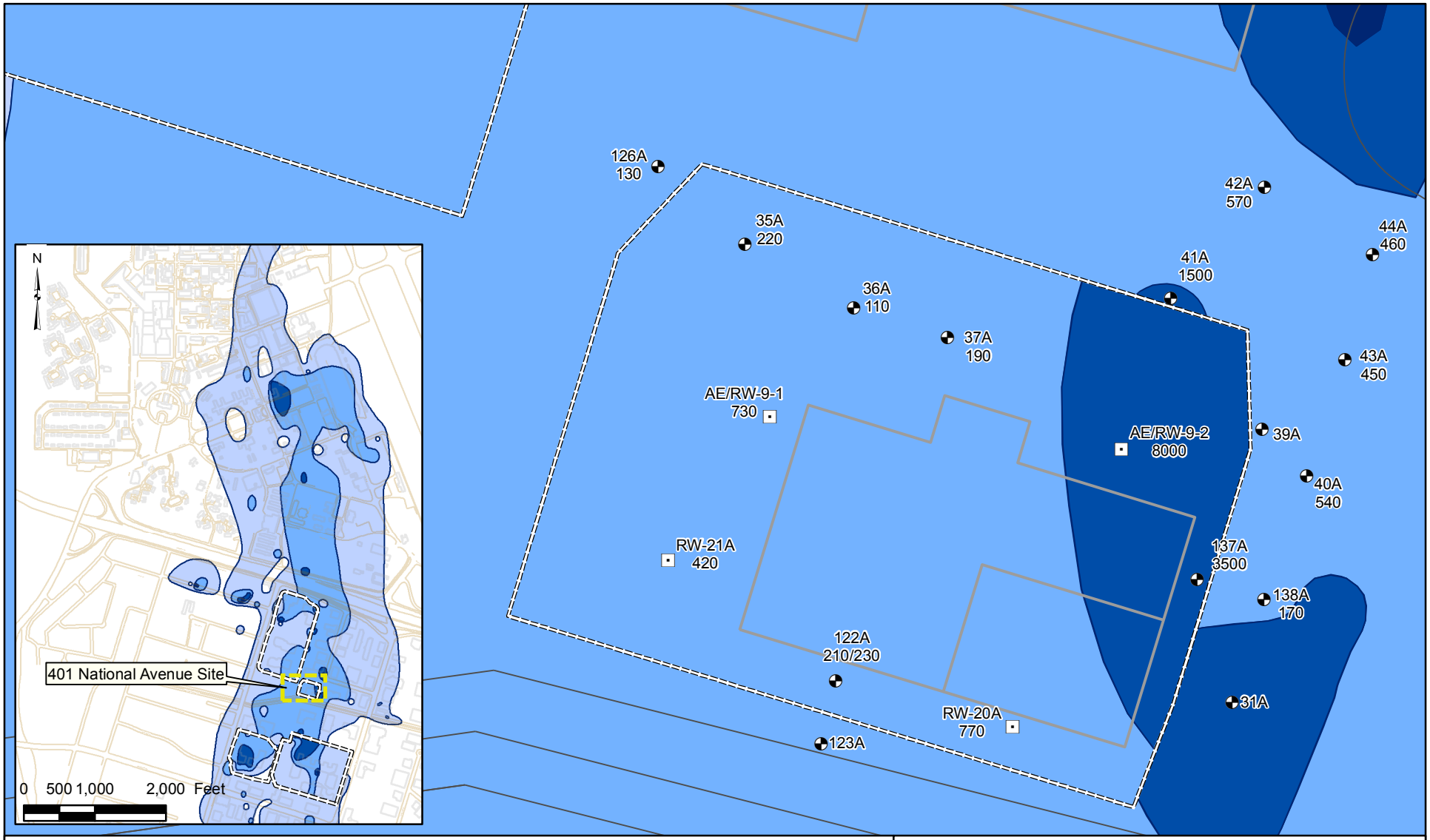
401 National Avenue
Mountain View, California

Geosyntec consultants

Oakland | December 2013

Figure 1

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



Legend

- Recovery Well
- Monitoring Well
- 138A / 170 — 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

==== 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.
*The slurry wall location in the north eastern portion of the site was revised based on information collected during 2013 utility location activities. Revised location is shown on Figure 4.

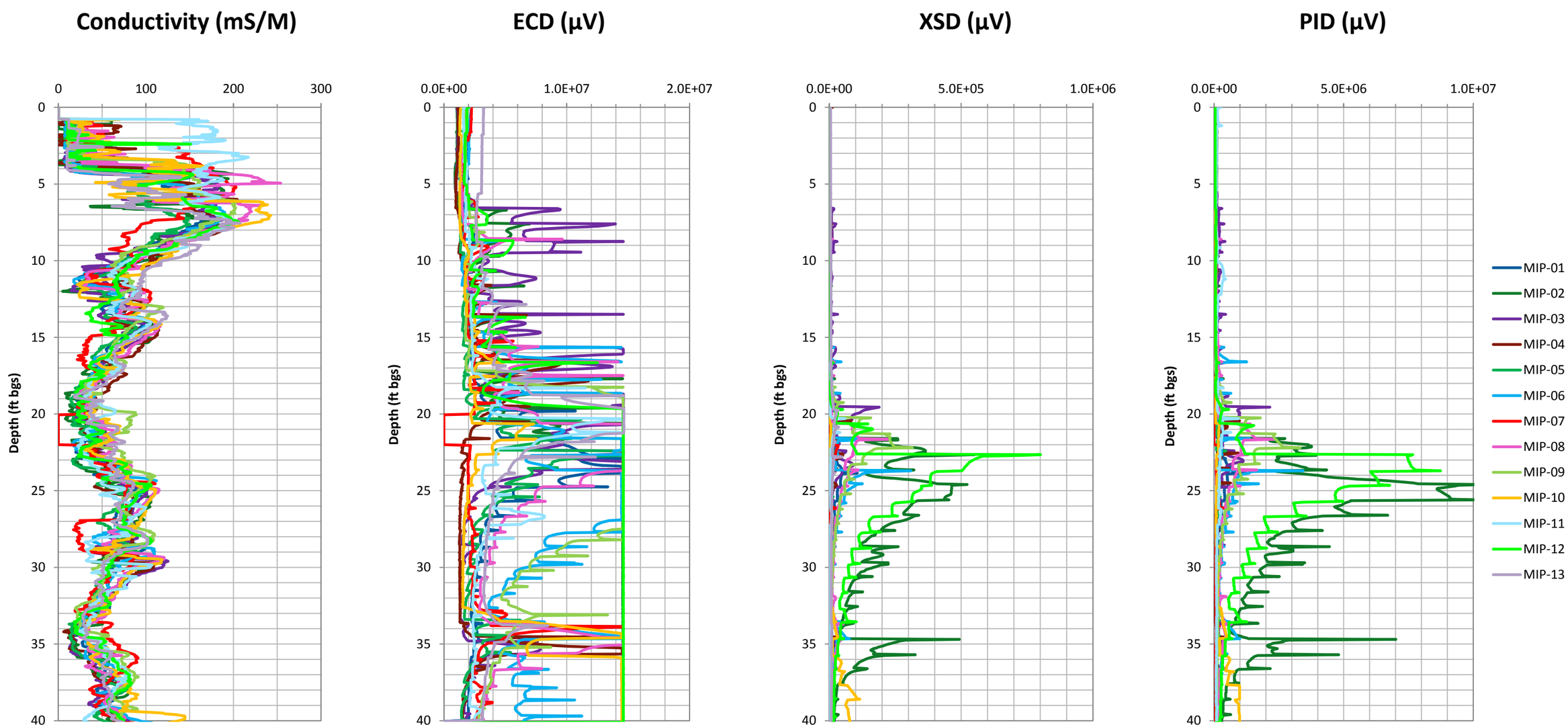
A-Zone TCE Concentrations in Groundwater
September/October 2012
401 National Avenue
Mountain View, California

Geosyntec consultants

Oakland | December 2013

Figure 2

P:\GIS\MEW\Project\Fairchild\Building9\2013_ISBWorkpan\Fig02_A-ZoneTCEConcentrationsInGW.mxd 11/27/2013 2:17:42 PM



Notes:

ft bgs = feet below ground surface
MIP = Membrane Interface Probe
ECD = Electron Capture Detector
XSD = Halogen-Specific Detector
PID = Photo-ionization Detector
MIP locations are shown in Figure 4

mS/M = millisiemens per meter
µV = millivolts

Data for MIP-07 is approximate due to a computer failure at 20 ft bgs. It is likely that no data was collected between 20 and 22 ft bgs.

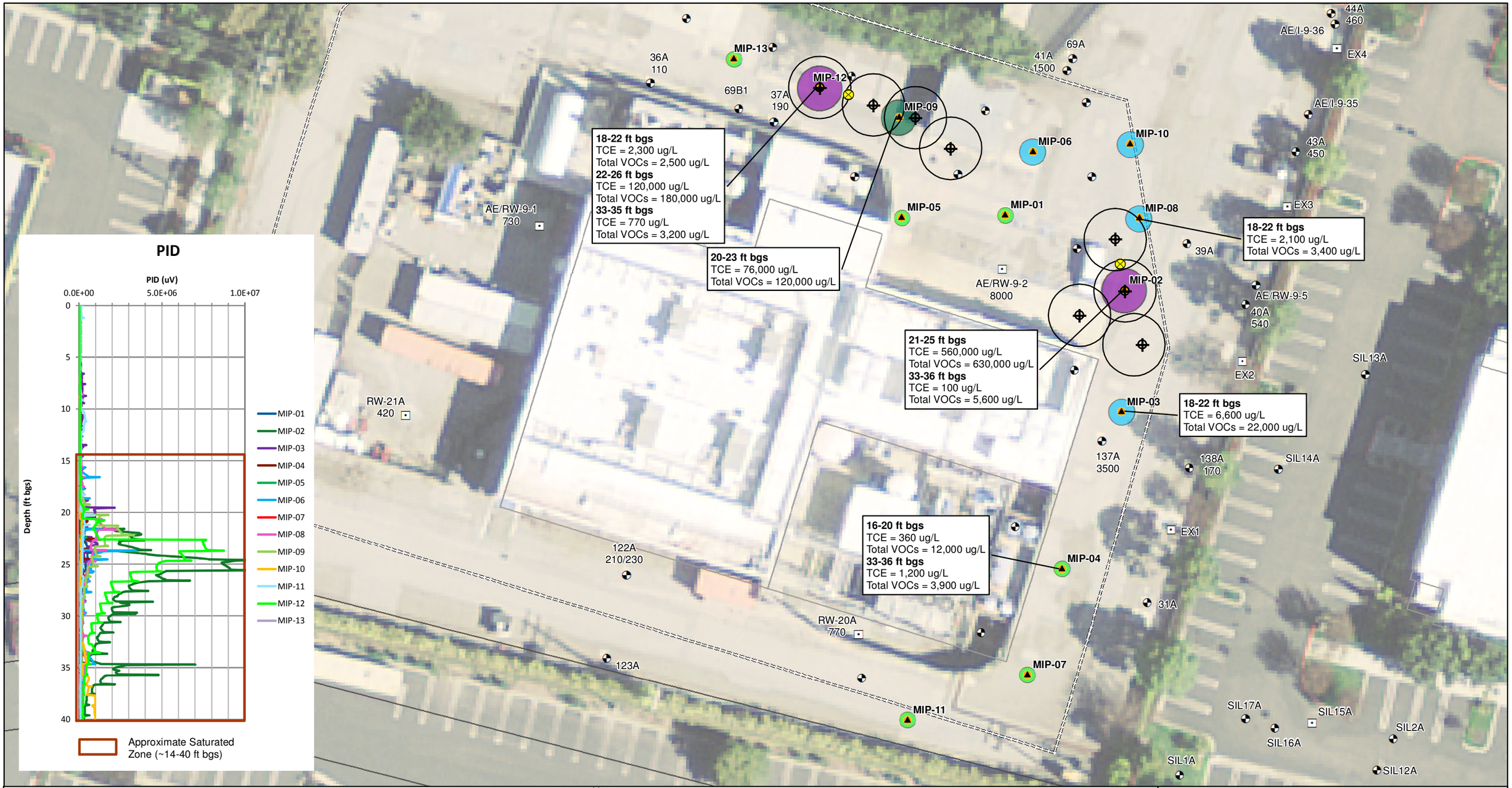
Soil Conductivity and MIP Profiles

401 National Avenue
Mountain View, California

Geosyntec consultants

WR1133A | December 2013

Figure 3



Legend

- Recovery Well On
- Monitoring Well
- 138A / 170 — Well ID / TCE Concentration (From 2012)
- MIP Location
- ====== Slurry Wall*
- Proposed Injection Point with Estimated Radius of Influence
- Hydropunch Sampling Location

20-23 ft bgs
TCE = 76,000 ug/L
Total VOCs = 120,000 ug/L

Sample Depth Interval
TCE Concentration
Total VOCs Concentration

Sum of PID Responses in the Saturated Zone

- 0 - 1.0E+08 µV
- 1.0E+08 - 2.0E+08 µV
- 2.0E+08 - 3E+08 µV
- >3E+08 µV

Notes:
µV - microvolts
ug/L - micrograms per liter
ft bgs - feet below ground surface
- Colored halos represent the sum of PID response measurements from 14-40 ft bgs. PID responses are measured every 0.05 ft bgs during MIP advancement.
* The slurry wall location in the north eastern portion of the site was revised based on information collected during 2013 utility location activities
- Data for MIP-07 is approximate due to a computer failure at 20 ft bgs. It is likely that no data was collected between 20 and 22 ft bgs.

- Injection at depth intervals 16-21 ft bgs, 21 to 26 ft bgs, and 32 to 37 ft bgs.

N

30 15 0 30 Feet

MIP/Hydropunch Results and Overview of Phase 1 Injections

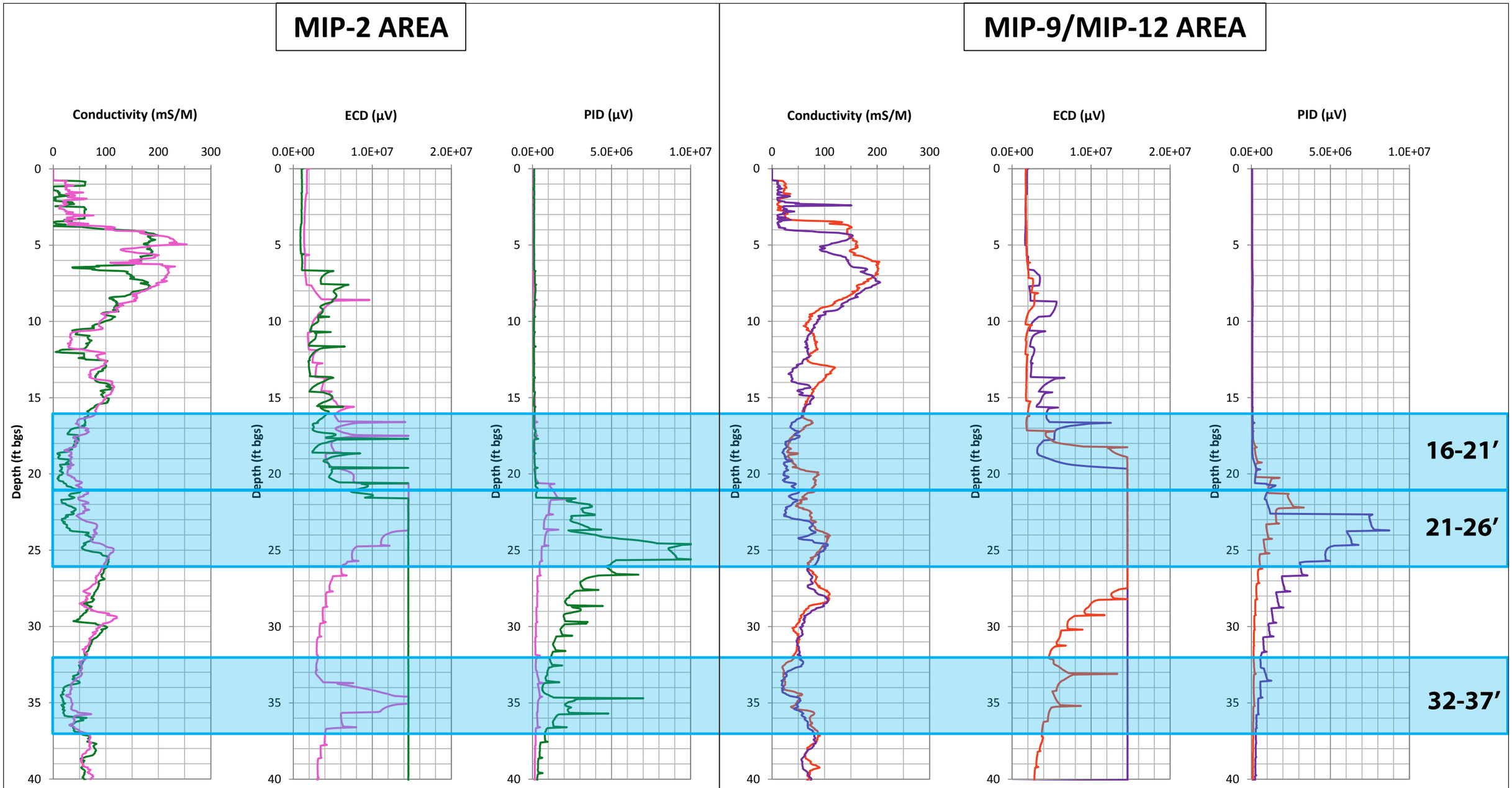
401 National Avenue
Mountain View, California

Geosyntec consultants

Oakland | December 2013

Figure 4

P:\GIS\MEW\Project\Fairchild\Building9\2013_ISBWorkpan\Fig04_MIPandHydropunchResultsandOverviewOfPhase1Injections_DASH.mxd 12/10/2013 8:51:24 AM



Notes:
ft bgs = feet below ground surface
ECD = Electron Capture Detector
PID = Photoionization Detector
mS/M = millisiemens per meter
µV = millivolts
MIP = Membrane Interface Probe

MIP-2
MIP-8
MIP-9
MIP-12

Phase I Target Injection Intervals

401 National Avenue
Mountain View, California

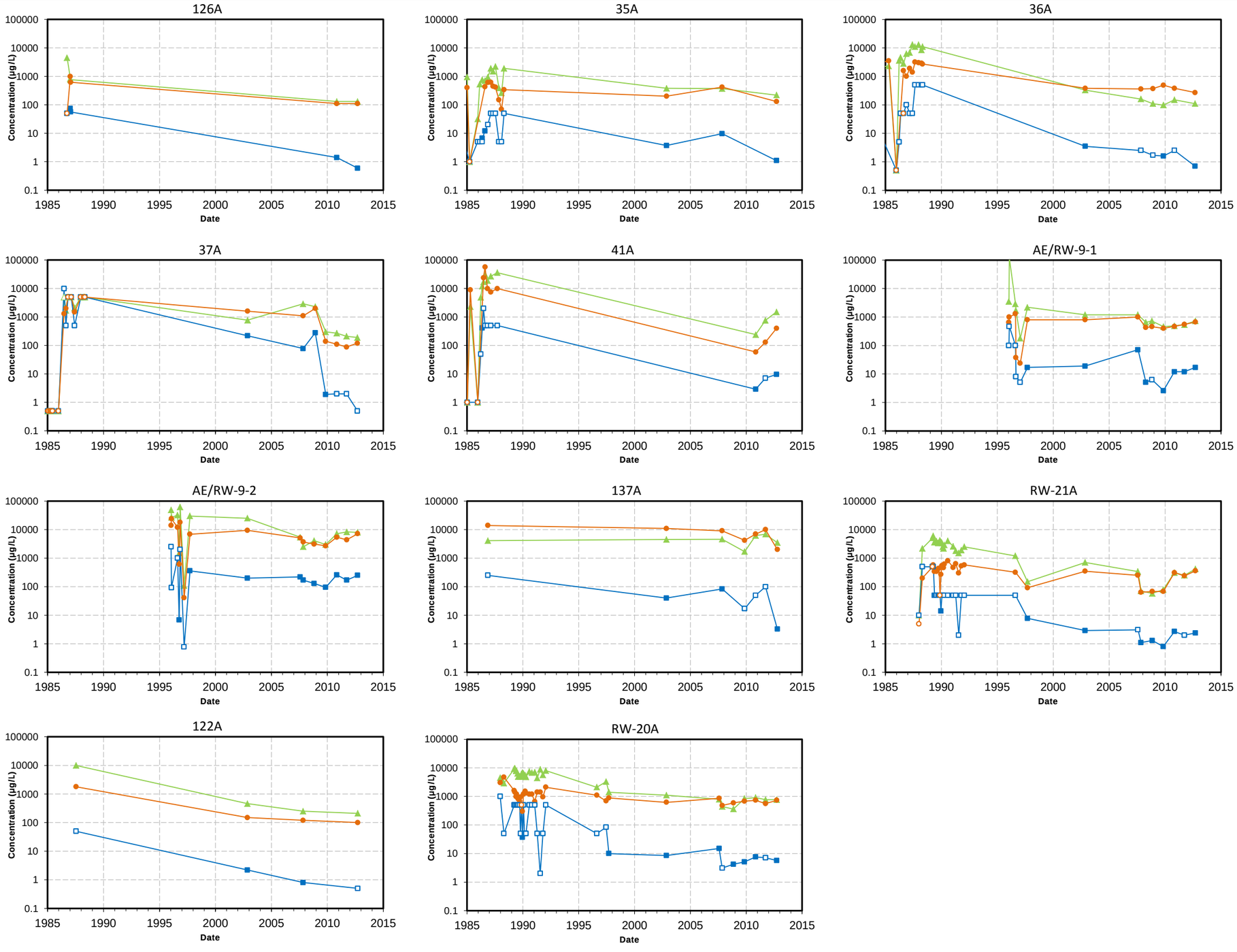
Geosyntec consultants

WR1133A | December 2013

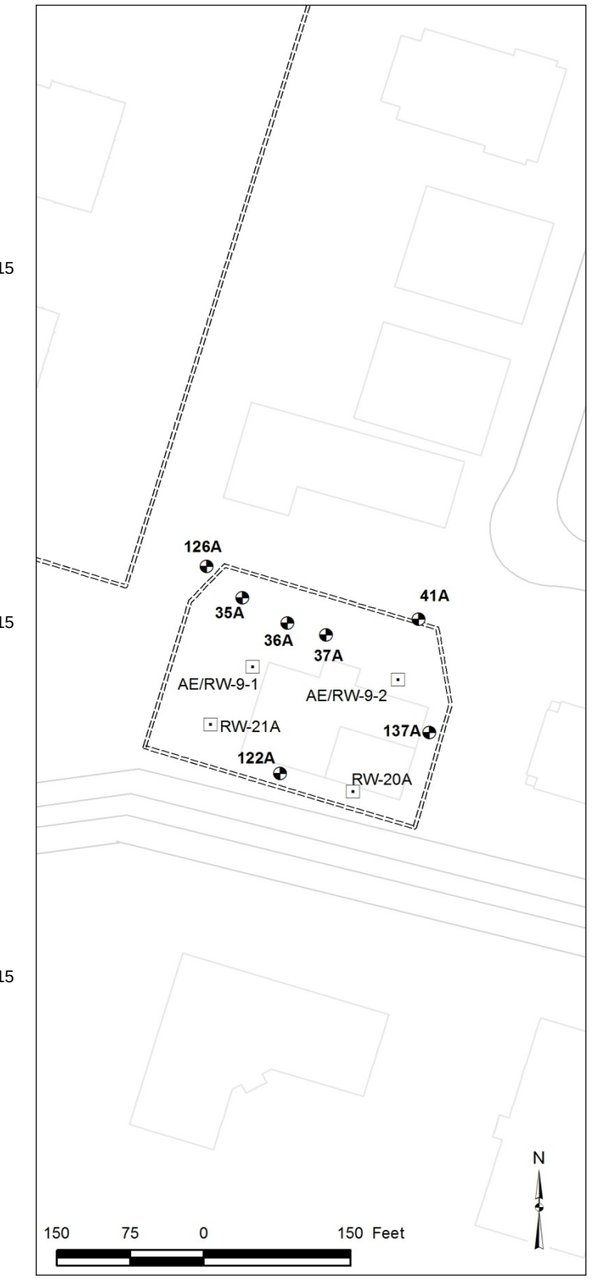
Figure 5

APPENDIX A

A-Zone Chlorinated Ethenes in Groundwater



Note:
Open symbols are non-detects, presented at limit of quantification



35A Monitoring Well

RW-21A Extraction Well (On)

Chlorinated Ethenes in Groundwater
A-Zone
401 National Avenue
Mountain View, California

Geosyntec consultants

Oakland | November 2013

Figure **A-1**

P:\GIS\MEW\Excel\Fairchild\Building9\2013_ISBWorkpan\[FigA-1_TimeSeries.xlsx]

APPENDIX B
MSDS of Newman Zone® and Wilclear Plus

Remediation and Natural Attenuation Services Incorporated
6712 West River Road
Brooklyn Center, MN 55430

Product Information: 763-585-6191 Issue Date: June 14, 2013

==========

Section 1: IDENTIFICATION

1.1 Product Name: Newman Zone –Buffered Nonionic Formulation 190-6730
1.2 Product Type: Edible Industrial Nutrient for Microbial Organisms
1.3 Hazard Rating: Health: 1 Fire: 1 Reactivity: 1
1.4 Formula: Proprietary

Substances Subject to SARA 313 Reporting Are Indicated by "#"

It is our opinion that the above named product does not meet the definition of “hazardous Chemical” as defined in the OSHA “Hazard Communication Standard” regulation 29 CFR 1910.1200. This material Safety Data Sheet is provided as general information for health and safety guidelines.

==========

Section 2: INGREDIENTS/COMPOSITION

	CAS No.	%	PEL	(mg/m^3) TWA
Soybean Oil (food grade)	8001-22-7	46	15(Mist)	10(Mist)
Sodium-L-Lactate	867-56-1	4		
Sodium Bicarbonate	144-55-8	1		
Food Additives/Emulsifiers/Preservatives	(Proprietary)	<10		
Water		<45		

EMERGENCY ONLY, 24-HOUR SERVICE: CHEMTREC: 1-800-424-9300

==========

Section 3: PHYSICAL AND CHEMICAL CHARACTERISTICS

This section completed per formulation ingredient data unless stated.

- Solubility: Dispersible in water (product)
- PH: 8.0-8.5 (product)
- Specific Gravity: 0.99 (product)
- Boiling Point: NA
- Vapor Pressure: NA
- Vapor Density: NA
- Percent Volatile By Volume (%): NA
- Evaporation Rate: NA
- Viscosity: 23.6 cps @ 68°F (Brookfield)(product)
- Product Appearance and Odor: White opaque liquid, vegetable oil odor.

==========

Section 4: FIRE AND EXPLOSION HAZARDS

This section completed per formulation ingredient data unless stated.

4.1 Special Fire Hazards: Product - none, does not support combustion.

Flash Point: >540 degrees F (Pure Soybean Oil Closed Cup).
Flammable Limits
LEL ND
UEL ND

4.2 Fire Fighting Methods: Use method appropriate for surrounding fire.

4.3 Extinguishing Media: Dry Chemical or CO_2 Preferable; water may cause spattering or spreading.

==========

Section 5: HEALTH HAZARD DATA

5.1 THIS PRODUCT IS USED FOR SOIL AND GROUND WATER REMEDIATION BUT IS FORMULATED USING FOOD AND FOOD GRADE ADDITIVES. PROCESSING, PACKAGING, SANITATION AND STORAGE OF THE PRODUCT FOLLOWS THE BEST PRACTICES USED FOR FOOD PRODUCTS.

5.2 Effects of Overexposure: NA

5.3 Emergency and First Aid Procedures: If inhaled, remove from contaminated atmosphere. For eye contact immediately flush eyes with large amounts of water. Ensure rinsing entire surface of eye & under lid. For skin contact wash affected areas thoroughly with soap and water. Seek medical help for persistent irritation.

5.4 Hydrolyzed soy protein has been identified by the United States Food and Drug Administration as a food allergen. Symptoms include swelling of the lips, stomach cramps, vomiting, diarrhea, skin hives, rashes, eczema and breathing problems.

5.5 Occupational Exposure Limits [8-hour time weighted averages (TWA)]:

	CAS No.	mg/m^3 OSHA PEL/ACGIH TLV
Soybean Oil (food grade)	8001-22-7	15(Mist)/10(Mist)

==========

Section 6: REACTIVITY DATA

This section completed per formulation ingredient data unless stated.

6.1 Stability: Stable under normal conditions.

6.2 Conditions to Avoid: NA

6.3 Incompatibilities: None known

6.4 Hazardous Decomposition Products: Product - None identified. Ingredients – Carbon oxides. Biological decomposition (spoilage) may result in offensive odors.

6.5 Hazardous Polymerization; None known

==========

Section 7: SPILL OR LEAK PROCEDURES

This section completed per formulation ingredient data unless stated.

7.1 Spill Response: Water dispersible. Same as for vegetable oil spills: isolate spill, prevent from entering waterways, and sewer systems. Sorb or remove spilled materials as soon as possible. Oils and specific quantities of oils may be reportable under federal, state, or local regulations.

7.2 Waste Disposal Method: This product is not hazardous, however, wastes must be disposed in accordance with local, state or federal regulations. Consult with local sewer authority, or solid waste facility prior to disposition.

==========

Section 8: SPECIAL PRECAUTIONS

No protective equipment is necessary under normal use conditions.

8.1 Eyes: If splashing may occur, eye protection recommended.
8.3 Skin: Wear impervious gloves for prolonged or repeated exposure.
8.4 Respiratory: Avoid breathing mists of this product

==========

Section 9: TRANSPORTATION PRECAUTIONS

This section completed per formulation ingredient data unless stated.

9.1 Transportation Considerations: This product is not classified as dangerous in the meaning of transport regulations. Shippers and transporters may need to meet packaging and transportation requirements for certain oils and respective quantities under CFR 49 Part 130.

The above information is believed to be correct with respect to the formula used to manufacture the product in the country of origin. As data, standards, and regulations change, and conditions of use and handling are beyond our control, NO WARRANTY, EXPRESS OR IMPLIED, IS MADE AS TO THE COMPLETENESS OR CONTINUING ACCURACY OF THIS INFORMATION.

MATERIAL SAFETY DATA SHEET

WILCLEAR PLUS®
LACTATE w/ACCELERITE®

SECTION I PRODUCT IDENTIFICATION

PRODUCT NAME:	Wilclear Plus® Lactate with Accelerite®
PRODUCT USE:	Bioremediation
SUPPLIER:	JRW Bioremediation, LLC 14321 W. 96th Terrace Lenexa, KS 66215 913-438-5544
EMERGENCY TELEPHONE:	800-779-5545 (24 hrs)
DATE PREPARED:	2-9-2011

SECTION II COMPOSITION/INFORMATION ON INGREDIENTS

Name	CAS #	% by Weight
Sodium lactate	72-17-3	29%
Sodium propionate	137-40-6	0-8%
Sodium acetate	127-09-3	0-8%
Sodium butyrate	156-54-7	0-8%
Carbohydrates & fermentation metabolites	68476-78-8	21%
Water	7732-18-5	39%

SECTION III PHYSICAL/CHEMICAL CHARACTERISTICS

Boiling point:	> 100ºC
Vapor pressure (Mg Hg):	Not determined
Vapor density (air = 1):	Not determined
Solubility in water:	Completely soluble
Appearance and odor:	Light brown liquid
Specific gravity (H_2O = 1):	> 1
Melting point:	Not determined
Evaporation rate:	Not determined
pH	Not determined

SECTION IV FIRE AND EXPLOSION HAZARD DATA

Flash point:	Not determined
Flammable limits:	Not determined
LEL:	Not determined
UEL:	Not determined
Extinguishing media:	Water, carbon dioxide, or dry chemical.
Special Fire Fighting procedures:	Standard procedure for chemical fires.
Unusual Fire Fighting hazards:	Thermal decomposition may lead to release of irritating gases and vapors.

SECTION V REACTIVITY DATA

Stability:	Unstable Stable X
Conditions to avoid:	Avoid temperatures above 150ºC

Incompatibility (materials to avoid):	Fermentation can occur when diluted with water.
Hazardous decomposition or byproducts:	Thermal decomposition may lead to release of irritating gases and vapors.
Hazardous polymerization:	May Occur Will Not Occur X

SECTION VI HEALTH HAZARD DATA Based on concentration as sold

Route/s of Entry:

Inhalation: Inhalation of mist may cause mild irritation of respiratory system. Move to fresh air.

Skin contact: Dermal contact with liquid may cause mild irritation. Remove all contaminated clothes, and wash skin with soap and water.

Eye contact: Mild irritation upon contact. Rinse immediately with plenty of water for at least 15 minutes, lifting eyelids to facilitate irrigation. Get medical attention if necessary.

Ingestion: If swallowed, get medical attention.

Health hazards (acute and chronic):	No specific data. Low order of toxicity. The chemical, physical, and toxicological properties have not been thoroughly examined.
Carcinogenicity:	Not determined.
Signs and symptoms of exposure:	Mild irritation to skin and eyes upon contact; mild irritation to respiratory system upon inhalation.
Medical conditions aggravated by exposure:	Not determined.

SECTION VII PRECAUTIONS FOR SAFE HANDLING AND USE

Steps to be taken in case material is released or spilled:	Contain spill and place material in drum for disposal. Dispose of according to all local, state, and federal regulations at an approved waste treatment facility.
Precautions to be taken in handling and storage:	Use personal protective equipment. Prevent spills and leakage. Keep container tightly closed. Keep in properly labeled containers. Store in a cool, dry area.
Other precautions:	No special environmental precautions required. Material is a natural product that readily biodegrades.

SECTION VIII CONTROL MEASURES

Respiratory protection (specify type):	No personal respiratory protective equipment normally required in well ventilated areas.
Ventilation:	Use adequate mechanical ventilation, especially in confined spaces.
Protective gloves:	Rubber gloves.
Eye protection:	Safety glasses.
Other protective clothing or equipment:	Unnecessary if other control measures are used.
Hygiene practices:	Avoid contact with skin. When using, do not eat, drink, or smoke. Remove and wash contaminated clothing before re-use.

APPENDIX C
KB-1® Plus Specification Sheet

KB-1 plus®

Bioaugmentation Culture

Overcome Inhibition at Mixed Chlorinated Solvent Sites

KB-1® Plus are custom-blended microbial culture formulations for bioaugmentation of sites with inhibitory concentrations of chlorinated ethanes and chlorinated methanes, which are often comingled with chlorinated ethenes. KB-1® Plus has been demonstrated to dechlorinate in excess of 200 milligrams per liter (mg/L) of 1,1,1-trichloroethane (1,1,1-TCA) to chloroethane and carbon tetrachloride, chloroform to dichloromethane (DCM) to non-chlorinated end products. Chloroethane can be further degraded under aerobic conditions. These cultures have been developed by SiREM in collaboration with the University of Toronto[1,2] and the United States Geological Survey[3].

Benefits of KB-1® Plus include:

- Overcome inhibition of chloroethene dechlorination caused by 1,1,1-TCA and chloroform
- Only a single application required
- Works with all commonly used electron donors
- Natural microbial culture (not genetically modified)
- Pathogen free
- Rigorous quality control ensures each shipment is effective, stable and safe
- Shipped overnight in specially designed stainless-steel vessels that prevent exposure to air and are safe and easy to handle

All KB-1® Plus purchases include:

- KB-1® Plus Guarantee*
- Technical support to ensure a successful application to your site
- Complimentary Gene-Trac® *Dehalococcoides* and *Dehalobacter* tests to verify the successful delivery, growth and persistence of KB-1® Plus microbes in site groundwater

Contact SiREM for a quotation or more information on our line of leading bioaugmentation products.

toll free: 1-866-251-1747
phone: (519) 822-2265

References

[1]Grostern, A. and E. A. Edwards. 2006. Growth of *Dehalobacter* and *Dehalococcoides* spp. during Degradation of Chlorinated Ethanes. *Appl. Environ. Microbiol*. 72: 428–436.

[2]Grostern, A., M. Duhamel, S. Dworatzek and E. A. Edwards. 2010. Chloroform respiration to dichloromethane by a *Dehalobacter* population. *Environmental Microbiology*. In press.

[3]Jones E. J. P., M. A. Voytek, M.M. Lorah, J. D. Kirshtein. 2006. Characterization of a Microbial Consortium Capable of Rapid and Simultaneous Dechlorination of 1,1,2,2-Tetrachloroethane and Chlorinated Ethane and Ethene Intermediates. *Bioremediation Journal,* Volume 10: 153-168.

**Some conditions apply*

APPENDIX D
ESTCP Substrate Design Tool for Electron Donor Calculations

APPENDIX D

ESTCP SUBSTRATE DESIGN TOOL FOR ELECTRON DONOR CALCULATIONS

The Substrate Design Tool (ESTCP, 2010) was used to determine Site-specific electron acceptor demand and to estimate the electron donor (hydrogen) required to meet that demand. Electron acceptor demand calculations were based on Hydropunch sampling results for cVOCs (Section 3.2.3 of the work plan) and baseline groundwater sampling results for the other electron acceptors (Section 3.2.5 of the work plan). The input parameters and other assumptions used for these calculations are provided in Appendix D. The electron acceptor demand calculations suggest that:

- About 5 pounds (lbs) of hydrogen are required per 10,000 gallons of groundwater for "higher concentration depth intervals" where total VOCs concentrations are anticipated to be greater than 100,000 μg/L (i.e. 21 to 26 feet bgs); and,
- About 2 lbs hydrogen are required per 10,000 gallons of groundwater for depth intervals where total VOCs concentrations are anticipated to be one to two orders of magnitude less than 100,000 μg/L.

These calculations are based on dissolved concentrations and do not take into account the potential for sorbed or residual separate phase cVOCs in the treatment area. Therefore, in order to account for the potential presence additional cVOC mass and other uncertainties, a safety factor of 50 was used to design the amendment dosing at the Site.

Table S.1 Input for Substrate Requirements in Hydrogen Equivalents

Site Name: 401 National, Mountain View, CA

RETURN TO COVER PAGE

NOTE: Unshaded boxes are user input.

1. Treatment Zone Physical Dimensions	Values	Range	Units	User Notes
Width (Perpendicular to predominant groundwater flow direction)	45	1-10,000	feet	
Length (Parallel to predominant groundwater flow)	45	1-1,000	feet	
Saturated Thickness	5	1-100	feet	5-foot injection interval (21-26' bgs)
Treatment Zone Cross Sectional Area	225	--	ft^2	
Treatment Zone Volume	10,125	--	ft^3	
Treatment Zone Total Pore Volume (total volume x total porosity)	18,939	--	gallons	
Treatment Zone Effective Pore Volume (total volume x effective porosity)	11,363	--	gallons	
Design Period of Performance	5.0	.5 to 5	year	
Design Factor (times the electron acceptor hydrogen demand)	1.0	2 to 20	unitless	
2. Treatment Zone Hydrogeologic Properties				
Total Porosity	25%	.05-50	percent	
Effective Porosity	15%	.05-50	percent	
Average Aquifer Hydraulic Conductivity	0.01	.01-1000	ft/day	limited flux within the slurry wall
Average Hydraulic Gradient	0.001	0.0001-0.1	ft/ft	
Average Groundwater Seepage Velocity through the Treatment Zone	0.00	--	ft/day	
Average Groundwater Seepage Velocity through the Treatment Zone	0.0	--	ft/yr	
Average Groundwater Discharge through the Treatment Zone	6	--	gallons/year	
Soil Bulk Density	1.64	1.4-2.0	gm/cm^3	
Soil Fraction Organic Carbon (foc)	0.05%	0.01-10	percent	
3. Native Electron Acceptors				
A. Aqueous-Phase Native Electron Acceptors				
Oxygen	2.2	0.01 to 10	mg/L	Table 3
Nitrate	7.00	0.1 to- 20	mg/L	Table 2
Sulfate	150	10 to 5,000	mg/L	Table 2
Carbon Dioxide (estimated as the amount of Methane produced)	10.0	0.1 to 20	mg/L	
B. Solid-Phase Native Electron Acceptors				
Manganese (IV) (estimated as the amount of Mn (II) produced)	2	0.1 to 20	mg/L	
Iron (III) (estimated as the amount of Fe (II) produced)	5	0.1 to 20	mg/L	
4. Contaminant Electron Acceptors				
Tetrachloroethene (PCE)		--	mg/L	
Trichloroethene (TCE)	500	--	mg/L	Table 1
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	100	--	mg/L	Table 1
Vinyl Chloride (VC)		--	mg/L	
Carbon Tetrachloride (CT)		--	mg/L	
Trichloromethane (or chloroform) (CF)		--	mg/L	
Dichloromethane (or methylene chloride) (MC)		--	mg/L	
Chloromethane		--	mg/L	
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)		--	mg/L	
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)		--	mg/L	
Dichloroethane (1,1-DCA and 1,2-DCA)		--	mg/L	
Chloroethane		--	mg/L	
Perchlorate		--	mg/L	
5. Aquifer Geochemistry (Optional Screening Parameters)				
A. Aqueous Geochemistry				
Oxidation-Reduction Potential (ORP)	-100	-400 to +500	mV	Table 3
Temperature	22	5.0 to 30	ºC	
pH	7.5	4.0 to 10.0	su	Table 3
Alkalinity		10 to 1,000	mg/L	
Total Dissolved Solids (TDS, or salinity)		10 to 1,000	mg/L	
Specific Conductivity		100 to 10,000	µs/cm	
Chloride		10 to 10,000	mg/L	
Sulfide - Pre injection		0.1 to 100	mg/L	
Sulfide - Post injection		0.1 to 100	mg/L	
B. Aquifer Matrix				
Total Iron		200 to 20,000	mg/kg	
Cation Exchange Capacity		1.0 to 10	meq/100 g	
Neutralization Potential		1.0 to 100	Percent as $CaCO_3$	

NOTES:

Table S.2 Substrate Calculations in Hydrogen Equivalents

Site Name: 401 National, Mountain View, CA

RETURN TO COVER PAGE

NOTE: Open cells are user input.

1. Treatment Zone Physical Dimensions

	Values	Range	Units
Width (Perpendicular to predominant groundwater flow direction)	45	1-10,000	feet
Length (Parallel to predominant groundwater flow)	45	1-1,000	feet
Saturated Thickness	5	1-100	feet
Treatment Zone Cross Sectional Area	225	--	ft^2
Treatment Zone Volume	10,125	--	ft^3
Treatment Zone Effective Pore Volume (total volume x effective porosity)	11,363	--	gallons
Treatment Zone Effective Groundwater Volume (total volume x effective porosity)	11,363	--	gallons
Design Period of Performance	5	.5 to 5	year

2. Treatment Zone Hydrogeologic Properties

Total Porosity	0.25	.05-50	
Effective Porosity	0.15	.05-50	
Average Aquifer Hydraulic Conductivity	0.01	.01-1000	ft/day
Average Hydraulic Gradient	0.001	0.1-0.0001	ft/ft
Average Groundwater Seepage Velocity through the Treatment Zone	0.00	--	ft/day
Average Groundwater Seepage Velocity through the Treatment Zone	0.0	--	ft/yr
Average Groundwater Flux through the Treatment Zone	6	--	gallons/year
Soil Bulk Density	1.64	1.4-2.0	gm/cm^3
Soil Fraction Organic Carbon (foc)	0.0005	0.0001-0.1	

3. Initial Treatment Cell Electron-Acceptor Demand (one total pore volume)

A. Aqueous-Phase Native Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Oxygen	2.2	0.21	7.94	0.03	4
Nitrate (denitrification)	7.0	0.66	12.30	0.05	5
Sulfate	150	14.22	11.91	1.19	8
Carbon Dioxide (estimated as the amount of methane produced)	10.0	0.95	1.99	0.48	8
Soluble Competing Electron Acceptor Demand (lb.)				**1.75**	

B. Solid-Phase Native Electron Acceptors (Based on manganese and iron produced)	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Manganese (IV) (estimated as the amount of Mn (II) produced)	1.5	0.14	27.25	0.01	2
Iron (III) (estimated as the amount of Fe (II) produced)	5.0	0.48	55.41	0.01	1
Solid-Phase Competing Electron Acceptor Demand (lb.)				**0.01**	

C. Soluble Contaminant Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	0	0.00	20.57	0.00	8
Trichloroethene (TCE)	500	47.41	21.73	2.18	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	100	9.48	24.05	0.39	4
Vinyl Chloride (VC)	0	0.00	31.00	0.00	2
Carbon Tetrachloride (CT)	0	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	0	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	0	0.00	21.06	0.00	4
Chloromethane	0	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	0	0.00	22.06	0.00	6
Dichloroethane (1,1-DCA and 1,2-DCA)	0	0.00	24.55	0.00	4
Chloroethane	0	0.00	32.00	0.00	2
Perchlorate	0	0.00	12.33	0.00	6
Total Soluble Contaminant Electron Acceptor Demand (lb.)				**2.58**	

D. Sorbed Contaminant Electron Acceptors (Soil Concentration = Koc x foc x Cgw)	Koc (mL/g)	Soil Conc. (mg/kg)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	263	0.00	0.00	20.57	0.00	8
Trichloroethene (TCE)	107	26.75	27.73	21.73	1.28	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	45	2.25	2.33	24.05	0.10	4
Vinyl Chloride (VC)	3.0	0.00	0.00	31.00	0.00	2
Carbon Tetrachloride (CT)	224	0.00	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	63	0.00	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	28	0.00	0.00	21.06	0.00	4
Chloromethane	25	0.00	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	117	0.00	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	105	0.00	0.00	22.06	0.00	6
Dichloroethane (1,1-DCA and 1,2-DCA)	30	0.00	0.00	24.55	0.00	4
Chloroethane	3	0.00	0.00	32.00	0.00	2
Perchlorate	0.0	0.00	0.00	12.33	0.00	6
Total Sorbed Contaminant Electron Acceptor Demand (lb.)					**1.37**	

(continued)

4. Treatment Cell Electron-Acceptor Flux (per year)

A. Soluble Native Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Oxygen	2.2	0.00	7.94	0.00	4
Nitrate (denitrification)	7.0	0.00	10.25	0.00	5
Sulfate	150	0.01	11.91	0.00	8
Carbon Dioxide (estimated as the amount of Methane produced)	10	0.00	1.99	0.00	8
Total Competing Electron Acceptor Demand Flux (lb/yr)				**0.0**	

B. Soluble Contaminant Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	0	0.00	20.57	0.00	8
Trichloroethene (TCE)	500	0.03	21.73	0.00	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	100	0.01	24.05	0.00	4
Vinyl Chloride (VC)	0	0.00	31.00	0.00	2
Carbon Tetrachloride (CT)	0	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	0	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	0	0.00	21.06	0.00	4
Chloromethane	0	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	0	0.00	22.06	0.00	6
Dichloroethane (1,1-DCA and 1,2-DCA)	0	0.00	24.55	0.00	4
Chloroethane	0	0.00	32.00	0.00	2
Perchlorate	0	0.00	12.33	0.00	6
Total Soluble Contaminant Electron Acceptor Demand Flux (lb/yr)				**0.00**	

Initial Hydrogen Requirement First Year (lb)	**5.7**
Total Life-Cycle Hydrogen Requirement (lb)	**5.7**

5. Design Factors

Microbial Efficiency Uncertainty Factor	2X - 4X
Methane and Solid-Phase Electron Acceptor Uncertainty	2X - 4X
Remedial Design Factor (e.g., Substrate Leaving Reaction Zone)	1X - 3X
Design Factor	**1.0**
Total Life-Cycle Hydrogen Requirement with Design Factor (lb)	**5.7**

6. Acronyns and Abbreviations

^{o}C =degrees celsius
µs/cm = microsiemens per centimeter
cm/day = centimeters per day
cm/sec = centimeters per second
ft^2 = square feet
ft/day = feet per day
ft/ft = foot per foot
ft/yr = feet per year
gm/cm^3 = grams per cubic centimeter
kg of CaCO3 per mg = kilograms of calcium carbonate per milligram
lb = pounds

meq/100 g = milliequivalents per 100 grams
mg/kg = milligrams per kilogram
mg/L = milligrams per liter
m/m = meters per meters
mV = millivolts
m/yr = meters per year
su = standard pH units
wt/wt H2 = concetration molecular hydrogen, weight per weight

Table S.1 Input for Substrate Requirements in Hydrogen Equivalents

Site Name: 401 National, Mountain View, CA

RETURN TO COVER PAGE

NOTE: Unshaded boxes are user input.

1. Treatment Zone Physical Dimensions	Values	Range	Units	User Notes
Width (Perpendicular to predominant groundwater flow direction)	45	1-10,000	feet	
Length (Parallel to predominant groundwater flow)	45	1-1,000	feet	
Saturated Thickness	10	1-100	feet	Two 5-foot injection intervals (16-21' bgs and 32-37' bgs)
Treatment Zone Cross Sectional Area	450	--	ft^2	
Treatment Zone Volume	20,250	--	ft^3	
Treatment Zone Total Pore Volume (total volume x total porosity)	37,878	--	gallons	
Treatment Zone Effective Pore Volume (total volume x effective porosity)	22,727	--	gallons	
Design Period of Performance	5.0	.5 to 5	year	
Design Factor (times the electron acceptor hydrogen demand)	1.0	2 to 20	unitless	
2. Treatment Zone Hydrogeologic Properties				
Total Porosity	25%	.05-50	percent	
Effective Porosity	15%	.05-50	percent	
Average Aquifer Hydraulic Conductivity	0.01	.01-1000	ft/day	limited flux within the slurry wall
Average Hydraulic Gradient	0.001	0.0001-0.1	ft/ft	
Average Groundwater Seepage Velocity through the Treatment Zone	0.00	--	ft/day	
Average Groundwater Seepage Velocity through the Treatment Zone	0.0	--	ft/yr	
Average Groundwater Discharge through the Treatment Zone	12	--	gallons/year	
Soil Bulk Density	1.64	1.4-2.0	gm/cm^3	
Soil Fraction Organic Carbon (foc)	0.05%	0.01-10	percent	
3. Native Electron Acceptors				
A. Aqueous-Phase Native Electron Acceptors				
Oxygen	2.2	0.01 to 10	mg/L	Table 3
Nitrate	7.00	0.1 to- 20	mg/L	Table 2
Sulfate	150	10 to 5,000	mg/L	Table 2
Carbon Dioxide (estimated as the amount of Methane produced)	10.0	0.1 to 20	mg/L	
B. Solid-Phase Native Electron Acceptors				
Manganese (IV) (estimated as the amount of Mn (II) produced)	2	0.1 to 20	mg/L	
Iron (III) (estimated as the amount of Fe (II) produced)	5	0.1 to 20	mg/L	
4. Contaminant Electron Acceptors				
Tetrachloroethene (PCE)		--	mg/L	
Trichloroethene (TCE)	50	--	mg/L	Table 1
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	10	--	mg/L	Table 1
Vinyl Chloride (VC)		--	mg/L	
Carbon Tetrachloride (CT)		--	mg/L	
Trichloromethane (or chloroform) (CF)		--	mg/L	
Dichloromethane (or methylene chloride) (MC)		--	mg/L	
Chloromethane		--	mg/L	
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)		--	mg/L	
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)		--	mg/L	
Dichloroethane (1,1-DCA and 1,2-DCA)		--	mg/L	
Chloroethane		--	mg/L	
Perchlorate		--	mg/L	
5. Aquifer Geochemistry (Optional Screening Parameters)				
A. Aqueous Geochemistry				
Oxidation-Reduction Potential (ORP)	-100	-400 to +500	mV	Table 3
Temperature	22	5.0 to 30	ºC	
pH	7.5	4.0 to 10.0	su	Table 3
Alkalinity		10 to 1,000	mg/L	
Total Dissolved Solids (TDS, or salinity)		10 to 1,000	mg/L	
Specific Conductivity		100 to 10,000	µs/cm	
Chloride		10 to 10,000	mg/L	
Sulfide - Pre injection		0.1 to 100	mg/L	
Sulfide - Post injection		0.1 to 100	mg/L	
B. Aquifer Matrix				
Total Iron		200 to 20,000	mg/kg	
Cation Exchange Capacity		1.0 to 10	meq/100 g	
Neutralization Potential		1.0 to 100	Percent as $CaCO_3$	

NOTES:

Table S.2 Substrate Calculations in Hydrogen Equivalents

Site Name: 401 National, Mountain View, CA

RETURN TO COVER PAGE

NOTE: Open cells are user input.

1. Treatment Zone Physical Dimensions

	Values	Range	Units
Width (Perpendicular to predominant groundwater flow direction)	45	1-10,000	feet
Length (Parallel to predominant groundwater flow)	45	1-1,000	feet
Saturated Thickness	10	1-100	feet
Treatment Zone Cross Sectional Area	450	--	ft2
Treatment Zone Volume	20,250	--	ft3
Treatment Zone Effective Pore Volume (total volume x effective porosity)	22,727	--	gallons
Treatment Zone Effective Groundwater Volume (total volume x effective porosity)	22,727	--	gallons
Design Period of Performance	5	.5 to 5	year

2. Treatment Zone Hydrogeologic Properties

Total Porosity	0.25	.05-50	
Effective Porosity	0.15	.05-50	
Average Aquifer Hydraulic Conductivity	0.01	.01-1000	ft/day
Average Hydraulic Gradient	0.001	0.1-0.0001	ft/ft
Average Groundwater Seepage Velocity through the Treatment Zone	0.00	--	ft/day
Average Groundwater Seepage Velocity through the Treatment Zone	0.0	--	ft/yr
Average Groundwater Flux through the Treatment Zone	12	--	gallons/year
Soil Bulk Density	1.64	1.4-2.0	gm/cm^3
Soil Fraction Organic Carbon (foc)	0.0005	0.0001-0.1	

3. Initial Treatment Cell Electron-Acceptor Demand (one total pore volume)

A. Aqueous-Phase Native Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Oxygen	2.2	0.42	7.94	0.05	4
Nitrate (denitrification)	7.0	1.33	12.30	0.11	5
Sulfate	150	28.45	11.91	2.39	8
Carbon Dioxide (estimated as the amount of methane produced)	10.0	1.90	1.99	0.95	8
Soluble Competing Electron Acceptor Demand (lb.)				**3.50**	

B. Solid-Phase Native Electron Acceptors (Based on manganese and iron produced)	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Manganese (IV) (estimated as the amount of Mn (II) produced)	1.5	0.29	27.25	0.01	2
Iron (III) (estimated as the amount of Fe (II) produced)	5.0	0.95	55.41	0.02	1
Solid-Phase Competing Electron Acceptor Demand (lb.)				**0.03**	

C. Soluble Contaminant Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	0	0.00	20.57	0.00	8
Trichloroethene (TCE)	50	9.48	21.73	0.44	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	10	1.90	24.05	0.08	4
Vinyl Chloride (VC)	0	0.00	31.00	0.00	2
Carbon Tetrachloride (CT)	0	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	0	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	0	0.00	21.06	0.00	4
Chloromethane	0	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	0	0.00	22.06	0.00	6
Dichloroethane (1,1-DCA and 1,2-DCA)	0	0.00	24.55	0.00	4
Chloroethane	0	0.00	32.00	0.00	2
Perchlorate	0	0.00	12.33	0.00	6
Total Soluble Contaminant Electron Acceptor Demand (lb.)				**0.52**	

D. Sorbed Contaminant Electron Acceptors (Soil Concentration = Koc x foc x Cgw)	Koc (mL/g)	Soil Conc. (mg/kg)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	263	0.00	0.00	20.57	0.00	8
Trichloroethene (TCE)	107	2.68	5.55	21.73	0.26	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	45	0.23	0.47	24.05	0.02	4
Vinyl Chloride (VC)	3.0	0.00	0.00	31.00	0.00	2
Carbon Tetrachloride (CT)	224	0.00	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	63	0.00	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	28	0.00	0.00	21.06	0.00	4
Chloromethane	25	0.00	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	117	0.00	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	105	0.00	0.00	22.06	0.00	6
Dichloroethane (1,1-DCA and 1,2-DCA)	30	0.00	0.00	24.55	0.00	4
Chloroethane	3	0.00	0.00	32.00	0.00	2
Perchlorate	0.0	0.00	0.00	12.33	0.00	6
Total Sorbed Contaminant Electron Acceptor Demand (lb.)					**0.27**	

(continued)

4. Treatment Cell Electron-Acceptor Flux (per year)

A. Soluble Native Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Oxygen	2.2	0.00	7.94	0.00	4
Nitrate (denitrification)	7.0	0.00	10.25	0.00	5
Sulfate	150	0.02	11.91	0.00	8
Carbon Dioxide (estimated as the amount of Methane produced)	10	0.00	1.99	0.00	8
Total Competing Electron Acceptor Demand Flux (lb/yr)				**0.0**	

B. Soluble Contaminant Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	0	0.00	20.57	0.00	8
Trichloroethene (TCE)	50	0.01	21.73	0.00	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	10	0.00	24.05	0.00	4
Vinyl Chloride (VC)	0	0.00	31.00	0.00	2
Carbon Tetrachloride (CT)	0	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	0	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	0	0.00	21.06	0.00	4
Chloromethane	0	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	0	0.00	22.06	0.00	6
Dichloroethane (1,1-DCA and 1,2-DCA)	0	0.00	24.55	0.00	4
Chloroethane	0	0.00	32.00	0.00	2
Perchlorate	0	0.00	12.33	0.00	6
Total Soluble Contaminant Electron Acceptor Demand Flux (lb/yr)				**0.00**	

Initial Hydrogen Requirement First Year (lb)	**4.3**
Total Life-Cycle Hydrogen Requirement (lb)	**4.3**

5. Design Factors

Microbial Efficiency Uncertainty Factor	2X - 4X
Methane and Solid-Phase Electron Acceptor Uncertainty	2X - 4X
Remedial Design Factor (e.g., Substrate Leaving Reaction Zone)	1X - 3X
Design Factor	**1.0**
Total Life-Cycle Hydrogen Requirement with Design Factor (lb)	**4.3**

6. Acronyns and Abbreviations

^{o}C =degrees celsius
µs/cm = microsiemens per centimeter
cm/day = centimeters per day
cm/sec = centimeters per second
ft^2 = square feet
ft/day = feet per day
ft/ft = foot per foot
ft/yr = feet per year
gm/cm^3 = grams per cubic centimeter
kg of CaCO3 per mg = kilograms of calcium carbonate per milligram
lb = pounds

meq/100 g = milliequivalents per 100 grams
mg/kg = milligrams per kilogram
mg/L = milligrams per liter
m/m = meters per meters
mV = millivolts
m/yr = meters per year
su = standard pH units
wt/wt H2 = concetration molecular hydrogen, weight per weight