

**REVISED  
WORKPLAN**

**For**

**SEMI-PASSIVE GROUNDWATER  
REMEDiation  
DEMONSTRATION PROJECT  
At**

**Site 1, Alameda Naval Air Station  
California**

Prepared for

Department of the Navy  
Naval Facilities Engineering Command  
San Bruno, California

Prepared by

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December 1996

**WORK PLAN FOR  
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DEMONSTRATION PROJECT**

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- Appendix F - Health and Safety Plan
- Appendix G - Analytical Procedures for the External Lab
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- Appendix J - QAPP for External Lab
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Note: Plates are not included in Revision 1 (are same as Version 0)

Plate 1      Cross Section of the Total Chlorinated VOC Distribution at the  
                 Demonstration Site

Plate 2      Cross Section of the Total BTEX Distribution at the Demonstration  
                 Site

## ACRONYMS AND TERMS

µg/L	micrograms per liter		
AATDF	Advanced Alternative Treatment Demonstration Facility	ppmv	parts per million by volume
BTEX	benzene, toluene, ethylbenzene, and total xylenes	PVC	polyvinyl chloride
CA	chloroethane	QAPP	quality assurance project plan
cm/day	centimeters per day	QA/QC	quality assurance / quality control
CoC	chain of custody	RO	remedial objectives
CVOC	chlorinated volatile organic compound	T	treatment monitoring well
1,2-DCE	1,2-dichloroethene	TCE	trichloroethene
DNAPL	dense non-aqueous-phase liquid	TDS	total dissolved solids
DQO	data quality objective	TS	treatability study
EPA	United States Environmental Protection Agency	VC	vinyl chloride
FID	flame ionization detector	VOA	volatile organic analysis
FSP	field sampling plan	VOC	volatile organic compound
ft <sup>3</sup>	cubic feet	Fe	iron
ft <sup>2</sup>	square feet	Na	sodium
gal/day/ft	gallons per day per foot	Mg	magnesium
GC	gas chromatograph	Ca	calcium
gpm	gallons per minute	K	potassium
ISPFS	In situ permeable flow sensor	Mg	manganese
lb	pounds	Ni	nickel
LNAPL	light non-aqueous-phase liquid	Cr	chromium
MCL	maximum contaminant level	Cd	cadmium
MDL	method detection limit	Zn	zinc
mg/L	milligrams per liter	Pb	lead
MS	matrix spike	Cl	chloride
MSD	matrix spike duplicate	SO <sub>4</sub>	sulphate
msl	mean sea level	NO <sub>3</sub>	nitrate
P	performance monitoring well	NO <sub>2</sub>	nitrite
PCE	perchloroethene	NH <sub>4</sub>	ammonium
PID	photoionization detector	HCO <sub>3</sub>	alkalinity (as bicarbonate)

PAGE 1

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# 1. INTRODUCTION

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## 1.1 PROJECT BACKGROUND

A range of remedial responses to groundwater contamination is currently available (Cherry et al., 1996), from removing the source and the current contaminated groundwater to allowing natural attenuation (intrinsic remediation) to provide adequate environmental protection. Research is currently underway at the University of Waterloo (UW) that investigates an intermediate remedial approach; the cutting off of a contaminant plume with in situ contaminant treatment (Barker et al., 1994; Cherry et al, 1996).

Passive and semi-passive approaches to reducing environmental risk posed by contaminated groundwater are of interest to the Department of Defence (DOD). So, DOD established the Advanced Applied Technology Demonstration Facility (AATDF) at Rice University (Rice) under Grant DACA 39-93-1-002. AATDF is supporting research into more passive, in situ treatment of contaminated groundwater within a groundwater control structure termed a funnel-and-gate (Starr and Cherry, 1994). Here, contaminated groundwater is "funnelled" into a small, in situ treatment zone (the "gate") from which remediated groundwater exits. The treatment gate must be passive or semi-passive if the technology is to be cost competitive with other remediation approaches.

It is not unusual for contaminated groundwater to contain several organic contaminants at once. These substances may be treatable with existing in situ technologies, but they are often not treatable with the same technology. This research is aimed at combining two technologies known to degrade organic pollutants in situ, to treat a plume containing a mixture of contaminants. These technologies will be adapted for use in sequence in a funnel-and-gate system, operated in a semi-passive fashion.

The AATDF project consists of two technical parts: a detailed field testing program being conducted at C.F.B. Borden, Canada, and a follow-up, pilot-scale demonstration to be conducted at NAS Alameda, CA. The first part is to evaluate the relative performances of four passive and semi-passive treatment technologies employed in combination in a well-controlled field trial. The second part is applying the preferred technologies at a "real site" in a pre-existing plume. This will be done at pilot-scale: small enough to be cost effective but large enough to encompass challenges anticipated in applying this technique at full scale.

## 1.2 PROJECT OBJECTIVES

The overall objectives of the AATDF research project are to critically evaluate and compare the performance of several in situ treatment technologies in a semi-passive and passive flow control structure and to apply selected technologies to the remediation of a contaminated site. A pilot-scale demonstration is proposed in the southern part of Site 1, NAS, Alameda (Figure 1-1).

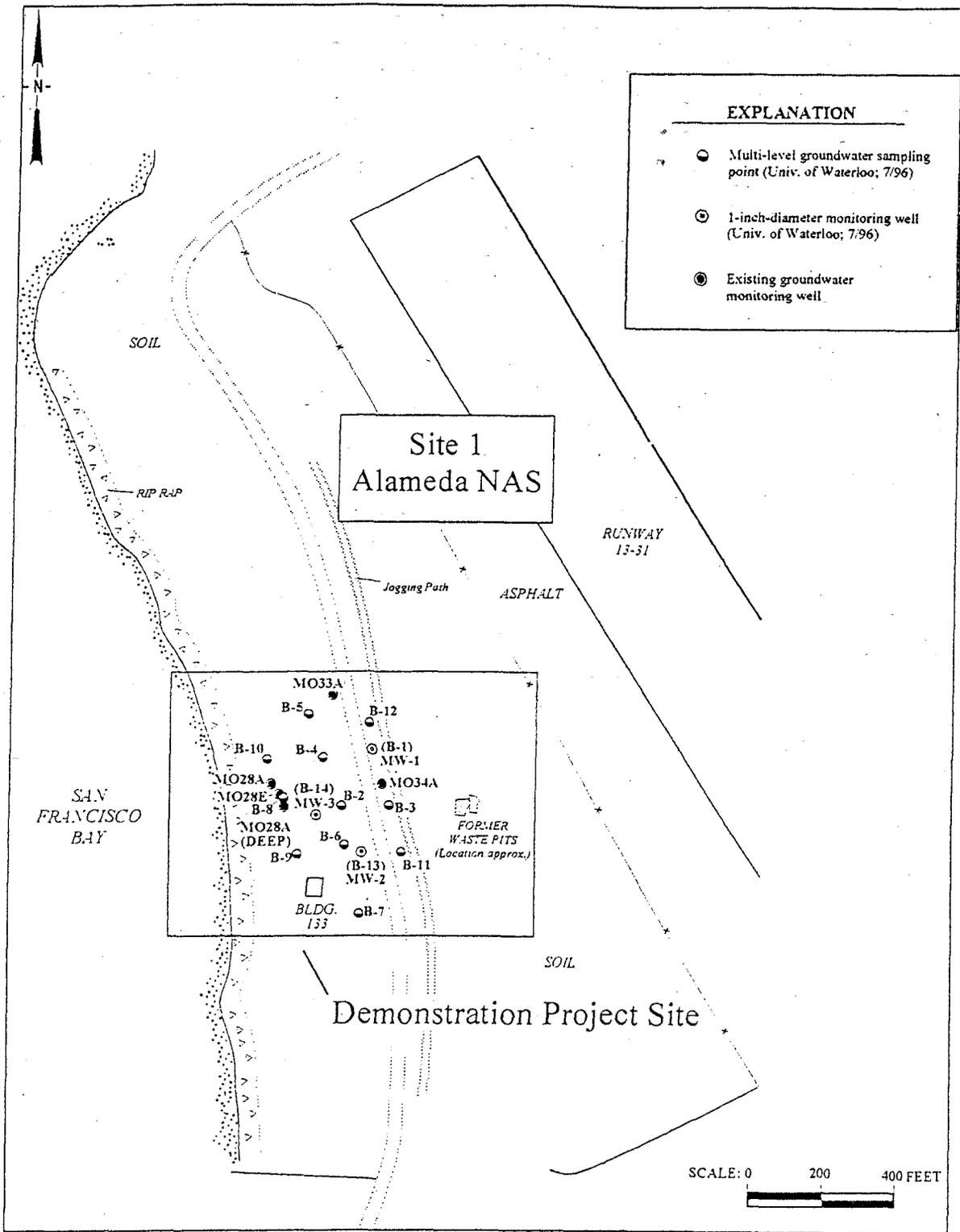


Figure 1-1. Site Map and Location Study Area

For the pilot-scale field demonstration at Site 1, NAS Alameda, the specific objectives are:

1. to demonstrate the attainment of remedial objectives for target organics, Fe, and the attainment of near-neutral pH (5 to 8.5)
2. to provide clear guidance and advice for applying this remedial technology at full-scale here and at other sites.

A pilot-scale funnel-and-gate, in situ remedial system will be installed and its performance evaluated by analysing groundwaters for contaminants before, during and at the end of the groundwater's passage through the remedial gate. A control (unremediated) gate will also be installed to assess intrinsic remediation.

The contaminants of interest for this experiment consist of both chlorinated volatile organic compounds (CVOCs) such as TCE, DCE isomers, and VC as well as monaromatic hydrocarbons, specifically BTEX. In the vicinity of the proposed pilot-scale field demonstration, CVOCs range up to about 80 mg/L while BTEX ranges up to about 8 mg/L (Appendix A). These compounds may reasonably be expected to transform under the conditions imposed by the treatment modules and so will provide a clear test of the effectiveness of sequential treatment within a gate. A table of representative groundwater concentrations from Site 1 for these organics is shown as Table 1-1. The specific locations (BH03-1 and MW-3) represent the area in which the gate will be placed.

While the AATDF research project is most concerned with a clear and critical demonstration of the remedial technology's capabilities and limitations, it is proposed to set remedial objectives (ROs) for the proposed demonstration treatment system at Alameda. The ROs should approach typical maximum contaminant levels (MCLs), but could also reflect more relaxed levels typically developed in site-specific, risk management approaches or typically proposed where additional natural attenuation is available before receptors are impacted. The AATDF project can still be considered a success if the ROs are not attained, as long as the capabilities and limitations of the technology are clearly defined. The remedial objectives proposed for this demonstration are listed in Table 1-1 along with California's MCLs for drinking water quality criteria and US EPA Marine Ambient Water Quality Data (USEPA, 1992).

Table 1-1. Remedial objectives for Site 1, NAS Alameda, California, MCLs, and Marine Ambient Water Quality Criteria.

Chemical Parameter	BH03-1 (ug/L)	MW-3 (ug/L)	Proposed Remedial Objective (ug/L)	California MCL (ug/L)	Ambient Water Quality (ug/L)
TCE	240	8	5	5	2000
1,1 DCE	390	43	6	6	224,000
trans 1,2 DCE	320	68	10	10	224,000
cis 1,2 DCE	219,000	22,400	10	6	224,000
VC	167,000	4,800	2	0.5	--
Benzene	290	55	10	1	5100
Toluene	8800	960	150	150	5000
Ethylbenzene	170	51	150	700	430
Xylenes, total	1000	160	150	1750	--
Iron		10.5 (mg/l)	0.5 mg/L	--	--
pH			5 - 8.5 (pH units)	--	--

Note: -- no reported criteria.

### 1.3 PROJECT OVERVIEW

A segment of the shallow, water-table aquifer at Site 1 at NAS Alameda has been found to contain a mixed-organic plume (section 2.0) and has been selected as the demonstration site. The construction of the funnel-and-gate system is scheduled to begin in November, 1996, with performance evaluation scheduled from December, 1996 to August, 1997, contingent upon approval of the work plan.

The pilot-scale funnel-and-gate remedial system will have two gates: one in which the remedial system will be operated and the other where no system will be installed (see Figure 1-2). The latter will act as an unremediated control, to define the extent of intrinsic remediation. This will permit clearer attribution of remediation success in the remedial gate to the remedial system.

Groundwater sampling throughout the remedial and control gates will provide the data to assess the operation and success of the remedial system. A final report in October 1997 will present the results and will discuss the potential for full-scale remediation using this remedial approach here and at other sites.

Site assessment studies were completed in August, 1996 and are described in Appendix A.

Additional site work was conducted in October, 1996, involving depth-discrete groundwater sampling at five locations and selected coring at two locations. While sufficient site assessment was completed in August to design the pilot-scale system, the additional subsurface investigation:

1. assisted in optimizing the location of the demonstration system
2. confirmed the depth and characterisation of the top of the aquitard at between 22 and 24 ft. below ground surface (bgs), which will facilitate construction contractor bidding
3. better defined the site material contamination levels to better anticipate disposal requirements
4. will provide for the recommendation of the level of subsurface investigation required to design and install a funnel-and-gate system at other sites by "over investigating" this site

This document presents the work plan for the pilot-scale demonstration at Site 1, NAS Alameda.

## **1.4 TECHNOLOGY DESCRIPTION**

Groundwater in a shallow, unconfined, sand aquifer at Site 1, NAS Alameda has been found to contain both chlorinated ethenes (TCE, DCE isomers, VC) and monoaromatic hydrocarbons (i.e., BTEX). The in situ technologies planned for testing at NAS Alameda to treat such groundwaters through: 1) reductive dechlorination of chlorinated ethenes by contact with zero valent iron ( $Fe^0$ ) in a permeable, reactive barrier, and 2) in situ aerobic bioremediation of petroleum hydrocarbons, stimulated by minimal oxygen addition using an in situ biosparge system.

### **1.4.1 Sequential Treatment System**

The novel aspect of this technology is the combination of the  $Fe^0$  and  $O_2$  biosparge systems sequentially within a funnel-and-gate system. Sheet piling "funnels" will direct contaminated groundwater into a remedial gate (see Figure 1-2). The initial gate segment will provide contact with  $Fe^0$  for remediation of the chlorinated ethenes followed by contact with carbonate minerals. Then the groundwater will pass into a biosparge zone, where oxygen addition will support aerobic biodegradation of aromatic hydrocarbons.

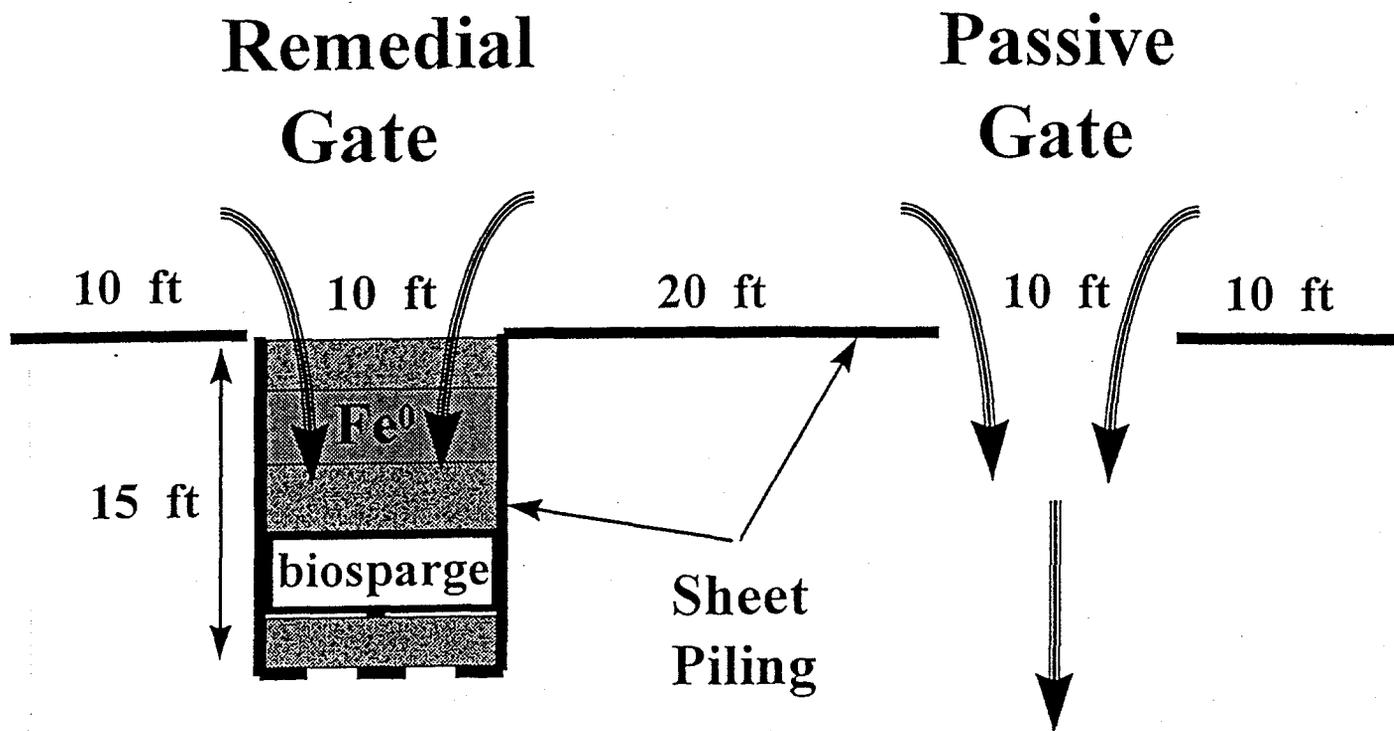


Figure 1-2. Schematic Layout of the pilot scale system showing both the remedial and control gates.

### 1.4.2 Fe<sup>0</sup> Treatment Technology

Laboratory and field tests have shown that under highly reducing conditions and in the presence of metallic surfaces, certain dissolved chlorinated organic compounds in groundwater will degrade to non-toxic compounds such as ethene, ethane, and chloride. The process appears to be abiotic reductive dehalogenation, with the metal serving to lower the Eh in solution and serving as an electron source in the reaction (Gillham & O'Hannesin, 1994; Gillham, 1996). Using iron as the reactive metal, reaction half-lives (the time required to degrade one half of the original contaminant mass) are commonly several orders of magnitude lower than those measured under natural conditions. Because of these high rates of degradation, the low cost of the iron, the passive nature of the reaction, and because the compounds are degraded with production of very little hazardous (chlorinated) organic by-products, the technology appears to have great promise for the remediation of contaminated groundwater. Envirometal Technologies Inc. (ETI) apply and license this technology (Focht et al, 1996).

The in-situ application of the technology involves the installation of permeable treatment walls containing iron across a plume of groundwater containing CVOC. Dissolved CVOCs are degraded as they move through the wall with groundwater under naturally occurring flow conditions

Over 30 successful bench-scale (laboratory) studies of the Fe<sup>0</sup> technology using groundwater from various industrial sites have been completed in the past two years. A successful in situ field trial has been operating at the University of Waterloo Borden test site since 1991 (O'Hannesin, 1993), and nine other field-scale in-situ installations have occurred during the past two years. The technology is being used successfully to treat trichloroethene (TCE), cis-1,2-dichloroethene (cDCE) and vinyl chloride (VC) at several field installations

Based on previous studies the iron zone will be able to treat the major chlorinated aliphatics present at Site 1. The inorganic geochemistry of the groundwater at Alameda is similar to others that have been tested and should not pose an impediment to technology application.

### 1.4.3 Biosparge Technology

To enhance the biodegradation of petroleum hydrocarbons, oxygen must be added to the contaminated groundwater. The ongoing studies at CFB Borden, sponsored by AATDF, are evaluating a number of methods for adding O<sub>2</sub> to groundwater:

1. funnelling the contaminated groundwater through a zone containing oxygen-releasing solid compound (ORC) which releases O<sub>2</sub> to dissolve in the groundwater
2. introducing pure O<sub>2</sub> gas into the contaminated groundwater via a bubbling system, termed a biosparge system
3. allowing O<sub>2</sub> to diffuse through plastic tubing into the contaminated groundwater

Additional experience at other field sites is being gained in ongoing projects with the above listed systems: system 1 (Chapman et al., 1996; Granger, in prog.), system 2 (Gorman, J., 1995; Bowles et al., 1995), and system 3 (Wilson and Mackay, 1995). All systems produce the desired biodegradation of BTEX with rates of biodegradation apparently site specific.

Based on the Borden studies and these other experiences we have selected the O<sub>2</sub> biosparge system for the pilot-scale field demonstration. Porous tubing, installed in the bottom of a zone in the Treatment gate and pressurised with O<sub>2</sub> gas, emits small O<sub>2</sub> bubbles into the groundwater. The zone contains only groundwater and bacteria growth support material. The sparged O<sub>2</sub> dissolves in the groundwater, supporting the biodegradation of the hydrocarbons by natural aerobic bacteria attached to the growth support material.

The excess O<sub>2</sub> gas, perhaps containing some volatile organic compounds (VOCs), are contained in an in situ headspace bioreactor, where aerobic biodegradation of any BTEX is completed, if necessary.

## 1.5 PROJECT ORGANIZATION

The project organization for this project is shown in Figure 1-3.

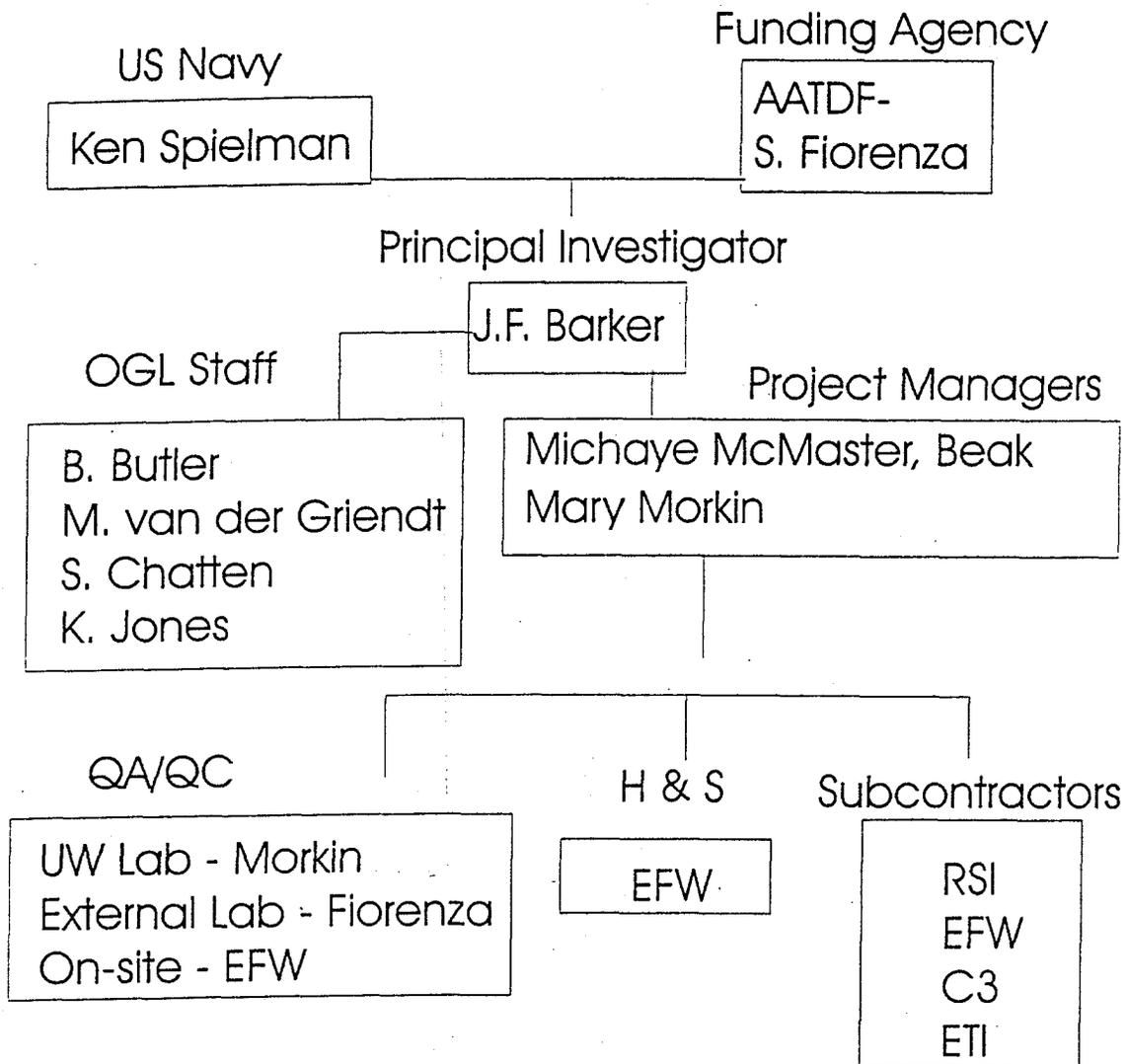


Figure 1-3. Organizational chart for the Field Demonstration Project

## 2. SITE DESCRIPTION

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### 2.1 SITE 1 HISTORY

Located in the northwestern part of Alameda NAS, Site 1 is constructed on artificial fill placed on top of natural Bay Mud estuarine deposits (silts and clays). Historical information indicates that filling occurred in the late 1930's (PRC, 1993). The fill soil was dredged from around Alameda island and was hydraulically placed on top of the Bay Mud.

Beginning in the 1940's, cleaning solvents and waste petroleum hydrocarbons were disposed of in unlined waste pits excavated in the fill soil in Site 1. Small quantities of solid waste were also disposed of in the waste pits. One historic disposal area, labelled as "Former Waste Pits" in Figure 1-1, is apparently the source of a plume of dissolved chlorinated organics and petroleum hydrocarbons that flows westward to the San Francisco Bay. This dissolved plume is the location of this demonstration project. The locations of the waste pits have been defined from historic aerial photographs (PRC, 1993). The depth of the waste pits is unknown, however, it is unlikely that the waste disposers would have excavated the pits much deeper than the groundwater table (4 to 7 feet below ground surface [bgs]) because of flowing sand conditions.

### 2.2 HYDROGEOLOGY

#### 2.2.1 Site 1 Area

##### 2.2.1.1 Geology

Site 1 overlies a 400- to 500-foot-thick sequence of Quaternary unconsolidated sediments that unconformably overlie Jurassic/Cretaceous Franciscan bedrock (Rogers and Figuers, 1991). The upper 100 or so feet of these sediments are, from oldest to youngest, Late Pleistocene Estuarine Deposits, Late Pleistocene/Holocene Alluvial/Eolian Deposits, Holocene Bay Mud Unit, and Artificial Fill (PRC, 1993). A cross section drawn along the western edge of Site 1, along the margin of the San Francisco Bay, is included at the end of Appendix A. The location of the cross section is shown on a map included at the end of Appendix A.

As shown in the cross section, sandy artificial fill occurs from the ground surface to a depth of approximately 20 feet bgs. The sandy fill rests on top of Holocene Bay Mud (silt and clay) which was the sea floor prior to placement of the fill. As shown in the cross section, the Bay Mud Unit is approximately 15- to 20-foot-thick in the western portion of Site 1.

##### 2.2.1.2 Groundwater Occurrence and Flow

The sediments beneath Site 1 are subdivided into two aquifers. The deeper one, which contains brackish water, consists of undivided Pliocene/Pleistocene coarse-grained terrestrial

deposits at a depth greater than 200 feet bgs (PRC, 1993). The shallower aquifer, which occurs within 100 feet of the ground surface, consists of two separate water-bearing zones. The shallowest water-bearing zone in the upper aquifer consists of the sandy artificial fill. Groundwater within this unit is unconfined, with a water table that fluctuates seasonally. The second water-bearing zone occurs within sandy sediments below the Holocene Bay Mud Unit, from a depth of approximately 35 to 75 feet bgs (see cross section in Appendix A). Groundwater within this unit is semi-confined (PRC, 1993).

In the conceptual hydrogeologic model of the site, shallow groundwater is recharged through unpaved surface areas at NAS Alameda and flows radially outward to the Bay (PRC, 1993). As the fresh groundwater nears the edge of the island, it mixes with saline water in the Bay. This conceptual model is complicated by the internal structure of the artificial fill and by tidal effects.

A review of historic aerial photographs indicates that the artificial fill was placed in east-west-trending rows (PRC, 1993). Since the fill was placed into standing water, graded deposits may have developed as the sediments settled in the water. Thus, the permeability of the fill may be anisotropic, having a greater horizontal permeability parallel with the east-west-trending rows of artificial fill.

Since Site 1 is surrounded on two sides by the San Francisco Bay, tidal effects in the shallow aquifer are pronounced. A comprehensive study of the hydraulic effects of the tides was performed in April 1992 (PRC, 1993). In that study, tidal fluctuations in site groundwater monitoring wells was monitored using electronic pressure transducers. As would be expected, the most pronounced water level changes occurred in wells located near the edge of the Bay. Also, tidal fluctuations were relatively small in the uppermost artificial fill water-bearing zone. This is due to the unconfined nature of the unit (unconfined aquifers have large storage coefficients, therefore, they show smaller water level changes).

Calculating the mean groundwater flow direction in aquifers affected by tidal fluctuations requires filtering the water-level data. Average groundwater elevation contours for the uppermost artificial fill water-bearing zone were calculated in April 1992 using the method of Serfes (PRC, 1993). A contour map showing groundwater contours corrected for tidal effects is included at the end of Appendix A. As shown in the contour map, the averaged groundwater elevation contours mimic the shape of the northern part of Alameda Island, with higher elevation contours in the interior of the island and lower contours along the margin of the Bay. This supports the conceptual groundwater flow model of groundwater flowing radially from the center of the island outward to the Bay. Groundwater flow in the Site 1 area is estimated to be primarily horizontal due to the presence of the underlying Bay Mud aquitard and the location of groundwater recharge and discharge areas. As shown in the contour map (Appendix A), groundwater in the Site 1 area flows to the west where it discharges to the Bay. The average groundwater gradient in the Demonstration Site area in April 1992 was approximately  $1.8 \times 10^{-3}$ . Given a hydraulic conductivity (K) value of  $2.2 \times 10^{-3}$  centimetres per second (cm/sec.) and an assumed effective porosity of 20%, the average groundwater tracer velocity in April 1992 was  $5.7 \times 10^{-2}$  feet per day (approximately 21 feet per year).

### 2.2.1.3 Inorganic Groundwater Quality

Groundwater in the first aquifer beneath Site 1 is affected by saltwater intrusion or mixing with saline Bay water to various degrees. Salt water impacts to the uppermost artificial fill water-bearing zone are relatively minor in the Site 1 area. Samples collected from groundwater monitoring wells within the artificial fill water-bearing zone (designated with an "A" or "E" suffix) during the 1993 SWAT investigation contained total dissolved solids (TDS) ranging from 800 to 8,700 mg/l. This is much lower than TDS concentrations within the same hydrogeologic unit further south in Site 2. The reason for the relatively fresh water quality within the artificial fill in Site 1 likely has to do with the source of groundwater recharge there. Groundwater in the fill in Site 1 is recharged directly by infiltration of precipitation. There are large unpaved and grassy areas that allow infiltration of precipitation (PRC, 1993).

Groundwater in the underlying Pleistocene/Holocene deposits (the second water-bearing zone in the first aquifer) contains much higher concentrations of TDS than the overlying artificial fill water-bearing zone. Groundwater samples collected from monitoring wells completed in the deeper unit (i.e., monitoring wells labelled with a "B" or "C" suffix) contained TDS ranging from 11,900 to 19,600 mg/l in April 1992 (PRC, 1993). This suggests that groundwater within the deeper water-bearing zone is in direct hydraulic communication with San Francisco Bay (PRC, 1993).

### 2.2.2 Demonstration Project Site

The Waterloo Demonstration Project Site is located in the southwestern part of Site 1, adjacent to San Francisco Bay (see Figures 1-1 and 2-1). As discussed in Section 1, this area was selected for the experiment because of its hydrogeologic characteristics and contaminant blend and distribution. The demonstration site is located within a small contaminant plume that apparently emanates from two historic waste disposal pits near Runway 13-31 and flows westward before discharging to San Francisco Bay (Figure 2-1). The contaminant plume was identified during an earlier investigation of groundwater contamination at Alameda NAS. Several monitoring wells were subsequently installed to further define the hydrogeology and contaminant plume (Figure 2-1).

A more focused, three-dimensional evaluation of the subsurface conditions at the Demonstration Project Site was performed by the University of Waterloo in July 1996. During that investigation, a University of Waterloo scientist, along with Einarson, Fowler & Watson (EFW), a subcontracted hydrogeologic consulting firm, further characterised the site hydrogeology and nature and extent of groundwater contamination. During the July 1996 investigation, continuous soil cores were collected at three locations to further delineate small-scale lithologic variations within the artificial fill. Depth-discrete groundwater samples

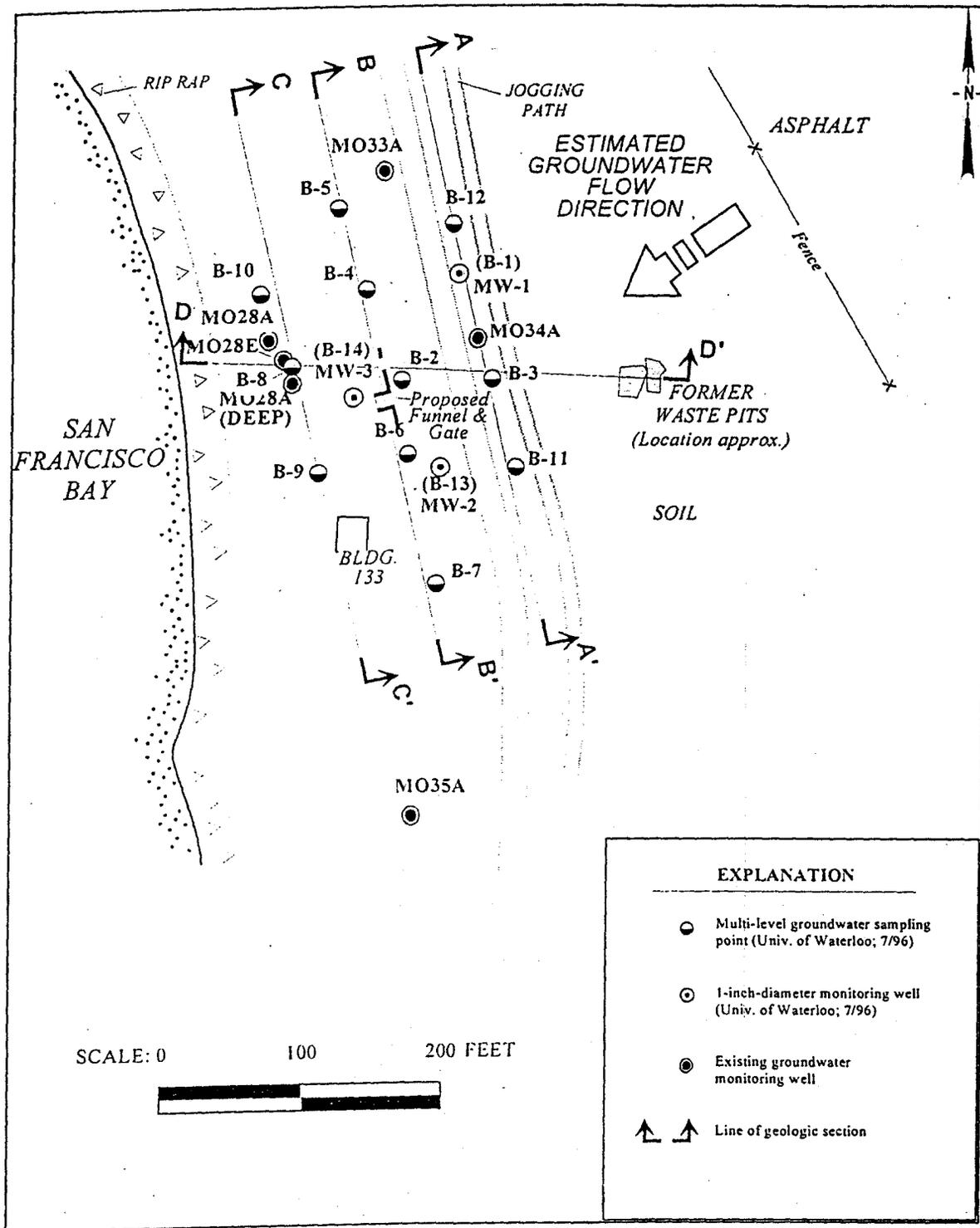


Figure 2-1. Demonstration Project Site

were collected using the Waterloo drive-point profiler, a direct-push groundwater sampling tool that can collect groundwater samples from multiple depths without installing permanent monitoring wells. Stabilised groundwater elevations were measured, and hydraulic tests (slug tests) were performed in three new 1-inch-diameter monitoring wells screened across the entire artificial fill water-bearing zone. Groundwater samples were also collected for inorganic chemical analyses, and bulk groundwater samples were collected for the treatability study. All chemical analyses were performed at the University of Waterloo. Details of the July 1996 investigation, including boring logs and slug test calculations are documented in a August 7, 1996 letter report from EFW to Dr. Jim Barker, AATDF Principal Investigator. A copy of that letter report is included as Appendix A in this workplan.

The results of the additional investigation in October, 1996 is also presented in Appendix A. This investigation included the collection of depth discrete groundwater samples at about 8.5, 11, 13, 16, and 20 ft bgs at 5 locations. Additionally, core was recovered from 2 locations to obtain samples for chemical characterisation and to visually define the depth to the aquitard in the area anticipated for the demonstration project. Basically, the aquitard was encountered at a greater depth (24 versus 22 ft bgs) than in the previous investigation, causing some design changes for the funnel-and-gate system. As in the July groundwater sampling, organic contaminants were found to be very stratified. Very high concentrations were encountered at shallow depths (11 and 13 ft bgs) at the north end of the demonstration site, with VC ranging up to 14 mg/L, c 11 DCE ranging up to 211 mg/L, and toluene up to 4 mg/L. In the south section of the demonstration site, 1 - 3 mg/L levels of VC and c12 DCE were encountered only in the deepest groundwater sample; a very different distribution compared to all previous investigations.

#### 2.2.2.1 Geology of Artificial Fill Unit

The artificial fill in the vicinity of the Demonstration Project Site is generally silty sand to sand (SM to SP in the Unified Soil Classification System [USCS]), containing from approximately 5 to 15% fines (i.e., soil having a grain size smaller than a number 200 sieve). However, the very upper portion of the unit, to a depth of approximately 4 feet, contains more silt-size sediment, up to 40% of the sample. Moreover, a thin (approximately 2-foot thick), dark gray sandy clayey silt layer was penetrated in all three exploratory borings from a depth of approximately 4 feet to 6 feet bgs. The base of the sandy artificial fill occurs at the contact with the underlying Bay Mud clay, at a depth of approximately 22 - 24 feet bgs (Appendix A).

#### 2.2.2.2 Groundwater Depth and Flowfield

2.2.2.3 Unconfined groundwater was encountered at a depth of approximately 4 to 7 feet bgs during the July 1996 investigation. Groundwater contours were constructed using stabilized groundwater elevations in the three newly-installed monitoring wells (Figure 2-2). The groundwater flow direction depicted in Figure 2 is toward the west, consistent with the Site 1 regional groundwater flow direction. Note, however, that the groundwater contours shown in

the figure were constructed using a single elevation measurement (measured on July 27, 1996). The groundwater contours were not constructed using filtered data to account for tidal effects.

#### 2.2.2.4 Groundwater Velocity

Using the hydraulic gradient calculated from Figure 2-2, the mean hydraulic conductivity value obtained from the July 1996 slug tests, and an assumed effective porosity of 30 percent, the groundwater seepage velocity is  $6.09 \times 10^{-6}$  feet per day (approximately 9.5 feet per year).

Note, however, that the calculated groundwater gradient may be significantly influenced by the tidal cycle. Therefore, firm conclusions regarding groundwater velocity in the Demonstration Project Site should not be drawn without considering variations in the hydraulic gradient caused by the fluctuating tides.

#### 2.2.2.5 Inorganic Groundwater Quality

Samples of groundwater were collected from newly-installed well MW-3 during the July 1996 investigation and analysed for inorganic constituents, including major ions. Chloride was measured in the sample at a concentration of 1130 mg/L. This concentration is similar to concentrations measured in samples collected from the artificial fill water-bearing zone during previous investigations (PRC, 1993).

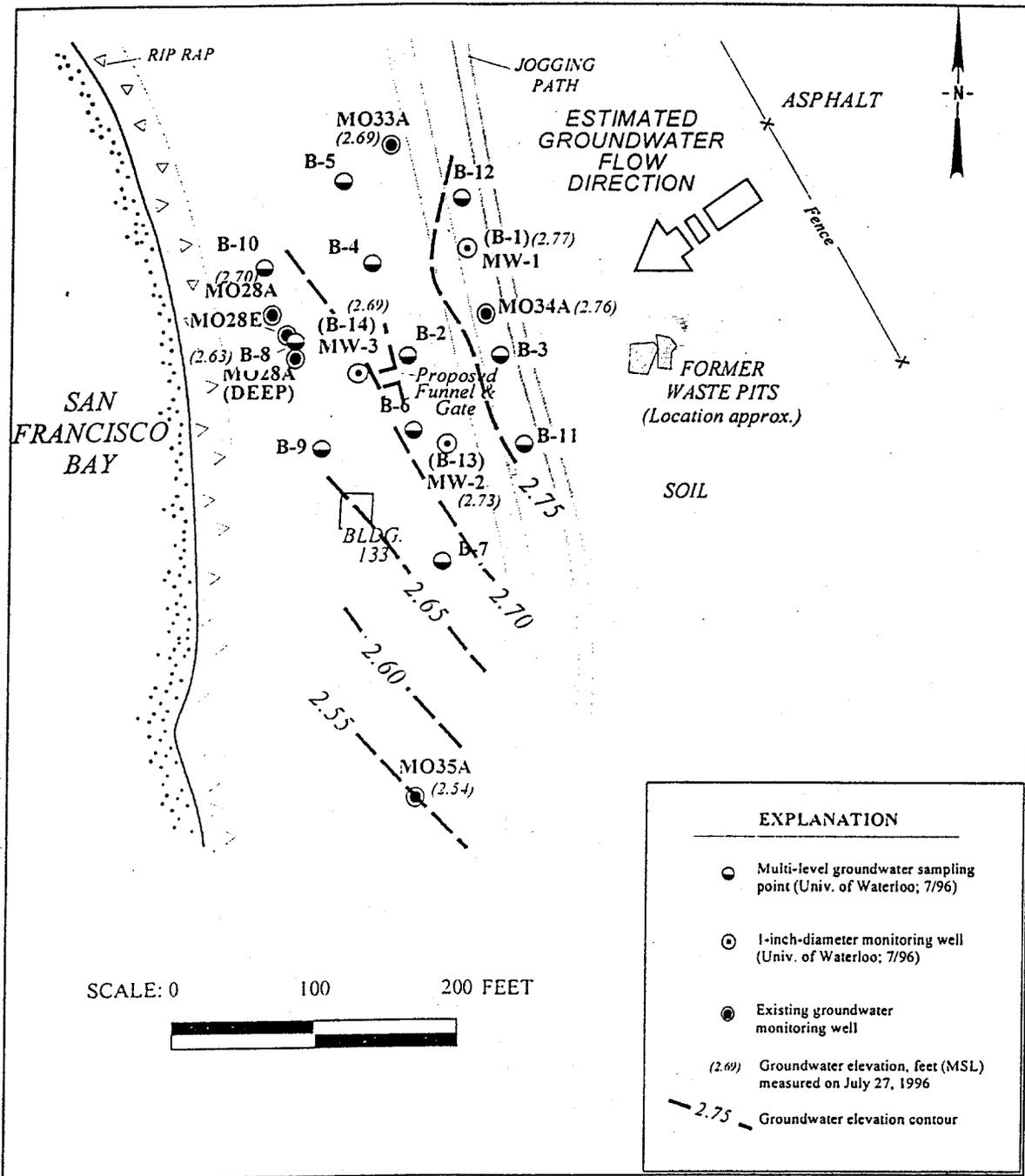


Figure 2-2. Groundwater Contours, July, 1996

## **2.3 NATURE AND EXTENT OF CONTAMINATION IN DEMONSTRATION PROJECT**

### **2.3.1 Chlorinated Organics**

High concentrations of dissolved chlorinated organic compounds, primarily cis 1,2, dichloroethene (cis 1,2 DCE) and vinyl chloride (VC), occur in groundwater beneath the Demonstration Project Site (a summary of the organic analyses is included at the end of Appendix A). The July 1996 field investigation provided a clear view of the three-dimensional distribution of these contaminants (Plate 1). Note that the highest concentrations of CVOCs occurs within the upper portion of the artificial fill water-bearing zone. Since groundwater flow within the unit is primarily horizontal, this suggests that the source of the contamination is relatively shallow. The former waste pits were apparently not excavated very deep below the watertable. Also, the shallow occurrence of dissolved contamination suggests that DNAPL does not occur near the base of the artificial fill unit. If it did, higher concentrations of dissolved CVOCs would have been measured at the base of the artificial fill unit downgradient from the source area.

To show the location of the contaminant plume in plan view, the peak concentrations in each sampling probe have been contoured and are shown Figure 2-3. Inspection of this figure clearly shows a contaminant plume emanating from the former waste disposal pits. The plume has a fairly narrow core of high concentrations of contaminants (i.e., greater than 1,000 µg/L of total CVOCs), which is aligned east-west from the suspected source area through new well MW-3 and existing well M028E. The west-trending orientation of the contaminant plume supports the regional and site-specific conceptual model of groundwater flowing to the west and discharging to the San Francisco Bay.

### **2.3.2 Petroleum Hydrocarbons**

Moderate concentrations of benzene, toluene, ethylbenzene, and xylenes (BTEX) were detected in many of the groundwater samples collected during the July 1996 investigation (see Appendix A). These compounds apparently result from the historic disposal of petroleum hydrocarbons in the suspected waste pits. The vertical distribution of total BTEX in the subsurface is depicted in Plate 2. Contours of peak concentrations from multi-level samples are shown in Figure 2-4. The core of high total BTEX (i.e., greater than 1,000 ug/l) coincides with high total chlorinated hydrocarbon concentrations aligned east-west with the suspected source area.

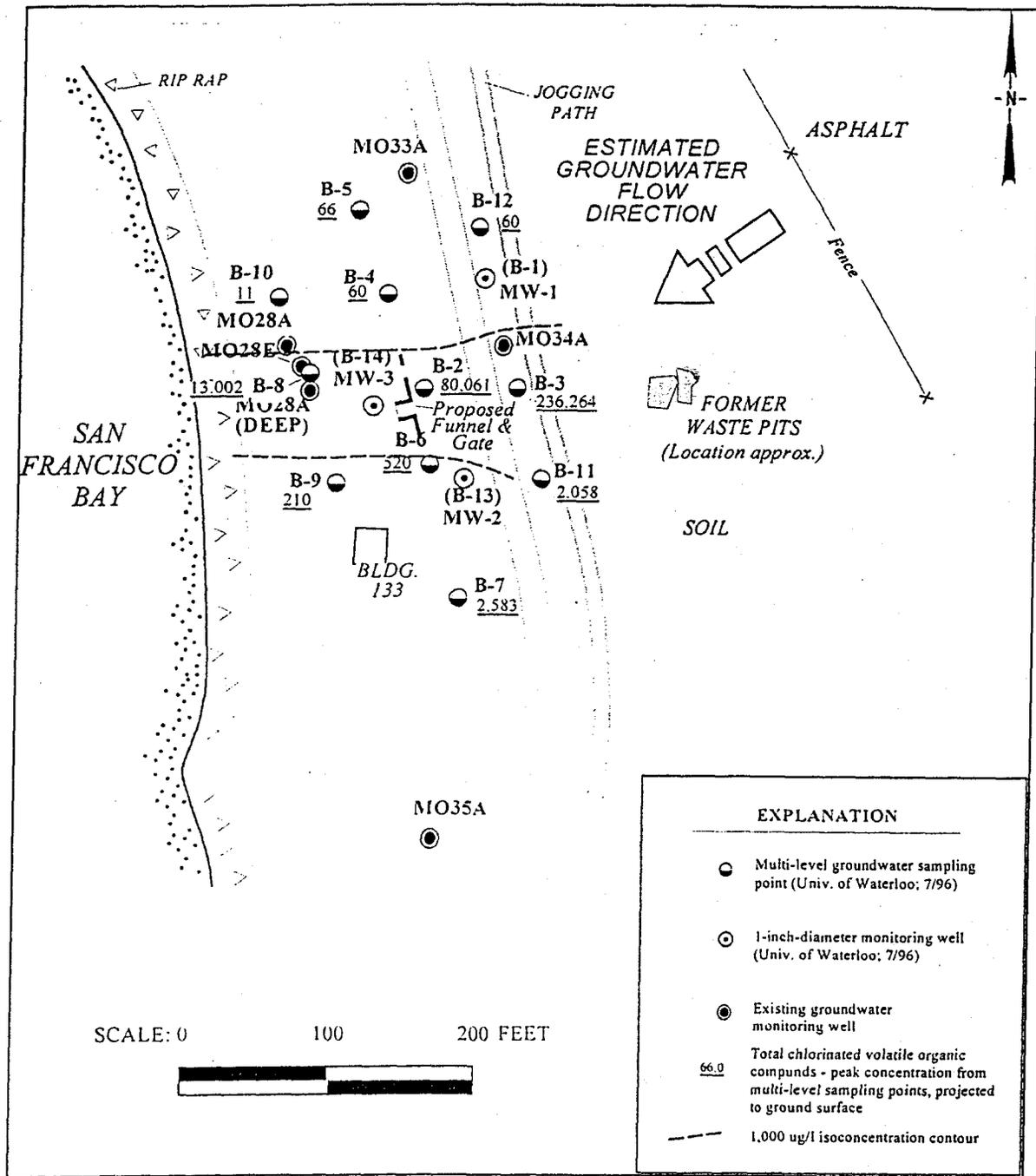


Figure 2-3. Total Chlorinated Organic Compounds in Groundwater, July, 1996

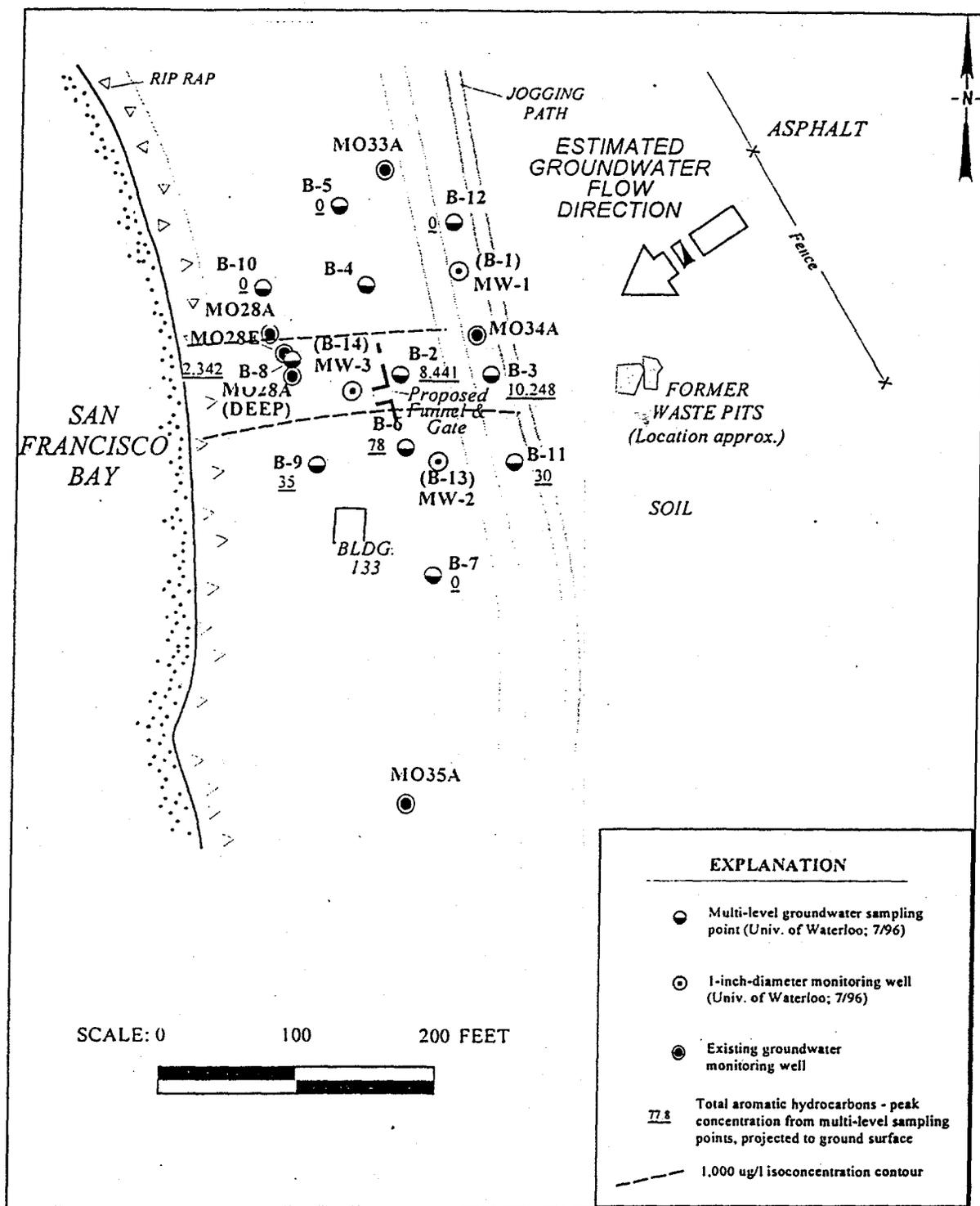


Figure 2-4. Total BTEX in Groundwater, July 1996

While BTEX are common indicators of dissolved petroleum hydrocarbon contamination, they may underestimate the amount of hydrocarbons dissolved in the groundwater. Soil samples collected during the July 1996 field investigation suggest that the petroleum hydrocarbon release may have occurred long ago. Soil samples collected near the water table in the Demonstration Project Site area were commonly gray-black and had a faint to moderate petroleum odor (see Appendix A). This may indicate that free LNAPL or high amounts of residual petroleum hydrocarbons were once present in the artificial fill water-bearing zone and have since biodegraded.

### 2.3.3 Radioactive Wastes

Radioactive instrument dials were disposed in some parts of Site 1. A comprehensive survey of near-surface gamma radiation was performed at the site in 1996 (PRC, 1996). This work resulted in discovery and removal of several "hot spots" of low level gamma radiation, some of which were near the Demonstration Project Site (PRC, 1996). During the July 1996 site investigation, soil cores were screened for gamma radiation. No radioactivity was detected in any of the soil cores.

While all known radiation hot spots were removed, some unknown radiation sources may occur beneath the ground surface in the project area. However, residual gamma radiation is limited to the area immediately around the sources. Moreover, low-level radiation is not imparted to flowing groundwater, so radiation plumes are not an issue. Potential low-level radiation in the project area from unknown residual sources is a concern from a health-and-safety standpoint, however. Health and safety hazards and precautions are described in detail in Appendix F of this workplan.

### **3. DEMONSTRATION PROJECT DESIGN AND SPECIFICATIONS**

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#### **3.1 OVERVIEW**

A funnel-and-gate system has been designed to meet the objectives of the Demonstration Project at Site 1. These objectives are:

1. to demonstrate the attainment of ROs for target organics, Fe, and the attainment of near-neutral pH in remediated groundwater, and
2. to provide clear guidance and advice for applying this remedial technology at full-scale here and at other sites.

While the focus of the treatability study is the treatment gate, a funnelling structure must be designed and an untreated or control gate will be included to clarify the extent of intrinsic remediation in the demonstration site. The design of the hydraulic performance of this funnel-and-gate system is important in that it will define the flux of groundwater moving through the treatment and control gates. However, a secondary objective of this design is to provide a system that could be upgraded to full-scale operation with minimal costs to meet at least some potential remedial objectives at Site 1.

The site geology (section 2.0) permits the funnel-and-gate structure to be extended to the aquitard, at about 22 - 24 ft bgs, underlying the shallow, contaminated, water table aquifer. This "keying in" of the system to the aquitard minimises underflow of contaminated groundwater and so permits more complete and reliable funnelling of contaminated groundwater through the gate. This improves the reliability of the performance assessment since little untreated groundwater can enter the treatment gate monitoring network after bypassing part of the treatment system in the gate. It also improves the potential for full scale plume treatment performance. The narrow, high-concentration chlorinated ethenes - BTEX plume in the groundwater at Site 1 can probably be captured by cost-effective extension of the proposed pilot-scale funnel-and-gate system into a full-scale system. This could conceivably be accomplished by installing a treatment gate in the control gate and extending lateral sheet piling funnels.

A funnel and gate layout will be designed with two gates, one gate will receive the remedial installation, while the other will be undisturbed aquifer material acting as an unremediated control gate to document natural (intrinsic) remediation processes. Figure 1-2 shows a schematic layout of the pilot scale system.

The concept is to have the contaminated groundwater first pass through a permeable zone packed with sand or pea gravel which has been mixed with granular iron ( $Fe^0$ ), approximately 3-5% by weight. The next zone is a permeable zone containing 100% granular iron ( $Fe^0$ ). This is followed by a sand or pea gravel zone containing calcium carbonate gravel (ca. 5% by weight) to precipitate iron, which may be discharged from the  $Fe^0$  treatment zone, as carbonates. Groundwater will then enter a zone where aerobic biodegradation is enhanced

through oxygen addition, termed the biosparge zone. Finally, the gate will have a final sand/gravel zone to facilitate groundwater monitoring and groundwater extraction.

### 3.2 FLUX TO THE GATE

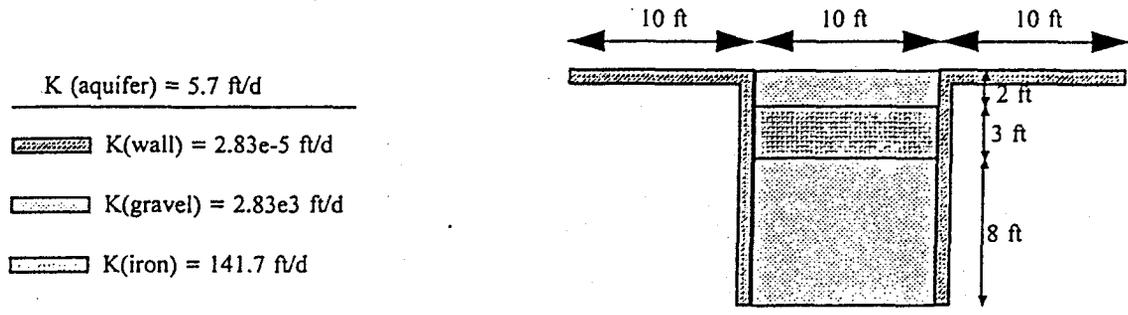
Numerical simulations were used to aid in the design of the funnel & gate configuration, to provide estimates of groundwater discharge rate or groundwater flux through the gate(s), and to provide additional insight into the expected flow system as an aid in the design of the monitoring strategy. The software package Visual MODFLOW (1995) was used to simulate the steady state flow of groundwater and particle tracking at the proposed funnel-and-gate site. Details of the modelling are provided in Appendix B.

Installing the funnel-and-gate system into the underlying aquitard permitted use of a two-dimensional plan view numerical analysis. The shallow, contaminated, aquifer is therefore conceptualized as a single layer that is 22 ft. thick, with a water table 7 ft bgs, a groundwater gradient of 0.005, a porosity of 0.3, and a hydraulic conductivity of 5.7 ft/d. Under these conditions the ambient groundwater velocity was east to west at 0.094 ft/d.

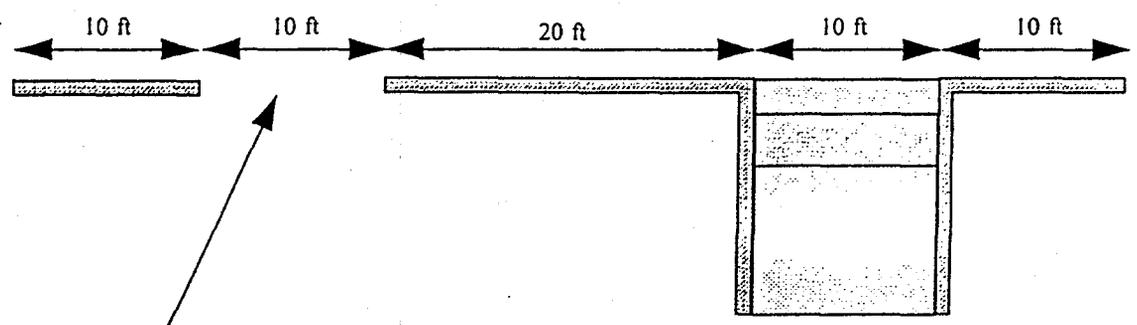
A series of simulations was performed using three funnel and gate configurations (Figure 3-1) and assumed hydraulic properties of the gate materials (see Appendix B). Simulation 2 was selected as the preferred design configuration as it combined a desirable increase in groundwater flow through the gate compared to ambient flow in the aquifer and it was sufficiently wide to capture much of the target plume without capturing the non-plume groundwater (see Appendix B for the other simulation options). With this configuration, groundwater velocity through the gate gravel and through the more-porous  $Fe^0$  was about 0.27 ft/d and 0.20 ft/d, respectively, compared to the ambient groundwater velocity of 0.094 ft/d. These were acceptable in terms of allowing cost efficient treatment zones to be built that still provided adequate residence times (see sections 3.2 and 3.3) in the remedial treatment zones.

The funnel and gate can be designed with a gate width of about 10 ft. The length of the gate does not appear to be an issue, except to note that the groundwater flow paths and velocities through the treatment gate, with its sheet piling sides, will be different than in the control gate. The preferred length of funnels (10 ft beyond gates and 20 ft between remedial and control gates) should produce a flux of groundwater through the remediation gate of about 12.2 ft<sup>3</sup>/day.

# Simulation 1



# Simulation 2



control gate

remedial gate

# Simulation 3

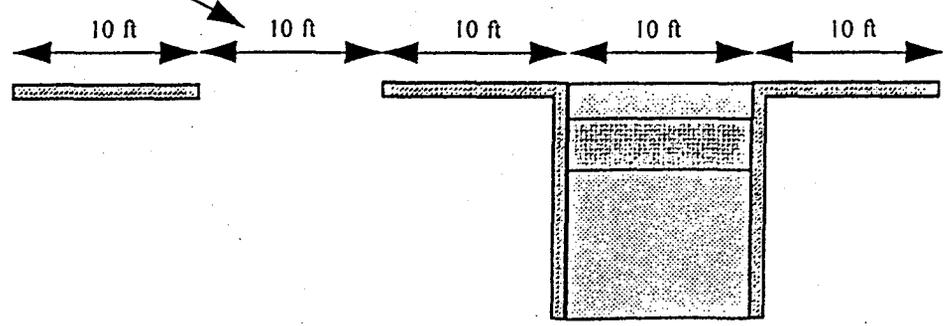


Figure 3-1. Simulation of Funnel-and-Gate configurations.

Additional insights into the monitoring plan were also gained by this modelling. Flow paths for monitoring the progress of the water chemistry are probably available down the center of both gates. More detailed particle tracking reveals that groundwater moves through the treatment gate faster than through the control gate. Therefore, sampling at similar distances into each gate will not represent similar travel times. In addition, groundwater velocity is not consistent across the treatment gate. Groundwater flowing nearest the lateral sides of the treatment gate has the highest velocity and therefore the lowest residence time.

### 3.3 $Fe^0$ TREATMENT ZONE

#### 3.3.1 Required Residence Time of Groundwater in the $Fe^0$ Treatment Zone

An estimate of the residence time required for treatment of groundwater CVOCs in the  $Fe^0$  treatment zone was made using typical CVOC influent concentrations found in groundwater near the demonstration site, degradation half lives derived from a bench scale treatability study (see Appendix C), and inputting this data into a first-order kinetic model (see Appendix C).

The estimate used groundwater concentrations from BH02-1 and monitoring well MW-03 (Table 3-1) as influent concentrations in the calculations. Data from BH02-1 might be considered a high local value, while data from MW-03 may represent a vertically averaged aquifer concentration. The data used is as follows:

Table 3-1: Influent concentration data, remedial objective values and measured degradation rates or compound half-lives.

CVC	Concentration BH2-1 ( $\mu\text{g/l}$ )	Concentration MW-03 ( $\mu\text{g/l}$ )	Remedial Objectives ( $\mu\text{g/l}$ )	Measured Half-Life (hr)
TCE	29.3	7.6	5	1.5
c12DCE	72838.9	22380.6	10	12.1
VC	6766.7	4792.5	2	11.2

Note: Trans-1,2DCE and 1,1DCE will degrade in the time taken for c12DCE to degrade therefore are omitted from this table

Also listed in the above table are measured field degradation rates, shown in terms of half-lives (the time taken to reduce the concentration by 50%). These influent concentrations and degradation rates were input into a first-order kinetic model incorporating concurrent production and degradation of the various organics present (i.e., VC from cDCE and TCE etc.) to calculate the cumulative residence time required for degradation of all compounds to their Federal MCLs, which are close to our ROs. The result of the model is shown graphically in Appendix C. A required residence time of between 7 and 8 days was estimated using data from BH2-1 and from MW-03.

### 3.3.2 Flow-Through Thickness of the Fe<sup>0</sup> Treatment Zone

The design (section 3.2.1) requires 7 or 8 days residence time for groundwater in the Fe<sup>0</sup> material which is assumed to have a porosity of 0.4. At the estimated ambient groundwater flow rate of 0.2 ft/day through the Fe<sup>0</sup>, the flow through thickness of the Fe<sup>0</sup> zone should be at least 1.6 ft.

The treatment gate will initially be operated at an accelerated groundwater velocity, hence the required flow-through thickness will increase as the groundwater velocity increases. At the higher flow flux of 45 ft<sup>3</sup>/d and corresponding flow rate of 0.74 ft/d through the Fe<sup>0</sup> zone, anticipated during initial pumping phases, a flow through thickness of 5.2 and 5.9 ft is estimated. Since the chlorinated solvent plume is not uniform and CVOCs were encountered at one location in concentrations even higher than used in Table 3-1, this thickness may not be adequate locally. However, since mixing and some dilution will occur within the remedial gate subsequent to the Fe<sup>0</sup> zone, and since the potential for breakthrough is only significant during the short phase of accelerated pumping, and since a cost-effective design is desired, it has been decided to implement only a 5 ft flow through thickness for the Fe<sup>0</sup> zone. A flow through thickness of 5 ft will likely attain RO's except, perhaps, at the accelerated flux, and is practical from the construction perspective, and so appears to be the desired thickness in the flow direction. Note that a small portion of Fe<sup>0</sup> (3-5% by weight) will be incorporated into the up gradient sand zone and this should provide additional treatment of CVOCs. Thus, the design requirement for constructing the Fe<sup>0</sup> zone is that it have a minimum thickness in the flow direction of 5 ft.

### **3.4 BIOSPARGE ZONE**

The design objective is to provide sufficient oxygen to groundwater in the biosparge zone for the aerobic biodegradation of the BTEX to ROs. A number of designs were considered, ranging from vertical caissons to gravel-filled zones, to zones without fill. The design selected is an 3 ft flow-through thick, open zone, maintained by sheet piling on the sides and slotted or perforated sheet piling making the up and down gradient ends. Oxygen will be added as a gas, sparged into the gate to raise the resident groundwater DO to about 20 mg/L. The frequency of biosparging will be based on the flux of BOD entering the biosparge zone, but will likely be

less than once per week. The space overlying the water table but under the ground surface will be utilized as a headspace bioreactor, where excess biosparged  $O_2$ , perhaps containing traces of VOCs can reside for sufficient time that the VOCs biodegrade. Appendix D presents the support for the following design and operation approach of the biosparge zone.

The remedial gate should be operated at a flux no greater than about  $45 \text{ ft}^3/\text{day}$ . This flux can be treated by the  $Fe^0$  system and the BOD flux through the biosparge zone can be practically provided by an  $O_2$  gas biosparge system with a flow-through thickness of 3 ft.

Achievement for remedial objectives should be tested at the exit of the biosparge zone and at a point <3 feet down gradient in the final sand or pea gravel zone. It is anticipated that compliance can be attained at the exit from the biosparge zone, but compliance within the engineered gate would also be acceptable. Compliance down gradient of the gate could occur if sufficient DO remains in the groundwater that leaves the biosparge gate to support subsequent, intrinsic aerobic biodegradation of the BTEX in that groundwater. This would likely be acceptable at this and other sites, but additional monitoring and additional uncertainty would be introduced and so is not planned in this pilot-scale test.

### 3.5 REMEDIAL GATE SPECIFICATIONS

Based on the geologic information provided in the July and October detailed subsurface investigations (Appendix A) the gate will be located near MW-3 (monitoring well 3, see figure 2-1). Note that design dimensions are approximate, with some variation allowed to take advantage of cost savings and construction limitations. To secure the system, the sheet piling will be installed into this clay aquitard at 22 - 24 ft bgs. The water table depth varies, but is normally at 7 ft BGS, hence the saturated thickness is approximately 15 ft. The pilot-scale design, as shown in Figure 3-1, consists of a rectangular "box" 10 ft wide by 15 ft in the direction of groundwater flow, flanked by 10 ft of impermeable sheet piling on either side of the remedial and control gates. Therefore, 20 feet (edge to edge) of impermeable sheet piling will separate the remedial gate and the control gate. The "box" will be constructed of sheet piles driven to a depth of about 30 ft (6 - 8 ft into the confining layer). Native unconsolidated material will then be removed to the aquitard, and the various reactive gate zones will be placed within the box. The sand or pea gravel and reactive iron zones will extend through the saturated zone to the aquitard. The reactive iron will be separated from the native material on the upgradient side by a 2 ft thick (in the direction of groundwater flow) sand zone containing 3-5%  $Fe^0$ . The granular  $Fe^0$  will have a minimum thickness of 4.5 ft. Downgradient of the granular iron will be a pea gravel zone (approximately 3 ft thick).

The biosparge system will distribute DO to the groundwater via porous tubing, located at the bottom of the open caisson. This tubing will have small openings to permit small oxygen bubbles to be sparged into the groundwater. The open zone will contain rigid, plastic bacterial growth support medium throughout the saturated thickness. The sparged oxygen dissolves in the groundwater, supporting biodegradation of the hydrocarbons by natural aerobic bacteria attached to the growth support medium.

It is accepted that not all of the sparged oxygen will dissolve into the groundwater, resulting in small quantities of 'off gas' moving up through the biosparge zone into the sealed, unsaturated bioreactor. This bioreactor will be created by extending the sides of the sheet piling up to the ground surface and then sealing it with a top plate. The headspace bioreactor will contain approximately one foot of soft plastic foam which will act as a bacterial growth support media. Any contaminants derived from passive partitioning from the groundwater to the vapour phase, and from volatilisation that occurs during the sparge events will be treated in this zone.

The bottom of the all zones, up and down gradient of the granular iron, will be lined with an impermeable layer, such as concrete, to restrict underlying material from penetrating the treatment zone (phrase deleted; next sentence deleted). After the sections have been installed, the sand and/or pea gravel and granular iron sections will be covered with a geotextile layer and then fill (e.g. clean sand) will be added up to the ground surface. A temporary shed will cover the remedial gate.

The last sand or pea gravel section contains the pumping wells and is approximately 2 feet thick. Groundwater extraction pumps and the last groundwater sampling point can then be located within the engineered remedial gate. Once this section has been installed, the same media will be added up to ground surface and then will be covered by an impermeable liner to prevent any recharge from entering the remedial gate.

Once the remedial gate has been constructed, clean water will be pumped into the gate via the open biosparge gate. This clean water will be used as a tracer test (see section 6.2.1.1). After the gate has been filled, the upgradient end of the box will be removed and the downgradient pumps turned on, forcing groundwater to be pulled into the gate, allowing the experiment to begin.

## **4. DEMONSTRATION PROJECT CONSTRUCTION**

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This section discusses the procedures used to construct the pilot-scale treatment system. C3 Environmental (C3) will provide assistance with construction design, bid documents, bid selection, on site construction and QA/QC support. A State-licensed contractor will be selected for excavation and pile driving activities, based on a competitive bid procedure. The sheet piling will be Waterloo Barrier™ sheet pile fabricated solely by Canadian Metal Rolling Mills Ltd., of Cambridge Ont. Waterloo Barrier™ sheet pile specifications will be followed during the installation. The reactive iron will be supplied by EnviroMetal Technologies, Inc. (ETI). Einarson Fowler and Watson (EFW) will act as the general site engineer/site manager for the project.

The following sections provide an overview of the construction tasks. All work will be performed consistent with the Site Health and Safety Plan (HASP, Appendix F), and the Environmental Protection Plan (Appendix L).

### **4.1 CONSTRUCTION OF THE TREATMENT AND MONITORING SYSTEMS**

A schematic of the proposed as-built treatment gate is shown in Figure 4-1 (following). Final design and construction plans will be produced after discussions with the contractor selected to install the demonstration system, since their input will likely produce a more practical and cost-effective structure. Construction drawings, meeting State requirements, and certified by a Professional Engineer, will be completed once the work plan is approved.

The generalized sequence for construction of the treatment zone includes:

- pre-construction activities including establishing work zones, staging materials and equipment, clearing underground utilities, and conducting radiation surveys
- sheet pile and granular iron media handling
- sheet pile installation & sealing the joints.
- excavation of 'box'
- placement of iron, pea gravel, and biosparge sections with simultaneous installation of all monitoring wells
- flooding of system with uncontaminated water
- sheet pile removal on upgradient side of box

The following sections provide more specific details for each construction step.

#### **4.1.1 Pre-construction Activities**

Before construction activities start, work zones will be established, and the job site will be secured by a standard six-foot cyclone fence. As described in the HASP (Appendix F), the

site will have three primary work areas associated with it: (1) an exclusion zone, which includes the Treatment gate area and stockpile/screening areas for excavated materials, (2) a contamination reduction zone, where cleaning and decontamination take place, and (3) a support zone, which will be the work area used for material and equipment storage.

Before conducting any invasive work, all underground utilities will be located, and the area cleared by an underground utilities locating service. The area will be surveyed for radioactive materials prior to moving in equipment. The survey will be conducted by walking a series of traverses correlating to a 4-foot-centre grid pattern on the area to be surveyed using a radiation survey meter and a scintillation counter and a sodium-iodide crystal detector. Section 7 and the HASP discuss radiation survey methods in more detail.

Stockpile/screening areas in the exclusion zone will be constructed in areas where the ground surface has been cleared of any vegetation and debris, and graded, as necessary, to control run on and run off. Section 7 discusses these areas in greater detail.

#### 4.1.2 Sheet Pile and Granular Iron Media Handling

C3 will co-ordinate the shipping of sheet piling specifically designed for installation of the funnel and gate. The Contractor will offload sheet piling and decontaminate according to procedures outlined in Section 7. ETI will arrange for delivery of the granular iron in 1,000 to 3,000 lb fibre superbags. The Contractor will offload ETI-provided iron material and place it in a convenient location in the working area. The iron should remain dry at all times prior to installation. The Contractor will likely provide and will handle the sand or pea gravel material.

#### 4.1.3 Sheet Pile Installation and Sealing the Joints

The Contractor probably will assemble/thread and drive the sheet piling in multiple phases. This will ensure that critical specifications are attained in the completed structure. Sealable joint sheet piling will be installed to length, width and depth as described in section 3.5. Joints between sheet piles will be grouted by C3. A bentonite grout will be used to seal the joints on the long axis of the box. Temporary inflatable seals will likely be placed in the joints on the upgradient, short axis of the box. The downgradient short side of the gate will likely be sealed with a permanent yet removable grout.

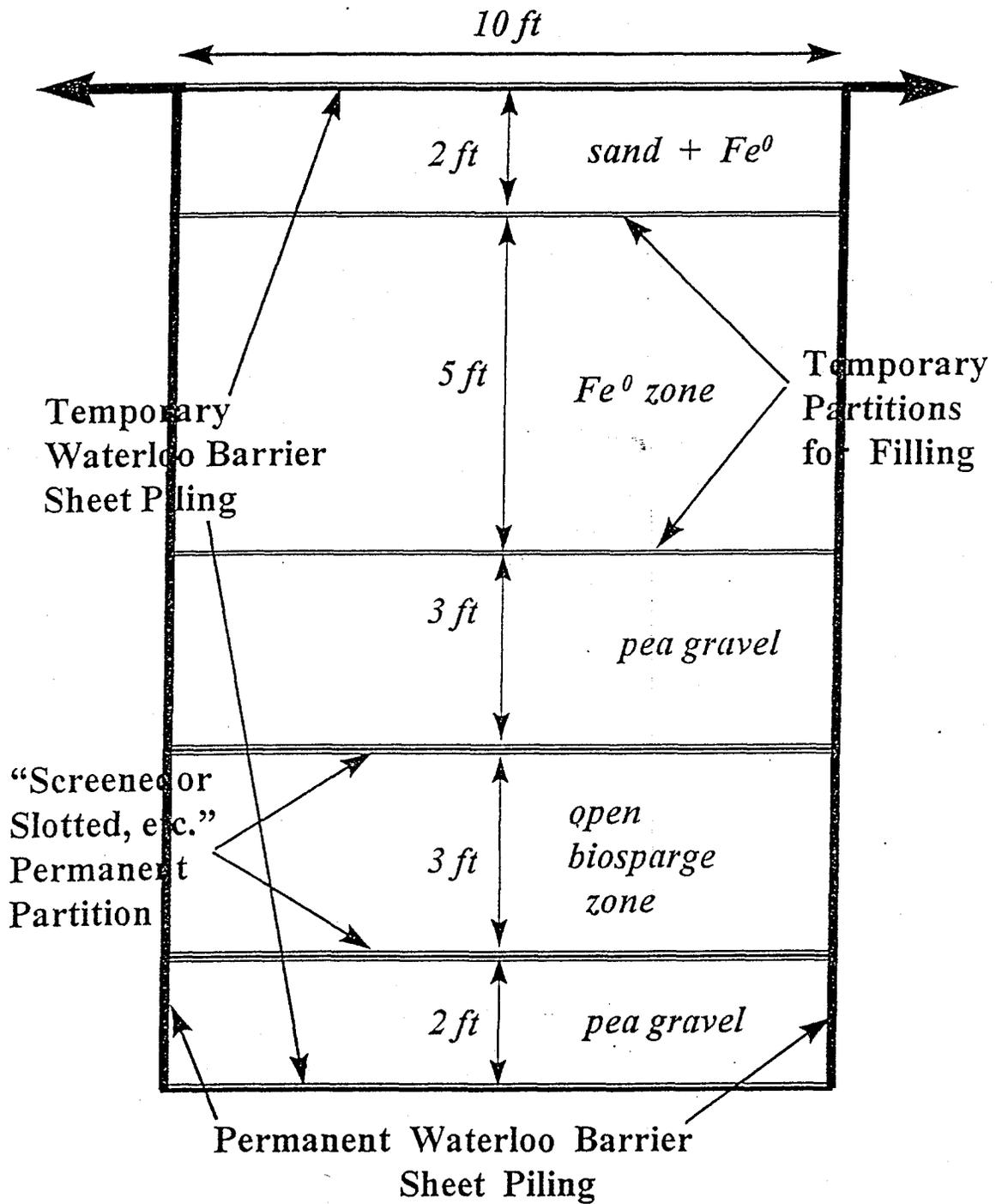


Figure 4-1. Schematic showing the construction of the treatment gate.

The funnel sections will be made of sealable joint sheet piling which will be grouted using bentonite .

#### 4.1.4 Excavation of the 'Box'

Using a conventional backhoe or other suitable excavation equipment, the Contractor will excavate native materials from the sheet pile box and dewater the box if necessary. The box will be braced as required typically using structural steel. Native material will be screened, segregated, sampled and stored on site until appropriate off site disposal is undertaken. Disposal of all native material will be the responsibility of the Contractor who will follow all appropriate state and local laws. The wastewater generated from the excavation will be analysed, stored temporarily on site and then, if appropriate will be sent to the Industrial Wastewater Treatment Plant (IWTP), located on base. These arrangements will be made by the Contractor.

During excavation all field personnel will be briefed according to details outlined in the HASP (see Appendix F).

#### 4.1.5 Placement of Iron, Pea Gravel, and Biosparge Sections with Simultaneous Installation of all Monitoring Wells

The box will then be dewatered prior to backfilling. The Contractor will place temporary partitions in the box to separate the sand or pea gravel sections from the reactive iron section. The Contractor will then "hang" plumb groundwater performance, treatment monitoring wells and flow measuring wells/devices. Sand or pea gravel and granular iron will then be backfilled into the excavation. Backfilling will likely involve lifts of approximately 1 foot to 2 feet. The Contractor will then remove the temporary partitions, and place a geotextile liner over the reactive iron and sand or pea gravel material. Unsaturated clean material will then be backfilled to grade and recompacted taking care not to damage wells. At ground surface, an impermeable liner will cover the sand or pea gravel and granular iron sections to prevent recharge from penetrating into the gate.

To construct the biosparge zone two permanent partitions (likely sheet piling) will be installed (as shown in Figure 4-1). These partitions will have small holes screened with a fine mesh will so that groundwater will be able to flow into the biosparge zone. To prevent any lower aquitard material from entering into the open caisson, an impermeable base (e.g. cement) will be installed. The sparge tubing will be attached to a metal grid and secured to the impermeable base. The Contractor will then "hang" plumb groundwater performance and treatment monitoring wells, as per UW specifications. The bacterial support medium will then be placed in the open caisson.

The headspace bioreactor (see Figure 4-2) will be created by extending the sides of the caisson (sheet piling) up to the ground surface and then sealing it with a top plate. The headspace bioreactor will contain approximately one foot of soft plastic foam which will act as a bacterial growth support media. Once complete, the biosparge will be sealed.

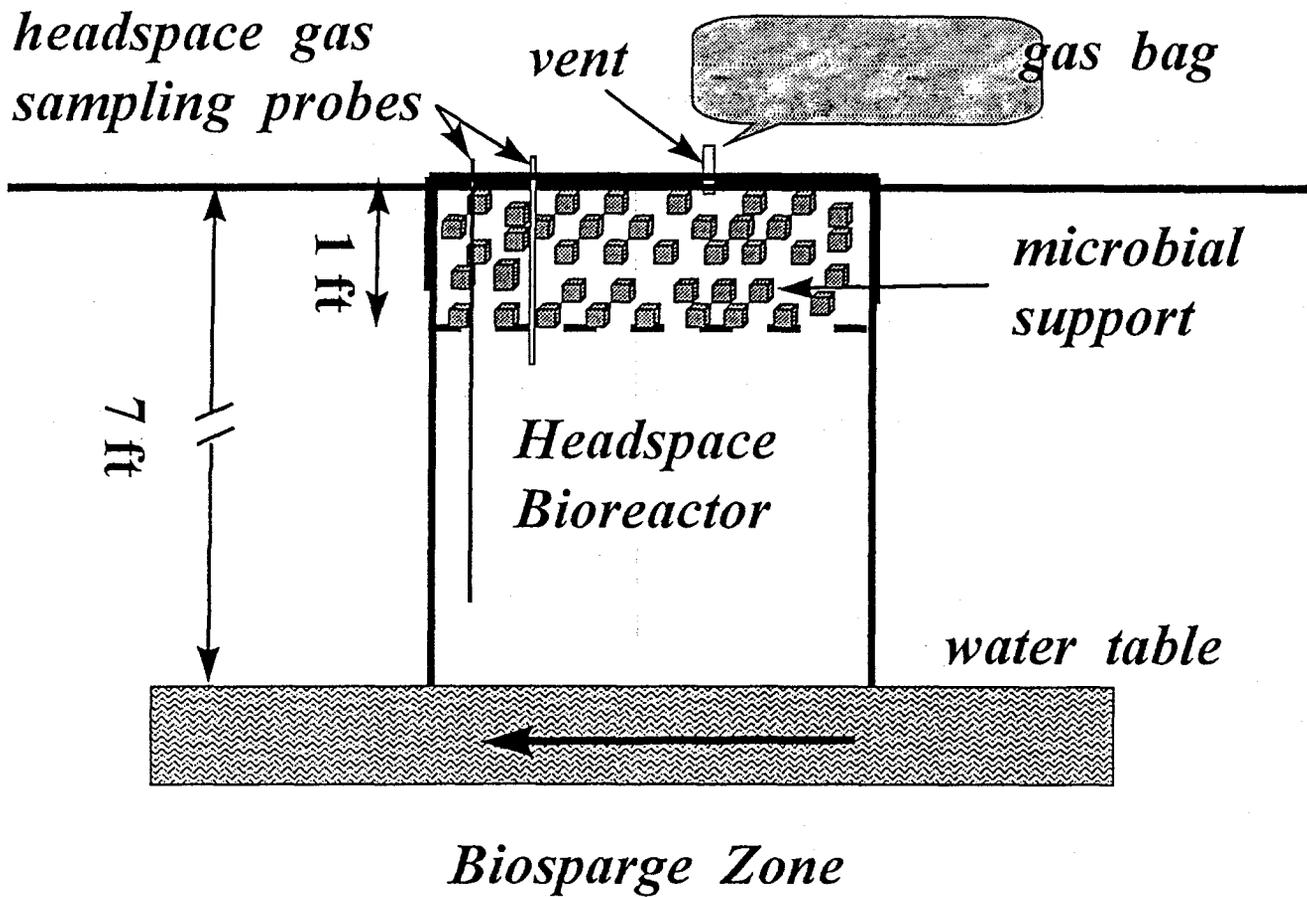


Figure 4-2. Schematic of the headspace bioreactor.

The last section will consist of sand or pea gravel and will house the pumping wells and the last groundwater sampling points. Before the sand or pea gravel will be installed, the groundwater performance wells, treatment monitoring wells and the two extraction wells will be "hung" plumb. Sand or pea gravel will then be added in 1 to 2 foot lifts up to ground surface. An impermeable liner will then be placed over the sand or pea gravel section to prevent recharge.

#### 4.1.6 Final Monitoring Wells and Support Structures

Upon completion of the funnel-and-gate system, the final 1.5" PVC monitoring wells and multilevel wells will be installed in the control gate and in row 1, immediately upgradient of the treatment gate (Figure 6-1, following). Methods will be similar to those used in the July, 1996 investigation (Appendix A). A shed to cover the treatment gate and to house oxygen sparging equipment, extraction pumps, electrical outlets, etc. will be erected over the treatment gate. A fence will then be installed to enclose the demonstration site. This fence will meet the requirements of the facility.

#### 4.1.7 Flooding of the System with Uncontaminated Water

Once the remedial gate has been constructed, clean water will be pumped into the gate via the open biosparge gate. This clean water will be used as a tracer test (see section 6.2.1.1). After the gate has been filled, the sheet piling comprising the upgradient end of the box will be removed and the extraction pumps turned on, forcing groundwater to be pulled into the gate, allowing the experiment to begin.

## 5. DEMONSTRATION PROJECT OPERATION

### 5.1.1 Operating Phases

Following construction, the treatment gate will be filled with fresh water. Then, the up gradient sheet piling end of the treatment gate will be removed and gate operation begun. Initially, the gate will be operated with the down gradient end sealed by the temporary sheet piling. Subsequently, this sheet piling will be removed and the gate will function under natural groundwater flow conditions. In total, about 4 gate volumes of contaminated groundwater will be completely processed during this pilot scale test. The phases of operation are outlined below:

Table 5-1: The phases of operation for the Demonstration Project

Operational Phase	Objectives	Approximate Duration
OP-1	<ul style="list-style-type: none"><li>flush fresh water from Treatment gate</li><li>establish biosparge operation frequency</li><li>establish groundwater velocity under accelerated, controlled groundwater flow rate</li></ul>	6 weeks
OP-2	<ul style="list-style-type: none"><li>evaluate zone performances at accelerated, controlled groundwater flow rate</li><li>establish groundwater velocity under accelerated, controlled groundwater flow rate</li></ul>	6 weeks
OP-3	<ul style="list-style-type: none"><li>evaluate gate performance under "natural", but controlled, groundwater flow rate</li><li>establish groundwater velocity under natural, controlled groundwater flow rate</li></ul>	8 weeks
OP-4	<ul style="list-style-type: none"><li>evaluate gate performance under natural groundwater flow conditions</li><li>establish groundwater velocity under natural, controlled groundwater flow rate</li></ul>	16 weeks

### 5.1.2 Operating Phase 1 (OP-1)

Upon completion of gate construction and filling with clean, fresh water, an initial monitoring will be conducted to establish the initial conditions (see MP1, section 6.2.4.1). Then, the up gradient end sheet piling will be removed and the two pumping wells near the down gradient end of the treatment gate will be operated at about 45 ft<sup>3</sup>/day in total. Extracted groundwater will be stored on site until testing, with subsequent disposal either to the wastewater treatment facility on base or to an off site facility.

The volume of water in the constructed gate will be about 1100 ft<sup>3</sup>. OP-1 will attempt to remove essentially all the construction/fresh water and this is estimated to require extraction of about 2000 ft<sup>3</sup> of water, requiring about 45 days or nominally 6 weeks. The electrical conductivity of the extracted groundwater will be monitored and OP-1 pumping continued until these measurements suggest > 90% of the construction/fresh water has been extracted.

The biosparge O<sub>2</sub> volume required to provide about 20 mg/L DO to the biosparge zone water will be established during OP-1. The objective is to use a minimum volume of O<sub>2</sub> gas to attain about 20 mg/L in the groundwater. About 3 ft<sup>3</sup> of O<sub>2</sub> will be added over 1 - 4 hours, depending on the biosparge tubing delivery, and DO measurements in the biosparge zone groundwater will be made. This will be repeated until about 30 mg/L DO is consistently found in the groundwater. Then, the O<sub>2</sub> volume required to produce 20 mg/L in the zone groundwater will be identified and this volume of O<sub>2</sub> will be used in subsequent biosparging.

At least twice during OP-1 the groundwater flow velocity will be measured in the In Site Permeable Flow Sensors (ISPFS) and GeoFlow meter locations using these devices. The ISPFS device will undergo a calibration by the supplier's staff earlier in OP-1.

#### 5.1.3 Operating Phase 2 (OP-2)

Pumping at about 45 ft<sup>3</sup>/d will continue for an additional 6 weeks to facilitate monitoring of Fe<sup>0</sup> zone and biosparge zone performance. At least twice during OP-2 the groundwater flow velocity will be measured in the ISPFS and GeoFlow meter locations using these devices. During this period about 1900 ft<sup>3</sup> of groundwater will be extracted, representing about 2 treatment gate volumes.

#### 5.1.4 Operating Phase OP-3

Pumping will be reduced to about 12 ft<sup>3</sup>/d, estimated to be the ambient flux through the treatment gate (section 3.1). This phase will continue for about 8 weeks, resulting in about 670 ft<sup>3</sup> of groundwater being extracted (about 0.7 gate volumes).

Monitoring (MP3) will assess the treatment progress and performance. In addition, at least twice during OP-3 the groundwater flow velocity will be measured in the ISPFS and GeoFlow meter locations using these devices.

#### 5.1.5 Operating Phase OP-4

The sheet piling at the down gradient end of the treatment gate will be removed and the groundwater extraction discontinued. Groundwater is expected to continue to flow through the treatment gate at a velocity of 0.27 ft/d (n = 0.3) with a flux of about 12 ft<sup>3</sup>/d. Monitoring of treatment progress and gate performance will continue for about 16 weeks (MP3), by which time an additional about 1.5 gate volumes will have entered the treatment gate.

As well as measuring the groundwater velocity using the ISPFS and GeoFlow devices in the

up gradient section of the gate, the pumping wells will now be available for measuring groundwater velocity with the GeoFlow meter. Measuring groundwater velocity at all these locations will be done at least twice during OP-4. The biosparge zone may also be used for a tracer test if the biodegradation aspect of the gate is satisfactory. This test will involve dissolving KBr in the well-mixed biosparge zone, and then monitor the decline in concentration of Br in that zone over time. This dilution rate is related to the groundwater flux through the treatment gate and so this flux will be defined. A detailed proposal and work plan for this activity will be provided in a Technical Memorandum, likely during OP-3, when the biosparge zone performance can be assessed.

## **6. DEMONSTRATION PROJECT MONITORING**

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### **6.1 TYPES OF MONITORING : PERFORMANCE AND TREATMENT**

Throughout the duration of this demonstration project, two types of monitoring will be conducted:

1. Performance Monitoring: Used to assess the performance of the system, emphasizing the fate of target organics, possible breakdown products, and other critical parameters
2. Treatment Monitoring: Used to follow the extent of treatment to understand the rate and processes involved.

Chemical data to be gathered in this project are classed as "Performance", P, and "Treatment Monitoring", T. Performance data are essential for evaluating the success of the in situ treatment relative to the project objectives. The T data are more relevant to the assessment of processes operating within the in situ remedial system.

The critical parameters include target organics and breakdown products as well as inorganic water quality parameters of particular concern with these remedial technologies. Tables 6-1 and 6-2 lists the DQO's for the aqueous critical parameters for the performance and treatment wells.

Table 6-1. Aqueous Performance parameters and their DQO's including method detection limits (MDLs), accuracy and precision (at the remediation goal concentration).

Parameter	Rationale	Data Level	MDL
TCE	critical contaminant being remediated	III	0.02 ug/L
1,1 DCE	"	III	0.05 ug/L
t1,2 DCE	"	III	0.03 ug/L
c1,2 DCE	"	III	0.06 ug/L
VC	"	III	0.04 ug/L
Benzene	critical contaminant being remediated	III	0.03 ug/L
Toluene	"	III	0.08 ug/L
Ethylbenzene	"	III	0.03 ug/L
Xylenes, each	"	III	0.06 ug/L
pH	remediation may alter beyond RO range	I	pH range of 5 - 12.
Fe <sup>0</sup>	remediation may increase above RO	III	0.05 mg/L

Note: CVOC's and Fe to be submitted to a Navy certified laboratory, remainder of parameters are field measurements.

Table 6-2. Aqueous Treatment parameters and their DQO's including method detection limits (MDLs), accuracy and precision (at the remediation goal concentration).

Parameter	Rationale	Data Levels	MDL
TCE	critical contaminant remediation	III	5
1,1 DCE	"	III	7
t1,2 DCE	"	III	20
c1,2 DCE	"	III	20
VC	"	III	5
Benzene	as above	III	2
Toluene	"	III	5
Ethylbenzene	"	III	5
m + p-Xylene	"	III	5
o-Xylene	"	III	5
ethene, methane	potential products of remediation	III	20 ug/L each
DO	required addition in biosparge gate	I	0.2 mg/L
alkalinity	measures CO <sub>2</sub> from biodegradation	III	1 mg/L
other inorganics	general water quality indicators	III	0.1 mg/L each
BOD	determines DO needs in biosparge zone	III	5 mg/L.
Fe	remediation may increase above RO	III	0.05 mg/L
EC	establish initial flux through gate	I	0.5 uS
Hydraulic head	required to estimate plume capture	II	--
Groundwater velocity	estimate residence time in remedial zones		0.1 ft/day

**Note:** Samples to be sent to UW OGL and Inorganic Lab. EC, pH and DO parameters are field measurements

Performance monitoring wells will also be sampled for T parameters occasionally.

The performance monitoring will use 1.5" PVC wells, screened over most of the saturated aquifer thickness (6' - 21'). They will represent the vertically-integrated concentrations at that

location. All sampling of performance wells will be done using established methods (section 6.2.2) and all samples will be analysed in a Navy EPA certified lab. The performance wells are shown as circles in Figure 6-1 and occur in rows 1,5, 7. After the wells in row 8 are no longer pumped, they will be sampled as performance wells.

Single 1.5" PVC performance monitoring wells will be established in the control gate at rows 1, 5, and 8 to follow the progress of intrinsic remediation in the aquifer for a distance similar to that monitored in the treatment gate. Note that groundwater velocity will be different in the two gates, so these control monitoring wells will relate to distance travelled, not residence times.

The treatment monitoring will be conducted in three-point, multilevel wells. Each point will be stainless steel tubing (1/8") screened with stainless steel at the bottom. These will provide a point sample and will be used to monitor the extent of treatment and other processes-oriented parameters. Typically, target organics, indicators and other chemicals will be assessed with these wells. Sampling of treatment monitoring wells will use methods established in other field research by the University of Waterloo and described in section 6.2.4. All analyses of treatment monitoring samples will be completed at the University of Waterloo's Organic Geochemistry Lab and the Inorganic Geochemistry lab, except where concentrations are anticipated to be at or below their MDLs. Then, samples will be submitted to the Navy and EPA certified lab providing analyses of performance monitoring samples. The treatment monitoring wells are shown as squares in Figure 6-1 and are found in rows 1, 2, 3, 4, 5, and 6. The 1.5" P monitoring wells will, on occasion, also be sampled as part of T monitoring.

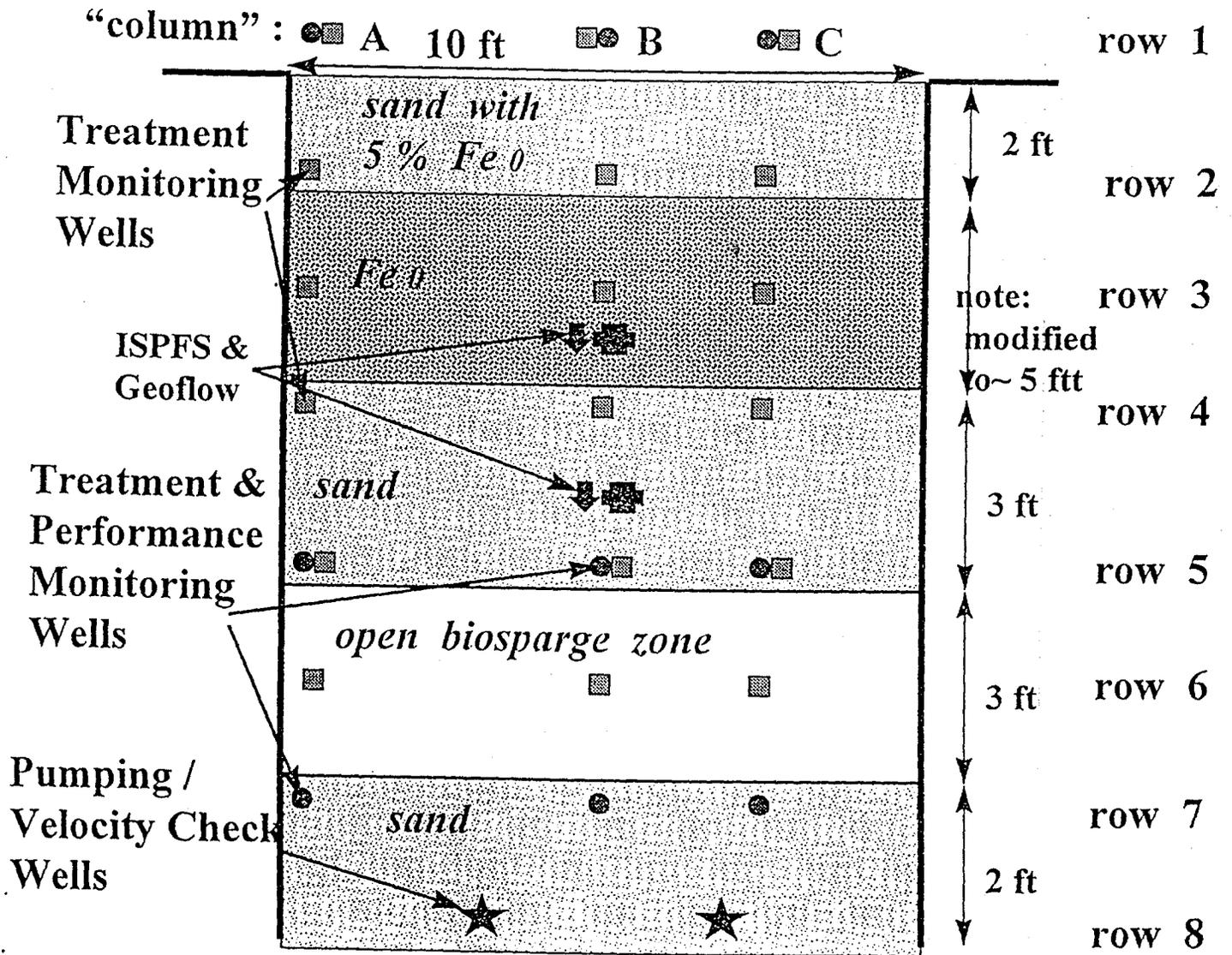


Figure 6-1: Schematic layout of the remedial gate showing the location of the P & T wells, ISPFS and Geoflow meters and pumping wells.

The following is a brief outline explaining the rationale for the particular type of sampling for each row:

1. These will define what groundwater quality enters the gate. Sampled as P and T for critical organics (BTEX, chlorinated ethenes and ethene), general inorganic chemistry including DO, and critical indicators (pH, Fe, Cl). Initially, the T samples will be useful to establish the spatial variability of organic contaminants entering the treatment gate.
2. Defining groundwater quality just before the  $Fe^0$  zone to assess the chemical changes brought about by the  $Fe^0$ -sand mixture up gradient. Treatment monitoring only.
3. To determine the rate and extent of reductive dechlorination. Treatment monitoring only.
4. This is the final point where reductive dechlorination is anticipated. Treatment monitoring only will be done, since the subsequent sand unit is considered part of the  $Fe^0$  treatment technology, and performance, especially pH adjustment, likely continues to row 5.
5. Row 5 will define the final water quality produced by the  $Fe^0$  system. These also define the input into the aerobic treatment system. P monitoring will include critical organics and critical indicators (pH and Fe) as well as two T parameters, DO and Cl. T monitoring will include these on occasion, and BOD on a continuing basis, to establish the biosparging operation frequency.
6. T monitoring will include DO, BTEX, chlorinated ethenes (if found in row 7) and BOD within the gate to follow extent of BTEX biodegradation.
7. While pumping, these will be assessed (P monitoring) for critical organics, critical inorganics (pH and Fe) and 2 T parameters, DO and Cl as an indication of the final water quality produced by the treatment system. When not pumping, these wells will be sampled as P monitoring points to assess the final water quality produced by the treatment system.

## 6.2 FIELD SAMPLING PLAN

The objective of this Field Sampling Plan (FSP) is to describe the procedures that will be used during the field portion of the pilot scale treatability study at Alameda NAS. The field program includes the following activities:

- Tracer test
- Groundwater sampling
- Air sampling

There will be two methods of sampling for the groundwater: performance sampling and treatment sampling both of which are explained in section 6.1.

Health and safety procedures that will be followed during each field program are presented in the Health and Safety Plan (HASP), which is included in this document as Appendix F.

### 6.2.1 Tracer Test Sampling Procedures

Once the gate has been constructed, and before the temporary sheet pile at the up gradient end has been removed, the gate will be refilled to the ambient water table level with clean water having a dissolved solids load much lower than the site groundwater. This difference in water chemistry and thus electrical conductivity is the basis for the tracer test.

To fill the gate, approximately 1100 ft<sup>3</sup> of clean water is required. This water will be added until the water level inside the sheet piling is within +/- 2" of the water table measured directly adjacent to the gate.

Groundwater will be sampled from selected T wells (see Figure 6-1) and will be analysed by on-site measurements of its electrical conductivity (EC). The sampling will define the C/C<sub>0</sub> values of the breakthrough of contaminated groundwater to each monitoring point.

Monitoring of a point will begin when the up gradient point(s) indicate a +/-20% change in EC, indicating that the contaminated water is breaking through at the up gradient row. This should ensure that the critical part of the breakthrough curve (C/C<sub>0</sub> from 0.2 to 1.0) is obtained at each point. Monitoring of a particular point will cease after the EC approaches within +/-10% of the value of the contaminated groundwater in at least two consecutive monitoring events. The time required for the concentration to reach 50% of the EC of the influent, contaminated groundwater (or the maximum EC at that monitoring point), divided by the distance to the front of the gate will define the groundwater travel time through the gate to the monitoring point. This will establish the residence time of groundwater in the various segments of the remedial gate.

### 6.2.2 Groundwater Sampling Procedures

Prior to sampling, each well will be checked for proper identification and the well head will be examined for signs of tampering. A field log book will record any notes about the condition of the wellhead.

The fact that this demonstration project will be undertaken in a shallow aquifer greatly simplifies the problem of groundwater collection. Low volume, minimal drawdown purging and sampling procedures will be used to collect representative groundwater samples from wells and minimize waste generation.

The groundwater sampling will be divided into two sections, performance and treatment, see section 6.1 for descriptions of each. The types of sample containers, volume collected, preservation required and holding times for each type of analyte are listed in table 6-3.

Table 6-3. Sample containers, holding times, preservatives, and required volume for Performance, Treatment and QC groundwater samples.

Analyte	Volume collected	Container	Preservation	Maximum Holding Time (days)
CVOC's (includes TCE, DCEs, VC, BTEX)	P: 40 mL EPA VOA T: 18 mL hypovial	glass, Teflon septa	Outside Lab HCl to pH < 2. OGL 0.4 mL sodium azide	14
EC	20 mL	plastic	4°C	10
ethene, ethane, methane	40 mL EPA VOA	glass	4°C	4 days
pH	20 mL	plastic	none	0
cations	20 mL	plastic	filter (0.45 µm), acidify to pH < 2, cool to 4°C	28
anions	20 mL	plastic	4°C	28
DO by probe	20 mL	plastic	none	0
DO by chemetric	20 mL	glass or plastic	4°C	4 hours
BOD	500 mL	plastic	4°C	2
alkalinity	100 mL	plastic	4°C	4
organic vapour from (biosparge)	1L	Tedlar gas sampling bag	none	5 days
Equipment blanks	40 mL (P) 18mL (T)	glass, Teflon septa	Outside Lab HCl to pH < 2. OGL 0.4 mL sodium azide	14 days
Field blanks	40 mL (P) 18mL (T)	glass, Teflon septa	Outside Lab HCl to pH < 2. OGL 0.4 mL sodium azide	14 days
Triplicate blanks	40 mL (P) 18mL (T)	glass, Teflon septa	Outside Lab HCl to pH < 2. OGL 0.4 mL sodium azide	14 days
Matrix spike (MS)	40 mL (P)	glass, Teflon septa	Outside Lab HCl to pH < 2.	14 days

### 6.2.3 Performance Sampling

Prior to the sampling event, the static water level will be measured using an electric water-level indicator. A sensitivity control compensates for very saline or conductive water. The electric sounder is decontaminated by rinsing with a detergent solution then distilled water after each use. Depth to water is recorded to the nearest 0.001 foot and will be recorded in the field log book.

Performance wells will also be checked for presence of LNAPL, (free floating hydrocarbons) and this will be done using an interface meter or using a clear bailer. The interface meter works on a principal similar to the electric sounder, measuring both conductive and non-conductive liquid within the well. Floating product can also be measured using a clear, bottom-filling bailer. The bailer is lowered slowly into the well until the bailer is approximately half submerged. The bailer is then retrieved from the well and the thickness of floating product in the bailer is measured. The thickness of floating product is recorded to the nearest 0.01 foot in the field log book.

Well total depth is measured by lowering a probe to the bottom of the well and measuring the depth. Well total depth, used to calculate purge volumes and to determine whether the well screen is partially obstructed by silt, is typically recorded to the nearest 0.1 in the field log book. The condition of the well head will also be examined during each round of performance sampling.

All performance wells will be equipped with dedicated Watern Inertial Lift Pump made of about 3/8" ID Teflon tubing with a hard plastic bottom check valve. The pump will be suspended in the well between sampling events. Groundwater sampling will consist of purging a consistent volume of water, usually three well volumes, starting from near the water table. Pumping rate will not exceed 1 L/min.. Following purging, a sample will be pumped from a depth of 15 +/- 1 ft bgs at a flow rate of < 1 L/min. for all wells. After purging about 2 well volumes, and immediately prior to and immediately after sample collection has been completed, groundwater pH, temperature, and specific conductance will be monitored and recorded in the field log book. This will document the change, if any in general groundwater quality during purging/sampling.

Clean glass bottles of at least 40 millilitres volume fitted with Teflon-lined septa are used to collect samples for volatile organic analyses. These bottles are completely filled to prevent air from remaining in the bottle. A positive meniscus forms when the bottle is completely full. All sample bottles will contain the required preservative (see Table 6-3 for preservatives). A convex Teflon septum is placed over the positive meniscus to eliminate air. After capping, the bottles are inverted and tapped to verify that they do not contain air bubbles.

All sample containers are labelled immediately following collection. Samples are kept cool with blue ice until received by the external laboratory. At the time of sampling, each sample is logged on a chain-of-custody record which accompanies the samples to the laboratory.

#### 6.2.4 Treatment Sampling

Groundwater sampling will consist of purging at least three tubing volumes followed by sample collection using a multiple tubing sampling device as described by Mackay et al. (1986) and Hubbard et al. (1994). In a shallow sandy environment, groundwater can be extracted by peristaltic pumping according to the methods of Mackay et al. (1986) with little or no degassing and no significant loss of volatile contaminant mass. This has been the experience of the University of Waterloo at C.F.B Borden for over a decade. The use of multilevel piezometers also greatly simplifies groundwater sampling. Because the tubing volumes are small, minimal purging is required to flush the system before sample collection. Samples for organics are taken using peristaltic pumps with a manifold sampling system (shown schematically in Figure 6-2) and are collected in 18 ml glass vials (40 ml VOA bottles when submitted to external lab) which are crimped sealed immediately after adding a preservative. Duplicates of each sample will be taken. The groundwater contacts only Teflon, stainless steel, and glass during filling of the organic VOA vial. To prevent biotransformation of the solutes after sample collection, 0.4 cm<sup>3</sup> of sodium azide is added to each glass VOA with a syringe prior to capping. The samples receive no exposure to the atmosphere except for a few seconds while the sodium azide is added, and the vials are capped with Teflon-lined silicon septa.

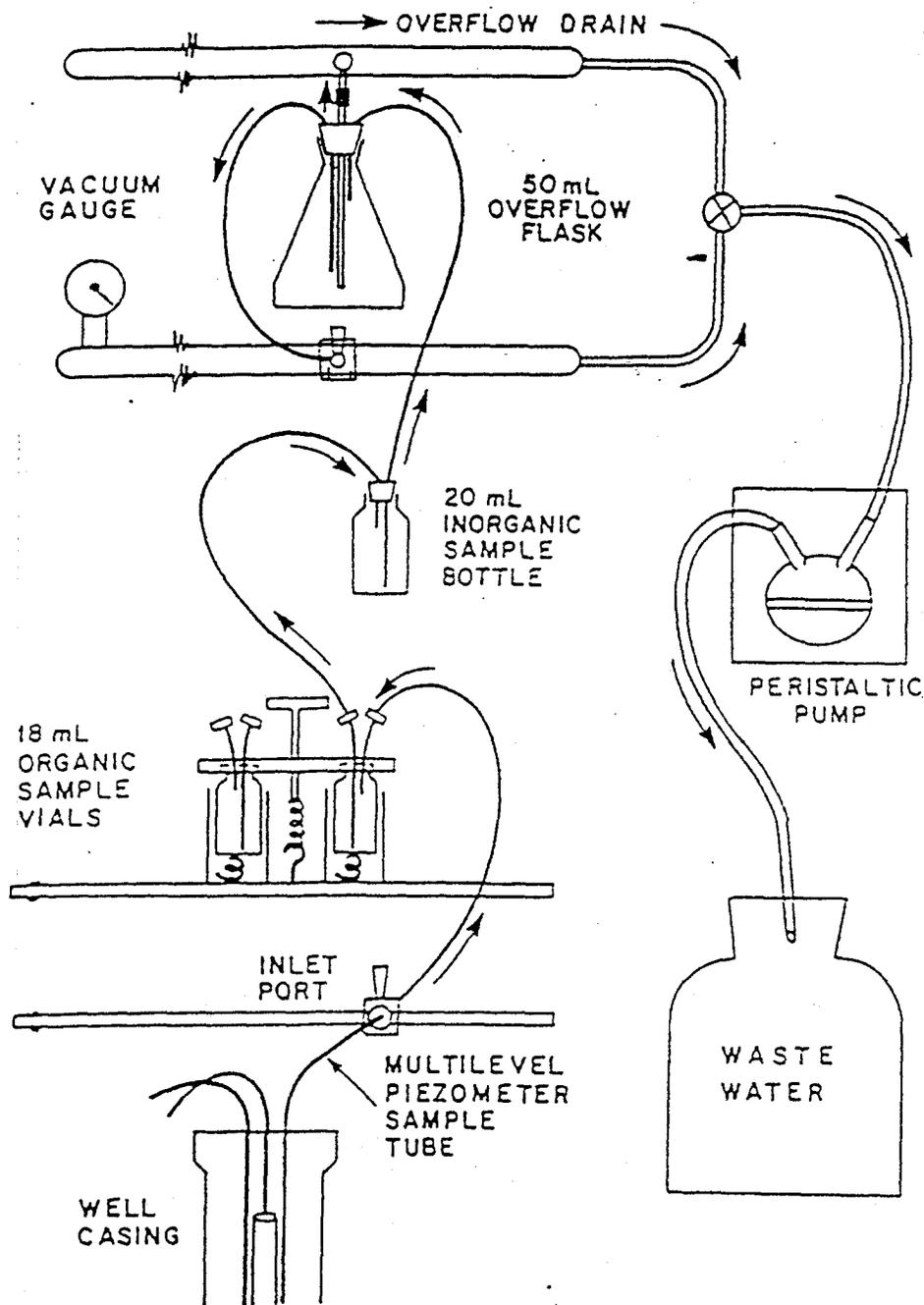


Figure 6-2. Schematic diagram explaining the method for T sample collection.

As required, an additional 20 cm<sup>3</sup> sample can be taken for selected inorganic analyses (DO, pH, Fe, etc.). Alternately, when CVOCs are not being sampled, the 18 cm<sup>3</sup> vial can be replaced by a 40 ml VOA bottle for low-MDL monitoring or by a 40 cm<sup>3</sup> vial for these inorganic samples.

Glass vials and septa are purchased pre-cleaned or will be cleaned thoroughly using procedures verified by Hubbard et al. (1994) before transport to the field. The glass VOA vials are soaked in commercial alkaline cleaning solution, rinsed with deionized water, dilute nitric acid, and more deionized water. The septa are prepared by boiling in water for one hour. The glass VOA vials and septa are baked overnight at 110°C, then wrapped in foil for transport.

Samples intended by organic analysis will be stored with blue ice-packs in insulated coolers and transported to the University of Waterloo Organic Geochemistry Laboratory for analysis at the close of each sampling event, or after three days, if sampling takes longer. They will be stored at 4°C until analysis. The samples will be labelled and shipped according to the procedures outlined in Section 4.0 of the QAPP.

Dissolved oxygen samples are collected in 18 ml hypovials (T sampling) or as VOA bottles (T sampling). All analyses will be conducted in the field using CHEMtest test kits. Here, a partially evacuated ampoule containing an oxygen-sensitive solution is broken at a scored line while submerged in the glass sample bottle. The sample water is thus drawn into the ampoule where a reaction occurs. Quantitation is by either comparison to coloured standards or by use of an adsorption measuring field detector (preferred), operated as per manufacturer's instructions.

Samples collected for cations analyses will be filtered in line (0.45 µm) and preserved with HNO<sub>3</sub> in the field, those samples for anions will be filtered but otherwise unpreserved.

## 6.2.5 Sample Handling and Designation

### 6.2.5.1 Sample Handling

To ensure that samples are identified correctly and remain representative of the environment, specific documentation and sample handling will be followed during sample collection and analysis. Standard sample documentation and custody procedures, will be used during each sampling program to maintain and document sample integrity during collection, transportation, storage, and analysis. The Field Team Leader, to be designated at the time of the investigation, will be responsible for ensuring proper documentation and custody procedures are initiated at the time of sample collection, and that individual samples can be tracked from the time of sample collection until the samples are relinquished to the laboratory. The laboratory will be responsible for maintaining sample custody and documentation from the time the samples are relinquished to the lab until final sample disposition. A full discussion on the exact sample handling procedures can be found in the QAPP, Appendix K.

### 6.2.5.2 Sample Designation

Each sample will be identified with an alphanumeric code. These abbreviations will be as follows:

<u>Sample Code</u>	<u>Definition</u>
R	Row
#	Row number (see figure 6-1 )
P	Performance well
T	Treatment well
A, B, or C	Well designation
-1, -2, or -3	Depth (Treatment wells only)

Treatment wells consist of a nest of three multilevel, 1/8" piezometers. The shallowest depth is represented as a 1, the next depth down from ground surface as a 2 and the deepest depth as a 3. A typical sample identification for a treatment well and a performance well for row 1, well A is:

R1TA-1

R1PA

### 6.2.6 Air Sampling Procedures

Oxygen coming from the biosparge system will be monitored by sampling from the port preceding plastic gas bag (see section 6.2.1.5) attached to the sealed, in situ biosparge unit. Sampling will occur immediately prior to a biosparge event and at least once near the end of the biosparge event. Methods are outlined in Appendix E.

Two stainless steel soil vapour sampling tubes, equipped with teflon-septum, MiniInert™ sampling valves and installed in the in situ, headspace bioreactor, will be sampled immediately before and immediately after a biosparge event. Sufficient gas will be drawn from the sampling tubes to flush them three times and then a sample will be drawn into a Tedlar gas sampling bag as described in Appendix E.

Discussions with the Bay Area Air Quality Management District (BAAQMD) regulatory agencies are underway to establish the requirements for handling, sampling, and treatment of oxygen gas displaced from the in situ headspace bioreactor. At present, we anticipate this project will discharge less than 100 ft<sup>3</sup> of oxygen gas, perhaps containing a few ug/L of VOCs, per week; far less than 0.007 lbs/day of VC and 0.02 lbs/day of benzene and so the demonstration project may be exempt from monitoring requirements. However, the following

plan is subject to revision via a technical memorandum to be submitted for approval prior to biosparging during operating phases. During each biosparge event, the gas that is displaced will be collected in the plastic bag. This gas will then be released to the atmosphere after it has gone through an activated carbon canister. Initially and at least twice thereafter, the gas bag will be sampled before release and the effluent from the activated carbon canisters will also be sampled to demonstrate the concentrations of BTEX and chlorinated ethenes are adequately low.

### **6.3 ANALYTICAL PROCEDURES**

Groundwater samples collected according to performance and treatment methods will be analysed using analytical methods outlined in Appendix G and H respectively.

### **6.4 SAMPLING SCHEDULE**

There will be four monitoring phases for this demonstration project:

- MP-1: Characterisation
- MP-2: Initial tracer
- MP-3: Treatment and Performance during Accelerated Groundwater Flow
- MP-4: Treatment and Performance during Natural Groundwater Flow

The relationship of these monitoring phases to the four operating phases (section 5.1) is shown in Figure 6-3. The weeks in which performance or treatment monitoring or flow measurement are to be conducted are also shown. Table 6-4 summarizes the samples that will be collected during each monitoring event.

#### **6.4.1 Monitoring Phase 1 (MP-1)**

MP-1 is concerned with the initial characterisation of the remedial gate. Before the up gradient end of the sheet piling has been removed, the remedial gate will be filled with fresh water. Once this is done and before the up gradient end has been removed, column B performance wells in rows 5, 7, and 8 will be sampled (as P samples) for residual contamination by organics. The three control gate monitoring wells will also be sampled for long term intrinsic remediation data. MP-1 should last 2 days.

Week	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52				
Flux	45 ft <sup>3</sup> /day			45 ft <sup>3</sup> /day			12 ft <sup>3</sup> /day				12 ft <sup>3</sup> /day											
OP-1	█																					
OP-2				█																		
OP-3							█															
OP-4										█												
MP-1	█																					
MP-2	← EC →																					
MP-3	T	T	PT	PT	T	T	█															
MP-4							T	T	PT					PT			PT	T	PT			
Flow Measure	█																		█			█

Figure 6-3. Monitoring schedule. "T" indicates treatment monitoring and "P" indicates performance monitoring events.

Table 6-4. Sampling schedule for MP-1, 3, and 4 showing the numbers of samples to be collected each week that monitoring is undertaken.

Monitoring Type	Week	Rows	Column	Three Flow Paths Only	Parameters	# of Points Monitored
<b>MP-1</b>						
Performance		1, 5, 7, CG	B	-	all Table 6-1	6
<b>MP-3</b>						
Treatment	18	1, 2	all	-	VOCs, pH, Fe	18
	19	1, 5, 7, 8	all	-	H, V	11
	20	1, 2, 3, 4, 5	all	-	VOCs, pH, Fe; rows 5 +: DO, BOD also; H in wells	45
	22	1 to 8	all	-	"	56
	24	1 to 8	-	yes	"	20
	26	1 to 8	-	yes	“, H, V (appropriate Wells)	H, V: 13
	28	1 to 8	-	yes	" + IN	20
Performance	21	P wells, CG	1, 5, 7, 8	-	Table 6-1; IN, BOD	12
	23	"	"	-	"	12
	29	"	"	-	"	12
<b>MP-4</b>						
Treatment	31	1 to 8	-	yes	VOCs, pH, Fe; rows 5 +: DO, BOD also; H in wells	20
	34	"	-	yes	"	20
	37	"	-	yes	“, H, V	20; 13
	43	all	-	yes	"	20
	49	all	-	yes	"	20
	52	all	-	yes	"	20
Performance	36	P wells, CG	1, 5, 7, 8	-	Table 6-1; IN, BOD	14
	42	"	"	-	"	14
	48	"	"	-	"	14
	53	"	"	-	“, H, V	14; 13

VOCs: CVOCs, BTEX, ethene, methane  
 IN: alkalinity and other inorganics  
 H: hydraulic head (water level)  
 V: groundwater velocity  
 CG: Control Gate wells  
 Row 8 contains only pumping wells

#### 6.4.2 Monitoring Phase 2 (MP-2)

MP-2 is concerned with the tracer test. After MP-1 is complete, the up gradient end of the gate will be removed, the pumping wells will be turned on and the contaminated groundwater will be drawn into the gate. Electrical conductivity (EC) will be measured in all treatment wells along the length of the remedial gate and in the pumping well effluent. No performance wells will be sampled. The sampling frequency will be every four to twelve hours and will be initiated at a particular well based on up gradient monitoring results as discussed in section 6.2.1. MP-2 will last approximately 6 weeks, or until sufficient breakthrough of site groundwater has occurred at almost all monitoring points.

The biosparge zone will also be operated and sampled during MP-1 to determine the optimal biosparge rate for the system. Since only clean water will be processed during this testing, the cover plate of the headspace bioreactor will be removed to facilitate visual observations of bubble distribution on the water table and adjustments to the biosparge system. This will involve measuring DO from the multilevel monitoring points suspended within the biosparge zone (row 6). It is anticipated that a biosparge event will last from 1 to 4 hours and so these points will be sampled at least hourly during biosparging and at least once about 4 hours after biosparging ends to establish the final DO concentration that biosparge event has produced. This monitoring will last approximately one week.

#### 6.4.3 Monitoring Phase 3 (MP-3)

MP-3 is concerned with the progress of the groundwater remediation during accelerated groundwater flow through the Treatment gate (OP-1 and OP-2). The nominal groundwater velocity will be about 1 ft/d ( $n = 0.3$ ). Both performance and treatment monitoring will be completed during MP-3.

##### 6.4.3.1 Treatment monitoring

Sampling for organics (including ethene, etc.), DO, pH, and Fe will be emphasized. Treatment monitoring points in rows 1 and 2 will be sampled in weeks 18, 20, and 22 with additional treatment monitoring points included in this biweekly monitoring as site groundwater moves through the treatment gate. After about 6 weeks (end of OP-1), about three flow paths will be identified for continued treatment monitoring emphasis. These selected points will continue to be sampled in weeks 24, 26, and 28 for T parameters: VOCs, (CVOCs, BTEX, ethene, methane), pH, Fe, and additionally for points in rows 5 to 7, DO and BOD, Wells in row 7 will be included in this selected sampling, with sampling methods appropriate for P sampling, but samples collected and analysed as per the above listing for weeks 24, 26, and 28.

##### 6.4.3.2 Performance monitoring

In weeks 21 and 23 all performance monitoring wells and the two pumping wells will be sampled for all P parameters and for T parameters: DO, alkalinity, other inorganics, EC, and,

for wells in rows 5 and 7 and the pumping wells, BOD.. All wells in the control gate will also be sampled. This will establish the initial performance at the accelerated groundwater extraction, with perhaps 1 gate volume of groundwater having been processed.

By week 29, another 2 gate volumes of groundwater should have been processed and so the performance monitoring wells will be sampled in week 29 for the same set of parameters.

Gas sampling of the headspace bioreactor and of the gas going into the gas bag will be conducted for each biosparge event in OP-1 and OP-2.

#### 6.4.3.3 Groundwater Velocity Monitoring

In weeks 19 and 26 the ISPFS and GeoFlow devices will be monitored as per manufacturers/suppliers suggestions to evaluate the groundwater velocity through the system at this high flow rate.

#### 6.4.4 Monitoring Phase 4 (MP-4)

##### 6.4.4.1 Treatment monitoring

With the pumping reduced to about 12 ft<sup>3</sup>/d and the nominal groundwater velocity reduced to about 0.27 ft/d, treatment monitoring will be less frequent in MP-4. The selected treatment monitoring points along the three flow paths will be monitored during weeks 31, 34, and 37. With the pumps off and the down gradient end of the gate open, treatment monitoring along the three flow paths will continue in weeks 43, 49, and 51. Monitoring will again include only: VOCs (CVOCs, BTEX, ethene, methane), pH, Fe, and, additionally, for points in rows 5 and 7, DO, BOD.

##### 6.4.4.2 Performance monitoring

The performance monitoring wells will be sampled in weeks 36, 48, and 53 during OP-3 and OP-4 for P parameters. The control gate wells will also be sampled for P parameters during these weeks. The T parameters: VOCs, pH, Fe, and, additionally, for points in rows 5 and 7, DO and BOD will also be sampled for in weeks 42 and 53 and then only from one approximate flow path or "column".

Gas monitoring of the headspace bioreactor and off gas from the gas bag will be conducted for only two biosparge events, unless air quality concerns dictate additional monitoring.

##### 6.4.4.3 Groundwater velocity monitoring

The ISPFS and GeoFlow systems will be used to determine the groundwater velocity in the up gradient end of the treatment gate during weeks 37 and 53. Additionally in week 35, the GeoFlow meter will be used to assess groundwater velocity in the former pumping wells.

During OP-4 (weeks 38 - 53), tracer tests may be conducted in the biosparge zone to determine the flux through this zone. These will involve adding a tracer such as  $\text{Br}^-$  to the mixed groundwater in the biosparge zone and subsequently sampling selected points in row 6 for  $\text{Br}^-$  to determine the rate of dilution of the tracer by groundwater passing through this zone. The water level in the biosparge zone also needs to be monitored between biosparge events to assess the change in water stored in the zone. A technical memorandum proposing these tests in detail will be issued for approval of this work before the end of OP-2.

## **7. DECONTAMINATION AND MATERIALS DISPOSAL**

### **7.1 DECONTAMINATION PROCEDURES**

#### **7.1.1 Equipment Decontamination**

During the project, all contaminated equipment will be either properly disposed of, or decontaminated within an appropriate, designated area at the project site. As described in the project HASP (Appendix F), the site will have three primary work areas associated with it: (1) an exclusion zone, which includes contaminated areas, (2) a contamination reduction zone, where cleaning and decontamination take place, and (3) a support zone, which is an uncontaminated area used for material and equipment storage. Decontamination facilities will be constructed within the designated contaminant reduction zone, located adjacent to the exclusion zone to minimise the possible spread of contamination. The facilities will be designed to control, collect, and contain rinse waters by using containers, shields, liners, berms, and sumps, as appropriate. All water used for decontamination and resulting residues (including filters) will be collected and temporarily stored until characterisation and disposal (Section 7.2). All disposable equipment will be discarded into labelled drums, and disposed of properly (Section 7.2).

Contaminated equipment used for excavating and screening soil and debris will be decontaminated and surveyed for radioactive contamination. Equipment will be decontaminated by a high-pressure wash. Brushes and a detergent solution may be used. After the equipment has been cleansed of mud and/or dirt, it will be steam-cleaned, followed by a fresh water rinse. Decontamination procedures may be modified and/or revised based upon data obtained from field screening and/or the sampling and analysis of waste materials.

Construction materials and equipment, such as sheet piling, well casings, etc., will be washed with high-pressure hot water in the field at a decontamination facility, or before mobilization to the site.

Reusable soil-sampling equipment will be thoroughly cleaned, before and after each use, by washing with high pressure hot water and/or washing with a laboratory-grade detergent and rinsing with deionized, distilled, or fresh water.

Groundwater sampling equipment will be decontaminated as follows:

- Accessible exterior and interior portions of groundwater pumps will be washed using high pressure hot water or washed with a detergent solution before use at each sampling location. Unreachable interior pump areas will be cleaned either by flushing near-boiling clean water through the pump and discharge lines, or by flushing the pump and discharge lines with a detergent solution and rinsing with clean water.
- Teflon or stainless steel bailers will be washed with high pressure hot water or

washed with a detergent solution and rinsed with clean water before use at each sampling location. Bailer ropes will be replaced after use in each boring or well/piezometer and, while in use, will be protected from contact with the ground or chemically affected equipment and/or skin.

Electric water level meters, interface probes, transducers, and water quality meters to be will be decontaminated as follows:

- If particulate matter or other debris is present on the equipment, a tap water rinse may be applied to remove the debris.
- If particulates or other debris are still present, or if the probe has come into contact with non-aqueous-phase liquids (NAPL), it will be scrubbed or washed with a detergent solution.
- The probe will be rinsed with a detergent solution and deionized water, followed by a deionized water rinse.

The tapes for the interface probe and the water-level meter will be decontaminated using the same steps, but will be wiped with paper towels moistened with deionized water, instead of rinsed.

Reusable filter apparatus, if necessary, will be washed with Alconox and rinsed with distilled water. New fittings and new 0.45-micron filters will be used at each sampling location, and factory-new Tygon or polyethylene tubing will be dedicated for use in each well.

Decontamination fluids will not be reused. After each decontamination round, the tubs and/or splash containers will be emptied into appropriate containers for appropriate waste management (Section 7.2).

### 7.1.2 Personal Decontamination

Personal decontamination procedures are discussed in Section 12 of the site HASP (Appendix F).

## **7.2 RESIDUALS MANAGEMENT**

Field activities will generate both solid and liquid wastes that will require handling, testing, storage, disposal, and/or other on and off-site management. In general, solid waste, primarily excavated soil, will be disposed of off site, after proper characterization. Wastewater will be sent to the NAS Alameda Industrial Wastewater Treatment Plant (IWTP) for treatment and disposal.

Water and soil will be sampled according to procedures outlined in Test Methods for Evaluating Solid Wastes (EPA SW-846). Clean, properly labelled, EPA-approved containers will be used for all samples, which will be placed on ice and transported with chain-of-custody documentation to Navy-approved laboratories for analyses. The soil and water analyses will

include those specified by the appropriate disposal facility.

### 7.2.1 On-site Management of Excavated Soil and Debris

Approximately 100 in-place cubic yards of material will be excavated to construct the funnel and gate system. Due to past disposal practices, the upper ten feet of the area to be excavated may contain debris, some of which may be radioactive. Material from this horizon will therefore be field-screened to evaluate the presence of radioactive contamination. Material identified as radioactive will be segregated from the remainder of the soil and debris so that it may be disposed of separately.

Unsaturated soil and debris that is excavated will first be stockpiled in a prepared, lined and bermed area (described below). Stockpiled soil will be spread in a layer about 6 inches thick to prepare it for screening. The soil spreading will be consistent with the Bay Area Air Quality Management District requirements for aerating soil (Regulation 8, Rule 40).

Spread soil will be screened with a radiation survey meter and scintillation counter having a 2-inch-by-2-inch, sodium-iodide crystal detector (Ludlum Model 19 survey meter and 44-10 detector, or equivalent). The survey will be conducted by walking a series of traverses across the spread soil in a controlled manner (about six-inches wide traverses at a rate of about 20 feet per minute). The detector will be held in close proximity to the soil. The response time of the survey meter will be set at 3 seconds.

Radioactivity measurements three times above background will be used to preliminarily identify potentially radioactive material. If the source can be identified, it will be segregated from the soil, and the area re-surveyed. If the area is still identified as containing potentially radioactive material it will be marked for segregation. Radiation survey results will be recorded on a Radiation Survey Data Form (HASP attachment, Appendix F).

Segregated radioactive material will be placed in an appropriately labelled drum and placed in a secure area at the project site. The Navy will provide for the identification, removal, and proper disposal of such radioactive waste.

Saturated, excavated soil and debris will be stockpiled in a lined and bermed drainage pad before screening. This saturated material from the upper 10-foot horizon will be drained separately from the lower, non-debris-containing, 10-foot horizon consisting of sand and sandy silt. After draining, previously-saturated soil and debris will be screened and as described above.

Screened soil will be loaded into 40 cubic yard roll-off bins for proper disposal, after characterisation (Section 7.2.2).

All stockpiled and spread material will be properly contained in lined and bermed pads to minimize the release of contaminants into the environment. Containment pads will be constructed within the exclusion zone, in areas where the ground surface has been cleared of

any vegetation and debris, and graded, as necessary, to control run on and run off. Drainage pads for saturated material will allow for the collection of water in an internal "sump". Sumps will be constructed at the topographically lowest corner of each pad. Each containment and drainage pad will be bermed with clean soil or sandbags placed along the perimeter. Pot holes, cracks, or uneven surfaces will be filled before placing a 10-mil polyethylene or Visqueen™ liner over an area, including its berm. The berm will be constructed to allow equipment access. The liner will be anchored with sandbags or dirt. Above the liner on drainage pads, a layer of sand will be placed to facilitate draining saturated soil and debris. The sand layer will also act as a protective layer for the plastic liner. All excavated soil and debris that is stockpiled or placed on a drainage pad will be covered with secured plastic sheeting at the end of each working day during construction.

Stockpile areas and drainage pads will be established before excavation begins.

Water that accumulates in sumps will be removed and managed with that generated by dewatering activities associated with funnel-and-gate construction (Section 7.2.5).

#### 7.2.2 Characterization of Excavated Soil and Debris

A four-point composite sample will be collected from each roll-off bin for analysis of chlorinated VOCs and BTEX (EPA Method 8260), total oil and grease (TOG, EPA Method 418.1), and total petroleum hydrocarbons as gasoline (TPHG, EPA Method 8015M). If the previous analyses indicate the soil could be disposed of as non-hazardous waste, a sample from each bin will be composited for metals analysis (CAM 17 metals, EPA Method series 6000 and 7000), semivolatile organics analysis (EPA method 8270). A composite sample will also be collected for analysis of corrosivity, ignitability, reactivity, toxicity (using fathead minnows), and polychlorinated biphenyls (PCBs, EPA method 8080). This sampling and analysis strategy should meet the profiling requirements for RCRA Subtitle D or Class III waste disposal facilities, and will allow the greatest flexibility with evaluating waste disposal options. The adequacy of the sampling and analysis strategy will be verified with Navy-approved disposal facilities before implementation.

#### 7.2.3 Off-site Management of Hazardous Solid Waste

Excavated soil and debris that has been determined to be hazardous waste will be sent for off-site treatment and/or disposal at a permitted RCRA Subtitle C or state-permitted facility, as appropriate, depending on the waste classification. Pertinent information for handling and management of these solid wastes will be recorded on a Waste Log Sheet.

Waste loads will be properly labelled and manifested in accordance with the requirements of the State of California and the U.S. Department of Transportation. A licensed hazardous waste hauler will be used to transport the waste.

#### 7.2.4 Off-site Management of Nonhazardous Solid Waste

Solid waste that has been determined not to be hazardous waste may be sent for off-site disposal at a permitted RCRA Subtitle D or Class III waste disposal facility. Alternatively, depending on volume, logistics, and cost, the waste may be managed as hazardous waste (e.g., when the cost of classification exceeds the cost of off-site hazardous waste disposal). Materials in this class may include drummed, disposable personal protective equipment (PPE), and waste construction materials. Pertinent information for handling and management of these solid wastes will be recorded on a Waste Log Sheet.

#### 7.2.5 On-site Management of Nonhazardous Liquid Waste

The wastewater generated from the project will be disposed of at the Industrial Wastewater Treatment Plant (IWTP), located at NAS Alameda. Wastewater will be generated during the initial dewatering of the excavation. An ongoing stream of wastewater will then be generated during the first three phases of the demonstration project as groundwater is pumped to control the groundwater gradient. The volume of pumped groundwater requiring treatment is relatively low: during the initial operation of the system, approximately 160 gallons of wastewater will be generated per day (1,150 gallons per week). This volume decreases to approximately 90 gallons per day (628 gallons per week) during the third operating phase of the project. Minor amounts of wastewater may also be collected in the soil and debris drainage pads during the excavation of the treatment cell. Note that if radiation is detected during the excavation of the treatment cell, the water drained from the soil and debris will be filtered to remove potentially-radioactive particulate matter. Finally, a small amount of wastewater will be generated from the cleaning of sampling tools and equipment.

All wastewater will be temporarily stored at the demonstration site in 5,000 gallon polyethylene tanks. Fifty-gallon drums may also be used to temporarily collect water used for decontaminating equipment before its added to the tank. The wastewater will be sampled and analysed prior to disposal

Wastewater will be periodically transported to the on-site IWTP for disposal.

## **8. DECOMMISSIONING & SITE CLOSURE**

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When monitoring is completed, the remedial facility will be closed. As per the agreement with NAS Alameda, a one month period will be allowed for the Site to inform UW of its desire for closure. Much of the demonstration facility may remain, but the following closure activity is proposed as the default closure plan.

Monitoring equipment will be removed and all on-site materials will be removed. This will include the storage shed, groundwater storage tanks. All 1.5 in and 2 in PVC monitoring wells will be filled with grout and cut off at ground level. Multilevel monitoring wells will be pulled out.

As required, the subsurface materials (gravel, Fe<sup>0</sup> filings, open caisson) will be removed and disposed of off site. This will be accomplished by re-installing sheet piling in the up and down gradient ends of the remedial gate, dewatering the enclosed materials, removing these materials, replacing the material with clean granular fill, and finally removing all sheet piling.

All electrical systems will be disconnected. The perimeter fence will be removed and any regarding required will be completed.

## 9. REPORTING

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It is proposed to combine reporting to the AATDF and to Alameda - EFA West. Details of content will be reviewed with stakeholders to insure relevance. Reporting will likely include:

brief monthly progress reports outlining accomplishments, difficulties, scheduling, and a financial report,

a detailed report of the constructed facility to be completed within 2 months of construction completion (anticipated Dec., 1996); to include detailed, "as is" drawings, material descriptions and costs, construction details, including field log and costs, problems and variations, recommendation for future construction of such a facility.

- brief report within 1 month of completion of each operating phase: including a brief summary of accomplishments, problems, monitoring summary, and apparent performance preliminary interpretation.
- occasional (three?) brief, non-technical reports on the progress of the Demonstration Project, mainly for distribution to the local public and stakeholders; perhaps also distributed to AATDF and to UW and/or Waterloo Centre for Groundwater Research vehicles.
- a final report, due in draft form in late August, 1997 and in final form in October, 1997: this will likely include a number of separate reports on:
  - facility construction, cost, and operation summary, with recommendations for constructing and operating a full scale remedial system at Site 1, Alameda and in general.
  - summary of performance and Treatment monitoring data; essentially a compilation of the data generated in the demonstration, organized to support other documents
  - a report of the remedial system performance, including an assessment of how well each zone performed, what the controlling processes were and how they interacted, technology limitations, problems encountered and solutions employed, and recommendation for full scale implementation here and for implementation generally at other site.
- short overview papers and short technical papers for submission to referred journals and conference proceedings.

## 10. PROJECT SCHEDULE

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The Demonstration Project at NAS Alameda has been divided in several tasks and operational phases with the following actions:

1. Conduct site assessment studies to gather sufficient information to design and implement the pilot-scale test (majority completed, August, 1996; additional work to be completed in October, 1996)
2. Develop the work plan for the pilot-scale test, conducting laboratory feasibility testing as needed (completed, September, 1996)
3. Install the hardware for the pilot-scale demonstration (planned for November, 1996)
4. Conduct Operating Phase 1 (OP-1) tracer testing, biosparge testing, and remove construction water at enhanced groundwater velocity to prepare the system for evaluation of its treatment capability (OP-1 planned start in December, 1996; 6 weeks)
5. Conduct operating phase 2 (OP-2) testing which involves operating the remedial system at enhanced groundwater velocity with the operation of groundwater extraction wells (6 weeks; planned for late January - early March, 1997).
6. Conduct OP-3 testing which involves operating the remedial system at expected field groundwater velocity/flux, but still with the operation of groundwater extraction wells (8 weeks; planned for early March - May, 1997).
7. Conduct OP-4 testing which involves operating the remedial system under actual site groundwater velocity/flux through the treatment gate (about 16 weeks; planned for May - August, 1997).
8. Completion of the Final Technical Report & Technology Evaluation Report and other reports to NAS Alameda and EFS-West (October, 1997)
9. Decommission of the test site and remove installations as required by NAS Alameda (October, 1977).

Refer to Figure 10-1 for a complete project schedule .

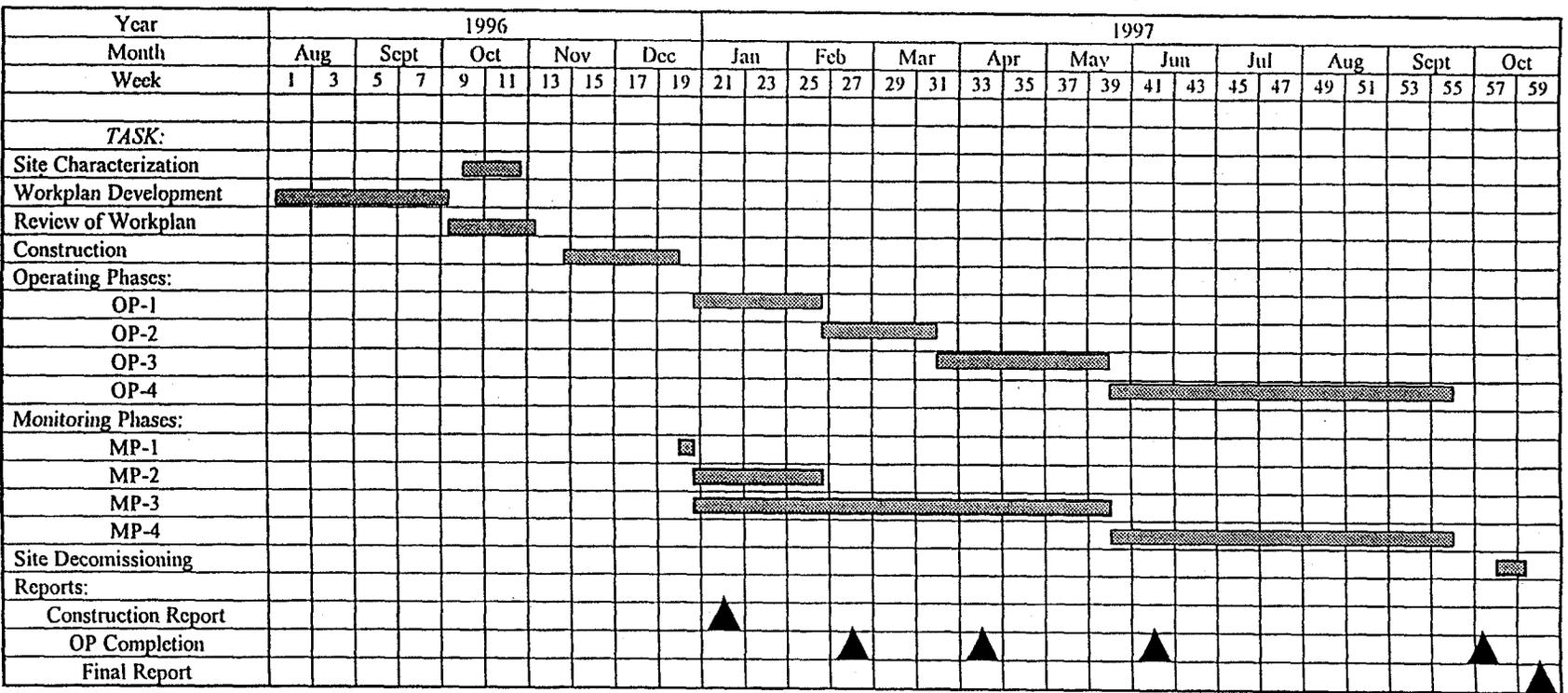


Figure 10-1. Demonstration Project Schedule.

## 11. REFERENCES

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**APPENDIX A**

**JULY AND OCTOBER 1996 SITE INVESTIGATION REPORTS**

August 7, 1996  
Project ANA101

Dr. Jim Barker  
Department of Earth Sciences  
200 University Avenue West, BFG Building  
Waterloo, Ontario N2L 3G1

Re: Site Characterization at Site 1, Alameda Naval Air Station

Dear Jim:

This letter documents the completion of the site characterization at the Alameda Naval Air Station.

We finished the subsurface investigation with Precision Sampling on Friday July 26 as planned. We collected depth-discrete groundwater samples at 11 locations with the Waterloo Profiler and cored 3 boreholes to the bottom of the artificial fill "aquifer" (i.e., to a depth of approximately 22 feet). Soil cores from the borings were logged in detail by an Einarson, Fowler & Watson (EFW) hydrogeologist. We installed three 1"-diameter, fully-screened monitoring wells in the three borings. Hydrostratigraphic profiles of the borings and well construction diagrams are enclosed.

The aquifer was a little more fine-grained than we anticipated, so the collection of groundwater samples took longer than planned. Also, because of the low flow rates, it took more time than anticipated to fill the 250 mL flask we were using for field headspace analyses. Mary Morkin and I became concerned that most of the VOCs were being lost in the process and that our field headspace methods would be unreliable. We looked into renting a portable GC that could accommodate direct-injection of a small amount of headspace gas so that we could fill a smaller vial. In the end we chose to contract with a local mobile lab (On-site Environmental Laboratories, Inc), at a reduced rate, to give us rapid GC/MS analyses of water samples collected on the last two days of the investigation. We received results overnight, showing the concentrations of VOCs in the samples. The analytical results were plotted on cross sections in the field in order to select additional profiling locations. Mary has the originals of these cross sections.



Dr. Jim Barker

August 7, 1996

Page 2

Mary, Rob Langdon and I completed the field work on Saturday, July 27, performing slug tests in the newly-installed wells, surveying, and collecting groundwater samples for inorganic analyses.

The locations of all sampling and monitoring points were surveyed and recorded on a base map along with the locations of the existing wells in the area. We surveyed the elevations of the "top-of-casing" (TOC) of the new wells and the existing wells to 0.01'. Elevations are tied to a temporary site datum (a cross etched into the bottom concrete step of Building 133) and to feet-MSL using the reported TOC elevation of Well M28A (1991). Mary has the original copy of our field map.

We have completed our analysis of the slug test data using the Bouwer & Rice method. Calculated hydraulic conductivity values are approximately  $2 \times 10^{-3}$  cm/sec, which agrees with slug test results calculated by PRC during an earlier investigation. We used the computer program AQTESOLV (V.2.0) to calculate the results, but also performed manual calculations on one test (MW-2 falling head) to check the computer-generated values. The AQTESOLV results and our calculations are enclosed.

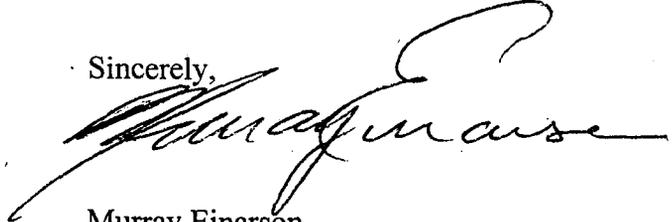
We marked the locations of underground utilities (located prior to beginning the field investigation by a subcontracted utility locator) with coloured flags so that the locations of the utility lines will still be apparent if/when Waterloo proceeds with the experiment. We anticipate that the coloured flags will remain at the site through Fall 1996.

We generated less than 5 gallons of waste soil, which is contained in a labeled and sealed metal bucket. We placed the bucket inside of PRC's fenced-in yard adjacent to Site 1. I received an E-mail from Rich Halket at PRC indicating that PRC will take care of disposing of the waste soil in the near future. No radiation was detected in the soil removed from any boring. Four drums of steam-cleaning rinsate were generated and remain on site. The drums are labeled with their contents and identify Ken Spielman as the point-of-contact. The liquid in the drums should be analyzed and disposed of appropriately. We understand that the Navy will take care of this. We would be happy to assist in this task if requested.

Dr. Jim Barker  
August 7, 1996  
Page 3

We enjoyed working with you on this interesting project. Please call us if we can be of any further assistance.

Sincerely,

A handwritten signature in black ink, appearing to read "Murray Einarson". The signature is fluid and cursive, with a large loop at the end.

Murray Einarson  
Principal Hydrogeologist

Enclosures:

Hydrostratigraphic profiles  
Well construction diagrams  
Slug test calculations

cc:

Mary Morkin (University of Waterloo)

cc (w/o enclosures):

Rich Halket (PRC)  
Ken Spielman (USN)  
Mike Baldwin (USN)  
Norma Bishop (USN)



**APPENDIX A – JULY AND OCTOBER 1996  
SITE INVESTIGATION REPORTS**

**SHEET 2 OF 2  
HYDROSTRATIGRAPHIC PROFILE  
BORING NO. B-1, WELL NO. MW-1**

**REVISED WORK PLAN  
FOR SEMI-PASSIVE GROUNDWATER  
REMEDATION DEMONSTRATION PROJECT AT  
SITE 1**

**THE ABOVE IDENTIFIED PAGE IS NOT  
AVAILABLE.**

**EXTENSIVE RESEARCH WAS PERFORMED BY  
NAVFAC SOUTHWEST TO LOCATE THIS PAGE.  
THIS PAGE HAS BEEN INSERTED AS A  
PLACEHOLDER AND WILL BE REPLACED  
SHOULD THE MISSING ITEM BE LOCATED.**

**QUESTIONS MAY BE DIRECTED TO:**

**DIANE C. SILVA  
RECORDS MANAGEMENT SPECIALIST  
NAVAL FACILITIES ENGINEERING COMMAND  
SOUTHWEST  
1220 PACIFIC HIGHWAY  
SAN DIEGO, CA 92132**

**TELEPHONE: (619) 532-3676**



APPENDIX A – JULY AND OCTOBER 1996  
SITE INVESTIGATION REPORTS

SHEET 2 OF 2  
HYDROSTRATIGRAPHIC PROFILE  
BORING NO. B-13, WELL NO. MW-2

REVISED WORK PLAN  
FOR SEMI-PASSIVE GROUNDWATER  
REMEDICATION DEMONSTRATION PROJECT AT  
SITE 1

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1220 PACIFIC HIGHWAY  
SAN DIEGO, CA 92132

TELEPHONE: (619) 532-3676



APPENDIX A – JULY AND OCTOBER 1996  
SITE INVESTIGATION REPORTS

SHEET 2 OF 2  
HYDROSTRATIGRAPHIC PROFILE  
BORING NO. B-14, WELL NO. MW-3

REVISED WORK PLAN  
FOR SEMI-PASSIVE GROUNDWATER  
REMEDICATION DEMONSTRATION PROJECT AT  
SITE 1

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AVAILABLE.

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NAVFAC SOUTHWEST TO LOCATE THIS PAGE.  
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PLACEHOLDER AND WILL BE REPLACED  
SHOULD THE MISSING ITEM BE LOCATED.

QUESTIONS MAY BE DIRECTED TO:

**DIANE C. SILVA**  
**RECORDS MANAGEMENT SPECIALIST**  
**NAVAL FACILITIES ENGINEERING COMMAND**  
**SOUTHWEST**  
**1220 PACIFIC HIGHWAY**  
**SAN DIEGO, CA 92132**

**TELEPHONE: (619) 532-3676**

BORING DESIGNATION: B-1

**INSTALLATION**

DATE: 7/22/96 BY: Precision

**DIMENSIONS**

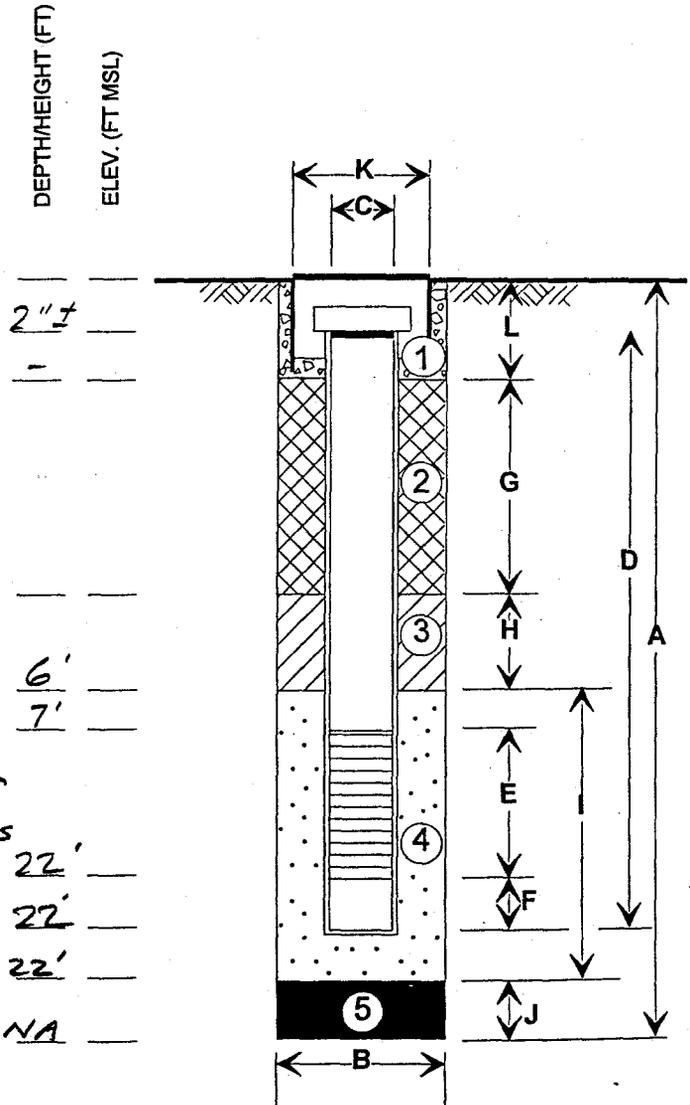
A Total Depth of Boring (ft.)	<u>22'</u>
B Borehole Diameter (in.)	<u>2 3/8"</u>
C Well Casing Diameter (in.)	<u>1" PVC</u>
D Well Casing Length (ft.)	<u>22'</u>
E Well Casing Slotted Interval (ft.)	<u>15'</u>
F Well Casing End Cap or Sump (ft.)	<u>plug</u>
G Annular Seal Interval (ft.)	<u>6'</u>
H Annular Seal Interval (ft.)	<u>-</u>
I Sand Pack Interval (ft.)	<u>16'</u>
J Bottom Material Interval (ft.)	<u>-</u>
K Protective Cover Diameter (in.)	<u>6"</u>
L Monument Footing Interval (ft.)	<u>-</u>
Well Centralizer Depth(s) (ft.)	<u>-</u>

**MATERIALS DATA**

Monument Footing	①	<u>Temp steel cover</u>	
Annular Seal	②	<u>Bentonite pellets</u>	
Annular Seal	③	<u>-</u>	<u>22'</u>
Sand Pack	④	<u>Natural</u>	<u>22'</u>
Bottom Material	⑤	<u>none</u>	<u>22'</u>
Slotted Casing		<u>0.010"</u>	<u>NA</u>
Well Casing		<u>1" Sch. 40 PVC</u>	
Well Centralizers		<u>none</u>	
Protective Cover		<u>Temp steel.</u>	

WELL DESIGNATION

MW-1



SECTION VIEW (not to scale)

NOTES: No lock.  
Water-tight expansion  
plug.

SITE: Alameda NAS  
PROJ. NO: ANA101  
N. E. -  
WELL PERMIT NO: -

BORING DESIGNATION: B-13

INSTALLATION

DATE: 7/26/96 BY: Precision

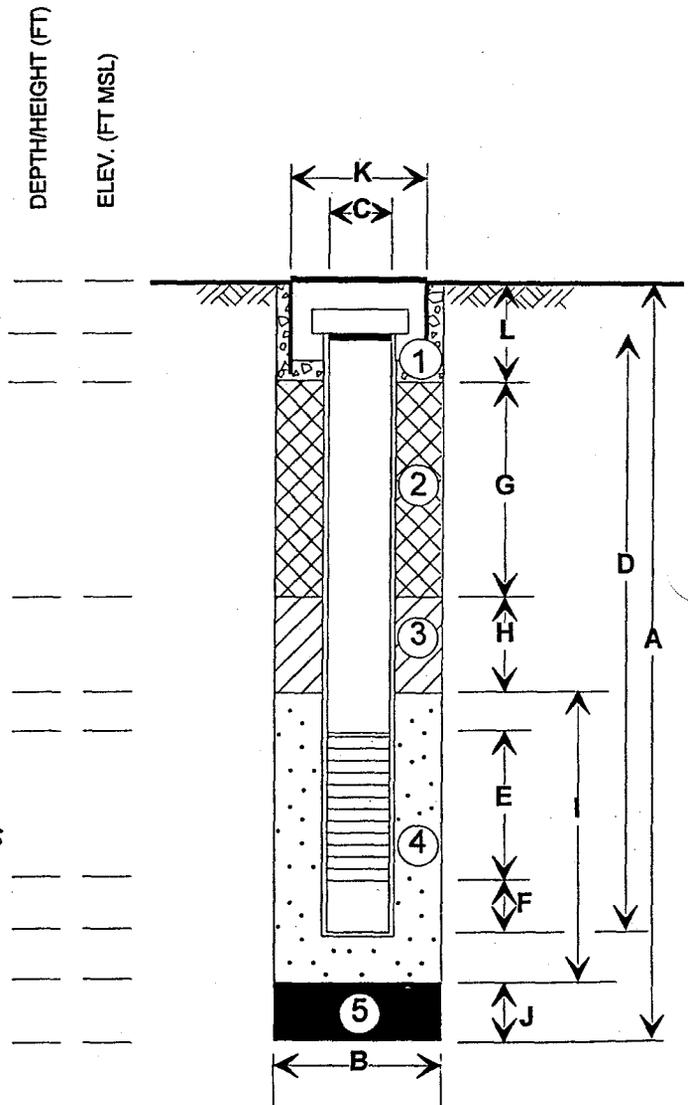
DIMENSIONS

A Total Depth of Boring (ft.)	<u>21'</u>
B Borehole Diameter (in.)	<u>2 3/8"</u>
C Well Casing Diameter (in.)	<u>1" PVC</u>
D Well Casing Length (ft.)	<u>21'</u>
E Well Casing Slotted Interval (ft.)	<u>15'</u>
F Well Casing End Cap or Sump (ft.)	<u>Plug</u>
G Annular Seal Interval (ft.)	<u>4.5'</u>
H Annular Seal Interval (ft.)	<u>-</u>
I Sand Pack Interval (ft.)	<u>16.5'</u>
J Bottom Material Interval (ft.)	<u>-</u>
K Protective Cover Diameter (in.)	<u>6"</u>
L Monument Footing Interval (ft.)	<u>-</u>
Well Centralizer Depth(s) (ft.)	<u>-</u>

MATERIALS DATA

Monument Footing	①	<u>Temp steel cover</u>
Annular Seal	②	<u>Bentonite pellets</u>
Annular Seal	③	<u>-</u>
Sand Pack	④	<u>Natural</u>
Bottom Material	⑤	<u>none</u>
Slotted Casing		<u>0.010"</u>
Well Casing		<u>1" Sch. 40 PVC</u>
Well Centralizers		<u>none</u>
Protective Cover		<u>Temp steel</u>

WELL DESIGNATION  
MW-2



SECTION VIEW (not to scale)

NOTES: Water-tight Plug.  
No lock

SITE: Alameda NAS  
PROJ. NO: ANA  
N. E. -  
WELL PERMIT NO: -

BORING DESIGNATION: B-14

**INSTALLATION**

DATE: 7/26/96 BY: Precision

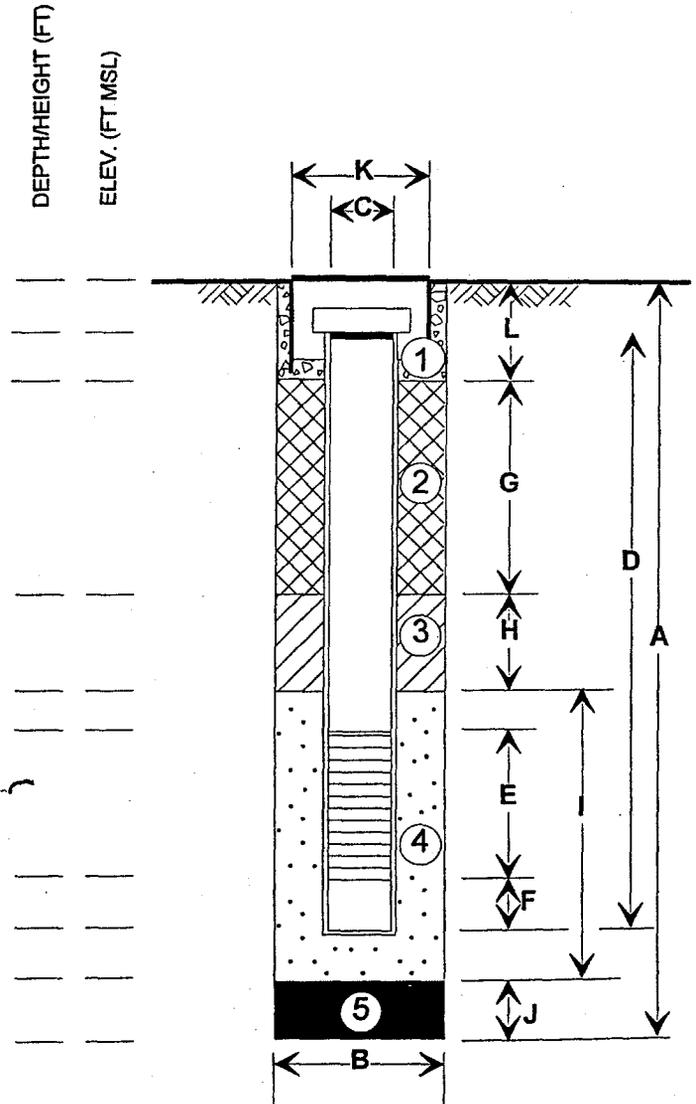
**DIMENSIONS**

A Total Depth of Boring (ft.)	<u>22'</u>
B Borehole Diameter (in.)	<u>2 3/8"</u>
C Well Casing Diameter (in.)	<u>1" PVC</u>
D Well Casing Length (ft.)	<u>22'</u>
E Well Casing Slotted Interval (ft.)	<u>15'</u>
F Well Casing End Cap or Sump (ft.)	<u>plug</u>
G Annular Seal Interval (ft.)	<u>2.5'</u>
H Annular Seal Interval (ft.)	<u>-</u>
I Sand Pack Interval (ft.)	<u>19.5'</u>
J Bottom Material Interval (ft.)	<u>-</u>
K Protective Cover Diameter (in.)	<u>6"</u>
L Monument Footing Interval (ft.)	<u>-</u>
Well Centralizer Depth(s) (ft.)	<u>-</u>

**MATERIALS DATA**

Monument Footing	①	<u>Temp Steel Cover</u>
Annular Seal	②	<u>Bentonite Pellets</u>
Annular Seal	③	<u>-</u>
Sand Pack	④	<u>Natural</u>
Bottom Material	⑤	<u>None</u>
Slotted Casing		<u>0.010"</u>
Well Casing		<u>1" Sch 40 PVC</u>
Well Centralizers		<u>None</u>
Protective Cover		<u>Temp. steel</u>

WELL DESIGNATION  
MW-3



SECTION VIEW (not to scale)

NOTES: Water-tight plug  
No lock

SITE: Alameda NAS  
PROJ. NO: ANA 101  
N. E. -  
WELL PERMIT NO: -

# CALCULATION SHEET

Sheet 1 of 3

Client: U. Waterloo

Prepared by: R. Longdon

Date: 8/7/96

Project Name: Alemeda NAS

Reviewed by: M. Einarson

Date: 8/8/96

Project No.: ANA 101

Approved by: M. Einarson

Date: 8/8/96

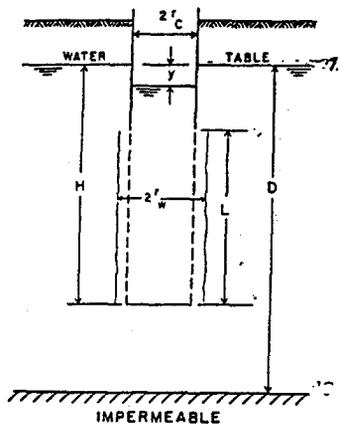
Manual calculation of Well MW-2 falling head test to compare to Agtesolve results.

Assumptions:

Source: Bouwer & Rice, 1976

- 1) System unconfined
- 2)  $r_c = r_w =$  inside diameter of 1" PVC pipe
- 3) Screen length = 14'
- 4) Aquifer thickness (D) = static head height (H).

Figure 1



Given:

$$\begin{aligned}
 r_c &= 0.04275' \\
 L &= 14' \\
 y_0 &= 0.9929 \text{ (see Agtesolve plot)} \\
 t &= 8 \text{ sec} \quad \text{---} \\
 y_F &= 0.18' \quad \text{---} \\
 H &= 14.36' \\
 D &= 14.36' \\
 r_w &= 0.04275' \text{ (no sand pack)}
 \end{aligned}$$

# CALCULATION SHEET

Sheet 2 of 3

Client: U. Waterloo

Prepared by: R. Langdon

Date: 8/17/96

Project Name: Alameda NAS

Reviewed by: M. Einerson

Date: 8/18/96

Project No.: ANA101

Approved by: M. Einerson

Date: 8/18/96

Since  $H = D$

Equation 1: 
$$\ln \frac{Re}{r_w} = \left( \frac{1.1}{\ln 4/r_w} + \frac{C}{L/r_w} \right)^{-1}$$

FIGURE 2

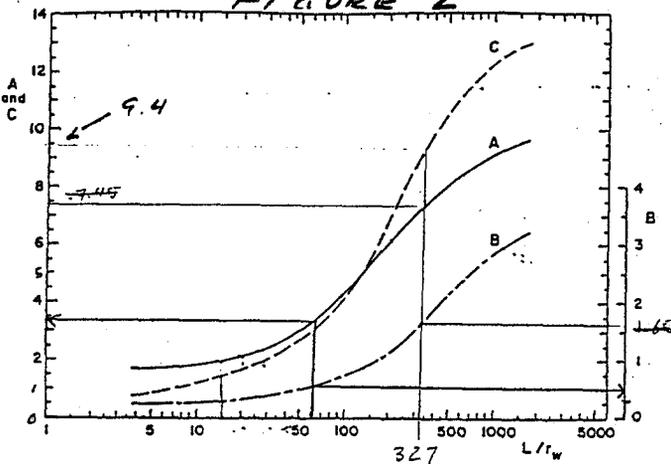


Fig. 3. Curves relating coefficients A, B, and C to  $L/r_w$ .

$$L/r_w = \frac{14}{0.04275} = 327$$

∴ from Figure 2,

$$C = 9.4$$

From Equation 1,

$$\ln \frac{Re}{r_w} = \left( \frac{1.1}{\ln \left( \frac{14.36}{0.04275} \right)} + \frac{9.4}{327.4} \right)^{-1}$$

$$= 4.591$$

Equation 2:

$$K = \frac{r_c^2 \ln \left( \frac{Re}{r_w} \right)}{2L} \frac{1}{t} \frac{\ln y_0}{y_0}$$

# CALCULATION SHEET

Sheet 3 of 3Client: U. WaterlooPrepared by: R. LangdonDate: 8/7/96Project Name: Alameda NASReviewed by: M. EinarsonDate: 8/8/96Project No.: ANA101Approved by: M. EinarsonDate: 8/8/96

From Equation 2  
and the Agresive  
data plot,

$$K = \frac{(0.04275)^2 (4.591)}{28} \frac{1}{8} \ln \frac{0.9929}{0.18}$$

$$= 6.4 \times 10^{-5} \text{ ft/sec}$$

$$= 2 \times 10^{-3} \text{ cm/sec}$$

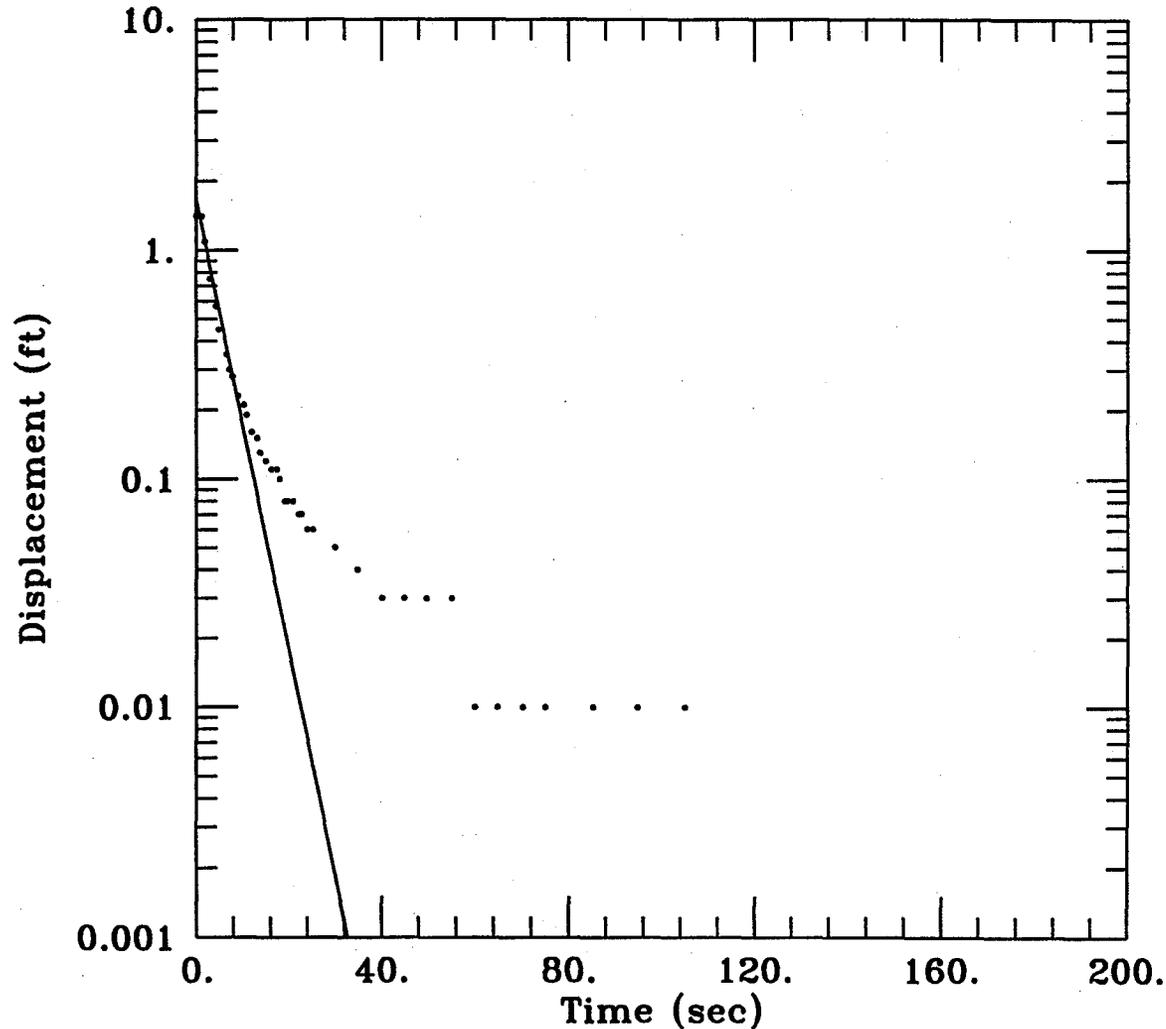
Client: UNIVERSITY OF WATERLOO

Company: EINARSON, FOWLER & WATSON

Location: ALAMEDA NAS, SITE #1

Project: ANA 101

## ALAMEDA NAS, MW-1 FALLING HEAD SLUG TEST



DATA SET:  
MW1T3A.DAT  
08/06/96

AQUIFER MODEL:  
Unconfined  
SOLUTION METHOD:  
Bouwer-Rice

PROJECT DATA:  
test date: JULY 27, 1996

TEST DATA:  
H0 = 1.41 ft  
rc = 0.04275 ft  
rw = 0.04275 ft  
L = 14. ft  
b = 16.75 ft  
H = 16.75 ft

PARAMETER ESTIMATES:  
K = 6.992E-05 ft/sec  
y0 = 1.662 ft

$2.1 \times 10^{-3} \text{ cm/sec}$

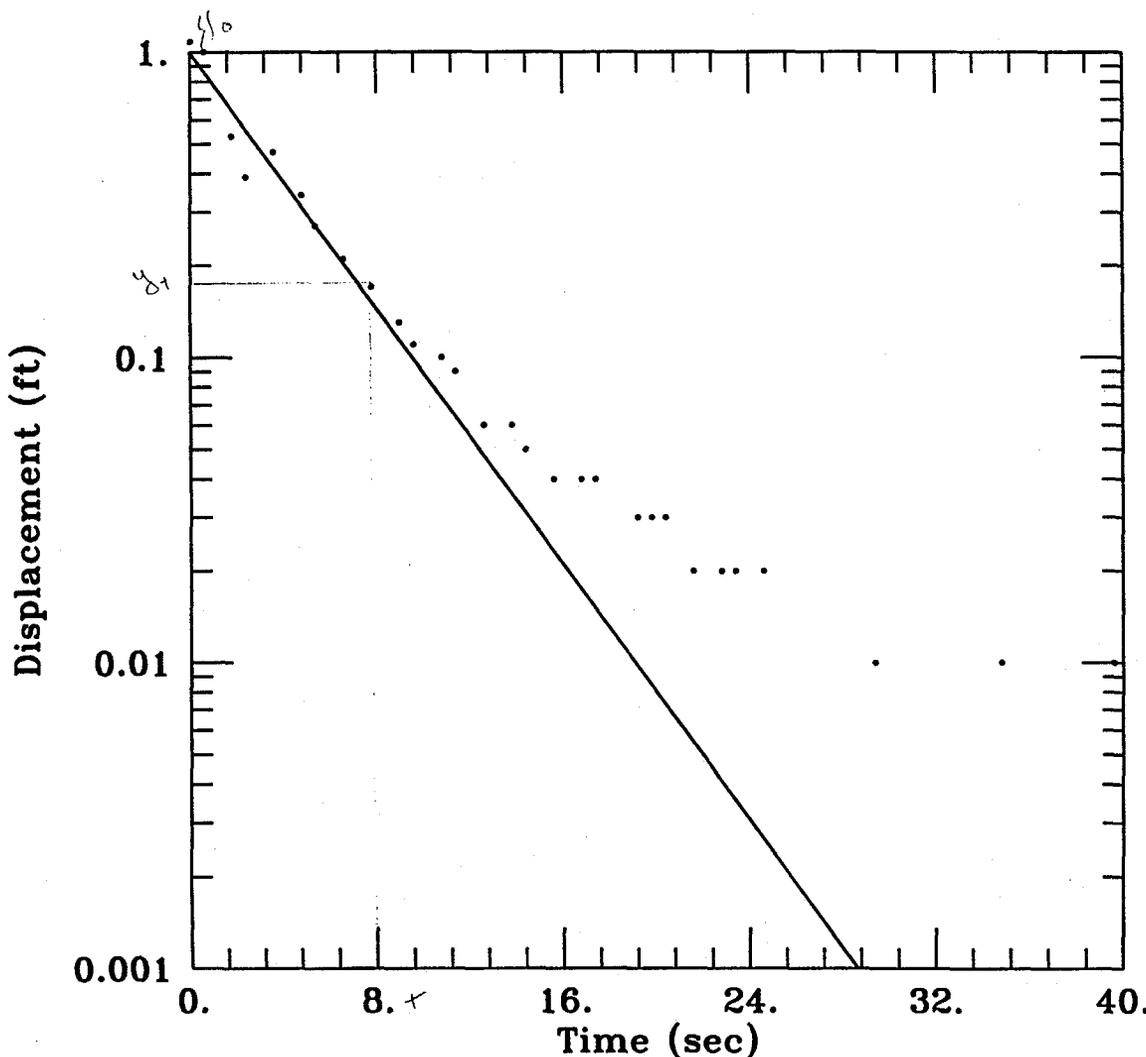
Client: UNIVERSITY OF WATERLOO

Company: EINARSON, FOWLER & WATSON

Location: ALAMEDA NAS, SITE #1

Project: ANA 101

# ALAMEDA NAS, MW-2 FALLING HEAD SLUG TEST



DATA SET:  
MW2T2A.DAT  
08/06/96

AQUIFER MODEL:  
Unconfined  
SOLUTION METHOD:  
Bouwer-Rice

PROJECT DATA:  
test date: JULY 27, 1996

TEST DATA:  
H0 = 1.08 ft  
rc = 0.04275 ft  
rw = 0.04275 ft  
L = 14. ft  
b = 14.36 ft  
H = 14.36 ft

PARAMETER ESTIMATES:  
K = 7.26E-05 ft/sec  
y0 = 0.9929 ft

$2.2 \times 10^{-2}$  cm/sec

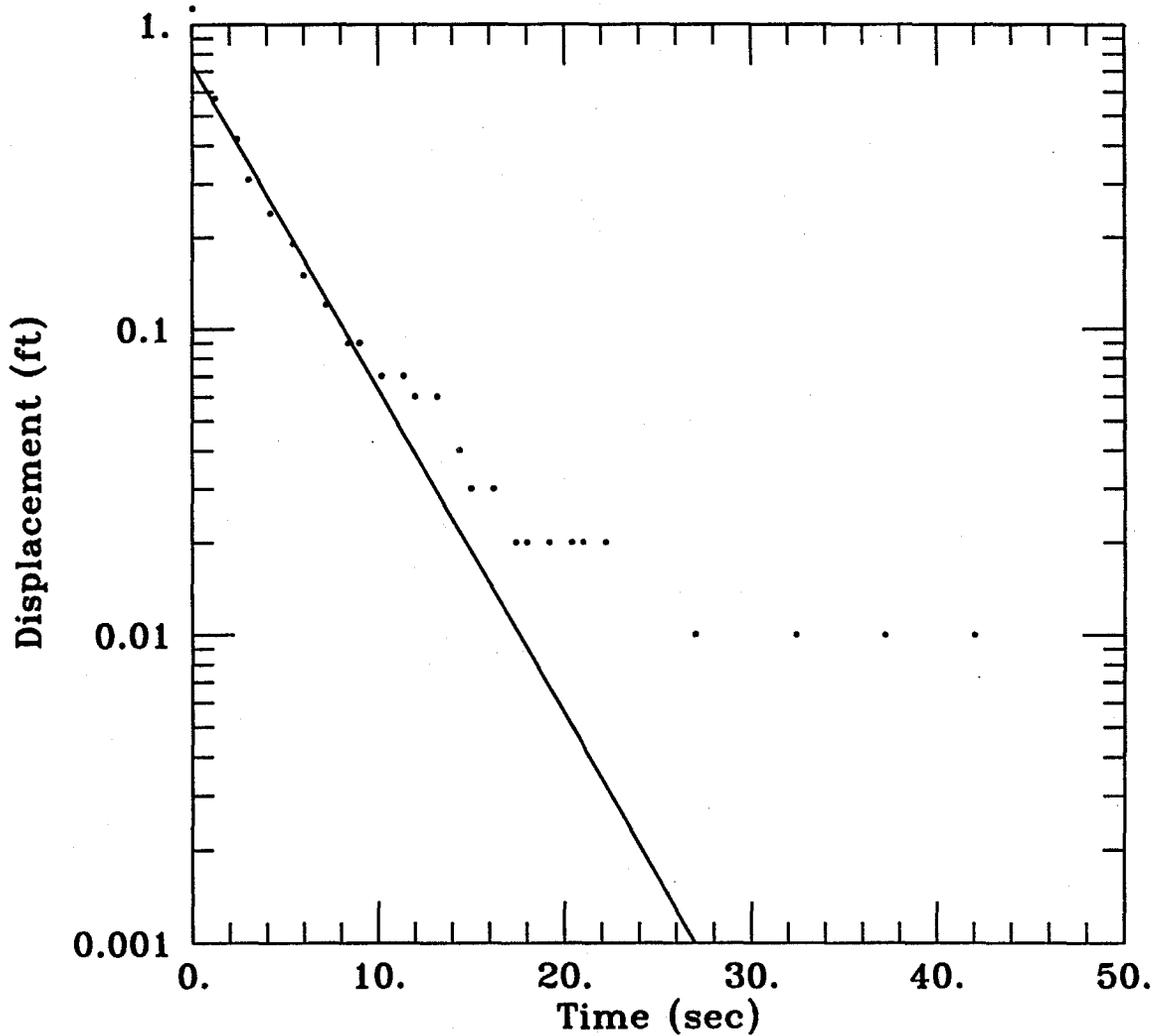
Client: UNIVERSITY OF WATERLOO

Company: EINARSON, FOWLER & WATSON

Location: ALAMEDA NAS, SITE #1

Project: ANA 101

## ALAMEDA NAS, MW-3 FALLING HEAD SLUG TEST



DATA SET:  
MW3T3A.DAT  
08/06/96

AQUIFER MODEL:  
Unconfined  
SOLUTION METHOD:  
Bouwer-Rice

PROJECT DATA:  
test date: JULY 27, 1996

TEST DATA:  
H0 = 1.13 ft  
rc = 0.04275 ft  
rw = 0.04275 ft  
L = 14. ft  
b = 14.61 ft  
H = 14.61 ft

PARAMETER ESTIMATES:  
K = 7.381E-05 ft/sec  
y0 = 0.7296 ft

$2.2 \times 10^{-3}$  cm/sec

October 17, 1996  
Project No. ANA101

Mr. Ken Spielman  
Engineering Field Activity, West  
Naval Facilities Engineering Command  
900 Commodore Dr., Code 1831.4  
San Bruno, CA 94066-5006

Re: Workplan Addendum, Hydrogeologic Investigation, Site 1, Naval Air Station  
Alameda, California

Dear Mr. Spielman:

On behalf of the Department of Earth Sciences, University of Waterloo (UW), Einarson, Fowler & Watson (EFW) is presenting this addendum to the July 1996 Hydrogeologic Investigation Workplan (Workplan-Einarson, Fowler & Watson, 1996) for activities related to additional hydrogeologic characterization for Site 1, Naval Air Station Alameda, California.

### **INVESTIGATION TASKS**

The following scope of work is designed to provide additional hydrogeologic characterization of the Demonstration Project Site (Figure 1). The scope has been broken down into the following tasks, which are described below:

- Soil Coring and Sampling
- Temporary Monitoring Well Installation
- Geochemical Groundwater Profiling

The locations of soil core holes, monitoring well, and groundwater profiling points are shown on Figure 1.

### **Soil Coring and Sampling**

In order to further define the site hydrogeology within the Demonstration Project Site, EFW will advance direct push probes to determine aquitard depth and obtain soil cores across the



Mr. Ken Spielman

October 17, 1996

Page 2

sand/aquitard boundary. In one of these borings, two soil samples from the center of the dissolved chlorinated organic plume will be collected and analyzed for waste characterization. One soil sample from approximately 7 to 8 feet below ground surface (bgs) will be analyzed for total oil and grease (TOG, EPA Method 418.1), semivolatile organics (EPA Method 8270), BTEX (EPA Method 8020), and metals (CAM 17 metals, EPA Method series 6000 and 7000). A deeper soil sample from approximately 10 to 11 feet bgs will be analyzed for volatile organic compounds (VOCs, EPA Method 8240). Soil coring will be performed by Precision Sampling, Inc. (PSI) of San Rafael, California. Soil cores will be collected using the Enviro-Core<sup>®</sup> system or piston sampler method. A discussion of both soil coring methods is presented in the July 1996 Workplan.

### **Temporary Monitoring Well Installation**

One boring will be converted to a shallow, temporary monitoring well following completion of soil coring. This well will be screened across the water table from approximately 4 to 9 feet bgs to check for the presence of light nonaqueous phase liquids (LNAPLs). Well construction will consist of a Schedule 40, 1.25-inch-diameter polyvinyl-chloride (PVC) pipe with approximately five feet of slotted PVC screen placed across the water table. Bentonite pellets and Portland cement will be used for an annular seal.

### **Geochemical Groundwater Profiling**

In order to further evaluate the distribution of organic contaminants in the shallow aquifer, a Waterloo Drive-Point Profiler will be used to collect five depth-discrete water samples (8, 10, 12, 16, and 20 feet bgs) at approximately five locations (Figure 1). A thorough discussion of the Waterloo Drive-Point Profiler is presented in the July 1996 Workplan. Groundwater samples collected during profiling will be sent to the University of Waterloo and analyzed for VOCs.

Upon completion of groundwater profiling and coring, the remaining holes will be grouted to the surface using a cement-bentonite slurry.

### **HEALTH AND SAFETY**

Health and safety practices during this additional investigation will follow those outlined in the July 1996 Workplan. This health and safety plan addresses expected hazards, monitoring, and proposed mitigation for potential exposure to low-level VOCs and low-level radioactivity.

### **WASTE DISPOSAL**

All groundwater samples, purge water, and soil cores will be screened in the field for levels of VOCs and radioactivity using hand-held field instrumentation. Soil waste will be placed in a 5-gallon metal bucket, secured in a low level RAD waste yard, and disposed of properly by PRC Environmental. Because of the geological and geochemical profiling methods used

during this investigation, only a small volume of waste soil is expected to be generated (less than 1 cubic foot). Waste water generated during the investigation will be contained in 55-gallon drums and placed in a fenced compound. Disposal of waste water generated during this investigation will be coordinated with Randy Cate, NAS Alameda Environmental Office. Waste water will be disposed of at the Industrial Waste Water Treatment Plant (IWTP).

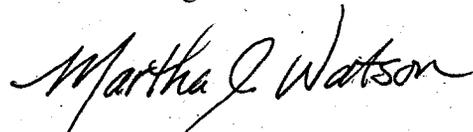
### SCHEDULE

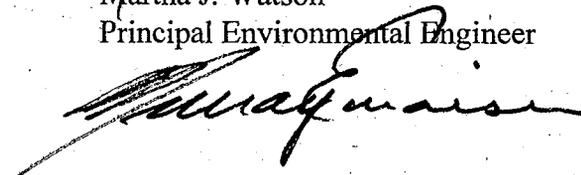
We intend to begin field work Monday October 21, 1996. It is estimated that field work will last three days.

If you have any questions about this workplan addendum, please call us at (415) 843-3828.

Sincerely,  
Einarson, Fowler & Watson

  
Robert E. Langdon  
Staff Geologist

  
Martha J. Watson  
Principal Environmental Engineer

  
Murray D. Einarson, C.H.  
Principal Hydrogeologist

cc: Mary Morkin, University of Waterloo

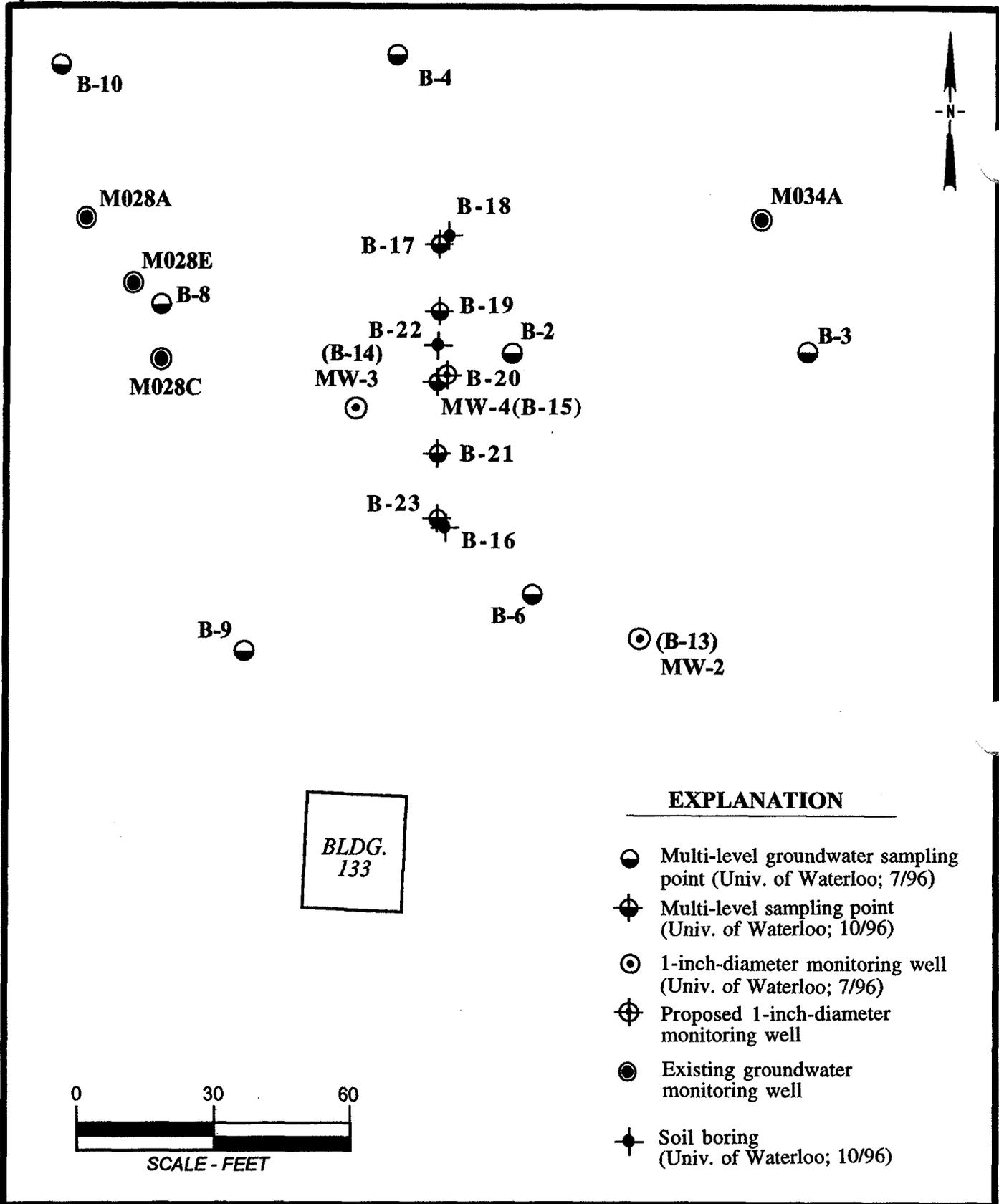
Attachments:

Figure 1 - Demonstration Project Site

Mr. Ken Spielman  
October 17, 1996  
Page 4

**LIST OF REFERENCES**

Einarson, Fowler & Watson, July 16, 1996 Letter to Ken Spielman, Engineering Field Activity, West Re: *Hydrogeologic Investigation, Site 1, Alameda Naval Air Station, Alameda, California.*



ADDITIONAL HYDROGEOLOGIC INVESTIGATION  
 ALAMEDA NAVAL AIR STATION  
 ALAMEDA, CALIFORNIA

---

DEMONSTATION PROJECT SITE  
 PROPOSED MONITORING POINTS

FIGURE  
**1**  
 PROJECT N  
 ANA101









CONTRACT LABORATORY: <sup>UW</sup> Waterloo, ONT TURN-AROUND TIME: \_\_\_\_\_

Project No. <b>ANA 101</b>		Site Name <b>Alameda NAS</b>				Analyses					<div style="border: 1px solid black; width: 100%; height: 100%; background: repeating-linear-gradient(45deg, transparent, transparent 2px, black 2px, black 4px);"></div>
Sampler(s): (printed) <b>Robert Langdon</b>		(signature) <i>Robert Langdon</i>									
Sample I.D.	Lab I.D.	Collection		Matrix	Depth	Container Information				Remarks	
		Date	Time			Type/Volume	Qty	Filt	Prsrv.		
<b>EB-3</b>		<b>10.23</b>	<b>1050</b>	<b>H<sub>2</sub>O</b>	<b>—</b>	<b>VOA / 40ml</b>	<b>2</b>	<b>—</b>	<b>Acide</b>	<b>Taken before B21-1</b>	
<del>B21-1</del>			<b>1145</b>		<b>10'</b>						
<b>B21-2</b>			<b>1230</b>		<b>11.5</b>						
<b>B21-3</b>			<b>1240</b>		<b>13.5</b>						
<b>B21-4</b>			<b>1245</b>		<b>16'</b>						
<b>B21-5</b>			<b>1325</b>		<b>20</b>						
<del>UBA</del>											
<b>EB-4</b>			<b>1430</b>		<b>—</b>					<b>Taken before B23-1</b>	
<b>B23-1</b>			<b>1450</b>		<b>9.5</b>						
<b>B23-2</b>			<b>1500</b>		<b>11.5</b>						
<b>B23-3</b>			<b>1510</b>		<b>13.5</b>						
<b>B23-4</b>			<b>1520</b>		<b>16</b>						
<b>B23-5</b>			<b>1540</b>		<b>20</b>						

Relinquished by: (signature) <i>Robert Langdon</i>	Received by: (signature)	Date/Time:	<b>Send Results To:</b> <b>Attn:</b> <b>EINARSON, FOWLER &amp; WATSON</b> 2650 East Bayshore Road Palo Alto, CA 94303 Phone (415) 843-3828 Fax (415) 843-3815
Relinquished by: (signature)	Received by: (signature)	Date/Time:	
Relinquished by: (signature)	Received by: (signature)	Date/Time:	

CONTRACT LABORATORY: SE(D) AW

TURN-AROUND TIME: STANDARD

PO:   

Project No.		Site Name				Analyses						Remarks
ANA101		Alameda NAS				<div style="border: 1px solid black; padding: 5px; transform: rotate(-90deg); display: inline-block;">                 82410 82270 CAM-17 METALS             </div>						
Sampler(s): (printed)		Sampler(s): (signature)										
Robert Langdon		Robert P. Langdon										
Sample I.D.	Lab I.D.	Collection		Matrix	Depth	Container Information						
		Date	Time			Type/Volume	Qty	Filt	Prsrv.			
RW-2		10.23.96	1630	H <sub>2</sub> O	—	Amb/1L	2	N	—	X		
						VOA/40ml	4	N	HCl	X		
						HDE/1L	4	N	HNO <sub>3</sub>		X	

Relinquished by: (signature)  
*Robert P. Langdon*

Received by: (signature)  
*De V.*

Date/Time:  
10.24.96 7:10

Send Results To:  
Attn: *Ms. Martha Watson*  
EINARSON, FOWLER & WATSON  
2650 East Bayshore Road  
Palo Alto, CA 94303  
Phone (415) 843-3828  
Fax (415) 843-3815

Relinquished by: (signature)

Received by: (signature)

Date/Time:

CONTRACT LABORATORY: 4000 Ave.

TURN-AROUND TIME: Standard

PO # \_\_\_\_\_

Project No.		Site Name				Analyses					Remarks		
ANA 101		NAS Alameda				<div style="display: flex; justify-content: space-between;"> <div style="writing-mode: vertical-rl; transform: rotate(180deg);">TOG (4811)</div> <div style="writing-mode: vertical-rl; transform: rotate(180deg);">(8240)</div> <div style="writing-mode: vertical-rl; transform: rotate(180deg);">BEX (8240)</div> <div style="writing-mode: vertical-rl; transform: rotate(180deg);">CAM (8240)</div> <div style="writing-mode: vertical-rl; transform: rotate(180deg);">WYS (8240)</div> </div>							
Sampler(s): (printed)		(signature)											
Robert Langston		Robert Langston											
Sample I.D.	Lab I.D.	Collection		Matrix	Depth	Container Information							
		Date	Time			Type/Volume	Qty	Filt	Prsrv.				
BK/7-7/2		10-21-96	1200	Soil	7-7/2	55 Ring	1	1	None	X	X	X	
BK/10/2-11		↓	1225	↓	10/2-11	↓	1	↓	↓			X	

Relinquished by: (signature) <i>Robert Langston</i>	Received by: (signature)	Date/Time: 10-22-96	<b>Send Results To:</b> Attn: Mr. Murray Einarson EINARSON, FOWLER & WATSON 2650 East Bayshore Road Palo Alto, CA 94303 Phone (415) 843-3828 Fax (415) 843-3815
Relinquished by: (signature)	Received by: (signature)	Date/Time:	
Relinquished by: (signature)	Received by: (signature)	Date/Time: 10/22/96 1350	

**ORGANIC GEOCHEMISTRY IAB**

University of Waterloo  
885-1211 ext 6370

Nov 6 , 1996

RICE  
ALAMEDA SITE  
LABJOB# 961025

Dear Mary:

Attached you will find the results for samples submitted Oct 29, 1996. All data has been computed using Rick's program . Many of the samples submitted had to be diluted due to the very high levels of vinyl chloride and c12DCE. Sample ids with a D beside them refer to this and results noted with a \*C means the value reported was over the calibration range. As you will see sometimes there are 2 or more reported values for a sample which shows the diluted and undiluted values. I had some problems with the vinyl chloride standard curve as you can see by the regression data (due to some integration problems) and am still working on this. I will send you an updated version at a later date, but I don't think it should change results too much. If you have any questions or concerns please don't hesitate to contact me.

Sincerely,



Shirley Chatten  
Technician

RICE  
ALAMEDA SITE  
CRIT ANALYSIS  
LABJOB# 9610205

DATE SUBMITTED OCT 29, 96  
DATE ANALYZED OCT 30,31, 96  
REPORT DATE NOV 6, 96

ORGANIC GEOCHEM LAB  
UNIVERSITY OF WATERLOO  
885-1211 EXT 6370

PCE

-----REGRESSION DATA-----

SEG	PTS	SLOPE	INTERCEPT	+/-SLOPE	+/-INTERC.	DL	R2	G/O
1	15	265.21	0.0000E+00	18.049	0.0000E+00	5.89	0.951	0
2	23	289.20	0.0000E+00	10.085	0.0000E+00	7.54	0.984	0
3	32	271.62	0.0000E+00	5.0758	0.0000E+00	20.1	0.995	0
4	39	282.84	0.0000E+00	3.8019	0.0000E+00	28.8	0.997	0
5	42	272.00	0.0000E+00	4.7279	0.0000E+00	53.3	0.995	0

THE LIMIT OF QUANTIFICATION: 11.8 X UNITS USING SEGMENT 1

-----INTERROGATION-----

SAMPLE	SEG	Y	X (PCE)	X +/-	X +/- %
B18110/22	1	0.0000E+00	0.0000E+00	5.891	0.0000E+00
B18210/22	1	0.0000E+00	0.0000E+00	5.891	0.0000E+00
B18310/22	1	0.0000E+00	0.0000E+00	5.891	0.0000E+00
B18410/22	1	0.0000E+00	0.0000E+00	5.891	0.0000E+00
B18510/22	1	0.0000E+00	0.0000E+00	5.891	0.0000E+00
B18610/22	1	0.0000E+00	0.0000E+00	5.891	0.0000E+00
B19110/22	1	0.0000E+00	0.0000E+00	5.891	0.0000E+00
B19210/22	1	1155.	4.355	5.898	135.4
B19310/22	1	0.0000E+00	0.0000E+00	5.891	0.0000E+00
B19410/22	1	0.0000E+00	0.0000E+00	5.891	0.0000E+00
B19510/22	1	0.0000E+00	0.0000E+00	5.891	0.0000E+00
B20110/23	1	438.0	1.652	5.892	356.8
B20210/23	1	1098.	4.140	5.898	142.4
B20310/23	1	0.0000E+00	0.0000E+00	5.891	0.0000E+00
B20410/23	1	0.0000E+00	0.0000E+00	5.891	0.0000E+00
B20510/23	1	0.0000E+00	0.0000E+00	5.891	0.0000E+00
B21110/23	1	0.0000E+00	0.0000E+00	5.891	0.0000E+00
B21210/23	1	451.0	1.701	5.892	346.5
B21310/23	1	505.0	1.904	5.892	309.4
B21410/23	1	0.0000E+00	0.0000E+00	5.891	0.0000E+00
B21510/23	1	0.0000E+00	0.0000E+00	5.891	0.0000E+00
B23110/23	1	1161.	4.378	5.898	134.7
B23210/23	1	789.0	2.975	5.894	198.1
B23310/23	1	1015.	3.827	5.897	154.1
B23410/23	1	600.0	2.262	5.893	260.5
B23510/23	1	0.0000E+00	0.0000E+00	5.891	0.0000E+00
EB1ALA	1	0.0000E+00	0.0000E+00	5.891	0.0000E+00
EB2ALA10/23	1	0.0000E+00	0.0000E+00	5.891	0.0000E+00
EB3ALA10/23	1	0.0000E+00	0.0000E+00	5.891	0.0000E+00
EB4ALA10/23	1	0.0000E+00	0.0000E+00	5.891	0.0000E+00

all concentration units are ug/L

D signifies sample was diluted

\*C signifies value exceeds calibration values

## DCM

## -----REGRESSION DATA-----

SEG	PTS	SLOPE	INTERCEPT	+/-SLOPE	+/-INTERC.	DL	R2	G/O
1	18	76.307	0.0000E+00	5.1911	0.0000E+00	11.7	0.958	0
2	26	73.236	0.0000E+00	2.4060	0.0000E+00	14.2	0.985	0
3	35	65.443	545.72	1.6054	443.93	42.7	0.995	1
4	42	67.010	0.0000E+00	0.65549	0.0000E+00	31.6	0.998	0

THE LIMIT OF QUANTIFICATION: 23.4 X UNITS USING SEGMENT 1

## -----INTERROGATION-----

SAMPLE	SEG	Y	X (DCM)	X +/-	X +/- %
B18110/22	1	0.0000E+00	0.0000E+00	11.66	0.0000E+00
B18210/22	1	0.0000E+00	0.0000E+00	11.66	0.0000E+00
B18310/22	1	0.0000E+00	0.0000E+00	11.66	0.0000E+00
B18410/22	1	0.0000E+00	0.0000E+00	11.66	0.0000E+00
B18510/22	1	0.0000E+00	0.0000E+00	11.66	0.0000E+00
B18610/22	1	0.0000E+00	0.0000E+00	11.66	0.0000E+00
B19110/22	1	0.0000E+00	0.0000E+00	11.66	0.0000E+00
B19210/22	1	0.0000E+00	0.0000E+00	11.66	0.0000E+00
B19310/22	1	0.0000E+00	0.0000E+00	11.66	0.0000E+00
B19410/22	1	0.0000E+00	0.0000E+00	11.66	0.0000E+00
B19510/22	1	0.0000E+00	0.0000E+00	11.66	0.0000E+00
B20110/23	1	0.0000E+00	0.0000E+00	11.66	0.0000E+00
210/23	1	0.0000E+00	0.0000E+00	11.66	0.0000E+00
B20310/23	1	0.0000E+00	0.0000E+00	11.66	0.0000E+00
B20410/23	1	525.0	6.880	11.67	169.7
B20510/23	1	0.0000E+00	0.0000E+00	11.66	0.0000E+00
B21110/23	1	0.0000E+00	0.0000E+00	11.66	0.0000E+00
B21210/23	1	0.0000E+00	0.0000E+00	11.66	0.0000E+00
B21310/23	1	0.0000E+00	0.0000E+00	11.66	0.0000E+00
B21410/23	1	0.0000E+00	0.0000E+00	11.66	0.0000E+00
B21510/23	1	0.0000E+00	0.0000E+00	11.66	0.0000E+00
B23110/23	1	0.0000E+00	0.0000E+00	11.69	0.0000E+00
B23210/23	1	0.0000E+00	0.0000E+00	11.69	0.0000E+00
B23310/23	1	0.0000E+00	0.0000E+00	11.69	0.0000E+00
B23410/23	1	0.0000E+00	0.0000E+00	11.66	0.0000E+00
B23510/23	1	0.0000E+00	0.0000E+00	11.66	0.0000E+00
EB1ALA	1	0.0000E+00	0.0000E+00	11.66	0.0000E+00
EB2ALA10/23	1	0.0000E+00	0.0000E+00	11.66	0.0000E+00
EB3ALA10/23	1	0.0000E+00	0.0000E+00	11.66	0.0000E+00
EB4ALA10/23	1	0.0000E+00	0.0000E+00	11.66	0.0000E+00

## CTET

## -----REGRESSION DATA-----

SEG	PTS	SLOPE	INTERCEPT	+/-SLOPE	+/-INTERC.	DL	R2	G/O
1	15	63.143	0.00000E+00	6.8948	0.00000E+00	18.7	0.881	0
2	23	63.511	0.00000E+00	2.4819	0.00000E+00	16.9	0.977	0
3	32	54.576	625.17	1.7939	518.80	55.2	0.992	1
4	39	57.661	0.00000E+00	0.79279	0.00000E+00	44.4	0.997	0
5	42	56.254	0.00000E+00	0.93444	0.00000E+00	64.8	0.995	0

THE LIMIT OF QUANTIFICATION: 33.7 X UNITS USING SEGMENT 2

## -----INTERROGATION-----

SAMPLE	SEG	Y	X (CTET)	X +/-	X +/- %
B18110/22	2	0.0000E+00	0.0000E+00	16.86	0.0000E+00
B18210/22	2	0.0000E+00	0.0000E+00	16.86	0.0000E+00
B18310/22	2	0.0000E+00	0.0000E+00	16.86	0.0000E+00
B18410/22	2	0.0000E+00	0.0000E+00	16.86	0.0000E+00
B18510/22	2	0.0000E+00	0.0000E+00	16.86	0.0000E+00
B18610/22	2	0.0000E+00	0.0000E+00	16.86	0.0000E+00
B19110/22	2	0.0000E+00	0.0000E+00	16.86	0.0000E+00
B19210/22	2	0.0000E+00	0.0000E+00	16.86	0.0000E+00
B19310/22	2	0.0000E+00	0.0000E+00	16.86	0.0000E+00
B19410/22	2	0.0000E+00	0.0000E+00	16.86	0.0000E+00
B19510/22	2	0.0000E+00	0.0000E+00	16.86	0.0000E+00
B20110/23	2	0.0000E+00	0.0000E+00	16.86	0.0000E+00
B20210/23	2	0.0000E+00	0.0000E+00	16.86	0.0000E+00
B20310/23	2	0.0000E+00	0.0000E+00	16.86	0.0000E+00
B20410/23	2	0.0000E+00	0.0000E+00	16.86	0.0000E+00
B20510/23	2	0.0000E+00	0.0000E+00	16.86	0.0000E+00
B21110/23	2	0.0000E+00	0.0000E+00	16.86	0.0000E+00
B21210/23	2	0.0000E+00	0.0000E+00	16.86	0.0000E+00
B21310/23	2	0.0000E+00	0.0000E+00	16.86	0.0000E+00
B21410/23	2	0.0000E+00	0.0000E+00	16.86	0.0000E+00
B21510/23	2	0.0000E+00	0.0000E+00	16.86	0.0000E+00
B23110/23	2	0.0000E+00	0.0000E+00	16.86	0.0000E+00
B23210/23	2	0.0000E+00	0.0000E+00	16.86	0.0000E+00
B23310/23	2	0.0000E+00	0.0000E+00	16.86	0.0000E+00
B23410/23	2	0.0000E+00	0.0000E+00	16.86	0.0000E+00
B23510/23	2	0.0000E+00	0.0000E+00	16.86	0.0000E+00
EB1ALA	2	0.0000E+00	0.0000E+00	16.86	0.0000E+00
EB2ALA10/23	2	0.0000E+00	0.0000E+00	16.86	0.0000E+00
EB3ALA10/23	2	0.0000E+00	0.0000E+00	16.86	0.0000E+00
EB4ALA10/23	2	0.0000E+00	0.0000E+00	16.86	0.0000E+00

TOLUENE

-----REGRESSION DATA-----

SEG	PTS	SLOPE	INTERCEPT	+/-SLOPE	+/-INTERC.	DL	R2	G/O
1	15	147.28	0.00000E+00	5.1061	0.00000E+00	5.48	0.991	0
2	23	162.03	0.00000E+00	5.5998	0.00000E+00	14.7	0.987	0
3	32	156.47	0.00000E+00	2.7407	0.00000E+00	37.6	0.996	0
4	39	160.29	0.00000E+00	1.8545	0.00000E+00	49.6	0.998	0
5	42	155.91	0.00000E+00	2.5029	0.00000E+00	98.3	0.996	0

THE LIMIT OF QUANTIFICATION: 11.0 X UNITS USING SEGMENT 1

-----INTERROGATION-----

SAMPLE	SEG	Y	X (TOL)	X +/-	X +/- %	X (CORR)
B18110/22	1	0.0000E+00	0.0000E+00	5.482	0.0000E+00	
B18210/22	1	5680.	38.57	5.643	14.63	
B18310/22	5	0.4410E+06	2829.	108.3	3.829	*C
B183D10/22	3	0.3228E+05	206.3	37.76	18.30	2950.09
B18410/22	3	0.6894E+05	440.6	38.37	8.709	
B18510/22	1	940.0	6.382	5.487	85.97	
B18610/22	1	0.0000E+00	0.0000E+00	5.482	0.0000E+00	
B19110/22	5	0.6233E+06	3998.	117.4	2.937	*C
B191D10/22	3	0.4277E+05	273.3	37.89	13.86	3908.19
B19210/22	5	0.6305E+06	4044.	117.8	2.914	*C
B192D10/22	3	0.4042E+05	258.3	37.86	14.66	3693.69
B19310/22	5	0.3285E+06	2107.	104.0	4.935	
B193D10/22	3	0.2308E+05	147.5	37.67	25.55	2109.25
B19410/22	2	0.1352E+05	83.46	15.02	17.99	
B19510/22	1	1233.	8.372	5.490	65.58	
B20110/23	3	0.2718E+05	173.7	37.71	21.71	
B20210/23	4	0.1296E+06	808.8	50.48	6.242	
B20310/23	3	0.7516E+05	480.3	38.51	8.019	
B20410/23	1	714.0	4.848	5.485	113.1	
B20510/23	1	1104.	7.496	5.489	73.22	
B21110/23	1	8232.	55.89	5.815	10.40	
B21210/23	1	2949.	20.02	5.526	27.60	
B21310/23	1	764.0	5.187	5.485	105.7	
B21410/23	1	0.0000E+00	0.0000E+00	5.482	0.0000E+00	
B21510/23	1	0.0000E+00	0.0000E+00	5.482	0.0000E+00	
B23110/23	2	0.1474E+05	91.00	15.07	16.56	
B23210/23	1	9888.	67.14	5.956	8.872	
B23310/23	1	2640.	17.92	5.518	30.78	
B23410/23	1	1206.	8.188	5.490	67.04	
B23510/23	1	0.0000E+00	0.0000E+00	5.482	0.0000E+00	

TOLUENE

-----REGRESSION DATA-----

SEG	PTS	SLOPE	INTERCEPT	+/-SLOPE	+/-INTERC.	DL	R2	G/O
1	14	147.28	0.00000E+00	5.3359	0.00000E+00	5.73	0.989	0
2	22	162.03	0.00000E+00	5.7482	0.00000E+00	15.1	0.986	0
3	31	156.47	0.00000E+00	2.7893	0.00000E+00	38.3	0.996	0
4	38	160.29	0.00000E+00	1.8811	0.00000E+00	50.3	0.998	0
5	41	155.91	0.00000E+00	2.5411	0.00000E+00	99.8	0.996	0

THE LIMIT OF QUANTIFICATION: 11.5 X UNITS USING SEGMENT 1

-----INTERROGATION-----

SAMPLE	SEG	Y	X (TOLUENE)	X +/-	X +/- %	X (CORR)
B181B10/22	1	0.0000E+00	0.0000E+00	5.729	0.0000E+00	
B182B10/22	1	5724.	38.86	5.900	15.18	
B183B10/22	5	0.4976E+06	3192.	112.6	3.527	*C
B183BD10/22	2	0.1574E+05	97.15	15.51	15.97	2778.49
B184B10/22	3	0.7423E+05	474.4	39.17	8.258	
B185B10/22	1	2113.	14.35	5.753	40.10	
B186B10/22	1	518.0	3.517	5.731	162.9	
B191B10/22	5	0.8754E+06	5614.	135.4	2.412	*C
B191BD210/22	3	0.6190E+05	395.6	38.90	9.831	5657.08
B192B10/22	5	0.6087E+06	3904.	118.4	3.032	*C
B192BD210/22	3	0.4269E+05	272.8	38.56	14.13	3901.04
B193B10/22	5	0.4710E+06	3021.	111.3	3.684	*C
B193BD110/22	1	5838.	39.64	5.906	14.90	2831.4
B194B10/22	1	0.1026E+05	69.69	6.261	8.984	
B195B10/22	1	934.0	6.342	5.734	90.42	
B201B10/23	3	0.2811E+05	179.6	38.38	21.37	
B202B10/23	4	0.1308E+06	816.1	51.22	6.276	
B203B10/23	3	0.7614E+05	486.6	39.22	8.060	
B204B10/23	1	577.0	3.918	5.731	146.3	
B205B10/23	1	525.0	3.565	5.731	160.8	
B211B10/23	1	7194.	48.84	5.996	12.28	
B212B10/23	1	2367.	16.07	5.759	35.83	
B213B10/23	1	625.0	4.244	5.731	135.1	
B214B10/23	1	0.0000E+00	0.0000E+00	5.729	0.0000E+00	
B215A1D10/23	1	0.0000E+00	0.0000E+00	5.729	0.0000E+00	
B215A2D10/23	1	0.0000E+00	0.0000E+00	5.729	0.0000E+00	
B215B10/23	1	699.0	4.746	5.732	120.8	
B231B10/23	2	0.1429E+05	88.17	15.45	17.52	
B232B110/23	2	0.1113E+05	68.69	15.32	22.31	
B232B210/23	2	0.1056E+05	65.16	15.30	23.49	
B233B10/23	1	498.0	3.381	5.730	169.5	
B234B10/23	1	1093.	7.421	5.735	77.29	
B235B10/23	1	649.0	4.406	5.731	130.1	
TREATIN111/01	4	0.1392E+06	868.3	51.34	5.912	

VINYL CHLORIDE

-----REGRESSION DATA-----

SEG	PTS	SLOPE	INTERCEPT	+/-SLOPE	+/-INTERC.	DL	R2	G/O
1	11	549.84	0.00000E+00	28.978	0.00000E+00	20.8	0.984	0
2	14	322.32	19788.	70.172	18624.	220.	0.893	1
3	16	385.56	0.00000E+00	37.485	0.00000E+00	174.	0.948	0

THE LIMIT OF QUANTIFICATION: 41.5 X UNITS USING SEGMENT 1

-----INTERROGATION-----

SAMPLE	SEG	Y	X (VC)	X +/-	X +/- %	X (CORR)
B18110/22	1	0.0000E+00	0.0000E+00	20.76	0.0000E+00	
B18210/22	1	0.2654E+05	48.27	20.91	43.33	
B18310/22	3	0.3811E+07	9885.	976.7	9.880	*C
B183D10/22	3	0.3666E+06	950.7	197.0	20.73	13595.01
B18410/22	3	0.9156E+06	2375.	289.1	12.17	*C
B18510/22	1	0.4384E+05	79.74	21.18	26.56	
B18610/22	1	0.4309E+05	78.36	21.16	27.01	
B19110/22	3	0.3398E+07	8812.	874.3	9.921	*C
B191D10/22	3	0.2824E+06	732.5	188.0	25.67	10474.75
B19210/22	3	0.1833E+07	4753.	493.8	10.39	*C
B192D10/22	3	0.1640E+06	425.3	178.9	42.06	6081.79
B19310/22	3	0.2418E+07	6272.	634.1	10.11	*C
B193D10/22	3	0.2106E+06	546.3	181.9	33.31	7812.09
410/22	3	0.8868E+05	230.0	175.5	76.28	
B19510/22	3	0.1053E+06	273.2	176.0	64.43	
B20110/23	3	0.4135E+06	1072.	202.9	18.92	
B20210/23	3	0.1643E+07	4262.	449.4	10.54	*C
B20310/23	3	0.1089E+07	2825.	325.1	11.51	*C
B20410/23	1	0.5708E+05	103.8	21.47	20.68	
B20510/23	3	0.1495E+06	387.8	178.1	45.92	
B21110/23	3	0.1731E+06	449.0	179.4	39.96	
B21210/23	1	0.5015E+05	91.22	21.31	23.36	
B21310/23	1	0.5553E+05	101.0	21.43	21.22	
B21410/23	1	0.5885E+05	107.0	21.51	20.10	
B21510/23	3	0.8980E+06	2329.	285.6	12.26	*C
B23110/23	3	0.1857E+06	481.7	180.2	37.41	
B23210/23	3	0.3212E+06	833.0	191.9	23.04	
B23310/23	1	0.7788E+05	141.6	22.06	15.57	
B23410/23	1	0.5749E+05	104.6	21.48	20.54	
B23510/23	3	0.1082E+07	2805.	323.5	11.53	*C
EB1ALA	1	0.0000E+00	0.0000E+00	20.76	0.0000E+00	
EB2ALA10/23	1	0.0000E+00	0.0000E+00	20.76	0.0000E+00	
EB3ALA10/23	1	0.0000E+00	0.0000E+00	20.76	0.0000E+00	
EB4ALA10/23	1	0.6122E+05	111.3	21.57	19.37	

VINYL CHLORIDE

-----REGRESSION DATA-----

SEG	PTS	SLOPE	INTERCEPT	+/-SLOPE	+/-INTERC.	DL	R2	G/O
1	11	549.84	0.00000E+00	28.978	0.00000E+00	20.8	0.984	0
2	14	322.32	19788.	70.172	18624.	220.	0.893	1
3	16	385.56	0.00000E+00	37.485	0.00000E+00	174.	0.948	0

THE LIMIT OF QUANTIFICATION: 41.5 X UNITS USING SEGMENT 1

-----INTERROGATION-----

SAMPLE	SEG	Y	X (VC)	X +/-	X +/- %	X(CORR)
B181B10/22	1	0.0000E+00	0.0000E+00	20.76	0.0000E+00	
B182B10/22	1	0.1805E+05	32.84	20.83	63.44	
B183B10/22	3	0.4036E+07	0.1047E+05	1032.	9.863	*C
B183BD10/22	3	0.1575E+06	408.6	178.5	43.69	11685.96
B184B10/22	3	0.9592E+06	2488.	298.0	11.98	*C
B184BD10/22	1	0.8600E+05	156.4	22.33	14.28	2236.52
B185B10/22	1	0.7595E+05	138.1	22.00	15.92	
B186B10/22	1	0.0000E+00	0.0000E+00	20.76	0.0000E+00	
B191B10/22	3	0.4004E+07	0.1039E+05	1025.	9.866	*C
B191BD210/22	3	0.3874E+06	1005.	199.6	19.86	14371.5
B192B10/22	3	0.1910E+07	4954.	512.1	10.34	*C
B192BD210/22	3	0.1528E+06	396.4	178.2	44.96	5668.52
B193B10/22	3	0.2822E+07	7320.	732.7	10.01	*C
B193BD110/22	1	0.5372E+05	97.71	21.39	21.89	6985.55
B194B10/22	1	0.7930E+05	144.2	22.11	15.33	
B195B10/22	1	0.7491E+05	136.2	21.96	16.12	
B201B10/23	3	0.4423E+06	1147.	206.7	18.02	
B201BD10/23	1	0.6969E+05	126.7	21.81	17.21	905.905
B202B10/23	3	0.1692E+07	4390.	460.9	10.50	*C
B202BD10/23	3	0.3196E+06	829.0	191.8	23.13	5927.35
B203B10/23	3	0.1055E+07	2736.	317.9	11.62	*C
B203BD10/23	3	0.1877E+06	487.0	180.3	37.04	3482.05
B204B10/23	1	0.3279E+05	59.64	20.99	35.20	
B205B10/23	3	0.1755E+06	455.2	179.6	39.45	
B211B10/23	3	0.1368E+06	354.8	177.4	50.00	
B212B10/23	1	0.7323E+05	133.2	21.91	16.45	
B213B10/23	1	0.4856E+05	88.31	21.27	24.09	
B214B10/23	1	0.3366E+05	61.21	21.01	34.32	
B215A1D10/23	3	0.1264E+06	327.7	176.9	53.98	2343.0
B215A2D10/23	3	0.1419E+06	368.0	177.7	48.28	2631.2
B215B10/23	3	0.7316E+06	1898.	253.6	13.37	*C
B231B10/23	3	0.2609E+06	676.6	186.0	27.50	
B232B110/23	3	0.3713E+06	962.9	197.6	20.52	
B232B210/23	3	0.3685E+06	955.7	197.3	20.64	
B233B10/23	1	0.7356E+05	133.8	21.92	16.39	
B234B10/23	1	0.5434E+05	98.84	21.40	21.65	
B235A1D10/23	3	0.1401E+06	363.4	177.6	48.86	2598.31
B235B10/23	3	0.1169E+07	3033.	342.4	11.29	*C

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t12DCE

-----REGRESSION DATA-----

SEG	PTS	SLOPE	INTERCEPT	+/-SLOPE	+/-INTERC.	DL	R2	G/O
1	18	192.70	0.00000E+00	12.108	0.00000E+00	5.44	0.963	0
2	26	205.97	0.00000E+00	6.1083	0.00000E+00	6.41	0.988	0
3	35	188.20	0.00000E+00	3.3501	0.00000E+00	19.1	0.996	0
4	42	193.27	0.00000E+00	2.1586	0.00000E+00	24.0	0.998	0

THE LIMIT OF QUANTIFICATION: 10.9 X UNITS USING SEGMENT 1

-----INTERROGATION-----

SAMPLE	SEG	Y	X (t12DCE)	X +/-	X +/- %
B18110/22	1	1717.	8.910	5.467	61.36
B18210/22	1	1678.	8.708	5.466	62.77
B18310/22	2	0.1169E+05	56.74	6.625	11.68
B18410/22	1	4219.	21.89	5.610	25.62
B18510/22	1	0.0000E+00	0.0000E+00	5.439	0.0000E+00
B18610/22	1	0.0000E+00	0.0000E+00	5.439	0.0000E+00
B19110/22	3	0.2980E+05	158.3	19.34	12.22
B19210/22	3	0.4522E+05	240.3	19.61	8.160
B19310/22	3	0.2366E+05	125.7	19.27	15.33
B19410/22	1	1538.	7.981	5.462	68.43
B19510/22	1	422.0	2.190	5.440	248.4
B20110/23	2	6950.	33.74	6.486	19.22
B20210/23	2	0.1084E+05	52.65	6.596	12.53
B20310/23	2	0.1158E+05	56.21	6.621	11.78
B20410/23	1	2340.	12.14	5.492	45.23
B20510/23	1	594.0	3.083	5.442	176.5
B21110/23	1	4062.	21.08	5.598	26.55
B21210/23	1	2299.	11.93	5.490	46.02
B21310/23	1	2402.	12.46	5.495	44.08
B21410/23	1	2222.	11.53	5.487	47.58
B21510/23	1	4966.	25.77	5.675	22.02
B23110/23	3	0.4342E+05	230.7	19.57	8.483
B23210/23	3	0.3981E+05	211.5	19.50	9.219
B23310/23	3	0.1830E+05	97.23	19.21	19.76
B23410/23	1	3736.	19.39	5.573	28.75
B23510/23	2	0.1132E+05	54.94	6.612	12.04
EB1ALA	1	0.0000E+00	0.0000E+00	5.439	0.0000E+00
EB2ALA10/23	1	0.0000E+00	0.0000E+00	5.439	0.0000E+00
EB3ALA10/23	1	0.0000E+00	0.0000E+00	5.439	0.0000E+00
EB4ALA10/23	1	0.0000E+00	0.0000E+00	5.439	0.0000E+00

t12DCE

-----REGRESSION DATA-----

SEG	PTS	SLOPE	INTERCEPT	+/-SLOPE	+/-INTERC.	DL	R2	G/O
1	17	192.70	0.00000E+00	12.540	0.00000E+00	5.63	0.960	0
2	25	205.97	0.00000E+00	6.2464	0.00000E+00	6.55	0.987	0
3	34	188.20	0.00000E+00	3.4045	0.00000E+00	19.4	0.996	0
4	41	193.27	0.00000E+00	2.1915	0.00000E+00	24.3	0.998	0

THE LIMIT OF QUANTIFICATION: 11.3 X UNITS USING SEGMENT 1

-----INTERROGATION-----

SAMPLE	SEG	Y	X (t12dce)	X +/-	X +/- %
B181B10/22	1	1618.	8.396	5.659	67.40
B182B10/22	1	3140.	16.29	5.731	35.17
B183B10/22	2	0.1230E+05	59.70	6.799	11.39
B184B10/22	1	4347.	22.56	5.821	25.80
B185B10/22	1	0.0000E+00	0.0000E+00	5.633	0.0000E+00
B186B10/22	1	0.0000E+00	0.0000E+00	5.633	0.0000E+00
B191B10/22	3	0.3994E+05	212.2	19.82	9.339
B192B10/22	3	0.4291E+05	228.0	19.88	8.718
B193B10/22	3	0.3123E+05	166.0	19.68	11.86
B194B10/22	1	1995.	10.35	5.673	54.79
B195B10/22	1	966.0	5.013	5.642	112.5
B201B10/23	2	9388.	45.58	6.697	14.69
B202B10/23	2	0.1310E+05	63.61	6.831	10.74
B203B10/23	2	0.1246E+05	60.50	6.805	11.25
B204B10/23	1	2488.	12.91	5.695	44.11
B205B10/23	1	1267.	6.575	5.649	85.91
B211B10/23	1	4236.	21.98	5.811	26.44
B212B10/23	1	2490.	12.92	5.695	44.07
B213B10/23	1	0.0000E+00	0.0000E+00	5.633	0.0000E+00
B214B10/23	1	2122.	11.01	5.678	51.56
B215B10/23	1	3956.	20.53	5.789	28.20
B231B10/23	3	0.3394E+05	180.3	19.72	10.93
B232B110/23	3	0.4560E+05	242.3	19.93	8.228
B232B210/23	3	0.4483E+05	238.2	19.92	8.361
B233B10/23	3	0.1578E+05	83.82	19.50	23.27
B234B10/23	1	3973.	20.62	5.790	28.08
B235B10/23	2	0.1185E+05	57.52	6.781	11.79

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TCE

-----REGRESSION DATA-----

SEG	PTS	SLOPE	INTERCEPT	+/-SLOPE	+/-INTERC.	DL	R2	G/O
1	18	172.55	0.00000E+00	15.281	0.00000E+00	7.67	0.930	0
2	26	177.71	0.00000E+00	6.7301	0.00000E+00	8.18	0.980	0
3	35	168.56	0.00000E+00	2.9114	0.00000E+00	18.6	0.996	0
4	42	174.21	0.00000E+00	2.0565	0.00000E+00	25.3	0.998	0

THE LIMIT OF QUANTIFICATION: 15.4 X UNITS USING SEGMENT 1

-----INTERROGATION-----

SAMPLE	SEG	Y	X (TCE)	X +/-	X +/- %	X (CORR)
B18110/22	1	0.0000E+00	0.0000E+00	7.665	0.0000E+00	
B18210/22	1	0.0000E+00	0.0000E+00	7.665	0.0000E+00	
B18310/22	1	1037.	6.010	7.684	127.9	
B18410/22	1	440.0	2.550	7.669	300.7	
B18510/22	1	0.0000E+00	0.0000E+00	7.665	0.0000E+00	
B18610/22	1	0.0000E+00	0.0000E+00	7.665	0.0000E+00	
B19110/22	1	534.0	3.095	7.670	247.8	
B19210/22	4	0.7282E+06	4180.	55.47	1.327	*C
B192D10/22	3	0.4443E+05	263.6	19.12	7.252	3769.48
B19310/22	3	0.1939E+05	115.0	18.67	16.23	
B19410/22	1	4397.	25.48	7.991	31.36	
R19510/22	1	778.0	4.509	7.676	170.2	
110/23	1	791.0	4.584	7.676	167.4	
210/23	1	1553.	9.000	7.707	85.63	
B20310/23	1	1048.	6.074	7.684	126.5	
B20410/23	1	0.0000E+00	0.0000E+00	7.665	0.0000E+00	
B20510/23	1	0.0000E+00	0.0000E+00	7.665	0.0000E+00	
B21110/23	1	668.0	3.871	7.673	198.2	
B21210/23	1	0.0000E+00	0.0000E+00	7.665	0.0000E+00	
B21310/23	1	0.0000E+00	0.0000E+00	7.665	0.0000E+00	
B21410/23	1	0.0000E+00	0.0000E+00	7.665	0.0000E+00	
B21510/23	1	0.0000E+00	0.0000E+00	7.665	0.0000E+00	
B23110/23	1	2187.	12.67	7.747	61.12	
B23210/23	1	1473.	8.537	7.703	90.23	
B23310/23	1	1307.	7.575	7.695	101.6	
B23410/23	1	0.0000E+00	0.0000E+00	7.665	0.0000E+00	
B23510/23	1	0.0000E+00	0.0000E+00	7.665	0.0000E+00	
EB1ALA	1	0.0000E+00	0.0000E+00	7.665	0.0000E+00	
EB2ALA10/23	1	0.0000E+00	0.0000E+00	7.665	0.0000E+00	
EB3ALA10/23	1	0.0000E+00	0.0000E+00	7.665	0.0000E+00	
EB4ALA10/23	1	0.0000E+00	0.0000E+00	7.665	0.0000E+00	

TCE

-----REGRESSION DATA-----

SEG	PTS	SLOPE	INTERCEPT	+/-SLOPE	+/-INTERC.	DL	R2	G/O
1	17	172.55	0.0000E+00	15.826	0.0000E+00	7.94	0.923	0
2	25	177.71	0.0000E+00	6.8822	0.0000E+00	8.37	0.979	0
3	34	168.56	0.0000E+00	2.9587	0.0000E+00	18.9	0.996	0
4	41	174.21	0.0000E+00	2.0879	0.0000E+00	25.7	0.998	0

THE LIMIT OF QUANTIFICATION: 15.9 X UNITS USING SEGMENT 1

-----INTERROGATION-----

SAMPLE	SEG	Y	X (TCE)	X +/-	X +/- %	
B181B10/22	1	0.0000E+00	0.0000E+00	7.939	0.0000E+00	
B182B10/22	1	993.0	5.755	7.956	138.3	
B183B10/22	1	900.0	5.216	7.953	152.5	
B184B10/22	1	0.0000E+00	0.0000E+00	7.939	0.0000E+00	
B185B10/22	1	0.0000E+00	0.0000E+00	7.939	0.0000E+00	
B186B10/22	1	0.0000E+00	0.0000E+00	7.939	0.0000E+00	
B191B10/22	1	2334.	13.53	8.035	59.40	
B192B10/22	4	0.6782E+06	3893.	53.27	1.368	
B192BD210/22	3	0.4684E+05	277.9	19.49	7.013	3973.97
B193B10/22	3	0.1655E+05	98.16	18.95	19.30	
B194B10/22	1	3552.	20.59	8.160	39.64	
B195B10/22	1	893.0	5.175	7.953	153.7	
B201B10/23	1	1749.	10.14	7.993	78.86	
B202B10/23	1	2359.	13.67	8.037	58.79	
B203B10/23	1	941.0	5.453	7.955	145.9	
B204B10/23	1	0.0000E+00	0.0000E+00	7.939	0.0000E+00	
B205B10/23	1	0.0000E+00	0.0000E+00	7.939	0.0000E+00	
B211B10/23	1	708.0	4.103	7.948	193.7	
B212B10/23	1	0.0000E+00	0.0000E+00	7.939	0.0000E+00	
B213B10/23	1	490.0	2.840	7.943	279.7	
B214B10/23	1	0.0000E+00	0.0000E+00	7.939	0.0000E+00	
B215B10/23	1	0.0000E+00	0.0000E+00	7.939	0.0000E+00	
B231B10/23	1	1217.	7.053	7.965	112.9	
B232B110/23	1	1693.	9.812	7.990	81.43	
B232B210/23	1	1633.	9.464	7.986	84.38	
B233B10/23	1	1470.	8.519	7.977	93.64	
B234B10/23	1	741.0	4.294	7.949	185.1	
B235B10/23	1	0.0000E+00	0.0000E+00	7.939	0.0000E+00	

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CHLOROFORM

-----REGRESSION DATA-----

SEG	PTS	SLOPE	INTERCEPT	+/-SLOPE	+/-INTERC.	DL	R2	G/O
1	18	33.513	0.0000E+00	3.9851	0.0000E+00	20.4	0.875	0
2	26	32.563	0.0000E+00	1.4575	0.0000E+00	19.3	0.972	0
3	35	29.998	200.44	0.68581	189.64	39.8	0.996	1
4	42	31.026	0.0000E+00	0.38679	0.0000E+00	40.2	0.997	0

THE LIMIT OF QUANTIFICATION: 38.6 X UNITS USING SEGMENT 2

-----INTERROGATION-----

SAMPLE	SEG	Y	X (CFORM)	X +/-	X +/- %
B18110/22	2	0.0000E+00	0.0000E+00	19.31	0.0000E+00
B18210/22	2	0.0000E+00	0.0000E+00	19.31	0.0000E+00
B18310/22	2	0.0000E+00	0.0000E+00	19.31	0.0000E+00
B18410/22	2	0.0000E+00	0.0000E+00	19.31	0.0000E+00
B18510/22	2	0.0000E+00	0.0000E+00	19.31	0.0000E+00
B18610/22	2	0.0000E+00	0.0000E+00	19.31	0.0000E+00
B19110/22	2	0.0000E+00	0.0000E+00	19.31	0.0000E+00
B19210/22	2	0.0000E+00	0.0000E+00	19.31	0.0000E+00
B19310/22	2	0.0000E+00	0.0000E+00	19.31	0.0000E+00
B19410/22	2	0.0000E+00	0.0000E+00	19.31	0.0000E+00
B19510/22	2	0.0000E+00	0.0000E+00	19.31	0.0000E+00
R20110/23	2	0.0000E+00	0.0000E+00	19.31	0.0000E+00
1210/23	2	0.0000E+00	0.0000E+00	19.31	0.0000E+00
J310/23	2	0.0000E+00	0.0000E+00	19.31	0.0000E+00
B20410/23	2	0.0000E+00	0.0000E+00	19.31	0.0000E+00
B20510/23	2	0.0000E+00	0.0000E+00	19.31	0.0000E+00
B21110/23	2	0.0000E+00	0.0000E+00	19.31	0.0000E+00
B21210/23	2	0.0000E+00	0.0000E+00	19.31	0.0000E+00
B21310/23	2	0.0000E+00	0.0000E+00	19.31	0.0000E+00
B21410/23	2	0.0000E+00	0.0000E+00	19.31	0.0000E+00
B21510/23	2	0.0000E+00	0.0000E+00	19.31	0.0000E+00
B23110/23	2	850.0	26.10	19.35	74.13
B23210/23	2	669.0	20.54	19.34	94.12
B23310/23	2	0.0000E+00	0.0000E+00	19.31	0.0000E+00
B23410/23	2	0.0000E+00	0.0000E+00	19.31	0.0000E+00
B23510/23	2	0.0000E+00	0.0000E+00	19.31	0.0000E+00
EB1ALA	2	0.0000E+00	0.0000E+00	19.31	0.0000E+00
EB2ALA10/23	2	0.0000E+00	0.0000E+00	19.31	0.0000E+00
EB3ALA10/23	2	0.0000E+00	0.0000E+00	19.31	0.0000E+00
EB4ALA10/23	2	0.0000E+00	0.0000E+00	19.31	0.0000E+00

CHLOROFORM

-----REGRESSION DATA-----

SEG	PTS	SLOPE	INTERCEPT	+/-SLOPE	+/-INTERC.	DL	R2	G/O
1	17	33.513	0.0000E+00	4.1272	0.0000E+00	21.1	0.863	0
2	25	32.563	0.0000E+00	1.4905	0.0000E+00	19.8	0.971	0
3	34	29.972	211.20	0.70276	197.17	40.4	0.996	1
4	41	31.026	0.0000E+00	0.39269	0.0000E+00	40.9	0.997	0

THE LIMIT OF QUANTIFICATION: 39.5 X UNITS USING SEGMENT 2

-----INTERROGATION-----

SAMPLE	SEG	Y	X (CFORM	X +/-	X +/- %
B181B10/22	2	0.0000E+00	0.0000E+00	19.75	0.0000E+00
B181B10/22S	2	0.0000E+00	0.0000E+00	19.75	0.0000E+00
B182B10/22	2	0.0000E+00	0.0000E+00	19.75	0.0000E+00
B183B10/22	2	0.0000E+00	0.0000E+00	19.75	0.0000E+00
B184B10/22	2	0.0000E+00	0.0000E+00	19.75	0.0000E+00
B185B10/22	2	0.0000E+00	0.0000E+00	19.75	0.0000E+00
B186B10/22	2	0.0000E+00	0.0000E+00	19.75	0.0000E+00
B191B10/22	2	0.0000E+00	0.0000E+00	19.75	0.0000E+00
B192B10/22	2	0.0000E+00	0.0000E+00	19.75	0.0000E+00
B193B10/22	2	0.0000E+00	0.0000E+00	19.75	0.0000E+00
B194B10/22	2	0.0000E+00	0.0000E+00	19.75	0.0000E+00
B195B10/22	2	885.0	27.18	19.79	72.82
B201B10/23	2	0.0000E+00	0.0000E+00	19.75	0.0000E+00
B202B10/23	2	0.0000E+00	0.0000E+00	19.75	0.0000E+00
B203B10/23	2	0.0000E+00	0.0000E+00	19.75	0.0000E+00
B204B10/23	2	0.0000E+00	0.0000E+00	19.75	0.0000E+00
B205B10/23	2	0.0000E+00	0.0000E+00	19.75	0.0000E+00
B211B10/23	2	0.0000E+00	0.0000E+00	19.75	0.0000E+00
B212B10/23	2	0.0000E+00	0.0000E+00	19.75	0.0000E+00
B213B10/23	2	0.0000E+00	0.0000E+00	19.75	0.0000E+00
B214B10/23	2	0.0000E+00	0.0000E+00	19.75	0.0000E+00
B215B10/23	2	0.0000E+00	0.0000E+00	19.75	0.0000E+00
B231B10/23	2	1322.	40.60	19.84	48.86
B232B110/23	2	1514.	46.49	19.87	42.73
B232B210/23	2	1550.	47.60	19.87	41.75
B233B10/23	2	0.0000E+00	0.0000E+00	19.75	0.0000E+00
B234B10/23	2	0.0000E+00	0.0000E+00	19.75	0.0000E+00
B235B10/23	2	0.0000E+00	0.0000E+00	19.75	0.0000E+00

11DCE

-----REGRESSION DATA-----

SEG	PTS	SLOPE	INTERCEPT	+/-SLOPE	+/-INTERC.	DL	R2	G/O
1	18	192.52	0.00000E+00	6.7210	0.00000E+00	3.02	0.989	0
2	26	208.26	0.00000E+00	4.9707	0.00000E+00	5.16	0.994	0
3	35	193.92	0.00000E+00	3.9209	0.00000E+00	21.7	0.994	0
4	42	199.64	0.00000E+00	2.2835	0.00000E+00	24.5	0.998	0

THE LIMIT OF QUANTIFICATION: 6.05 X UNITS USING SEGMENT 1

-----INTERROGATION-----

SAMPLE	SEG	Y	X (11DCE)	X +/-	X +/- %
B18110/22	1	0.0000E+00	0.0000E+00	3.022	0.0000E+00
B18210/22	1	0.0000E+00	0.0000E+00	3.022	0.0000E+00
B18310/22	2	0.1008E+05	48.38	5.285	10.92
B18410/22	1	0.0000E+00	0.0000E+00	3.022	0.0000E+00
B18510/22	1	0.0000E+00	0.0000E+00	3.022	0.0000E+00
B18610/22	1	0.0000E+00	0.0000E+00	3.022	0.0000E+00
B19110/22	3	0.3906E+05	201.4	22.11	10.98
B19210/22	4	0.8372E+05	419.4	25.01	5.964
B19310/22	3	0.2942E+05	151.7	21.95	14.47
B19410/22	1	1396.	7.251	3.032	41.82
B19510/22	1	0.0000E+00	0.0000E+00	3.022	0.0000E+00
P20110/23	1	660.0	3.428	3.024	88.21
210/23	1	925.0	4.805	3.026	62.99
310/23	1	1426.	7.407	3.033	40.94
B20410/23	1	0.0000E+00	0.0000E+00	3.022	0.0000E+00
B20510/23	1	0.0000E+00	0.0000E+00	3.022	0.0000E+00
B21110/23	1	0.0000E+00	0.0000E+00	3.022	0.0000E+00
B21210/23	1	0.0000E+00	0.0000E+00	3.022	0.0000E+00
B21310/23	1	0.0000E+00	0.0000E+00	3.022	0.0000E+00
B21410/23	1	0.0000E+00	0.0000E+00	3.022	0.0000E+00
B21510/23	1	726.0	3.771	3.025	80.21
B23110/23	1	868.0	4.509	3.026	67.11
B23210/23	2	0.1050E+05	50.40	5.296	10.51
B23310/23	1	0.0000E+00	0.0000E+00	3.022	0.0000E+00
B23410/23	1	0.0000E+00	0.0000E+00	3.022	0.0000E+00
B23510/23	1	995.0	5.168	3.027	58.57
EB1ALA	1	0.0000E+00	0.0000E+00	3.022	0.0000E+00
EB2ALA10/23	1	0.0000E+00	0.0000E+00	3.022	0.0000E+00
EB3ALA10/23	1	0.0000E+00	0.0000E+00	3.022	0.0000E+00
EB4ALA10/23	1	0.0000E+00	0.0000E+00	3.022	0.0000E+00

11DCE

## -----REGRESSION DATA-----

SEG	PTS	SLOPE	INTERCEPT	+/-SLOPE	+/-INTERC.	DL	R2	G/O
1	17	192.52	0.0000E+00	6.9606	0.0000E+00	3.13	0.989	0
2	25	208.26	0.0000E+00	5.0831	0.0000E+00	5.27	0.993	0
3	34	193.92	0.0000E+00	3.9846	0.0000E+00	22.1	0.994	0
4	41	199.64	0.0000E+00	2.3183	0.0000E+00	24.9	0.998	0

THE LIMIT OF QUANTIFICATION: 6.26 X UNITS USING SEGMENT 1

## -----INTERROGATION-----

SAMPLE	SEG	Y	X (11DCE)	X +/-	X +/- %
B181B10/22	1	0.0000E+00	0.0000E+00	3.130	0.0000E+00
B182B10/22	1	0.0000E+00	0.0000E+00	3.130	0.0000E+00
B183B10/22	2	0.1064E+05	51.09	5.419	10.61
B184B10/22	1	2670.	13.87	3.169	22.85
B185B10/22	1	0.0000E+00	0.0000E+00	3.130	0.0000E+00
B186B10/22	1	0.0000E+00	0.0000E+00	3.130	0.0000E+00
B191B10/22	3	0.4982E+05	256.9	22.71	8.840
B192B10/22	4	0.8044E+05	402.9	25.36	6.293
B193B10/22	3	0.3688E+05	190.2	22.43	11.79
B194B10/22	1	1029.	5.345	3.136	58.66
B195B10/22	1	1012.	5.257	3.135	59.64
B201B10/23	1	1845.	9.584	3.149	32.85
B201BD10/23	1	0.0000E+00	0.0000E+00	3.130	0.0000E+00
B202B10/23	1	2323.	12.07	3.160	26.19
B203B10/23	1	2658.	13.81	3.169	22.95
B204B10/23	1	5149.	26.75	3.276	12.25
B205B10/23	1	0.0000E+00	0.0000E+00	3.130	0.0000E+00
B211B10/23	1	0.0000E+00	0.0000E+00	3.130	0.0000E+00
B212B10/23	1	0.0000E+00	0.0000E+00	3.130	0.0000E+00
B213B10/23	1	0.0000E+00	0.0000E+00	3.130	0.0000E+00
B214B10/23	1	0.0000E+00	0.0000E+00	3.130	0.0000E+00
B215B10/23	1	1202.	6.244	3.138	50.25
B231B10/23	1	1349.	7.007	3.140	44.81
B232B110/23	2	0.1243E+05	59.68	5.471	9.167
B232B210/23	1	2765.	14.36	3.172	22.09
B233B10/23	1	0.0000E+00	0.0000E+00	3.130	0.0000E+00
B234B10/23	1	0.0000E+00	0.0000E+00	3.130	0.0000E+00
B235A1D10/23	1	0.0000E+00	0.0000E+00	3.130	0.0000E+00
B235A1D10/23	1	0.0000E+00	0.0000E+00	3.130	0.0000E+00
B235B10/23	1	1531.	7.953	3.143	39.52

c12DCE

-----REGRESSION DATA-----

SEG	PTS	SLOPE	INTERCEPT	+/-SLOPE	+/-INTERC.	DL	R2	G/O
1	18	103.01	0.00000E+00	9.6052	0.00000E+00	8.07	0.920	0
2	26	98.295	0.00000E+00	4.0381	0.00000E+00	8.88	0.976	0
3	35	91.049	0.00000E+00	1.6451	0.00000E+00	19.4	0.996	0
4	42	93.536	0.00000E+00	0.99754	0.00000E+00	22.9	0.998	0

THE LIMIT OF QUANTIFICATION: 16.2 X UNITS USING SEGMENT 1

-----INTERROGATION-----

SAMPLE	SEG	Y	X (c12DCE)	X +/-	X +/- %	X (CORR)
B18110/22	1	0.0000E+00	0.0000E+00	8.071	0.0000E+00	
B18210/22	1	0.0000E+00	0.0000E+00	8.071	0.0000E+00	
B18310/22	4	0.2196E+07	0.2347E+05	251.4	1.071	*C
B183D10/22	4	0.1585E+06	1695.	29.16	1.721	24238.5 *C
B18410/22	4	0.2793E+06	2986.	39.21	1.313	*C
B18510/22	3	7420.	81.49	19.48	23.90	
B18610/22	2	3926.	39.94	9.027	22.60	
B19110/22	4	0.7960E+07	0.8510E+05	907.9	1.067	*C
B191D10/22	4	0.6692E+06	7154.	79.65	1.113	102302.2 *C ←
B19210/22	4	0.1032E+08	0.1103E+06	1177.	1.067	*C
B192D10/22	4	0.1383E+07	0.1478E+05	159.3	1.078	211354 *C ←
B19310/22	4	0.5971E+07	0.6384E+05	681.2	1.067	*C
B193D10/22	4	0.4680E+06	5004.	58.06	1.160	71557.2 *C
B19410/22	4	0.1472E+06	1573.	28.38	1.804	*C
B194D10/22	3	0.1034E+05	113.6	19.53	17.20	1624.48
B19510/22	3	0.2421E+05	265.9	20.01	7.525	
B20110/23	4	0.3393E+05	362.7	23.21	6.399	
B20210/23	4	0.1112E+06	1189.	26.17	2.200	*C
B20310/23	4	0.5601E+06	5988.	67.84	1.133	*C
B20410/23	2	3665.	37.29	9.008	24.16	
B20510/23	3	9608.	105.5	19.52	18.49	
B21110/23	3	0.1375E+05	151.0	19.61	12.99	
B21210/23	1	1150.	11.16	8.138	72.89	
B21310/23	1	695.0	6.747	8.095	120.0	
B21410/23	3	7222.	79.32	19.48	24.55	
B21510/23	4	0.1162E+06	1242.	26.44	2.129	
B23110/23	2	6769.	68.86	9.317	13.53	
B23210/23	3	0.1619E+05	177.8	19.69	11.07	
B23310/23	1	690.0	6.698	8.095	120.9	
B23410/23	1	1334.	12.95	8.160	63.02	
B23510/23	4	0.1182E+06	1263.	26.56	2.102	*C
EB1ALA	1	0.0000E+00	0.0000E+00	8.071	0.0000E+00	
EB2ALA10/23	1	0.0000E+00	0.0000E+00	8.071	0.0000E+00	
EB3ALA10/23	1	0.0000E+00	0.0000E+00	8.071	0.0000E+00	
EB4ALA10/23	1	0.0000E+00	0.0000E+00	8.071	0.0000E+00	

c12DCE

-----REGRESSION DATA-----

SEG	PTS	SLOPE	INTERCEPT	+/-SLOPE	+/-INTERC.	DL	R2	G/O
1	17	103.01	0.00000E+00	9.9477	0.00000E+00	8.36	0.913	0
2	25	98.295	0.00000E+00	4.1294	0.00000E+00	9.08	0.975	0
3	34	91.049	0.00000E+00	1.6718	0.00000E+00	19.7	0.996	0
4	41	93.536	0.00000E+00	1.0131	0.00000E+00	23.2	0.998	0

THE LIMIT OF QUANTIFICATION: 16.8 X UNITS USING SEGMENT 1

-----INTERROGATION-----

SAMPLE	SEG	Y	X (c12DCE)	X +/-	X +/- %		
B181B10/22	1	0.0000E+00	0.0000E+00	8.358	0.0000E+00		
B182B10/22	1	0.0000E+00	0.0000E+00	8.358	0.0000E+00		
B183B10/22	4	0.2397E+07	0.2563E+05	278.6	1.087		
B183BD10/22	4	0.8539E+05	912.9	25.26	2.767	26108.94	
B184B10/22	4	0.3096E+06	3310.	42.73	1.291		
B184BD10/22	3	0.2159E+05	237.2	20.21	8.522	3391.96	
B185B10/22	3	9517.	104.5	19.83	18.97		
B186B10/22	2	4773.	48.56	9.304	19.16		
B191B10/22	4	0.8949E+07	0.9567E+05	1036.	1.083		*C
B191BD110/22	4	0.8738E+05	934.2	25.35	2.714	133590.6	
B191BD210/22	4	0.9138E+06	9770.	108.3	1.109	139711	*C
B192BD110/22	4	0.6748E+05	721.5	24.52	3.399	206349	
B192B10/22	4	0.1028E+08	0.1100E+06	1191.	1.083		*C
B192BD210/22	4	0.1369E+07	0.1464E+05	160.2	1.095	209423.5	*C
B193B10/22	4	0.7656E+07	0.8185E+05	886.9	1.083		*C
B193BD110/22	4	0.1208E+06	1291.	27.13	2.101	92306.5	*C
B194B10/22	4	0.1110E+06	1187.	26.56	2.238		*C
B194BD10/22	2	4182.	42.55	9.252	21.75	1216.93	
B195B10/22	3	0.2156E+05	236.8	20.21	8.536		
B201B10/23	4	0.4165E+05	445.3	23.74	5.331		
B201BD10/23	2	6418.	65.29	9.483	14.52	466.895	
B202B10/23	4	0.1099E+06	1175.	26.50	2.256		
B202BD10/23	3	0.1684E+05	185.0	20.03	10.83	1322.75	
B203B10/23	4	0.5661E+06	6052.	69.55	1.149		
B203BD10/23	4	0.8548E+05	913.9	25.26	2.764	6534.385	
B204B10/23	2	3883.	39.50	9.228	23.36		
B205B10/23	3	0.1081E+05	118.7	19.86	16.73		
B211B10/23	3	0.1183E+05	130.0	19.88	15.30		
B212B10/23	1	702.0	6.815	8.384	123.0		
B213B10/23	1	1009.	9.795	8.412	85.88		
B214B10/23	2	6500.	66.13	9.493	14.36		
B215A1D10/23	3	0.1569E+05	172.3	19.99	11.60	1231.945	
B215A2D10/23	3	0.1628E+05	178.8	20.01	11.19	1278.42	
B215B10/23	4	0.9287E+05	992.9	25.61	2.579		*C
B231B10/23	2	6706.	68.22	9.519	13.95		
B232B110/23	3	0.1717E+05	188.6	20.04	10.63		
B232B210/23	3	0.1769E+05	194.3	20.06	10.32		
B233B10/23	1	1155.	11.21	8.428	75.17		
B234B10/23	1	1273.	12.36	8.443	68.32		

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TOLUENE

-----REGRESSION DATA-----

SEG	PTS	SLOPE	INTERCEPT	+/-SLOPE	+/-INTERC.	DL	R2	G/O
1	15	156.44	0.00000E+00	4.2700	0.00000E+00	14.0	0.992	0
2	24	156.06	0.00000E+00	3.3888	0.00000E+00	115.	0.995	0

THE LIMIT OF QUANTIFICATION: 28.1 X UNITS USING SEGMENT 1

-----INTERROGATION-----

SAMPLE	SEG	Y	X(TOLUENE)	X +/-	X +/- %	X (CORR)
B18110/22	1	0.0000E+00	0.0000E+00	14.04	0.0000E+00	
B18210/22	1	5060.	32.34	14.07	43.49	
B18310/22	2	0.4399E+06	2819.	129.9	4.609	*C
B183D10/22	2	0.3207E+05	205.5	114.7	55.81	2938.65
B18410/22	2	0.6862E+05	439.7	115.0	26.16	
B18510/22	1	940.0	6.009	14.04	233.7	
B18610/22	1	0.0000E+00	0.0000E+00	14.04	0.0000E+00	
B19110/22	2	0.6233E+06	3994.	143.7	3.599	*C
B191D10/22	2	0.4269E+05	273.5	114.8	41.96	3911.05
B19210/22	2	0.6305E+06	4040.	144.3	3.573	*C
B192D10/22	2	0.4030E+05	258.2	114.8	44.44	3692.26
B19310/22	2	0.3283E+06	2104.	123.4	5.865	
B193D10/22	1	0.2308E+05	147.5	14.61	9.902	2109.25
P19410/22	1	0.1318E+05	84.24	14.23	16.89	
510/22	1	1233.	7.882	14.04	178.2	
U110/23	1	0.2716E+05	173.6	14.82	8.537	
B20210/23	2	0.1285E+06	823.2	116.0	14.09	
B20310/23	2	0.7477E+05	479.1	115.1	24.02	
B20410/23	1	834.0	5.331	14.04	263.4	
B20510/23	1	1104.	7.057	14.04	199.0	
B21110/23	1	8232.	52.62	14.11	26.82	
B21210/23	1	2967.	18.97	14.05	74.08	
B21310/23	1	0.0000E+00	0.0000E+00	14.04	0.0000E+00	
B21410/23	1	0.0000E+00	0.0000E+00	14.04	0.0000E+00	
B21510/23	1	0.0000E+00	0.0000E+00	14.04	0.0000E+00	
B23110/23	1	0.1468E+05	93.84	14.27	15.21	
B23210/23	2	0.3068E+05	196.6	114.7	58.34	
B23310/23	1	690.0	4.411	14.04	318.3	
B23410/23	1	0.0000E+00	0.0000E+00	14.04	0.0000E+00	
B23510/23	1	0.0000E+00	0.0000E+00	14.04	0.0000E+00	
EB1ALA	1	0.0000E+00	0.0000E+00	14.04	0.0000E+00	
EB2ALA10/23	1	0.0000E+00	0.0000E+00	14.04	0.0000E+00	
EB3ALA10/23	1	0.0000E+00	0.0000E+00	14.04	0.0000E+00	
EB4ALA10/23	1	0.0000E+00	0.0000E+00	14.04	0.0000E+00	

BENZENE

-----REGRESSION DATA-----

SEG	PTS	SLOPE	INTERCEPT	+/-SLOPE	+/-INTERC.	DL	R2	G/O
1	15	127.96	0.00000E+00	2.7213	0.00000E+00	10.9	0.995	0
2	24	124.40	0.00000E+00	2.4245	0.00000E+00	103.	0.996	0

THE LIMIT OF QUANTIFICATION: 21.9 X UNITS USING SEGMENT 1

-----INTERROGATION-----

SAMPLE	SEG	Y	X(BENZENE)	X +/-	X +/- %
B18110/22	1	2527.	19.75	10.95	55.43
B18210/22	1	8875.	69.36	11.04	15.92
B18310/22	1	0.1414E+05	110.5	11.19	10.13
B18410/22	1	6053.	47.30	10.99	23.22
B18510/22	1	0.0000E+00	0.0000E+00	10.94	0.0000E+00
B18610/22	1	0.0000E+00	0.0000E+00	10.94	0.0000E+00
B19110/22	1	0.1914E+05	149.6	11.39	7.617
B19210/22	1	0.2109E+05	164.8	11.49	6.970
B19310/22	1	8726.	68.19	11.04	16.18
B19410/22	1	745.0	5.822	10.94	187.9
B19510/22	1	0.0000E+00	0.0000E+00	10.94	0.0000E+00
B20110/23	1	8563.	66.92	11.03	16.48
B20210/23	1	0.1202E+05	93.96	11.12	11.84
B20310/23	1	1473.	11.51	10.94	95.06
B20410/23	1	704.0	5.502	10.94	198.8
B20510/23	1	0.0000E+00	0.0000E+00	10.94	0.0000E+00
B21110/23	1	6377.	49.84	10.99	22.05
B21210/23	1	4021.	31.42	10.96	34.88
B21310/23	1	1356.	10.60	10.94	103.3
B21410/23	1	946.0	7.393	10.94	148.0
B21510/23	1	563.0	4.400	10.94	248.6
B23110/23	2	0.2762E+05	222.0	103.0	46.40
B23210/23	2	0.5434E+05	436.8	103.3	23.64
B23310/23	1	0.1111E+05	86.85	11.09	12.77
B23410/23	1	2503.	19.56	10.95	55.97
B23510/23	1	784.0	6.127	10.94	178.6
EB1ALA	1	0.0000E+00	0.0000E+00	10.94	0.0000E+00
EB2ALA10/23	1	0.0000E+00	0.0000E+00	10.94	0.0000E+00
EB3ALA10/23	1	0.0000E+00	0.0000E+00	10.94	0.0000E+00
EB4ALA10/23	1	0.0000E+00	0.0000E+00	10.94	0.0000E+00

BENZENE

-----REGRESSION DATA-----

SEG	PTS	SLOPE	INTERCEPT	+/-SLOPE	+/-INTERC.	DL	R2	G/O
1	14	127.96	0.00000E+00	2.8440	0.00000E+00	11.4	0.994	0
2	23	124.40	0.00000E+00	2.4849	0.00000E+00	105.	0.996	0

THE LIMIT OF QUANTIFICATION: 22.9 X UNITS USING SEGMENT 1

-----INTERROGATION-----

SAMPLE	SEG	Y	X(BENZENE)	X +/-	X +/- %
B181B10/22	1	2090.	16.33	11.44	70.03
B182B10/22	1	8857.	69.22	11.54	16.67
B183B10/22	1	0.1502E+05	117.4	11.73	9.992
B184B10/22	1	5819.	45.48	11.48	25.24
B185B10/22	1	0.0000E+00	0.0000E+00	11.43	0.0000E+00
B186B10/22	1	0.0000E+00	0.0000E+00	11.43	0.0000E+00
B191B10/22	2	0.2588E+05	208.0	105.6	50.76
B192B10/22	1	0.1986E+05	155.2	11.94	7.696
B193B10/22	1	0.1311E+05	102.5	11.66	11.38
B194B10/22	1	938.0	7.331	11.43	156.0
B195B10/22	1	0.0000E+00	0.0000E+00	11.43	0.0000E+00
B201B10/23	1	9620.	75.18	11.55	15.37
B202B10/23	1	0.1290E+05	100.8	11.65	11.56
B203B10/23	1	2436.	19.04	11.44	60.10
B204B10/23	1	744.0	5.814	11.43	196.6
B205B10/23	1	0.0000E+00	0.0000E+00	11.43	0.0000E+00
B211B10/23	1	5472.	42.76	11.47	26.83
B212B10/23	1	3841.	30.02	11.45	38.15
B213B10/23	1	877.0	6.854	11.43	166.8
B214B10/23	1	886.0	6.924	11.43	165.1
B215B10/23	1	858.0	6.705	11.43	170.5
B231B10/23	2	0.5765E+05	463.4	105.9	22.85
B232B110/23	2	0.5848E+05	470.1	105.9	22.53
B232B210/23	2	0.5850E+05	470.2	105.9	22.52
B233B10/23	1	9611.	75.11	11.55	15.38
B234B10/23	1	2124.	16.60	11.44	68.91
B235B10/23	1	563.0	4.400	11.43	259.9

ET-BENZENE

-----REGRESSION DATA-----

SEG	PTS	SLOPE	INTERCEPT	+/-SLOPE	+/-INTERC.	DL	R2	G/O
1	15	170.64	0.00000E+00	5.7771	0.00000E+00	17.4	0.988	0
2	24	167.73	0.00000E+00	3.9495	0.00000E+00	124.	0.995	0

THE LIMIT OF QUANTIFICATION: 34.8 X UNITS USING SEGMENT 1

-----INTERROGATION-----

SAMPLE	SEG	Y	X(ET-BEN)	X +/-	X +/- %
B18110/22	1	0.0000E+00	0.0000E+00	17.42	0.0000E+00
B18210/22	1	4432.	25.97	17.44	67.14
B18310/22	1	0.1343E+05	78.72	17.62	22.38
B18410/22	1	6122.	35.88	17.46	48.66
B18510/22	1	0.0000E+00	0.0000E+00	17.42	0.0000E+00
B18610/22	1	0.0000E+00	0.0000E+00	17.42	0.0000E+00
B19110/22	1	0.1267E+05	74.26	17.60	23.69
B19210/22	1	0.2122E+05	124.4	17.92	14.41
B19310/22	1	0.1053E+05	61.69	17.54	28.43
B19410/22	1	0.0000E+00	0.0000E+00	17.42	0.0000E+00
B19510/22	1	0.0000E+00	0.0000E+00	17.42	0.0000E+00
B20110/23	1	0.2274E+05	133.2	17.99	13.50
B20210/23	1	0.2533E+05	148.5	18.13	12.21
B20310/23	1	0.1420E+05	83.20	17.64	21.20
B20410/23	1	0.0000E+00	0.0000E+00	17.42	0.0000E+00
B20510/23	1	0.0000E+00	0.0000E+00	17.42	0.0000E+00
B21110/23	1	0.2460E+05	144.1	18.09	12.55
B21210/23	1	0.1166E+05	68.30	17.57	25.72
B21310/23	1	1008.	5.907	17.42	294.8
B21410/23	1	0.0000E+00	0.0000E+00	17.42	0.0000E+00
B21510/23	1	0.0000E+00	0.0000E+00	17.42	0.0000E+00
B23110/23	1	0.2747E+05	161.0	18.25	11.33
B23210/23	2	0.4340E+05	258.8	124.5	48.12
B23310/23	1	6170.	36.16	17.46	48.28
B23410/23	1	0.0000E+00	0.0000E+00	17.42	0.0000E+00
B23510/23	1	0.0000E+00	0.0000E+00	17.42	0.0000E+00
EB1ALA	1	0.0000E+00	0.0000E+00	17.42	0.0000E+00
EB2ALA10/23	1	0.0000E+00	0.0000E+00	17.42	0.0000E+00
EB3ALA10/23	1	0.0000E+00	0.0000E+00	17.42	0.0000E+00
EB4ALA10/23	1	0.0000E+00	0.0000E+00	17.42	0.0000E+00

ET-BENZENE

-----REGRESSION DATA-----

SEG	PTS	SLOPE	INTERCEPT	+/-SLOPE	+/-INTERC.	DL	R2	G/O
1	14	170.64	0.00000E+00	6.0371	0.00000E+00	18.2	0.985	0
2	23	167.73	0.00000E+00	4.0481	0.00000E+00	127.	0.994	0

THE LIMIT OF QUANTIFICATION: 36.4 X UNITS USING SEGMENT 1

-----INTERROGATION-----

SAMPLE	SEG	Y	X (ETBEN)	X +/-	X +/- %
B181B10/22	1	0.0000E+00	0.0000E+00	18.20	0.0000E+00
B182B10/22	1	4604.	26.98	18.22	67.54
B183B10/22	1	0.1493E+05	87.49	18.46	21.10
B184B10/22	1	6160.	36.10	18.24	50.54
B185B10/22	1	0.0000E+00	0.0000E+00	18.20	0.0000E+00
B186B10/22	1	0.0000E+00	0.0000E+00	18.20	0.0000E+00
B191B10/22	1	0.1903E+05	111.5	18.62	16.70
B192B10/22	1	0.2024E+05	118.6	18.68	15.74
B193B10/22	1	0.1554E+05	91.07	18.48	20.30
B194B10/22	1	568.0	3.329	18.20	546.7
B195B10/22	1	0.0000E+00	0.0000E+00	18.20	0.0000E+00
B201B10/23	1	0.2476E+05	145.1	18.91	13.03
B202B10/23	1	0.2622E+05	153.7	18.99	12.36
B203B10/23	1	0.1491E+05	87.40	18.46	21.12
B204B10/23	1	0.0000E+00	0.0000E+00	18.20	0.0000E+00
B205B10/23	1	0.0000E+00	0.0000E+00	18.20	0.0000E+00
B211B10/23	1	0.2162E+05	126.7	18.74	14.79
B212B10/23	1	0.1224E+05	71.71	18.38	25.62
B213B10/23	1	1013.	5.937	18.20	306.6
B214B10/23	1	0.0000E+00	0.0000E+00	18.20	0.0000E+00
B215B10/23	1	0.0000E+00	0.0000E+00	18.20	0.0000E+00
B231B10/23	2	0.4924E+05	293.6	127.7	43.48
B232B110/23	2	0.5842E+05	348.3	127.7	36.68
B232B210/23	2	0.4816E+05	287.1	127.6	44.45
B233B10/23	1	6438.	37.73	18.25	48.37
B234B10/23	1	646.0	3.786	18.20	480.7
B235B10/23	1	0.0000E+00	0.0000E+00	18.20	0.0000E+00

P/M-XYLENE

-----REGRESSION DATA-----

SEG	PTS	SLOPE	INTERCEPT	+/-SLOPE	+/-INTERC.	DL	R2	G/O
1	15	202.56	0.00000E+00	11.111	0.00000E+00	28.2	0.969	0
2	24	194.43	0.00000E+00	5.0166	0.00000E+00	136.	0.993	0

THE LIMIT OF QUANTIFICATION: 56.5 X UNITS USING SEGMENT 1

-----INTERROGATION-----

SAMPLE	SEG	Y	X(P/M XYL)	X +/-	X +/- %
B18110/22	1	1307.	6.452	28.22	437.3
B18210/22	1	0.1788E+05	88.27	28.63	32.43
B18310/22	2	0.6152E+05	316.4	136.7	43.19
B18410/22	1	0.2597E+05	128.2	29.08	22.68
B18510/22	1	0.0000E+00	0.0000E+00	28.22	0.0000E+00
B18610/22	1	0.0000E+00	0.0000E+00	28.22	0.0000E+00
B19110/22	2	0.5769E+05	296.7	136.6	46.04
B19210/22	2	0.9859E+05	507.1	137.0	27.03
B19310/22	2	0.5068E+05	260.6	136.6	52.40
B19410/22	1	2826.	13.95	28.23	202.3
B19510/22	1	580.0	2.863	28.22	985.4
B20110/23	2	0.5192E+05	267.1	136.6	51.15
B20210/23	2	0.6335E+05	325.8	136.7	41.94
B20310/23	2	0.4004E+05	205.9	136.5	66.29
B20410/23	1	1617.	7.983	28.22	353.5
B20510/23	1	892.0	4.404	28.22	640.8
B21110/23	1	0.2020E+05	99.71	28.74	28.82
B21210/23	1	3670.	18.12	28.23	155.8
B21310/23	1	4320.	21.33	28.24	132.4
B21410/23	1	1108.	5.470	28.22	515.9
B21510/23	1	0.0000E+00	0.0000E+00	28.22	0.0000E+00
B23110/23	1	0.1810E+05	89.34	28.64	32.05
B23210/23	1	0.3253E+05	160.6	29.56	18.41
B23310/23	1	5849.	28.88	28.26	97.87
B23410/23	1	1560.	7.701	28.22	366.4
B23510/23	1	2202.	10.87	28.22	259.6
EB1ALA	1	0.0000E+00	0.0000E+00	28.22	0.0000E+00
EB2ALA10/23	1	0.0000E+00	0.0000E+00	28.22	0.0000E+00
EB3ALA10/23	1	0.0000E+00	0.0000E+00	28.22	0.0000E+00
EB4ALA10/23	1	0.0000E+00	0.0000E+00	28.22	0.0000E+00

P/M XYLENE

-----REGRESSION DATA-----

SEG	PTS	SLOPE	INTERCEPT	+/-SLOPE	+/-INTERC.	DL	R2	G/O
1	14	202.56	0.00000E+00	11.611	0.00000E+00	29.5	0.963	0
2	23	194.43	0.00000E+00	5.1418	0.00000E+00	140.	0.993	0

THE LIMIT OF QUANTIFICATION: 59.0 X UNITS USING SEGMENT 1

-----INTERROGATION-----

SAMPLE	SEG	Y	X (P/M XYL)	X +/-	X +/- %
B181B10/22	1	1293.	6.383	29.49	461.9
B182B10/22	1	0.1969E+05	97.22	30.01	30.87
B183B10/22	2	0.7071E+05	363.7	140.1	38.53
B184B10/22	1	0.2863E+05	141.4	30.58	21.63
B185B10/22	1	922.0	4.552	29.49	647.8
B186B10/22	1	0.0000E+00	0.0000E+00	29.49	0.0000E+00
B191B10/22	2	0.8543E+05	439.4	140.3	31.93
B192B10/22	2	0.9376E+05	482.2	140.4	29.11
B193B10/22	2	0.7627E+05	392.3	140.2	35.74
B194B10/22	1	2694.	13.30	29.49	221.8
B195B10/22	1	0.0000E+00	0.0000E+00	29.49	0.0000E+00
B201B10/23	2	0.5641E+05	290.1	140.0	48.26
B202B10/23	2	0.6848E+05	352.2	140.1	39.79
B203B10/23	2	0.5015E+05	257.9	140.0	54.27
B204B10/23	1	895.0	4.418	29.49	667.3
B205B10/23	1	722.0	3.564	29.49	827.2
B211B10/23	1	0.1643E+05	81.09	29.85	36.81
B212B10/23	1	2700.	13.33	29.49	221.3
B213B10/23	1	2124.	10.49	29.49	281.3
B214B10/23	1	2216.	10.94	29.49	269.6
B215B10/23	1	0.0000E+00	0.0000E+00	29.49	0.0000E+00
B231B10/23	2	0.5057E+05	260.1	140.0	53.83
B232B110/23	1	0.2531E+05	125.0	30.34	24.28
B232B210/23	2	0.3585E+05	184.4	139.9	75.87
B233B10/23	1	1384.	6.833	29.49	431.6
B234B10/23	1	2289.	11.30	29.49	261.0
B235B10/23	1	0.0000E+00	0.0000E+00	29.49	0.0000E+00

## O-XYLENE

## -----REGRESSION DATA-----

SEG	PTS	SLOPE	INTERCEPT	+/-SLOPE	+/-INTERC.	DL	R2	G/O
1	15	162.77	0.0000E+00	5.8829	0.0000E+00	18.6	0.986	0
2	24	161.59	0.0000E+00	3.4142	0.0000E+00	112.	0.996	0

THE LIMIT OF QUANTIFICATION: 37.2 X UNITS USING SEGMENT 1

## -----INTERROGATION-----

B18110/22	SEG	Y	X(O-XYL)	X +/-	X +/- %
B18210/22	1	0.0000E+00	0.0000E+00	18.59	0.0000E+00
B18310/22	1	7364.	45.24	18.66	41.25
B18510/22	1	0.2219E+05	136.3	19.23	14.11
B18610/22	1	8059.	49.51	18.68	37.72
B19110/22	1	0.0000E+00	0.0000E+00	18.59	0.0000E+00
B19210/22	1	0.0000E+00	0.0000E+00	18.59	0.0000E+00
B19310/22	1	0.2160E+05	132.7	19.20	14.47
B19410/22	2	0.3225E+05	199.6	111.7	55.98
B19510/22	1	0.1888E+05	116.0	19.06	16.43
B20110/23	1	571.0	3.508	18.59	530.0
B20210/23	1	0.0000E+00	0.0000E+00	18.59	0.0000E+00
B20310/23	1	0.1196E+05	73.48	18.78	25.56
B20410/23	1	0.1984E+05	121.9	19.11	15.67
B20510/23	1	0.1668E+05	102.5	18.96	18.50
B21110/23	1	575.0	3.533	18.59	526.3
B21210/23	1	0.0000E+00	0.0000E+00	18.59	0.0000E+00
B21310/23	1	4407.	27.08	18.62	68.76
B21410/23	1	943.0	5.793	18.59	320.9
B21510/23	1	3024.	18.58	18.60	100.1
B23110/23	1	1315.	8.079	18.59	230.2
B23210/23	1	0.0000E+00	0.0000E+00	18.59	0.0000E+00
B23310/23	1	3322.	20.41	18.61	91.16
B23410/23	1	0.1044E+05	64.14	18.74	29.21
B23510/23	1	4632.	28.46	18.62	65.43
EB1ALA	1	4386.	26.95	18.62	69.09
EB2ALA10/23	1	2000.	12.29	18.60	151.3
EB3ALA10/23	1	0.0000E+00	0.0000E+00	18.59	0.0000E+00
EB4ALA10/23	1	0.0000E+00	0.0000E+00	18.59	0.0000E+00
EB3ALA10/23	1	0.0000E+00	0.0000E+00	18.59	0.0000E+00
EB4ALA10/23	1	0.0000E+00	0.0000E+00	18.59	0.0000E+00

O XYLENE

-----REGRESSION DATA-----

G	PTS	SLOPE	INTERCEPT	+/-SLOPE	+/-INTERC.	DL	R2	G/O
1	14	162.77	0.00000E+00	6.1468	0.00000E+00	19.4	0.983	0
2	23	161.59	0.00000E+00	3.4993	0.00000E+00	114.	0.995	0

THE LIMIT OF QUANTIFICATION: 38.9 X UNITS USING SEGMENT 1

-----INTERROGATION-----

SAMPLE	SEG	Y	X (O XYL)	X +/-	X +/- %
B181B10/22	1	0.0000E+00	0.0000E+00	19.43	0.0000E+00
B182B10/22	1	6427.	39.49	19.48	49.34
B183B10/22	1	0.2226E+05	136.8	20.10	14.70
B184B10/22	1	8089.	49.70	19.52	39.27
B185B10/22	1	0.0000E+00	0.0000E+00	19.43	0.0000E+00
B186B10/22	1	0.0000E+00	0.0000E+00	19.43	0.0000E+00
B191B10/22	2	0.3329E+05	206.0	114.5	55.58
B192B10/22	2	0.3435E+05	212.6	114.5	53.87
B193B10/22	2	0.2900E+05	179.5	114.5	63.79
B194B10/22	1	0.0000E+00	0.0000E+00	19.43	0.0000E+00
B195B10/22	1	0.0000E+00	0.0000E+00	19.43	0.0000E+00
B201B10/23	1	0.1310E+05	80.48	19.66	24.43
B202B10/23	1	0.1729E+05	106.2	19.84	18.67
B203B10/23	1	0.1492E+05	91.68	19.73	21.52
B204B10/23	1	0.0000E+00	0.0000E+00	19.43	0.0000E+00
B205B10/23	1	0.0000E+00	0.0000E+00	19.43	0.0000E+00
B211B10/23	1	3898.	23.95	19.45	81.20
B212B10/23	1	646.0	3.969	19.43	489.5
B213B10/23	1	1259.	7.735	19.43	251.2
B214B10/23	1	1291.	7.931	19.43	244.9
B215B10/23	1	0.0000E+00	0.0000E+00	19.43	0.0000E+00
B231B10/23	1	0.1330E+05	81.68	19.67	24.08
B232B110/23	1	9999.	61.43	19.56	31.85
B232B210/23	1	0.1957E+05	120.3	19.95	16.59
B233B10/23	1	1121.	6.887	19.43	282.1
B234B10/23	1	787.0	4.835	19.43	401.8
B235B10/23	1	819.0	5.032	19.43	386.1

## **APPENDIX B**

### **NUMERICAL SIMULATIONS FOR THE FUNNEL AND GATE**

## Numerical simulations for funnel & gate design considerations at Alameda, NAS

### Introduction

The purpose of the numerical simulations is to aid in the design of the funnel & gate configuration and to provide estimates of groundwater discharge rates through the gate(s). Additional insight into the expected flow system and capture zone will also aid in the design of the monitoring strategy.

The general approach to the modelling effort was to focus on the physical hydrogeology of a pilot scale remediation system. Ideally, plume concentrations entering both the remedial and control gates would be the same, necessitating a design of limited lateral extent across the assumed plume location. The issues regarding scale-up for complete plume remediation will be investigated at a later date. The model was developed to produce a conservative estimate of gate fluxes to ensure adequate residence time within the Fe<sup>0</sup> treatment zone.

### Conceptual Model

Description of the site hydrogeology can be found in Section 2.1. The installation of the funnel & gate system will be completed into the clay material at depth and as a result, the groundwater flow regime surrounding the fully penetrating funnel & gate system can be approximated using a two-dimensional plan view numerical analysis. The site is therefore conceptualized as a single layer that is 22 ft. thick, representing an unconfined aquifer with an impermeable base.

The area of consideration is 300 ft. by 300 ft. centered around MW3 (Figure 1). This large area was chosen to minimize uncharacterized boundary effects because the San Francisco Bay represents the only physically-defined vertical boundary in the model domain. This eastern domain boundary as well as the western boundary are represented as constant head boundary conditions while the remaining north and south boundaries are considered as no-flow. This induces flow from the east towards the west. Both the top and bottom of the domain are also considered no-flow (ie. no recharge, and no leakage). Because of the variability in the groundwater flow velocity and perhaps direction due to seasonal and tidal influences, hydraulic conditions based on data collected in April 1995 (Appendix A) were chosen as the basis for design considerations. It should be noted that the seasonal and tidal influence on the groundwater regime may significantly limit the applicability of these results.

### Model Design

The software package Visual MODFLOW (1995) was used to simulate the flow of groundwater and particle tracking at the site. Visual MODFLOW provides pre- and post-processing capabilities for the U.S. Geological Survey's MODFLOW (McDonald and Harbaugh, 1988) and MODPATH. Results from the three dimensional, finite difference flow package, MODFLOW are used by MODPATH to conduct particle tracking and calculate capture zones.

The 300 ft. by 300 ft model domain is discretized with 5 ft. spacing in both the x and y directions, with refinement to 1 ft. spacing beginning at distance of 20 ft. adjacent to the funnel & gate system, and 0.5 ft at zones of intense convergent and divergent flow. As an example, the discretization used for Simulation 3 is shown in Figures 2a and 2b. The vertical dimension is represented as a single layer. The total number of cells is approximately 13 600.

The hydraulic conductivity, K, of the aquifer is assumed to be homogeneous and isotropic with a value of 5.7 ft/d ( $2 \times 10^{-3}$  cm/s) based on slug tests in the vicinity of M028-A. Assumed values for porosity of 0.30, specific storage of  $1 \times 10^{-3}$  ft<sup>-1</sup>, and 0.32 for specific yield were chosen based on typical sandy aquifer values.

A hydraulic gradient value of 0.005 (April, 1995) was established by setting the eastern and western boundary to a constant head of 14.25 ft and 15.75 ft, respectively (ie. 7.75 ft and 6.25 ft bgs, respectively). Without the presence of the funnel & gate, this results in a watertable surface 7 ft bgs in the vicinity of the funnel & gate and induces uniform flow within the aquifer from east to west at a velocity of 0.094 ft/day (2.9 cm/day). No recharge was allowed on the top boundary. Due to the seasonal and tidal influences on the site hydrology and the limited amount of field data within the model domain, verification of the model was not conducted.

The funnel & gate designs shown in Section 3.0 are approximated using the hydraulic properties seen in Table 1. These funnel & gate hydraulic properties are based on values typically used by ETI. The remedial funnel & gate consists of funnel walls (both parallel and orthogonal to the ambient groundwater flow direction) to direct contaminated water first through a zone of gravel, followed by iron, and then through another zone of gravel (Figure 3 - simulation 1). The control gate was simulated by simply leaving an opening between two funnel walls, with aquifer material remaining in the gate and no side walls parallel to the ambient groundwater flow direction (Figure 3 - simulations 2, 3).

Table 1: Hydraulic properties

<i>Property</i>	<i>K (ft/d)</i>	<i>porosity</i>
aquifer	5.669	0.30
gate gravel	2830	0.30
gate iron	141.7	0.40
funnel wall	$2.83 \times 10^{-5}$	0.10

Large contrasts in K, which become an issue when simulating the funnel walls and the O<sub>2</sub> biosparge zone, may cause numerical difficulties. These numerical problems may manifest itself by inducing a poor water balance or anomalous trends in hydraulic head data. Representation of the funnel walls using the Horizontal-Flow-Barrier (HFB) Package available in MODFLOW instead of the hydraulic properties listed in Table 1 did not improve the already low water balance error and allowed more leakage through the wall itself, thus it was not invoked. No anomalous trends in equipotential plots were apparent using the hydraulic properties listed in Table 1. Representation of the O<sub>2</sub> biosparge zone is conceptually more difficult to apply in the model because it represents an open body of water. Assigning boundary conditions to this zone would "fix" the solution precluding estimation of predicted volumetric discharge rates through the gate (Q<sub>gate</sub>). Initially, modelling of the site using FLOWPATH (a 2D plan view finite difference code) showed that using a K of greater than 2.83×10<sup>5</sup> ft/d to represent the sparge zone produced physically unrealistic results. It was decided for the sake of simplicity that a value equal to the gate gravel would be used. This approximation is not unrealistic as the flow through the gate will be governed by the bulk gate harmonic K, or in other words, the lowest K zone in the system, namely the aquifer material beyond the gate exit.

In all cases, the model was run to steady state with the Waterloo Hydrogeologic Software solver.

Terminology commonly used to describe funnel & gate geometries includes the funnel to gate ratio (F:G) which is the ratio of the surface area of both funnels walls added together to the gate surface area normal to the direction of groundwater flow. Because both the walls and gate are assumed to be installed to the same depth, the F:G is simply the width of both funnel walls to the width of the gate.

#### Model Application

To determine the gate residence time, two methods were applied. The first involved particle tracking by applying MODPATH. Particles were released at the entrance to the gate and time markers were added to coincide with physical boundaries such as the beginning and end of the Fe<sup>0</sup> zone. Knowing the distance then, the groundwater velocity was calculated. The resolution on the time discretization, however, is on the order of days and therefore an exact time match to boundaries was sometimes not possible. A more accurate estimate was based on applying the Zone Budget Package in MODFLOW which calculates the volumetric discharge through a specified zone, such as the gate entrance, giving Q<sub>gate</sub>. The groundwater velocity,  $\bar{v}$ , from which the travel time could be calculated was obtained by evaluating:  $\bar{v} = \frac{Q_{gate}}{n \times A}$

where:

- n is the porosity
- A is the cross-sectional area for flow

The cross-sectional area for flow was determined by plotting equipotentials (to determine the water table elevation) coinciding with the gate entrance to represent the saturated

thickness between the water table and the clay aquitard and multiplying this value by the gate width. In all cases, the two methods of calculation produced similar results.

### Results

Various scenarios of single funnel & gate systems were simulated to get an estimate of  $Q_{gate}$  for F:G of 2:1, 4:1 and 6:1, all using a gate width of 10 ft.. The 2:1 geometry (referred to as Simulation 1) was decided upon for the basis of future simulations as it produced the smallest capture zone for the expected plume of limited lateral extent (Figure 3).

Addition of the control gate to the design involved two additional simulations (Figure 3). Simulation 2 involved a single 2:1 funnel & gate attached to a control gate consisting of funnel walls each 10 ft. wide. Simulation 3 involved the same 2:1 funnel & gate, but attached to a control gate consisting of only one funnel wall, 10 ft. wide, on the flank of the system. Estimates of gate volumetric discharge, specific discharge, and velocity for all 2:1 cases are found in Table 2 below:

Table 2: Simulation results-  $Q_{gate}$ ,  $q$ , and velocity

Simulation	$Q_{gate}$ (ft <sup>3</sup> /day)	$q$ (ft/d)	velocity in ft/day, (cm/day)	
			$n=0.40$ ie. $Fe^0$	$n=0.30$ ie. gravel
1 (remedial gate)	9.082	0.061	0.15, (4.6)	0.20, (6.2)
2 (remedial gate)	12.159	0.081	0.20, (6.2)	0.27, (8.3)
(control gate)	9.036	0.060	0.15, (4.6)	0.20, (6.1)
3 (remedial gate)	10.898	0.073	0.18, (5.6)	0.24, (7.4)
(control gate)	7.386	0.049	0.12, (3.8)	0.16, (5.0)

From these results, it shows that the addition of the funnels more than doubles the flow velocity in the remedial gate from the ambient groundwater velocity of 0.094 ft/day (2.9 cm/day).

Particle tracking and capture zone plots for Simulations 1 to 3 can be seen in figures 4 to 11.

### References

Waterloo Hydrogeologic Software. 1995. Visual MODFLOW. Version 1.97. 180 Columbia Street, Unit 1104. Waterloo, Ontario.

McDonald, M.G., and A.W. Harbaugh. 1988. A modular three-dimensional finite difference ground-water flow model: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 6, Chapter A1.

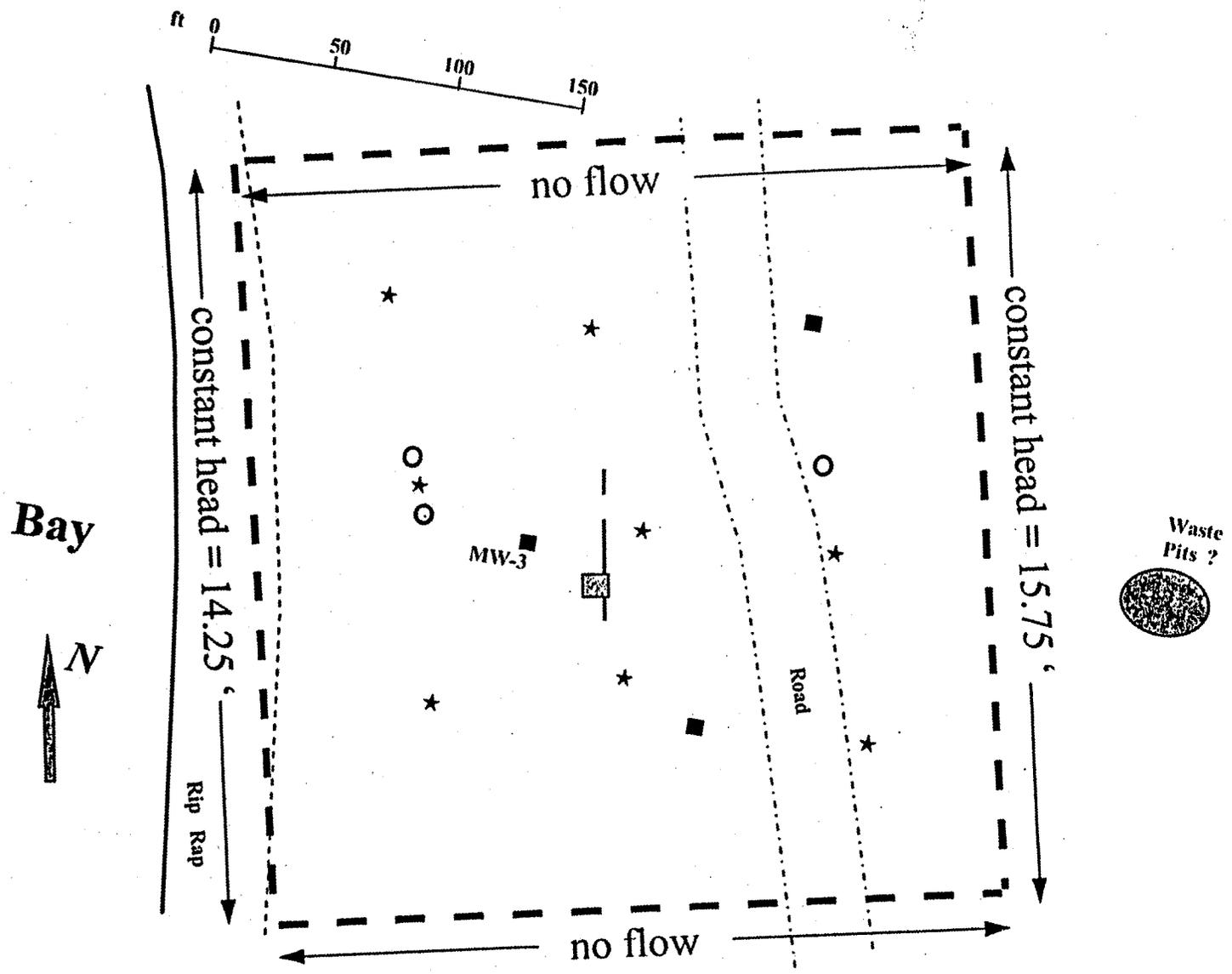
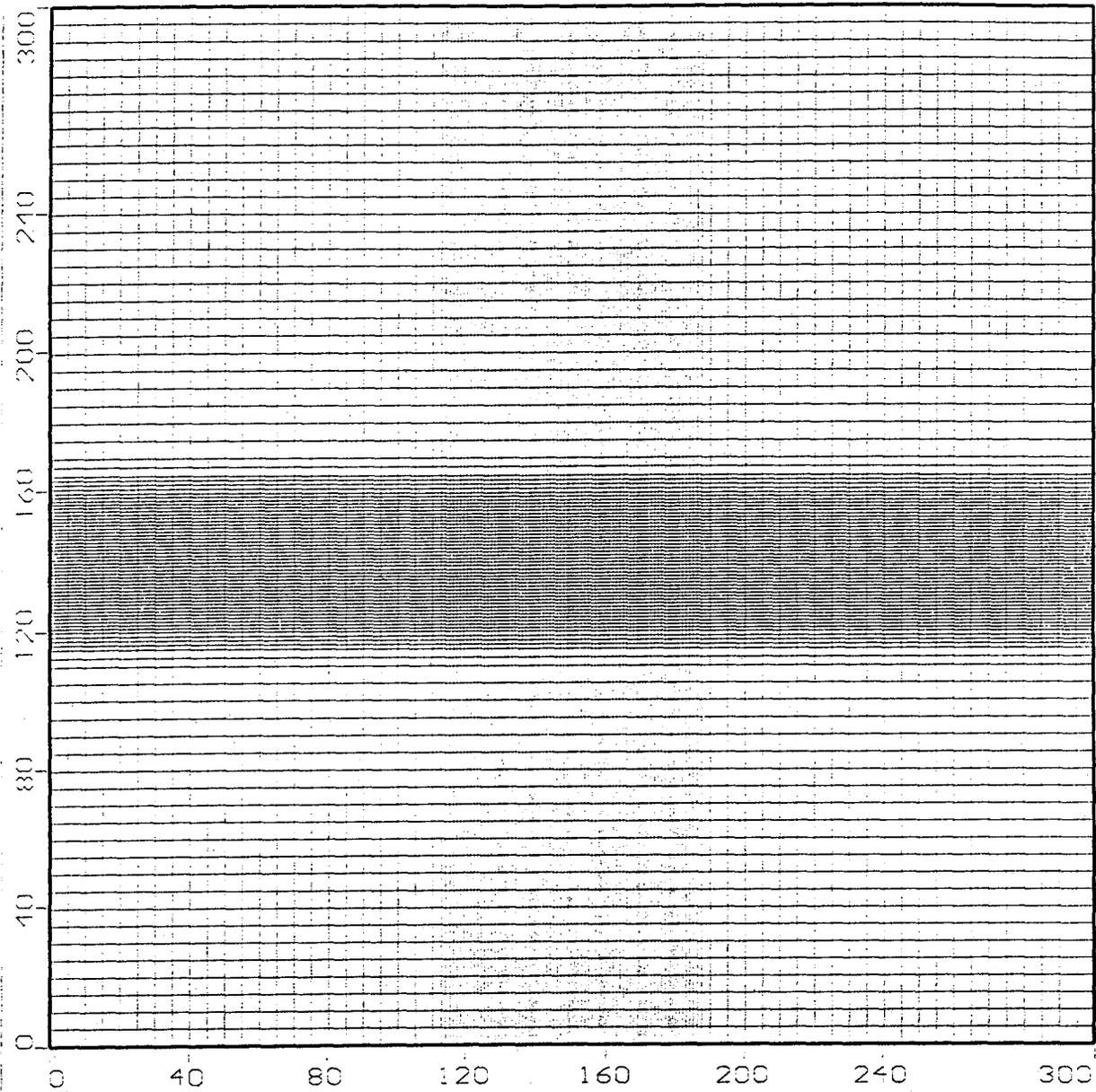


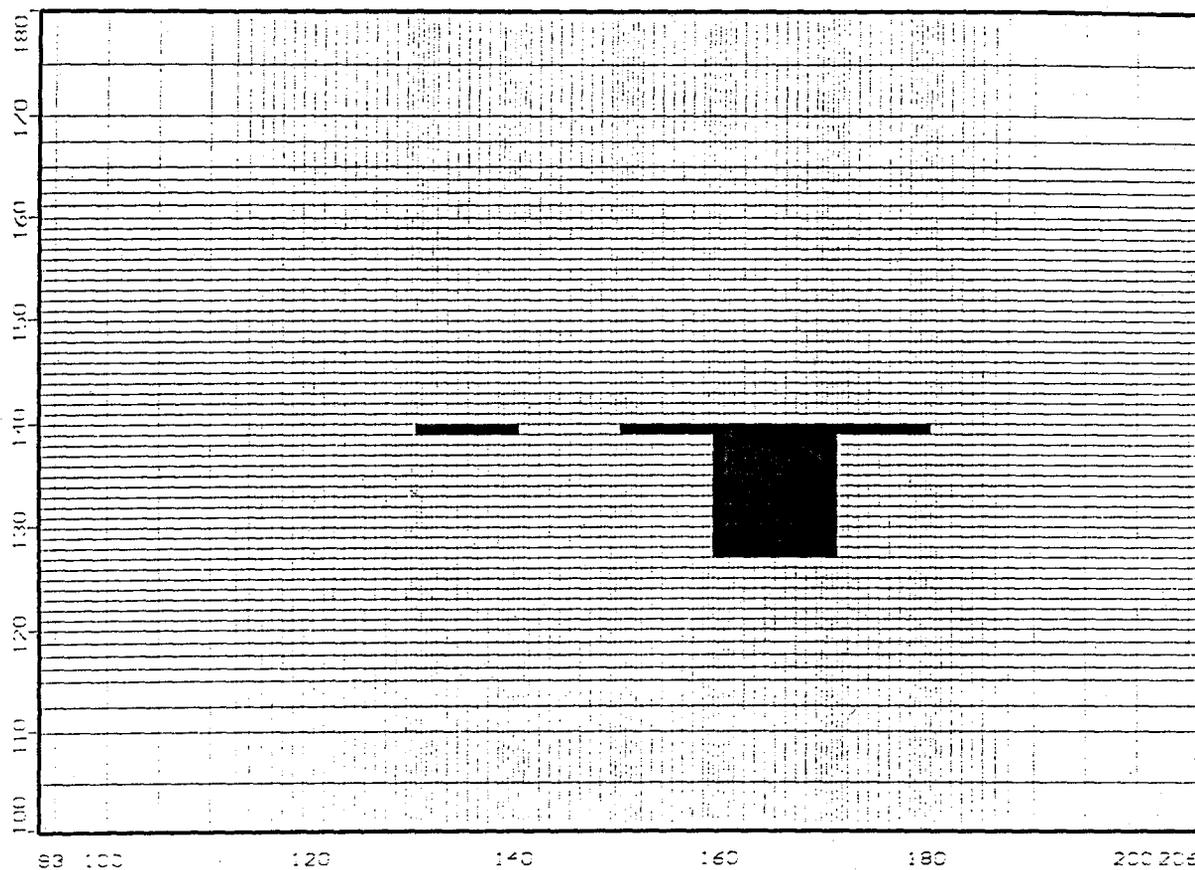
Figure 1: Model domain and boundary conditions



TEST  
Project: Alameda NAS  
Description: Finite Difference Grid  
Modeller: C.A.  
9 Sep 98

Visual MODFLOW v.2.00 beta, (c) 1995  
Waterloo Hydrogeologic Software  
NC: 138 NR: 100 NL: 1  
Current Layer: 1

**Figure 2a: Simulation 3 - Finite difference grid**

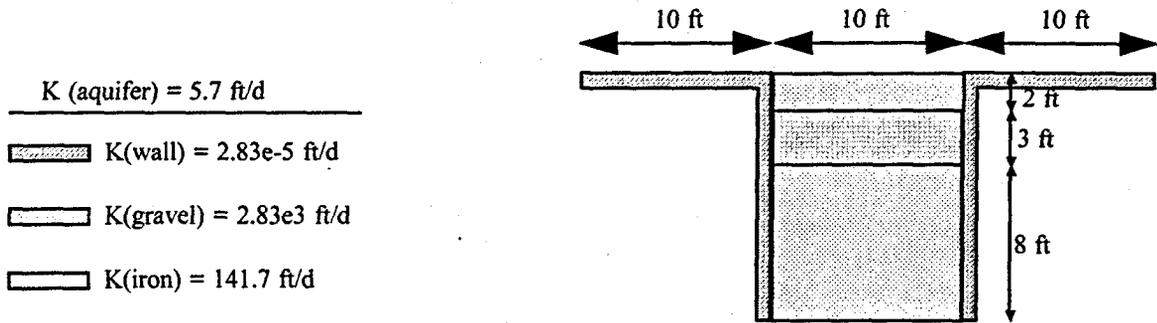


**TEST**  
 Project: Alameda NAS  
 Description: Finite Difference Grid  
 Modeller: C.A.  
 9 Sep 96

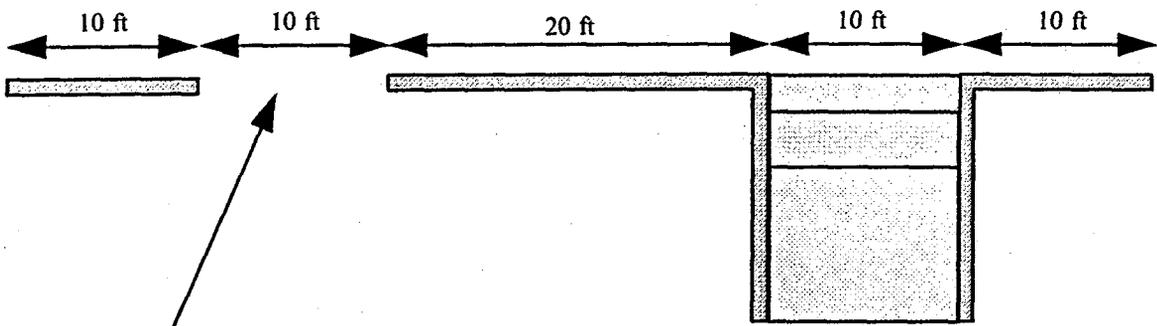
Visual MODFLOW v.2.00 beta, (c) 1995  
 Waterloo Hydrogeologic Software  
 NC: 138 NR: 100 NL: 1  
 Current Layer: 1

**Figure 2b: Simulation 3 - Close-up of finite difference grid**

# Simulation 1



# Simulation 2



control gate

remedial gate

# Simulation 3

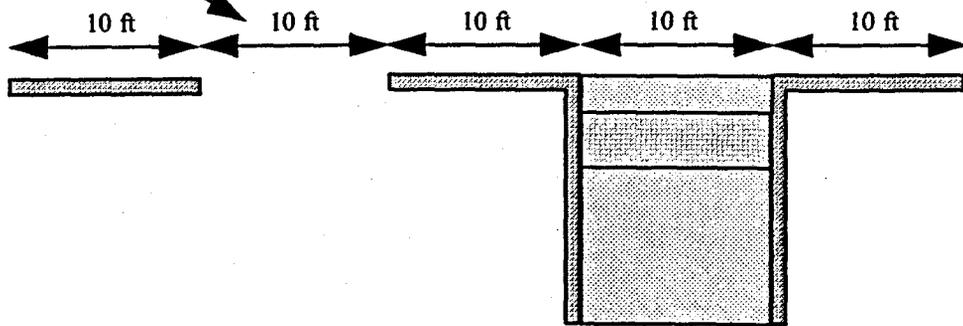
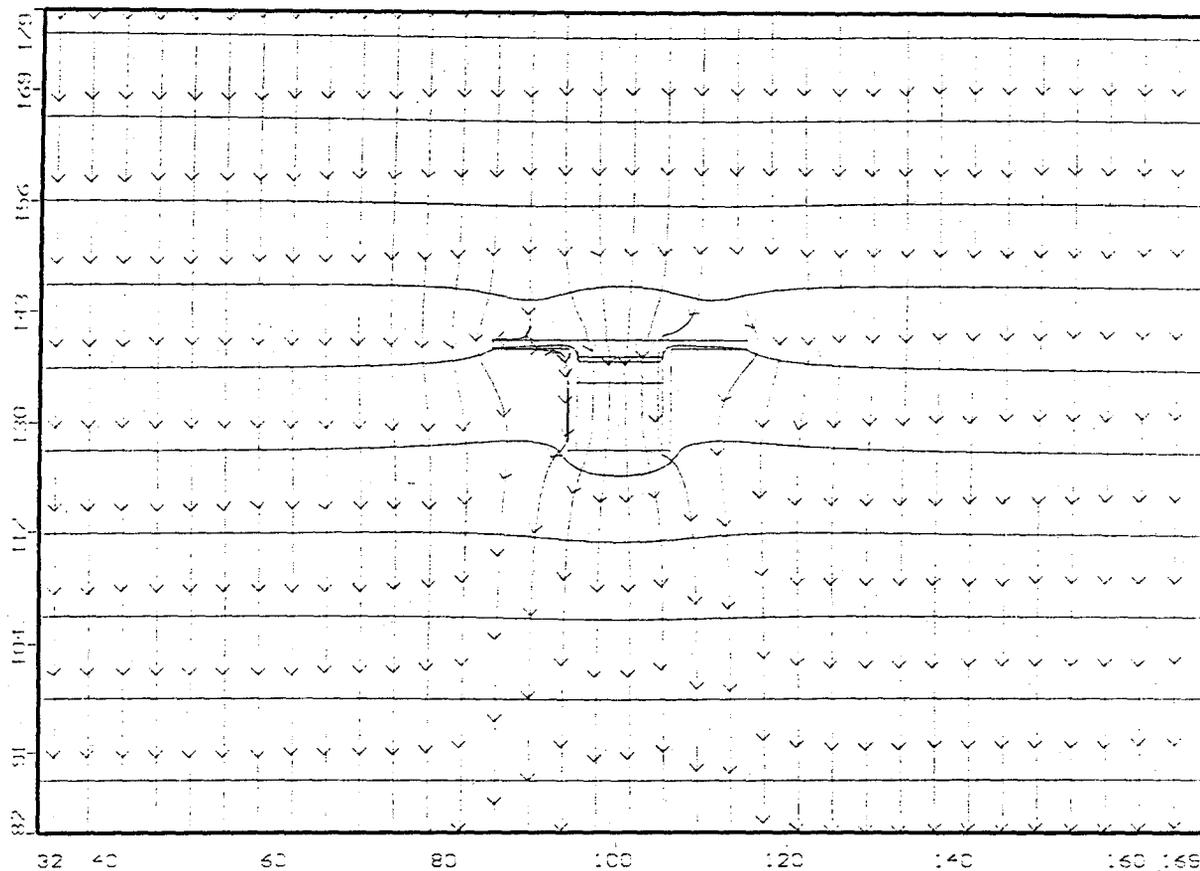


Figure 3: Funnel & gate configuration

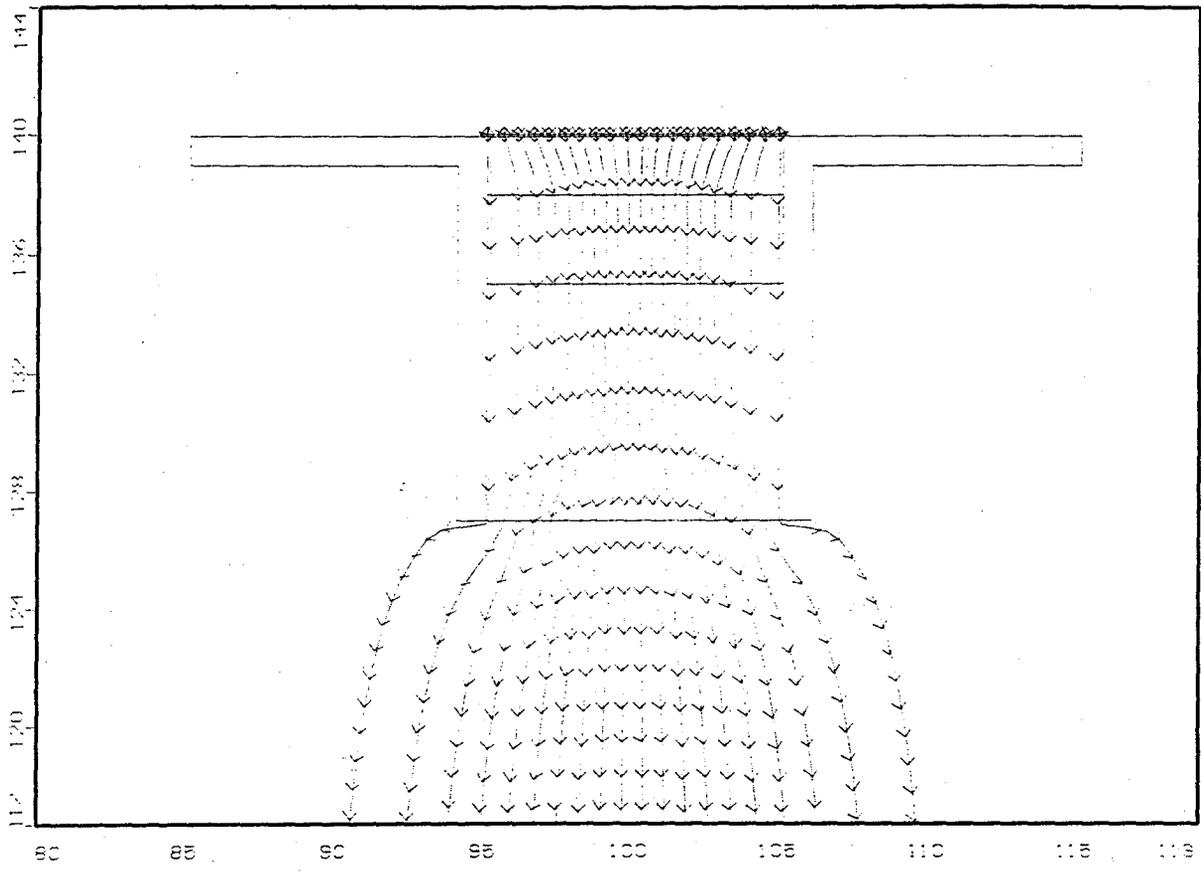


**Equipotential contours: 0.05 ft**  
**Time marker interval: 100 days**

**TEST**  
**Project: Alameda NAS**  
**Description: Flownet**  
**Modeller: C.A.**  
**10 Sep 96**

**Visual MODFLOW v.2.00 beta, (c) 1995**  
**Waterloo Hydrogeologic Software**  
**NC: 96 NR: 92 NL: 1**  
**Current Layer: 1**

**Figure 4: Simulation 1 - Equipotentials and flowlines**

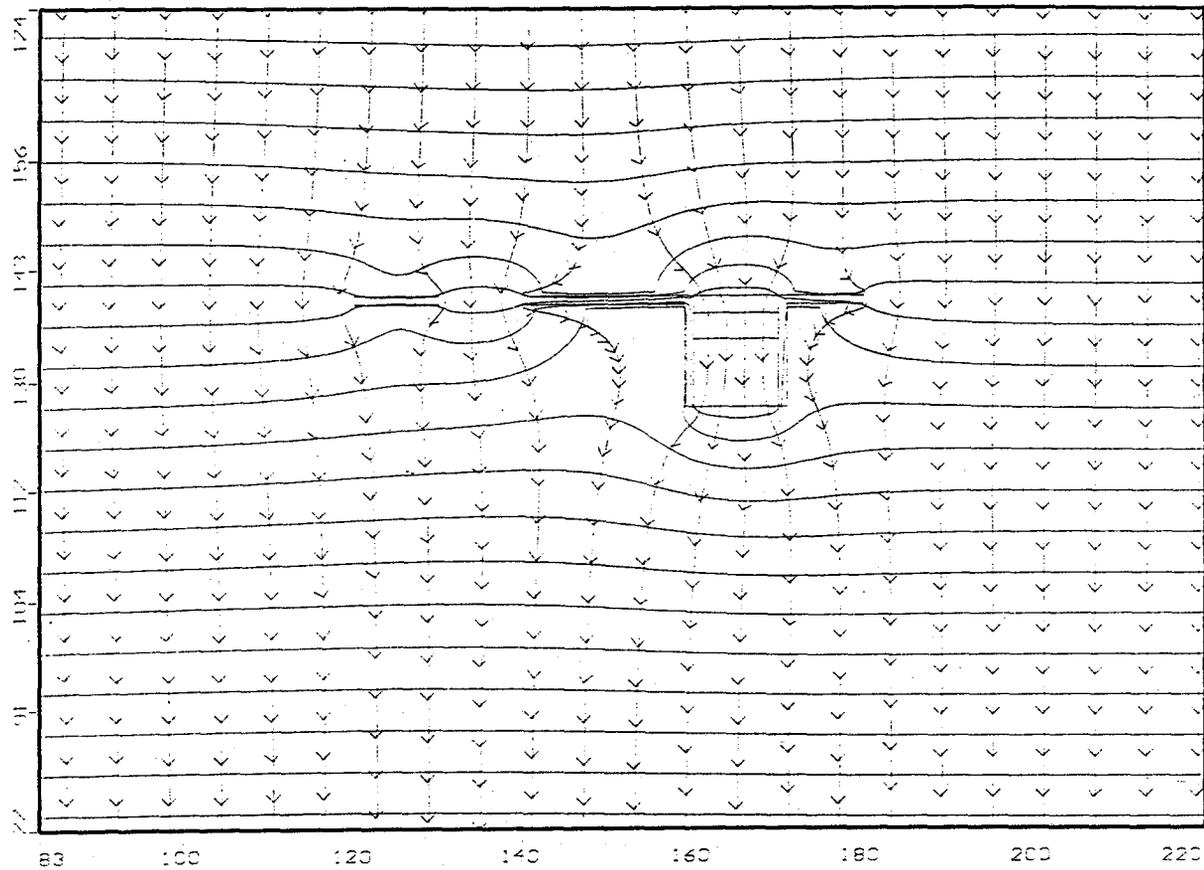


**Time marker interval: 10 days**

TEST  
 Project: Alameda NAS  
 Description: Pathlines  
 Modeller: C.A.  
 10 Sep 96

Visual MODFLOW v.2.00 beta, (c) 1995  
 Waterloo Hydrogeologic Software  
 NC: 96 NR: 92 NL: 1  
 Current Layer: 1

**Figure 5: Simulation 1 - Pathline travel times through remedial gate**

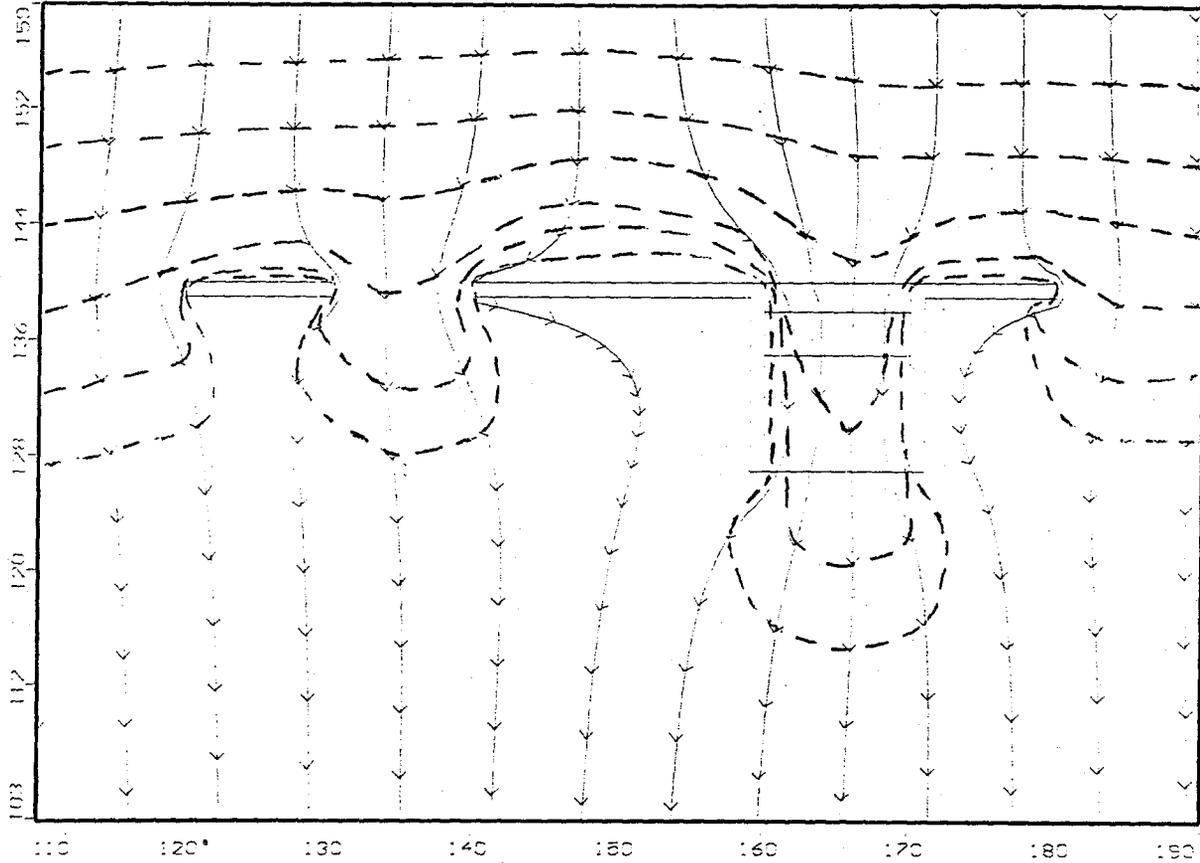


**Equipotential contours: 0.025 ft**  
**Time marker interval: 50days**

**TEST**  
**Project: Alameda NAS**  
**Description: Equipotentials**  
**Modeller: C.A.**  
**23 Sep 96**

**Visual MODFLOW v.2.00 beta, (c) 1995**  
**Waterloo Hydrogeologic Software**  
**NC: 136 NR: 100 NL: 1**  
**Current Layer: 1**

**Figure 6a: Simulation 2 - Equipotentials and flowlines**

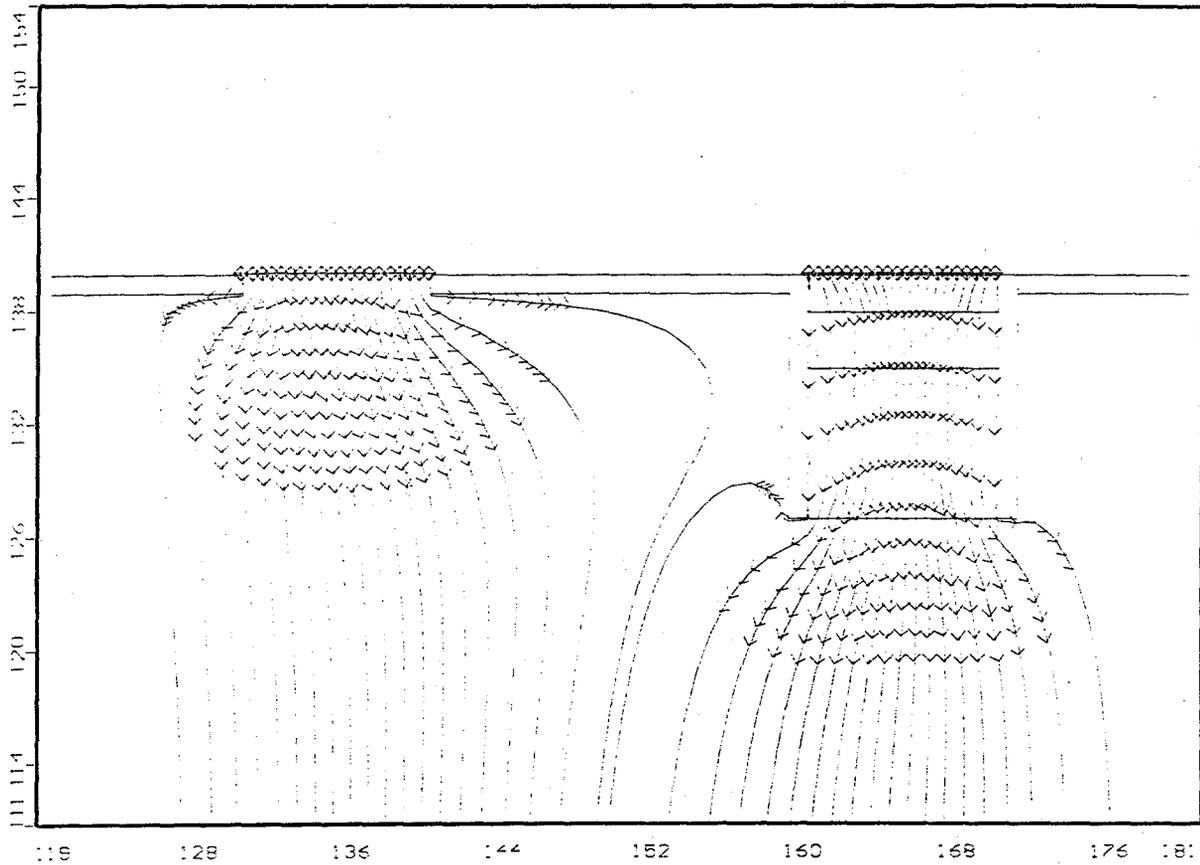


**Time marker interval: 50days**

TEST  
 Project: Alameda NAS  
 Description: Pathlines  
 Modeller: C.A.  
 24 Sep 96

Visual MODFLOW v.2.00 beta, (c) 1995  
 Waterloo Hydrogeologic Software  
 NC: 136 NR: 100 NL: 1  
 Current Layer: 1

**Figure 6b: Simulation 2 - Close-up of flowlines  
 (with isochrons)**

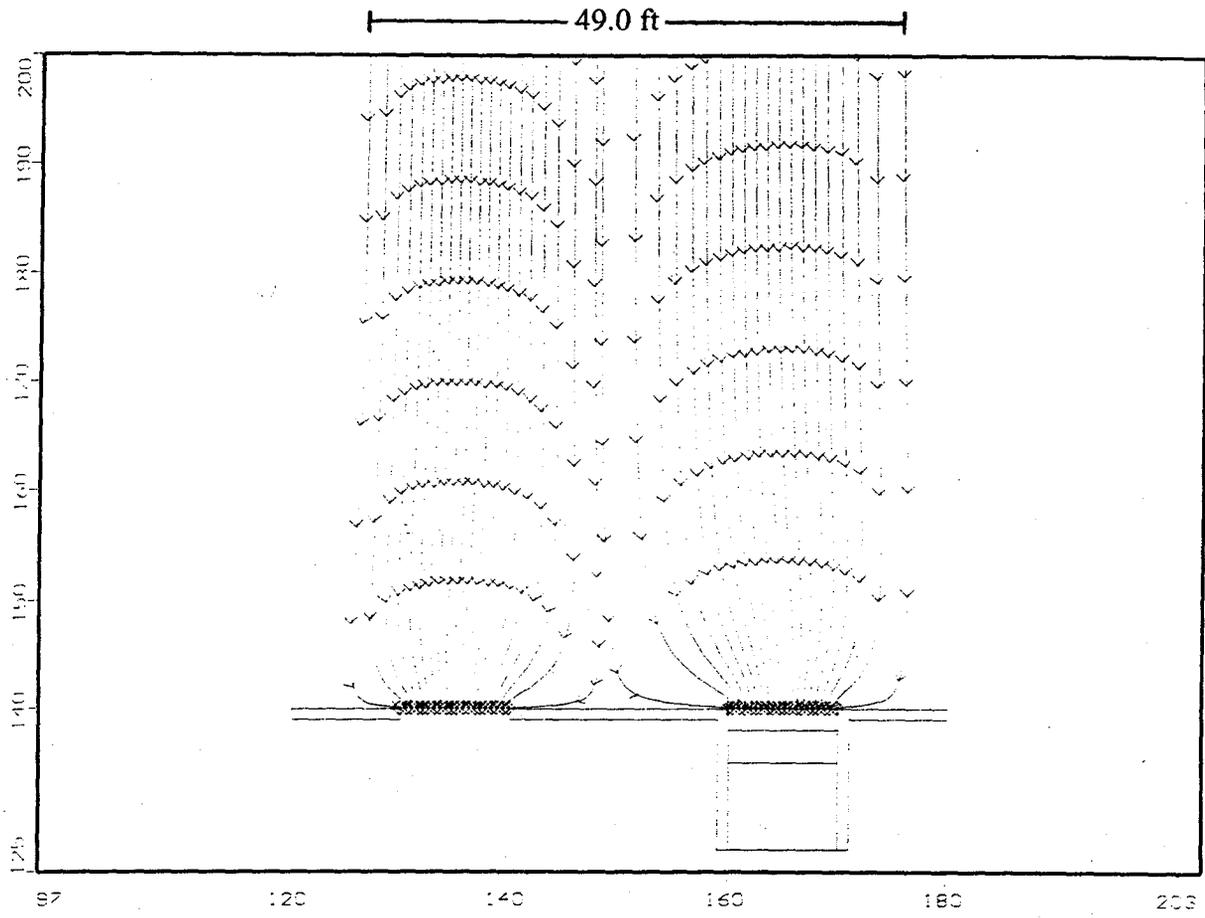


**Time marker interval: 10 days**

TEST  
 Project: Alameda NAS  
 Description: Pathlines  
 Modeller: C.A.  
 4 Sep 96

Visual MODFLOW v.2.00 beta, (c) 1995  
 Waterloo Hydrogeologic Software  
 NC: 136 NR: 100 NL: 1  
 Current Layer: 1

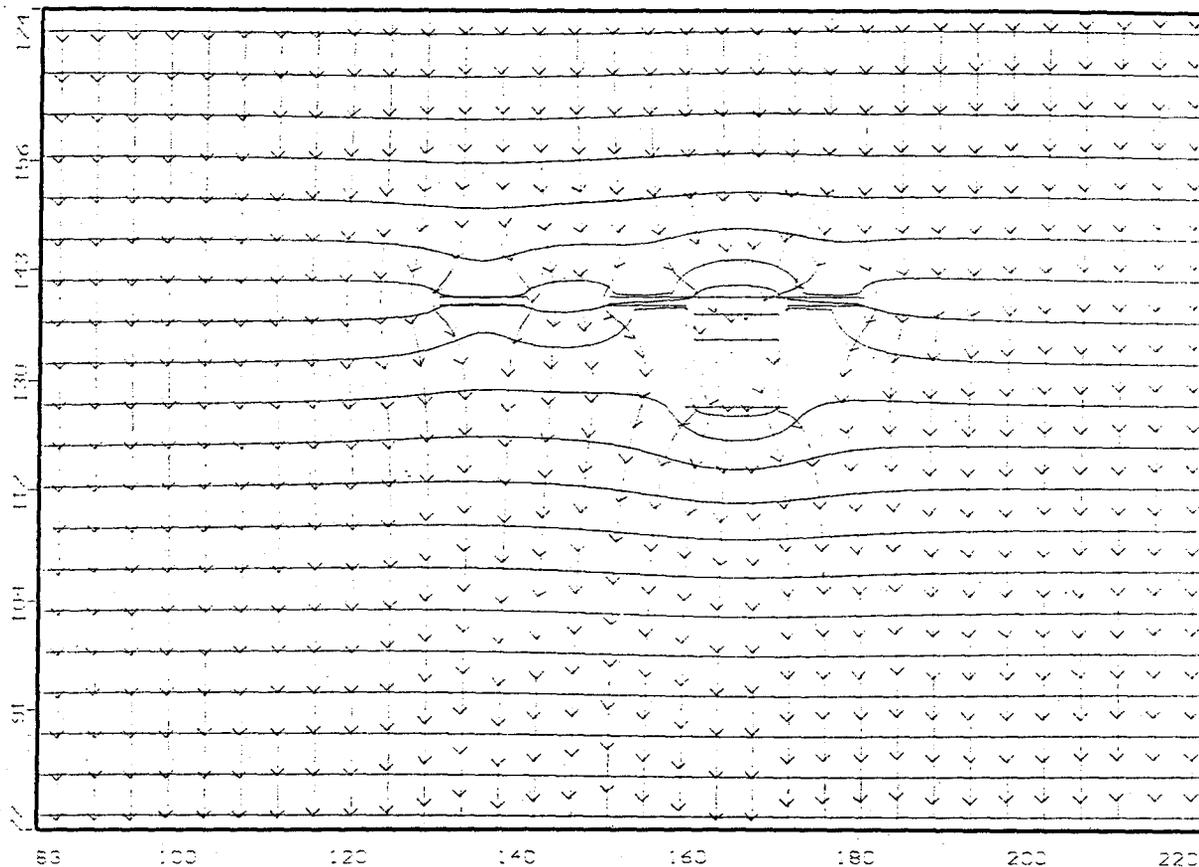
**Figure 7: Simulation 2 - Pathline travel times through gates**



**Time marker interval: 100 days**

<p>TEST          Project: Alameda NAS          Description: Capture zones          Modeller: C.A.          10 Sep 96</p>	<p>Visual MODFLOW v.2.00 beta, (c) 1995          Waterloo Hydrogeologic Software          NC: 136 NR: 100 NL: 1          Current Layer: 1</p>
--	---

**Figure 8: Simulation 2 - Close-up of gate capture zones**

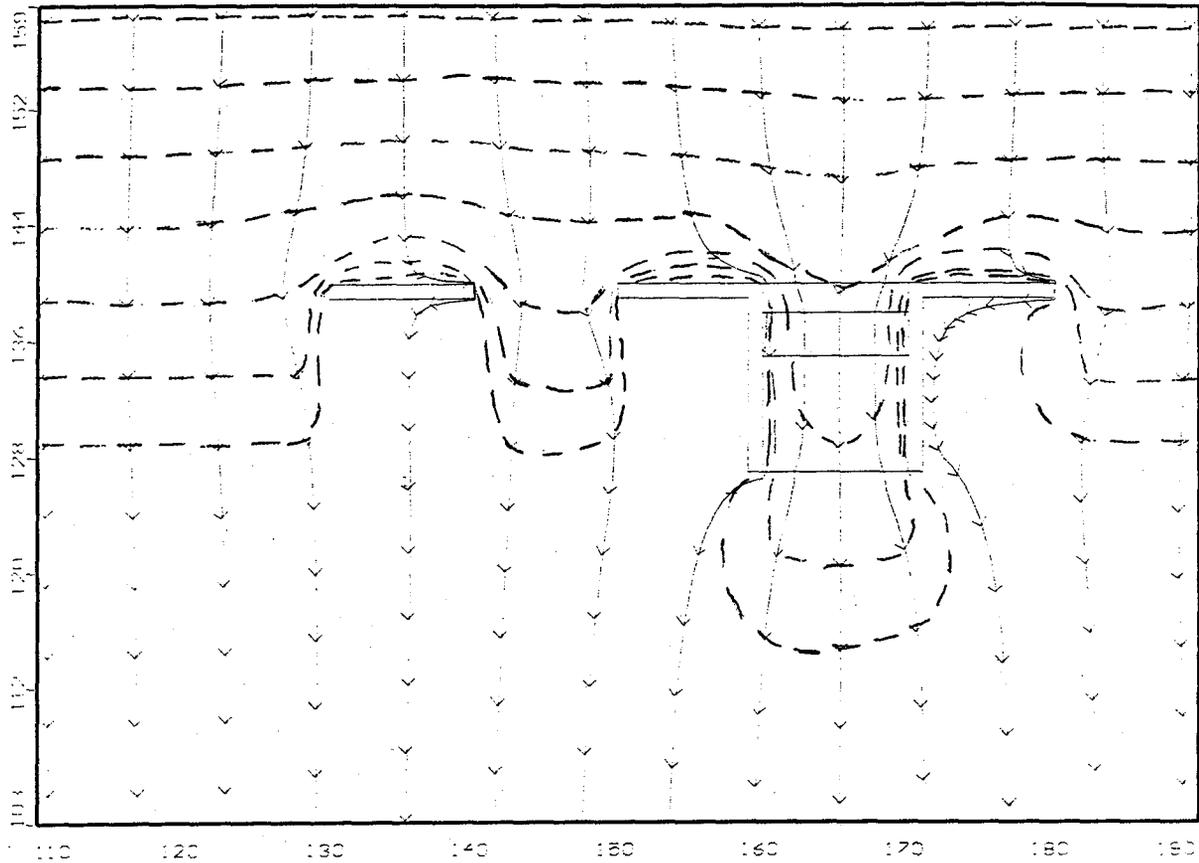


**Equipotential contours: 0.025 ft**  
**Time marker interval: 50days**

TEST  
 Project: Alameda NAS  
 Description: Equipotentials  
 Modeller: C.A.  
 4 Sep 96

Visual MODFLOW v.2.00 beta, (c) 1995  
 Waterloo Hydrogeologic Software  
 NC: 138 NR: 100 NL: 1  
 Current Layer: 1

**Figure 9a: Simulation 3 - Equipotentials and flowlines**

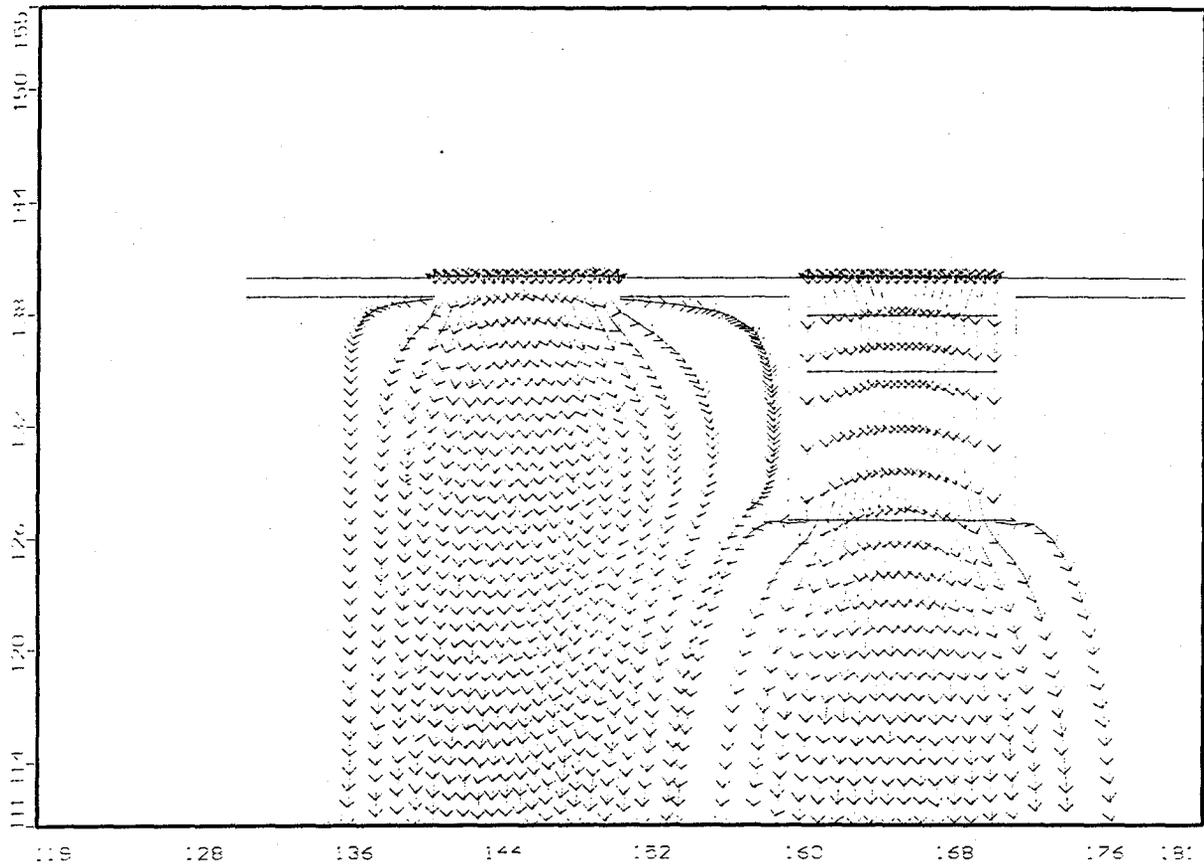


**Time marker interval: 50days**

TEST  
 Project: Alameda NAS  
 Description: Pathlines  
 Modeller: C.A.  
 24 Sep 98

Visual MODFLOW v.2.00 beta, (c) 1995  
 Waterloo Hydrogeologic Software  
 NC: 138 NR: 100 NL: 1  
 Current Layer: 1

**Figure 9b: Simulation 3 - Close-up of flowlines  
 (with isochrons)**

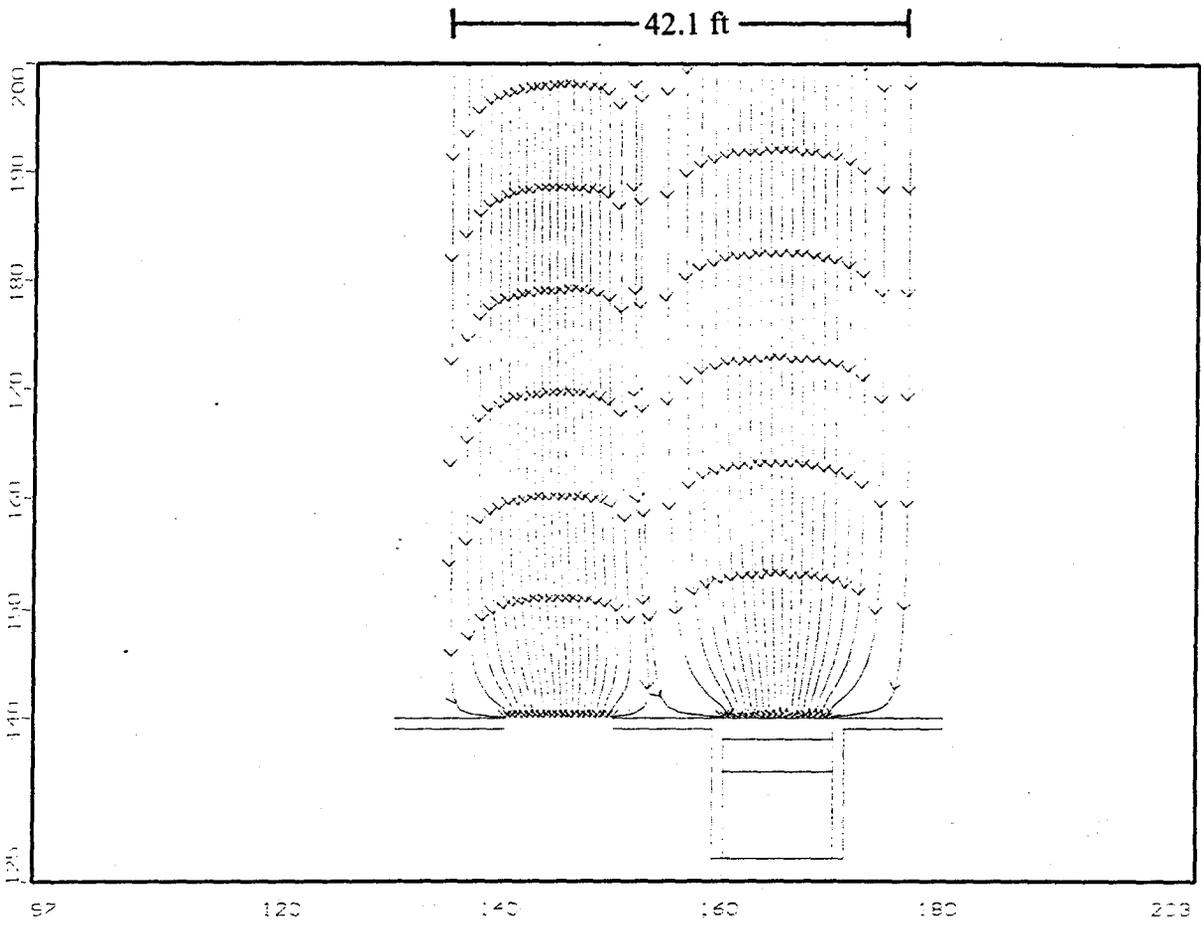


**Time marker interval: 10 days**

TEST  
 Project: Alameda NAS  
 Description: Pathlines  
 Modeller: C.A.  
 4 Sep 96

Visual MODFLOW v.2.00 beta, (c) 1995  
 Waterloo Hydrogeologic Software  
 NC: 138 NR: 100 NL: 1  
 Current Layer: 1

**Figure 10: Simulation 3 - Pathline travel times through gates**



**Time marker interval: 100 days**

TEST  
 Project: Alameda NAS  
 Description: Capture zones  
 Modeller: C.A.  
 10 Sep 96

Visual MODFLOW v.2.00 beta, (c) 1995  
 Waterloo Hydrogeologic Software  
 NC: 138 NR: 100 NL: 1  
 Current Layer: 1

**Figure 11: Simulation 3 - Close-up of gate capture zones**

## APPENDIX C

### DESIGN OF THE $Fe^0$ TREATMENT ZONE

## DESIGN OF THE Fe<sup>0</sup> TREATMENT ZONE

### DESIGN BASED ON FIRST-ORDER KINETIC MODEL

The following paragraphs describe how to determine the preliminary flow-through thickness of the Fe<sup>0</sup> treatment zone using chlorinated volatile organic carbon (CVOC) influent concentrations, degradation half lives from previous studies and inputting this data into a first-order kinetic model. A bench scale treatability study has been initiated at the University of Waterloo using Site 1 groundwater and if the results of the study suggest a different flow-through thickness for the Fe<sup>0</sup> treatment zone, the initial estimate of the flow through thickness will be modified accordingly.

To estimate the flow-through thickness required for the Fe<sup>0</sup> treatment zone to degrade the mixed organic plume, CVOC degradation rate data from previous field studies (Appendix 2) was used to estimate the residence time needed to treat the anticipated CVOCs in groundwater entering the system. Groundwater from BH2-1 and monitoring well MW-03, was used as influent concentrations in the calculations. Data from BH2-1 might be considered a high local value, while data from MW-03 may represent a vertically averaged aquifer concentration. Table 1 is a list the data used for this first-order kinetic model.

Trans-1,2DCE and 1,1DCE will degrade in the time taken for c12DCE to degrade, and therefore are omitted from this table.

Also listed in the above table are assumed field degradation rates, shown in terms of half-lives (the time taken to reduce the concentration by 50%). These influent concentrations and degradation rates were input into a first-order kinetic model incorporating concurrent production and degradation of the various organics present (i.e., VC from cDCE and TCE) to calculate the cumulative residence time required for degradation of all

Table 1 - Influent Concentration Data, Federal MCLs  
and Assumed Compound Half-Lives

CVOC	Concentration BH2-1 (µg/l)	Concentration MW-03 (µg/l)	Federal MCL (µg/l)	Assumed Half-Life (hr)
TCE	29.3	7.6	5	2
c12DCE	72838.9	22380.6	70	6
VC	6766.7	4792.5	2	6

compounds to their MCLs. The result of the model is shown graphically in Figures 1 and 2 for BH2-1 and MW-03 data, respectively. As shown therein, a residence time of 103 hours (4.3 d) is estimated using data from BH2-1, and 92 hours (3.8 d) using data from MW-03.

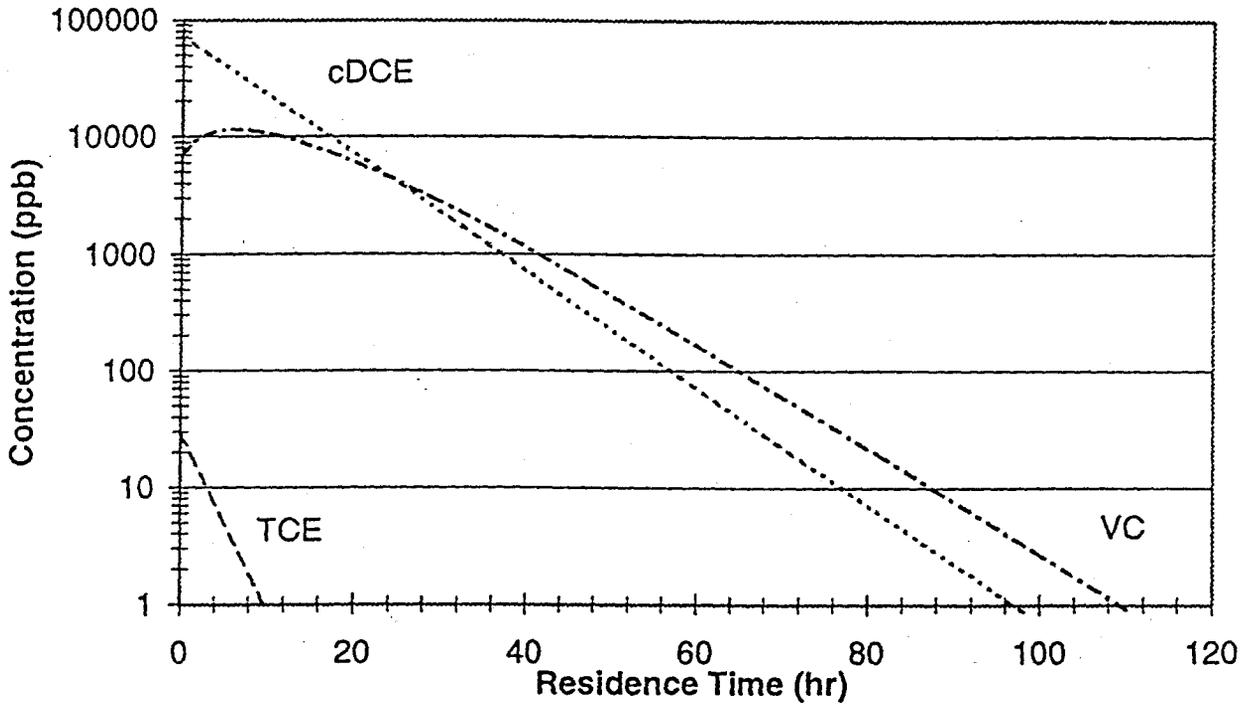


Figure 1: Graphical representation of the required residence time for complete degradation using data from BH2-1.

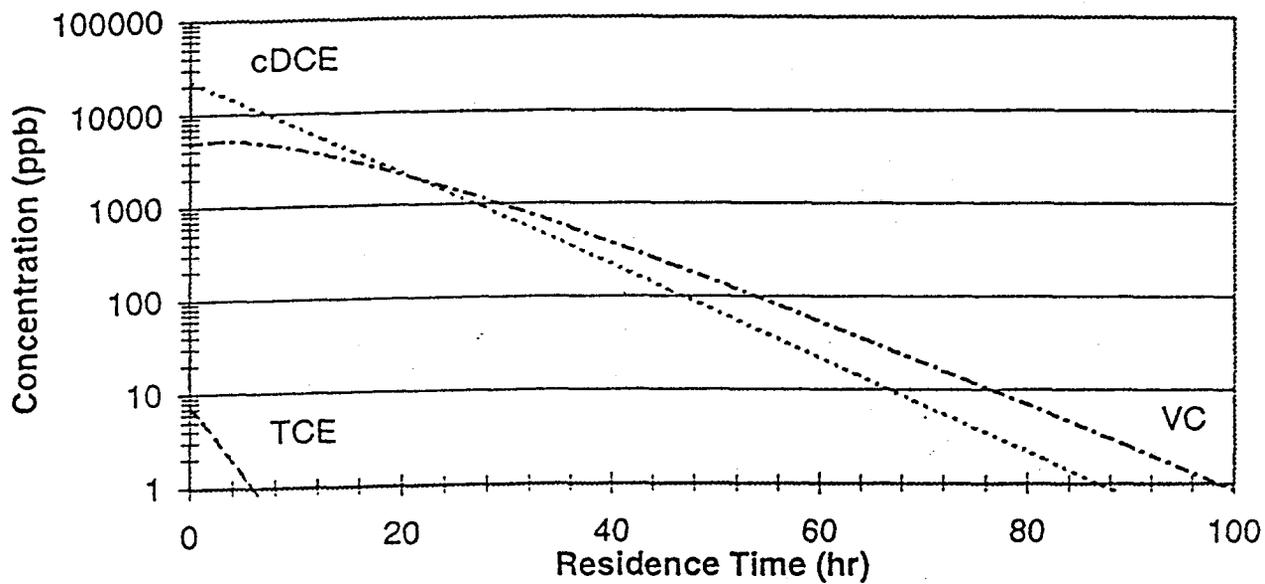


Figure 2: Graphical representation of the required residence time for complete degradation using data from MW-03.

## **DESIGN BASED ON A BENCH SCALE COLUMN STUDY**

The following details the scope of work for the bench-scale evaluation of the zero-valent metal enhanced dechlorination to treat dissolved CVOCs present in groundwater at Site 1, Naval Air Station Alameda. The main goal of this bench scale study is to quantify cDCE and VC degradation rates so the dimensions of the flow-through thickness of the iron treatment zone presented in the preliminary design can be modified.

The remainder of this section describes the objectives and scope of the column test, test methodology and means of interpreting column test data.

### Scope of Work and Objectives

#### **Bench Scale Study Objectives**

As stated above the general objective of the Bench Scale Study is to examine CVOC degradation rates which will be used in the design of the field treatment gate. Samples collected during laboratory column tests will be used to evaluate the following list of specific objectives

1. degradation rate constants for trichloroethene (TCE), cis and trans isomers of 1,2-dichloroethene (DCE), and VC in influent site groundwater
2. how much VC will be produced from DCE degradation, and how this affects the residence time needed in the treatment zone.

### Experimental Design

Groundwater obtained from well MW-03 will be pumped at a rate of about 1 to 2 pore volumes/day into a column containing granular iron. This flow rate will allow the test to be completed in about 1 month's time, so that the data can be incorporated into the ongoing design effort. The concentration of CVOCs in groundwater will be monitored along the length of each column and the study continued until a steady-state concentration profile develops in each column (i.e., the concentrations at a point along the column remain stable over time).

### Study Methods

This section describes the methods to be used to conduct the study and present and interpret the data from this study. Analytical and QA/QC procedures are summarized herein and are presented in more detail in Appendix J. The study will be conducted by the Institute for Groundwater Research, University of Waterloo (U of W) with input from ETI on test design and interpretation of the test results. The laboratory's Health and Safety Plan is contained in Appendix F.

### Groundwater Shipment and Storage

Groundwater from the site will be shipped to U of W for use in the study in 4L amber bottles with no headspace.

### Column Equipment and Materials

All equipment has been set up and is maintained in strict accordance with manufacturer's specifications.

The 100 cm long, 3.8 cm inside diameter (ID) plexiglass columns used in this study is equipped with several sampling ports along the length of the column, as well as the influent and effluent. The sampling port consists of a nylon Swagelok fitting (0.16 cm) tapped into the column side, with a sterilized syringe needle (0.12 cm outside diameter (OD) x 0.17 cm ID x 3.8 cm long) placed inside. To prevent column packing materials from entering the needle, glass wool will be placed in the barrel. This sampling port allows the sample to be collected from the midpoint of the column. Each syringe needle is fitted with a Luer-Lok fitting, to which a syringe may be attached to collect a sample. The sampling ports are sealed by a Luer-Lok plug which is twisted snugly into the syringe needle between sampling events.

The commercial iron used will be obtained from Peerless Metal Powders and Abrasive (PL). The PL iron has been used in several treatability tests and field applications and also was used in the phase 1 Borden experiment. It is therefore most suitable for use in these tests.

To fill the column with reactive material, aliquots of material are packed vertically in lift sections within the column. The column is packed to assure a homogeneous mixture. Each aliquot is tamped down with a flat metal rod. Care is taken to avoid layering, by roughing up the top of each layer before applying the next layer. All measurements are determined gravimetrically. Average bulk densities, porosity, and pore volume measurements are determined by weight. All column experiments are performed at room temperature.

A collapsible Teflon<sup>®</sup> bag feeds a source solution containing the organic compounds of interest (in this case, groundwater from the Site) into the bottom influent end of the column via a laboratory Ismatec IPN pump at a constant flow velocity. The Teflon<sup>®</sup> bag is filled by gravity, leaving no headspace. The pump tubing consists of Viton<sup>®</sup> tubing, and all the other tubing is Teflon<sup>®</sup> (1/8-inch O.D. x 1/16-inch I.D.).

### Data Collection (Sampling Protocols)

As discussed previously, the column is sampled over time until a steady-state profile is achieved at a given velocity. After removing a flush volume from the sampling port needle, 2.0 mL to 3.0 mL samples are collected for analyses for CVOCs from each port. Groundwater samples are also collected from the influent and from the effluent overflow

bottle.

PCE, TCE, DCE isomers and VC concentrations will be monitored at the inlet, outlet, and sampling ports of each column to determine when steady state has been reached. These profiles will likely be collected every 5 to 10 pore volumes. Periodic Eh and pH profiles will also be collected during this time. Flow rates are measured initially using a graduated cylinder and stopwatch; then volumetric flow measurements are made concurrently with each profile.

We will also collect and analyse the column influent and a minimum of two effluent (outlet) samples from the column for additional major cations ( $\text{Ca}^{+2}$ ,  $\text{Mg}^{+2}$ ,  $\text{Na}^+$ ,  $\text{Fe}$ ,  $\text{Mn}^{2+}$ ,  $\text{K}^+$ ), major anions ( $\text{SO}_4^{-2}$ ,  $\text{Cl}^-$ ,  $\text{NO}_3^-$ ,  $\text{NO}_2^-$ ) and alkalinity ( $\text{HCO}_3^-$ ) at each flow rate.

### Analytical Protocols

The analytical protocols employed by the University of Waterloo's Organic Geochemistry lab and Inorganic Geochemistry lab for organic and inorganic analyses respectfully are described in detail in Appendix H. In summary, the following methods will be used:

- select CVOCs will be analysed using micro-extraction techniques (a modification of the method of Henderson et al., 1976) and gas chromatography using an election capture detector or using headspace analysis techniques and gas chromatography using a photoionization detector;
- pH and Eh using reference electrodes;
- dissolved cations using inductively coupled plasma methods;
- anions using ion chromatography or colorimetry; and
- alkalinity using a titration method.

QA/QC procedures are described in detail in Appendix K. Method detection limits for organic and inorganic compounds are shown in Tables 2 and 3 respectively.

### Column Data Presentation and Interpretation

For each test column at each velocity, CVOC concentration will be plotted as a function of distance along the column after steady-state conditions have been achieved. The flow rate will be used to calculate the residence time at each sampling position for each profile. The results of the column tests are plotted as concentration of the CVOCs in  $\mu\text{g/L}$  versus time in hours. Graphs will be prepared illustrating these results. Degradation rate constants will be calculated for each organic compound originally present in the groundwater, using the first-order kinetic model:

$$C = C_0 e^{-kt}$$

(1)

where: C = CVOC concentration in solution at time t,  
C<sub>o</sub> = initial CVOC concentration of the influent solution,  
k = first order rate constant, and  
t = time.

By rearranging and taking the natural log, equation (1) becomes:

$$\ln (C/C_o) = -kt \quad (2)$$

The time at which the initial concentration declines by one-half, (C/C<sub>o</sub> = 0.5), is the half-life, which, by rearranging equation (2), is given by:

$$t_{1/2} = 0.693 / k \quad (3)$$

The decay constants k [ 1/time ], will be computed from the slope of the first-order model, obtained by fitting equation (2) to the experimental data. Half-lives, along with corresponding correlation coefficients (r<sup>2</sup>) values are provided. The r<sup>2</sup> values indicate how well the first-order model fits to the experimental data.

A similar approach will be used for quantifying the observed degradation of any chlorinated breakdown product. The peak concentration of the breakdown product will be used as C<sub>o</sub> in these calculations.

Plots of Eh, pH and concentrations of degradation products versus column distance (residence time) will be made for each test.

Inorganic chemical results from the column tests will be reviewed and interpreted to evaluate the possible extent of mineral precipitates on field-scale technology application. Changes in dissolved calcium, iron, and alkalinity between column influent and effluent samples are of particular interest when examining the potential for carbonate and/or hydroxide mineral precipitation. Samples of the iron will be taken from the column and studied for formation of any precipitates.

### Reporting

A report will be prepared after the column tests have concluded to address the objectives of these studies as outlined in this work plan. The report will contain the following topics:

- any deviations from this work plan and their rationale will be described;
- test design, test procedures, and sampling and analytical protocols will be summarized;

- CVOC degradation rates from the column will be tabulated. The production and subsequent degradation of chlorinated products will also be quantitatively discussed. The potential effect of changing concentrations (i.e. the possible range of variability in field influent concentrations) and field groundwater temperature on these rate constants will be discussed;
- recommended modifications to the design of the iron zone ( i.e. the flow through thickness) which are required based as these results will be presented

**TABLE 2: METHOD DETECTION LIMITS - ORGANIC COMPOUNDS**

Compound	MDL ( $\mu\text{g/L}$ )
Tetrachloroethene (PCE)	2.2
Trichloroethene (TCE)	1.7
1,1-Dichloroethene (11DCE)	1.2
cis-1,2-Dichloroethene (cDCE)	9.7
trans-1,2-Dichloroethene (tDCE)	4.0
Vinyl Chloride (VC)	2.6

**TABLE 3: DETECTION LIMITS (DL) - INORGANIC COMPOUNDS**

<u>Inorganic Compounds</u>	<u>DL (mg/L)</u>
<b>Cations</b>	
Iron (Fe <sup>0</sup> )	0.02
Sodium (Na)	0.1
Magnesium (Mg)	0.1
Calcium (Ca)	0.1
Potassium (K)	0.1
Manganese (Mn)	0.1
Nickel (Ni)	0.1
Chromium (Cr)	0.005
Cadmium (Cd)	0.003
Zinc (Zn)	0.005
Lead (Pb)	0.02
<b>Anions</b>	
Chloride (Cl)	1.0
Sulphate (SO <sub>4</sub> )	2.0
Nitrate (NO <sub>3</sub> )	0.05
Nitrite (NO <sub>2</sub> )	0.05
Ammonium (NH <sub>4</sub> )	0.05
Alkalinity (as HCO <sub>3</sub> )	1.0



enviro**metal**  
technologies  
inc.

15 November 1996

University of Waterloo  
Waterloo, Ontario  
N2L 3G1

Attention: Dr. Jim Barker

Dear Jim:

**Reference: 31173.10 - Column Testing of the EnviroMetal Process Using  
Groundwater From Naval Air Station Alameda**

Please find attached as Appendix A the laboratory test report describing the column tests of groundwater from the Naval Air Station Alameda facility for your review and comment. A summary of the results and a brief discussion of their implications with respect to the design of the in-situ iron zone to be installed at the site is presented below.

## **1.0 OBJECTIVE**

The main objective of these column studies was to determine VOC degradation rates in order to refine the design for an in-situ treatment zone which was presented in our correspondence of 6 September 1996. These rates, coupled with anticipated flow velocities, are used to determine the dimensions of the iron zone needed for degradation of these compounds to research objectives.

## **1.2 Test Methodology**

Groundwater from monitoring well MW-3 was pumped through a column containing 100% Peerless iron at a flow velocity of 7.3 feet/day. This velocity was selected primarily to meet the scheduling requirements of the project. A schematic of the column is shown in Figure 1 of the laboratory report. Groundwater from MW-3 as received contained about 32 ppm mg/L cis-1,2-dichloroethene (cDCE) and 25 mg/L vinyl chloride (VC). These levels, while within the range of concentrations reported on-site, were higher than recent concentrations measured in well MW-3. Lower levels (10's of ppb) of tetrachloroethene (PCE), trichloroethene (TCE) and the

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other DCE isomers were also detected.

Concentration of VOCs were monitored along the length of the column until concentrations at each point in the column became relatively stable over time (i.e., the column reached "steady-state" conditions). The flow rate was then used to calculate the residence time of groundwater relative to the influent end of the column at each sample point, converting the distance profile to a time profile. These VOC concentration vs time profiles were then used to calculate degradation rates for each compound using a first-order kinetic model. Inorganic parameters were monitored in column influent and effluent to gauge the potential for mineral precipitation.

## **2.0 RESULTS**

### **2.1 VOC Degradation**

The observed VOC degradation in the column test may be summarized as follows:

- i) Influent cDCE degraded at measured half-lives (the time taken to reduce the concentration by 50%) of 12.1 hrs at steady-state conditions. This half-life is somewhat longer than those observed in other tests with this compound.
- ii) VC degraded at a similar rate, at a half-life of 11.2 hrs. Some VC was produced as a result of cDCE degradation, causing the concentrations vs distance curves to have poor  $r^2$  (goodness of fit) values. This production is taken into account when calculating the residence time required in treatment zones, as described below.
- iii) The other minor VOCs present also degraded rapidly.

To calculate the possible residence times required in the iron gate sections, we used a recently developed mathematical model describing VOC degradation. The model calculates the time needed for these assumed influent concentrations to reach specified criteria. In this model, potential breakdown products are concurrently produced and degraded. This residence time calculation is shown conceptually in Figure 1. Using the first order rate equations presented below, the model equates change of concentration of a given compound to its loss via degradation and its formation from a more chlorinated parent compound.

In the following equation, B = concentration of the first breakdown product,  $k_2$  = degradation rate constant for B, A = concentration of the next more chlorinated "parent" compound (e.g. TCE relative to cDCE),  $k_1$  = degradation rate constant for this compound, f = fraction of more

chlorinated compound (A) going to the breakdown product (B). Subscript 0 = initial condition.

$$dA/dt = k_1 A \quad (1)$$

$$dB/dt = k_2 B + fk_1 A \quad (2)$$

Solving the Equation 1 gives the standard first order expression:

$$A = A_0 e^{-k_1 t} \quad (3)$$

Substituting Equation 3 into Equation 2 yields:

$$dB/dt = k_2 B + fk_1 A_0 e^{-k_1 t} \quad (4)$$

Equation 4 can be integrated using the integrating factor  $e^{k_2 t}$  and the initial condition  $B = B_0$  at  $t = 0$  to give:

$$B = fk_1 A_0 [e^{-k_1 t} / (k_2 - k_1) + e^{-k_2 t} / (k_1 - k_2)] + A_0 e^{-k_2 t} \quad (5)$$

As noted above, 'B' in this case represents cDCE production from TCE. A similar equation was developed to represent the concentration of vinyl chloride at a given time t. These equations were solved using the initial concentrations given above and laboratory rate constants. In these simulations, 50% conversion of TCE to cDCE and of cDCE to VC was assumed.

Recall that the major controls on treatment zone dimensions (the flow-through thickness of iron zone) are the influent concentrations and degradation rates of cis-1,2-dichloroethene (cDCE) and vinyl chloride (VC) present in groundwater entering the system. A residence time requirement of 4 days was estimated in previous correspondence, based on concentrations reported to that time from well MW-03 (near the proposed installation), and previously measured half-lives.

The following table shows the concentrations and half-lives measured for these VOCs in the bench scale study relative to those previously assumed:

VOC	Concentration Used Previously in Design (µg/L)	Measured Concentration in Laboratory (µg/L)	Half-Life Used Previously in Design (hr)	Measured Half-Life (hr)
TCE	29.3	10	2	1.5
cDCE	22380	32154	6	12.1
VC	4792	25625	6	11.2

These increased half-lives cause the estimated required residence time in the iron zone to increase from about 4 days to between 7 and 8 days. This "new" residence time was calculated using the above concentrations and revised effluent criteria of 5 µg/L, 10 µg/L, and 0.5 µg/L for TCE, cDCE and VC respectively.

Our review of the workplan for this study suggests that the predicted velocity through the iron zone of the funnel and gate system will be about 0.2 ft/day in the unpumped situation (Section 3.2 of the workplan). According to the workplan this represents a flux of about 12.2 ft<sup>3</sup>/day through the system. It is our understanding that the maximum pumping rate to be used during the trial is designed to create a velocity of about 3 times background, or about 0.6 ft/day through the iron zone. At 0.2 ft/day, a flow through thickness of 1.6 ft would provide an 8 day residence time. A flow through thickness of 4.8 ft would be required to create an 8 day residence time if a velocity of 0.6 ft/day occurred in the system. If a "safety factor" of 1.25 is applied to the maximum estimated value, a flow through thickness of 6.0 ft results.

Given the uncertainties involved in these estimates, a flow through thickness of 5 to 6 ft will probably promote degradation of the VOCs to the research objectives during most of the test. This thickness could probably be finalized based on consideration of constructability and cost issues.

## 2.2 Inorganic Results

A significant portion of the carbonate alkalinity (about 3.5 mmol/L) present in the groundwater was removed as groundwater moved through the column, as well as about 2.5 to 3 mmol/L calcium. No increase in effluent iron concentrations was observed, even though several mmol of dissolved iron is introduced into solution from corrosion of the iron metal. These results

indicate that calcite ( $\text{CaCO}_3$ ) and siderite ( $\text{FeCO}_3$ ) precipitated in the reactive media. Calcite forms as the buffering capacity of the groundwater responds to the influx of  $\text{OH}^-$  ions into solution (i.e. the increase in pH) caused by iron corrosion. Bicarbonate ions are converted to carbonate ions, which subsequently combine with dissolved calcium ions. Some of the  $\text{Fe}^{2+}$  ions produced from iron corrosion also combine with the carbonate ions in solution forming siderite. It is likely some iron hydroxides ( $\text{Fe}(\text{OH})_2$ ) were also formed in the material.

These inorganic data are entirely consistent with other studies. The extrapolation of these data to *in-situ* conditions is somewhat tenuous (the water is supersaturated with respect to calcite prior to entering the columns, which would not occur to the same extent *in-situ*). The reliability of the column data to gauge the potential effect of precipitates on system performance is dependent on the location of precipitation sites *in-situ*, as well as the extent and kinetics of precipitation under field conditions. From the interior calcium and alkalinity profiles collected during other column tests, and from data in other above-ground field trials, it appears that most of this carbonate precipitation would occur in the upgradient section of an *in-situ* reactive wall. It is also likely that carbonate and iron hydroxide precipitation will not occur concurrently, under flowing conditions. That is, significant hydroxide precipitation will not occur until the carbonate buffering capacity is exhausted. In other studies decreases in calcium and alkalinity are accompanied by large increases in dissolved iron concentrations in the "upstream" portion of the reactive media. Iron concentrations then drop in the downgradient portions.

It is our understanding that the monitoring program will document the location and extent of precipitation under field conditions in the treatment gates. These data will be useful in gauging the potential need for periodic rejuvenation of the material to ameliorate porosity losses.

### 3.0 SUMMARY

Results from the column test are generally consistent with other studies. Longer half-lives for cDCE and VC will indicate a longer flow-through thickness of iron treatment zone should be incorporated into the field-scale design.

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Dr. Jim Barker  
University of Waterloo

Page 6

Reference: 31173.10  
15 November 1996

If you have any questions regarding this report, please call me.

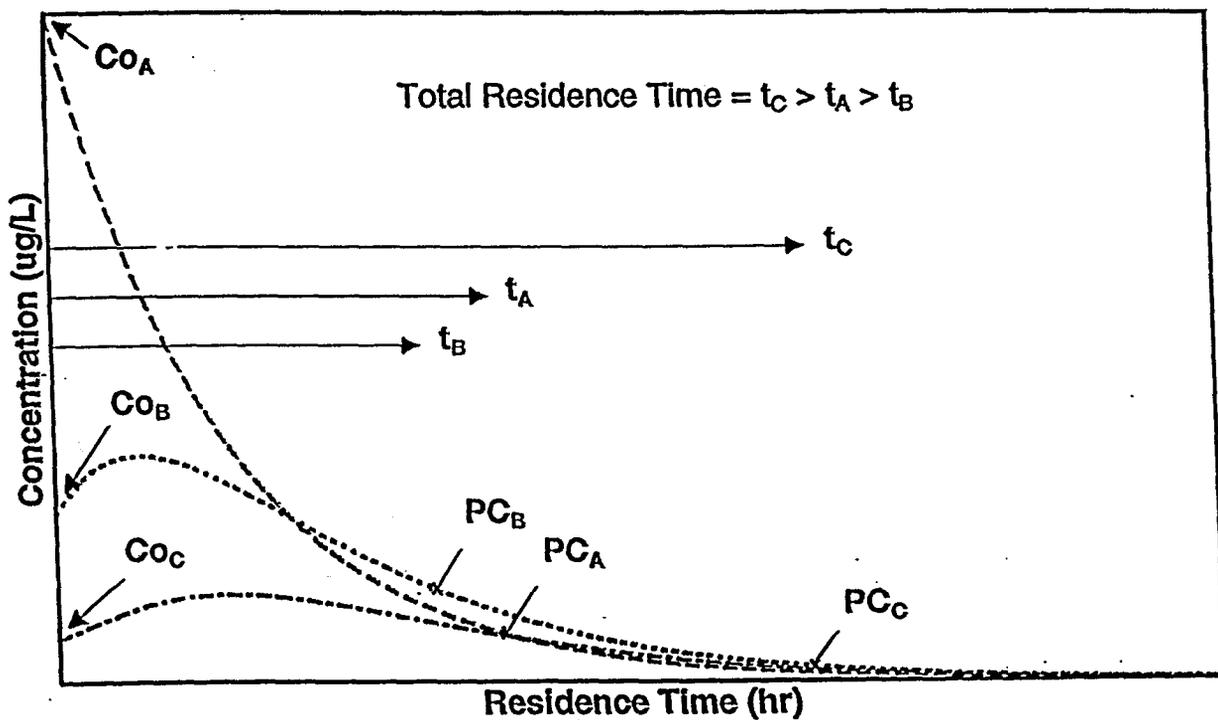
Sincerely,

ENVIROMETAL TECHNOLOGIES INC.



John Vogan, M.Sc.  
Manager

JV/cf  
eti31173-10.rpt



- $Co$  - Initial Concentration
- $PC$  - Performance Criteria
- $t$  - Residence Time

Figure 1: Illustration of residence time calculations using a first-order kinetic model assuming concurrent and sequential degradation

**APPENDIX A**  
**Laboratory Test Report**



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## **Bench Scale Study on Ground Water from the Site 1, Alameda Naval Air Station, California**

### **Prepared For:**

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**24 October 1996**



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## Bench Scale Study

### **1.0 Introduction**

A laboratory column test was conducted using the EnviroMetal Process (Gillham, 1996; Gillham and O'Hannesin, 1992, 1994) to determine the rates of degradation of the chlorinated organic compounds that are present in ground water from Site 1, Alameda Naval Air Station, California.

The objectives of the column test were to determine if the organic compounds would degrade under conditions of flow through the reactive material, and to obtain parameters that would ultimately assist in the design of a field treatment system (Focht et al., 1996).

### **2.0 Laboratory Column Methods**

Water was collected by Einarson Fowler & Watson, from the Alameda Naval Air Station, and sent to the Institute for Groundwater Research, University of Waterloo. Water was collected from the field monitoring well, identification number MW-3, which was considered by both the University of Waterloo and Einarson Fowler & Watson to be representative of site conditions and suitable for use in the column test.

One reactive column experiment was set up, which contained 100% granular iron by weight. The mass of iron to volume of solution ratio, along with other column parameters are shown in Table 1.

The granular iron used in these tests was obtained from Peerless (PL) Metal Powders and Abrasives, Detroit, Michigan (-8 to +50 US Standard Sieve Mesh #). The grain size of the iron ranged in diameter from 0.25 to 2.0 mm. The specific surface area was 0.7 m<sup>2</sup>/g, determined by the BET method (Brunauer et. al., 1938) and the particle density was 6.98 g/cm<sup>3</sup>, determined by the pycnometer method (ASA, 1986).

The column was constructed of Plexiglass™ with a length of 3.3 ft (100 cm) and an internal diameter of 1.5 in (3.8 cm). Seven sampling ports were positioned along the length of each column at distances of 0.16, 0.33, 0.66, 1.0, 1.3, 2.0 and 2.6 ft (5, 10, 20, 30, 40, 60 and 80 cm) from the inlet end (Figure 1). The column also allowed for collection of samples from the influent and effluent solutions. Each sampling port consisted of a nylon Swagelok® fitting (0.06 cm) tapped into the side of the column, with a syringe needle (16G) secured by the fitting. Glass wool was placed in the needle to prevent the entry of solid material. The needles were positioned such that water samples were obtained along the central axis of the column. Each sampling port was fitted with a Luer-Lok™ fitting, such that a glass syringe could be attached to the port to collect a sample. When not in operation the ports were sealed by Luer-Lok™ plugs.

The column was carefully packed insuring that the iron would be homogeneously distributed. Aliquots of iron were packed in lifts, taking care to avoid layering by roughening the surface of the preceding layer before adding the next layer. All measurements were determined gravimetrically. As shown in Table 1, the pore volume measurement was determined experimentally by weight, giving a value of 574 mL, with a porosity of 0.50. The column was initially flushed with carbon dioxide to avoid air entrapment during wetting. Several pore volumes of distilled water were flushed through the column before the site water was introduced. The column experiment was performed at room temperature ( $\approx 23^{\circ}\text{C}$ ).

An Ismatec™ IPN pump was used to feed the site water from a collapsible Teflon® bag to the bottom influent end of the column. The pump tubing was Viton®; all other tubing was Teflon® (0.13 in x 0.06 in). The column was sampled periodically over time and at steady state. After removing stagnant water from a sampling needle, 2.0 to 3.0 mL samples were collected from the sampling ports using glass on glass syringes and transferred to glass sample bottles and analysed immediately (no holding time). Samples for organic analyses and for redox potential (Eh) and pH measurements were collected from each port. Samples for inorganic and organic analyses, as well as for Eh and pH measurements were obtained from both the influent solution and the effluent overflow bottles.

A flow velocity of 7.3 ft/day (222 cm/day) was used in this study.

### **3.0 Analytical Procedures**

#### **3.1 Organic Analyses**

The analyses were performed on two types of gas chromatographs. For the more volatile compounds such as cis 1,2-dichloroethene (cDCE), trans 1,2-dichloroethene (tDCE), 1,1-dichloroethene (11DCE) and vinyl chloride (VC), 2.5 mL samples were collected in glass on glass syringes and placed in 5.0 mL glass sample bottles, allowing for a 2.5 mL headspace. The samples were placed on a rotary shaker for 15 minutes to allow equilibration between the water and gas phases. For analysis, a 500  $\mu$ L gas sample was injected directly onto a Hewlett Packard 5890 Series II gas chromatograph. The chromatograph was equipped with a HNU photoionization detector (PID) with a bulb ionization potential of 10.2 eV. The gas chromatograph was fitted with a fused silica capillary NSW-PLOT column (15 m x 0.53 mm ID). An isothermal oven temperature of 160°C and a detector temperature of 120°C were used. The carrier gas was helium with a flow rate of 4.1 mL/min.

For the less volatile halogenated organics such as tetrachloroethene (PCE) and trichloroethene (TCE) were extracted from the water sample within the glass sample bottle using pentane with an internal standard of 1,2-dibromoethane, at a water to pentane ratio of 2.0 to 2.0 mL. The samples were placed on a rotary shaker for 10 minutes to allow equilibration between the water and pentane phases. Using a Hewlett Packard 7673 auto sampler, a 1.0  $\mu$ L aliquot of pentane with internal standard was automatically injected directly onto a Hewlett Packard 5890 Series II gas chromatograph. The chromatograph was equipped with a Ni<sup>63</sup> electron capture detector (ECD) and DB-624 megabore capillary column (30 m x 0.538 mm ID, film thickness 3  $\mu$ m). The gas chromatograph had an initial temperature of 50°C, with a temperature time program of 5°C/minute reaching a final temperature of 105°C. The detector temperature was 300°C. The carrier gas was helium and makeup gas was 5% methane and 95% argon, with a flow rate of 30 mL/min.

Benzene, toluene, ethylbenzene and p,m,o-xylene (BTEX) were collected using glass on glass syringes and were extracted from the water using pentane with an internal standard of metafluorotoluene at a water to pentane ratio of 4.5 to 0.5. The samples were placed on a rotary shaker for 15 minutes to allow equilibration between the water phase and pentane phase. For analysis, a 6.0  $\mu$ L aliquot of pentane sample was injected directly onto a Shimadzu GC-9A gas chromatograph. The chromatograph was equipped with a flame ionization detector (FID) and a Supelcowax 10 fused silica capillary column ( 60 m x 0.32 mm ID) with a stationary phase of 0.5  $\mu$ m. The gas chromatograph had an column temperature of 115°C and the detector was set at 300°C.

Method detection limits were determined for each compound as the minimum concentration of a substance that can be identified, measured and reported with 99% confidence that the analyte concentration is greater than zero. The method detection limits were determined from analysis of samples from a solution matrix containing the analytes of interest. Detection limits for all compounds studied, as given in Table 2, were determined using the EPA procedure for Method Detection Limit (MDL) (US EPA, 1982).

### 3.2 Inorganic Analyses

Redox potential (Eh) was determined using a combination Ag/AgCl reference electrode with a platinum button and a Markson™ Model 90 meter. The electrode was standardized with ZoBell™. Millivolt readings were converted to Eh, using the electrode reading and the standard potential of the Ag/AgCl electrode at a given temperature. The pH measurements were made using a combination pH/reference electrode and a Markson™ Model 90 meter, standardized with the pH buffer 7 and the appropriate buffer of either 4 or 10. A 2.0 mL sample was collected with a glass on glass syringe and analysed immediately for Eh and then pH.

A total of four water samples were collected at over the test, two from the influent and two from the effluent of each column and sent to MDS Environmental Services Ltd, 6850 Goreway Drive, Mississauga, Ontario for cation and anion analyses. Cation analyses, included Fe (total), Na,

Mg, Ca, K, Mn and a suite of other cations. These analyses were performed using inductively coupled plasma (ICP). The unfiltered, 60 mL samples were acidified to a pH of 2 with nitric acid and stored at 4°C until analyzed. Anion analyses, including Cl and SO<sub>4</sub>, were performed on 60 mL unfiltered samples. Detection limits for the inorganic parameters are included in Table 2.

#### **4.0 Results and Discussion**

The main organic compounds detected in the site water were cis 1,2-dichloroethene (cDCE) and vinyl chloride (VC). Trace amounts of trichloroethene (TCE), tetrachloroethene (PCE), trans 1,2-dichloroethene (tDCE), 1,1-dichloroethene (11DCE) and benzene, toluene, ethylbenzene, p,m,o-xylene (BTEX) were also detected. Another compound was also detected, but was not identified during the study. The site water was siphoned from the 4 L amber bottles used for shipping into a collapsible 22 L Teflon® bag. As noted in Appendix A by reservoir number (RN), the collapsible bag was filled four times [a-d] over the course of the test.

#### **4.1 Organic Results**

Concentration profiles along the columns were measured at intervals of approximately 5-7 pore volumes. The results are listed in Appendix A. The results obtained when steady state conditions were reached are plotted as concentration (µg/L) versus distance along the column (ft). The profiles of most interest are the steady state concentration profiles. If the reaction is indeed first-order, then at steady state, an exponential decline in concentration along the column would be expected.

Steady state concentration profiles are shown for the 100% granular iron column in Figures 2-3. At a flow velocity of 7.3 ft/day (222 cm/day), a total of 62 pore volumes of water had passed through the column. In this case, one pore volume corresponds to a residence time of 10.9 hr. At 60 pore volumes, initial concentrations of 32154 and 25265 µg/L were measured for cDCE and VC, respectively. Figure 2A shows a decline in both the cDCE and VC concentration along

the column. The observed decline in concentration with distance reflects the rate at which the organic compounds are degrading within the iron. The cDCE showed minor fluctuations in concentration, however, an overall decline was observed with an effluent concentration of 16788  $\mu\text{g/L}$  at the 3.3 ft distance. A decline in the VC concentration to 8093  $\mu\text{g/L}$  was observed at the 2.0 ft distance, followed by a slight increase in concentration (11799  $\mu\text{g/L}$ ) towards the effluent end of the column. This trend appeared to be consistent (Appendix A) and was attributed to the dechlorination of the cDCE. Figure 2B shows the steady decline in the relative concentration ( $C/C_0$ ) observed for the unidentified compound with an effluent relative concentration of about 10% at the 3.3 ft distance. The decline in concentration along the column of the trace compounds detected in the site water are shown in Figure 3. Both TCE and PCE show steady declines from initial concentrations of 10 and 34  $\mu\text{g/L}$  to non-detectable concentrations at the 2.6 ft distance and for the remainder of the column profile. Trace amounts of 11DCE (55  $\mu\text{g/L}$ ) and tDCE (24  $\mu\text{g/L}$ ) were detected in the site water. The profiles for these compounds were somewhat variable, but showed an overall decline in concentration.

Once the columns achieved steady state, two sampling profiles were undertaken for BTEX. The influent BTEX concentration was somewhat variable for all compounds, as shown in Appendix A, however, no apparent degradation was observed.

Using the flow velocity, the distance along the column was converted to time and the degradation rate constants were calculated for the organic compounds using the first-order kinetic model:

$$C = C_0 e^{-kt} \quad (1)$$

where  $C$  is the organic concentration in solution at time  $t$ ,  $C_0$  is the initial concentration (organic concentration in the influent solution),  $k$  is the first order rate constant, and  $t$  is time. By rearranging and taking the natural log, equation 1 becomes:

$$\ln (C/C_0) = -kt \quad (2)$$

The time at which the initial concentration declines by one-half, ( $C/C_0 = 0.5$ ), is the half-life, which, by rearranging equation 1, is given by:

$$t_{1/2} = 0.693 / k \quad (3)$$

The decay constants,  $k$  [1/time], were computed from the slope of the first-order model, obtained by fitting equation 2 to a semi-log plot of the experimental data. Half lives and the corresponding coefficients of variation ( $r^2$ ) were calculated for steady state profiles which are listed in Table 3. The  $r^2$  values indicate the degree to which the first-order model represents the experimental data.

The first-order decay model provided only a reasonable fit to the cDCE data, with an  $r^2$  value of 0.84. The corresponding half life was 12.1 hrs (Table 3). Also the half life obtained for VC was 11.2 hr with a poor  $r^2$  value of 0.44. This poor fit was the result of the increase in the VC concentration from the dechlorination of cDCE. The half lives obtained for the unidentified compound, TCE and PCE were 2.8, 1.5 and 1.3 hr with  $r^2$  values  $>0.97$ . Half lives for 11DCE and tDCE were not obtained due the fluctuations in concentrations.

## 4.2 Inorganic Results

Table 4 shows the results of the inorganic analyses for duplicate samples from the influent and steady state effluent of the column. Appendix B includes all inorganic data, with the Eh and pH profiles in Appendix A.

There appeared to be very little change in the sodium (Na), magnesium (Mg) and potassium (K) concentrations with passage through the column. The effluent concentrations of manganese (Mn) and sulphate ( $SO_4$ ) were slight lower than the influent values. The total iron (Fe) decreased from 5 mg/L in the influent to a concentration range of 0.3 to 0.6 mg/L in the effluent. Silica (Si) decreased from 56 mg/L in the influent to 0.8 mg/L in the effluent and chloride (Cl) increased slightly from 223 to 233 mg/L in the effluent due to the dechlorination of the organic

compounds. Calcium (Ca) decreased by about 120 mg/L between the influent and effluent samples and the alkalinity decreased by about 210 mg/L. The Eh profiles showed reducing conditions, ranging from -50 to -350 mV (Figure 4A). The pH increased from values of 7.0 to 9.0 (Figure 4B).

## 5.0 Conclusions

All chlorinated compounds tested showed declines in concentration using the EnviroMetal Process. The less volatile compound, TCE, PCE and the unidentified compound, degraded steadily along the length of the column and followed the first order decay model. Rates of degradation of cDCE and VC were somewhat slower; however, significant declines in concentrations were observed.

Of the inorganic species that were examined, only calcium and alkalinity showed substantial changes. The concentration of calcium declined by 120 mg/L, while the alkalinity showed declines of about 210 mg/L. The decline in concentration of both calcium and alkalinity is strong evidence for the precipitation of calcium carbonate within the reactive material. Also the generally low values of total iron in the effluent suggest that iron carbonated (siderite,  $\text{FeCO}_3$ ) and ferric hydroxide [ $\text{Fe}(\text{OH})_2$ ] may also be precipitating.

## 6.0 References

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United States Environmental Protection Agency, 1982. Methods for organic chemical analysis of municipal and industrial wastewater; EPA-600/4-82-057, J.E. Longbottom and J.J. Lichtenberg (eds.); Cincinnati, Ohio; Appendix A.

**Table 1: Column properties**

	100% Iron
Flow Velocity (FV) ( ft/day ) ( cm/day )	7.3 222
Residence Time (hours)	10.9
Pore Volume ( mL )	574
Porosity	0.50
Hydraulic Conductivity ( cm/sec )	8.43E-02
Bulk Density ( g/cm <sup>3</sup> )	2.87
Iron to Volume of Solution Ratio ( g:mL )	5.7 : 1
Surface Area ( m <sup>2</sup> /g )	0.70
Surface Area to Volume of Solution Ratio (m <sup>2</sup> :mL)	4.0 : 1

Column test conducted: Sept 6, 1996 - Oct 4, 1996.

**Table 2: Method Detection Limits (MDL) and Detection Limits (DL)**

---

<b><u>Organic Compounds</u></b>	<b><u>MDL (µg/L)</u></b>
Tetrachloroethene (PCE)	1.0
Trichloroethene (TCE)	0.74
cis 1,2-Dichloroethene (cDCE)	9.7
trans 1,2-Dichloroethene (tDCE)	4.0
1,1-Dichloroethene (11DCE)	1.2
Vinyl Chloride (VC)	2.6
Benzene	2.8
Toluene	2.2
Ethylbenzene	3.5
p-Xylene	5.4
m-Xylene	2.2
o-Xylene	3.3
<b><u>Inorganic Compounds</u></b>	<b><u>DL (mg/L)</u></b>
Iron, total (Fe)	0.02
Sodium (Na)	0.10
Magnesium (Mg)	0.10
Calcium (Ca)	0.10
Potassium (K)	0.50
Manganese (Mn)	0.01
Silica (Si)	0.05
Zinc (Zn)	0.01
Chloride (Cl)	1.0
Sulphate (SO <sub>4</sub> )	2.0
Alkalinity (as HCO <sub>3</sub> )	7.0

---

**Table 3: Half lives generated from the reactive column test conducted using groundwater collected from the Alameda Naval Air Station. The coefficients of variation ( $r^2$ ) were determined by fitting the first-order decay equation to the experimental data.**

Compounds	100% Iron Flow Velocity = 7.3 ft/day		
	$C_o$	HL	$r^2$
	( $\mu\text{g/L}$ )	(hrs)	
cis 1,2-Dichloroethene (cDCE)	32154	12.1	0.840
Vinyl Chloride (VC)	25265	11.2	0.440
Unidentified Copound	NA	2.8	0.998
Trichloroethene (TCE)	10	1.5	0.971
Tetrachloroethene (PCE)	34	1.3	0.996

$C_o$  = Initial Concentration

HL = Half life

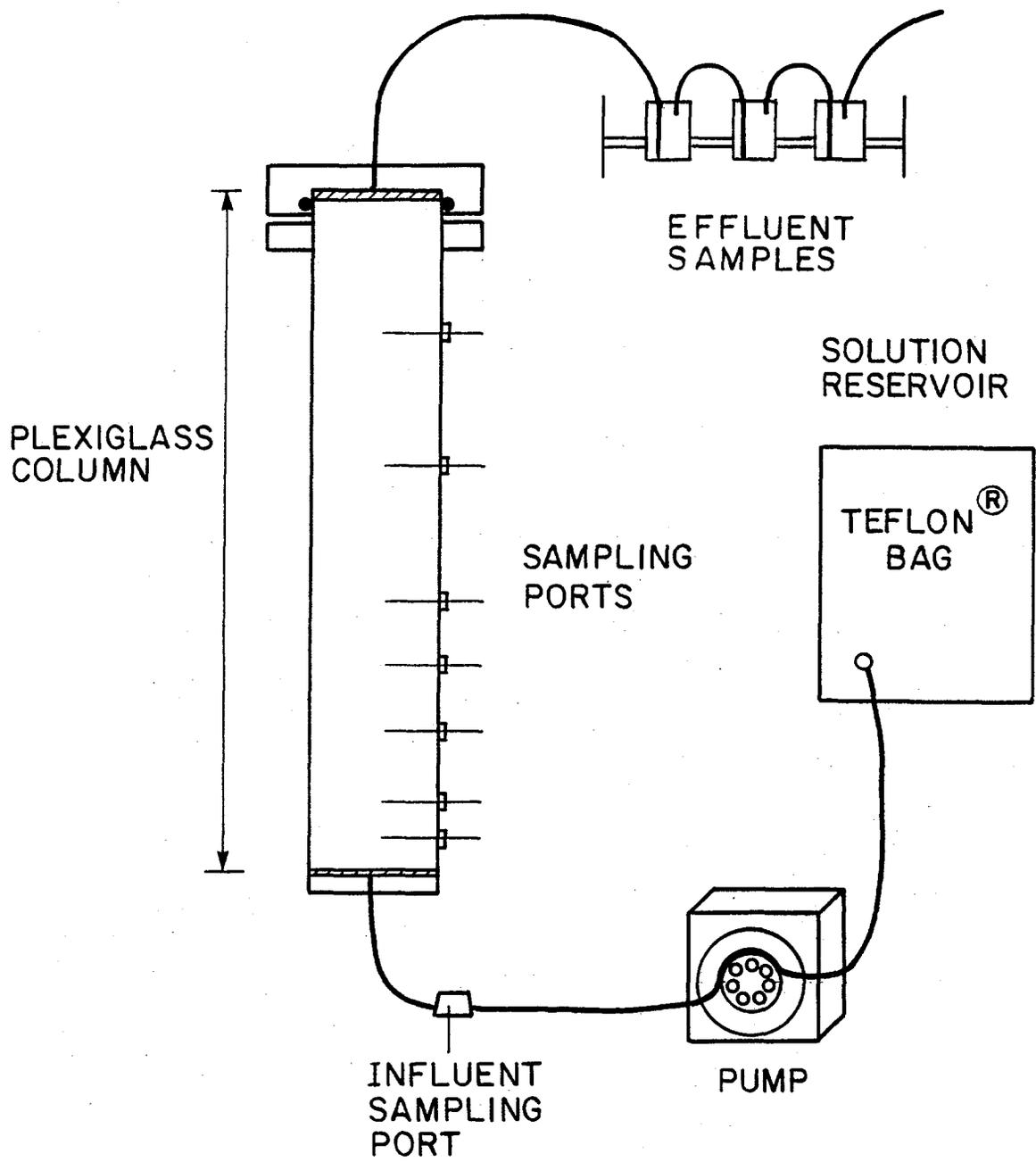
$r^2$  = Coefficient of Variation

NA = not applicable

**Table 4: Inorganic concentrations of the 100% iron column for both influent and effluent samples at steady state conditions.**

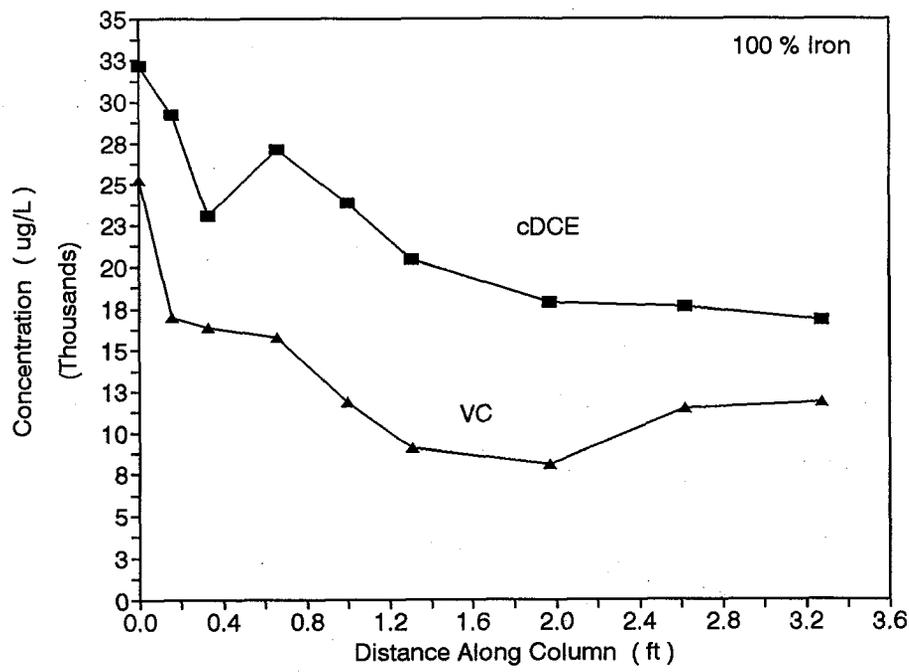
	Influent Concn	100% Iron Effluent Concn
	(mg/L)	(mg/L)
<b>Cations</b>		
Iron, total (Fe)	5.4	0.6
	2.1	0.3
Sodium (Na)	111	109
	110	108
Magnesium (Mg)	30	25
	29	25
Calcium (Ca)	142	18
	115	19
Potassium (K)	27	27
	26	25
Manganese (Mn)	1.8	0.4
	1.8	0.3
Silica (Si)	57	0.8
	56	0.8
Zinc (Zn)	0.02	nd
	nd	nd
<b>Anions</b>		
Chloride (Cl)	223	233
	224	237
Sulphate (SO <sub>4</sub> )	3	nd
	3	nd
Alkalinity (as HCO <sub>3</sub> )	371	156
	368	162

nd = not detected

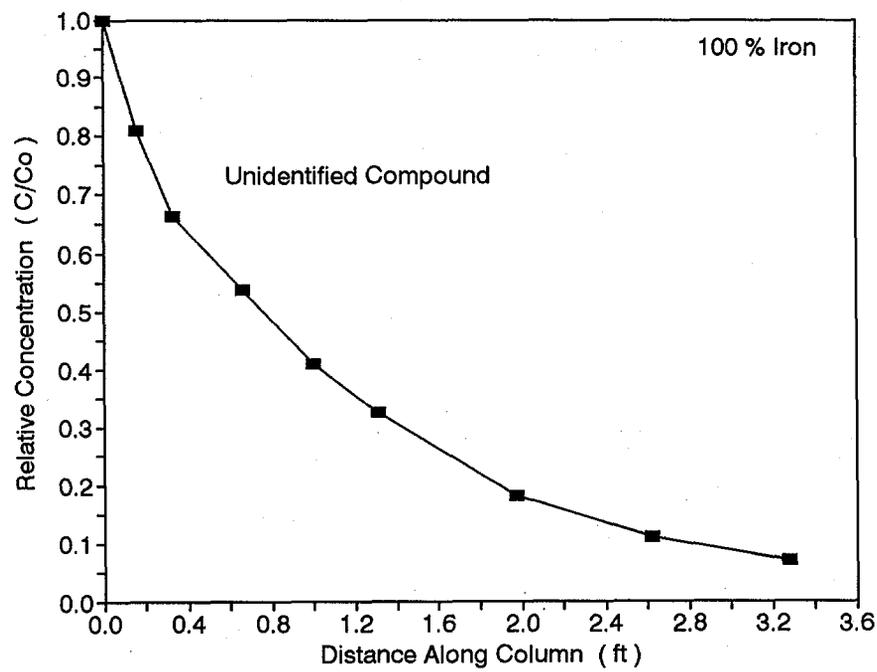


**Figure 1:** Schematic of the apparatus used in the column experiments.

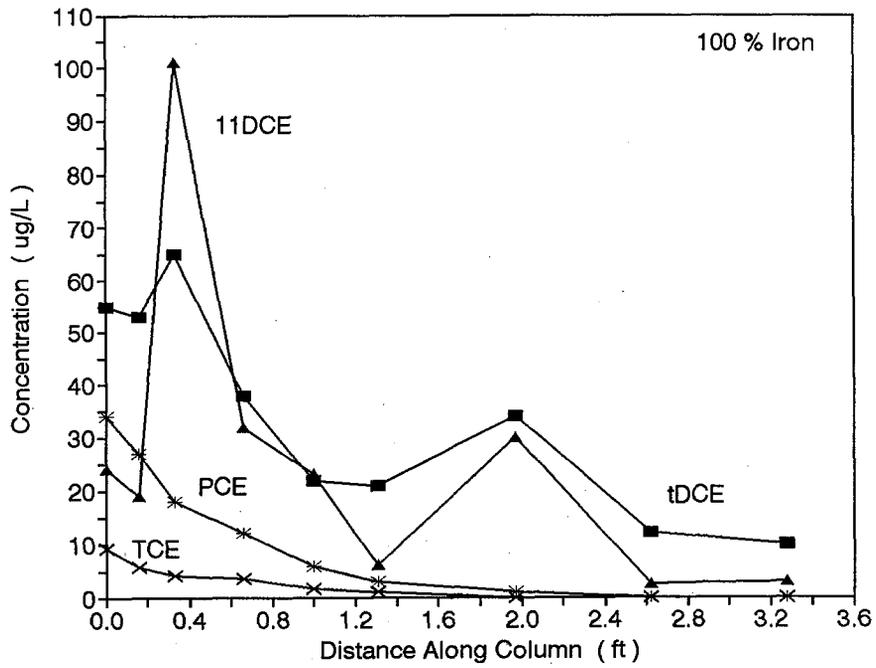
A)



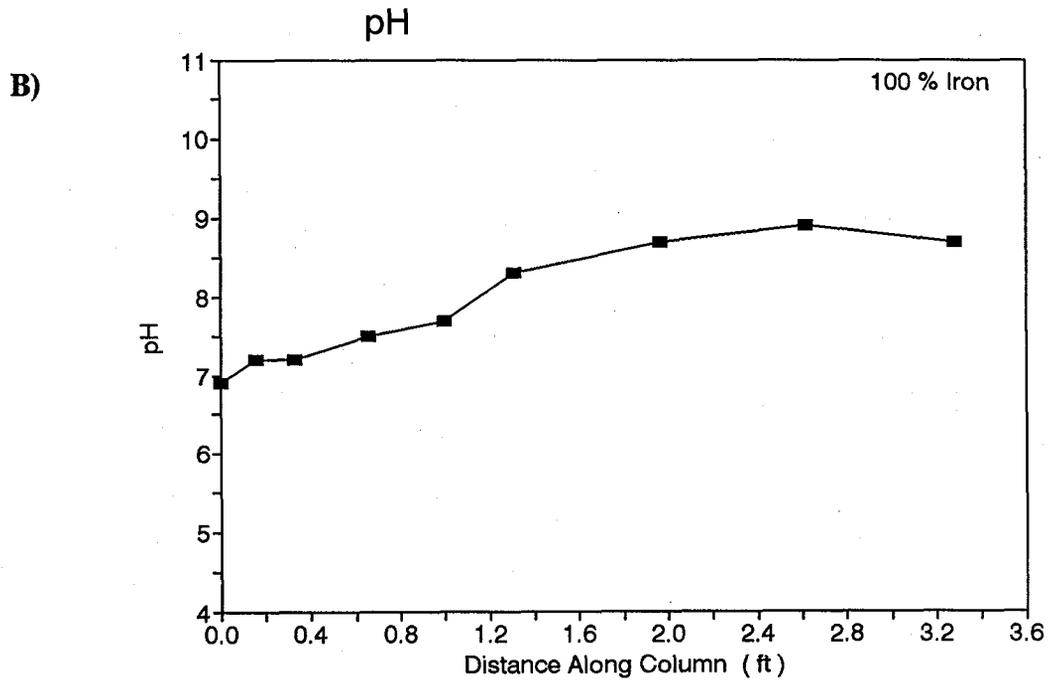
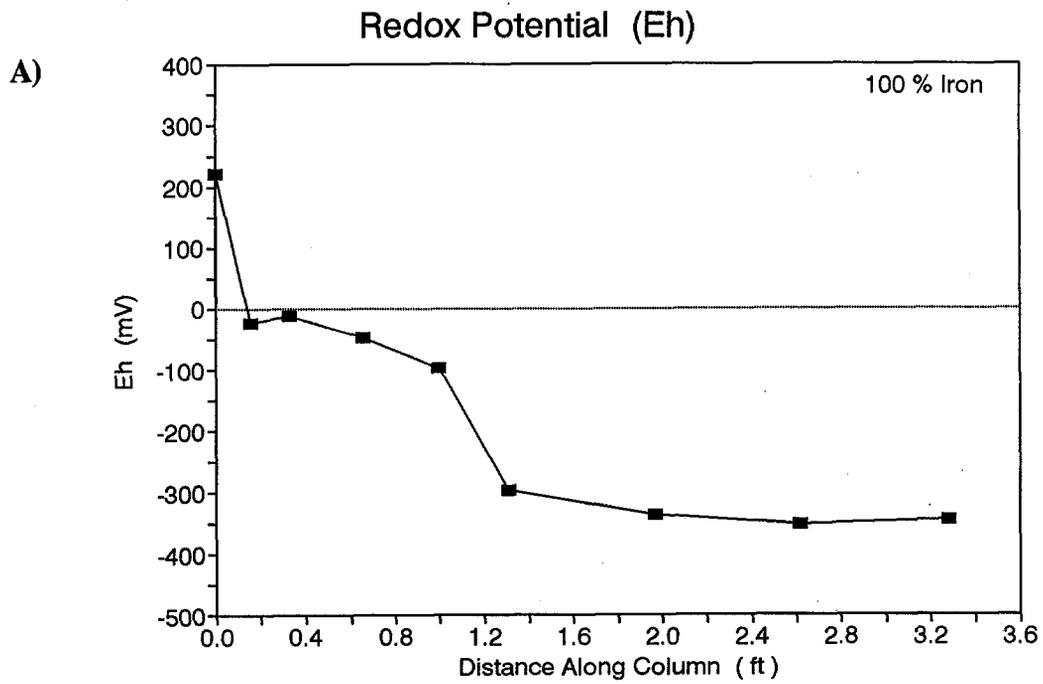
B)



**Figure 2:** 100% Granular Iron - Flow velocity = 7.3 ft/day  
Concentration ( $\mu\text{g/L}$ ) versus distance (ft) along the column.  
A) cDCE and VC B) Unidentified Compound



**Figure 3:** 100% Granular Iron - Flow velocity = 7.3 ft/day  
 Organic concentration ( $\mu\text{g/L}$ ) versus distance (ft) along the column.  
 For TCE, PCE, tDCE and 11DCE



**Figure 4:** A) Redox potential (Eh) vs distance along the column  
 B) pH vs distance along the column

**Appendix A**

**Organic Column Data**

REACTIVE COLUMN  
157

Column Composition: 100% Peerless Iron

Pore Volume (PV): 574  
Porosity: 0.5  
Flow Velocity : 222 cm/day (7.3 ft/day )  
Residence Time : 10.9 hr

Distance Along Column (ft)

0.00	0.16	0.33	0.66	1.0	1.3	2.0	2.6	3.3
------	------	------	------	-----	-----	-----	-----	-----

PV	RN	Influent	Organic Concentration ( ug/L )							Effluent	HL	r2
<b>cDCE</b>												
6.5	a	19257	21107	20483	16217	15086	12699	13612	10232	9419		
12.7	a	17455	13756	13530	13620	13643	12308	11714	6329	6431		
21.9	a	17061	5206	15746	15757	19742	15153	19019	9439	3031		
31.0	b	32266	26799	18651	24830	36791	<b>36379</b>	20617	18395	21314	8.7	0.532
37.8	b	17918	13673	15345	18576	15414	14364	13836	14239	12448	30.6	0.442
42.1	b	29341	13769	19287	16367	9326	7345	8121	7399	8571	6.9	0.591
46.3	b	30978	28827	28534	8246	7972	<b>18744</b>	10833	7778	7751	5.0	0.856
53.4	c	31154	29454	23054	27034	20568	22576	18854	18130	17212	13.6	0.807
55.6	d	32154	29228	23054	27102	23860	20436	17810	17574	16788	12.1	0.840
<b>VC</b>												
6.5	a	19776	20716	20324	15571	14392	12250	12437	8581	8196		
12.7	a	17154	10478	10294	10358	10344	9402	9138	4519	4541		
21.9	a	19945	14207	17912	16339	18337	14655	19823	10025	4803		
31.0	b	23907	22088	13334	17244	<b>25981</b>	19443	14822	12721	13151	7.9	0.818
37.8	b	18668	17715	<b>21473</b>	15930	17993	17604	16621	17225	16206	44.9	0.299
42.1	b	28041	19139	19027	18099	5743	9236	<b>10557</b>	7751	8438	13.3	0.493
46.3	b	26890	23548	28036	12970	6145	<b>17205</b>	14623	6146	7865	4.7	0.714
59.9	d	25265	16972	16376	15756	11799	9032	8093	11478	11799	11.2	0.444
<b>Unidentified Compound (Relative Concentration, C/Co)</b>												
53.4	c	1.000	0.775	0.485	0.727	0.369	0.301	0.151	0.114	0.074	2.9	0.955
55.6	d	1.000	0.471	0.544	0.350	0.254	0.183	0.106	0.066	0.044	2.6	0.966
62.2	d	1.000	0.810	0.664	0.538	0.409	0.326	0.181	0.110	0.070	2.8	0.998
<b>tDCE</b>												
6.5	a	38	NA	22	NA	nd	nd	nd	nd	nd		
12.7	a	23	nd	nd	nd	nd	nd	nd	nd	nd		
21.9	a	20	24	21	15	nd	nd	nd	3.3	nd		
31.0	b	51	48	45	55	46	46	30	7.8	14		
37.8	b	41	38	45	39	11	46	51	55	22		
42.1	b	49	41	24	3.2	22	27	6.2	6.0	4.4		
46.3	b	40	92	16	38	39	10	7.9	11	NA		
59.9	d	55	53	65	38	22	21	34	12	10		

REACTIVE COLUMN  
157

Column Composition: 100% Peerless Iron  
 Pore Volume (PV): 574  
 Porosity: 0.5  
 Flow Velocity : 222 cm/day (7.3 ft/day)  
 Residence Time : 10.9 hr

		Distance Along Column (ft)											
		0.00	0.16	0.33	0.66	1.0	1.3	2.0	2.6	3.3			
PV	RN	Influent	Organic Concentration (ug/L)								Effluent	HL	r2
<b>11DCE</b>													
6.5	a	18	22	NA	20	nd	nd	nd	nd	nd			
12.7	a	nd	nd	nd	nd	nd	nd	nd	nd	nd			
21.9	a	24	13	12	nd	nd	nd	nd	1.6	nd			
31.0	b	49	46	48	49	48	7.7	12	5.6	2.6			
37.8	b	29	27	30	20	5.6	15	6.2	11	4.2			
42.1	b	29	42	7.1	1.7	10	31	2.0	4.6	nd			
46.3	b	28	254	10	80	10	17	nd	2.7	NA			
59.9	d	24	19	101	32	23	6.1	30	2.5	3.0			
<b>PCE</b>													
53.4	c	32	17	17	8.8	5.5	3.4	1.1	nd	nd			
55.6	d	36	14	12	8.8	5.7	3.7	1.2	nd	nd	1.5	0.957	
62.2	d	34	27	18	12.0	5.8	3.0	1.1	nd	nd	1.3	0.996	
<b>TCE</b>													
53.4	c	11	5.8	5.0	10.0	2.0	1.3	nd	nd	nd			
55.6	d	11	3.9	3.5	2.8	4.5	1.0	2.1	nd	nd			
62.2	d	9.1	5.6	4.2	3.6	1.7	1.0	nd	nd	nd	1.5	0.971	
<b>Benzene</b>													
28.9	b	83	35	42	65	47	47	45	105	48			
40.1	b	50	44	41	45	34	88	NA	38	15			
<b>Toluene</b>													
28.9	b	1141	1060	1058	1554	1023	935	703	522	624			
40.1	b	589	505	531	740	873	704	737	742	731			
<b>Ethylbenzene</b>													
28.9	b	57	66	52	94	44	22	21	21	21			
40.1	b	10	13	20	NA	12	37	12	69	nd			

REACTIVE COLUMN  
157

Column Composition: 100% Peerless Iron  
 Pore Volume (PV): 574  
 Porosity: 0.5  
 Flow Velocity : 222 cm/day (7.3 ft/day )  
 Residence Time : 10.9 hr

Distance Along Column ( ft )

0.00	0.16	0.33	0.66	1.0	1.3	2.0	2.6	3.3
------	------	------	------	-----	-----	-----	-----	-----

PV	RN	Influent	Organic Concentration ( ug/L )								Effluent	HL	r2
pXylene													
28.9	b	42	42	34	55	39	7.4	6.1	nd	nd			
40.1	b	nd	8.2	6.4	5.7	24	29	8	33	3.6			
mXylene													
28.9	b	56	66	62	96	45	30	24	8.5	5.0			
40.1	b	nd	nd	6.3	6.5	24	28	31	40	4.1			
oXylene													
28.9	b	59	55	51	72	45	48	65	5.5	8.1			
40.1	b	2.8	NA	18	27	46	39	10	53	15			
pH Along Column													
pH													
10.6	a	6.9	7.1	7.5	8.0	8.3	8.5	8.7	8.7	7.9			
26.8	b	6.5	6.3	6.3	8.0	8.2	8.3	8.2	7.8	7.4			
38.2	b	6.9	7.1	7.2	7.6	8.0	8.5	8.8	8.6	8.7			
42.4	b	6.9	7.1	7.2	7.6	8.0	8.3	8.5	8.5	8.5			
55.6	d	6.9	7.2	7.2	7.5	7.7	8.3	8.7	8.9	8.7			
Redox Potential Along Column ( mV )													
Eh													
10.6	a	254	-375	-354	-379	-379	-382	-401	-406	-413			
26.8	b	233	-7	-203	-306	-439	-444	-446	-437	-447			
38.2	b	256	-8	-12	-234	-385	-378	-338	-294	-205			
42.4	b	322	10	0	-27	-174	-198	-165	-176	-203			
55.6	d	223	-23	-12	-47	-97	-297	-337	-353	-346			

nd = not detected  
 RN = reservoir number  
 HL = half life  
 r2 = coefficient of variation  
 NA = not applicable  
 Bold = HL calculated from peak concentration  
 eof//

**Appendix B**

**Inorganic Influent and Effluent Data**

MDS Environmental Services Limited.

Report of Analysis

Client : University Of Waterloo  
 Contact: Stephanie F. O'Hannesin

Report Date: October 10/96  
 MDS Ref # : 966842  
 MDS Quote #: 96-564-BG

Analysis of Water

INFUENT  
RNB
INFUENT EFFluent  
RNB B 37.8 PV
EFFluent  
B 40.1 PV

Parameter	LOQ	Units	UW-24	UW-24	UW-25	UW-26	UW-27
			Replicate				
Ammonia(as N)	0.05	mg/L	0.92	0.85	0.86	nd	nd
Chloride	1	mg/L	223	221	224	233	237
Nitrate(as N)	0.05	mg/L	nd	nd	nd	nd	nd
Nitrite(as N)	0.01	mg/L	nd	nd	nd	nd	nd
Orthophosphate(as P)	0.01	mg/L	nd	nd	nd	nd	nd
Sulphate	2	mg/L	3	3	3	nd	nd
Aluminium	0.025	mg/L	-	-	-	-	-
Barium	0.005	mg/L	-	-	-	-	-
Beryllium	0.005	mg/L	-	-	-	-	-
Bismuth	0.05	mg/L	-	-	-	-	-
Boron	0.01	mg/L	-	-	-	-	-
Cadmium	0.005	mg/L	-	-	-	-	-
Calcium	0.1	mg/L	142	143	115	18.2	18.7
Calcium	0.1	mg/L	-	-	-	-	-
Chromium	0.005	mg/L	-	-	-	-	-
Cobalt	0.005	mg/L	-	-	-	-	-
Copper	0.003	mg/L	-	-	-	-	-
Copper	0.01	mg/L	nd	nd	nd	nd	nd
Iron	0.02	mg/L	5.43	5.23	2.05	0.57	0.90
Iron	0.02	mg/L	-	-	-	-	-
Magnesium	0.1	mg/L	29.7	28.6	29.3	25.1	24.8
Magnesium	0.1	mg/L	-	-	-	-	-
Manganese	0.005	mg/L	-	-	-	-	-
Manganese	0.01	mg/L	1.82	1.76	1.75	0.39	0.26
Molybdenum	0.01	mg/L	-	-	-	-	-
Nickel	0.01	mg/L	-	-	-	-	-
Phosphorus	0.1	mg/L	-	-	-	-	-

LOQ = Limit of Quantitation = lowest level of the parameter that can be quantified with confidence.  
 - = Not Requested  
 nd = parameter not detected ! = LOQ higher than listed due to dilution ( ) Adjusted LOQ

### Report of Analysis

Client : University Of Waterloo  
 Contact: Stephanie F. O'Hannesin

Report Date: October 10/96  
 MDS Ref # : 966842  
 MDS Quote #: 96-564-EG

Analysis of Water

INFLUENT      INFLUENT      EFF B      EFF B  
 RWB            RWB            37.0 DV      10.1 DV

Parameter	LOQ	Units	UW-24	UW-24	UW-25	UW-26 <sup>U</sup>	UW-27
				Replicate			
Potassium	0.1	mg/L	-	-	-	-	-
Potassium	0.5	mg/L	27.3	25.8	26.3	26.8	25.0
Reactive Silica(SiO2)	0.5	mg/L	56.7	60.6	56.1	0.8	0.8
Silver	0.003	mg/L	-	-	-	-	-
Sodium	0.1	mg/L	111	107	110	109	108
Sodium	0.1	mg/L	-	-	-	-	-
Strontium	0.005	mg/L	-	-	-	-	-
Tin	0.05	mg/L	-	-	-	-	-
Titanium	0.05	mg/L	-	-	-	-	-
Vanadium	0.01	mg/L	-	-	-	-	-
Zinc	0.005	mg/L	-	-	-	-	-
Zinc	0.01	mg/L	0.02	0.01	nd	nd	nd
Lead	0.002	mg/L	-	-	-	-	-

LOQ = Limit of Quantitation = lowest level of the parameter that can be quantified with confidence.  
 - = Not Requested  
 nd = parameter not detected ! = LOQ higher than listed due to dilution ( ) Adjusted LOQ

B-23  
 B-24

## APPENDIX D

### DESIGN OF THE BIOSPARGE ZONE

## Design of the Biosparge Zone

### 1. Objectives and Basic Zone Layout

The design objective is to provide sufficient oxygen to groundwater in the biosparge zone for the aerobic biodegradation of the BTEX to MCLs. Pure oxygen will be added or sparged into the open zone. To insure that sufficient  $O_2$  is added, monitoring of dissolved oxygen (DO) within the biosparge gate will occur during zone operation. Meanwhile, the design needs to establish the residence time of the groundwater in the biosparge zone, so that the sparging frequency can be estimated.

A number of biosparge zone layouts were considered, including open "boxes" and vertical caissons. From a construction and cost perspective the open box layout was selected. The open box will stretch across the width of the gate (10 ft) and will extend from the water table (7 ft bgs) to the aquitard (22 ft bgs) for a depth of 15 ft.

### Residence Time of Groundwater in the Biosparge Zone

A variety of thicknesses in the flow direction were considered for the biosparge zone and the residence time for these under the potential groundwater fluxes and velocities are shown in Table 1. The residence time is the biosparge zone volume occupied by groundwater (10 ft x 15 ft x zone thickness) divided by the groundwater flux.

Table 1: Residence time (days) for groundwater in the biosparge zone considering different groundwater fluxes and different thicknesses of the biosparge zone in the direction of flow.

Groundwater velocity (ft/d)		0.20	0.27	0.65	1.0	1.5
Groundwater flux (ft <sup>3</sup> /d)		9.0	12.2	29.3	45.0	67.5
Zone thickness (ft)	Zone volume (ft <sup>3</sup> )	Residence time (days)				
2	300	33	25	10	7	4
3	450	50	37	15	10	7
4	600	67	49	20	13	9
5	750	83	61	26	17	11
6	900	100	74	31	20	13

Note: Bolded values are those velocities exceeding the  $Fe^0$  treatment capability and will not be used.

The residence days listed in Table 1 are also the time available for biodegradation to take the BTEX below target levels within the biosparge zone as is the remediation target. If

sufficient oxygen can be added to the resident groundwater so that the groundwater exiting the gate has sufficient dissolved oxygen (DO), then aerobic degradation can be allowed to occur beyond the biosparge zone. That is, there will be sufficient O<sub>2</sub> in the groundwater to subsequently degrade the BTEX, down gradient. This would move the compliance point beyond the biosparge zone and would necessitate additional down gradient monitoring and longer experiment time to demonstrate compliance. While an acceptable situation, it requires additional attenuation distance and monitoring in the hydraulically uncontrolled aquifer, and so is less desirable than compliance within the biosparge zone itself.

### Biological Oxygen Demand (BOD) of Groundwater

For the target aromatic hydrocarbons, the BOD is typically 3.5 - 3.8 x the BTEX (in mg/L). The BOD in the groundwater entering the biosparge gate can be measured in the field, but, for design purposes, it was estimated in the following two ways:

1. as the BOD from BTEX (4 x BTEX in mg/L) in the nearby monitoring point BH02-1, the highest local value of BTEX.
2. as the BOD from BTEX in the fully screened well MW-03, a more realistic estimate of the average concentration entering the fully penetrating gate.

The calculated BOD for these two situations are 34 and 5 mg/l, respectively. This was then used to calculate the biosparge frequency.

### Biosparge Frequency

It is assumed that each biosparging event will add 20 mg/L DO and so one biosparge event can satisfy 20 mg/L BOD. Note that groundwater saturated with pure O<sub>2</sub> will have about 50 mg/L DO, so the 20 mg/L should be achievable.

To add sufficient DO to satisfy the potential BOD (5 or 34 mg/L) will, in principle, require the zone be biosparged only every 0.25 or 1.7 residence times, respectively. A more conservative estimate was taken for subsequent calculations. It was assumed that biosparging would be necessary 0.5 or 2 times per mean zone residence time to handle the potential 5 or 34 mg/L BOD. For the various groundwater velocities and biosparge zone thickness in the flow direction of 3 ft, the following table of days between sparging events is constructed. The number of biosparge events required for each zone residence time (0.5 or 2 for groundwater BOD of 5 or 34 mg/L) is multiplied by that residence time in days. Note that the 1.6 ft/day velocity is not considered because it does not appear to provide sufficient residence time in the Fe<sup>0</sup> zone for attainment of the target concentrations of chlorinated ethenes.

Table 2: Frequency of biosparge events to provide DO sufficient to promote aerobic biodegradation of BOD in groundwater in the biosparge zone.

Velocity (ft/day)	0.20		0.27		0.65		1.0	
	Residence Time (days)							
	50		37		15		10	
BOD (mg/L)	5	34	5	34	5	34	5	34
# Sparge / Res. Time	0.5	2	0.5	2	0.5	2	0.5	2
	Days Between Biosparge Events							
	100	25	74	18	30	7	20	5

This calculation assumes water reaches 20 mg/L DO with the biosparge event, that there is complete mixing in the biosparge zone, and that no other major source of BOD is present. Only in the highest groundwater velocities (1.0 ft/day) and then only for the highest BOD case (34 mg/L) is it required to biosparge more than every week. Therefore, weekly biosparging is considered practical and sufficiently passive.

#### Summary: Recommendations for the Biosparge Zone

The biosparge zone should have an open box configuration and should be about 3 ft thick in the flow direction. Oxygen should be added as a gas, sparged into the gate to raise the resident groundwater DO to about 20 mg/L. The frequency of biosparging should be based on the flux of BOD entering the biosparge but will likely be less than once per week.

#### Off Gas from Sparge System

Off gas will be allowed to move through an unsaturated, in situ headspace bioreactor installed over the biosparge zone (Figure 4-2, in section 4). This zone will be created by extending the sides of the biosparge zone "box" to the surface and installing a sealed top plate. The headspace biosparge will be required to support biodegradation of BTEX both sparged from the biosparge zone groundwater during the actual biosparge events and passively partitioning from the groundwater to the vapor phase in the biosparge zone. The headspace bioreactor will include a porous, plastic microbial growth support about 1' thick. The volume of this headspace bioreactor is taken as the width (10 ft) and thickness in flow direction (3 ft) of the biosparge zone x the nominal depth to water table (7 ft), i.e., 210 ft<sup>3</sup>.

Biodegradation of all remaining BTEX is anticipated in this in situ bioreactor. The in situ bioreactor will be sealed and gas released during each biosparge event will be collected in a Tedlar gas bag and analyzed. The gas will be passed through an activated carbon canister and then will be released to the atmosphere. This will ensure no unacceptable transfer of organic contaminants to the atmosphere occurs during the experiment. An air emission permit will be obtained to permit this testing. It is anticipated that this technology will be shown to have no air emissions of CVOCs and can subsequently be operated without off gas control.

#### Biosparging Operation and Off Gas Generation

Gas will be delivered from a cylinder of compressed O<sub>2</sub> to emitter tubing placed in the bottom of the biosparge zone. Sufficient O<sub>2</sub> must be delivered so that the groundwater contains 20 mg/L dissolved oxygen (DO) to support aerobic biodegradation of the organics in that groundwater. The volume of O<sub>2</sub> will be delivered over short (< 4 h) periods, termed biosparge events, at a pressure just sufficient for gas to flow. Precisely how much gas must be provided to attain the target 20 mg/L DO will be assessed during pre-Phase 1 testing. Excess O<sub>2</sub> will probably go into the headspace bioreactor which will help support biodegradation of any BTEX that comes out of the groundwater. Using a minimum volume of gas ensures a longer residence time of volatilized organics in the in situ bioreactor and a minimum of off gas emission. For design purposes, the off gas volume per biosparge event is estimated as follows. The volume of oxygen required to add 20 mg/L ( $0.625 \times 10^{-3}$  mole/L) to the 210 ft<sup>3</sup> or 5950 L of groundwater is 83.3 L or 2.94 ft<sup>3</sup>, (as determined from the Ideal Gas Relationship, i.e., 1 mole of gas occupies 22.4 L or 0.79 ft<sup>3</sup> at 20 C and atmospheric pressure). A range of additional gas volumes going into the headspace with 1, 5, or 10 x the volume dissolving in water is examined. The 2.94, 14.7, or 29.4 ft<sup>3</sup> of O<sub>2</sub> going into the headspace bioreactor represents only 1.4, 7, or 14% of the headspace bioreactor volume (210 ft<sup>3</sup>), respectively. Thus, the mean residence time of off gas in the headspace bioreactor is 70, 14, or 7 x the time between biosparge events, which is itself at least 7 days. This is likely adequate for aerobic biodegradation of any sparged BTEX to reduce concentrations below reasonable air quality objectives.

## APPENDIX E

### VAPOUR SAMPLING METHOD

## VAPOR SAMPLING

### Vapor Sampling Equipment

Vapor sampling involves the following equipment:

1. Vacuum-tight sampling box, with (1) vacuum gauge, (2) a small valve to adjust/release vacuum, (3) sample-train tubing (small-diameter teflon tubing that penetrates the box, with silicone tubing and squeeze clamps used as adaptors/connectors on each end), and (4) a port for attaching a vacuum pump.
2. Field instrumentation [e.g., flame-ionization detector (FID), photoionization detector (PID)] that can be inserted into the sample train (out side of vacuum box) for field screening and/or optimization of purge volumes.)
3. Sample container (one-liter Tedlar bag or Summa cannister).  
(Note: If holding times greater than 72 hours are required, Summa canisters should be used instead of Tedlar bags for sample collection. Summa canisters are evacuated (that is, under vacuum) so a vacuum pump and box are not needed to collect a vapor sample.)
4. A non-chilled, light-tight, insulated cooler for sample transport to the laboratory, and chain-of-custody documents.

### Vapor Sampling Procedures

Vapor sampling involves the following procedures:

1. To collect a sample, attach the silicone tubing adapter (clamp closed) on the Teflon sample-line tubing penetrating the vacuum box to the gas-collection bag. Attach the vacuum pump to the vacuum box at its port.
2. Place a clean Tedlar bag in the vacuum box. Prior to placing in the vacuum box, label the bag with an appropriate sample identification. Attach the valve on the Tedlar bag to the tubing connecting the vacuum box to the probe sample line. Open the valve on the Tedlar bag and seal the vacuum box.
3. Open the valve on the gas-collection bag and the clamp on the silicone adapter tubing, engage the vacuum pump, and allow a vapor sample to be drawn into the Tedlar bag. Control the vacuum, and therefore the sample flow rate, using the small valve and the pressure gauge on the vacuum box. Sample at a vacuum of less than 6 in-Hg and a flow rate of 1 to 2 liters per minute.
4. When sufficient sample has been obtained, close the clamp on the sample line and turn off the vacuum pump. Release the vacuum from the vacuum box and open the box.

Close the Tedlar bag valve and disconnect the tubing from the bag to the probe line valve.

5. Immediately place the pre-labeled, Tedlar bag in the non-chilled, light-tight, insulated cooler for transport to the laboratory.
6. Collect duplicate or laboratory split samples as required or specified by the project QA/QC plan.
7. Complete the chain-of-custody appropriately.

## **APPENDIX F**

### **HEALTH AND SAFETY PLAN**

**HEALTH AND SAFETY PLAN**  
**SEMI-PASSIVE GROUNDWATER**  
**REMEDICATION**  
**DEMONSTRATION PROJECT**

**Site 1**  
**Naval Air Station Alameda**  
**California**

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December 1996

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## ABBREVIATIONS AND ACRONYMS

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μCi	microcurie	HAZWOPER	Hazardous Waste Operations and Emergency Response
μg/L	micrograms per liter	HEPA	high efficiency particulate air
ACGIH	American Conference of Governmental Industrial Hygienists	HSC	Health and Safety Coordinator
ANSI	American National Standards Institute	HSP	Health and Safety Plan
BTEX	benzene, toluene, ethylbenzene, and total xylenes	ICRP	International Commission on Radiological Protection
C3	C3 Environmental	IP	ionization potential
Cal/OSHA	California Occupational Safety and Health Administration	LEL	lower explosive limit
CA	chloroethane	mr/hr	milliroentgens per hour
CB	chlorobenzene	MSHA	Mine Safety and Health Administration
CCR	California Code of Regulations	NAS	Naval Air Station
CFR	Code of Federal Regulations	NIOSH	National Institute for Occupational Safety and Health
CGA	compressed gas association	O <sub>2</sub>	oxygen
CIH	Certified Industrial Hygienist	OSHA	Occupational Safety and Health Administration
CPR	cardiopulmonary resuscitation	OVM	organic vapor monitor
cm <sup>2</sup>	square centimeters	PCE	perchloroethene
cpm	counts per minute	PID	photoionization detector
CPR	cardiopulmonary resuscitation	PPE	personal protective equipment
dBA	decibels measured on the A-weighted scale	ppm	parts per million
1,2-DCE	1,2-dichloroethene	RASO	Radiological Affairs Support Office
DHHS	U.S. Department of Health and Human Services	RSO	Radiation Safety Officer
DNAPL	dense non-aqueous-phase liquid	SSO	Site Safety Officer
dpm	disintegrations per minute	TCE	trichloroethene
dps	disintegrations per second	TLD	thermoluminescent dosimeters
EFA West	Engineering Field Activities West	TLV	threshold limit value
EFW	Einarson, Fowler & Watson	TWA	time-weighted average
EHC	Environmental Health Consultants	UW	University of Waterloo
eV	electron volt	VC	vinyl chloride
Fe <sup>0</sup>	zero valent iron	VOC	volatile organic compound
FID	flame ionization detector		
GFCI	ground fault circuit interrupter		

# 1 INTRODUCTION

---

This site-specific health and safety plan (HSP) has been prepared to describe the necessary health and safety procedures for the installation and operation of a pilot-scale, funnel-and-gate remediation system at Site 1, Naval Air Station (NAS) Alameda. This work, referred to as the pilot study in this HSP, is described in the *Workplan for Funnel and Gate Remediation Demonstration Project* (Workplan, University of Waterloo [UW], 1996). The purpose of the pilot study is to ascertain the viability of using in situ treatment technologies in a funnel and gate system as a means to remediate groundwater containing chlorinated volatile organic compounds (VOCs) and petroleum hydrocarbons, particularly the aromatic compounds benzene, toluene, ethyl benzene, and xylenes (BTEX).

## 1.1 SCOPE AND PURPOSE

This HSP describes standard operating safety procedures, as well as specific responsibilities, requirements, and procedures for the protection of personnel while performing the field work associated with the pilot study at Site 1, NAS Alameda. This HSP provides guidelines and requirements for the Health and Safety Coordinator (HSC) to follow to protect field-team members engaged in work at the site. The work covered by this HSP includes only installation, operation, and dismantling of the pilot system. In order to ensure the safety and health of all project participants, this HSP will be in force for the duration of all UW and subcontractor activities related to the remedial system installation and sampling performed by members of the project team.

The HSP has been prepared to assure that Occupational Safety and Health Administration (OSHA) requirements promulgated in Title 29 of the Code of Federal Regulations (CFR) 1910.120(b)(4) Site-Specific Safety and Health Plan, and in Title 8 of the California Code of Regulations (CCR), Section 5192(b)(1) are met. The HSP will be provided to all field personnel who may be exposed to hazardous on-site conditions. Field personnel shall read this HSP and document their agreement to comply with it on the Compliance Agreement Form (Attachment 3).

This HSP focuses primarily on health and safety related issues as they pertain to site preparation and construction for the pilot-scale study. This document also addresses health and safety related issues related to funnel-and-gate operations. As funnel-and-gate construction and operations

may be revised during the initial design phase, portions of this HSP may require update or modification.

Relevant references that were used in the preparation of this document include the following.

- Code of Federal Regulations, Title 29, Section 1910.120 (29 CFR 1910.120), Hazardous Waste Operations and Emergency Response.
- 29 CFR 1926, Subpart P, Excavation
- 10 CFR 20, Standards for Protection Against Radiation.
- California Code of Regulations, Title 8, Section 5192 (8 CCR 5192), Hazardous Waste Operations and Emergency Response
- 8 CCR 3203, Illness and Injury Prevention Plans
- 8 CCR 5144, Respiratory Protection
- 8 CCR 1541, Excavation Safety Standard
- U.S. Department of Health and Human Services (DHHS), National Institute for Occupational Safety and Health (NIOSH), 1994, *Pocket Guide to Chemical Hazards*, Publication No. 94-116.
- American Conference of Governmental Industrial Hygienists (ACGIH), 1994-1995, *Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices*.
- U.S. DHHS, NIOSH/OSHA/USCG/EPA, 1985, *Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities*.

All federal, state and activity health, safety, and fire regulations will be complied with; at no time will the provisions of this HSP supersede these regulations.

## **2 RESPONSIBILITIES**

---

This HSP applies to all field personnel working on the pilot study at Site 1, including subcontractors and visitors. The UW Program Manager, contractor Project Managers, and the HSC will be responsible for implementation and enforcement of the health and safety provisions of this HSP. Their duties are described below along with the duties of other project personnel.

### **2.1 UW PROGRAM MANAGER**

Dr. Jim Barker is the UW Program Manager. He is responsible for reviewing proposed activities and safety precautions at the pilot study site. Dr. Barker is also the UW Principal Investigator.

### **2.2 PROJECT CERTIFIED INDUSTRIAL HYGIENIST**

Ms. Irene Fanelli, Certified Industrial Hygienist (CIH), of Environmental Health Consultants (EHC), has the overall responsibility for the health and safety activities at the Site 1, UW pilot study site. She reviewed and approved this HSP. No changes may be made to this HSP without her written approval.

### **2.3 C3 PROJECT MANAGER**

Mr. Murray Gamble is the Project Manager for C3 Environmental (C3). With the assistance of the HSC, he is responsible for the job-related health and safety of construction personnel.

### **2.4 EFW PROJECT MANAGER**

Mr. Murray Einarson is the Project Manager for Einarson Fowler and Watson (EFW). With the assistance of the HSC, he is responsible for the job-related health and safety of UW and EFW site personnel.

### **2.5 HEALTH AND SAFETY COORDINATOR**

Mr. Greg Smith of EFW is the Health and Safety Coordinator (HSC) for the pilot study. He is the primary enforcement authority for compliance with the policies and provisions of this HSP. Mr. Smith shall also be responsible for conducting periodic site inspections to identify and to assure that hazards previously noted have been corrected.

## **2.6 C3 SITE SUPERINTENDENT**

C3 will designate a Site Superintendent. The Site Superintendent will direct all field activities during construction, including emergency response operations. The Site Superintendent will supervise necessary preparation and coordination for all site operations during construction, including health and safety.

## **2.7 SITE SAFETY OFFICER (SSO)**

The Site Safety Officer (SSO) is either the HSC, Site Superintendent, or their designee that has proper 29 CFR 1910.120 supervisor training. He or she will have the daily enforcement responsibility for compliance with the HSP at the site. The SSO will monitor site operations and direct work to protect worker health and safety.

## **2.8 RADIATION SAFETY OFFICER (RSO)**

The Radiation Safety Officer (SSO) will have the appropriate training to provide proper monitoring of radiation hazards at the work site. He or she will report to the SSO.

## **2.9 SUBCONTRACTOR MANAGEMENT AND PERSONNEL**

Each subcontractor responsible for workers required to enter a hazardous waste site controlled work zone shall comply with the requirements of 29 CFR 1910.120, 8 CCR 5192, and with the requirements of this HSP. Compliance with these requirements is not intended to either supersede or replace the contractor's own illness and injury prevention plans required by 8 CCR 3203.

Subcontractors will designate a qualified person to serve as a health and safety representative concerning the activities of their own employees. Each subcontractor has overall responsibility for enforcement of the HSP concerning their own personnel and operations, with the assistance of the HSC.

Additionally, subcontractors are responsible for providing health and safety training to their employees and implementing a medical monitoring program. Each subcontractor must provide documentation indicating compliance with OSHA-required health and safety training and medical monitoring requirements prior to the start of its operations. This documentation will be

in the form of a letter on company letterhead, signed by an authorized representative of the company, including a completed Records Verification Matrix form (Attachment 3). The letter will state that the named employees have been trained and medically certified to work on hazardous waste sites and are medically approved to wear respirators. The letter should be addressed to one of the Project Managers. The existence and maintenance of the appropriate certification for the duration of the subcontractor's participation in the project will be made a condition of any contract with that subcontractor. Each subcontractor is responsible for ensuring proper certification of equipment and any necessary personal training of their employees. Prior to start of its operations, each subcontractor must provide documentation indicating compliance with appropriate OSHA-required certification and training, and its activity hazard analysis and/or plan.

## **2.10 FIELD TEAM MEMBERS**

Health and safety precautions are of paramount importance during on-site activities. Despite thorough preparation, a field team member may not have complete knowledge of site conditions, and it is impossible to anticipate every health and safety hazard that could arise. Therefore, field team members should use common sense, experience, and the best professional judgment at all times. The field team member should notify the Site Superintendent or HSC and potentially affected fellow team members whenever a potential hazard is observed.

## **2.11 VISITORS**

Site visitors are also required to adhere to this HSP. Either the EFW Project Manger, Site Superintendent, or the HSC shall brief site visitors on site health and safety hazards when they first arrive on site. Site visitors will not be allowed access to controlled work zones unless they have demonstrated compliance with the medical surveillance and training requirements of this HSP. Visitors must log in, and provide and wear the personnel protective equipment required to be allowed access to controlled work zones.

### 3 BACKGROUND INFORMATION

---

NAS Alameda is located on the east side of San Francisco Bay in Alameda, California, on the western end of the island of Alameda. Most of the eastern half of the station is developed with office and industrial facilities. Runways and support facilities occupy the western part of the station. The pilot-project site is within the area known as Site 1, west of the base's northern runway (no. 13-31) (Figure 1).

#### 3.1 SITE DESCRIPTION

Site 1 is constructed on artificial fill placed in the late 1930's on top of natural Bay Mud estuarine deposits. The fill soil was dredged from around Alameda island and was hydraulically placed on top of the Bay Mud.

Beginning in approximately 1943, cleaning solvents and waste petroleum hydrocarbons were disposed of in unlined waste pits excavated in the fill soil in Site 1. Small quantities of solid waste were also disposed of in the waste pits. This historic disposal practice is apparently the source of a plume of dissolved chlorinated organics and petroleum hydrocarbons that flows westward to the San Francisco Bay. This dissolved plume is the focus of the pilot study.

Additionally, low-level radiological wastes were deposited in the Site 1 area between 1943 and 1956. These materials consist primarily of instrument dials, gauge faces, and deck markers painted with radioluminescent paints that contained radium-226, or possibly strontium-90. A recent surficial radiation survey indicated some areas of low-level impact in the larger Site 1 area, but not in the pilot-study area.

#### 3.2 PROJECT DESCRIPTION

As stated in the introduction, the purpose of the pilot study is to ascertain the viability of using in situ treatment technologies in a funnel-and-gate system as a means to remediate groundwater containing chlorinated VOCs (tetrachloroethene [PCE], trichloroethene [TCE], dichloroethene [DCE] isomers, vinyl chloride [VC], and chlorobenzene [CB]) and BTEX. The project is aimed at combining two in situ technologies, each known to degrade either chlorinated VOCs or petroleum hydrocarbons, to treat the groundwater plume containing a mixture of these

contaminants. The in situ technologies planned for the pilot study treat such groundwater through:

- 1) Reductive dechlorination of chlorinated ethenes by contact with zero valent iron ( $\text{Fe}^0$ ) in a permeable, reactive barrier
- 2) In situ aerobic bioremediation of petroleum hydrocarbons, stimulated by minimal oxygen addition using an in situ biosparge system

These technologies will be adapted for use in sequence in a funnel-and-gate system. The funnel-and-gate is a groundwater control structure where contaminated groundwater is “funneled” into a small, in situ treatment zone (the “gate”) from which remediated groundwater exits.

The major part of the pilot study involves the installation of the funnel-and-gate system, followed by the sampling and analysis program designed to monitor the system’s performance. The pilot study field activities include the tasks listed below:

- Installing field offices, staging equipment, clearing underground utilities, and preparing for field work
- Handling sheet piles and granular iron media
- Installing sheet piles and sealing joints
- Excavating soil and debris
- Stockpiling and spreading soil and debris
- Placing iron, pea gravel, and biosparge sections with simultaneous installation of monitoring points
- Installing upgradient monitoring wells
- Flooding the system with uncontaminated water
- Removing the sheet piles on the upgradient side of the box
- Operating the different phases of the pilot project
- Monitoring the operation and performance of the system, including groundwater and vapor sampling

## 4 HAZARD ANALYSIS AND MITIGATION

---

As indicated in Section 3.2, there are a variety of field activities associated with the pilot study, each of which is associated with various hazards. Recognition of specific physical, environmental biological, chemical, and radiological, hazards that may be encountered during the pilot study field work are discussed below. Potential site physical, environmental, and biological hazards, analyses, mitigation, and personal protective equipment (PPE) requirements for this project are summarized on Table 1 in Attachment 1. Potential chemical and radiological hazards, analyses, mitigation, monitoring, and PPE requirements are summarized on Table 2 in Attachment 1.

### 4.1 PHYSICAL HAZARDS

There are several physical hazards associated with the pilot study. Analysis and proposed mitigation of each of the potential physical hazards are discussed below.

#### 4.1.1 Buried Utilities/Overhead Power Lines

Prior to beginning site work, all utilities in and around the proposed work area will be located by a utility-locating company. Identified underground utilities will be marked and protected. Underground utilities within excavation and sheet pile driving areas will be exposed and protected. A distance of 20 feet from overhead utilities will be maintained at all times. The C3 and EFW Project Managers, Site Superintendent, and HSC shall coordinate the necessary arrangements to either disconnect or de-energize power lines wherever possible.

#### 4.1.2 Construction Equipment

Excavation and earth-moving equipment, cranes, and trucks will be used during the pilot study. The following precautions should be observed whenever heavy equipment is in use:

- Only trained, experienced, and licensed operators (as appropriate to equipment) shall be involved with equipment assembly and operations.
- Only properly inspected, certified, and proof-load-tested cranes an, hoist, and accessory equipment must be used.
- Vehicle and systems must be checked for proper operation at the beginning of each day.

- Heavy equipment shall maintain a sufficient distance from excavations, deep fills, cut banks, and steep slopes to prevent overturning the vehicle or the probability of dangerous slides or movement of material.
- Excavating equipment shall not operate if employees are working below.
- No one shall be allowed to work under a live load.
- Construction traffic must have right-of-way over regular traffic.
- Personnel must use appropriate PPE, including steel-toed boots, safety glasses, and hard hats.
- Personnel must at all times be aware of the location and operation of heavy equipment and take precautions to avoid getting in the way of its operation. Personnel must never assume that the equipment operator sees them; eye contact and standard construction hand signals should be used to communicate with the equipment operator.
- Traffic safety vests are required for personnel working near mobile heavy equipment.
- Personnel should never walk directly behind, or to the side of, heavy equipment without the operator's knowledge.
- Nonessential personnel shall be kept out of the work area.
- Backup alarms and rollover protection will be used, as appropriate.

Section 9.7 provides additional safe operational procedures.

#### **4.1.3 Drilling Operations**

Most of the same precautions noted for construction equipment also apply to drilling operations. Drilling equipment will be properly maintained and operated by trained personnel only. All personnel working near the drill rig will maintain Level D PPE at a minimum as described in Section 5. All personnel working around the drill rig will wear hearing protection. No work will take place closer than 5 feet to the roadway or the jogging path running through the general area of the investigation unless traffic is properly rerouted on the road or pathway allowing a safe working distance. All proposed drilling locations will be cleared for utilities by a utility locating company, prior to commencing subsurface activities. Section 9.7 provides additional safe operational procedures.

#### **4.1.4 Noise**

Noise may result primarily from sheet-pile driving, drill rig operation, excavation equipment, and other equipment or machinery. The use of heavy equipment may generate noise above the

Cal/OSHA permissible exposure limit for noise of 90 decibels measured on the A-weighted scale (dBA) for an 8-hour time-weighted average (TWA), in accordance with the Cal/OSHA requirements in 8 CCR 5096. Workers shall wear ear plugs when operating or working near heavy equipment. If loud noise is present or normal conversation becomes difficult, hearing protection in the form of ear plugs, or equivalent, will be required.

#### **4.1.5 Excavations**

All excavations and ground openings will be protected from inadvertent entry. Any openings left open will be barricaded and/or covered to prevent entry by unauthorized personnel. Any excavations deeper than four and one-half feet into which personnel will be entering will be appropriately sloped, shored, and/or benched., Appropriate OSHA permitting and notifications will be made for excavations equal to or deeper than five feet. All excavations will be maintained with adequate means of egress for personnel working within. Workers shall not enter excavations or trenches greater than 4 feet in depth without first obtaining approval from the Project CIH, and only after monitoring to verify safe conditions for entry and donning appropriate PPE (Section 10.3.2). When working near the open excavation, lifelines and safety belts/harnesses will be used as appropriate. Side slopes shall not be steeper than 1:1 without a written report from a qualified civil or geotechnical engineer. Excavation spoils shall be stockpiled at a minimum of 2 feet from trenches, or greater to maintain the stability of the excavation. All excavations shall be in accordance with the Cal/OSHA Excavation Safety Standard, 8 CCR 1541.

#### **4.1.5 Confined Space Entry**

IF CONFINED SPACE ENTRY IS REQUIRED, APPROPRIATE CONFINED SPACE ENTRY PROCEDURES, INCLUDING MONITORING PROCEDURES, MUST BE IMPLEMENTED PRIOR TO ENTRY, AS OUTLINED IN SECTION 10. Entry into any excavation must be evaluated for confined space conditions, including oxygen deficiency, limited egress, etc. In addition, confined space entry must only be conducted with continuous on-site supervision by the HSC or his appropriately-trained designee.

#### **4.1.6 Electric Shock**

All electrical equipment to be used during field activities will be suitably grounded and insulated. Ground fault circuit interrupters (GFCIs) will be utilized with all heavy electrical equipment to reduce the potential for electrical shock. Appropriate lock-out/tag-out procedures must be

developed for the installation and operation of treatment system equipment once it has been specified. Section 9.8 provides additional safe operational procedures to prevent electrical shock.

#### **4.1.7 Slip, Trip, and Fall**

Slip, trip and fall hazards on the work site are typically caused by poor housekeeping, lack of awareness of one's surroundings, or by the use of unstable stepstools, etc. This kind of accident will be minimized by proper housekeeping techniques and proper training of workers. Any obviously uneven terrain which poses a tripping hazard will be filled in or otherwise protected to prevent injury. Likewise, cleared walkways will be established around any debris and equipment on the ground, in order to minimize any tripping/contact hazard. All open excavations and ground openings will be protected from inadvertent entry. Any openings left open will be barricaded and/or covered to prevent entry by unauthorized personnel.

#### **4.1.8 Materials Handling**

Major materials handling tasks include unloading sheet piles, granular iron media contained in "superbags" of up to 3,000 pounds, and excavation backfill materials such as sand and gravel. Most incidents leading to injury, occupational illness, and property damage stem from failure to observe safe materials handling procedures. Employees must not be required to lift heavy or bulky objects that might overtax them physically. Wherever possible, material handling during the pilot study will be done mechanically. Where manual handling is absolutely necessary, personnel will be instructed in safe handling techniques, and will be instructed to use the appropriate protective gear to prevent abrasions, cuts, and struck-by accidents. Mechanical devices must be appropriate for the lifting or moving task and must be operated only by personnel trained and authorized to operate them. Planning for safe-rigging and lifting, and lifting procedures must be developed by the Contractor and approved by the Site Supervisor for the installation of the sheet piles and treatment gate materials.

#### **4.1.9 Compressed Gas**

Compressed gas, specifically pure oxygen, is expected to be used during pilot-study operations. The oxygen will likely be supplied from standard nine-inch-diameter, fifty-inch-long compressed-gas cylinders. Compressed gases should be handled only by those knowledgeable in the equipment and in proper handling procedures. Compressed gas equipment should never be jerry-rigged. Jerry-rigging includes the use of non-standard regulators, hoses, or fittings, and is especially dangerous if high- and low-pressure fittings are inter-mixed. Low-pressure fittings

hooked into high-pressure applications will burst. Always use the proper CGA fittings for the gasses. Secure all cylinders from falling. Large cylinders should be secured to a stable structure by the means of straps, ropes, or wire, or they may be laid down if they do not pose a tripping hazard and if they are secured from rolling. When a cylinder is being moved, its regulator must be removed and its cylinder cap must be in place. Always keep the cylinder caps on when the cylinder is not in use.

#### **4.1.10 Hot Work**

Installing and bracing the sheet pile structures will involve hot work. Hot work includes welding, torching, and cutting or any operation involving application of an open flame or electric arc. Hazards to workers can include fire, explosions, burns, and exposure to fumes. For all hot work, a checklist/permit system must be implemented. Before any hot work on site, the work area will be inspected for fire hazards and all combustible materials will be removed. Hot work will not be allowed where "free product" or hydrocarbon saturation is present in the soil. Vapor monitoring will be conducted before the work to assure the work space contains an atmosphere at or below 10% of the lower explosive limit (LEL). Appropriate PPE must be used by any personnel performing hot work. Vapor monitoring must continue throughout the duration of the work. A fire watch must be implemented such that one observer is continuously present to watch for fire hazard, and assist in the event of a fire. At least 2 fire extinguishers must be present in the work area. Site personnel must be familiar with the use of fire extinguishers as well as emergency notification procedures in the event of a fire requiring outside assistance.

## **4.2 ENVIRONMENTAL HAZARDS**

### **4.2.1 Heat Stress**

Because the majority of the work on the project will occur during winter, heat stress hazards will be minimal. However, all on-site personnel will be made familiar with the symptoms of the different forms of heat stress, and the conditions during which they may occur. Heat stress can occur rapidly, especially for workers wearing protective clothing. In its early stages, heat stress (heat exhaustion) can cause rashes, cramps, discomfort, nausea, headache, lightheadedness, lack of coordination or decreased job performance, or slurred speech. Continued heat stress can lead to heat stroke and death. Heat stroke symptoms include red, dry or moist skin, and high body temperature. If site conditions warrant, the Site Superintendent will instruct personnel to monitor for heat stress and implement work/rest regimens based on heart rates. A strict delineation of atmospheric conditions requiring action is not prudent given the extreme differences in personal

tolerance and physiological and psychological reaction to heat. If physiological monitoring is instituted due to the potential for heat stress, the work/rest cycles will be adjusted according to the results. Potable water will be available on-site at all times.

#### **4.2.2 Inclement Weather/Cold Stress**

Rain and/or high wind conditions may occur during the time period of a scheduled work activity. In such cases, all employees will be trained in the hazards of exposure to cold and/or wet conditions. Exposure can lead to lack of coordination or decreased job performance, drowsiness, impaired judgment, fatigue, pulled muscles, numb toes and fingers, and hypothermia. Protective clothing for wet conditions will be used as necessary. Heavy rains or high winds may result in the cessation of site activities, at the discretion of a Project Manager or HSC.

### **4.3 BIOLOGICAL HAZARDS**

Biological hazards include poisonous insects, ticks, and other biting insects. During activities involving the opening of valve boxes or other buried structures, personnel should be aware of the potential for insect bites. The biggest hazard and most common cause of fatalities from insect bites—particularly bees, wasps, and spiders—is a sensitivity reaction called anaphylactic shock. This reaction from stings can lead to severe reactions in the circulatory, respiratory, and central nervous systems. Personnel should inform their supervisor and work buddy of their sensitivities. Insect bites will be administered to using proper first aid. A tick removal kit, complete with instructions, will be maintained on site for all personnel. It is recommended to buddy up and check each other for ticks periodically (every few hours). After returning indoors, site workers should remove their own clothing and check their own body for the presence of ticks.

### **4.4 CHEMICAL HAZARDS**

Potential chemical hazards include the presence of chlorinated and non-chlorinated VOCs in the groundwater. Chemicals to which workers may be exposed include PCE, TCE, DCE isomers, VC, CB, and BTEX. Descriptions of the chemicals of concern are presented in Attachment 2.

Dermal exposure to these constituents poses little risk, and will be minimized by use of appropriate PPE. The route of exposure of greatest concern is inhalation. Specific chemical hazards, analyses, mitigation, monitoring, and PPE requirements are summarized on Table 2 in Attachment 1.

Expected inhalation exposure to most of the chemical constituents in groundwater is minimal, but of concern for a few constituents. Based on previous investigations, there is the potential for high concentrations of 1,2-DCE and VC, possibly due to dense, non-aqueous-phase liquid (DNAPL). In some areas, volatilized concentrations of these constituents may be high, particularly at the top of sampling rods, wells, or excavations open to groundwater.

Inhalation exposure will be evaluated periodically during operations by monitoring workers' breathing space as described in Section 6 of this HSP. On the basis of monitoring results, the HSC or Site Superintendent may upgrade PPE to provide respiratory protection. PPE is described in Section 5.

#### **4.5 RADIOLOGICAL HAZARDS**

Work at the site may encounter radium-226 and its decay products (lead-214 and bismuth-214), possibly strontium-90, or both in concentrations above naturally expected background levels. Radium-226 has a half-life of about 1,600 years, and decays by emission of an alpha particle, with associated gamma emissions. Radium-226 decay products emit more abundant and higher energy gamma radiation than Radium-226. This permits detection of radium sources—the instrument dials, gauge faces, and deck markers that were painted with radioluminescent paints. These materials may be buried in the work area and may have corroded, locally dispersing radium-containing material into the surrounding soil. The gamma radiation from radium decay products can usually be detected in areas covered by less than 1 foot of soil. According to the Navy's Radiological Affairs Support Office (RASO), the radioluminescent items that may be present typically have activities of 1 microcurie ( $\mu\text{Ci}$ ), or 37,000 disintegrations per second (dps).

Strontium-90 has a half-life of about 29 years, and decays by emission of beta particles. It was little used in radioluminescent instruments, but was used in deckmarkers. The interaction of the beta particles with the steel housing of the deckmarkers, produces bremsstrahlung radiation, which is similar to X-ray and gamma radiations. Bremsstrahlung radiation can be detected with radiation survey equipment using a 2-inch by 2-inch detector having a sodium iodide crystal.

Radium-226 and strontium-90 are primarily of concern because they are carcinogens and mutagens when taken into the body. Both are "bone-seekers", replacing calcium in metabolic processes. The primary route of exposure for radionuclides is by inhalation, and secondarily ingestion of impacted dust. Care will be taken, therefore, not to raise excessive dust from surface

activities. If needed, the area will be sprayed down with a light mist of water to keep dust down. Prior to lunch breaks, and before leaving the site, workers shall wash hands and face. Based on the monitoring for radionuclides, as described in Section 6, the SSO may upgrade PPE, particularly respiratory protection.

## 5 PERSONAL PROTECTIVE EQUIPMENT (PPE)

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The variety of tasks associated with the pilot study will require different levels of PPE to protect personnel from hazards and potential hazards they are likely to encounter. These levels of PPE are discussed below.

### 5.1 LEVEL D PERSONAL PROTECTIVE EQUIPMENT

The initial designated level of protection for site work is Level D. Monitoring will be routinely conducted using real-time air monitoring devices to determine if upgrading to Level C is necessary. Level D will be permitted as long as monitoring data indicate that concentrations of chemicals of concern are maintained below the site-specific action levels defined in Section 6.1.2 of this HSP. The following PPE is specified as the Level D protection required to conduct activities at the pilot study site.

- Work clothes (work shirt and long pants)
- ANSI-approved hard hat
- ANSI-approved safety glasses fitted with side shields.
- Steel-toed boots or safety shoes

Other forms of PPE shall be maintained on site, readily available for use, if necessary, including:

- Sturdy work gloves
- Hearing protection (plugs or muffs) for operations with noise levels exceeding 85 dBA
- Chemical-resistant gloves (nitrile or vinyl) for sample collection activities or when direct contact with chemical-impacted soil or groundwater is anticipated.
- Chemical-resistant clothing (Tyvek or polycoated Tyvek) when direct contact with chemical-impacted soil or groundwater is anticipated.
- Chemical-resistant boot covers (or chemical resistant knee-high boots with steel toes and shank in lieu of safety boots and covers) when direct contact with chemical-impacted soil or groundwater is anticipated.

Other forms of task-specific PPE will be used as necessary. For example, appropriate eye and skin protection shall be worn when welding.

## **5.2 LEVEL C PERSONAL PROTECTIVE EQUIPMENT**

If monitoring indicates that the site-specific action levels defined in Section 6.1.2 are exceeded, workers in the affected area(s) will upgrade PPE to Level C. In addition to the protective equipment specified for Level D, Level C also includes the following:

- Half-mask respirators with organic vapor cartridges or half-mask respirators with high-efficiency, particulate air (HEPA) filters. Because both organic vapor cartridges and HEPA filters may be required together, combination organic vapor/HEPA cartridges will also be available at the site. Cartridges should be changed after break through is detected or estimated to occur.
- If air monitoring indicates that the site-specific action levels defined in Section 6.1.2 are exceeded, workers in the affected areas will upgrade to full-face respirators in lieu of half-face respirators and safety glasses.
- Chemical-resistant clothing (Tyvek or polycoated Tyvek).
- Chemical-resistant boot covers (or chemical resistant knee-high boots with steel toes and shank in lieu of safety boots and covers) when direct contact with chemical-impacted soil or groundwater is anticipated.
- Nitrile outer gloves and latex or nitrile surgical inner gloves.

## **5.3 RESPIRATOR SELECTION AND FIT TEST**

Within the requirements of 8 CCR 5144, all respiratory protective equipment must be NIOSH-MSHA approved. This equipment will be chosen by, or on the advice of, the Project CIH. All equipment will be selected in light of anticipated field conditions, potential for exposure, expected magnitude of exposure, and the specific chemical of concern. Personnel who may be expected to use respirators will have a current medical examination (within one year) noting the employee's physical capability to use such equipment. Personnel using respirators shall be clean-shaven. Mustaches and sideburns are acceptable, so long as there is no interference with the facepiece seal. No one may wear contact lenses while using any respiratory protection.

Except for emergency response equipment, all respirators will be individually assigned. For sanitary reasons, respirators should not be shared. Each individual will be responsible for inspection of his/her own respirator prior to each use. Personnel must complete the positive and negative pressure fit tests for cartridge respirators prior to each use. Each individual is responsible for cleaning and storage of assigned respirators.

## 6 EXPOSURE MONITORING

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### 6.1 VOC MONITORING

#### 6.1.1 VOC Monitoring Methods

Air monitoring will be conducted for the purpose of establishing or verifying work area protection levels, to designate appropriate work zones, and to supplement or trigger medical monitoring requirements. This monitoring will be performed by conducting representative monitoring for specific work tasks or groups of employees exposed to similar hazards under similar conditions.

An organic vapor monitor (OVM) with a flame ionization detector (FID) such as the Foxboro OVA, or a photoionization detector (PID) with a 10.2 electron volt (eV) bulb, such as the Photovac MicroTIP will be used to evaluate worker exposure to airborne concentrations of VOCs. The air in workers' breathing space will be monitored at least every half hour or at peak expected exposure times (i.e., excavating and spreading wet soil, breaking drill rods, etc.) using an OVM. A sufficient number of OVMs (a minimum of two) will be maintained on site to properly monitor tasks occurring in the active work areas in the Exclusion Zone (Section 7.3). All direct reading air-monitoring equipment will be calibrated and its batteries charged before and after each period of use, in accordance with standard industrial hygiene practice and each instrument's manufacturer's directions. These directions will be present for each instrument on site.

A properly calibrated and charged combustible gas indicator (Gastech Model 201, or equivalent) will also be used to monitor percentage of oxygen and LEL of combustible gases in air during confined-space entry operations or prior to entry into excavations (see Section 10).

A log of all air monitoring will be maintained for each instrument used. The log will include the date of the monitoring information, instrument type, calibration data, sample time, type and identification, monitoring results, and the personnel for which the monitoring applies. A copy of an Air Sampling Log is included in Attachment 2.

All monitoring results will be communicated to the individual monitored and to his or her employer, as appropriate. Written monitoring reports will be provided to the individual monitored and to his or her employer, as appropriate. In the case of exposure emergencies, a copy of the monitoring results will be provided to the attending physician.

## 6.1.2 VOC Action Levels

The following action levels were developed for exposure monitoring with OVA. The air monitoring data will determine required PPE levels at the site during all scheduled intrusive soil and groundwater activities. The action levels for VOCs are based on sustained readings indicated by the OVA. Air monitoring will be performed at up to 15-minute intervals. If during this time, sustained measurements are observed (average airborne concentration maintained for a period of 5 minutes in the breathing zone), the following actions will be instituted.

Activity/Location	Action Level <sup>1</sup>	Level of Personal Protection
All intrusive activities	0 to 10 ppm	Level D: No respiratory protection required.
	11 to 50 ppm	Level C: Half-face air-purifying respirator fitted with organic vapor filter cartridges
	51 to 100 ppm	Level C: Full-face air-purifying respirator fitted with organic vapor filter cartridges.
	> 100 ppm	Cease operations and evacuate work area. Contact Project CIH and HSC immediately.

<sup>1</sup> Parts per million (ppm) above background

All activities will cease if more than 100 parts per million (ppm) of total VOCs are detected by breathing zone monitoring with the PID/FID, and the HSC, Project Managers, and Project CIH, will be immediately contacted. Personnel will evacuate the area and follow the procedures outlined in Section 14 of this HSP. VOC action levels may be modified based upon verifiable field conditions.

## 6.2 RADIOLOGICAL MONITORING

### 6.2.1 Radiological Monitoring Methods

Radiological hazards will be monitored by several means. The presence of radium-226 and strontium-90 will be evaluated by monitoring with a hand-held radiation survey meter, scintillation counter having a 2-inch-by-2-inch, sodium-iodide crystal detector (Ludlum Model 19 survey meter and 44-10 detector, or equivalent, properly calibrated by the manufacturer), and cone shield. This equipment will be used to primarily monitor tasks such as clearing intrusive work areas and screening soil. A hand-held radiation survey meter and Geiger-Mueller pancake probe (Victoreen 450 P, or equivalent) will be used to evaluate gamma radiation contamination on surfaces (e.g., testing decontamination efficacy). A sufficient number of radiation survey

meter/detectors will be maintained on site (i.e., properly field response source tested) to properly monitor tasks. The RSO will conduct the radiological monitoring. An aerosol monitor (MIE PDM-3 MINIRAM) may also be used to evaluate airborne dust exposure. Personal thermoluminescent dosimeters (TLD) (Eberline, or equivalent) may also be required for some or all personnel.

Background was previously found to be 2,158 counts per minute (cpm) based on survey work completed at Site 1 (Site 1 and Site 2 Radiation Survey Report, June 1996, PRC Environmental Management, Inc.). Due to variable site conditions and equipment, background will be specifically determined for the project. Background will be checked at a minimum of 10 remote, surrounding locations that have similar site conditions (e.g., similar soil type, lack of an asphalt or concrete surface, etc.) A timed count of 1 minute will be used at each location. Background radionuclide measurements are also assumed to be equivalent to 0.02 milliroentgens per hour (mr/hr).

All proposed drilling, excavation, and soil and debris stockpile and spreading locations will be screened for the presence of radionuclides using radiation survey meter and scintillation counter prior to moving equipment into an area. The survey will be conducted by walking a series of traverses correlating to a 4-foot-center grid pattern on the area to be surveyed (0.5 minute count at each grid node). The detector will be held in close proximity to the soil.

Worker exposure to airborne concentrations of radioactive particles will be monitored at least hourly to measure the concentration of radioactive contaminants within the breathing zone of the workers.

Assuming site survey work detects the presence of radioactive contamination, workers and equipment will also be screened for radionuclides after decontamination, and prior to leaving the site. The person or item to be surveyed will be scanned at a rate of about 1 inch per second with the detector placed close to the surface.

Based on the results of the monitoring described above, the HSC may require TLD for some or all workers.

## 6.2.2 Radiological Action Levels

The following action levels were developed for exposure monitoring with the various devices. The monitoring data will determine required PPE levels at the site during all scheduled intrusive soil activities.

### Dose Rate

Activity/Location	Action Level <sup>1</sup>	Level of Personal Protection
All intrusive activities	background	Level D: No respiratory protection required.
	5 to 10 times background	Level C: Half-face air-purifying respirator fitted with HEPA filter cartridges
	> 10 times background	Cease operations and evacuate work area. Contact Project CIH and HSC immediately.

<sup>1</sup> Assumed to be 2158 cpm, or 0.02 mr/hr

### Surface Contamination

To evaluate decontamination efficacy the following criteria will be used.

	Fixed	Maximum	Removable
<b>Detector</b>	<b>Disintegrations per minute per 100 square centimeters (dpm/100 cm<sup>2</sup>)</b>		
pancake probe	1000	5000	500
	<b>counts per minute above background</b>		
gamma scintillator	Three times background		

### Air Monitoring

The following criteria will be used to evaluate the results of air sampling, if it is conducted. If site activities generate visible dust, wet control measures shall be implemented.

Activity/Location	Action Level <sup>1</sup>	Level of Personal Protection
All intrusive activities	< 5 mg/m <sup>3</sup>	Level D: No respiratory protection required.
	>5 mg/m <sup>3</sup>	Level C: Half-face air-purifying respirator fitted with HEPA filter cartridges
<b>Radioactivity Limits</b>		

Radionuclide	Concentration ( $\mu\text{Ci}/\text{cm}^3$ )	Annual Limit of Intake ( $\mu\text{Ci}$ )
radium	$2.7 \times 10^{-10}$	1.9 (oral) $5.4 \times 10^{-1}$ (inhalation)

At the discretion of the SSO, personal dosimetry may be required for some or all personnel. If used, when any detector exceeds background by a factor of 10, potential exposure in the work area will be re-evaluated.

## 7 SITE AND WORK AREA CONTROL MEASURES

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Site and work control measures must be implemented in each work area for site activities outlined in Section 3, to minimize potential worker exposure to any chemicals present and to limit chemical transport from the work area by personnel or equipment.

### 7.1 CONTROL SYSTEM

A control system is required to ensure that personnel and equipment working on hazardous waste sites are subjected to appropriate health and safety surveillance and work area access control.

The possibility of exposure or translocation of contaminants will be reduced or eliminated in a number of ways, including:

- Setting security or physical barriers at control points to regulate and/or exclude unnecessary personnel from the general area
- Minimizing the number of personnel and equipment in the work area, consistent with effective operations
- Establishing work zones, where appropriate, within the work area
- Conducting operations in a manner that will reduce the exposure of personnel and equipment
- Minimizing the airborne dispersion of contaminants (using dust control procedures)
- Implementing appropriate decontamination procedures for both personnel and equipment (Section 8)

### 7.2 SITE SECURITY

NAS Alameda has strict base security measures, which include Navy military police guards at base entrances and exits, and on-base patrols by Navy military police near the pilot project site. Security at the pilot project site will be maintained by NAS Alameda during non-work hours. To provide relevant information to security personnel any relevant Material Safety Data Sheets (MSDSs), and principal points of contact for the pilot project will be posted at the site.

The specific work areas for this investigation are normally open to base personnel. During this investigation, active work areas will be marked as described below to warn away foot traffic in the area.

Access inside the specified work area will be limited to authorized personnel. Only persons that have demonstrated compliance with the medical surveillance and training requirements of this HSP will be permitted in the designated, controlled work zones of the site. Logs of all personnel entering the controlled work zones will be maintained (Section 13).

At a minimum, all visitors entering the controlled work areas must wear the PPE required for pilot project personnel. Permission to enter the work area must be obtained from at least one of the personnel named in Section 2 of this HSP. All personnel entering controlled areas of the site will sign the signature page of this HSP, indicating they have read, and accept, the health and safety practices outlined in this HSP.

### **7.3 FIELD OPERATION WORK ZONES**

Work zones will be established based on anticipated contamination and projected work activities. Within these zones, prescribed operations will occur using appropriate PPE. Movement between zones will be controlled at checkpoints. The planned zones are:

- Exclusion Zone
- Contamination Reduction Zone
- Support Zone

These zones may be established using cones, barricades, tape, fencing, or other appropriate means.

#### **7.3.1 Exclusion Zone**

The Exclusion Zone is considered to have the highest potential for the presence of chemicals of concern. Within this area, the prescribed protection must be worn by personnel in the field, as determined by site conditions and air monitoring data. An entry checkpoint will be established at the periphery of the Exclusion Zone to control flow of personnel and equipment between contiguous zones and ensure that the procedures established to enter and exit each zone are followed.

The Exclusion Zone boundary will be conservatively established in the field by the HSC, or designated representatives, at the time the particular field activity is performed. Subsequent to initial operations, the boundary may be readjusted based on observations and/or measurements made in the field. The boundary will be physically secured and posted.

### **7.3.2 Contamination Reduction Zone**

The Contamination Reduction Zone will be established between the Exclusion and Support Zones. The purpose of this zone is to provide an area to prevent or reduce the transfer of chemicals that may have been picked up by personnel or equipment returning from the Exclusion Zone. All decontamination activities will occur in this area. The boundary between the Support Zone and the Contamination Reduction Zone is the contamination control line. This boundary separates the potentially contaminated area from the clean area of the Support Zone. Entry into the Contamination Reduction Zone from the clean area of the Support Zone will be through an access control point. Personnel entering at this station will wear the prescribed PPE for work in the Contamination Reduction Zone. Exiting the Contamination Reduction Zone to the clean area of the Support Zone requires the removal of any suspected or known contaminated PPE and compliance with the established decontamination procedures.

### **7.3.3 Support Zone**

The Support Zone is the outermost of the three concentric areas and is considered decontaminated, or the "clean area." It contains the field office for field operations and other elements necessary to support site activities. Normal street clothes or Level D PPE are appropriate apparel for this area.

### **7.3.4 Zone Dimensions**

Considerable judgment shall be used to determine zone dimensions to ensure a safe working area for each zone, balanced against practical work considerations. Physical and topographical barriers may constrain ideal locations and layouts. Field measurements combined with climatic conditions may, in part, determine the control zone distances. In work areas that do not require the use of chemical-resistant clothing or respirators, work zone procedures will still be necessary to limit the movement of personnel and retain adequate site control.

## 8 DECONTAMINATION PROCEDURES

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The pilot study will require different levels of decontamination that will depend on exposure to site contaminants. Consequently, decontamination for construction activities, and groundwater sampling will be more rigorous than for normal operations (e.g., changing O<sub>2</sub> cylinders), except for the maintenance or repair of contaminated operations equipment. Decontamination facilities will also differ for equipment and personnel at different stages of the project. The following describes general decontamination procedures.

### 8.1 GENERAL

As part of the system to prevent or reduce the physical transfer of contaminants by people and/or equipment from the work site, procedures will be instituted for decontaminating equipment and personnel leaving the Exclusion and Contamination Reduction Zones. These procedures will include decontamination of all personnel and equipment involved with intrusive activities at the site. Unless otherwise demonstrated, any item leaving the Exclusion Zone shall be considered contaminated. In general, decontamination at the work area may consist of rinsing equipment and PPE with a detergent solution followed by a clean water rinse. Reusable decontaminated PPE will be stored for air drying. The amount of decontamination necessary will be determined by the extent of contamination present during each site activity.

Decontamination is addressed in two ways: the physical arrangement and control of contamination zones, and the effective use of decontamination procedures.

The physical decontamination process uses cleaning solutions, followed by rinse solutions. Used solutions, brushes, sponges, and containers will be properly contained and disposed of.

### 8.2 EQUIPMENT DECONTAMINATION PROCEDURES

Equipment decontamination procedures are discussed in Section 7.1.1 of the pilot study Workplan.

### 8.3 PERSONAL DECONTAMINATION PROCEDURES

The amount of personal decontamination necessary will be dependent on the extent of contamination present and the level of PPE worn. It is anticipated that only Level D or Level C

PPE will be donned by site personnel during work activities. If higher levels of PPE are required due to unforeseen conditions at the site, this HSP will be modified to reflect the necessary procedures, at which time the Project CIH will also be consulted. Protective clothing and equipment will be replaced if the protective function is compromised through holes or tears. Respirator cartridges, if used, will be placed in a suitable disposal container on site at the end of each work day.

Standard decontamination procedures for Level D and Level C follow. Workers should use only applicable steps, dependent on the amount of PPE worn during work activities. Decontamination procedures may be modified, if necessary, with the approval of the Project CIH.

### **Level D Decontamination Sequence**

Level D decontamination will consist of the following steps:

- Equipment drop.
- Work glove removal; wash and rinse for non-disposable rubber or nitrile gloves.
- Inner glove removal and disposal.
- Field wash of hands and face.

### **Level C Decontamination Sequence**

Level C decontamination will consist of the following steps:

- Equipment drop.
- Outer glove wash and rinse for non-disposable gloves.
- Boot cover removal (if present).
- Outer glove removal.
- Suit removal.
- Boot wash and rinse.
- Inner glove wash and rinse.
- Respirator removal.
- Inner glove removal.
- Field wash for face and hands.

## **8.4 DECONTAMINATION DURING MEDICAL EMERGENCIES**

In the event of personal injury, first aid personnel must decide if the victim's injuries are potentially the type that would be aggravated by movement. If there is any doubt, or if the victim is unconscious and cannot respond, no attempt should be made to move the victim to the decontamination area unless there is another hazard that presents an imminent danger to the victim.

If indicated by site conditions, a surface radiation survey of the victim will be conducted before transport. If paramedics approve, the victim's PPE will be cut off in the Contamination Reduction Zone. If the decision is made not to remove the victim's PPE, he/she will be wrapped in an isolating barrier to protect the ambulance and crew during transport. The paramedics or emergency transport team will be notified of the chemical hazards present at the site so that they can take suitable precautions and inform the awaiting medical team. If the victim is contaminated with material that threatens to cause additional injury or immediate health hazards, the PPE will be carefully removed and the victim washed appropriately. In all instances, health considerations of an injured worker will take precedence over decontamination procedures.

## **8.5 DISPOSAL PROCEDURES**

Used but non-contaminated disposable protective clothing will be bagged and placed in drums for disposal as ordinary waste. Disposable sampling tools and visibly contaminated protective equipment shall be bagged and disposed of appropriately based on analytical results from soil or groundwater samples. Wash and rinse waters will be collected in drums and disposed of as described in Section 7.2 of the pilot study Workplan.

## **8.5 SANITATION**

Portable toilet facilities will be provided at the work site during construction activities. The facilities will be properly maintained (i.e., kept clean and supplied with toilet paper). Adequate washing facilities will be provided to address personal decontamination discussed above (Section 8.3). An adequate supply of potable water will also be supplied at the work site.

## 9 STANDARD SITE SAFETY PROCEDURES

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Pilot study field operations shall be conducted following the minimum safety practices described below.

### 9.1 SITE ENTRY

All field personnel will attend a site orientation meeting before work starts at the site. Thereafter, an on-site health and safety meeting will be held at the beginning of each work day to discuss pertinent health and safety issues. Attachment 3 contains a Safety Meeting Sign-off Sheet for persons who attended the meeting.

### 9.2 PERSONAL PRACTICES

- 1) Do not eat, drink, smoke, or chew gum or tobacco in the active work area Exclusion Zones.
- 2) Hands must be thoroughly washed when leaving a contaminated, or suspected contaminated, area before eating, drinking, or any other activities.
- 3) Whenever decontamination procedures for outer garments are in effect, the entire body should be thoroughly washed as soon as possible after the protective garment is removed.
- 4) No alcoholic beverages or illegal drugs will be allowed on the work site. Personnel under a physician's care and/or taking prescribed medicine must notify the HSC or appropriate designee. Prescribed drugs should not be taken by personnel in areas under conditions which the absorption, inhalation, or ingestion of toxic substances exists.

### 9.3 GENERAL SITE WORK

- 1) Changes in work practices or work rules will be implemented only after approval by the Project Manager and the corporate or designated site SSO.
- 2) Clean up at the end of the shift before leaving the work site, and always follow good housekeeping procedures during all phases of the work.
- 3) Removal of materials from protective clothing or equipment by blowing, shaking, or any means that may disperse materials into the air is prohibited.
- 4) Contaminated protective equipment shall not be removed from the regulated area until it has been properly containerized on site
- 5) Follow all emergency procedures explicitly.

- 6) Report all injuries and/or illnesses to your supervisor. This includes minor or slight injuries.
- 7) Be aware of site conditions, especially changes. If an unsafe condition is encountered, rectify or report it immediately.
- 8) Inform each other of subjective symptoms of chemical exposure such as headache, dizziness, nausea, and irritation of the respiratory tract.
- 9) Perform your job assignments according to the "buddy" system, maintaining a line-of-sight with co-workers at all times.
- 10) All operations personnel will, whenever possible, locate themselves so that they work upwind of excavation and soil spreading areas.
- 11) On-site personnel are to be thoroughly briefed about the anticipated hazards, equipment requirements, safety practices, emergency procedures and communications methods, initially and in daily briefings.
- 12) Always be over-prepared; come equipped with the proper tools, extra safety gear, extra supplies, the right vehicle, etc. Over-preparation minimizes jerry-rigging, which can be dangerous.

#### **9.4 SAFE WORKPLACE CONDITIONS**

- 1) A multipurpose portable fire extinguisher (at least one 20-pound ABC) and other emergency response equipment shall be located in the immediate vicinity of the work area.
- 2) Field equipment must be kept in good condition.
- 3) First aid supplies must be available at the work site in the Support Zone and/or in vehicles on site
- 4) Appropriate work areas designated for support, contamination reduction, and exclusion shall be maintained.
- 5) Cellular telephones and pagers shall be provided to facilitate communication in an emergency.
- 6) Incompatible materials shall be segregated and stored separately.
- 7) Have adequate emergency contingencies and equipment in place for even the shortest job.
- 8) Let others know where you will be before you leave. Have access to adequate communication while on the job.

#### **9.5 USE OF PROTECTIVE EQUIPMENT**

- 1) Use only the equipment for which you are trained and qualified.

- 2) Inspect, clean and maintain the protective equipment issued to you, each day of use. Report any noted defects in the equipment immediately to the designated site SSO.
- 3) Beards or long sideburns will not be allowed on sites where they interfere with respiratory protection. Trimmed sideburns and mustaches are acceptable. Report to work clean-shaven when there is a potential need for the use of respiratory protection.
- 4) Don all PPE before entering areas designated for wearing protective equipment.

## **9.6 WORK AROUND HEAVY EQUIPMENT**

- 1) Construction equipment always has the right-of-way over regular vehicles.
- 2) Listen for warning signals on, and yield to, construction equipment.
- 3) Equipment operators must pay deliberate attention to watching for workers on the ground who may be in their path, and provide warning to these people before moving.

## **9.7 SHEET-PILE DRIVING, EXCAVATION AND DRILLING OPERATIONS**

- 1) All the safety provisions of normal site operations should be followed. The work supervisor is responsible for the safety of everyone on the crew.
- 2) Use any and all resources to locate underground utilities prior to any excavation. These resources include Underground Service Alert (USA), site maps and drawings, other locators, site markings and conditions, and site personnel. Be especially wary of electrical, natural gas, and product lines.
- 3) Observe safe distances from overhead utilities of at least 20 feet.
- 4) Properly demarcate the area to be excavated with barricades, fencing, and/or flagging. Post warning signs conspicuously, and enforce them.
- 5) All drilling locations should be verified and marked by an authorized person.
- 6) Locate emergency shut-off valves and switches, and ensure all members of the crew know where they are and how to use them.
- 7) If an unknown is encountered, all operations will stop until the situation is evaluated. Augers should be left in the ground and cuttings and samples containerized.
- 8) Excavated soil or drill cuttings should be containerized or covered whenever feasible, and especially at the end of each work day. Drums should be labeled and placed in a secured area. Stockpiled soil area should be bermed to prevent run-on and run-off in case of rain.
- 9) Drilling materials such as augers and grout should be stored in a secured area.

- 10) Excavation materials and equipment such as buckets, or rippers should be stored in a secured area.
- 11) Hearing protection should be worn as necessary, especially during pile driving.
- 12) Loose or frayed clothing, or long hair, dangling ties, finger rings, etc., shall not be worn around moving machinery or other sources of entanglement. NEVER get hands near moving equipment parts.
- 13) During the presence of airborne contaminants emanating from a borehole or excavation, keep your face as far as possible from the hole.
- 14) Steam-cleaning of equipment should be performed with the appropriate protective equipment, which should always include foot, eye, and face protection. Never attempt to clean any body parts with pressure washers or steam cleaners.
- 15) Only authorized persons shall operate machinery or equipment.
- 16) Machinery shall not be serviced, repaired or adjusted while in operation, nor shall oiling of moving parts be attempted, except on equipment that is designed or fitted with safeguards to protect the person performing the work.
- 17) Where appropriate, lock-out/tag-out procedures shall be used.
- 18) Employees shall not work under vehicles supported by jacks or chain hoists, without protective blocking that will prevent injury if jacks or hoists should fail.
- 19) Air hoses shall not be disconnected at compressors until hose line has been bled.
- 20) All excavations shall be visually inspected before backfilling, to ensure that it is safe to backfill.
- 21) Excavating equipment shall not be operated near tops of cuts, banks, and cliffs if employees are working below.
- 22) Tractors, bulldozers, scrapers and carryalls shall not operate where there is possibility of overturning in dangerous areas like edges of deep fills, cut banks, and steep slopes.
- 23) When loading where there is a probability of dangerous slides or movement of material, the wheels or treads of loading equipment, other than that riding on rails, should be turned in the direction which will facilitate escape in case of danger, except in a situation where this position of the wheels or treads would cause a greater operational hazard.

## 9.8 USE OF TOOLS AND EQUIPMENT

- 1) Use the right tool for the job. Let the equipment work for you instead of trying to "muscle" the work.
- 2) All tools and equipment shall be maintained in good condition.

- 3) Damaged tools or equipment shall be removed from service and tagged "DEFECTIVE."
- 4) Pipe or Stillson wrenches shall not be used as a substitute for other wrenches.
- 5) Only appropriate tools shall be used for the job.
- 6) Wrenches shall not be altered by the addition of handle-extensions or "cheaters."
- 7) Files shall be equipped with handles and not used to punch or pry.
- 8) A screwdriver shall not be used as a chisel.
- 9) Wheelbarrows shall not be pushed with handles in an upright position.
- 10) Portable electric tools shall not be lifted or lowered by means of the power cord. Ropes shall be used.
- 11) Electric cords shall not be exposed to damage from vehicles.
- 12) In locations where the use of a portable power tool is difficult, the tool shall be supported by means of a rope or similar support of adequate strength.

## **9.9 CONFINED SPACES**

The procedures for confined spaces are found in Section 10. These must be followed explicitly. Entry into **any** excavation must be evaluated for confined space conditions, including oxygen deficiency, limited egress, etc. In addition, confined space entry must only be conducted with continuous on-site supervision by the SSO.

## **9.10 SOIL AND WATER SAMPLING**

- 1) Wear the appropriate protective gear for the operation.
- 2) Sample excavations remotely where possible. Where entry into excavations is necessary, evaluate the situation for proper sloping or shoring, confined space conditions, presence of equipment working in the area, etc.
- 3) Make sure others on site know when you will be entering into an excavation.
- 4) Be careful when opening wells, pipes, etc., that may have become pressurized. Vent off the pressure if possible, or provide shielding to avoid splashing of materials.

## **9.11 VEHICLE USE**

- 1) Only qualified, licensed drivers will be allowed to operate vehicles.
- 2) Seat belts should always be worn while traveling.
- 3) The use of alcohol or controlled substances while using vehicles is prohibited.

- 4) Vehicles should always be equipped with a first aid kit, fire extinguisher, road flares, and change for emergency phone calls.
- 5) Drivers are responsible for the maintenance of the vehicles. Any maintenance problems should be reported immediately. Serious maintenance problems, such as a flat or missing spare, should be rectified immediately before using the vehicle further.
- 6) Vehicles should be maintained in accordance with the manufacturer's specifications. Routine maintenance to be performed each time a vehicle is fueled includes:
  - Checking tire air pressure, inflating as necessary
  - Checking oil, radiator, automatic transmission, window washer fluid levels, filling as necessary.
  - Checking belts and hoses for cracks and leaks.
  - Checking lights, turn signals, backup lights.

## 9.12 COMPRESSED GASES

- 1) Compressed gases should be handled only by those knowledgeable in the equipment and in proper handling procedures.
- 2) COMPRESSED GAS EQUIPMENT SHOULD NEVER BE JERRY-RIGGED. DOING THIS CAN CAUSE SEVERE INJURY OR DEATH. Jerry-rigging includes the use of non-standard regulators, hoses, or fittings, and is especially dangerous if high- and low-pressure fittings are inter-mixed. Low-pressure fittings hooked into high-pressure applications will burst. Always use the proper CGA fittings for the gasses.
- 3) Secure all cylinders from falling. Small cylinders may be put securely in boxes or shelves. Large cylinders should be secured to a stable structure by the means of straps, ropes, or wire, or they may be laid down if they do not pose a tripping hazard and if they are secured from rolling.
- 4) Always cap the cylinder when moving or when it is not in use.
- 5) Use appropriate hazardous material shipping procedures when shipping cylinders.

## **10 CONFINED SPACE ENTRY PROGRAM**

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Confined spaces present a unique blend of hazards to the worker; failure to deal effectively with any one of these factors may result in serious injury, illness, or death. All confined space entries will be carried out in accordance with the requirements of the Cal/OSHA standards, 8 CCR 5156-5159 and the Federal standard, 29 CFR 1910.146.

### **10.1 DEFINITION**

A confined space is an area with limited means of ingress or egress which may be subject to hazardous concentrations of toxic chemicals which may result in illness or death, and where conditions may create an oxygen-deficient atmosphere. These locations are typically lacking in ventilation such that removal of hazardous materials or a supply of fresh air is insufficient.

### **10.2 PRE-ENTRY PROCEDURES**

For all confined space work, an entry checklist/permit system must be implemented. The purpose of the entry checklist is to assure that appropriate precautions are taken before entry. The checklist is to be completed by the Site Superintendent or the HSC and signed by the Site Superintendent, HSC, and the Project CIH prior to entry. The entry checklist is included in Attachment 3.

It is the responsibility of the Site Superintendent to make sure all adequate steps are taken to eliminate and/or control potential hazards. In addition, the Site Superintendent must make sure that all personnel understand the nature of the hazards which may remain, and the precautions to follow. The following steps must be completed prior to entry into a confined space:

- 1) The supervisor must complete the entry checklist/permit and advise the HSC and Project CIH of scheduled entry. Estimates of the number of employees involved, time required to accomplish the task, and the nature of the work must be documented on the entry checklist/permit.
- 2) The Project CIH must provide for training so that all employees have been made aware of the hazards associated with the job, how the hazards will be controlled, and the proper use of appropriate respiratory protection (as necessary).
- 3) If an employee working in a confined space can be injured by an accidental influx of steam, liquid, compressed air, or actuation of machinery, the energy source

must be disconnected, locked out and tagged out, or blinded before entry. These sources must remain out of service throughout the duration of the work.

- 4) The Site Superintendent must establish emergency procedures to be implemented in the event a problem develops.

### **10.3 ENTRY PROCEDURES**

#### **10.3.1 Air Testing**

Testing for flammability levels, toxic gases, and oxygen levels must be made before each entry. A properly calibrated and charged combustible gas indicator (Gastech Model 201, or equivalent) will first be used to test for combustible gas and oxygen by inserting the instrument probe into the confined atmosphere. If this first test registers concentrations greater than 10% of the LEL, additional ventilation is necessary before entry. If the initial test results are less than 10% of the LEL, but greater than zero, additional testing of the internal atmosphere is necessary for detection of organic vapors. The areas around all irregular surfaces of the interior should be tested if they can be reached without entry. If the atmosphere tests free of combustible gases and has an oxygen level between 19.5 and 22%, testing for toxic vapors must still be conducted. **IT IS IMPORTANT THAT SMOKING BE PROHIBITED DURING ENTRY AND WORK IN ANY CONFINED SPACE.**

Testing for toxic gas levels should begin with an FID such as the Foxboro OVA, or PID such as the HNu or Photovac MicroTIP. Background levels outside the confined space need to be obtained. After establishing the background level, the probe can be used to determine levels within the confined space. It is important that levels be measured throughout the depth of the structure.

Testing for Hydrogen Sulfide ( $H_2S$ ) is also necessary prior to entry, if there is reason to suspect the presence of this material. Draeger tubes or  $H_2S$  meters can determine the concentration of  $H_2S$  in the confined space.  $H_2S$  gas has a characteristic "rotten egg" odor. If this odor has been noticed in the area of the confined space, it should be anticipated that the detector will record positive. If the detector indicates the presence of  $H_2S$  at or above 10 ppm, SCBAs or supplied-air respirators with 5-minute escape SCBAs must be worn during the entry and work in the confined space. If the odor is present and seems to go away, employees should not assume the  $H_2S$  has gone away.  $H_2S$  will fatigue the sense of smell.

**AIR TESTING MUST CONTINUE DURING ENTRY AND WORK IN ANY CONFINED SPACE.**

### 10.3.2 Personal Protection

Appropriate action levels for use of protective clothing and respirators must be established by the SSO prior to entry, based upon the nature of the work required. Employees entering the confined space must be provided with all necessary protective clothing, protective gloves, and boots.

An attempt to establish mechanical ventilation adequate to eliminate the use of Level B respiratory protection shall be made.

Adequate means of emergency egress (ladders, etc.) must be provided. A safety harness attached to a life line must be worn when making an entry in a confined space. If it is not practical to keep the lines attached, the harnesses shall be worn and the lines kept ready at the confined space entry point. If the lines are not attached during work, another form of communication, either visual or voice, must be maintained. Wherever possible, entry should be made from the side of a work location. If access must be made through a vertical opening, a parachute harness and tripod with positive means of hoisting must be used.

### 10.3.3 Personnel Requirements

A minimum of three employees are required to be in attendance for a confined space entry. In addition to the employee actually entering the confined space, a standby observer and third employee must be present. As a minimum, the standby observer, and third employee must be trained in first aid and CPR.

**THE OBSERVER MUST REMAIN AT THE ENTRANCE TO THE CONFINED SPACE AND IS NOT TO BE SENT AWAY TO RUN ERRANDS, OBTAIN MATERIALS OR SUPPLIES, ETC., NO MATTER HOW SHORT A PERIOD OF TIME.** The standby observer must be physically capable and fully equipped to immediately carry out a rescue. Contact between the standby observer and the worker in the confined space (either visual, voice, or tie line) must be maintained at all times. Standby observers must be provided with, and use, all equipment (SCBA, etc.) necessary for emergency entrance into the confined space. **THE OBSERVER MAY ENTER THE CONFINED SPACE ONLY IN THE EVENT OF AN EMERGENCY.**

The third person may be working nearby, but must maintain line-of-sight contact with the standby observer. In the event of an emergency, the standby observer will indicate to the third employee that assistance is necessary. It is the function and responsibility of the third employee

to notify the appropriate site personnel for emergency assistance. After notification of site personnel, the third employee may provide assistance to the rescue.

### **10.3.4 Protection From Explosion**

Low voltage portable lights must be used in spaces which do not have adequate lighting.

In potentially flammable atmospheres, measures must be taken to reduce the possibility of sparks. Only explosion proof power tools, lights and non-sparking hand tools may be used in potentially flammable atmospheres.

Since static charges can ignite flammable vapors, the following conditions should be avoided: high velocity steam flow in a steam lance, high velocity compressed air for ventilation, high velocity flow of carbon dioxide fire extinguishers, clothing made of nylon, rayon, or dacron. These conditions and materials can produce static electricity. When ventilating a confined space, the metallic parts of the ventilating device and duct work must be electrically bonded to the confined space being ventilated.

Smoking or the carrying of matches into a confined space is prohibited.

All compressed gas cylinders (other than the respiratory equipment) should remain outside the confined space to help prevent accidental discharge, leakage, or rupture within the space.

All cutting torches must be removed from a confined space when not in use. Removal will prevent possible gas accumulation by leakage into the area.

When doing hot work in a confined space such as welding, cutting, burning, or other spark producing operations, combustible gas meter readings must be taken continuously. If the concentration of flammable vapors exceeds 10% of the LEL, stop the hot work until the confined space can be ventilated further to reduce the readings to less than 10% of the LEL.

## **10.4 CONFINED SPACE ENTRY TRAINING**

Prevention of employee injuries is expected to be accomplished when employees are properly trained and well equipped to recognize, understand, and control the hazards they may encounter.

All employees involved in entry into confined spaces, including emergency and rescue personnel, must receive instructions regarding the hazards, safety procedures, and the established company procedures which apply to the work. Review of these items must occur immediately prior to entry. The confined space training documentation form is attached in Attachment 3.

## 11 TRAINING REQUIREMENTS

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All personnel, including subcontractors and visitors conducting work in controlled areas of the site, must have completed the appropriate training as required by 29 CFR 1910.120 and 8 CCR 5192. Further site-specific training will be conducted by the HSC prior to the initiation of project activities. Daily tailgate safety meetings will also be held. Task-specific training will be conducted by the Project CIH, or designee, prior to the initiation of new activities, or activities such as confined-space entry.

### 11.1 HAZWOPER SAFETY TRAINING

General site workers, who include equipment operators, general laborers, and supervisory personnel engaged in hazardous substance removal or other activities that could expose them to hazardous substances and health hazards, must have successfully completed:

- An initial off-site, 40-hour Hazardous Waste Operations and Emergency Response (HAZWOPER) training course
- A minimum of three days actual field experience under the direct supervision of a trained, experienced supervisor

Occasional site workers, who include those only on site from time to time for specific limited tasks such as, but not limited to, groundwater level monitoring, must have successfully completed:

- A minimum of initial 24-hour off-site instruction
- A minimum of one day field experience under the direct supervision of a trained, experienced supervisor

Workers with 24 hours of training who become general site workers or who are required to wear respirators shall have the additional 16 hours and two days of training necessary for general site workers.

The training requirements for selected subcontractors will be waived if they only participate in non-intrusive activities where exposure to affected media is not anticipated. These subcontractors, however, will be required to have site-specific training (Section 11.2).

On-site managers and supervisors must have also completed eight additional hours of specialized hazardous waste operations management training.

In addition, each employee must have attended the eight (8)-hour annual refresher training course within twelve (12) months of any on-site work if their initial 40-hour or 24-hour training course was completed more than twelve months prior to the project. Appropriate evidence of training (certificates) will be required for all site personnel.

Personnel who conduct sampling and monitoring shall be trained in the operation of the equipment including, but not limited to, photoionization detectors (PIDs), flame ionization detectors (FIDs), radiation survey meters and detectors (scintillation and Geiger), and others such as combustible gas meters, as required. All monitoring equipment will be operated, and maintained, in strict accordance with the manufacturer 's specifications.

## **11.2 SITE-SPECIFIC SAFETY TRAINING**

Prior to the commencement of the project, the Project CIH and HSC will conduct a site safety briefing, which will include all personnel involved in site operations, including subcontractors. This meeting will include the following site-specific topics:

- Contents of this Health and Safety Plan
- Types of hazards at the site and means for minimizing exposure to them
- The type of monitoring that will be performed
- Personal protective equipment that will be used
- Action levels for upgrade and downgrade of personal protective equipment
- Site control measures and work zones
- Decontamination procedures
- Safe operating practices and communication and chain-of-command
- Emergency procedures and equipment (including the use of fire extinguishers)

In addition, the SSO will discuss the above topics with all personnel new to, or unfamiliar with, the site before they will be permitted to perform any activity at the site.

### 11.3 DAILY TAILGATE SAFETY MEETINGS

A daily tailgate safety meeting will be conducted by the Site Superintendent, HSC, or designee, prior to each day's activities to review pertinent safety issues, hazards anticipated during the day's activities, contingency procedures, and PPE to be worn. The meetings will be documented on a Tailgate Safety Meeting Form (Attachment 3).

In addition, task-specific safety training will be conducted by the Project CIH, or designee, prior to confined-space entry or the initiation of new site activities.

## 12 MEDICAL MONITORING REQUIREMENTS

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All personnel, including subcontractors and site visitors, who will or may work in the Exclusion Zone of the site must have fulfilled the appropriate medical monitoring requirements in accordance with 29 CFR 1910.120(f) and 8 CCR 5192(f). In general, these regulations require that medial surveillance be provided for those who:

- Are or may be exposed to hazardous substances at or above the permissible exposure limit, without regard to the use of respirators, for 30 or more days per year
- All employees who may be expected to use respirators will have a current medical examination (within one year) noting the employee's physical capability to use such equipment.
- All employees who are injured due to overexposure involving hazardous substances

Each individual must have completed an annual surveillance examination and/or an initial baseline examination within the last 12 months.

A signed physician's statement qualifying an individual for hazardous waste operations will be required for each site worker as part of the medical monitoring program. Documentation of physician's approval, spirometry testing, and blood testing will be maintained by the company or entity who employs the worker at the site. The medical requirements for selected subcontractors will be waived if they only participate in non-intrusive activities where exposure to affected media is not anticipated.

Site monitoring data will be maintained by the HSC for review by site personnel. After completion of the project, all pertinent health and safety and air monitoring records will be transferred to, and retained in, the project files.

### 13 SITE HEALTH AND SAFETY PROGRAM DOCUMENTATION

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The following list outlines the documentation requirements of the pilot study's health and safety program:

- This site-specific HSP
- Completed Health and Safety Plan Compliance Agreements stating that each field team member has read and understood the HSP and attended the requisite training
- Site Entry Log and Visitor's Log covering the duration of the project
- On-Site Safety Officer's Daily Log that includes pertinent observations such as direct-read instrumentation monitoring results and changes in implementation of the HSP (and their justification).
- Daily Tailgate Safety Meeting Forms signed by the attendees at each meeting and posted at the site. A file of tailgate safety meeting forms will be kept by the SSO. The SSO will conduct the tailgate safety meeting at the beginning of each shift, whenever new personnel arrive at the site, as conditions change, or as needed.
- Accident/Incident reports completed and filed with the Project CIH within 24 hours of the accident or incident, as discussed in Section 14.4.
- Health and safety inspection reports
- Logs of air monitoring, discussed in Section 6, including calibration logs.
- The results of respirator fit-tests, discussed in Section 5.4.
- Training certifications and medical records as noted in Section 11 and 12, respectively
- Documentation of contractor and subcontractor Health and Safety Programs
- Appropriate permits and notifications (e.g., those for excavations five feet deep or more, confined place entry, hot work, etc.)

Subcontractors are responsible for providing health and safety training to their employees and implementing a medical monitoring program. Documentation indicating compliance with OSHA-required health and safety training and medical monitoring requirements must be provided. This documentation will be in the form of a letter on company letterhead and must be signed by an authorized representative of the company. The letter will state that the named employees have been trained and medically certified to work on hazardous waste sites and are medically approved to wear respirators. The letter should be addressed to one of the Project Managers.

## 14 EMERGENCY PROCEDURES

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Possible emergency situations are generally considered to include worker injuries, contact with utilities, and acute exposure to contaminants. Worker injuries will be treated with first aid on site by the Site Superintendent or other trained worker, or by 911 emergency personnel if the injury requires immediate medical attention. If an injury requires more treatment than site first aid, but does not warrant a 911 call (as decided by the Site Superintendent), the Site Superintendent may decide to transport the individual to Alameda Hospital. Emergency phone numbers and routes to the East Gate and Hospital are in Attachment 4. Worker injuries shall be reported to the HSC and the Project CIH as soon as it is safe to do so.

### 14.1 GENERAL

- Before beginning field operations, an emergency medical assistance network will be established. The fire department, ambulance, and hospital with an emergency room are identified (with telephone numbers) in Attachment 4.
- Telephone numbers and locations (including the fastest routes) of the emergency room facilities will be posted at the site.
- A vehicle will be available on site during all activities to transport injured personnel to the identified emergency medical facilities.
- Items to be maintained in the active work area include: drinking water, wash water for hands, face, and eyes, mobile phone, charged 20-pound dry chemical fire extinguisher, an adequately stocked first aid kit, and air horn.
- The SSO will be the lead person in all emergency situations.
- Evacuation routes will be established by the SSO, and communicated to all personnel during the tailgate safety meeting conducted before each work shift.
- Either the SSO or the supervisor in the Exclusion Zone will carry a compressed air horn. In the event of fire, hazardous substance spill, vapor release, or other hazardous event, three short blasts will signal all personnel to evacuate the site. All personnel evacuating the Exclusion Zone will proceed to a predetermined location upwind, where the SSO will conduct a head count and provide further instructions.
- The SSO will be responsible for assuring that all site personnel understand emergency signals and procedures.

### 14.2 LIFE-THREATENING INJURIES, EXPOSURES, OR ILLNESSES

In the event of a life-threatening emergency, the injured person shall be given immediate first aid and emergency medical services will be contacted by dialing 911. The individual rendering first

aid shall follow directions given by emergency medical personnel via telephone. Two people certified in first aid and cardiopulmonary resuscitation (CPR) techniques, and trained in bloodborne pathogens will be present on site at all times during construction activities.

### **14.3 NON-LIFE-THREATENING INJURIES, EXPOSURES, OR ILLNESSES**

The extent and nature of the victim's injuries will be assessed and first aid will be rendered as appropriate. If necessary, the individual may be transported to Alameda Hospital. The mode of transportation and the eventual destination will be based on the nature and extent of the injury. Attachment 4 contains maps showing the location and route to the hospital.

### **14.4 GENERAL FIRST AID PROCEDURES**

#### **Skin and Eye Exposure**

Flush eyes immediately with a copious amount water. Remove all contaminated clothing. Wash affected skin with soap and rinse with a copious amount of water. Watch for signs of skin irritation. Seek medical attention at first signs of irritation.

#### **Inhalation**

Move victim to fresh air. Give artificial respiration if necessary. Observe victim for signs of shock. Seek medical attention immediately.

#### **Ingestion**

Call Poison Control Center. Seek immediate medical attention. If possible, a sample of ingested material will be collected and transported to hospital with the victim.

### **14.5 FIRE OR EXPLOSION**

Contact the Fire Department immediately in case of explosions or fires. Upon arrival of the Fire Department, the SSO, or designated representative, shall advise the commanding officer of the location, nature, and identification of hazardous materials on site. Only trained, experienced fire fighters should attempt to extinguish substantial fires at the site. Site personnel should not attempt to fight fire, unless properly trained and equipped to do so.

## 14.6 UNDERGROUND UTILITIES

In the event that an underground conduit is damaged during intrusive soil activities, all mechanized equipment will immediately be shut off until the nature of the utility can be determined and potential hazards assessed. Depending on the nature of the broken conduit (e.g., natural gas, water, communications, or electricity), contact the appropriate local utility.

## 14.7 SPILLS OR LEAKS

Locate the source of the leak and determine the hazard to the health and safety of site workers and the public. Attempt to stop or reduce the flow if it can be done without risk to personnel. Isolate the spill area and do not allow entry by unauthorized personnel. De-energize all sources of ignition within 100 feet of the spill, including vehicle engines. The Site Superintendent, HSC, and the Project CIH shall be advised immediately of the location, size, and nature of the spill. Should any spill be of the nature or extent that it cannot be safely contained, or poses an imminent threat to human health or the environment, call the NAS Alameda Hazardous Response Team as soon as possible. Spill containment and clean up measures listed below are examples of responses to spills.

- Upright or rotate containers to stop the flow of liquids. This step may be accomplished as soon as the spill or leak occurs, providing it is safe to do so.
- Sorbent pads, booms, or adjacent soil may be used to dike or berm materials, subject to flow, and to solidify liquids.
- Sorbent pads, soil, or booms, if used, shall be placed in appropriate containers after use, pending disposal.

## 14.8 EVACUATION

The SSO shall designate evacuation routes and refuge areas to be used in the event of an emergency. Site personnel shall stay upwind of vapors or smoke and upgradient of spills. If workers are in an Exclusion or Decontamination Reduction Zone at the start of an emergency, they should exit through the established decontamination areas whenever possible. If evacuation cannot be done through an established decontamination area, site personnel shall go to the nearest safe location and remove contaminated clothing there or, if possible, leave it near the Exclusion Zone.

All personnel shall assemble at the predetermined refuge following evacuation and decontamination. The SSO, or designated representative, shall count and identify personnel to ensure that all have been evacuated safely.

#### **14.9 ACCIDENT/INCIDENT REPORTING**

Any incident or accident shall be reported to a Project Manager and the HSC. An Accident/Loss Report shall be forwarded to the Project CIH and the Navy's Engineering Filed Activities (EFA) West Contracting Officer (see Pilot Project Contacts list in Attachment 4, Emergency Information). A report must be completed for the following circumstances:

- Injury to personnel of any magnitude
- Toxic agent exposure of inadequately protected personnel
- Radiation contamination exposure of inadequately protected personnel
- Fire or explosion of any magnitude
- Near miss incidents in which an injury could have occurred and which requires either preventive or corrective action to prevent re-occurrence
- Tool or equipment failure that results or could result in injury
- Any motor vehicle accident, regardless of fault
- Any accident that results in hospitalization of three or more, or the death of anyone at the work site
- Damage to property including land, equipment, buildings, or other possessions.

A copy of the Accident/Loss Report is included in Attachment 3. This report must be filed with the Project CIH and EFA West Contracting Officer within 24 hours of the accident or loss.

## 15 LIMITATIONS AND ADDENDA

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The Site Health and Safety Plan (HSP) for the funnel and gate remediation demonstration project, Site 1, NAS Alameda has been prepared based on currently available information. Addenda to this plan will be made, if necessary, as more information is gathered. These addenda, noted below, are to be incorporated into the HSP and made available to all involved personnel.

_____	_____	_____
Ms. Irene Fanelli, CIH	Addenda	Date
_____	_____	_____
Ms. Irene Fanelli, CIH	Addenda	Date
_____	_____	_____
Ms. Irene Fanelli, CIH	Addenda	Date
_____	_____	_____
Ms. Irene Fanelli, CIH	Addenda	Date
_____	_____	_____
Ms. Irene Fanelli, CIH	Addenda	Date

**ATTACHMENTS**

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# 1 HAZARD SUMMARY TABLES

**Table 1 - Physical, Environmental & Biological Hazard Summary**

Hazard	Analysis/Mitigation	Action/PPE	Activity
<b>PHYSICAL</b>			
Utilities	Locate all utilities Mark & protect underground utilities Maintain 20 ft. from overhead lines Disconnect/de-energize as appropriate	LEVEL D	Installing sheet piles Excavating soil and debris Installing upgradient monitoring wells
Construction Equipment	Proper training & awareness Eye contact & standard hand signals Use line of site to operator No nonessential people in area Backup alarms as appropriate	LEVEL D w/ hearing protection Traffic safety vests as appropriate	Staging equipment Handling sheet piles and granular materials Installing sheet piles and sealing joints Excavating soil and debris Placing backfill materials and monitoring points Flooding the system with uncontaminated water Removing sheet piles
Drilling Operations	Proper training & awareness See also utility hazard above	LEVEL D w/ hearing protection	Installing upgradient monitoring wells
Noise	Wear hearing protection for activities at >85dBA	LEVEL D w/ hearing protection	Installing sheet piles and sealing joints Installing upgradient monitoring wells Operating other heavy construction equipment Removing sheet piles
Excavations	Protect from inadvertent entry Barricade/cover as appropriate No entry to excavations greater than 4 ft. without proper permit Maintain adequate means of egress	LEVEL D Appropriate shoring, sloping or benching Cal/OSHA Excav. Safety Standard 8CCR 1541 Harness and line available CIH approval before entering excav. >4ft.	Excavating soil and debris Placing backfill materials and monitoring points
Confined Space Entry	Evaluate all excavations as confined space Appropriate monitoring and entry procedures	Defined by CIH as appropriate to evaluation No entry without continuous on-site supervision by HSC or appropriate substitute Monitor with OVA & LEL meters	Excavating soil and debris Placing backfill materials and monitoring points
Materials Handling	Mechanical handling of material Certified equipment and trained operators  Proper lifting technique for manual handling	LEVEL D Site Superintendent approval of materials handling plan Sturdy gloves, steel-toe boots	Staging equipment Handling sheet piles and granular materials Installing sheet piles and sealing joints Placing backfill materials and monitoring points Removing sheet piles

**Table 1 - Physical, Environmental & Biological Hazard Summary**

<b>Hazard</b>	<b>Analysis/Mitigation</b>	<b>Action/PPE</b>	<b>Activity</b>
Hot Work	Proper training No hot work without proper environment / safety check, permit, and fire watch	LEVEL D and non-flammable gloves, apron, suitable head and eye protection Monitor with OVA & LEL meters	Handling sheet piles and granular materials Installing sheet piles and sealing joints Placing backfill materials and monitoring points
Slip, Trip, and Fall	Use good housekeeping Mark or fill obvious holes	LEVEL D Steel-toe boots, adequate work clothes	All project activities
Electric Shock	Ground, insulate, de-energize	LEVEL D	Operating the pilot system
Compressed Gas	Proper training Proper lines and fittings Secure cylinders from falling Keep cap on cylinder when not in use	LEVEL D	Operating the pilot system
<b><u>ENVIRONMENTAL</u></b>			
Heat Stress	Take breaks, replenish fluids, rotate personnel	Water available	All project activities
Inclement Weather / Cold Stress	Training regarding exposure to cold or wet conditions Breaks, hot fluids, rotate personnel	Wear appropriate rain-protection clothing and boots	All project activities
<b><u>BIOLOGICAL</u></b>			
Insect Bites	Awareness, especially of allergic reactions	Proper first aid	All project activities

## 2 CHEMICAL HAZARDS

## 2 CHEMICAL HAZARDS

The following descriptions are presented for chemicals that may be present at the site. Each chemical description includes physical and odor recognition characteristics, the health effects associated with exposure, and exposure limits expressed as an 8-hour time-weighted average (TWA). Federal OSHA (OSHA) permissible exposure limits (PELs; located in 29 CFR 1910.1000); California OSHA (Cal/OSHA) PELs (located in 8 CCR 5155); and the American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit values (TLVs) are also presented.

### **Benzene**

Benzene is a clear, colorless, highly flammable and toxic liquid with a characteristic aromatic odor. It is a severe eye and moderate skin irritant. Human effects by inhalation and ingestion include: euphoria, changes in sleep and motor activity, nausea and vomiting, other blood effects, dermatitis, and fever. In industry, inhalation is the primary route of chronic benzene poisoning. If the liquid is aspirated into the lung it may cause pulmonary edema. Poisoning by skin contact has also been reported. Exposure to high concentrations (3,000 parts per million [ppm]) may result in acute poisoning, which is characterized by the narcotic action of benzene on the central nervous system. Chronic poisoning occurs most commonly through inhalation and dermal absorption. Benzene is a known human carcinogen that can cause leukemia. The ionization potential (IP) for benzene is listed as 9.24 electron volts (eV).

The OSHA PEL is listed as 1 ppm.

The Cal/OSHA PEL is listed as 1 ppm.

The TLV is listed as 0.3 ppm.

Note: Published exposure limits designate a skin notation that indicates dermal contact can contribute to the overall exposure.

### **Chlorobenzene**

Chlorobenzene is a clear, colorless, highly flammable and toxic liquid with a mild aromatic (almond-like) odor. Chlorobenzene is non-carcinogenic. This chemical is harmful if swallowed, inhaled or absorbed through skin. Vapor or mist is irritating to the eyes, mucous membranes and upper respiratory tract. Exposure to high concentrations may result in acute poisoning, which is characterized by the narcotic action of chlorobenzene on the central nervous system. Exposure may also cause kidney and liver damage. Chronic poisoning occurs most commonly through inhalation and dermal absorption. The IP for chlorobenzene is listed as 9.44 eV.

The OSHA PEL is listed as 75 ppm.

The Cal/OSHA PEL is listed as 75 ppm.

The TLV is listed as 10 ppm.

### **1,2-Dichloroethene (1,2-DCE)**

1,2-DCE, a mixture of the cis and trans isomers, is a liquid with a slightly acrid odor. Available data conflict on whether there is significant difference in the toxicity from short-term exposure to trans-1,2-DCE versus cis-1,2-DCE. Narcosis has been identified as the important effect of inhalation. The IP for 1,2-DCE is listed as 9.65 eV.

The OSHA PEL is listed as 200 ppm.

The Cal/OSHA PEL is listed as 200 ppm.

The TLV is listed as 200 ppm.

### **Ethylbenzene**

Ethylbenzene is a clear, colorless liquid. It is mildly toxic by inhalation and skin contact. Inhalation can cause eye, sleep, and pulmonary changes. It is an eye and skin irritant at levels as low as 0.1% (1,000 ppm) of the vapor in air. At higher concentrations, it is extremely irritating at first, then can cause dizziness, irritation of the nose and throat, and a sense of constriction in the chest. Exposure to high concentrations of ethylbenzene vapor may result in irritation of the skin and mucous membranes, dizziness, irritation of the nose and throat, and a sense of constriction of the chest. The IP for ethylbenzene is listed as 8.76 eV.

The OSHA PEL is listed as 100 ppm.

The Cal/OSHA PEL is listed as 100 ppm.

The TLV is listed as 100 ppm.

### **Tetrachloroethene (Perchloroethylene or PCE)**

Tetrachloroethene (also known as perchloroethylene) is a colorless liquid with an ether-like odor. Short-term exposure to PCE may cause headaches, nausea, drowsiness, dizziness, uncoordination, unconsciousness, irritation of the eyes, nose, and throat, and flushing of the face and neck. In addition, it may cause liver damage with such findings as yellow jaundice and dark urine. Liver damage may become evident several weeks after exposure. Skin contact may create a dry, scaly, itchy dermatitis. PCE is classified by the U.S. Environmental Protection Agency as a Group B2 probable human carcinogen. The IP for PCE is listed as 9.32 eV.

The OSHA PEL is listed as 100 ppm.

The Cal/OSHA PEL is listed as 25 ppm.

The TLV is listed as 25 ppm.

### **Toluene**

Toluene is a colorless liquid with a benzol-like odor. Human systemic effects of exposure to toluene include: central nervous system changes, hallucinations or distorted perceptions, motor activity changes, psychophysiological changes, and bone marrow changes. It is a severe eye irritant and an experimental teratogen. Inhalation of high vapor concentrations may cause impairment of coordination and reaction time, headaches, nausea, eye irritation, loss of appetite, a bad taste in the mouth, and lassitude. The IP for toluene is listed as 8.82 eV.

The OSHA PEL is listed as 200 ppm.  
The Cal/OSHA PEL is listed as 50 ppm.  
The TLV is listed as 50 ppm.

Note: Published exposure limits designate a skin notation that indicates dermal contact can contribute to overall exposure.

### **Trichloroethene (TCE)**

TCE is a clear, colorless liquid with a characteristic chloroform odor. It is a mildly toxic VOC that is also an experimental carcinogen, tumorigen, and teratogen. It can cause eye effects, hallucinations, and distorted perceptions when inhaled. TCE is an eye and severe skin irritant. Exposure to vapors may cause eye, nose, and throat irritation. Prolonged inhalation of moderate concentrations of vapor may cause headaches and drowsiness. Inhalation of high concentrations may cause narcosis and anesthesia. Severe, acute exposure can result in cardiac failure. Significant chronic exposure may damage liver and other organs. Prolonged repeated skin contact with the liquid may cause irritation and dermatitis. The IP for TCE is listed as 9.45 eV.

The OSHA PEL IS listed as 100 ppm.  
The Cal/OSHA PEL is listed as 25 ppm.  
The TLV is listed as 50 ppm.

### **Vinyl Chloride**

Vinyl chloride is a colorless gas with a sweet odor. It is a known human carcinogen that causes liver and blood tumors. It is a poison by inhalation. It is also a severe skin and eye irritant and can cause skin burns by rapid evaporation and consequent freezing. Chronic exposure has also shown liver injury. Short-term exposure to vinyl chloride can cause dizziness, light-headedness, nausea, dullness of visual and auditory responses, drowsiness, and unconsciousness. Irritation of the skin and eyes can also occur. Skin contact with the liquid can cause frostbite. Vinyl chloride is classified by the U.S. Environmental Protection Agency as a Group A human carcinogen. The IP for vinyl chloride is listed as 9.99 eV.

The OSHA PEL is listed as 1 ppm.  
The Cal/OSHA PEL is listed as 1 ppm.  
The TLV is listed as 5 ppm.

Note: Published exposure limits designate a skin notation that indicates dermal contact can contribute to overall exposure.

### **Xylene**

Xylene is a clear, colorless liquid. It exhibits the general chlorinated hydrocarbon central nervous system effects, olfactory (smell) changes, eye irritation, and pulmonary changes. It is a severe skin irritant. There are three isomers, ortho, meta, and para. Exposure to high concentrations of xylene vapor may result in eye and skin irritation. Eye irritation may occur at

concentrations of about 200 ppm. The IP is listed as 8.56 eV for o- and m-xylene, and 8.44 eV for p-xylene.

The OSHA PEL is listed as 100 ppm.

The Cal/OSHA PEL is listed as 100 ppm.

The TLV is listed as 100 ppm.

**3 FORMS**











# CONFINED SPACE ENTRY CHECKLIST

PROJECT NUMBER AND NAME \_\_\_\_\_

JOB DESCRIPTION \_\_\_\_\_

EMPLOYEES ASSIGNED \_\_\_\_\_ DATE \_\_\_\_\_

\_\_\_\_\_ TIME \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

## PRECAUTIONS TO BE TAKEN

1. Have employees been trained? \_\_\_\_\_

2. Combustible gas level (recorded in percent LEL) \_\_\_\_\_

3. Oxygen level (recorded in percent of atmosphere) \_\_\_\_\_

4. Organic Vapor Analyzer reading (ppm total hydrocarbon)  
above background level \_\_\_\_\_

5. Draeger tube reading for H<sub>2</sub>S \_\_\_\_\_

Mechanical ventilation used \_\_\_\_\_

7. Electrical equipment grounded and insulated \_\_\_\_\_

8. Measures implemented to reduce static charge \_\_\_\_\_

9. Protective equipment necessary \_\_\_\_\_

Type of respiratory protection \_\_\_\_\_

Protective clothing \_\_\_\_\_

Gloves \_\_\_\_\_

Boots \_\_\_\_\_

10. Emergency Procedures

Safety harnesses/life lines \_\_\_\_\_

Self-contained respiratory protection \_\_\_\_\_

Communications \_\_\_\_\_

Observation \_\_\_\_\_

Fire extinguisher \_\_\_\_\_

\_\_\_\_\_  
Supervisor

\_\_\_\_\_  
Health and Safety Officer





ACCIDENT/LOSS REPORT

\*\*\* THIS REPORT MUST BE COMPLETED IN FULL AND SUBMITTED WITHIN 24 HOURS OF THE ACCIDENT/LOSS TO PERSONNEL.

Date of Accident \_\_\_\_\_

Company \_\_\_\_\_

Time Occurred \_\_\_\_\_

Project Number \_\_\_\_\_

Where Occurred \_\_\_\_\_

Name and Location of Project \_\_\_\_\_

PART I - PROPERTY DAMAGE/LOSS

Equipment Involved \_\_\_\_\_

Names of Persons Involved \_\_\_\_\_

Describe Incident/Damage \_\_\_\_\_

Estimate Cost of Damage \_\_\_\_\_

Police Report must be filed on all automobile accidents and on all equipment thefts. Copy of Policy Report must also be submitted.

DRAW DIAGRAM OF INCIDENT ON THE BACK OF THIS REPORT

PART II - PERSONAL INJURY - Fill out only if personal injury occurred.

Name of Employee Injured \_\_\_\_\_ Age \_\_\_\_\_ Soc. Sec. # \_\_\_\_\_

Address \_\_\_\_\_ Occupation \_\_\_\_\_

What was employee doing when injured? \_\_\_\_\_

Exact location where injury occurred (station no. or prominent landmark) \_\_\_\_\_

Was place of accident or exposure on job site? \_\_\_\_\_

Describe injury \_\_\_\_\_

How did injury occur? \_\_\_\_\_

Did employee see a doctor or go to the hospital? \_\_\_\_\_ If yes, give name, address, and phone number of doctor or hospital \_\_\_\_\_

Did employee lose time? If yes, how long, date returned to work \_\_\_\_\_

Number of days employee usually worked a week \_\_\_\_\_ Number of hours worked \_\_\_\_\_

Date of birth \_\_\_\_\_ Wage rate \_\_\_\_\_ hr. \_\_\_\_\_ wk. \_\_\_\_\_ mo. \_\_\_\_\_ yr. Phone No. \_\_\_\_\_

(Continued on reverse side)

## 4 EMERGENCY INFORMATION

## 4 EMERGENCY INFORMATION

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### DIRECTIONS TO THE EAST GATE

From the work area, proceed north on the Perimeter Road. The road curves around to the east, then south to intersect Avenue A. Turn left on Avenue A. Turn right on Fifth Street. Turn left on Atlantic Avenue, which exits the site through the East Gate. A map to the East Gate is attached.

### DIRECTIONS TO ALAMEDA HOSPITAL

Exit the NAS Alameda through the East Gate (described above). Cross Main Street, continue east on Atlantic Avenue. Turn right onto Webster Street. Turn left onto Central Avenue. Turn right onto Sherman Avenue, then left onto Clinton Avenue. The hospital is on the right side between Chestnut Street and Willow Street. The emergency room entrance is on the western side of the hospital. The hospital address is 2070 Clinton Avenue. A map to the hospital is attached.

### EMERGENCY PHONE NUMBERS

#### Emergency Contacts

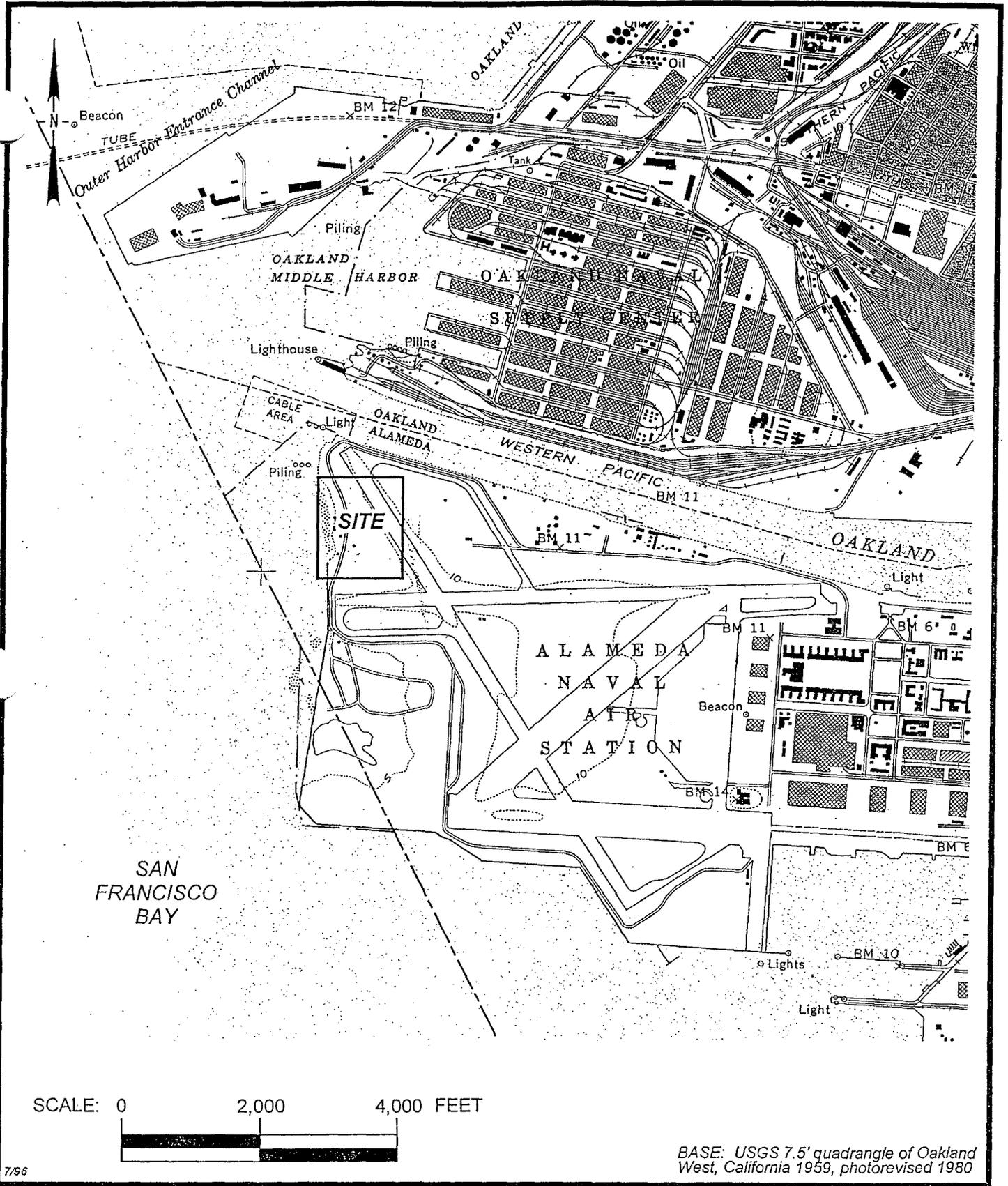
NAS Alameda Fire, Paramedics, Hazardous Response .....	911
Alameda Naval Air Station Fire Chief (business line) .....	510/263-3276
Ambulance .....	510/263-4444
Security .....	510/263-3758
.....	or 510/263-3767
Poison Control Center.....	800/356-3129
.....	or 510/476-6600

#### Hospital Facilities

Alameda Hospital.....	510/522-3700
Emergency Room.....	510/523-4357

#### Pilot Project Contacts

Einarson, Fowler & Watson.....	415/843-3828
Irene Fanelli, CIH, EHC .....	415/347-9205
Ken Spielman, EFA West.....	415/244-2539
LCDR Lino Fragoso, RASO.....	805/887-4692
Lieutenant Mike Baldwin .....	510/263-3706 x 15



796

 EINARSON  
FOWLER & WATSON

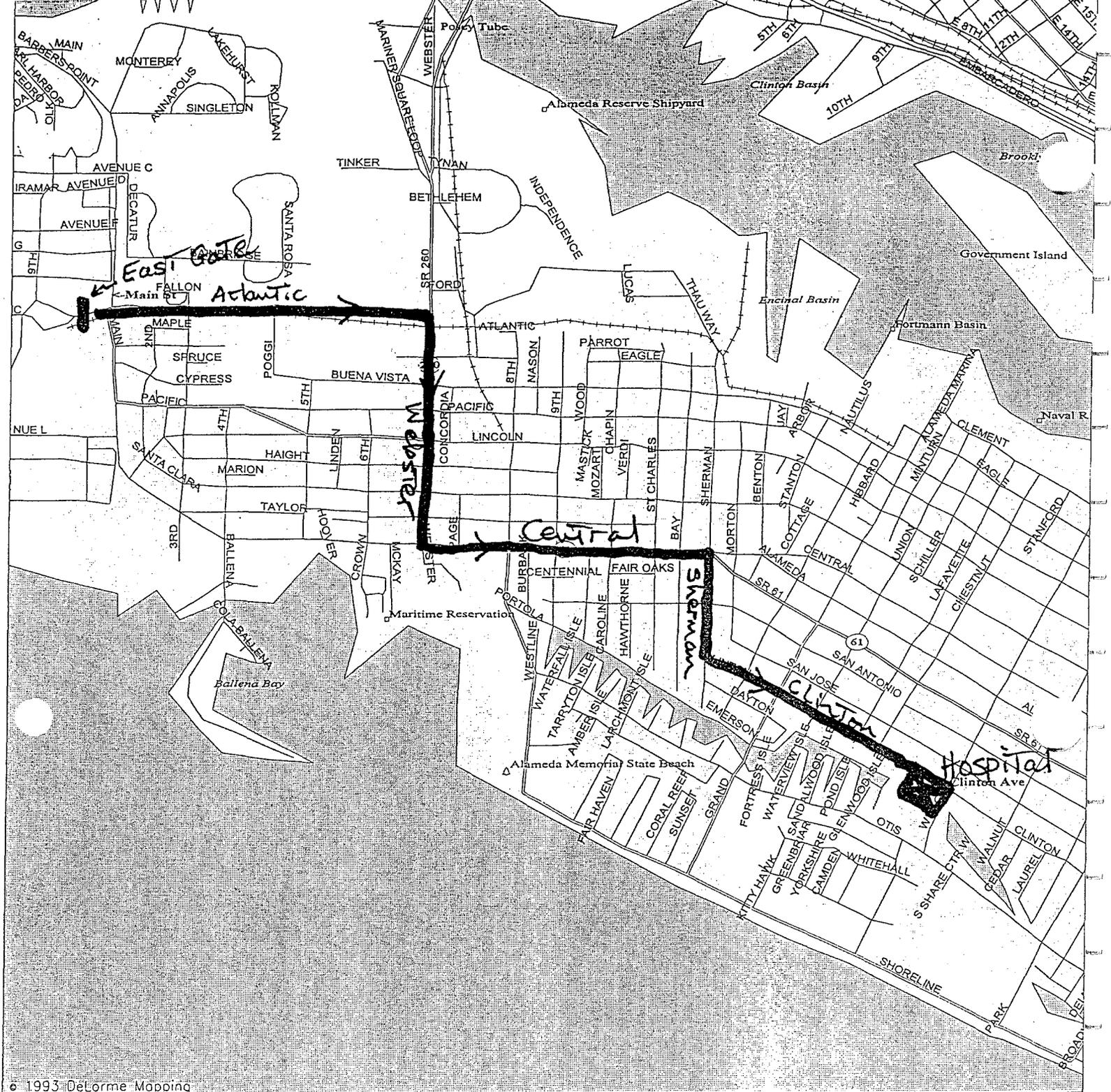
HYDROGEOLOGIC INVESTIGATION  
ALAMEDA NAVAL AIR STATION  
ALAMEDA, CALIFORNIA

SITE LOCATION MAP

FIGURE

1

PROJECT NO.  
ANA101



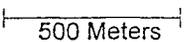
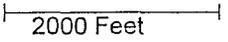
© 1993 DeLorme Mapping

**LEGEND**

- Population Center
- State Route
- ◇ Town, Small City
- ^ Park
- Street, Road
- == Major Street/Road
- == State Route
- == Interstate Highway

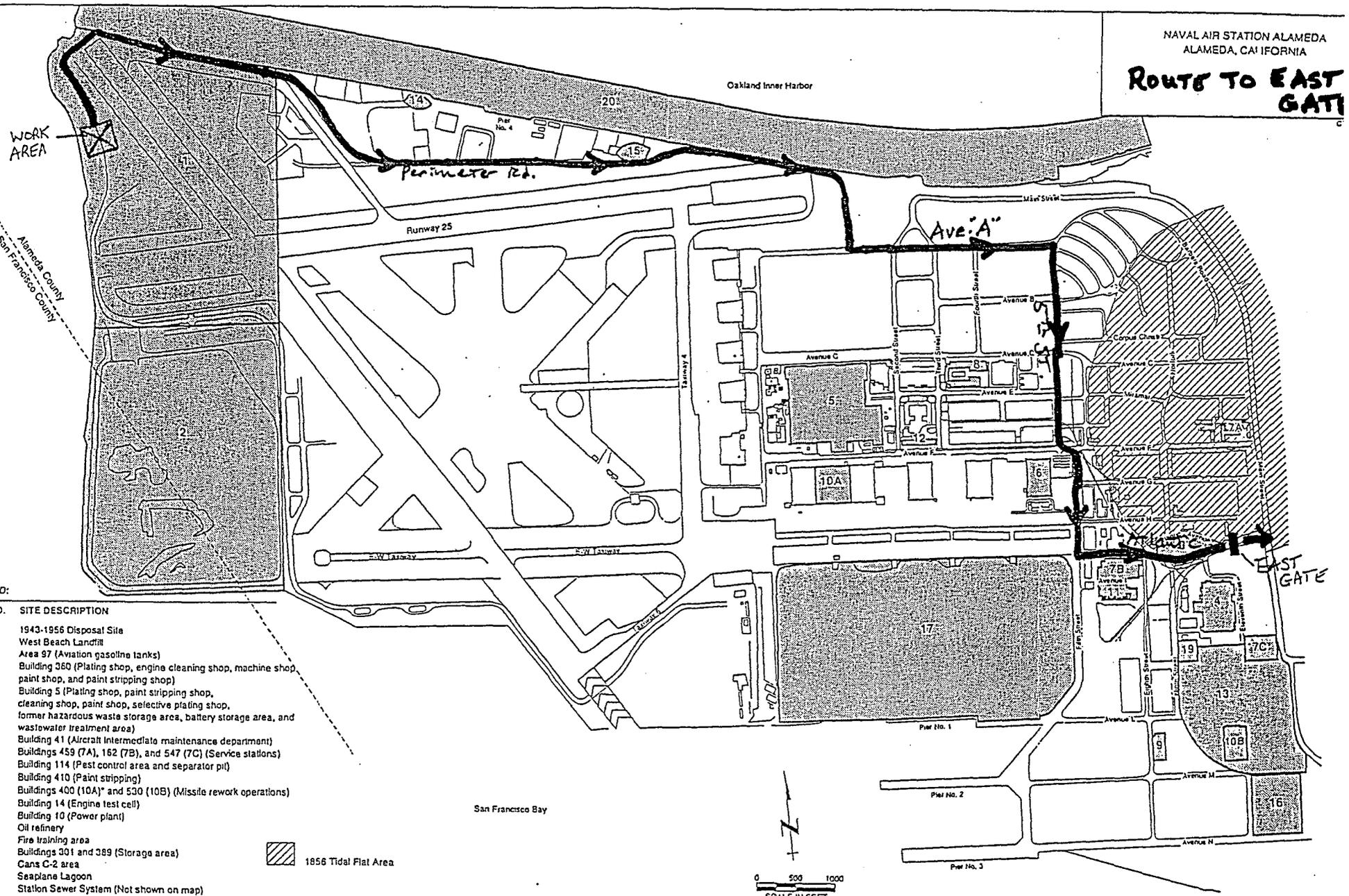
- +++ Railroad
- River
- Open Water

Scale 1:21,875 (at center)



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Fri Jul 19 11:07:22 1996

# ROUTE TO EAST GATE



**LEGEND:**

SITE NO.	SITE DESCRIPTION
1*	1943-1956 Disposal Site
2*	West Beach Landfill
3	Area 97 (Aviation gasoline tanks)
4	Building 360 (Plating shop, engine cleaning shop, machine shop, paint shop, and paint stripping shop)
5	Building 5 (Plating shop, paint stripping shop, cleaning shop, paint shop, selective plating shop, former hazardous waste storage area, battery storage area, and wastewater treatment area)
6	Building 41 (Aircraft intermediate maintenance department)
7	Buildings 459 (7A), 162 (7B), and 547 (7C) (Service stations)
8	Building 114 (Pest control area and separator pit)
9	Building 410 (Paint stripping)
10	Buildings 400 (10A)* and 530 (10B) (Missile rework operations)
11	Building 14 (Engine test cell)
12	Building 10 (Power plant)
13	Oil refinery
14	Fire training area
15	Buildings 301 and 389 (Storage area)
16	Cans C-2 area
17	Seaplane Lagoon
18	Station Sewer System (Not shown on map)
19	Yard D-13 (Hazardous waste solvents)
20	Estuary (Oakland Inner Harbor)

1856 Tidal Flat Area

\* Phases 5 and 6 sites

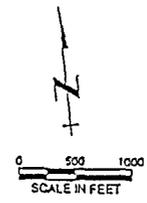


Table 2 - Chemical & Radiological Hazard Summary

Hazard	Analysis/Mitigation	Monitoring	Action Level <sup>1</sup>	Action/PPE
<b>Chemical Hazards</b>				
1,2-Dichloroethene	Potential volatilization of DNAPL	OVA every 30 min.	0 to 10 ppm	Level D plus vinyl or nitrile gloves
Vinyl Chloride	Potential volatilization of DNAPL	OVA every 30 min.		Continue work, continue monitoring
Tetrachloroethene	Limited concentrations, low risk	OVA every 30 min.	11 to 50 ppm	Level C: half-mask respirator with organic vapor cartridges
Trichloroethene	Limited concentrations, low risk	OVA every 30 min.		
1,1-Dichloroethene	Limited concentrations, low risk	OVA every 30 min.		
Benzene	Limited concentrations, low risk	OVA every 30 min.		
Toluene	Limited concentrations, low risk	OVA every 30 min.	51 to 100 ppm	Level C: full-face respirator with organic vapor cartridges
Ehtylbenzene	Limited concentrations, low risk	OVA every 30 min.		
Xylenes	Limited concentrations, low risk	OVA every 30 min.	>100 ppm	Cease operations, evacuate area
Chlorobenzene	Limited concentrations, low risk	OVA every 30 min.		
<b>Radiological</b>				
Radium-226 & Strontium-90 (alpha, beta, gamma & bremsstrahlung radiation)	Proximal exposure Airborne in dust	every 60 minutes gamma scintillator pancake probe	0 to 5 times background	Level D: no respiratory protection
			5 to 10 times background	Level C: half-mask respirator with HEPA filter cartridges
			>10 times background	Cease work, evacuate site pending further evaluation by CIH
	(potential air monitoring)	aerosol monitor	<5 mg/m <sup>3</sup>	Level D: no respiratory protection

<sup>1</sup> Above background

Radiation background assumed to be 2,158 counts per minute

Radionuclide background assumed to be 0.02 milliroentgens per hour