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FINAL WORK IMPLEMENTATION PLAN FOR SURFACTANT ENHANCED DNAPL REMOVAL TREATABILITY STUDY AT ALAMEDA POINT (SITE 5)

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AT
ALAMEDA POINT

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LIST OF ACRONYMS

BERC – Berkeley Environmental Restoration Center
BGS – below ground surface
BTEX – benzene, toluene, ethylbenzene, and xylenes
CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act
CFR – Code of Federal Regulations
CMC – critical micelle concentration
COC – chain of custody
DCA – 1,1-Dichloroethane
DCE – 1,1-Dichloroethene
DNAPL – dense non-aqueous phase liquids
DTSC – Department of Toxic Substance Control
EBMUD – East Bay Municipal Utility District
EPA – Environmental Protection Agency
FDA-Food and Drug Administration
FID – flame ionization detector
HPLC-High performance Liquid Chromatography
IW – injection well
LFR – Levine Fricke Recon
LNAPL – light non-aqueous phase liquids
MCLs-maximum concentration levels
MEUF – micellar enhanced ultrafiltration
MPP – macro porous polymer
MSDS – material safety data sheet
MW – monitor well
NCP – National Contingency Plan
OGISO – OGISO Environmental
OSHA-Occupational Safety and Health Administration
OU – University of Oklahoma
OVM – organic vapor monitor
PID – photo ionization detector
ppm-parts per million
PTT – partitioning tracer test
PVC-polyvinyl chloride
QA/QC – quality assurance/quality control
QAPP – Quality Assurance Project Plan
QC – quality control
RI/FS – Remedial Investigation/Feasibility Study
RW – recovery well
SAP – Sampling and Analysis Plan
SESR – Surfactant Enhanced Subsurface Remediation
SI – Site Investigation
SSO – site safety officer

SVOC – semi-volatile organic carbon
TCA – 1,1,1-Trichloroethane
TCE - Trichloroethene
TtEMI – Tetra Tech Environmental Management Inc.
VOC – volatile organic carbon
WIP – Work Implementation Plan

1.0 INTRODUCTION

1.1 Background

Tetra Tech EM Inc. (TtEMI) was requested by the Navy to conduct a surfactant enhanced subsurface remediation (SESR) treatability study at Alameda Point (formerly Naval Air Station Alameda) to demonstrate enhanced dense non-aqueous phase liquid (DNAPL) removal at the selected site. Surbec Environmental L.L.C. (Surbec) was selected to complete the treatability study.

The surfactant technology was developed because of the inability of traditional pump-and-treat remediation methods to remove non-aqueous phase liquids (NAPL) or sorbed contaminants from the subsurface. Surfactants can be used to remove residual DNAPL from porous media. Surfactants can greatly enhance the solubility and/or mobility of the chlorinated hydrocarbons, thereby increasing the removal of DNAPL constituents from the soil matrix. Previous demonstrations indicate that surfactant-enhanced recovery has the potential to be an effective technology. In previous demonstrations, between 37 percent and 99 percent of DNAPL has been recovered. The amount of contaminant mass recovered per mass of surfactant added may vary widely, depending on site characteristics. The treatment goal of this study is to remove at least 95 percent of the chlorinated solvent mass from the test area saturated zone above the Bay Mud.

Because of the complex nature of the behavior of chlorinated solvents in groundwater, a bench-scale study alone will not be sufficient to provide conclusive evidence regarding the effectiveness of the technology. Therefore, an *in situ* pilot-scale study will be performed; a bench-scale study will be used for surfactant selection only. The Navy will also conduct physical and chemical analyses of the aquifer material to determine an effective surfactant mixture for *in situ* removal of the chlorinated solvents.

Surbec will provide a complete technical evaluation of the treatment system at all stages of the treatability study. Evaluation will include, but will not be limited to, (1) the reliability and function of the process equipment, (2) capital, labor, operational, and maintenance costs, (3) process operating parameters, (4) sampling and analytical procedures, (5) ability to meet treatment objectives, (6) daily operation and problems encountered, (7) deviations from project plans, (8) process waste handling procedures and requirements, and (9) health and safety.

Design of this process is complicated and requires a multidisciplinary team to ensure the technology is applied correctly. The overall process can be broken down into four major aspects: Surfactant Screening and Selection, Injection/Extraction Systems, Subsurface Surfactant Performance and Above Ground Treatment and Separations. The proposed project team includes Surbec, the University of Oklahoma, and Levine Fricke Recon (LFR).

1.2 Site Description

The Alameda Point site is located on the San Francisco Bay in Alameda, California (refer to Figure 1.1). The selected test location, located near soil boring 2A-A, is on the east side of Building 5 in Site 5. In a review of available documents and data, Surbec has located a second site, which would be appropriate for this technology. The second site is also located on the east side of Building 5, approximately 100 yards south of soil boring 2A-A at soil boring 4B-C.

Building 5 is located between Monarch and Lexington Streets, and Avenues Midway and Tower within the Alameda Point Complex. Building 5 lies in the middle of the Alameda Point facility (Figure 1.2).

The building has been in operation since 1942 and houses shops used for cleaning, reworking, and manufacturing metal parts, tool maintenance, plating, and painting operations. Processes in the plating shop include degreasing, caustic and acid etching, metal stripping and cleaning, and chrome, nickel, silver, cadmium, and copper plating. The paint shop contains two paint bays and several smaller paint spray booths. Prior to 1972, the wastewater from operations in Building 5 was discharged without pretreatment to the San Francisco Bay, via the industrial sewers, the bulk of which emptied into the Seaplane Lagoon. From 1972 until 1991, the wastewater from the plating shop was split into two waste streams, one from the alkaline tanks and one from the cyanide tanks. The wastewater streams were kept separate until the cyanide stream was treated in a cyanide destruction unit. The two waste streams were then routed together to a treatment plant.

Three industrial waste sewer lines leave Building 5; there are two on the south side that join the main line running under W. Tower Ave., and one line on the northeast corner that joins the main line running under Lexington Street. Two sanitary sewer lines exit from the west side of the building and join the main under Monarch Street. Two additional sanitary sewer lines exit from the east side of the building and join the main lines in W. Midway Avenue. Storm sewer lines connect the building downspouts to mains under W. Tower Ave. and W. Midway Ave. Site layout and the configuration of the storm, sanitary, and industrial sewer lines are illustrated in Figure 1.2. Building 5 is still used for manufacturing, cleaning, and reworking metal parts, and painting operations. The plating shop was taken out of service in early 1991.

1.3 Objectives

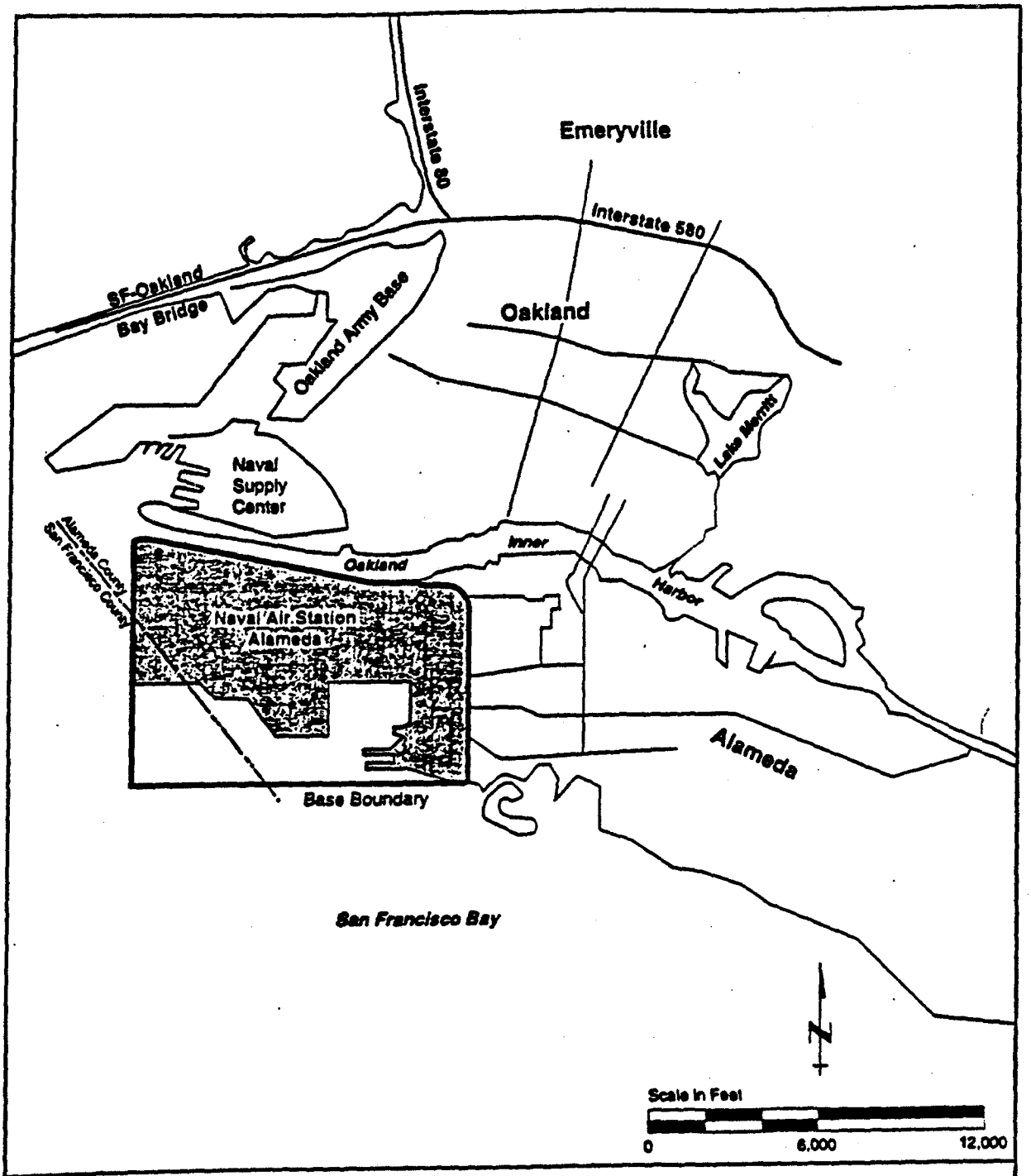
The Navy has identified one primary objective and three secondary objectives for the treatability study. The primary objective of the study is to:

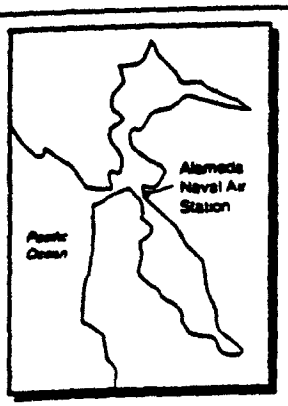
- Determine the effectiveness of the treatment system to remove chlorinated solvent mass that cannot be removed using conventional pumping techniques. The Navy has established a DNAPL removal goal of 95 percent (from the soil) for this study.

The Navy has also identified the following three secondary objectives for this study:

- Determine the properties of the porous media within the test area, including the hydraulic and sorption properties of the aquifer material
- Determine the optimal surfactant mixture for DNAPL removal
- Determine the efficiency of surfactant recovery from the test area

These objectives will be used to direct project activities and as evaluation criteria. The objectives will also be used as indicators for project corrections and additions.





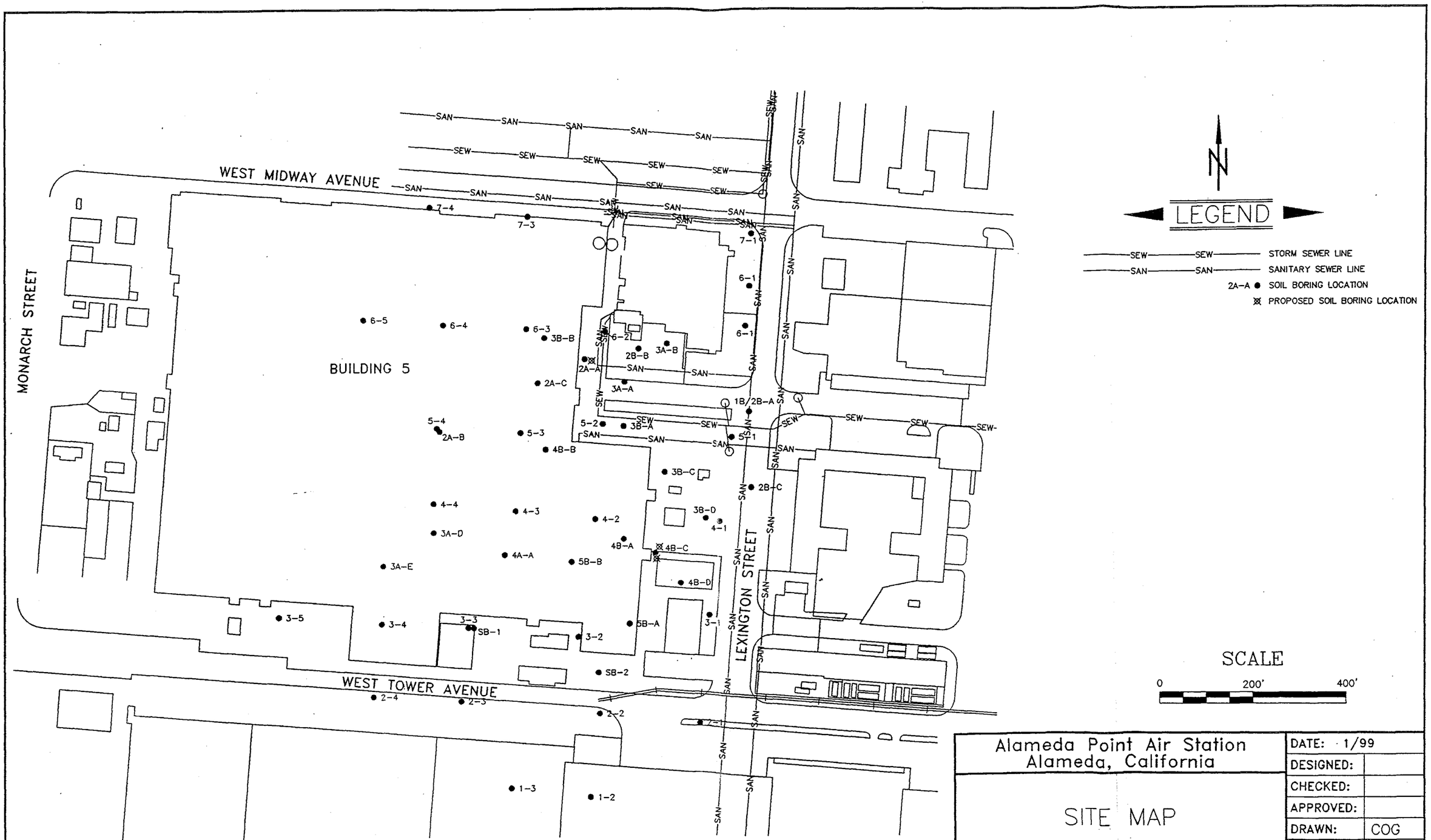
SURBEC ENVIRONMENTAL LLC

REGIONAL LOCATION MAP OF
NAS ALAMEDA

FIGURE 1.1

Source: Modified from CA State Automobile Assoc. map, Oakland/Berkeley/Alameda. Copyright 1980, revised 1989.

A-1



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SURBEC ENVIRONMENTAL, LLC Norman, Oklahoma	Figure 1.2

2.0 SITE INVESTIGATION SUMMARY

To gain an understanding of the site-specific conditions at soil boring 2A-A and 4B-C, Surbec reviewed several documents supplied by the Navy. The documents that were reviewed are as follows:

- Remedial Investigation/Feasibility Study Data Transmittal Memorandum Sites 4, 5, 8, 10A, 12, and 14. (PRC Environmental Management, Inc. and Montgomery Watson)
- Data Summary Report for Quarterly Groundwater Monitoring. (Tetra Tech EM Inc. and Uribe & Associates)
- Data Summary Report Background and Tidal Influence Studies and Additional Work at Sites 4 and 5, Naval Air Station, Alameda. (PRC Environmental Management, Inc. and Montgomery Watson)
- Remedial Investigation/Feasibility Study Phases 2B and 3 Data Summary Report. (PRC Environmental Management, Inc., and Montgomery Watson)
- Data Transmittal Memorandum for Sites 4 and 5 Chlorinated Solvent Plume Definition and Site 14 Sump Investigation at Alameda Point, Alameda, California. (Tetra Tech EM Inc.)

Surbec has concentrated the design efforts based on the document entitled "Data Transmittal Memorandum for Sites 4 and 5 Chlorinated Solvent Plume Definition and Site 14 Sump Investigation at Alameda Point, Alameda, California," which presents the data generated from two investigations directed toward definition of known chlorinated solvent plumes (Sites 4 and 5), and one soil and groundwater investigation of a sump area (Site 14) at Alameda Point, Alameda, California.

The data transmittal memorandum also includes a brief description of (1) the project objectives, (2) the scope of work performed for each investigation, (3) the investigation methods and field procedures, and (4) the findings of each investigation. The findings are presented in tabular form summarizing the analytical results and detailed isoconcentration maps and accompanying cross-sections. Copies of the Site 5 data summary tables are attached to the end of this section. Isocentration maps from the data transmittal memorandum (Figures 7, 8, and 9) for Trichloroethane (TCA), Dichloroethane (DCA), and Dichloroethene (DCE) are attached to show the extent and location of the contaminant plumes relative to the treatability study site location. TCA, DCA, and DCE have been selected because they are the constituents at the site with the highest concentrations and will be the contaminants that control the focus of the surfactant of choice.

2.1 Site Setting and Geology/Hydrogeology

NAS Alameda is located on the western end of Alameda Island, primarily in Alameda County, California. Alameda Island is located within the San Francisco Bay basin, which lies within the Coast Range physiographic province of California. The air station is bounded on the north by the Oakland Inner Harbor, on the west by the San Francisco Bay, and on the south by the San Francisco Bay and the Seaplane Lagoon.

Much of the land now occupied by the site was once covered by the waters of San Francisco Bay and most of the land not covered by the bay was occupied by tidal flats. The tidal flats and subtidal deposits are considered a portion of the Holocene Bay Mud stratigraphic unit (also called the Young Bay Mud). Within the air station boundaries, the Holocene Bay Mud is overlain by hydraulically placed fill material, which comprises the uppermost water-bearing zone. The fill ranges in thickness from 0 to 30 feet and underlies most of NAS Alameda, with the exception of the eastern portion of the base where there is no definable Holocene Bay Mud unit. The Holocene Bay Mud is underlain by Holocene and late Pleistocene alluvial and eolian deposits. These deposits are roughly equivalent to the Merritt Sand unit described by Trask and Rolston (1951). The Merritt Sand is underlain by Late Pleistocene estuarine deposits, which consist of dark greenish-gray silty clay in the vicinity of Alameda Point, and is considered an aquitard in this area.

Different authors have used different stratigraphic names and slightly different definitions when referring to the Late Pleistocene estuarine deposits. Trask and Rolston (1951) used the term San Antonio Formation for sediments, which are primarily composed of estuarine clays. However, Trask and Rolston's San Antonio Formation contains at least one relatively thick and laterally extensive sand bed. In contrast to Trask and Rolston, Sloan (1992) called the late Pleistocene estuarine deposits the Yerba Buena Mud. Sloan restricted the name Yerba Buena Mud to sediments composed of clay, and as a result the Yerba Buena Mud can be reasonably expected to act as an aquitard. Although the stratigraphic relationships are not entirely clear, Sloan (1981) believes that most of the San Antonio Formation is correlative with the Yerba Buena Mud. For the purpose of the data transmittal memorandum, the late Pleistocene estuarine deposits are referred to as the Yerba Buena Mud because the Yerba Buena Mud, being composed of clay, has more predictable hydrogeologic properties, and can be reasonably expected to act as an aquitard.

The hydrological units of primary importance to the SESR study are the Merritt Sand, the Holocene Bay Mud, and the overlying artificial fill material. These units make up the shallow aquifer. The shallow aquifer has two primary water-bearing zones; one above the Holocene Bay Mud, in the fill material (referred as the "first water-bearing zone") and the second below the Holocene Bay Mud in the Merritt Sand (referred as the "second water-bearing zone"). The Holocene Bay Mud has been found to be siltier and sandier in the western portion of the base, and discontinuous in the southeastern portion of the base. In the southeastern portion of the base, all units above the Yerba Buena Mud are considered to be in hydraulic connection (PRC 1991). The alluvial portion of undifferentiated Pleistocene deposits, which underlay the Yerba Buena Mud, comprise a second, deeper aquifer.

The lithology at Site 5 is characterized by a fill layer between 0 and 12 to 15 feet deep which consists of interbedded fine sands (well sorted), silty sands (moderately well sorted), and gravelly sand. Below the fill, the native soils consist of the Holocene Bay Mud deposits, which are primarily a lower permeability mixture of silty clay to sandy clay, with occasional sands and silts. At Site 5, the Bay Mud layer is approximately 15 to 20 feet thick.

The groundwater gradient at this test area (2A-A) generally ranges from 0. 001 feet per foot to 0. 002 feet per foot and is extremely variable in direction as reported by TtEMI. The groundwater gradient near 4B-C generally ranges from 0.004 to 0.006 feet per foot as reported in the BERC

Workplan. The depth to groundwater ranges from 5 to 9 feet below ground surface. Aquifer tests (slug tests) performed at Site 5 by TtEMI indicate a hydraulic conductivity of 1.7×10^{-3} cm/s to 2.6×10^{-4} cm/s. The slug tests were conducted over the entire saturated thickness of the upper fill layer.

2.2 Investigation Objectives

Focused groundwater investigations at Site 5 (Building 5) were conducted by TtEMI from January 21 to April 6, 1998. The investigation involved collection of discrete groundwater chemical data to evaluate the nature and extent of chlorinated solvent plumes caused by past releases at these sites. In addition to this data, BERC has reported data in their Treatability Study Workplan from investigations at Site 5 conducted during 1996 through 1998.

2.2.1 Previous Investigations

The general scope of work performed during these investigations included soil and groundwater sampling, laser induced fluorescence (LIF), membrane interface probe (MIP) sampling, and Geo Vis observations. The specific tasks performed for each site are outlined below. Surbec will focus on Site 5, locations 2A-A and 4B-C, because these sites are the potential locations of the treatability study.

2.2.2 TtEMI Investigations

Isoconcentration Maps and Cross Sections

All data from the chlorinated solvent plume investigations at Site 5 were presented in table format by constituent and by site. The analytical data from the tables are presented in graphical form on a total of 13 figures (Figures 2 through 14 of the data transmittal memorandum). Each of the figures presents four plan view isoconcentration maps and four isoconcentration cross sections for one analytical constituent. Data from a previous investigation conducted by OGISO Environmental was also used in the development of the maps and cross sections to supplement the data from the current investigations. Figures 7, 8, and 9 from the data transmittal memorandum are attached to show the contaminant plumes at the treatability study location and the surrounding areas.

The four plume maps shown on each figure present the data for four separate depth intervals. For Site 5 the depth intervals are 5.5 to 9.5 feet, 9.5 to 13.5 feet, 13.5 to 20.0 feet, and greater than 20 feet below ground surface (bgs).

Where there was more than one sample result in a given interval, the highest analytical result was used for contouring. The contour intervals are less than 0.5 micrograms per liter (ug/L), 0.50 to less than 50 ug/L, 50 to less than 100 ug/L, 100 to less than 500 ug/L, 500 to less than 1000 ug/L, 1000 to less than 10,000 ug/L, 10,000 to less than 100,000 ug/L and greater than 100,000 ug/L. Each map shows all four transect lines of the cross sections for reference.

Four cross sections were constructed for each site through the areas of highest concentration. Each cross section presents all the analytical data from a given boring located along the cross section line. All the borings and the sample intervals have been plotted at the correct elevation in the cross section views as determined from the site survey. The analytical data on the cross sections is contoured to the same concentration intervals as the plume maps.

Eight figures in the data transmittal memorandum (Figures 7 through 14) present the results of the investigation at Site 5. Seven constituents, (1,1,1-TCA; 1,1-DCA; 1,1-DCE; 1,2-DCE; chloroethane; TCE; and vinyl chloride) are presented in seven of the eight figures (Figures 7 through 13). The eighth figure (Figure 14) for Site 5 shows the distribution of dissolved oxygen and redox potential as measured in the field. This figure includes one plan view map with data presented at each location. Four cross sections are included in this figure with analytical data at each sampled interval.

Summary of Findings

The cross sections and plume maps of the Site 5 area, show additional detail of the chlorinated solvent plumes at each location. Although spacing between boring locations is relatively large (approximately 150'), a good definition of the plumes is achieved both laterally and vertically. Overall, contaminants were found to be more extensive than previously thought.

Site 5

Four distinct plumes have been defined at Site 5. The plumes are generally located within Building 5 and have for the most part been located by the previous OGISO Environmental investigations The extent and concentration levels of these plumes have been further defined laterally and vertically by this investigation. In particular, the westernmost plume was not well characterized by the previous investigations; however, this plume is now defined.

The focus areas are located near soil borings 2A-A and 4B-C. The proposed 20' x 20' treatability study area location, as proposed by TtEMI, is at 2A-A. Surbec has reviewed the site groundwater data and feels that location 4B-C may also be suitable if the concentrations of chlorinated solvents in the groundwater are high enough. Based upon the current isoconcentration maps, site 2A-A has a total volatile organic concentration of 58,525 ug/L as compared to location 4B-C, which has a total concentration of 195,448 ug/L.

The most extensive contaminant at Site 5 appears to be 1,1-DCA (Figure 8). 1,1-DCA is found at levels from 2,200 ug/L to 14,000 ug/L in the four separate plumes. The contaminant with the highest concentration is 1,1,1-TCA at 100,000 ug/L, however, this result is from the previous OGISO investigation. The highest concentration detected by TtEMI in this investigation was of a concentration greater than 34,000 ug/L 1,1-DCA at exploratory location 4-5.

Generally the depth intervals with the highest levels of contamination at Site 5 are 5.5 feet to 9.5 feet bgs and 9.5 feet to 13.5 feet bgs. Below 13.5 feet bgs, contamination is less prominent although significant levels of some constituents can be found. Below 20 feet bgs contamination is scarce and levels drop off considerably.

2.2.3 SCAPS/BERC Investigations

SCAPS surveys were completed in 1996, 1997, and 1998. The 1996 survey showed fluorescence intensities indicative of free product from 8.1 to 9.3 feet BGL at a location (IRS-02) immediately north of the waste oil/solvent tank location approximately 110 feet north of 4B-C. A soil sample from this location confirmed the fluorescence, indicating a soil concentration of 4360 mg/kg total VOCs and 2600 mg/kg TCE.

The following 1997 SCAPS survey positively identified the presence of NAPL using the Geo Vis video microscope. The NAPL was observed as separate phase droplets and ganglia existing in the pore space. Soil samples were also collected to quantify the VOC concentrations in the soils. The maximum TCE concentration was detected at 2700 mg/kg in a location near IR5-02 at a depth of 8.2 to 9.2 feet bgs.

In August 1998, a SCAPS survey was conducted to identify the outer boundaries of the NAPL in the vicinity of the waste oil/solvent UST. LIF and MIP were used to locate the NAPL outer limits. The thickest location appeared to be at PC-2 with thinning away in all directions. Soil samples were collected during this investigation with maximum total VOC concentrations of 3756 and 5890 mg/kg at locations S-30 and S-38, respectively. TEPH characterized as jet fuel ($C_{10} - C_{42}$) was detected at 25,000 and 9400 mg/kg in soil samples from 8.0 to 8.5 and 8.5 to 9.0 feet at location S-38. TCE was detected at a concentration of 2170 mg/kg in a soil sample from S-38. Groundwater samples were also collected using the MIP system. TCE was detected at a maximum concentration of 1786 ppm from location MIP37 located immediately north of the UST at a depth of 9 feet bgs.

In September 1998, BERC completed a soil sampling investigation to delineate the western and southern boundary of the NAPL at the waste oil/solvent UST location. BERC collected soil samples from four borings. High concentrations of TEPH were detected in TMW-7 at 11,000 mg/kg at the 7.5 to 8.0 foot depth. Total VOCs were detected at 68 mg/kg at this location. The three other locations were outside the NAPL plume boundaries.

Data summary tables for the SCAPS and BERC site investigations are attached. This data will also be included during the final modeling for well locations and screen depths along with the results of the Geoprobe investigation.

2.3 Site Selection Investigation (SSI)

The SI was conducted on January 30 and 31, 1999 and consisted of the following activities.

1. The completion of three (3) soil borings, one (1) 8 feet east of TtEMI sampling location 2A-A, and two (2) near TtEMI sampling location 4B-C, one (1) 10 feet north and one (1) 10 feet south of 4B-C (Figures 1 & 2).
2. The collection of one (1) soil sample for laboratory analyses of volatile organics by method 8260 from each boring.
3. The installation of groundwater monitor wells in each soil boring. and
4. The collection of groundwater samples from each well for analyses of volatile organics by method 8260.

2.3.1 Soil Sample Results

During the SI, soil samples were collected from each boring and analyzed with a Photovac 2020 organic vapor analyzer. The samples were composited on 1.0 to 2.0 foot intervals for field analyses. The field screening was used to determine the soil samples to be submitted to the laboratory for analyses of volatile organics by method 8260. The results are summarized in the following table.

Soil Sample Results

Contaminant	Soil Concentrations, ug/kg				
	4B-CN	4B-CS	2A-AE	4B-CS1	2A-AE1
Depth	12.0 ft.	12.0 ft.	7.5 ft.	10.0 ft.	12.0 ft.
1,1-Dichloroethene	ND	ND	ND	ND	230
1,1-Dichloroethane	3100	ND	ND	ND	ND
2-Butanone	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	ND	ND	ND	ND	ND
1,2-Dichloroethane	ND	ND	ND	ND	ND
Carbon Tetrachloride	ND	ND	ND	ND	ND
Chloroethane	ND	ND	ND	ND	ND
Cis-1,2-Dichloroethene	ND	ND	ND	ND	ND
Trichloroethene	ND	ND	ND	ND	ND
Vinyl Chloride	ND	ND	ND	ND	ND
Sec-Butylbenzene	ND	ND	260	ND	ND
Methylene Chloride	ND	ND	ND	4000	ND
TPH –purgeables(C7-C12)	NA	NA	820,000	NA	NA
TOTALS (8260)	3100	ND	260	4000	230

The results of the soil sample analyses indicate low levels of contamination. The sample from 4B-CN contained the highest concentration of suspected volatile organics 8260 (1,1-Dichloroethane) at 3.1 mg/kg. The sample 4B-CS1 from the 10.0 ft. depth contained 4.0 mg/kg of methylene chloride. Methylene chloride was not expected based upon the review of previous data during preparation of the WP. The other samples contained very low levels or were non-detect of volatile organics 8260.

The sample 2A-AE contained high concentrations of a possible fuel contaminant. A total petroleum hydrocarbons analyses was conducted to identify the range of hydrocarbons. The results indicated 828 ppm of C_7 to C_{12} purgeable hydrocarbons. Extractable hydrocarbons C_{12} to C_{22} could not be analyzed as the soil sample was preserved with methanol which would blow out the flame during the detection run.

2.3.2 Groundwater Sample Results

Groundwater samples were collected from the three (3) monitor wells installed in borings 4B-CN, 4B-CS, and 2A-AE. The wells were developed and purged, allowed to equilibrate for a period of time, and were then sample for analyses of volatile organics 8260. The results are summarized in the following table.

Groundwater Sample Results

Contaminant	Groundwater Concentrations, ug/l		
	4B-CN	4B-CS	2A-AE
1,1-Dichloroethene	6800	690	320
1,1-Dichloroethane	2200	2100	5000
2-Butanone	780	ND	ND
1,1,1-Trichloroethane	5800	270	510
1,2-Dichloroethane	250	ND	ND
Carbon Tetrachloride	ND	ND	ND
Chloroethane	ND	100	2300
Cis-1,2-Dichloroethene	ND	ND	480
Trichloroethene	ND	ND	170
Vinyl Chloride	ND	ND	840
Sec-Butylbenzene	ND	ND	ND
TOTALS	15830	3160	9620

The groundwater results indicate that the groundwater in the vicinity of monitor well 4B-CN contains the highest levels of volatile organics at 15.83 mg/l. The original proposed Study site, 2A-A, indicated a volatile organics (8260) groundwater concentration of 9.62 mg/l.

2.4 Data Needs

The data gathered during the SI indicates that the groundwater in the vicinity of 4B-C has a higher concentration of volatile organics than in the vicinity of 2A-A. The groundwater concentrations are significantly lower than the TtEMI reported groundwater concentrations possibly due to the dilution occurring in the Surbec well screens. The three (3) wells installed by Surbec were screened over the entire length of the aquifer whereas the samples collected by TtEMI were discrete samples collected over smaller intervals. Hence, discrete depths could yield much higher results as they are specific to that depth. As a result, Surbec feels that additional discrete sampling and analysis would remove much of the uncertainty and yield data necessary to select the final locations of the injection/recovery system wells.

Another concern discovered during the SI was the detection of a probable fuel contamination at location 2A-A. The results from 2A-A indicated the unexpected significant presence of LNAPLs. The LNAPLs at 2A-A introduce the question whether higher groundwater concentrations of DNAPLs are present and are being reduced due to solubility competition with the LNAPLs (i.e. Raolts Law).

Although the data indicates that 4B-C is potentially a more suitable site for the Study, Surbec proposes discrete sampling in the area of the three (3) wells to verify this conclusion. In addition, the direction of greatest contaminant concentrations at each sampling location is not known based upon the limited data collected in the SI. This area will be determined to assist in positioning the Study cell at the selected location.

2.5 Additional Geoprobe Investigation

Surbec will conduct an additional investigation of 2A-A and 4B-C as follows.

1. Four (4) additional geo-probe holes will be drilled near 2A-A to collect discrete groundwater and soil samples. The holes will be placed 15 feet northwest of 2A-A, 20 feet northeast of 2A-A, 10 feet south of 2A-A, and immediately adjacent to MW 2A-AE. The soil and groundwater sample results from these locations will add data to determine the vertical and horizontal direction of the source of contamination at 2A-A, and will also add data to determine the influence of the LNAPL on DNAPL detection and movement (Figure 2.1).

2. Six (6) additional geo-probe holes will be drilled near 4B-C to collect discrete groundwater and soil samples. The holes will be placed approximately 30 feet northwest of the northern well (4B-CN) installed at 4B-C, 15 feet northeast of 4B-CN, 15 feet east of 4B-C, immediately adjacent to MW 4B-CN, immediately adjacent to 4B-C, and 40 feet southwest of 4B-C inside the building (Figure 2.2).

The depth of the selected soil samples are documented on Table 3. The soil sample interval distance will decrease, or the sample frequency will increase, toward the Bay Mud, the suspected confining layer. A duplicate sample will be collected from each boring as shown on Table 3.

The soil samples will be collected from continuous cores samples obtained in plastic core samplers during the geoprobe activities. The plastic liner will be cut at the selected depths, and a syringe will be immediately inserted into the core. Approximately 7 cubic centimeters (cc), or 10 grams, of soil will be collected in the syringe and will immediately be placed into a 40 milliliter vial (VOA) which contains 20 milliliters of methanol. The empty VOA and VOA with the methanol will be pre-weighed by the analytical laboratory, and both weights will be recorded in the laboratory field book and on the VOA label. The purpose of this method is to decrease the potential loss of contaminant due to volatilization.

The soil samples will be shipped on ice under chain-of-custody to a Surbec associated laboratory (Environmental Analyst Ltd.) in Norman, Oklahoma for 8260 analyses. A duplicate soil sample from the 10.0 or 11.0 foot depth interval from each boring will be shipped to Curtis & Tompkins, Ltd in Berkeley, California for volatile organics analyses using method 8260 for QC.

As previously mentioned, the entire soil core from surface to total depth will be collected using plastic liners. These cores will be shipped to Surbec, sealed in the plastic liners, for additional analyses, including preliminary laboratory screening for a surfactant system.

Discrete groundwater samples will be collected from the same depths as the soil samples, excluding the 7.0 foot depth. The groundwater samples will be collected by inserting a screened sampling tip to the selected sample depth, and using a peristaltic pump, connected to the tubing attached to the screen tip, to pump the groundwater. Prior to collection of the sample, purging will be completed. The groundwater sample hole will be placed immediately adjacent to the soil core holes at each of the ten locations.

The purpose of collecting samples from different depths is to attempt to detect the presence of the DNAPL that may be perched, fingered, or setting at the base of the aquifer, with minimal dilution from the zone above and below. The samples collected from the locations immediately adjacent to wells 2A-AE and 4B-CN will be used to determine the amount of dilution, if any, seen in Surbec's wells previously installed which were screened across the entire aquifer. The samples collected adjacent to 4B-C will allow a correlation to be made with TtEMI's groundwater sampling results.

The groundwater samples will be packed on ice and shipped to a Surbec associated laboratory (Environmental Analyst Ltd) for 8260 analyses. A duplicate sample will be collected from the 12.0 foot depth from each boring at Sites 2A-A and 4B-C, and will be sent to Curtis & Tompkins, Ltd in Berkeley, California for QC.

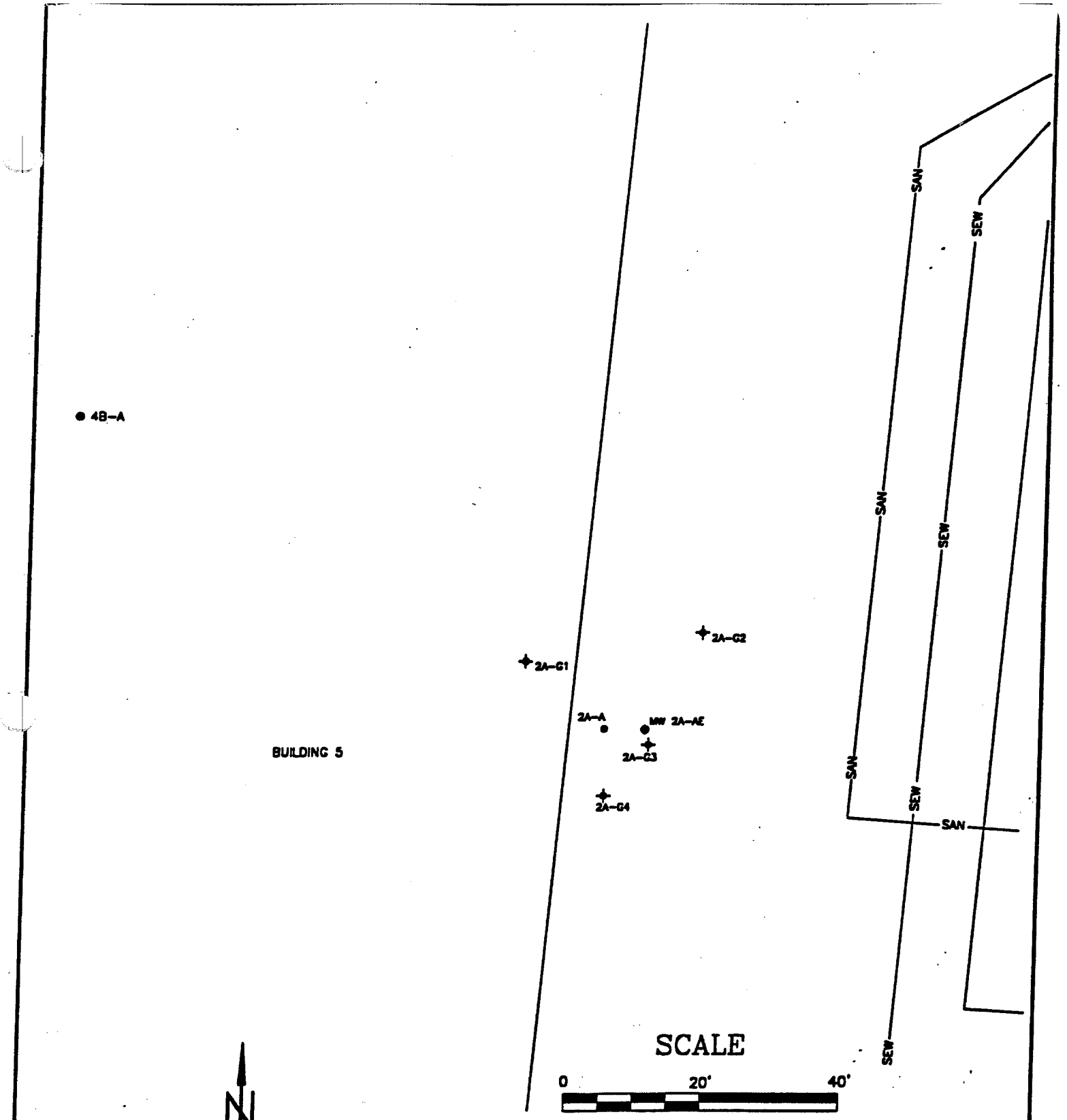
The following table summarizes the soil and groundwater sample locations.

Proposed Soil and Groundwater Sampling Depths

Site	Sample Type	Sample Depths[1] ft. BGS	Duplicate[2] Depth ft. BGS
2A-A	Soil	7.0, 10.0, 12.0, 14.0, 15.0	12.0
4B-C	Soil	7.0, 9.0, 11.0, 12.0, 13.0	11.0
2A-A	Groundwater	10.0, 12.0, 14.0, 15.0	12.0
4B-C	Groundwater	9.0, 11.0, 12.0, 13.0	12.0

Notes:

1. Samples to be sent to Environmental Analyst Ltd. (Surbec associated Lab.)
2. Samples to be sent to Curtis & Tompkins Ltd. (CA Certified Lab.)



LEGEND

SEW SEW	STORM SEWER LINE
SAN SAN	SANITARY SEWER LINE
MW 2A-AE ●	SURBEC SI MONITOR WELL
2A-G3 ✦	PROPOSED GEOPROBE LOCATION
2A-A ●	T&EMI SAMPLING LOCATION

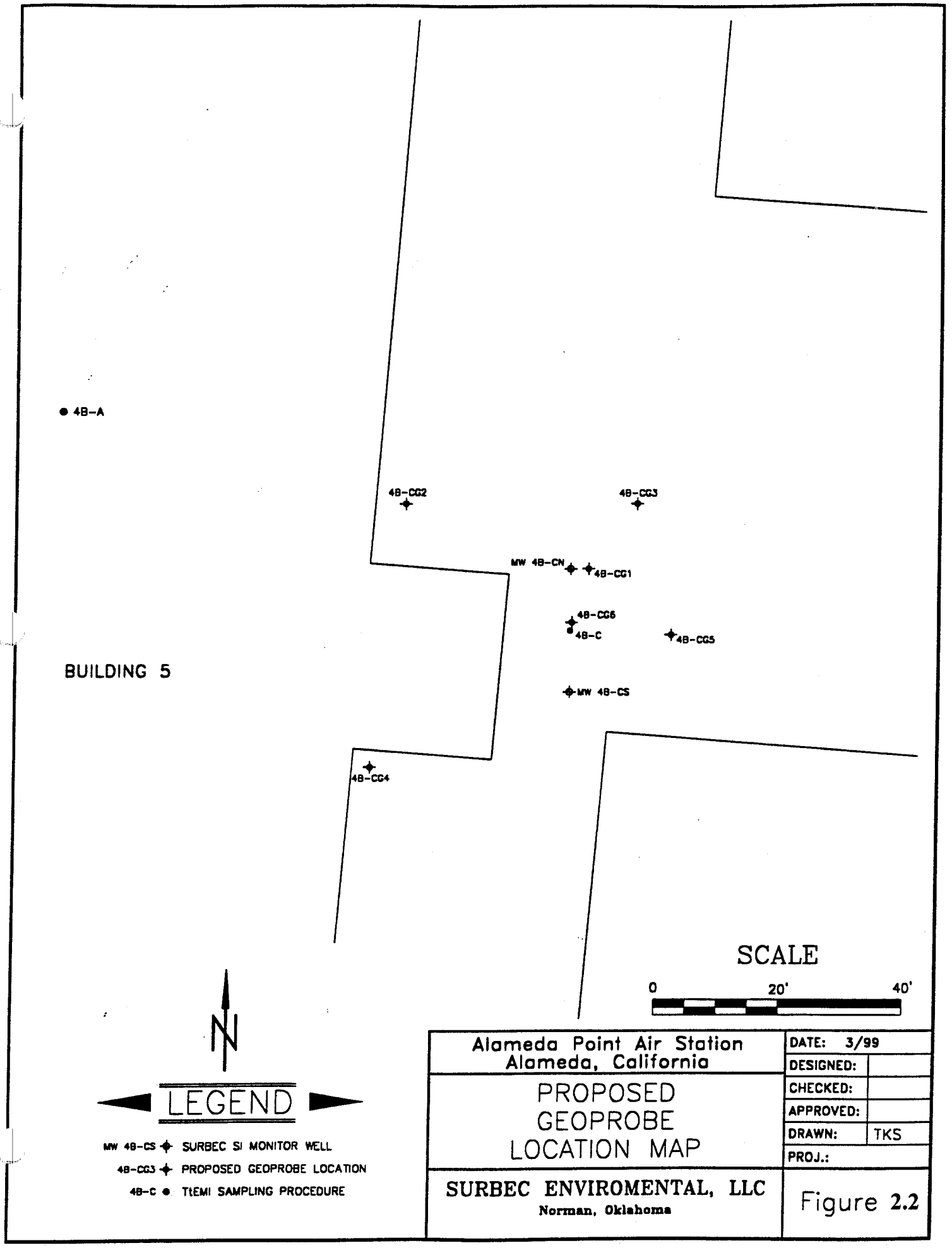
Alameda Point Air Station
Alameda, California

PROPOSED
GEOPROBE
LOCATION MAP

SURBEC ENVIROMENTAL, LLC
Norman, Oklahoma

DATE:	3/99
DESIGNED:	
CHECKED:	
APPROVED:	
DRAWN:	TKS
PROJ.:	

Figure 2.1


4B-A
4B-CG2
4B-CG3
MW 4B-CN
4B-CG1
4B-CG6
4B-C
4B-CG5
BUILDING 5
MW 4B-CS
4B-CG4
SCALE
0
20'
40'
N
LEGEND
MW 4B-CS SURBEC SI MONITOR WELL
4B-CG3 PROPOSED GEOPROBE LOCATION
4B-C TtEMI SAMPLING PROCEDURE
Alameda Point Air Station
Alameda, California
PROPOSED
GEOPROBE
LOCATION MAP
SURBEC ENVIROMENTAL, LLC
Norman, Oklahoma
DATE: 3/99
DESIGNED:
CHECKED:
APPROVED:
DRAWN: TKS
PROJ.:
Figure 2.2

TtEMI SOIL DATA
SUMMARY TABLES
AND
ISOCONCENTRATION MAPS,
TABLE 9 THROUGH 16
FIGURES 7, 8, AND 9
FROM TtEMI REPORT
(TtEMI and EFW 1998)

TABLE 9
SITE 5-SUMMARY OF ANALYTICAL RESULTS
1,1,1 TRICHLOROETHANE (ug/l)

Sample Location Number	Sample Intervals (ft.bgs)								
	5.5-7.5	7.5-9.5	9.5-11.5	11.5-13.5	13.5-15.5	15.5-20.0	20.0-25.0	25.0-30.0	30.0-35.0
1-2	<0.5								
1-3	<0.5	<0.5	<0.5	<0.5	<0.5				
2-1	1.7		5.9	1.4	<0.5	<0.5			
2-2	105	4.8	<0.5	<0.5	<0.5				
2-3	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5			
2-4	<0.5	1.4	0.8	<0.5	<0.5				
3-1	<0.5			<0.5	<0.5				
3-2	16	100		4.8	<0.5	200	<0.5		
3-3	2.9	<0.5	<0.5	<0.5	<0.5	<0.5			
3-4	4.3	1.9	<0.5	<0.5	<0.5	<0.5			
3-5	<0.5	<0.5	<0.5	<0.5	<0.5				
4-1	0.8	1.2	1.2			<0.5			
4-2		<0.5	<0.5	<0.5	<0.5	<0.5			
4-3	66	1.3	<0.5	<0.5	<0.5	0.5		<0.5	<0.5
4-4	35	3.4	<0.5	<0.5	<0.5	2.2		<0.5	<0.5
4-5		<0.5		130**		<0.5			
4-6	<0.5	<0.5	<0.5	<0.5					
5-1	0.5		<0.5	<0.5	<0.5				
5-2				<0.5	11	<0.5			
5-3	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5		
5-4	18	0.7	4.3		<0.5	<0.5			
5-5		<0.5	<0.5	<0.5					
6-1				<0.5	<0.5		<0.5		
6-2	<0.5			0.7		<0.5	<0.5		
6-3	<0.5			<0.5	<0.5	<0.5			
6-4	<0.5	<0.5							
6-5	<0.5		<0.5						
7-1					<0.5				
7-2					<0.5				
7-3					<0.5				
7-4	<0.5								

Note: Concentrations are taken directly from the Onsite Lab Certified Analytical Reports
** Estimated value, over calibration range
ft. bgs = feet below ground surface

TABLE 10
SITE 5-SUMMARY OF ANALYTICAL RESULTS
1,1 DICHLOROETHANE (ug/l)

Sample Location Number	Sample Intervals (ft.bgs)								
	5.5-7.5	7.5-9.5	9.5-11.5	11.5-13.5	13.5-15.5	15.5-20.0	20.0-25.0	25.0-30.0	30.0-35.0
1-2	<0.5								
1-3	<0.5	<0.5	<0.5	<0.5					
2-1	11		36	6.9	<0.5	<0.5			
2-2	7.9	13	8.1	7.5	3.9				
2-3	220**	170	310**	290**	2.7	4.9			
2-4	<0.5	1.2	16	78	19				
3-1	1.5			<0.5	<0.5				
3-2	140	44		1300**	670**	0.7	<0.5		
3-3	67	130	21	220**	13	48			
3-4	100	46	9.2	2200**	2900**	2			
3-5	15	47	100	1.7	<0.5				
4-1	11	6.6	13			<0.5			
4-2		1.8	3	1.2	<0.5	<0.5			
4-3	6.2	3.7	5.2	2.8	1.7	<0.5		<0.5	<0.5
4-4	180	54	210**	240	4.1	6.7		<0.5	<0.5
4-5		4400		34,000**		<0.5			
4-6	13	12	13	21					
5-1	<0.5		<0.5	<0.5	<0.5				
5-2				34	15	<0.5			
5-3	7.3	13	190**	8.4	<0.5	<0.5	<0.5		
5-4	850**	2600**	2400**		<0.5	<0.5			
5-5		<0.5	<0.5	<0.5					
6-1				<0.5	<0.5		<0.5		
6-2	2.2			170		820**	0.7		
6-3	1.3			<0.5	0.8	<0.5			
6-4	<0.5	0.5							
6-5	<0.5		<0.5						
7-1					<0.5				
7-2					<0.5				
7-3					<0.5				
7-4	<0.5								

Note: Concentrations are taken directly from the Onsite Lab Certified Analytical Reports
** Estimated value, over calibration range
ft. bgs = feet below ground surface

TABLE 11
SITE 5-SUMMARY OF ANALYTICAL RESULTS
1,1 DICHLOROETHENE (ug/l)

Sample Location Number	Sample Intervals (ft.bgs)								
	5.5-7.5	7.5-9.5	9.5-11.5	11.5-13.5	13.5-15.5	15.5-20.0	20.0-25.0	25.0-30.0	30.0-35.0
1-2	<0.5								
1-3	<0.5	<0.5	<0.5	<0.5					
2-1	<0.5		<0.5	<0.5	<0.5	<0.5			
2-2	13	6.7	<0.5	<0.5	<0.5				
2-3	3.8	<0.5	<0.5	<0.5	<0.5	<0.5			
2-4	<0.5	<0.5	<0.5	1.5	<0.5				
3-1	<0.5			<0.5	<0.5				
3-2	94	32		62	<0.5	<0.5	<0.5		
3-3	0.5	5.2	<0.5	26	<0.5	<0.5			
3-4	1.1	0.6	<0.5	<0.5	<0.5	<0.5			
3-5	<0.5	<0.5	<0.5	<0.5	<0.5				
4-1	0.62	1.4	<0.5			<0.5			
4-2		<0.5	<0.5	<0.5	<0.5	<0.5			
4-3	2.3	1.4	0.64	<0.5	<0.5	<0.5		<0.5	<0.5
4-4	10	5.8	8.5	11	<0.5	0.51		<0.5	<0.5
4-5		370		1400		<0.5			
4-6	3	2.9	2.9	0.8					
5-1	<0.5		<0.5	<0.5	<0.5				
5-2				0.67	<0.5	<0.5			
5-3	<0.5	<0.5	<0.5	1.3	<0.5	2.8	<0.5		
5-4	46	150	57		<0.5	<0.5			
5-5		<0.5	<0.5	<0.5					
6-1				<0.5	<0.5		<0.5		
6-2	<0.5			4.0		<0.5	<0.5		
6-3	<0.5			<0.5	<0.5	<0.5			
6-4	<0.5	<0.5							
6-5	<0.5		<0.5						
7-1					<0.5				
7-2					<0.5				
7-3					<0.5				
7-4	<0.5								

Note: Concentrations are taken directly from the Onsite Lab Certified Analytical Reports
ft. bgs = feet below ground surface

TABLE 12
SITE 5-SUMMARY OF ANALYTICAL RESULTS
cis 1,2 DICHLOROETHENE (ug/l)

Sample Location Number	Sample Intervals (ft.bgs)								
	5.5-7.5	7.5-9.5	9.5-11.5	11.5-13.5	13.5-15.5	15.5-20.0	20.0-25.0	25.0-30.0	30.0-35.0
1-2	<0.5								
1-3	<0.5	<0.5	<0.5	<0.5					
2-1	<0.5		17	1.6	<0.5	<0.5			
2-2	3.3	3.2	4.0	<0.5	<0.5				
2-3	72	4.3	33	42	<0.5	<0.5			
2-4	<0.5	<0.5	37	38	6.8				
3-1	<0.5			<0.5	<0.5				
3-2	9.0	6.0		136	3.6	<0.5	<0.5		
3-3	<0.5	1	3.5	38	<0.5	13			
3-4	28	28	2.8	0.83	<0.5	<0.5			
3-5	9.7	4.5	2.9	<0.5	<0.5				
4-1	1.2	1.4	0.64			<0.5			
4-2		1.0	4.0	<0.5	<0.5	<0.5			
4-3	<0.5	1.1	21	2.0	1.1	<0.5		<0.5	<0.5
4-4	<0.5	0.9	16	21	0.5	<0.5		<0.5	<0.5
4-5		<0.5		62		<0.5			
4-6	2.4	3.4	3.6	22					
5-1	<0.5		<0.5	<0.5	<0.5				
5-2				6.0	9.8	<0.5			
5-3	1.2	0.84	1.1	820	<0.5	64	17		
5-4	1.6	10	7.6		<0.5	<0.5			
5-5		<0.5	<0.5	<0.5					
6-1				<0.5	<0.5		<0.5		
6-2	3.3			15		1.4	<0.5		
6-3	<0.5			<0.5	<0.5	<0.5			
6-4	<0.5	1.0							
6-5	<0.5		<0.5						
7-1					<0.5				
7-2					<0.5				
7-3					<0.5				
7-4	<0.5								

Note: Concentrations are taken directly from the Onsite Lab Certified Analytical Reports
ft. bgs = feet below ground surface

TABLE 13
SITE 5-SUMMARY OF ANALYTICAL RESULTS
trans 1,2 DICHLOROETHENE (ug/l)

Sample Location Number	Sample Intervals (ft.bgs)								
	5.5-7.5	7.5-9.5	9.5-11.5	11.5-13.5	13.5-15.5	15.5-20.0	20.0-25.0	25.0-30.0	30.0-35.0
1-2	<0.5								
1-3	<0.5	<0.5	<0.5	<0.5					
2-1	<0.5		<0.5	<0.5	<0.5	<0.5			
2-2	<0.5	<0.5	<0.5	<0.5	<0.5				
2-3	18	15	<0.5	6.8	<0.5	<0.5			
2-4	<0.5	<0.5	<0.5	<0.5	<0.5				
3-1	<0.5			<0.5	<0.5				
3-2	<0.5	<0.5		37	11	<0.5	<0.5		
3-3	<0.5	<0.5	<0.5	7.7	1.5	<0.5			
3-4	<0.5	1.6	5.5	17	18	<0.5			
3-5	<0.5	0.63	<0.5	<0.5	<0.5				
4-1	<0.5	<0.5	0.59			<0.5			
4-2		<0.5	<0.5	1.3	<0.5	<0.5			
4-3	<0.5	<0.5	10	11	7.1	<0.5		<0.5	<0.5
4-4	<0.5	<0.5	5.1	8.4	<0.5	<0.5		<0.5	<0.5
4-5		<0.5		4.8		<0.5			
4-6	<0.5	0.6	0.6	7.6					
5-1	<0.5		<0.5	<0.5	<0.5				
5-2				3.4	<0.5	<0.5			
5-3	<0.5	<0.5	2.4	10	62	7.7	2.6		
5-4	<0.5	2.4	5.1		<0.5	<0.5			
5-5		<0.5	<0.5	<0.5					
6-1				<0.5	<0.5		<0.5		
6-2	<0.5			<0.5		<0.5	<0.5		
6-3	<0.5			<0.5	<0.5	<0.5			
6-4	<0.5	1.4							
6-5	<0.5		<0.5						
7-1					<0.5				
7-2					<0.5				
7-3					<0.5				
7-4	<0.5								

Note: Concentrations are taken directly from the Onsite Lab Certified Analytical Reports
ft. bgs = feet below ground surface

TABLE 14
SITE 5-SUMMARY OF ANALYTICAL RESULTS
CHLOROETHANE (ug/l)

Sample Location Number	Sample Intervals (ft.bgs)								
	5.5-7.5	7.5-9.5	9.5-11.5	11.5-13.5	13.5-15.5	15.5-20.0	20.0-25.0	25.0-30.0	30.0-35.0
1-2	<0.5								
1-3	<0.5	<0.5	<0.5	<0.5					
2-1	<0.5		2.7	<0.5	<0.5	<0.5			
2-2	<0.5	<0.5	0.8	<0.5	<0.5				
2-3	0.8	91	45	5.2	<0.5	<0.5			
2-4	<0.5	<0.5	<0.5	<0.5	14				
3-1	<0.5			<0.5	<0.5				
3-2	1.2	<0.5		17	10	<0.5	0.5		
3-3	<0.5	<0.5	<0.5	0.7	0.61	7.8			
3-4	22	290	840	1100	77	1.9			
3-5	<0.5	<0.5	<0.5	<0.5	<0.5				
4-1	<0.5	<0.5	0.58			<0.5			
4-2		<0.5	<0.5	0.84	<0.5	<0.5			
4-3	<0.5	<0.5	<0.5	0.6	0.6	<0.5		<0.5	<0.5
4-4	43	0.9	<0.5	6.3	48	1.7		<0.5	<0.5
4-5		230		200		<0.5			
4-6	<0.5	<0.5	<0.5	<0.5					
5-1	<0.5		<0.5	<0.5	<0.5				
5-2				<0.5	0.9	<0.5			
5-3	<0.5	<0.5	32	<0.5	<0.5	<0.5	<0.5		
5-4	4.8	<0.5	50		<0.5	<0.5			
5-5		<0.5	<0.5	<0.5					
6-1				<0.5	<0.5		<0.5		
6-2	<0.5			29		8.9	0.94		
6-3	<0.5			10	<0.5	<0.5			
6-4	<0.5	<0.5							
6-5	<0.5		<0.5						
7-1					<0.5				
7-2					<0.5				
7-3					<0.5				
7-4	<0.5								

Note: Concentrations are taken directly from the Onsite Lab Certified Analytical Reports
ft. bgs = feet below ground surface

TABLE 15
SITE 5-SUMMARY OF ANALYTICAL RESULTS
TRICHLOROETHENE (ug/l)

Sample Location Number	Sample Intervals (ft.bgs)								
	5.5-7.5	7.5-9.5	9.5-11.5	11.5-13.5	13.5-15.5	15.5-20.0	20.0-25.0	25.0-30.0	30.0-35.0
1-2	<0.5								
1-3	<0.5	<0.5	<0.5	<0.5					
2-1	<0.5		1.3	<0.5	<0.5	<0.5			
2-2	23	15	7.0	<0.5	<0.5				
2-3	3.6	<0.5	<0.5	<0.5	<0.5	<0.5			
2-4	<0.5	<0.5	<0.5	<0.5	<0.5				
3-1	<0.5			<0.5	<0.5				
3-2	36	24		61	0.75	<0.5	<0.5		
3-3	<0.5	<0.5	<0.5	14	<0.5	<0.5			
3-4	4.3	0.6	<0.5	0.56	<0.5	<0.5			
3-5	1.3	1.2	<0.5	<0.5	<0.5				
4-1	7.4	10	4.5			<0.5			
4-2		0.96	9.5	<0.5	<0.5	<0.5			
4-3	3.9	5.0	7.3	<0.5	<0.5	<0.5		<0.5	<0.5
4-4	1.7	0.7	8.4	11	<0.5	<0.5		<0.5	<0.5
4-5		<0.5		42		<0.5			
4-6	<0.5	<0.5	<0.5	0.8					
5-1	0.72		<0.5	<0.5	<0.5				
5-2				0.77	18	<0.5			
5-3	1.2	<0.5	0.7	1.5	<0.5	77	13		
5-4	8.1	27	7.8		<0.5	<0.5			
5-5		<0.5	<0.5	<0.5					
6-1				<0.5	<0.5		<0.5		
6-2	4.3			7.0		<0.5	<0.5		
6-3	<0.5			<0.5	<0.5	<0.5			
6-4	<0.5	0.72							
6-5	<0.5		<0.5						
7-1					<0.5				
7-2					<0.5				
7-3					<0.5				
7-4	<0.5								

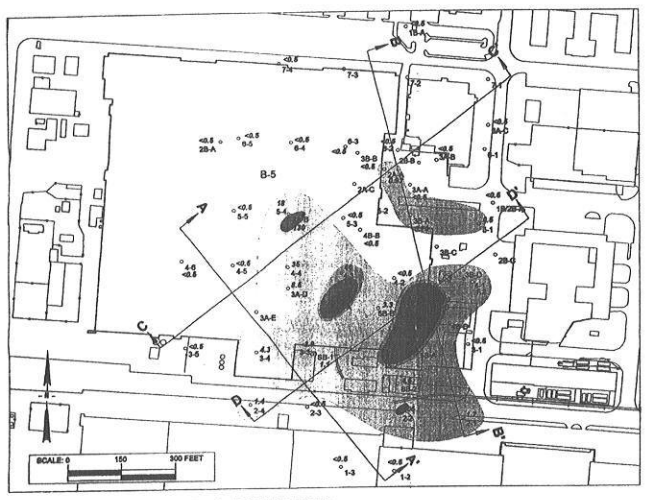
Note: Concentrations are taken directly from the Onsite Lab Certified Analytical Reports
ft. bgs = feet below ground surface

TABLE 16
SITE 5-SUMMARY OF ANALYTICAL RESULTS
VINYL CHLORIDE (ug/l)

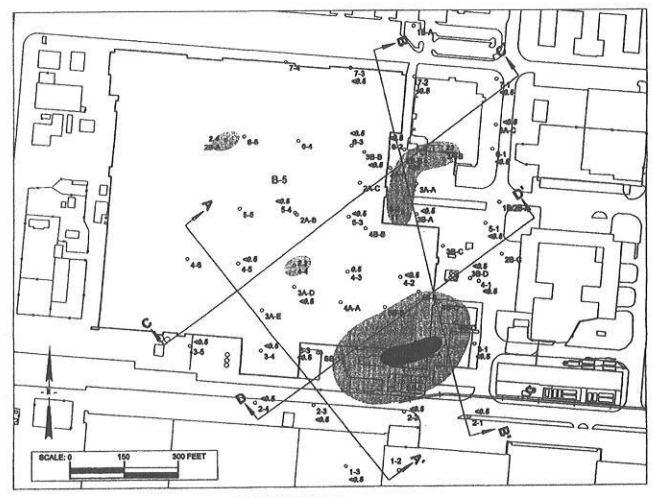
Sample Location Number	Sample Intervals (ft.bgs)								
	5.5-7.5	7.5-9.5	9.5-11.5	11.5-13.5	13.5-15.5	15.5-20.0	20.0-25.0	25.0-30.0	30.0-35.0
1-2	<0.5								
1-3	<0.5	<0.5	<0.5	<0.5					
2-1	<0.5		3.8	<0.5	<0.5	<0.5			
2-2	<0.5	<0.5	0.8	<0.5	<0.5				
2-3	76	5.2	81	93	<0.5	<0.5			
2-4	<0.5	<0.5	2.5	5.5	8.9				
3-1	<0.5			<0.5	<0.5				
3-2	1.8	<0.5		490	180	<0.5	<0.5		
3-3	<0.5	2	3.1	79	0.9	15			
3-4	4.5	12	1.7	1.5	2.4	<0.5			
3-5	<0.5	0.68	1.4	<0.5	<0.5				
4-1	<0.5	<0.5	0.52			<0.5			
4-2		<0.5	<0.5	<0.5	<0.5	<0.5			
4-3	<0.5	<0.5	<0.5	3.1	<0.5	<0.5		<0.5	<0.5
4-4	<0.5	1.3	4.4	7.3	<0.5	<0.5		<0.5	<0.5
4-5		200		230		<0.5			
4-6	<0.5	<0.5	<0.5	1.2					
5-1	<0.5		<0.5	<0.5	<0.5				
5-2				3.6	1.0	<0.5			
5-3	<0.5	<0.5	0.8	190	20	11	2.3		
5-4	1.8	39	21		<0.5	<0.5			
5-5		<0.5	<0.5	<0.5					
6-1				<0.5	<0.5		<0.5		
6-2	<0.5			18		4.0	<0.5		
6-3	<0.5			<0.5	<0.5	<0.5			
6-4	<0.5	1.9							
6-5	<0.5		<0.5						
7-1					<0.5				
7-2					3				
7-3					0.7				
7-4	<0.5								

Note: Concentrations are taken directly from the Onsite Lab Certified Analytical Reports
ft. bgs = feet below ground surface

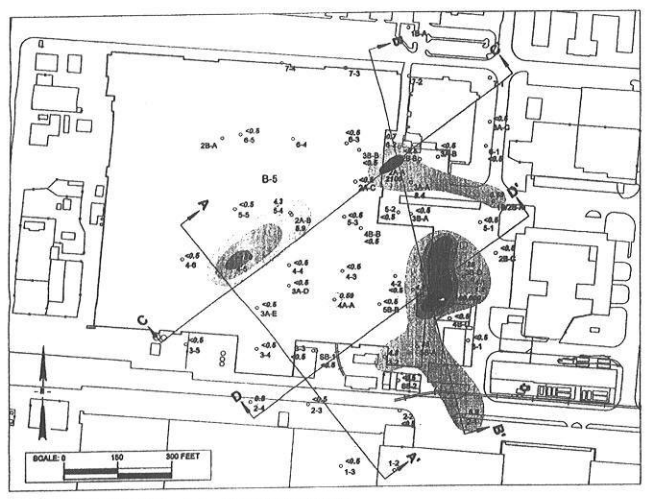
SITE 5 - 1,1,1-TCA



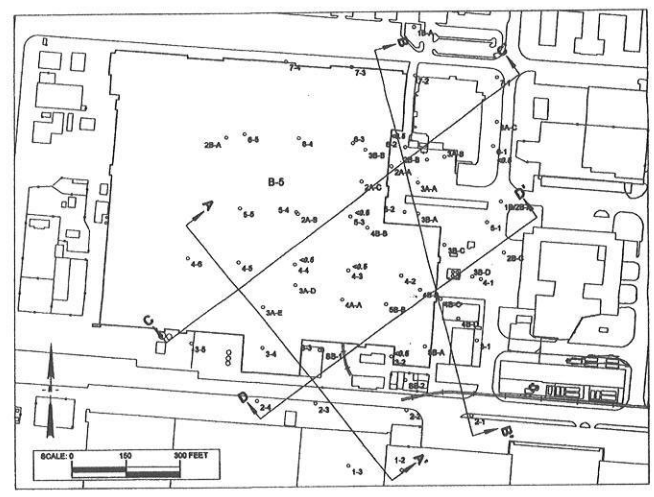
DEPTH INTERVAL: 5.5 - 9.5 FEET-BGS



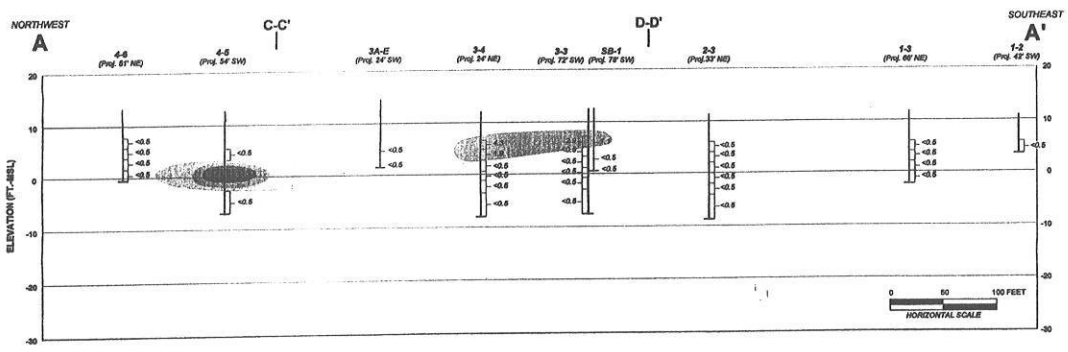
DEPTH INTERVAL: 13.5 - 20 FEET-BGS

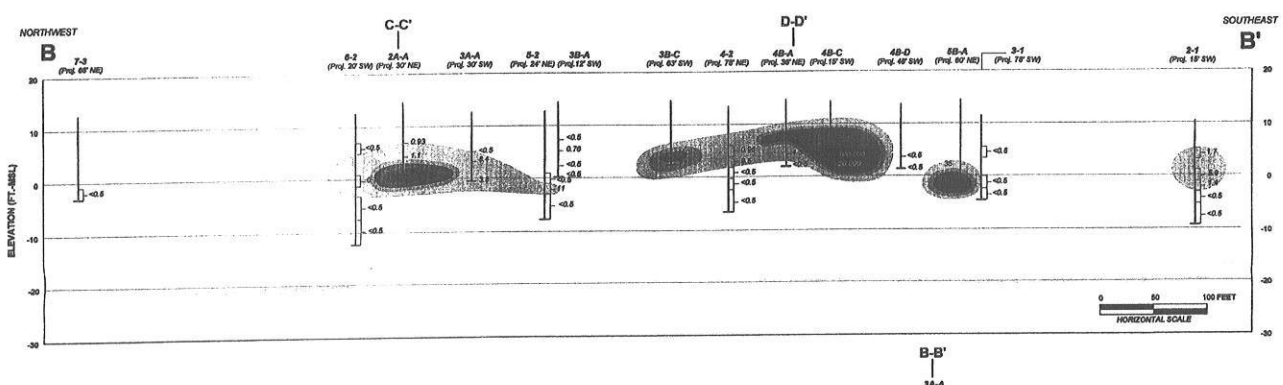


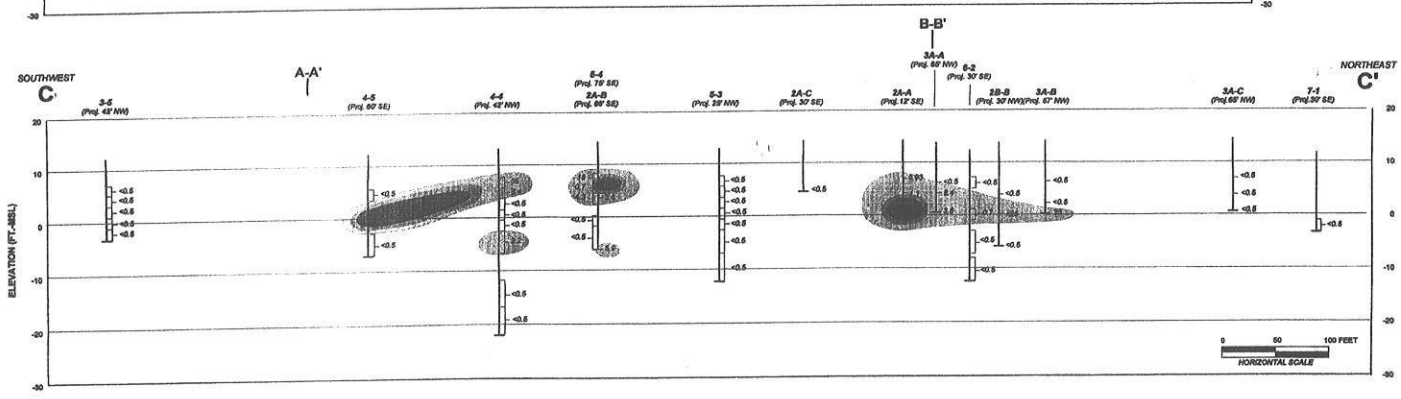
DEPTH INTERVAL: 9.5 - 13.5 FEET-BGS

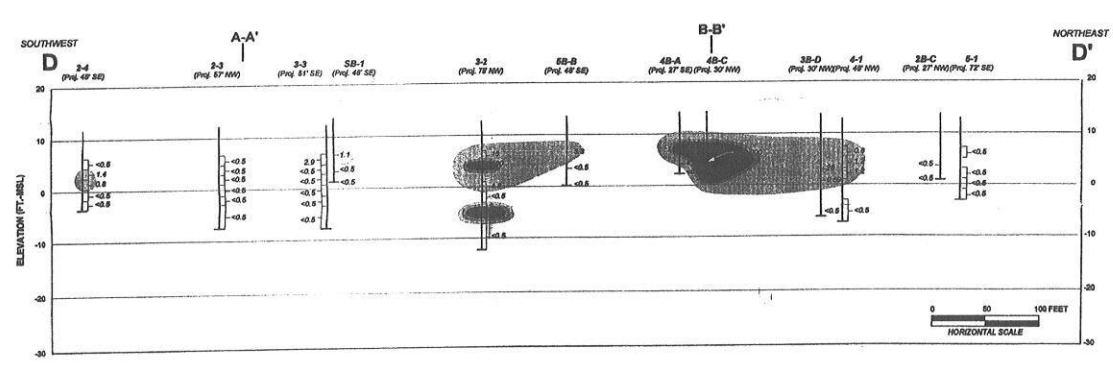


DEPTH INTERVAL: >20 FEET-BGS









EXPLANATION

1-3 Groundwater sampling location

34 1,1,1-TCA concentration (ug/L)

4-2 (Proj. 69' W) Boring designation showing projected perpendicular distance to line of section

Borehole

103 Sample interval showing concentration of 1,1,1-TCA in ug/L

<0.5

Bottom of boring

D D' Line of section

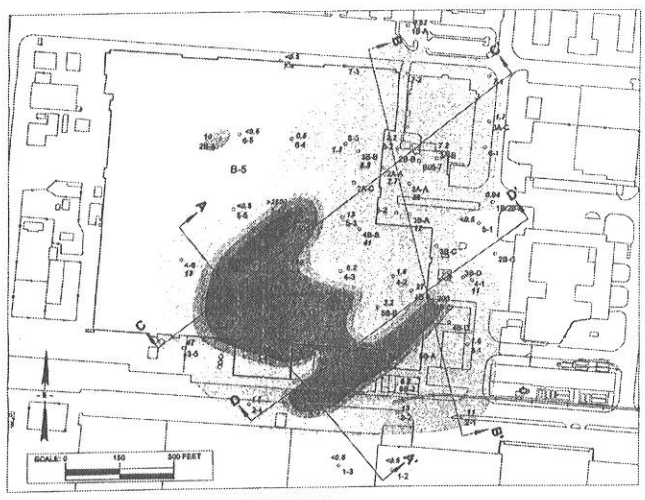
1,1,1-TCA isoconcentration contours

- <0.5 ug/L
- 0.5 - <50 ug/L
- 50 - <100 ug/L
- 100 - <500 ug/L
- 500 - <1000 ug/L
- 1000 - <10,000 ug/L
- 10,000 - <100,000 ug/L
- ≥100,000 ug/L

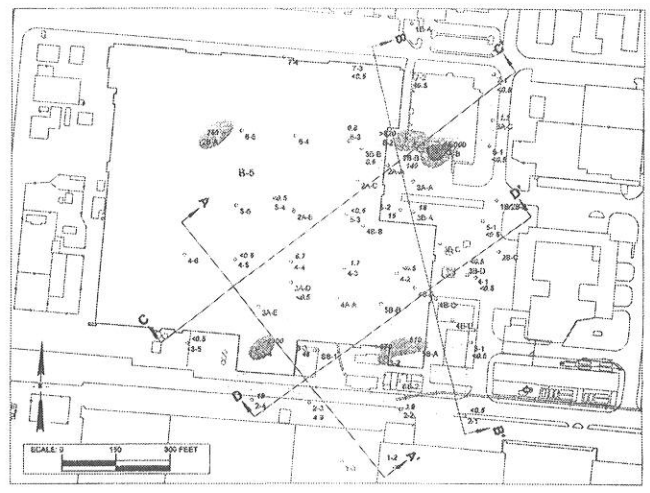
ALAMEDA POINT ALAMEDA COUNTY, CALIFORNIA	FIGURE 7
SITE 5 - 1,1,1-TCA	PROJECT APT 103

NOTE:
EPW boring locations and elevations determined by L. Wade Hammond, Land Surveyor.
OGISO boring locations and elevations provided to EPW by Tetra Tech, EM Inc.

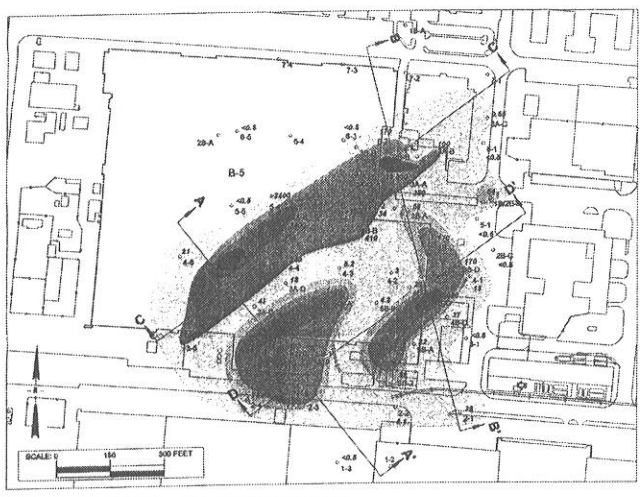
SITE 5 - 1,1-DCA



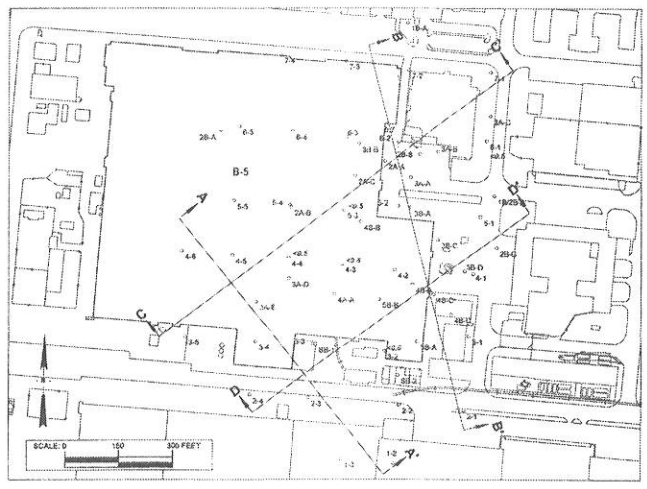
DEPTH INTERVAL: 5.5 - 9.5 FEET-BGS



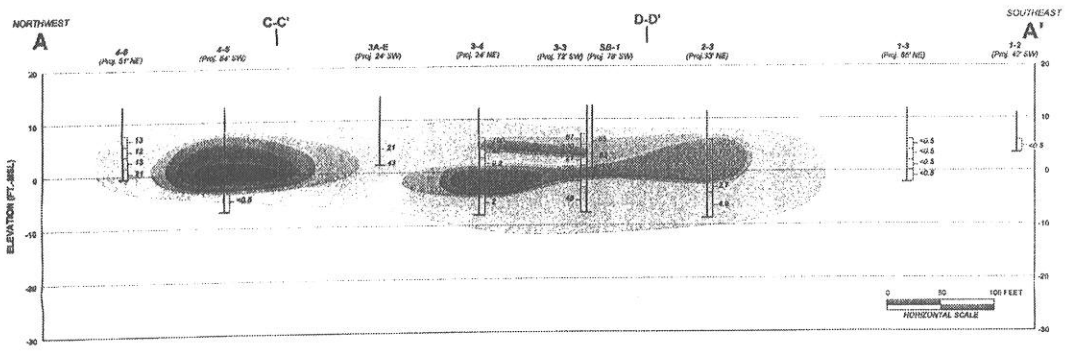
DEPTH INTERVAL: 13.5 - 20 FEET-BGS

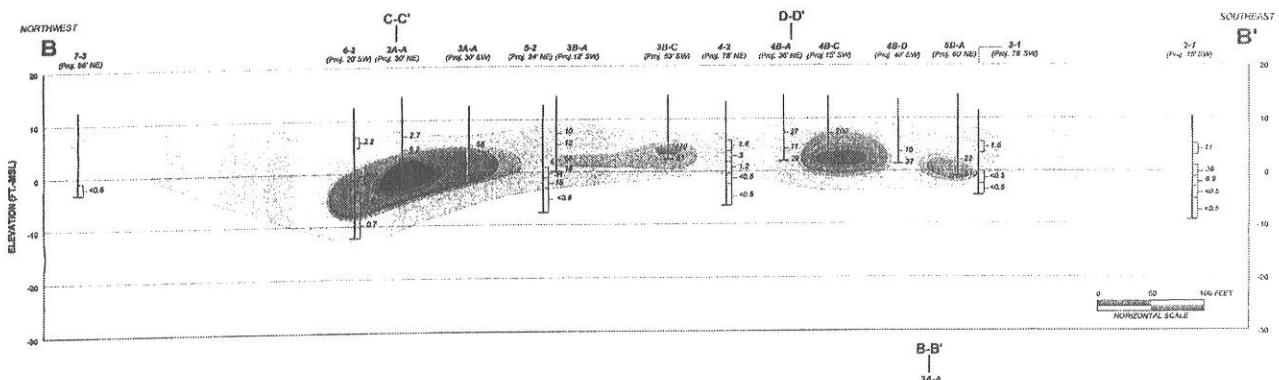


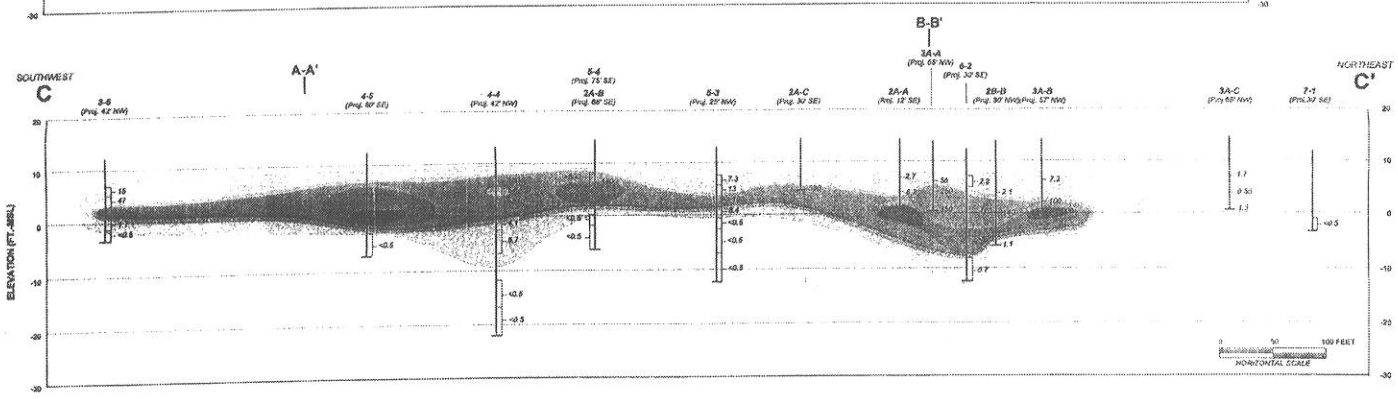
DEPTH INTERVAL: 9.5 - 13.5 FEET-BGS

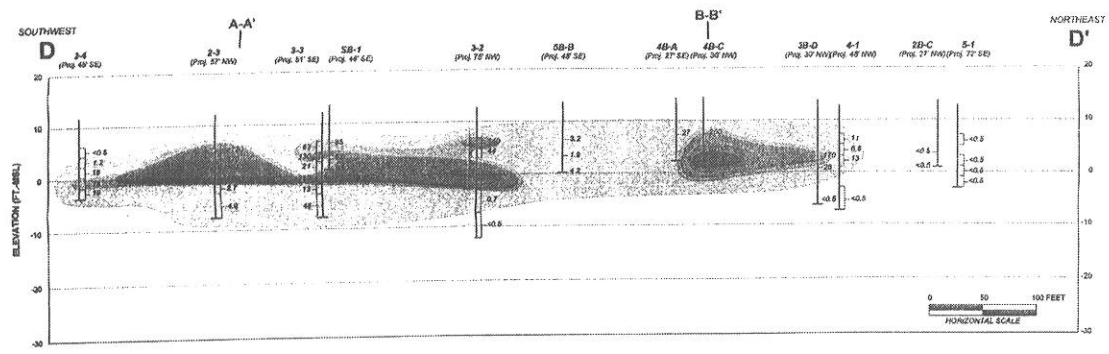


DEPTH INTERVAL: >20 FEET-BGS









EXPLANATION

- Groundwater sampling location
- 1,1-DCA concentration (ug/L)
- Boring designation showing projected perpendicular distance to line of section
- Borehole
- Sample interval showing concentration of 1,1-DCA in ug/L
- Bottom of boring
- D D' Line of section

1,1-DCA isoconcentration contours

- <0.5 ug/L
- 0.5 - <50 ug/L
- 50 - <100 ug/L
- 100 - <500 ug/L
- 500 - <1000 ug/L
- 1000 - <10,000 ug/L
- 10,000 - <100,000 ug/L
- ≥100,000 ug/L

ALAMEDA POINT
ALAMEDA COUNTY, CALIFORNIA

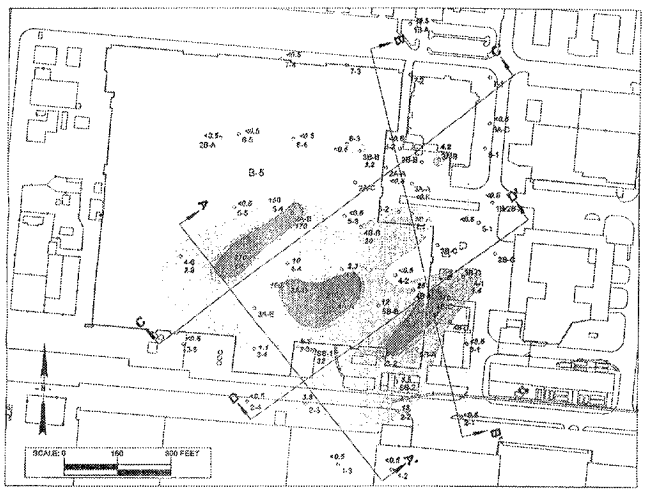
SITE 5 - 1,1-DCA

FIGURE 8

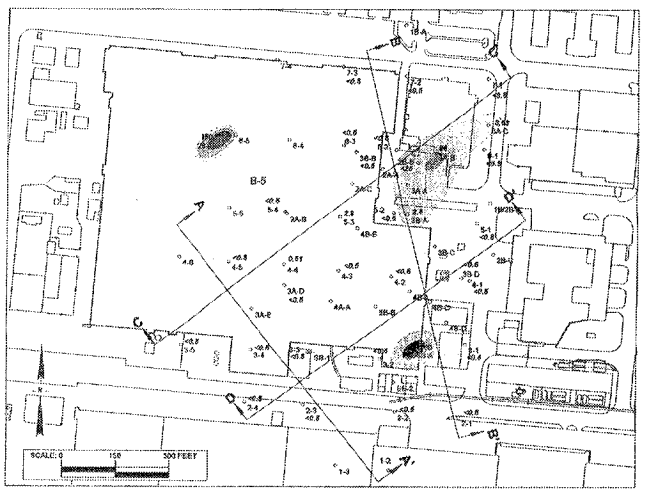
PROJECT APT 125

NOTE:
EPW boring locations and elevations determined by L. Wade Hammond, Land Surveyor.
OGSBO boring locations and elevations provided to EPW by Tetra Tech, EM Inc.

SITE 5 - 1,1-DCE

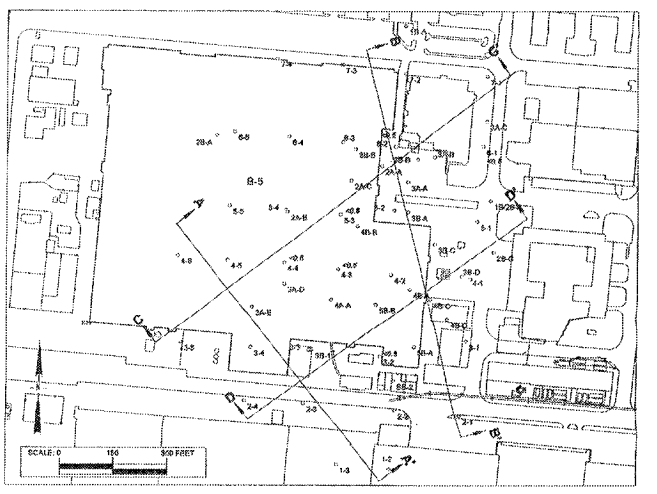


DEPTH INTERVAL: 5.5 - 9.5 FEET-BGS

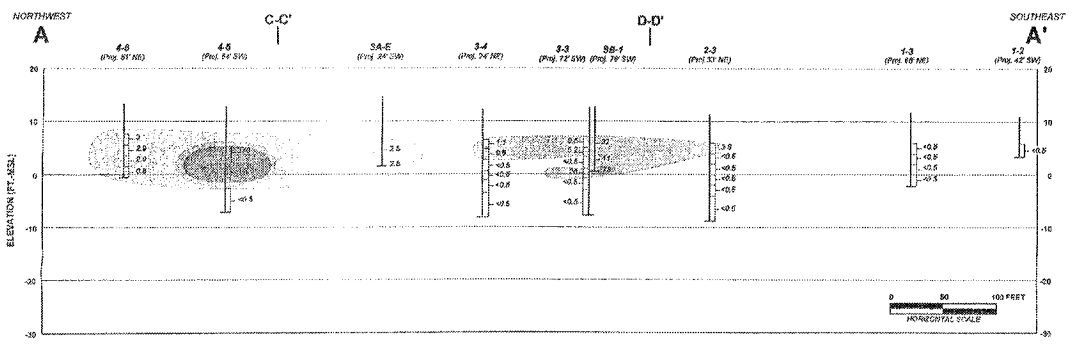


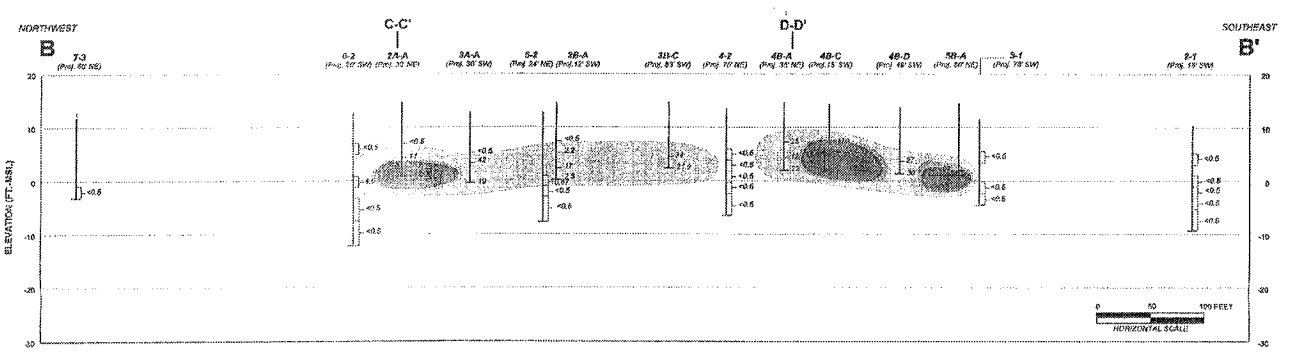
DEPTH INTERVAL: 13.5 - 20 FEET-BGS

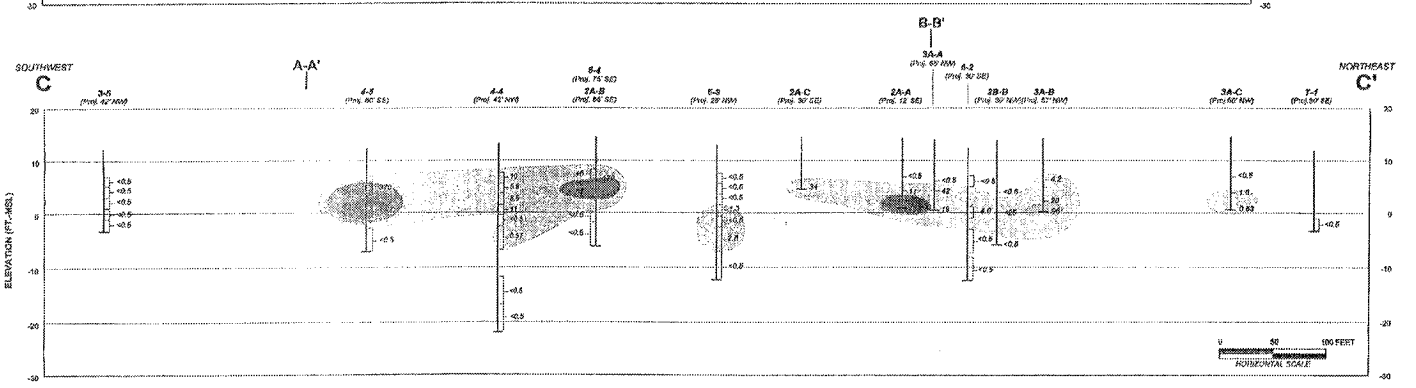
DEPTH INTERVAL: 9.5 - 13.5 FEET-BGS

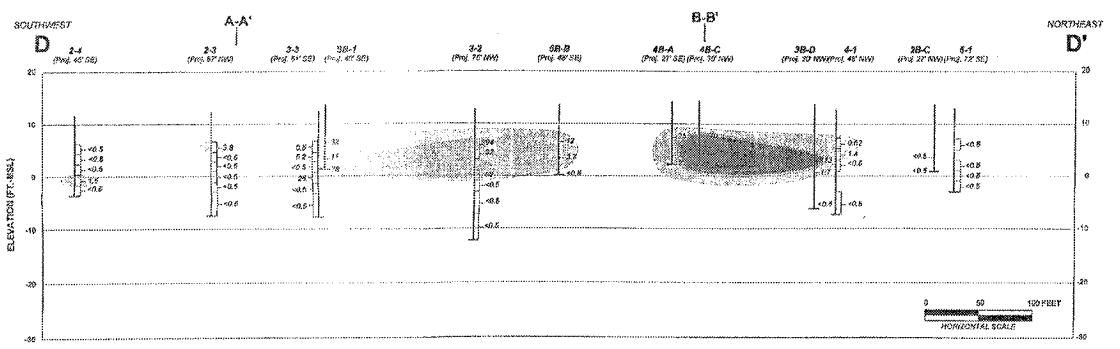


DEPTH INTERVAL: >20 FEET-BGS









EXPLANATION

1-3 — Groundwater sampling location

34 — 1,1-DCE concentration (ug/L)

4-2 (Proj. 65' W) — Boring designation showing projected perpendicular distance to line of section

Borehole

105 — Sample interval showing concentration of 1,1-DCE in ug/L

<0.5

Bottom of boring

D — D' — Line of section

1,1-DCE isoconcentration contours

- <0.5 ug/L
- 0.5 - <50 ug/L
- 50 - <100 ug/L
- 100 - <500 ug/L
- 500 - <1000 ug/L
- 1000 - <10,000 ug/L
- 10,000 - <100,000 ug/L
- ≥100,000 ug/L

NOTE:
EFW boring locations and elevations determined by L. Wade Hammond, Land Surveyor.
OSSO boring locations and elevations provided to EFW by Tetra Tech, Inc.

ALAMEDA POINT ALAMEDA COUNTY, CALIFORNIA	FIGURE 9
SITE 5 - 1,1-DCE	PROJECT AFT 105

SCAPS/BERC INVESTIGATION DATA TABLES
1996 THROUGH 1998

Table 2-1
Summary of Analytical Results for Soil Samples from 1998 SCAPS Investigation

Parameter	Analytical Method	Concentration, miligram per kilogram														
		S-28 6.5 feet	S-28 7.0 feet	S28 8.0 feet	S-29 5.0 feet	S-29 6.0 feet	S-29 8.0 feet	S-29 10.0 feet	S-29 11.0 feet	S-29 12.0 feet	S-30 4.6 feet	S-30 7.0 feet	S-30 8.0 feet	S-30 11.0 feet	S-38 8.0 feet	S-38 9.0 feet
Volatile Organic Compounds	8260															
n-Butylbenzene		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	4.21	<0.5	30.75	<0.5	8.23	<30
Chloroethane		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.51	<30
1,2-Dichlorobenzene		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.29	<0.5	3.14	<30
1,1-Dichloroethane		<0.5	<0.5	<0.5	<0.5	1.49	6.80	0.55	0.28	<0.5	1.76	0.65	6.83	<0.5	25.21	22.84
1,1-Dichloroethene		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	2.54	<0.5	1.18	<30
cis-1,2-Dichloroethene		<0.5	<0.5	<0.5	<0.5	1.34	2.25	2.09	2.98	5.66	2.68	1.48	15.13	<0.5	51.45	62.81
Ethylbenzene		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.46	<0.5	5.37	<0.5	3.50	<30
Freon 113		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.33	0.39	<0.5	3.06	0.53	87.86	<0.5	39.10	234
Isopropylbenzene		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.69	<0.5	4.49	<0.5	3.19	<30
p-Isopropyltoluene		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	3.29	<0.5	9.76	<0.5	6.17	<30
Methylene chloride		<0.5	<0.5	<0.5	<0.5	<0.5	0.26	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<30
Naphthalene		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	3.44	<0.5	48.81	<0.5	10.80	114
n-Propylbenzene		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1.61	<0.5	9.76	<0.5	<0.5	<30
sec-Butylbenzene		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1.99	<0.5	6.35	<0.5	5.66	<30
tert-Butylbenzene		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.44	<0.5	<0.5	<30
Tetrachloroethene		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	9.18	<0.5	30.26	<0.5	44.76	39.97
Toluene		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.69	<0.5	26.36	<0.5	20.58	68.52
1,1,1-Trichloroethane		<0.5	<0.5	<0.5	<0.5	0.45	0.68	0.61	<0.5	<0.5	12.24	1.2	180	<0.5	108	462
1,1,2-Trichloroethane		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.36	<30
Trichloroethene		0.47	0.49	0.52	0.70	4.85	12.55	10.47	10.11	2.45	84.16	7.12	1113	<0.5	453	2170
1,2,4-trimethylbenzene		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	13.77	<0.5	136	<0.5	72.03	109
1,3,5-trimethylbenzene		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	4.06	<0.5	41	<0.5	23.15	28.55
o-Xylene		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1.30	<0.5	17.57	<0.5	9.26	17.13
p,m-Xylenes		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1.99	<0.5	30.26	<0.5	14.92	34.26
Total Volatile Organic Compounds		0	0	1	0.7	8	23	14	14	8	151	11	1833	0	904	3363.08
Total Extractable Petroleum Hydrocarbons	8015M	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	25,000	9400

Notes:
< indicates consituent was not detected at the detection limit indicated
NA= Not Analyzed
Total extractable petroleum hydrocarbons are characterized as a Jet Fuel (C10-C42).

Table 2-2
Summary of Soil Analytical Results from NAPL Investigation

Analyte	Analytical Method	Concentration, mg/kg										
		TMW-6 7.5-8 feet	TMW-6 10.5-11.0 feet	TMW-7 5.5-6.0 feet	TMW-7 7.5-8.0 feet	TMW-7 10.5-11.0 feet	TMW-8 6.0-6.5 feet	TMW-8 7.0-7.5 feet	TMW-8 8.5-9.0 feet	TMW-9 4.8-5.3 feet	TMW-9 7.0-7.5 feet	TMW-9 10.0-10.5 feet
Volatile Organic Compounds	8260											
Benzene		<0.005	<0.005	<0.005	<1.700	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
n-Butylbenzene		<0.005	<0.005	<0.005	4.4	<0.005	<0.005	0.0086	<0.005	<0.005	<0.005	<0.005
sec-Butylbenzene		<0.005	<0.005	<0.005	2.2	<0.005	<0.005	0.0037 J	<0.005	<0.005	<0.005	<0.005
Carbon disulfide		<0.005	<0.005	<0.005	<1.700	<0.005	<0.005	<0.005	0.0064	<0.005	<0.005	<0.005
1,1-Dichloroethane		0.14	0.0093	0.012	<1.700	0.0039 J	0.0051	0.0085	0.017	<0.005	0.034	0.026
cis-1,2-Dichloroethene		0.13	0.022	0.012	<1.700	0.0046 J	0.015	0.025	0.032	0.0043 J	0.12	0.045
Freon 113		<0.005	<0.005	0.0078	1.3 J	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Methylene chloride		<0.020	<0.020	<0.020	<6.700	<0.020	<0.020	<0.020	<0.020	<0.020	0.022	<0.20
Naphthalene		<0.005	<0.005	<0.005	<1.700	<0.005	<0.005	0.0057	<0.005	<0.005	<0.005	<0.005
Para-isopropyl toluene		<0.005	<0.005	<0.005	3.8	<0.005	<0.005	0.0048 J	<0.005	<0.005	<0.005	<0.005
Propylbenzene		<0.005	<0.005	<0.005	2.2	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Tetrachloroethane		<0.005	<0.005	0.18	2	<0.005	<0.005	0.004 J	<0.005	<0.005	0.0031 J	<0.005
1,1,1-Trichloroethane		0.0012	<0.005	0.078	0.96 J	<0.005	<0.005	0.0032 J	<0.005	<0.005	0.0077	0.0048 J
Trichloroethene		0.14	0.0088	0.36	7.3	0.0033 J	0.01	0.029	0.026	0.0065	0.064	0.035
1,3,5-Trimethylbenzene		<0.005	<0.005	<0.005	12	0.0056	<0.005	0.0068	<0.005	<0.005	<0.005	<0.005
1,2,4-Trimethylbenzene		0.0028 J	<0.005	<0.005	27	0.017	<0.005	0.02	<0.005	<0.005	<0.005	<0.005
m,p-Xylenes		<0.005	<0.005	<0.005	2.7	0.0027 J	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
o-Xylene		<0.005	<0.005	<0.005	2	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Total Volatile Organic Compounds		0.414	0.0401	0.6498	67.86	0.0371	0.0301	0.1193	0.0814	0.0108	0.2508	0.1108
Total Extractable Petroleum Hydrocarbons	8015M	<1	<1	1300 YH	11000 YLH	5.9 YH	<1	4.1 YH	<1	1 YH	<1	<1

Notes:

< indicates consituent was not detected at the detection limit indicated
Y: Sample exhibits fuel pattern which does not resemble standard
H: Heavier hydrocarbons than indicated standard
L: Lighter hydrocarbons than indicated standard
J: Estimated value

Table 2-3

Summary of Analytical Results for Goundwater Samples from 1998 SCAPS Investigation by Analytical Method 8265

		Concentration, parts per million		
Location	Sample Depth, feet	Trichloroethene	Dichloroethene	Tetrachloroethene
MIP21	3.0	5	ND	ND
MIP21	4.0	4	ND	ND
MIP21	5.0	12	ND	ND
MIP21	6.0	12	ND	ND
MIP21	7.0	16	ND	ND
MIP21	8.0	42	ND	ND
MIP21	9.0	30	ND	ND
MIP21	10.0	18	ND	ND
MIP21	11.0	33	ND	ND
MIP21	12.0	15	ND	ND
MIP21	12.8	1.5	ND	ND
MIP21	14.0	ND	ND	ND
MIP21	15.0	ND	ND	ND
MIP22	3.0	ND	ND	ND
MIP22	4.0	2	ND	ND
MIP22	5.0	2	ND	ND
MIP22	6.0	1	ND	ND
MIP22	7.0	9	ND	ND
MIP22	8.0	113	ND	ND
MIP22	9.0	95	ND	ND
MIP22	10.0	4	ND	ND
MIP22	11.0	ND	ND	ND
MIP22	12.0	ND	ND	ND
MIP22	13.0	ND	ND	ND
MIP22	14.0	ND	ND	ND
MIP23	3.0	ND	ND	ND
MIP23	4.0	ND	ND	ND
MIP23	5.0	ND	ND	ND
MIP23	6.0	ND	ND	ND
MIP23	7.0	0.5	ND	ND
MIP23	8.0	ND	ND	ND
MIP23	9.0	ND	ND	ND
MIP23	10.0	ND	ND	ND
MIP23	11.0	ND	ND	ND
MIP23	12.0	ND	ND	ND
MIP24	3.0	ND	ND	ND
MIP24	4.0	ND	ND	ND

Table 2-3

Summary of Analytical Results for Goundwater Samples from 1998 SCAPS Investigation by Analytical Method 8265

		Concentration, parts per million		
Location	Sample Depth, feet	Trichloroethene	Dichloroethene	Tetrachloroethene
MIP24	5.0	ND	ND	ND
MIP24	6.0	ND	ND	ND
MIP24	7.0	ND	ND	ND
MIP24	8.0	ND	ND	ND
MIP24	9.0	ND	ND	ND
MIP24	10.0	ND	ND	ND
MIP24	11.0	ND	ND	ND
MIP24	12.5	ND	ND	ND
MIP25	3.0	ND	ND	ND
MIP25	4.0	ND	ND	ND
MIP25	5.0	1	ND	ND
MIP25	6.0	6	1	ND
MIP25	7.0	3	ND	ND
MIP25	8.0	2	ND	ND
MIP25	9.0	3	ND	ND
MIP25	10.0	5	ND	ND
MIP25	11.5	8	4	ND
MIP26	3.0	21	ND	ND
MIP26	4.0	ND	ND	ND
MIP26	5.0	52	ND	ND
MIP26	6.0	43	ND	ND
MIP26	7.0	4	ND	ND
MIP26	8.0	1	ND	ND
MIP26	9.0	0.5	ND	ND
MIP26	10.0	ND	ND	ND
MIP26	11.0	ND	ND	ND
MIP26	12.0	ND	ND	ND
MIP27	3.0	ND	ND	ND
MIP27	4.0	ND	ND	ND
MIP27	5.0	50	ND	ND
MIP27	6.0	10	ND	ND
MIP27	7.0	5	ND	ND
MIP27	8.0	550	ND	ND
MIP27	9.0	250	ND	ND
MIP27	10.0	ND	ND	ND
MIP27	11.0	ND	ND	ND
MIP27	12.0	ND	ND	ND

Table 2-3

Summary of Analytical Results for Goundwater Samples from 1998 SCAPS Investigation by Analytical Method 8265

		Concentration, parts per million		
Location	Sample Depth, feet	Trichloroethene	Dichloroethene	Tetrachloroethene
MIP31	3.0	ND	ND	ND
MIP31	4.0	ND	ND	ND
MIP31	5.0	ND	ND	ND
MIP31	6.0	ND	ND	ND
MIP31	7.0	4	ND	ND
MIP31	8.0	7	ND	ND
MIP31	9.0	7	ND	ND
MIP31	10.0	11	ND	ND
MIP31	11.0	11	ND	ND
MIP31	12.0	6	ND	ND
MIP31	13.0	ND	ND	ND
MIP31	14.0	ND	ND	ND
MIP32	3.0	ND	ND	ND
MIP32	4.0	ND	ND	ND
MIP32	5.0	ND	ND	ND
MIP32	6.0	ND	ND	ND
MIP32	7.0	ND	ND	ND
MIP32	8.0	3	ND	ND
MIP32	9.0	4	ND	ND
MIP32	10.0	5	ND	ND
MIP32	11.0	ND	ND	ND
MIP32	12.0	ND	ND	ND
MIP33	3.0	ND	ND	ND
MIP33	4.0	ND	ND	ND
MIP33	5.0	0.5	ND	ND
MIP33	6.0	1	ND	ND
MIP33	7.0	3	ND	ND
MIP33	8.0	4	ND	ND
MIP33	9.0	6	ND	ND
MIP33	10.0	5	ND	ND
MIP33	11.0	5	ND	ND
MIP33	12.0	1	ND	ND
MIP34	3.0	ND	ND	ND
MIP34	4.0	ND	ND	ND
MIP34	5.0	ND	ND	ND
MIP34	6.0	ND	ND	ND

Table 2-3

Summary of Analytical Results for Goundwater Samples from 1998 SCAPS Investigation by Analytical Method 8265

		Concentration, parts per million		
Location	Sample Depth, feet	Trichloroethene	Dichloroethene	Tetrachloroethene
MIP34	7.0	ND	ND	ND
MIP34	8.0	ND	ND	ND
MIP34	9.0	ND	ND	ND
MIP34	10.0	ND	ND	ND
MIP34	11.0	ND	ND	ND
MIP34	12.0	ND	ND	ND
MIP35	3.0	ND	ND	ND
MIP35	4.0	ND	ND	ND
MIP35	5.0	ND	ND	ND
MIP35	6.0	ND	ND	ND
MIP35	7.0	15	72	ND
MIP35	8.0	22	63	ND
MIP35	9.0	55	69	ND
MIP35	10.0	100	60	ND
MIP35	11.0	59	42	ND
MIP35	12.0	11	25	ND
MIP37	3.0	6	ND	ND
MIP37	4.0	78	ND	ND
MIP37	5.0	55	ND	ND
MIP37	6.0	47	ND	ND
MIP37	7.0	192	ND	ND
MIP37	8.0	1223	ND	ND
MIP37	9.0	1786	ND	ND
MIP37	10.0	998	ND	ND
MIP37	11.0	80	ND	ND
MIP37	12.0	35	ND	ND
MIP39	3.0	ND	ND	ND
MIP39	4.0	ND	ND	ND
MIP39	5.0	ND	ND	ND
MIP39	6.0	ND	ND	ND
MIP39	7.0	ND	ND	ND
MIP39	8.0	ND	ND	ND
MIP39	9.0	ND	ND	ND
MIP39	10.0	ND	ND	ND
MIP39	11.0	ND	ND	ND
MIP39	12.0	ND	ND	ND

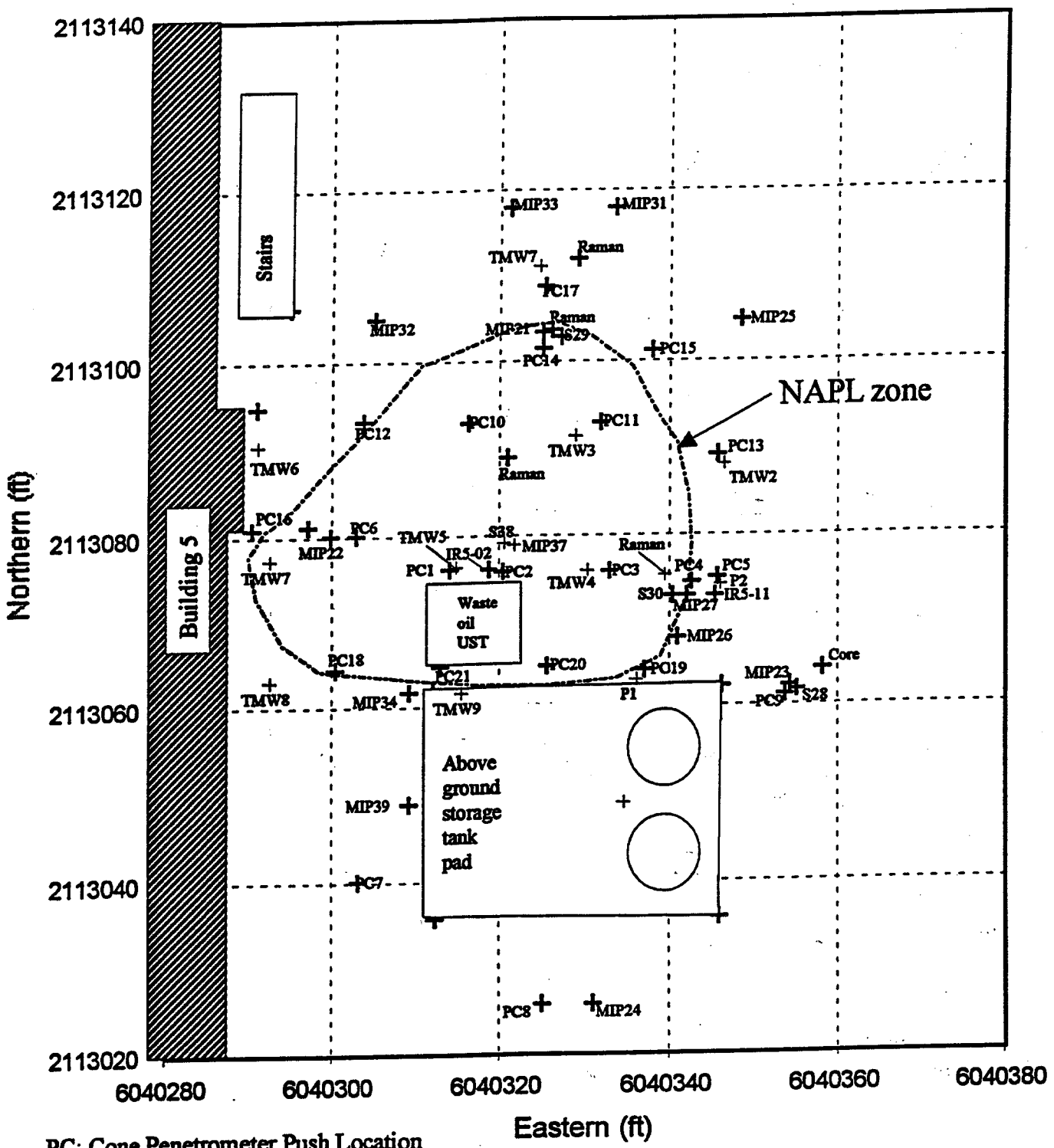
Table 2-4

Summary of Analytical Results for Goundwater Samples from 1996 Initial Investigation

Parameter	Analytical Method	Concentration, miligram per liter				
		3BC		3BD		
		10 feet	12 feet	10 feet	13 feet	20 feet
Volatile Organic Compounds	8260 Screen					
Benzene		<0.0005	0.0005	0.00093	0.00093	<0.0005
Carbon tetrachloride		0.022	0.012	0.0045	<0.0005	<0.0005
Chloroethane		0.0046	0.0006	0.00078	0.041	<0.0005
1,1-Dichloroethane		0.170	0.051	0.170	0.026	<0.0005
1,2-Dichloroethane		0.0006	0.0019	0.0019	<0.0005	<0.0005
1,1-Dichloroethene		0.034	0.0219	0.113	0.0017	<0.0005
cis-1,2-Dichloroethene		0.180	0.120	0.052	0.0007	<0.0005
trans-1,2-Dichloroethene		0.0025	0.013	0.024	0.0021	<0.0005
Ethylbenzene		<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Tetrachloroethene		0.023	0.0015	0.0038	<0.0005	<0.0005
Toluene		<0.0005	<0.0005	<0.0005	0.00083	<0.0005
1,1,1-Trichloroethane		0.150	0.077	0.028	0.00059	<0.0005
Trichloroethene		0.320	0.050	0.130	0.0025	<0.0005
Vinyl chloride		0.00085	0.012	0.046	0.0006	<0.0005
m,p-Xylenes		<0.0005	<0.0005	0.00077	0.00051	<0.0005
o-Xylene		<0.0005	<0.0005	0.0007	<0.0005	<0.0005
Total Volatile Organic Compounds		0.90755	0.3614	0.57638	0.07746	<0.0005

Notes:

< indicates consituent was not detected at the detection limit indicated



PC: Cone Penetrometer Push Location
S: Soil Core Sampling Location
MIP: Membrane Interface Probe Location
TMW: Thermocouple Monitoring Well
P: Monitoring Well Location Location

Figure 2.5 Estimated NAPL zone

3.0 TECHNOLOGY DESCRIPTION AND PROCESS DESCRIPTION

Surfactant-Enhanced Subsurface Remediation (SESR) is a unique technology for expediting subsurface remediation. The surfactants applied in SESR are nontoxic and commonly used in soaps, lotions, shampoo, and even food products. The surfactant system, usually an anionic or nonionic surfactant, is designed to remove organic contaminants, including chlorinated solvents, from contaminated soil. Surfactant/cosolvent systems can increase the solubility of hydrophobic organic compounds by several orders of magnitude and/or can significantly increase the mobility of nonaqueous phase liquids (NAPL). The result can be a significantly reduced remediation time, increased removal efficiency (up to 3 or 4 orders of magnitude), and reduced costs of removal.

The amphiphilic structure of the surfactant causes the surfactant molecules to prefer interfacial regions, thus making them "surface-active" (refer to Figure 3.1). The monomers will continue to accumulate at the air/water and soil/water interfaces until saturation occurs. When the surfactant concentration in aqueous solution reaches the point of interfacial surface saturation, or the "critical micelle concentration" (CMC), the surfactant molecules (monomers) will aggregate into dynamic clusters called micelles. The effective solubility of NAPL compounds in micellar surfactant solutions can be several orders of magnitude higher than in water alone because hydrophobic compounds will partition into the "oil-like" interior of the micelles.

Surfactant/cosolvent solution chemistry can be optimized to produce ultra high solubilization capacities without mobilization of the NAPL (ultra solubilization). Ultra solubilization can be achieved by optimizing the surfactant phase behavior between solubilization and mobilization (Figure 3.2). In general, micellar systems transition from normal to swollen micelles (Winsor Type I), to middle phase systems (Winsor Type III), and finally to reverse micelles that reside in the NAPL phase (Winsor Type II). For a given NAPL, this phase behavior can be regulated by solution salinity and hardness, temperature, and properties of the surfactant or surfactant mixture (Shiau et al., 1994).

If the interfacial tension (IFT) at the NAPL/water interface is sufficiently reduced, trapped droplets of NAPL can be released. However, there are special considerations that must be incorporated into the design of this process. One primary concern is the potential for increased vertical movement of DNAPLs. Hydraulic control systems could be designed to account for increased vertical flow potential. Another alternative is to design the system to counter vertical density gradients by adding sufficient low density substance (that is, cosolvent) to neutralize the effect. In addition, the viscosity of the flushed solution can be adjusted (increased) to offset the effects of reduced IFT. Also, the formation of middle phases (mobilization mechanism) is sensitive to changes in water chemistry. Consequently, the mechanism of choice for this site will be made based on careful review of soil/water geochemistry, contaminant distribution, and site geology.

Surfactant flushing solutions can be designed to be effective under most subsurface conditions. In most cases, the effectiveness of surfactant flushing solutions is not reduced due to the presence of more than one contaminant. Natural occurring divalent cations and salts can affect the performance of certain surfactants and may also affect the removal efficiency for cationic heavy metals.

However, it is possible to design an effective surfactant system for removal of the target contaminants under any of these conditions.

A number of factors influence the overall performance and cost effectiveness of SESR systems. These factors include:

- Local groundwater chemistry
- Soil chemistry (for example, sorption, precipitation)
- Ability to deliver the surfactant solution to the area of contamination
- Surfactant effects on biodegradation of the NAPL compounds and degradation of the surfactants themselves
- Public and regulatory acceptance
- Cost of the surfactant
- Recycling and reuse of the surfactant
- Treatment and disposal of waste streams

Surfactant reuse is important for economic optimization at most sites. High surfactant recovery from the subsurface and effluent stream improves the economics of the technology. In response to this requirement, Surbec and the University of Oklahoma jointly developed an integrated process of surfactant injection, recovery, separation, and concentration for reuse.

Some hurdles have been cleared in gaining regulatory approval for surfactant injection into aquifers. The University of Oklahoma (Knox et al., 1997) was able to gain regulatory approval for a surfactant injection in Michigan by using modeling studies, laboratory studies, and toxicity data to demonstrate that such a test was controllable and safe. Trust Environmental and Surbec recently received regulatory approval to implement a recirculating surfactant remediation system at an underground storage tank site in Shawnee, Oklahoma. Surbec obtained permission from the Oklahoma Department of Environmental Quality to perform a surfactant injection test at Tinker Air Force Base in Midwest City, Oklahoma. In each case, no physical barriers were required, and the surfactant was recovered using hydraulic control measures. Surbec has recently obtained permission from the EPA to inject and re-circulate surfactant for a demonstration at McClellan AFB in Sacramento, California.

A primary objective for the proposed flushing demonstration is contaminant separation from the surfactant. With regulatory approval, surfactant reinjection would be a valuable demonstration and would be a major step toward eventual commercialization of surfactant-enhanced remediation systems.

In order to reinject the surfactant, the contaminant must be separated from the surfactant in the waste stream, then the surfactant must be reconcentrated. An example of an overall treatment process is illustrated in Figure 3.3. The presence of surfactant lowers the efficiency of air-stripping and can potentially cause foaming. Models and design equations have been developed to account for the reduced efficiency of air stripping caused by surfactant; thus, air-strippers can be designed to achieve the desired removal efficiency (Lipe et al., 1996; Hasegawa et al., 1997).

Systems incorporating air-stripping for surfactant-contaminant separation along with micellar enhanced ultrafiltration (MEUF) for surfactant recovery and reuse have shown promise (Ang and Abdul, 1994; Lipe et al., 1996). The proposed MPP system should remove 99%+ of the VOC from the surfactant solution. In MEUF, ultrafiltration membranes allow water and surfactant monomers to pass through the membrane while the micelles are retained by the membrane. This effectively concentrates the surfactant in the extraction stream (which is more dilute than the injection stream) and allows for surfactant reuse.

Several air-stripping processes have been evaluated in the field. Packed columns have been successfully used at Hill AFB and Tinker AFB for contaminant removal from recovered surfactant streams. Also, hollow-fiber membrane strippers have been utilized for the same purpose. More recently, tray strippers have been evaluated for removal of surfactant monomers from solution (via foam fractionation), as well as for separation of the contaminants. This process was successfully demonstrated at Shawnee, Oklahoma. Surfactant monomers were removed in the foam produced in the air stripper effluent and captured in a storage tank. In addition, contaminant removal from the waste stream was enhanced.

Subsurface biological processes can complement surfactant-based technologies and allow for effective natural attenuation of both surfactants and contaminants, resulting in an environmentally friendly means of eliminating subsurface contamination. Work in several laboratories (Freedman and Gossett, 1989; Vogel and McCarty, 1985; and deBruin et al., 1992) has shown that complete conversion of Petrachloroethylene (PCE) to ethylene, and in some cases to ethane, is possible given the appropriate conditions. These conditions include the use of other substrates such as methanol or lactate. There have been several reports of bioremediation studies in which dechlorination of PCE was observed to occur at the aquifer level (Beeman et. al., 1994; and Major et. al., 1995).

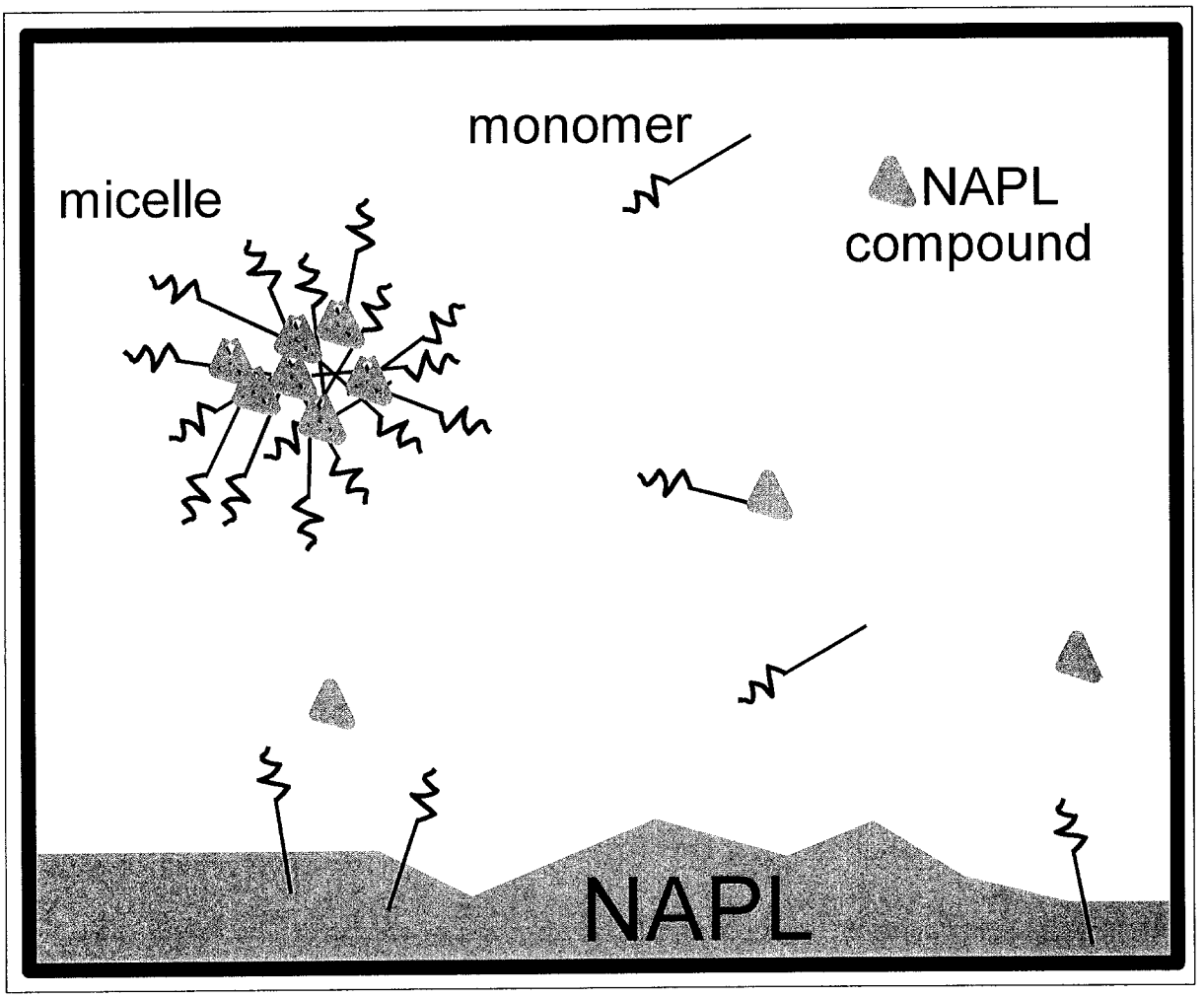


Figure 3.1: Schematic of Surfactant Solubilization

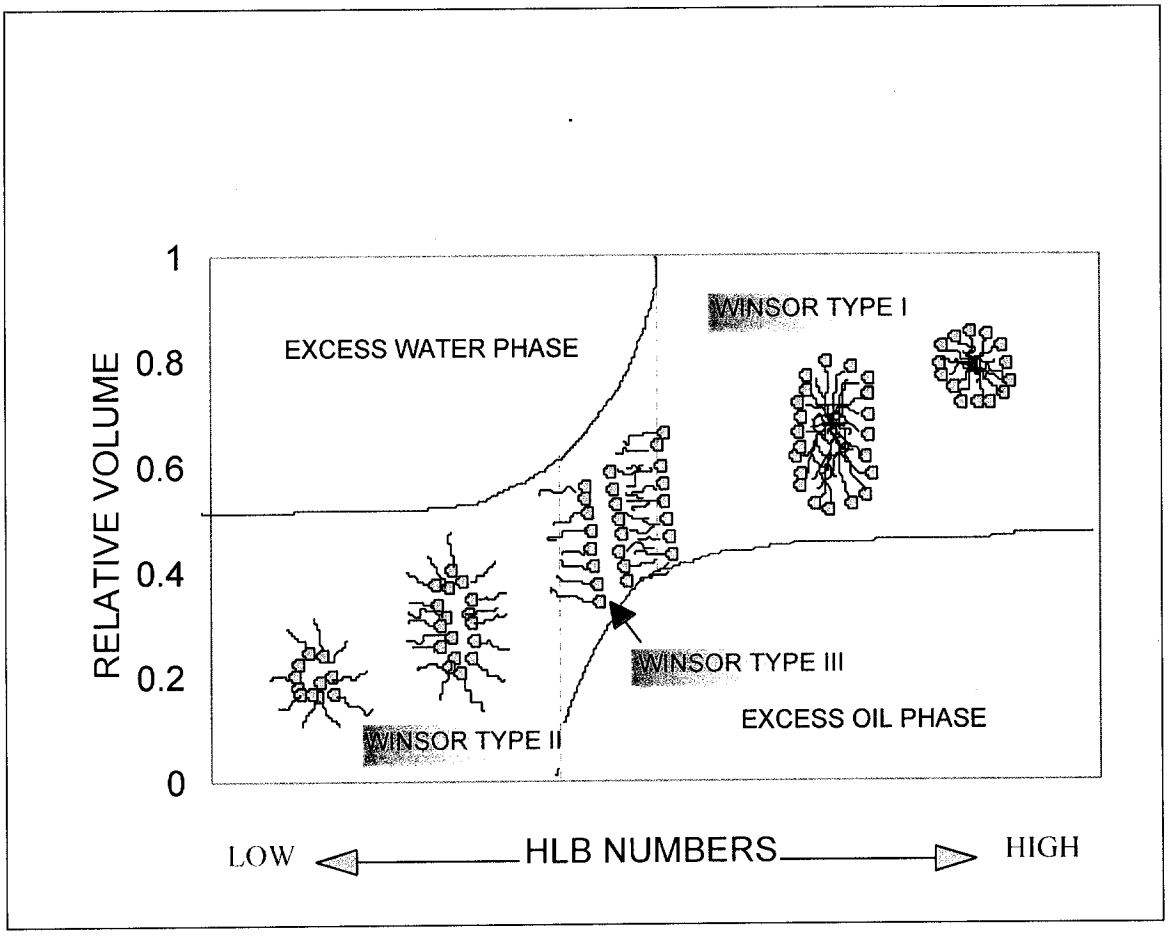


Figure 3.2: Winsor Phase Diagram

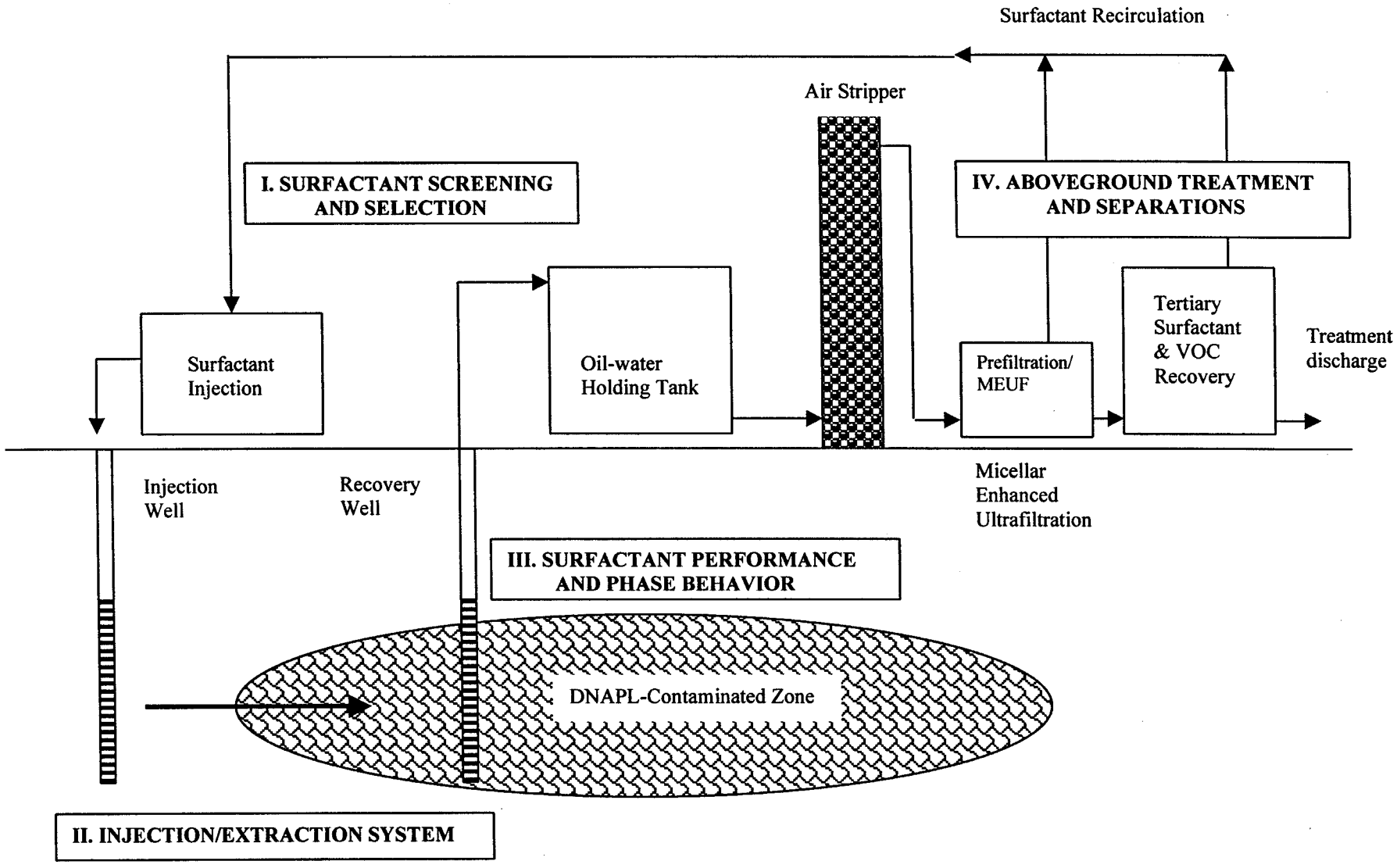


Figure 3.3: Generic Surfactant Remediation Process Flow Diagram

4.0 PROPOSED PROJECT WORK PLAN

The Navy's overall approach to the project is outlined in this section. This approach is based on the project goals, site-specific information and our past experience in this field. Each section outlines the project approach including site-specific design parameters. The proposed Work Plan follows the outline listed below. A schedule showing the expected duration of each project phase is included in Section 5.0.

1. **Regulatory Approvals:** Obtain necessary regulatory approvals prior to initiation of the field work.
2. **Site Investigation Well Installation/Aquifer Testing:** Install wells and collect appropriate samples.
3. **Process Equipment Design, Construction and Installation:** Provide for design of on site process equipment and test for proper operation.
4. **Surfactant Screening and Selection:** Identify optimal surfactant solution.
5. **Pre-Tracer Testing:** Conduct conservative tracer tests to confirm capture zones and partitioning tracer tests to confirm contaminant distribution and quantify pre-flushing NAPL mass.
6. **System Operation:** Implement the SESR flood.
7. **Post Test Partitioning Tracer Testing:** Evaluate post-flushing NAPL mass.
8. **Demobilization and Site Restoration:** Implement procedures for leaving the site in an acceptable condition after completing the demonstration.
9. **Residuals Management/Material Storage:** Follow storage requirements for raw materials, process water, and waste materials.
10. **Reporting:** Implement procedures for updating project progress and creating final report documents.

4.1 Regulatory Approvals

The Navy will obtain all regulatory approvals prior to initiation of any fieldwork. The approvals may include, but are not necessarily limited to, wastewater discharge of the recovered and treated groundwater and air discharge from the system.

Injection/Reinjection Permitting

Based upon a discussion with the U.S. Environmental Protection Agency (EPA), a permit waiver will not be necessary for injection of the surfactant solution, and reinjection of the retentate solution. California EPA (Cal/EPA) does not have a program in place to regulate injection, hence the governing of injection falls to the U. S. EPA under 40 CFR 144 (Underground Injection Control Program).

U. S. EPA Permitting

Based upon the Code of Federal Regulations (40 CFR 144), the injection wells for the treatability study will be considered Class IV injection wells. The regulations prohibit the construction or

use of Class IV injection wells except under 40 CFR 144.13(c). This regulation allows the permission of use of a Class IV injection for injection of contaminated groundwater that has been treated and is being injected into the same formation from which it was drawn, under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), 42 U.S.C. 9601-9657, or pursuant to requirements and provisions under the Resource Conservation and Recovery Act (RCRA), 42 U.S.C. 6901 through 6987. However, a waiver will not be required from the USEPA to reinject the retentate (solution retained behind the membrane) solution back into the groundwater system because the pilot project is being conducted as part of the ongoing CERCLA activities. The injection of the surfactant solution at the start of the project is allowable as long as none of the solution constituents exceed any Maximum Concentration Levels (MCLs).

Cal/EPA Department of Toxic Substances Control

The California Department of Toxic Substances Control DTSC does not regulate injection/reinjection, but does have regulations concerning "degradation" which will need to be addressed with the DTSC.

Air Permitting

Air permitting issues will be handled through the Bay Area Air Quality Management District. It is not anticipated that a permit will be required as the work will probably follow guidelines for the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) under CERCLA.

Wastewater Disposal

Upon discussion with the East Bay Municipal Utility District (EBMUD), a wastewater discharge permit will be required. The Navy is currently filing application with EBMUD. The EBMUD permit will be submitted in January 1999. The wastewater treatment facility has maximum allowable influent concentrations that must be met to allow for discharge to the facility. General acceptance standards are as follows:

- Total Benzene, Toluene, Ethylbenzene Xylene (BTEX) - 5 ug/L
- Total chlorinated solvents - 0.5 mg/L
- Chemical Oxygen Demand (COD) - 500 to 1000 mg/L

In the event that the EBMUD permit can not be obtained prior to the implementation of this project, the Navy will send wastes to a nonhazardous waste treatment facility. In order for that facility to accept residual fluids, all of the fluids must be below the characteristic hazardous waste levels.

4.2 Well Design and Installation

The following sections outline site investigation and the design and installation of injection/recovery system. Well locations were determined through the use of three-dimensional groundwater modeling analysis.

4.2.1 Preliminary Groundwater Modeling

MODFLOW and MT3D analysis were used to determine potential injection/extraction well

placement locations, evaluate hydraulic capture of the well system, determine potential groundwater production as a result of the recovery wells, and evaluate long-term fate of surfactant not recovered. Surbec and the University of Oklahoma have worked jointly on the groundwater modeling presented in this section.

In order to design an effective injection extraction system, the site geology and hydrogeology must first be understood. Surbec has thoroughly reviewed site investigation reports as documented in Section 2.0 of this report. Hydrogeological information, such as hydraulic conductivity, porosity, bulk density, and storage coefficient, was put into numerical groundwater models to simulate aquifer conditions. The model was not calibrated to site pump test data because this information was not available at the time of the preliminary model analysis.

4.2.1.1 Model Setup

The purpose of the MODFLOW analysis is to develop a preliminary design for the injection/extraction system and evaluate subsurface flow patterns beneath the site. To achieve the pre-design goals, simplifying assumptions were made (for example, homogeneity within a geological layer and uniform depths to each layer). The development of the model cross section (refer to Figure 4.1) was developed using the site-specific data included in Section 2.0 and other site information. Assigning conductivity distributions for the different models is key to the development of a realistic representation of the site. Sparse data from boring logs, sieve analyses and permeability measurements have led to the generation of a simple model is separated into two distinct hydrogeological units. The upper unit (0'-14') consists of fill material. The hydraulic conductivity of this layer was determined through the completion of several slug tests that resulted in a hydraulic conductivity ranging from 1 foot per day (ft/day) to 5 ft/day (refer to Section 2.0). Information provided by the Navy indicated that the hydraulic conductivity in the area is 8 ft/day. The lower section consists of Bay Mud (14' – 30') which has a hydraulic conductivity approximately four orders of magnitude less than the fill material. The model was setup using the information included in Table D1 (Refer to Appendix D). Groundwater flow direction is highly variable and can change direction by 180°. As a result, for modeling purposes it was assumed that groundwater flow was to the south.

4.2.1.2 Conceptual Well Location Scenario and Design

The line drive well configuration was evaluated in the modeling study (refer to Figure 4.2 and Figure 4.3). In this configuration IW-1 and IW-2 are the surfactant injection wells, IW-3 and IW-4 are hydraulic control wells and RW-1 through RW-4 are recovery wells. The model was set up so the wells were screened from 7'- 16' bgs (approximate depth of the Bay Mud). The well configuration was evaluated at injection rates ranging from 2 gallons per minute (gpm) to 3 gpm. The recovery rates in the recovery wells were also varied from 2 to 3 gpm. The model results indicated that the wells would pump dry at 3 gpm (assumes a 5-day pumping scenario and a hydraulic conductivity of 8 ft/day). The most efficient system appeared to consist of a balanced (1:1) injection/recovery ratio. For the optimal pre-design scenario, the injection wells IW-1 through IW-4 were set at 2 gpm and the recovery wells RW-1through RW-4 were set at 2 gpm.

A critical issue is the potential for uncontrolled vertical migration of the NAPL. The approach depends on the hydrogeologic conditions at the site. Since this project area is underlain by 14' to 30' of low permeability Bay Mud, vertical migration should not be an issue. However,

precautions will be taken to ensure vertical migration will not occur. During column testing in the laboratory, the potential for mobilization will be evaluated and quantified. If the laboratory analysis indicates that vertical migration could be an issue, methods such as neutral buoyancy, where alcohol is used to offset DNAPL density gradients, will be used to mitigate these effects. Another method is to use a surfactant concentration gradient in which the solubilization potential of the surfactant is low at first and increased as the flood progresses (refer to Section 4.2.6 for additional details).

In addition, a sampling point will be placed in the Bay Mud sediments at a depth of five (5) feet below the fill sand/Bay Mud contact. The expected depth of this sample point is twenty (20) feet bgs.

4.2.1.3 Surfactant Fate and Transport

All of the chemicals proposed for use at the site are non-toxic and nonhazardous. Most of them have food-grade additive status from the Food and Drug Administration and the remainder have food contact grade status (refer to Table 4.2). Surfactant injection should not have any significant effect on geochemical parameters such as pH. The only potential effect may be with respect to biodegradation. Surfactants can act as substrate for microbial activity, and any surfactant not recovered may become food for the microbial community. If the enhanced solubilization system is used, the calcium or sodium and chlorides in solution will increase the total dissolved solids at the site.

The surfactant transport has been simulated in the model by incorporating advection, dispersion and sorption mechanisms (MT3D). Advection is the primary driving force for plume migration and has been incorporated based on the preliminary site data. Dispersion has been assumed based on the lithology encountered for the most permeable zone. This assumption results in the least dispersion and highest migration potential. Sorption has been simulated using linear sorption constants observed at other sites for commonly used surfactant. The flushing model incorporates 5 days of surfactant, followed by 5 days of potable water, flushed through the treatment plot, subsequent to the surfactant flush. The breakthrough curve illustrated in Appendix D shows the predicted surfactant recovery concentrations and time for breakthrough. The model showed a higher efficiency with less flow through the center of the plume and good capture in the test area (refer to Appendix D Figures D1 through D5). Based on this information, it appears breakthrough of one complete pore volume occurs within 1 to 1.5 days. The shape of the breakthrough curves also indicates that the post surfactant test water flood duration of 5 days is sufficient to remove the majority of surfactant mass from the test cell area. An additional 2 days of pumping from the recovery wells will further reduce surfactant concentrations in the test cell (refer to Figure D5).

Subsequent to flushing activities, the MODFLOW/ MT3D simulation was run for 1 year to evaluate migration potential of remaining surfactant. The remaining surfactant migrated approximately 20 feet in the upper zone toward the south (the assumed direction of flow). The remaining surfactant plumes are very limited in size with maximum concentrations less than a few hundred parts per million.

4.2.2 Well Installation and Design

The location of the proposed wells with respect to the field site is identified in Figures 4.3 and 4.4. All utilities will be confirmed prior to installation of any wells and a dig permit will be obtained from the CSO. Prior to any soil boring activity, the exact boring location will be marked on concrete with paint. The location will be approved by TtEMI, and the proper digging permits and utility clearance will be acquired.

Borings will be advanced using a hollow stem auger rig equipped with a split barrel continuous coring device. Core samples will be collected on 5-foot intervals and sent to the University of Oklahoma (OU) for bench-scale analysis. Samples will be collected from the cores for volatile analyses (below the 5-foot depth) and preserved in methanol. Information on sample location and frequency is included in Table C1 in Appendix C. In addition, cores will be examined for lithology and described using the Unified Soil Classification system (ASTM D2488). The resulting soil types will be logged on a boring record log. Drill cuttings will be stored in drums at the site until they can be sampled and properly disposed of. Soil and groundwater samples will also be collected for the purpose of bench-scale analysis.

The soil borings will be completed as 4 inch wells (refer to Figure 4.4). The wells will consist of 0.02-inch slotted stainless steel screens, with polyvinyl chloride (PVC) casing to the surface. The screen will be fitted with a stainless steel end cap or sump. The screen will extend from the base of the aquifer across the water table. The entire saturated thickness will be screened. The entire annulus surrounding the screen will be filled with a clean #3 silica sand filter. The sand filter pack will extend from the base of the well to a depth of approximately 1.5 feet above the screen. A 1.5-foot-thick sodium bentonite chip seal will be placed above the filter pack. The remaining 2 feet will be filled with concrete and completed with a flush-mount water-tight protector. A water-tight sealing cap will be placed on the well. Monitor well completion diagrams will be generated for each well.

4.2.3 Well Development and Sampling

The wells will then be developed, purged, and sampled. The wells will be developed using a 2-inch Grundfos pump. The wells will be surged prior to pumping to loosen fine-grained particles from the filter pack and screen. Development pumping will continue until the water is free of sediment and the pH, conductivity, and temperature have stabilized.

The wells will be allowed to set for 24 hours prior to purging and sampling. The wells will be purged of three casing volumes using a Grundfos® pump or bailer. Purged water will be stored in storage tanks until Surbec can arrange for disposal at the EBMUD or equivalent wastewater treatment facility. Samples will be collected with a bailer and gently poured into the appropriate bottles to avoid aeration. One sample per well will be analyzed for VOCs using EPA method 8260B to determine baseline groundwater concentrations. Water samples will be stored on ice and sent to a Naval approved laboratory for analysis. Additional information with respect to sampling location, methodology, and analytes is included in the sampling plan (refer to Appendix C). Wells will be surveyed by a registered surveyor and gauged to create a potentiometric surface map within the test area (contours of groundwater surface).

4.2.4 Aquifer Testing

A 24-hour pump test will be conducted on IW-1 (refer to Figure 4.4). A submersible pump will be installed in IW-1 well and fluids stored in a 20,000-gallon tank. Pressure transducers will be placed in the recovery well and in RW-1, IW-4 and RW-4. Drawdown results of the 24-hour test will be downloaded and analyzed to determine hydraulic conductivity, storage coefficient, and transmissivity. Based on the site data included in the request for proposal and preliminary modeling results, it appears the maximum pumping rate will be 2 gpm. Assuming this flow rate, an estimated volume of 3000 gallons will be produced during the pump test.

4.2.5 DNAPL Mobility and Migration

Increased vertical mobility of DNAPL can be induced through two primary mechanisms:

- Mobilization of free phase NAPL through the reduction of interfacial tension
- Density gradient in dissolved solution due to increased solubilization of dense contaminants (i.e. TCE)

The vertical migration of mobilized NAPL can be mitigated through the existence of a lower confining geological zone, applying a gradient surfactant flood or utilizing neutral buoyancy. There is a lower confining clay layer at the site (Bay Mud) which will provide resistance to vertical migration. However, fractures may be present in this zone and other methodologies may be required to ensure vertical migration will not occur. The gradient surfactant flood system is initiated with a low surfactant solubilization potential and slowly increased by increasing salinity and/or co-surfactant. This results in contaminant solubilization before mobilization can occur. This will be demonstrated in column studies completed evaluating DNAPL removal on soils obtained from the site. To ensure that NAPL will not be mobilized, we will implement a gradient flushing system that will not reach middle phase mobilization or the ultra-low interfacial tensions.

Density gradients in the dissolved solution can be mitigated through hydraulic control and neutral buoyancy. The formula governing the flow velocity in the vertical direction is:

$$V_r = - Kz\,(\rho_w - \rho_s)$$

Thus the driving force for vertical flow is the density gradient (ρ_w - ρ_s) and is resisted by the vertical component of the hydraulic conductivity (Kz). The density of a solution with a TCE concentration of 100,000 mg/l is 1.04 with respect to water (if no alcohol is in solution). This can be converted to a hydraulic head gradient of 4 feet / 100 feet. The resistance through Kz is usually much greater than the horizontal resistance Kh. To ensure hydraulic capture, it must be shown that the flow vector of the solution will reach the recovery well. The modeling results for this site showed the horizontal flow gradient to be up to 6 feet (difference between groundwater elevation between injection and recovery wells) resulting in a horizontal flow gradient of 0.6. Based on an assumed vertical hydraulic to horizontal hydraulic conductivity assumption of 1:5, the solution will migrate downwards less than 0.4 foot for every 10 feet migrated (distance between recovery and injection wells) of horizontal migration.

Vertical migration can further be prevented through neutral buoyancy. In this case the alcohol in solution offset the increased density gradient of the solubilized DNAPL.

4.3 Process Equipment Design and Installation

Even when surfactant recycling is incorporated into the technology, surfactants can account for over 40 percent of total project costs. To make this technology economically competitive, surfactant recycling and reuse is essential. In past field demonstration projects, Surbec and its team members have designed and operated pilot-and full-scale process equipment to regenerate the surfactant stream.

The following section describes the design process and assumptions used for pre-design analysis of the aboveground treatment process. Field studies have verified this approach for the C16 DPDS surfactant. With the exception of Aerosol MA 80 (AMA), all the listed surfactants should behave similarly in the process equipment (AMA system is not recoverable in the ultrafiltration system).

Most surfactants are designed to degrade in municipal wastewater treatment systems. As a result, residual surfactant streams could be sent to municipal or industrial wastewater treatment systems. Discharge through a NPDES permit is possible, but surfactants can be toxic to amphibious aquatic life. To ensure no adverse effect to these life forms, the surfactant concentrations in the effluent would require reduction. If required, an aerobic bioreactor could be designed for surfactant degradation to allow for discharge through an NPDES permit.

A key point of the design is the effluent standards that must be achieved. Because discharge to a publicly owned treatment works (POTW) is desirable, EBMUD has been contacted and preliminary standards with regard to BTEX and chlorinated solvents obtained (refer to Table 4.3).

4.3.1 Summary of Design

The proposed design is documented in Figure 4.4. Key design parameters for all of the process equipment to be used in this project include flow rates, temperature, influent concentrations, and required effluent standards. A summary of the assumed design criteria is found in Table 4.3. The flow rate estimates were derived using the flow rates determined from the preliminary modeling efforts and incorporation of a factor of safety. Discharge criteria for BTEX and chlorinated solvents was obtained from EBMUD.

The design is purposely versatile and modular in form so that it will be functional regardless of the surfactant system selected for implementation. The system may require minor modifications, but the overall system will not significantly change. For example, the tray stripper may not be required depending on the surfactant system selected for the project.

As appropriate, operational functions of the treatment system will be automated. Sample valves will be operated manually. The process equipment will be trailer-or skid-mounted and modular in nature. The skids and trailers will be connected to the process piping via a 2 inch high pressure nylon hose with quick-connect fittings. The trailer-mounted equipment has been designed so that the flow is diverted through adjusting valves. For example, if it is determined that an air-

stripper is required, the flow can be diverted from the macro porous polymer (MPP) system and fed directly into the prefiltering system by the adjustment of two valves. All piping on the trailers will be galvanized steel.

As indicated in Figure 4.4 the injection/recovery system consists of four recovery wells, two surfactant injection wells, and two hydraulic control wells. In each recovery well a .5 horsepower (hp) submersible pump is installed to recover fluids. If extremely low flow conditions are encountered (yield of less than 0.5 gpm), a vacuum-enhanced recovery system will be installed in place of submersible pumps. Each recovery well is individually piped to a recovery system manifold using 1-inch carbon steel pipe. Each line is individually controlled with an electric solenoid valve and monitored with an electronic flow meter so the flow to each well is adjustable. The recovery well manifold is connected to an oil-water separator where any free phase DNAPLs will be recovered and stored in 55-gallon drums. Any additives to aid in the recovery of free phase DNAPL will be injected into the oil-water separator.

Using a 2 hp centrifugal pump, the groundwater effluent from the oil-water separator will be piped to the MPP system. The effluent from the MPP system will be pumped through the pre-filtration units and the MEUF unit. The permeate from the MEUF will be pumped directly into the storage tanks. The retentate will flow into the surfactant-recycling tank for reinjection. Makeup surfactant will be pumped into the surfactant recovery tank using a 1/3 hp bladder metering pump.

The recovered surfactant will then be pumped into the surfactant reinjection manifold (connected to IW-1 and 2). As with the recovery wells, each injection well will be individually piped to allow for greater control of injected fluids. All valves and flow meters will be located at the reinjection manifold. All injection piping will be polyethylene.

The injection into the hydraulic control wells will be directly from the fresh water feed. Each row of control wells has only one 1-inch polyethylene supply line.

4.3.2 MPP Design

The primary contaminant separations process is the MPP system developed by Akzo Nobel. The MPP system utilizes a Macro Porous Polymer to remove VOCs and semi-volatile organic carbon (SVOCs) from the recovered groundwater. The apparatus consists of two 1-meter columns connected in parallel. While one column is being operated, the other is being regenerated using steam. The MPP system has greater VOC removal efficiency using a much smaller apparatus than air-stripping. The column has minimal air emissions and produces free-phase organic product when regenerated. This technology has been selected because it is designed to have minimal air emissions and additional offgas treatment should not be required. Additional design information for this system is included in Appendix E.

Air-stripping was also considered for VOC removal from the groundwater. A preliminary design analysis has been conducted using the Hasegawa/Lipe model and it appears that two 8-meter by 1.5-meter air-stripping towers will be required to reduce the total solvent concentration to 0.5 mg/L. However, because offgas treatment would be required, this option was eliminated from consideration.

4.3.3 Surfactant Recovery (Micellar Ultrafiltration)
The second aspect of the treatment process is concentrating the surfactant stream for reinjection. Over pumping for hydraulic control results in surfactant dilution in the borehole, resulting in the need for this concentration step. With the exception of the AMA surfactant, the MEUF should be effective for re-concentrating all of the surfactant systems being considered. Past experience and design estimates indicate that it is capable of 80-95% recovery of the surfactant from the treated stream. The actual recovery potential is dependent on the surfactant system used.

The MEUF system to be used will be a spiral-wound cross flow. The pump is a 2 hp centrifugal capable of attaining 10 gpm at a pressure of 60 pounds per square inch (psi). Sampling ports will be manually operated. The design of the MEUF system is not dependent on the surfactant selected and will not change. However, the filter selected for use in the MEUF is surfactant dependent. The filters to be used will range between 2,000 molecular weight (MW) cutoff and 10,000 MW cutoff. Filter size will be evaluated during the bench screening activities and will be a function of the final surfactant system selected for the demonstration.

4.3.4 System Mobilization and Installation
All process equipment will be manufactured off site and shipped to the site for installation. Temporary hose and steel piping will be used to connect the treatment system with the recovery wells and other infrastructure. Required infrastructure will be three-phase 480-volt electrical power and clean water supply capable of 20 gpm. Surbec currently owns trailer-mounted process equipment including an air-stripper and MEUF. All key process equipment will include automated operational controls for primary flow operations, or the system will be monitored constantly during flushing operations.

4.4 Surfactant Screening and Selection

Surbec personnel and researchers from the Institute for Applied Surfactant Research (IASR) at OU have developed a formal protocol for laboratory tests to develop design information for surfactant-based remediation systems. The protocol is structured to progressively reduce the number of candidate surfactant systems without overlooking viable systems. The initial tests assess surfactant performance and losses in batch systems; only the most promising surfactants from these tests are used in subsequent column studies and bio-screening tests.

The project team will review existing site data and, in accordance with past experience, will determine a list of potential surfactants/co-solvents for evaluation. Potential surfactant/co-solvent systems are identified in Table 4.2. The actual surfactant will not be selected until the laboratory screening process has been completed. Candidate solutions will be screened for the following properties:

- Toxicity and food-grade additive status
- Biodegradability
- Potential enhancement of DNAPL removal
- Removal mechanism and adverse migration potential
- Potential for economic reuse and recovery of the surfactant/co-solvent
- Sorption of the surfactant/co-solvent onto the soil matrix

- Resiliency of the surfactant/co-solvent (that is, how the surfactant resists subsurface chemical reactions)
- Overall costs

The following paragraphs briefly discuss the laboratory surfactant screening tests. These tests will yield pertinent information about the surfactant/co-solvent systems being screened. Each test has been carefully selected to give information about the surfactant that will relate to its potential effectiveness for remediation. Additional details for each test and the analytical procedures are included in Appendix A. The tasks are listed in sequential order:

Contaminant Solubilization (includes mobilization systems) The objective of this tests is to quantify the solubilization (mobilization) potential of a range of surfactants and co-solvents. The ability to remove the target contaminant will most strongly influence the effectiveness of these systems.

Surfactant-Contaminant Phase Properties The objective of this test is to evaluate the phase behavior of the surfactant (or co-solvent) NAPL system in an effort to avoid significant reductions in the interfacial tension or unfavorable viscosities or densities that might result in unfavorable flow characteristics. Formation of middle-phase microemulsions is specific to the contaminant composition and the groundwater system (temperature, surfactant system, ionic strength, etc.). These phase behavior studies will identify robust surfactant/co-solvent systems capable of achieving high solubilizations for the existing groundwater conditions.

CMC Measurements The critical micelle concentration (CMC) is the concentration at which the surfactant monomers aggregate into micelles. The CMC affects several properties of the surfactant solution that could impact the effectiveness of the process including sorption, solubilization, and foaming.

Surfactant Sorption The objective of this test is to quantify the losses of the surfactants and co-solvents due to sorption onto the site-specific soil. Losses of surfactants and co-solvents will adversely affect the technical performance and economic viability of the remediation process.

Surfactant Precipitation The objective of surfactant precipitation is to quantify the precipitation boundaries of the surfactants, whether the phase boundary is crossed due to ionic composition (ionic surfactants) or groundwater temperature (nonionic surfactants).

Column Tests These tests are used to simulate one-dimensional flow through the aquifer. Valuable information that can be obtained from the column studies includes: solubilization enhancement under flowthrough conditions, potential headloss increases in the media, and unanticipated reactions. Column tests will also be conducted to calibrate the Partitioning Interwell Tracer Test (PITT).

Separations Testing: The purpose of these tests is to confirm the effectiveness of the treatment process on the site-specific surfactant and NAPL. MEUF testing will be conducted to optimize the configuration of the field unit. These tests will be conducted in a bench-scale cross flow membrane apparatus.

Modeling Analysis: As part of the bench-scale analysis, additional groundwater modeling will be conducted. All available site-specific information will be input into Visual MODFLOW model and the model will be calibrated against pump test results. The purpose of this analysis is to confirm the results of the preliminary model analysis. In addition, UTCHEM analysis will be conducted to predict potential VOC recovery concentration and time required to meet premeditation goals. These models will be further refined subsequent to the completion of Partitioning Interwell Tracer Testing.

Technical Memorandum: A technical memorandum will be prepared which summarizes the results of the initial soil and groundwater analysis, complete design drawing of process equipment, and results of bench-scale analysis. Also identified in the report will be the surfactant system best suited for application at the site (refer to Section 4.10)

4.5 Partitioning Interwell Tracer Testing

Tracer Testing

A combined partitioning/conservative tracer test (PTT) will be conducted prior to the SESR demonstration. The purpose of the conservative tracer test will be to demonstrate hydraulic capture of the injection/recovery system. The partitioning tracer test will be used to evaluate NAPL distribution in the test area, quantify pre-test NAPL concentrations in the flushed zone and target delivery of surfactant during remediation.

Based on the assumption that one pore volume can be flushed through the treatment area in 1 to 1.5 days (based on preliminary modeling), it is expected that the PTT will last 7 days. This duration is based on approximately seven pore volumes of fluid for complete tracer breakthrough. For additional background information regarding partitioning tracer test implementation details, refer to Attachment A.

Three to four tracers will be used; these tracers may include bromide, 1-propanol, 2-propanol methanol, hexanol, 1-heptanol, and 2, 4-dimethyl-3-pentanol. Selection of tracers will be finalized during lab-scale testing (included with the surfactant screening processes) and will be based on their partitioning coefficients into the NAPL. Bench-scale column tests will be used to calibrate the performances of the tracers. The column tests will be conducted using soil from the selected site with varying NAPL concentrations. The chromatographic separation observed between the tracers will be used to calibrate the field PTT flush. These results will be used to design and evaluate the field PTT. If prior to performing the PTT test, it is determined that one or more of the tracers needs to be substituted, Base officials will be contacted and materials safety data sheet (MSDS) information provided. Tracer concentrations in the injected solutions will range from 100 to 2000 parts per million (ppm). Tracers will be recovered in the test area, as well as by existing groundwater capture wells, to ensure the tracer is recovered from the aquifer.

Submersible pumps or, if required, a vacuum-enhanced recovery system will be installed in the recovery wells. They will be operated at the rates determined in the modeling efforts (estimated at 2 to 3 gpm per well). Fresh water injection (2 gpm per injection well) and extraction will

begin 12 hours prior to injection of the tracer to establish capture zones. An appropriate amount (for example, 1000 gallons) of tracer solution will be mixed and evenly distributed to the injection wells. The tracer will be gravity-fed into the wells at a rate of 2 gpm per injection well.

As a general rule, 30 samples should be collected from each recovery well and monitoring well and analyzed for tracers. Details on sample collection frequency and location are detailed in Appendix C. Recovered groundwater will be pumped through the MPP system to remove contaminants then sent to 20,000-gallon tanks for storage. Four 20,000-gallon tanks will be provided for fluid storage. Expected residual generation quantities are documented in Table 4.4 (12 gpm for 6 days).

Prior to system operation, additional modeling efforts will be conducted to optimize the injection recovery-pumping schedule. The information obtained during the pump and tracer testing will be input into Visual MODFLOW and UTCHEM (or comparable) for model refining. The additional analyses will be used to optimize the pumping schedule and help optimize surfactant-flushing efforts.

Push-Pull Testing: In order to confirm the effectiveness of the surfactant solution selected in the laboratory, a push-pull test will be conducted at the test site. One well will be selected for surfactant/co-solvent push-pull test. The well will be injected with up to 55 gallons of surfactant (concentrations of surfactant will be less than 8 wt. %). Groundwater sampling results obtained subsequent to the well installation (not to exceed 2 weeks) will be used to establish baseline VOC concentrations prior to surfactant injection. During the push-pull test, the groundwater will be analyzed for VOC concentration. Since surfactants will enhance the ultimate solubility of the VOCs in groundwater by over an order of magnitude, the existence of NAPL droplets will be evidenced by an increase in the VOC concentrations over that of the baseline results. An increase in VOC concentration in the groundwater over background by a factor of 1.5 or more indicates enhanced solubilization and the existence of NAPL within the radius of influence. The proposed surfactant to be utilized for the push–pull tests will be the surfactant of choice for the demonstration as determined by the laboratory testing (refer to Appendix F for MSDS and other chemical information).

The solution will be gravity-fed into the well at a rate of 1 gpm and allowed to equilibrate for at least 30 minutes. Then the injected surfactant will be recovered using a submersible pump. The recovery rate will be at least 1.5 times the injection rate and is anticipated to produce approximately 400 gallons of groundwater. The actual recovery rate and amount produced will be modeled for the specific well to be tested. The test will be designed to recover all the injected surfactant during the push-pull test or the remaining surfactant will be recovered during the surfactant demonstration or in plume-specific recovery wells. This information will be submitted to the Navy for approval prior to the performance of the push-pull test. As a general rule, the recovered volume should be at least five times the injected volume. Ten groundwater samples will be obtained from the recovered groundwater during the test (two from the storage tank and eight from the recovered stream). These samples will be sent to a Nave and California certified laboratory for VOC and surfactant analysis. Two duplicate VOC samples will be sent to a separate California approved laboratory for quality control (QC) analysis. One duplicate

surfactant sample will be collected for QC purposes. It is expected that the push-pull test will last 1 day.

Recovered fluids will be stored on site in tanks provided by Surbec. The water will be discharged during the demonstration with the recovered water from the surfactant flood.

4.6 System Operation

Prior to the operation of the system, a safety check will be completed to ensure that all aspects of the process are working properly and safely. The treatment goal of 95 percent DNAPL removal should be met within three to five pore volumes. The system operation has been prepared assuming that the entire 20-by 20-foot plot will be remediated. Initial calculations indicate that 10,000 gallons is the volume of groundwater in one pore volume of the treatment cell (20 by 20 by 10 feet at 35 percent porosity). Operation will allow for 5 days of surfactant flooding followed by 5 days of water flooding. Assuming that the surfactant will be injected at 6 wt. % in water, 600 gallons of surfactant will be required for the first pore volume. Assuming 80% recovery of surfactant, an additional 600 gallons will be required to supplement recovered surfactant. Surfactant will be brought to the site in drums and mixed with water in a 20,000-gallon storage tanks. The 20,000-gallon tank will be first filled with 10,000 gallons of water. The surfactant will be injected in the top of the tank and a 2 hp centrifugal pump will recirculate the water in the tank to mix the solution. Specific information with respect to the surfactant composition and quantities will be included in the technical memorandum.

In order to establish cones of depression, the recovery wells will be pumped for at least 3 hours prior to injection of surfactants. Sampling frequency will be spaced to obtain 20 to 30 data points from each recovery well during the surfactant flood (refer to Appendix C for sampling details). The groundwater will be sampled more frequently until steady state (relatively constant surfactant/co-solvent concentrations in production wells) is achieved, and less frequently thereafter. Other information such as flow rates (flow meter), pressures (pressure gauge) and temperature (inline thermometer) will be recorded on the field log sheets four times daily until steady state is reached and once a day thereafter. Flow meters will be equipped with totalizers to track total flow volumes.

A key aspect of this technology is the separation of the contaminant from the recovered surfactant stream and reuse of the surfactant. The recovered groundwater will be piped to the oil-water separator where free-phase DNAPL (if produced) will be recovered. The recovered groundwater will then be pumped through the MPP system where the contaminant will be separated from the surfactant. Since the MPP process utilizes steam recovery of the VOCs, no off gasses are expected.

The treated surfactant stream will then proceed to the MEUF unit to concentrate the surfactant for potential recirculation through the treatment zone. The performance of the MEUF system is largely dependent on the surfactant selected for the test. Surfactants with low CMCs can be concentrated more effectively than surfactants with high CMCs. Surfactants will be screened in

the laboratory for MEUF concentration efficiencies prior to the final design of the filtering system.

Until surfactant breakthrough occurs, effluent from the MPP system will be pumped directly into the storage tanks. After approximately 1 day, surfactant breakthrough should occur and fluids will be sent to the MEUF for surfactant recovery. Retentate will be piped to the surfactant recovery tank and sampled to ensure that reinjection concentrations of the surfactant solution meet project specifications. If required, makeup surfactant will be injected from barrels into the surfactant recovery tank. Permeate from the MEUF will be piped directly to the storage tanks. The foam produced in the tray stripper will be captured and piped to the surfactant recovery tanks for reuse. The permeate will be stored in tanks until proper disposal can be arranged.

4.7 Post Test Performance Analysis

A post-demonstration partitioning tracer test will be conducted. The primary purposes of this test will be to quantify the remaining NAPL concentrations and the distribution thereof in the flushed zone. The procedures to be followed for the final test will be similar to the pre-partitioning tracer test (refer to Section 4.5). Tracers for the post PTT may include bromide 1-propanol, 1-heptanol and 2- ethyl -1- hexanol.

Surbec will also drill four soil borings within 4 feet of each recovery well prior to abandoning these wells. These borings will be continuously cored, and samples corresponding to the pre-test soil sampling intervals will be collected. The soil sample results will assist in evaluating the effectiveness of the surfactant flushing technology.

4.8 Demobilization and Site Restoration

Subsequent to completion of all site activities, site demobilization will occur. All equipment associated with the project will be dismantled. Also, containment areas will be dismantled and the site will be restored to its original condition. All wells installed as part of the project, will be properly removed and sealed as required, unless the base indicates the desire to use these wells in the future.

4.9 Residual Management and Material Storage

This subsection describes the management of wastes generated during the demonstration. Representative samples of each type of waste (that is, cuttings, wastewater, liquids) will be collected and analyzed as appropriate for disposal. Surbec will ensure that all wastes are handled properly. Wastes that will be generated include:

Soil

The volume of soil generated is estimated to be 7 cubic yards (12 wells at 12 inches in diameter and 16 feet deep). Drill cuttings will be placed in drums and stored on site until disposal can be arranged.

Wastewater

The expected residuals generated for the demonstration have been broken down into categories and summarized in Table 4.4. Recovered fluids will be stored in 20,000-gallon tanks until disposal can be arranged (refer to Section 4.1). Surfactants are designed to degrade in POTW

facilities. As a result, it will be convenient to send the recovered fluids to such a facility. Since surfactants can be toxic to amphibians, direct discharge into streams and rivers should be avoided unless all surfactant can be removed through on site physical or biological treatment.

Offgas
Offgas treatment should not be required because the process equipment should not generate emissions to the air.

Solid Waste
Disposal activities will comply with base requirements. Refuse and trash will be placed into proper disposal bins.

Free Phase NAPL
Recovered free-phase NAPL will be stored in drums on site until proper disposal or recycling arrangements can be made.

Process Chemical Storage
MSDS information for chemicals to be used on site as stated will be kept on site in the Work Plan. Chemical storage will depend on the volume required for each chemical. The process chemicals will include tracer solution and surfactant/co-solvent solution. Surfactants will be stored in drums on site. Other chemicals used in the on-site laboratory will be stored in the appropriate container within the mobile laboratory.

4.10 Reporting

Reporting requirements will include monthly reports, brief technical memorandum, weekly update reports during the system operation, and a treatability study report. The monthly reports will update project progress, schedule, and budgetary information. Proposed changes in project procedures will also be identified. The monthly report will include:

- 1-to3-page summary of activities conducted during the month
- Brief summary of activities proposed for the next month
- An updated schedule
- Project cost summary update (Navy only)

TtEMI will forward a copy of the monthly report to the Navy.

The technical memorandum will summarize, in greater detail, the results of laboratory screening and preliminary site activities. These results will be tabulated and graphed. Any deviation from the original implementation plan will be identified and an alternate plan of action described. The technical memorandum will be submitted as indicated in the schedule (refer to Section 5.0).

Weekly reports will be submitted during operation of the flushing activities. The reports will be transmitted by letter, e-mail, or fax.

A treatability study report will be prepared and submitted in three stages: 1) a preliminary draft copy 2) a draft copy (which will include responses to comments on the draft copy) and 3) a final copy.

The report will present the data collected and tabulated. This information will also be graphed and plotted to illustrate system performance in key areas. These data will include: soil concentrations before and after treatment, extraction flow rates, cumulative flow volumes, temperature data, tracer test data, surfactant recovery, contaminant recovery, laboratory results and process equipment performance evaluation, and mass of contaminant removed as evaluated using the partitioning tracer information. Timeline plots will be created for mass of surfactant recovered in the groundwater, mass of contaminant recovered in the groundwater, mass of contaminant removed in the air-stripper, and mass of surfactant recovered in the MEUF. An analysis of these data for the effectiveness of the technology in remediating the test site will be performed and reported to assess the technology performance claim as stated in Section 2.0.

The results of this test will be compared to the results observed at other sites (Tinker AFB). An overall cost evaluation of the system will be conducted at the completion of the demonstration and will be included in the report. The system will be compared, based on capital and operating costs, with other conventional treatment technologies (such as pump and treat) used to treat a similar area and contaminant profile. Capital and operational costs will be compared on a present value basis with the conventional technology.

The report will also include the following key information:

- Effectiveness of the system in removing DNAPL at the test site
- Detailed diagram of the site, including monitoring well locations
- Groundwater monitoring and soil sampling plan, including a plan for collecting water level measurements and samples
- Surfactant screening, which will include phase behavior analysis for the product samples collected from the test area: and the following tests for soil samples collected from the test area; permeability, cation exchange capacity, surfactant-soil interaction, and grain size analysis
- Hydraulic testing, including slug tests of the installed monitoring wells
- A numerical simulation, including a three-dimensional model to simulate test flow conditions
- A surfactant flood, which will also include a water flood prior to surfactant injection, and a water flood following surfactant injection to displace mobilized product
- Problems encountered
- Deviations from project plans
- Process waste handling procedures and notes
- Health and safety procedures

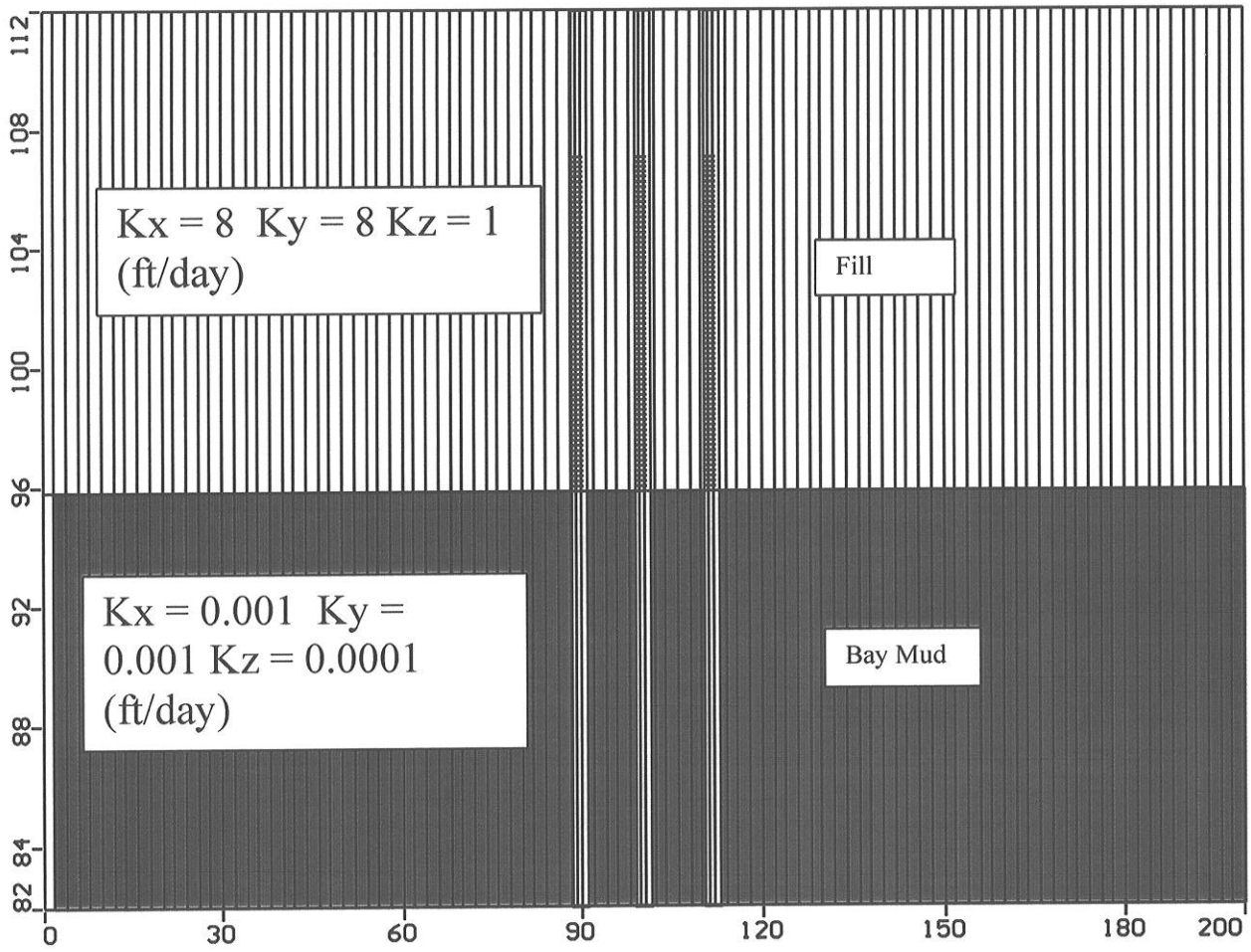


Figure 4.1: Modeled Cross-section (All units in feet)

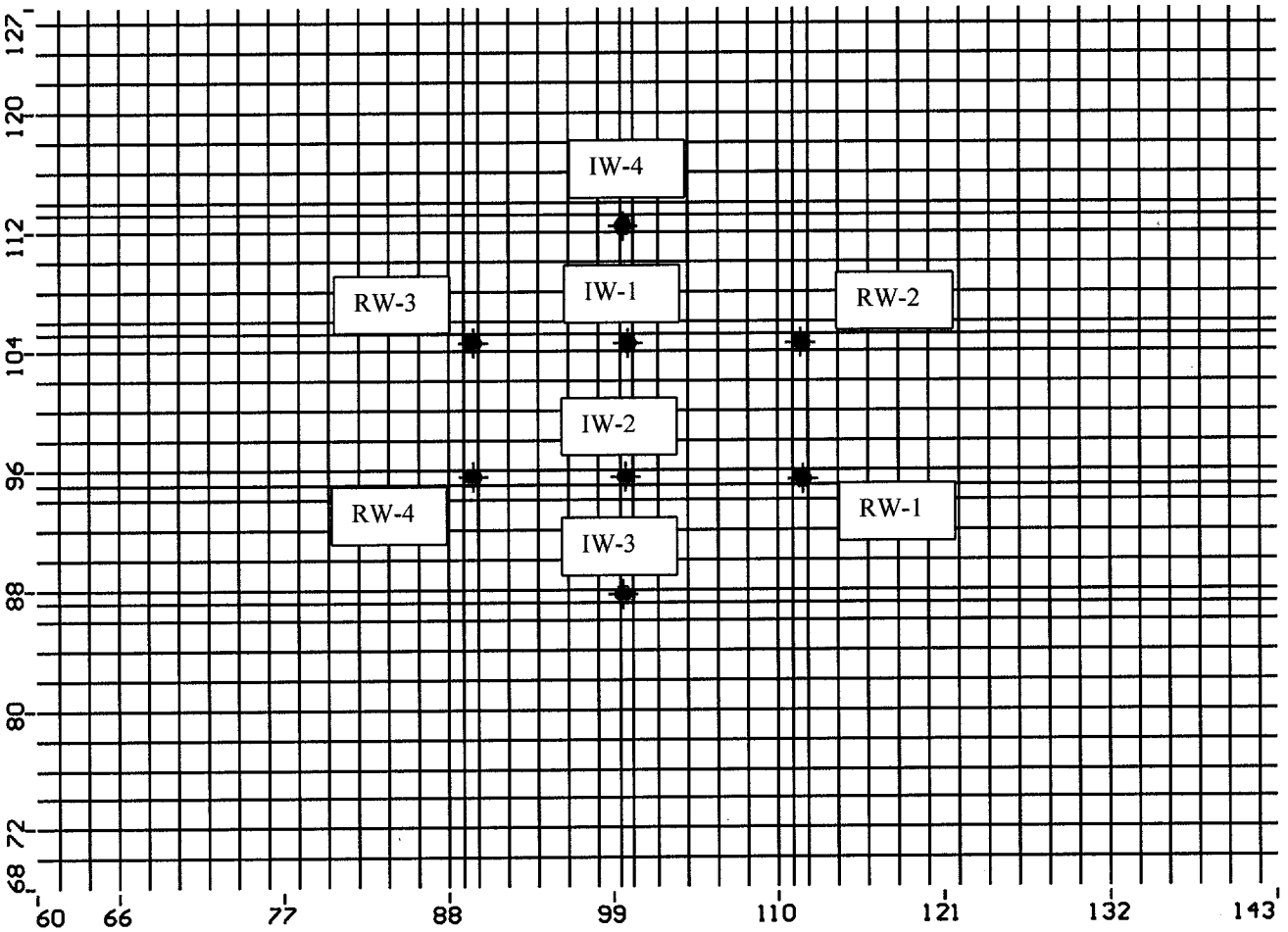


Figure 4.2: Optimal Well Locations As Determined Using Visual MODFLOW Analysis. (RW = Recovery Well; IW = Injection Well; all units in feet)

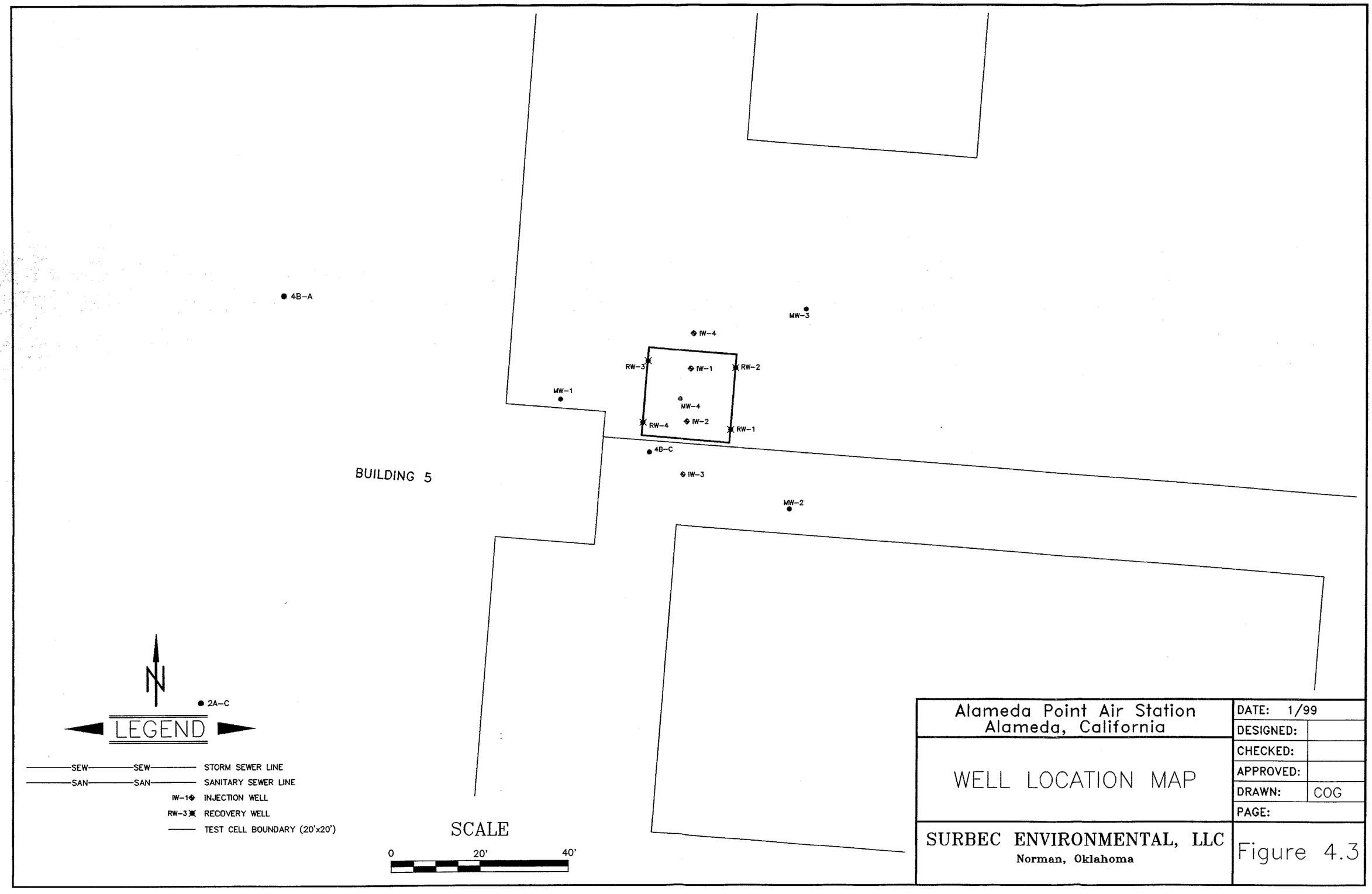

4B-A
MW-3
IW-4
RW-3
IW-1
RW-2
MW-1
MW-4
RW-4
IW-2
RW-1
4B-C
BUILDING 5
IW-3
MW-2
2A-C
N
LEGEND
SEW SEW STORM SEWER LINE
SAN SAN SANITARY SEWER LINE
IW-1 INJECTION WELL
RW-3 RECOVERY WELL
TEST CELL BOUNDARY (20'x20')
SCALE
0
20'
40'
Alameda Point Air Station
Alameda, California
WELL LOCATION MAP
SURBEC ENVIRONMENTAL, LLC
Norman, Oklahoma
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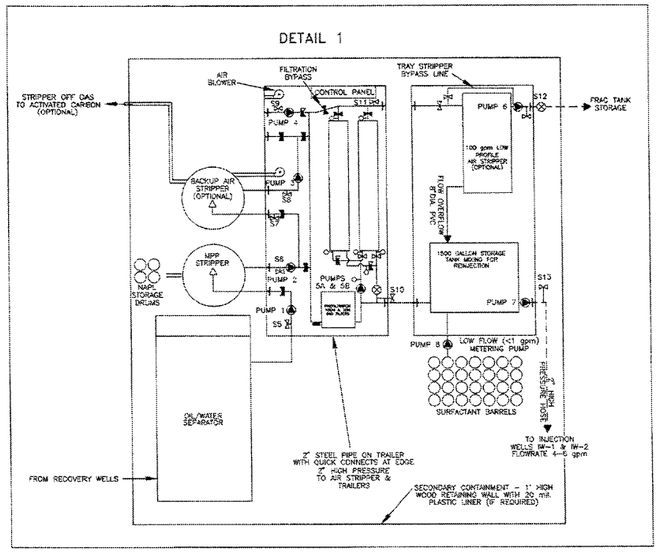
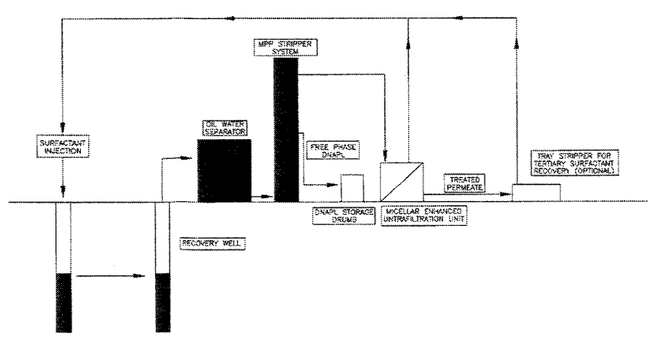
Figure 4.3

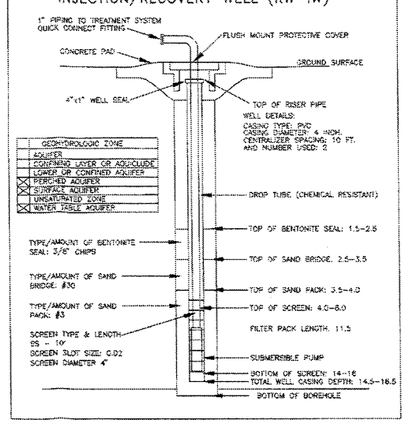
DETAIL 1

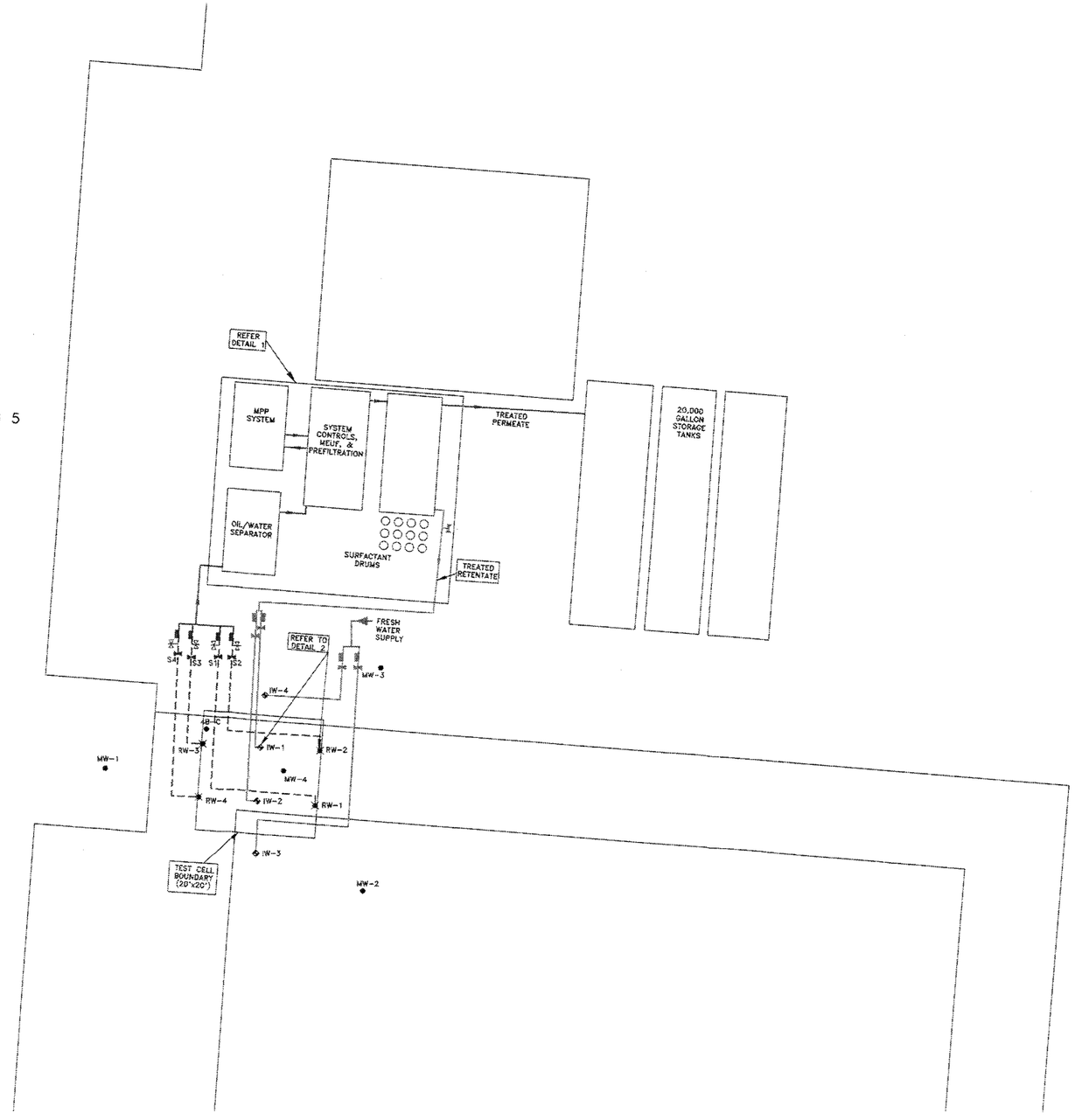


SYSTEM FLOW SCHEMATIC



DETAIL 2
INJECTION/RECOVERY WELL (RW-IW)





UTILITY REQUIREMENTS

ELECTRIC: 50 KW, 460 VOLT, 3 PHASE
WATER: 20 gpm @ 20 psi
PHONE: 1 LAND LINE

RECOVERY PUMPS 4	- 1/3 HP SINGLE PHASE SUBMERSIBLES OR VACUUM ENHANCED EXTRACTION (GROUDFOS 5S OR EQUIVALENT)
PUMP 1-4	- 4-2 HP, 3 PHASE, 460 VOLT, CENTRIFUGAL PUMPS
PUMP 5A	- 2 HP, 3 PHASE, 460 VOLT CENTRIFUGAL PUMPS
PUMP 5B	- 3 HP, 3 PHASE, 460 VOLT CENTRIFUGAL PUMPS
PUMP 6, 7	- 2-1.5 HP, 3 PHASE, 460 VOLT, CENTRIFUGAL PUMPS
PUMP 8	- 1-1/3 HP, 1 PHASE, 120 VOLT, BLADDEL PUMP
PUMP 9	- 1.5 HP SUBMERSIBLE PUMP
BLOWER 1-3	- 1.5 HP

SCALE

0 10' 20'

N

LEGEND

- SOIL BORING LOCATION
- PROPOSED INJECTION WELL
- PROPOSED RECOVERY WELL
- 1" BALL VALVE (AUTOMATED)
- SAMPLING PORT (MANUAL)
- FLOW METER
- PRESSURE GAUGE
- 1" INJECTION PIPING
- 1" RECOVERY WELL PIPING
- 1 1/2" RECOVERY WELL PIPING

NOTES:

1. THE MPP SYSTEM WILL BE TRAILER MOUNTED.
2. SYSTEM OPERATIONAL FUNCTIONS TO BE AUTOMATED AND COMPUTER CONTROLLED. SAMPLING WILL BE CONDUCTED MANUALLY.
3. NAPL COLLECTED IN OIL/WATER SEPARATOR TO BE PLACED IN DRUMS AND STORED ONSITE.
4. SECONDARY CONTAINMENT WILL CONSIST OF A 1' HIGH WOOD WALL WITH A 20 MIL. POLYETHYLENE.
5. THE BACKUP LOCATION FOR PROJECT IMPLEMENTATION WILL BE NEAR SOIL BORING 2A--A (REFER TO FIGURE 4.3).

Alameda Point Air Station Alameda, California	DATE: 1/99
	DESIGNED:
	CHECKED:
SESR DESIGN DRAWING	APPROVED:
	DRAWN: COG
	PAGE:
SURBEC ENVIRONMENTAL, LLC Norman, Oklahoma	Figure 4.4

Table 4.1: Site Contamination Levels and Cleanup Criteria

Contaminant of Concern	Site 2A-A Groundwater, ppb	Site 4B-C Groundwater, ppb	Cleanup Criteria ppb
1, 1, 1 -Trichloroethane	2100	100000	200(1)
1,1,-Dichloroethane	29000	24000	5(1)
1,1-Dichloroethene	14000	65000	NA
1,2-Dichloroethane	12	250	NA
cis-1,2-Dichloroethene	4600	250	6(1)
trans-1,1 Dichloroethene	150	8.7	10(1)
Benzene	6.4	ND	NA
Carbon Tetrachloride	320	2500	NA
Chloroethane	3900	0.66	NA
Ethylbenzene	3.6	ND	700(1)
Tetrachloroethene	40	8.6	NA
Toluene	85	370	150(1)
Trichloroethene	1700	160	NA
Vinyl Chloride	2600	2900	NA
m,p-Xylene	2.9	ND	1750(1)
o-Xylene	5.5	ND	1750(1)
Total	58525.4	195448	

1 - California Primary Drinking Water Maximum Contaminant Levels

Table 4.2: Potential Surfactants and Surfactant System Constituents

SURFACTANT TYPE	MW	% Active	Cost per lb	Trade Name	Food Additive status
C16 - DPDS	642	36	$1.09	Dowfax 8390	Indirect
Alkyl ethoxylated sulfate	442	28.7	$0.61	Steol CS330	Indirect
Ethoxylated (20) sorbitan mono oleate	1326	100	$2.31	Tween 80	Direct
Sodium dihexyl sulfosuccinate	388	80	$1.50	AMA	Direct
Alcohol ether sulfates	500-800	100	$1.50	Isalchem	Not tested
Ethanol	46	100	$0.44	NA	NA
Tartaric acid	75	100	Not Available	NA	NA
Na/Ca	23/40	NA	$0.15 / $0.07	NA	NA
Isoproponal (IPA)	60	100	$0.42	NA	NA
Potential Surfactant Systems					
C16 DPDS + tartaric acid + Na/Ca					Indirect
Isalchem + IPA+ Na/Ca					Not tested
AMA +IPA + Na/Ca					Direct
AMA (5%)+ Tween (5%) + Na/Ca					Direct

[a] = Rouse, et al. influence of anionic surfactants on bioremediation of hydrocarbons
NA=Not Applicable

Table 4.3: Design Criteria for Process Equipment

Target Constituent	Process	Flow rate	Influent	Target Effluent (East Bay MUD)	Temperature
		Gpm	Mg/l	Mg/l	Deg F
VOCs	Air Stripper	10-15	1000	BTEX = 0.005 Solvents = 0.5	50
	MPP System	10-15	1000	BTEX = 0.005 Solvents = 0.5	50
Surfactant	MEUF	10-15	20,000	2000 (permeate)	50

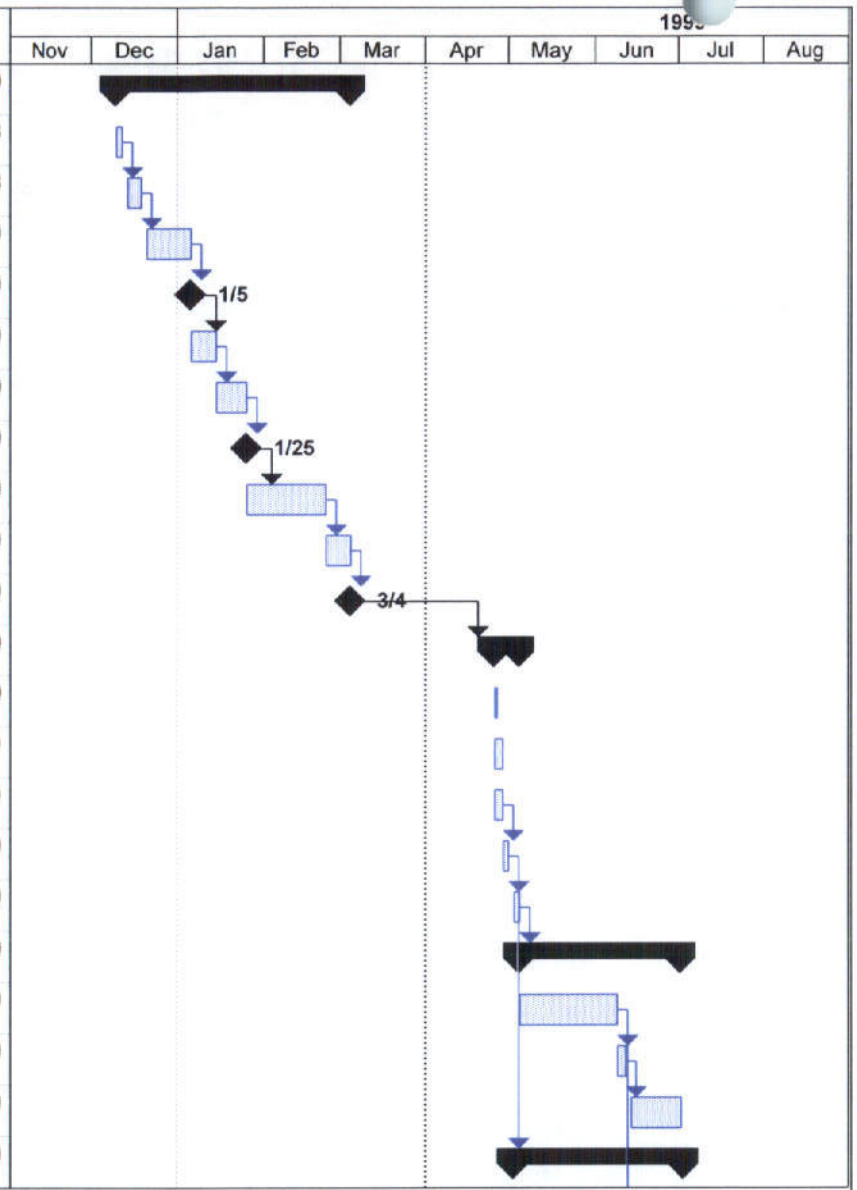
Table 4.4: Groundwater Residuals

Phase	Estimated Volume		Estimated Concentration in MEUF Permeate			
	Duration (Days)	Total Volume (gallons)	TCE Mg/l	Surfactant Wt %	Salinity Wt %	Co-solvent / Co-surf. Wt %
Well development, sampling & Pump test	4	8,000	GW conc.	0	0	0
Pre tracer test (6 PV)	6	100,000	MCL**	NA	NA	NA
Surfactant flood (5 PV)	5	86,000	0.001% - 1% of influent	0.01-0.2*	0.1-2	1-2
Post test flood (5 PV)	5	86,000	1% -5% of influent	0.2- 0.001	2 - 0.001	2 - 0.001
Post- tracer test (6 PV)	6	100,000	MCL	<0.001	<0.0001	<0.0001

Volume based on 12 gpm production for the estimated duration
*Assumes recycling of surfactant
** Assumes air stripping of solution

SCHEDULE

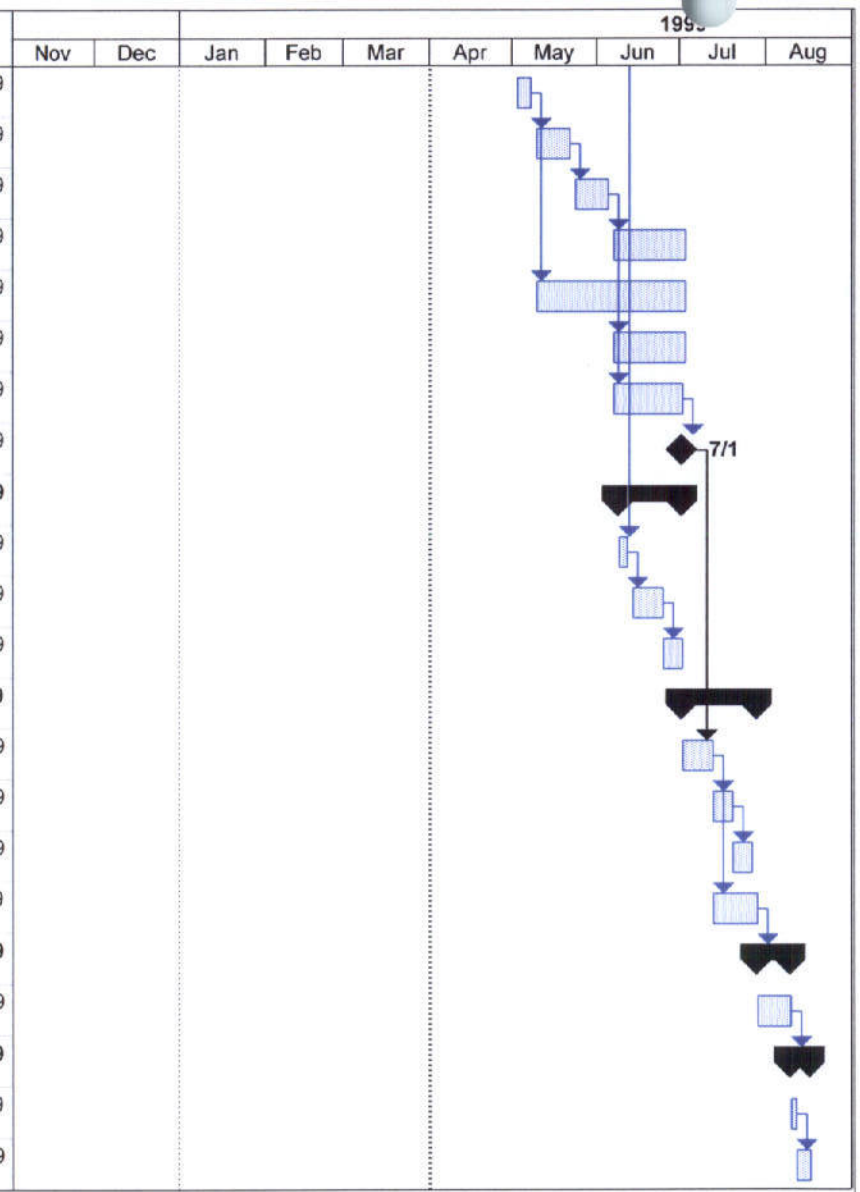
ID	Task Name	Duration	Start	Finish
1	**Treatability Study Work Plan**	**61 days**	**Thu 12/10/98**	**Thu 3/4/99**
2	Site visit	2 days	Thu 12/10/98	Fri 12/11/98
3	Design modeling	5 days	Mon 12/14/98	Fri 12/18/98
4	Work plan preparation	12 days	Mon 12/21/98	Tue 1/5/99
5	Submit preliminary draft	0 days	Tue 1/5/99	Tue 1/5/99
6	Navy review	7 days	Wed 1/6/99	Thu 1/14/99
7	Receive & incorporate comments	7 days	Fri 1/15/99	Mon 1/25/99
8	Submit draft	0 days	Mon 1/25/99	Mon 1/25/99
9	BCT, BRAC, RAB review	21 days	Tue 1/26/99	Tue 2/23/99
10	Receive & incorporate comments	7 days	Wed 2/24/99	Thu 3/4/99
11	Submit final	0 days	Thu 3/4/99	Thu 3/4/99
12	**Well Installation**	**7 days**	**Mon 4/26/99**	**Tue 5/4/99**
13	Mobilization & site prep.	1 day	Mon 4/26/99	Mon 4/26/99
14	Soil boring & sampling	3 days	Mon 4/26/99	Wed 4/28/99
15	Well installation	3 days	Mon 4/26/99	Wed 4/28/99
16	Well development and sampling	2 days	Thu 4/29/99	Fri 4/30/99
17	Aquifer testing	2 days	Mon 5/3/99	Tue 5/4/99
18	**Process Equipment**	**42 days**	**Wed 5/5/99**	**Thu 7/1/99**
19	Design and construction of skid system	25 days	Wed 5/5/99	Tue 6/8/99
20	Mobilization	3 days	Wed 6/9/99	Fri 6/11/99
21	Installation	14 days	Mon 6/14/99	Thu 7/1/99
22	**Surfactant Selection**	**45 days**	**Mon 5/3/99**	**Fri 7/2/99**



Project: sched1228mpx
Date: Thu 4/1/99

Task
Progress
Milestone
Summary
Rolled Up Task
Rolled Up Milestone
Rolled Up Progress
External Tasks
Project Summary
Split
Rolled Up Split

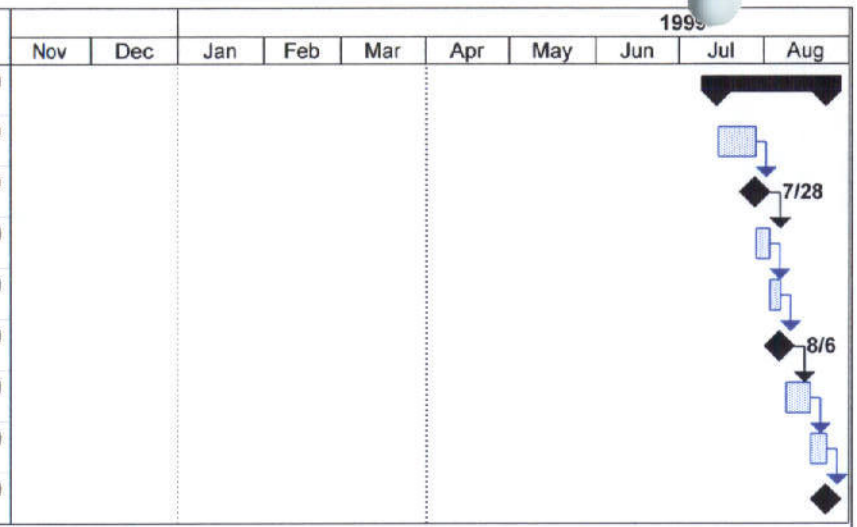
ID	Task Name	Duration	Start	Finish
23	Laboratory setup	5 days	Mon 5/3/99	Fri 5/7/99
24	Sorption	10 days	Mon 5/10/99	Fri 5/21/99
25	Phase behavior	10 days	Mon 5/24/99	Fri 6/4/99
26	Column (includes PITT Cal.)	20 days	Mon 6/7/99	Fri 7/2/99
27	Degradation (optional)	40 days	Mon 5/10/99	Fri 7/2/99
28	Separations	20 days	Mon 6/7/99	Fri 7/2/99
29	Prepare technical memorandum	19 days	Mon 6/7/99	Thu 7/1/99
30	Submit technical memorandum	0 days	Thu 7/1/99	Thu 7/1/99
31	**Pre-PITT and aquifer testing**	**17 days**	**Wed 6/9/99**	**Thu 7/1/99**
32	Mobilization	3 days	Wed 6/9/99	Fri 6/11/99
33	Pre-PITT	9 days	Mon 6/14/99	Thu 6/24/99
34	Optimization modeling	5 days	Fri 6/25/99	Thu 7/1/99
35	**Operation and Monitoring**	**19 days**	**Fri 7/2/99**	**Wed 7/28/99**
36	Setup & prepare injection solution	7 days	Fri 7/2/99	Mon 7/12/99
37	Begin surfactant injection	5 days	Tue 7/13/99	Mon 7/19/99
38	Begin fresh water injection	5 days	Tue 7/20/99	Mon 7/26/99
39	End flood -cont. residual management	12 days	Tue 7/13/99	Wed 7/28/99
40	**Post Partitioning Tracer Testing**	**8 days**	**Thu 7/29/99**	**Mon 8/9/99**
41	Post PTT	8 days	Thu 7/29/99	Mon 8/9/99
42	**Demobilization**	**5 days**	**Tue 8/10/99**	**Mon 8/16/99**
43	System tear down	2 days	Tue 8/10/99	Wed 8/11/99
44	Site restoration	3 days	Thu 8/12/99	Mon 8/16/99



Project: sched1228mpx
Date: Thu 4/1/99

Task
Progress
Milestone
Summary
Rolled Up Task
Rolled Up Milestone
Rolled Up Progress
External Tasks
Project Summary
Split
Rolled Up Split

ID	Task Name	Duration	Start	Finish
45	**Treatability Study Report**	**28 days**	**Thu 7/15/99**	**Mon 8/23/99**
46	Prepare preliminary draft	10 days	Thu 7/15/99	Wed 7/28/99
47	Submit preliminary draft	0 days	Wed 7/28/99	Wed 7/28/99
48	TTEMI review	3 days	Thu 7/29/99	Mon 8/2/99
49	Receive & incorporate comments	4 days	Tue 8/3/99	Fri 8/6/99
50	Submit draft	0 days	Fri 8/6/99	Fri 8/6/99
51	Navy review	7 days	Mon 8/9/99	Tue 8/17/99
52	Receive & incorporate comments	4 days	Wed 8/18/99	Mon 8/23/99
53	Submit final	0 days	Mon 8/23/99	Mon 8/23/99



Project: sched1228mpx
Date: Thu 4/1/99

Task		Rolled Up Task		Project Summary	
Progress		Rolled Up Milestone		Split	
Milestone		Rolled Up Progress		Rolled Up Split	
Summary		External Tasks			

APPENDIX A

QUALITY ASSURANCE PROJECT PLAN (QAPP)

Edward Ho, PE
Tetra Tech EMI Project Manager

Mark Hasegawa, PE
Surbec QC Manager

Dennis Wong
Naval RPM

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Table A-4 Quality Control Acceptance Criteria for General Chemistry And Miscellaneous Methods A-38

This section presents the Quality Assurance Project Plan (QAPP) for the SESR and specifies the procedures the demonstration will follow to ensure the generation of analytical data of known and accurate quality.

1.0 PROJECT OBJECTIVES

The primary goal of this project is to achieve a 95 percent removal of dense nonaqueous-phase liquids (DNAPL) contaminants for the selected site remediation at Alameda Point. Surbec Environmental (Surbec) has identified specific measurable objectives, listed below, have been identified for this treatability study to achieve the treatability study objectives set by Tetra Tech EM Inc. (TtEMI).

Objectives:

(1) To evaluate the use of surfactants/cosolvents for enhancing the removal of nonaqueous phase liquid (NAPL) from the subsurface.
- Achieve at least 95 percent removal of NAPL from the flushed zone at the 95 percent confidence level.
- Evaluate actual mass removal using pre- and post-test partitioning tracers and groundwater samples.

(2) To achieve good delivery and recovery of the surfactant solution within the plume area (surfactant or surfactant/cosolvent).
- Demonstrate that the delivery of the surfactant/cosolvent extraction fluid can be controlled through a properly designed delivery system.
- Demonstrate at least 90 percent capture of the injected surfactant/cosolvent is within the test area.
- Demonstrate that the remainder of the injected surfactant/cosolvent is degraded before leaving the site.

(3) To design and evaluate a system for surfactant regeneration and re-injection.
- Design an macro porous polymer (MPP) system to meet the discharge criteria from the surfactant/cosolvent effluent.
- Demonstrate that the use of micellar enhanced ultrafiltration (MEUF) can achieve 90 percent recovery of the surfactant for reuse.

(4) To evaluate the economic viability of a surfactant/cosolvent system for contaminant recovery.
- Identify and extrapolate the parameters that determine the cost of system setup, operation and maintenance.
- Conduct a comparison to conventional treatment technologies.

2.0 PROJECT ORGANIZATION AND KEY PERSONNEL

Surbec has compiled a team to complete this project that is unparalleled in past experience and expertise in the field of SESR. Surbec's team includes experts in the areas of subsurface flushing and surfactant recovery and reuse – Dr. David Sabatini, Dr. Jeff Harwell, and Dr. Robert Knox. Levine-Fricke-Recon (LFR) has been added as a valuable team member to provide on-site experience, engineering expertise, and a local presence. LFR is currently conducting site investigations at Alameda Point and is very familiar with the site and the California regulatory environment. The project organizational structure is included in this section. QA/QC and health and safety organizational structures have not been incorporated into this document. All personnel have the appropriate OSHA health and safety training. Specific information will be provided upon request.

Listed below are key team members and their respective roles in this phase of the project.

TtEMI
Mukul Shara-TtEMI Project Manager

Edward Ho-TtEMI Task Manager

Rafael Lago-TtEMI Project Engineer

Navy
Dennis Wong-Navy Remedial Projects Manger (RPM)

George Kikugawa-Navy Remedial Projects Manager

Surbec
Mark Hasegawa will serve as the Project Manager. He will coordinate project activities and ensure timeline requirements are met. Mr. Hasegawa has managed several SESR demonstrations and projects.

Dr. Robert Knox will review, compile, and analyze site hydrogeological data. He will also supervise the injection/recovery well design for the project and will oversee MODFLOW simulations.

Dr. Jeff Harwell will supervise the surfactant screening analysis. He will also work with Dr. Pope to determine candidate surfactants for application at the site.

Dr. Joe Suflita is a leader in the area of anaerobic degradation processes. Dr. Suflita will design surfactant and contaminant degradation screening tests. He will also aid Dr. Harwell to ensure that surfactants selected for screening are likely candidates for degradation.

Dr. David Sabatini will supervise the design of aboveground process equipment. He will work closely with Dr. Harwell to ensure that treatment processes are compatible with the surfactants selected and the DNAPL contaminant.

Dr. John Scamehorn will provide design and support for MEUF or foam fractionation processes implemented at the site.

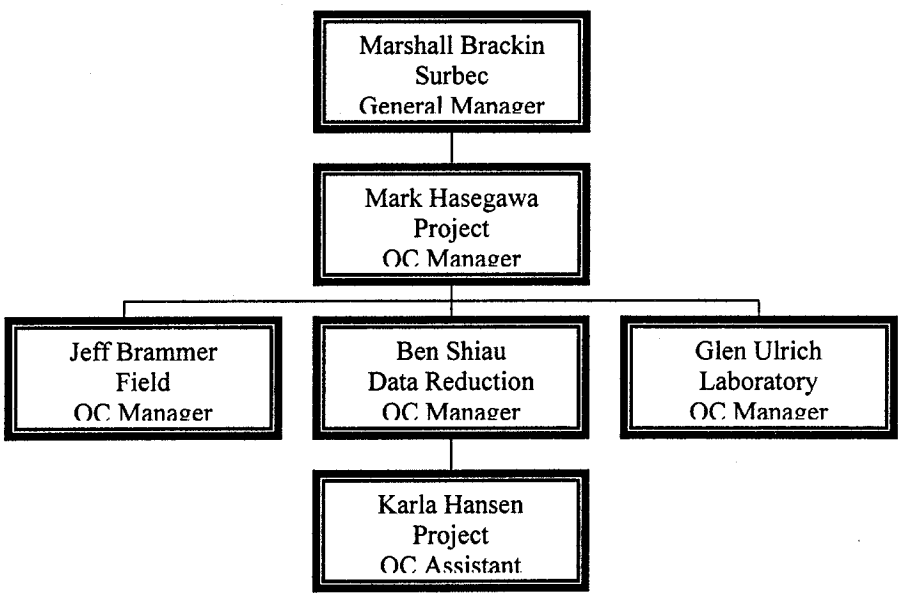
Jeffrey Brammer will assist Dr. Knox in reviewing, compiling and analyzing site hydrogeological data. He will also aid in groundwater modeling and well design for the project. Mr. Brammer will be the onsite Technical Manager for the project.

Levine Fricke Recon

Jeni Martin will coordinate all field work conducted by LFR personnel and will ensure the required resources (i.e. field equipment) are available to Surbec personnel.

Randy Sillan will manage work conducted with LFR personnel, provide design services and provide external review of reports.

A Surbec Quality Control/Quality Assurance organizational chart follows. This chart shows the lines of authority and personnel associated with specific QA/QC responsibilities.



3.0 MEASUREMENTS

Soil and groundwater samples will be collected prior to implementation of the demonstration, during the demonstration activities, and at the conclusion of the demonstration in order to assess the effectiveness of the technology. Approximately 700 samples will be obtained during the course of the project for the purpose of performance evaluation. A detailed list of sample analyses is located on tables C-1a through C-1f. The 700 samples are required to evaluate the Treatability Study tests. All QA procedures described in the following sections will apply to both onsite and offsite laboratories. Refer to Table A.1 for a list of possible analytes.

4.0 QUALITY ASSURANCE OBJECTIVES

The primary quality assurance objective (QAO) for this demonstration is to produce well-documented data of known quality. To this end, individual measurements must be assessed to ascertain that they meet quality assurance (QA) objectives that fulfill the data quality objectives. These objectives include quantitative QAOs for precision, accuracy, method detection limits, completeness, and mass balances, and qualitative QA objectives for comparability and representativeness. The QAOs stated here are consistent with those of the basewide remedial investigation and feasibility study (RI/FS). Table A.2 summarizes quality control (QC) field and laboratory requirements and corrective actions.

4.1 Project Data Quality Objectives (DQOs)

The following data quality objectives have been identified:

- Collect data to accurately determine the removal efficiencies (mass reduction) and rates for targeted organics (that is, chlorinated hydrocarbons).
- To collect data to evaluate the success of surfactant and cosolvent capture.
- To collect data to assess the extent to which the application of SESR is site-specific (that is, parameters governing SESR success).
- To collect data for preparing a cost estimate analysis for full-scale implementation of SESR at Alameda Point.

4.2 Data Quality Assurance Objectives

The following QAOs have been identified:

- Based on best-available technology and site-specific conditions, utilize sample collection and preservation methods that will yield results that are truly representative of the subsurface conditions at the site.
- Conduct replicate analyses (5% of samples) of single samples to assess the variability (or heterogeneity) within a given sample.
- Conduct standard replicate analyses (5% of samples) to determine the variability inherent in an analytical technique.
- Collect and analyze field blanks (10% of samples), trip blanks (1 set per ice chest of samples), and spikes (1 per week) to evaluate the potential compromises to sample integrity due to sampling techniques, holding techniques, and general ambient conditions that could potentially introduce false results. Sample spikes will be unscheduled and unidentified to the laboratory. The Project QA Manager will be responsible for submitted spiked samples to the laboratories.
- The individual analytical laboratory QA officers will be responsible for assuring that matrix spikes (1 per day) are added to samples to evaluate the accuracy of laboratory analytical methods.

Accuracy: Accuracy is the degree of agreement of a measurement with an accepted reference value, and indicates the degree of bias in a measurement system. Accuracy is assessed using laboratory control samples, matrix spikes, surrogate spikes and performance evaluation sample recoveries. Because sample measurement results from the use of laboratory equipment, the percent recovery of any of these sets of duplicate samples measures the accuracy of the laboratory equipment, calculated according to the following equation:

Equation 1.1 $\%R = (C_I - C_o)/C_t \times 100$

Where:

$\%R$ = percent recovery

C_I = measured concentration; spiked sample aliquot

C_o = measured concentration; unspiked sample aliquot

C_t = actual concentration of spike added

Precision: Precision is the reproducibility of duplicate measurements under a given set of conditions for a single sample. Precision is expressed as the variability of a group of measurements for a given sample compared to the average value. Variability may be attributable to field practices or chemical analyses. Precision is expressed as the relative percentage difference (RPD), using the following equation:

Equation 1.2 $RPD = (C_1 - C_2)/[(C_1 + C_2)/2] \times 100$

Where:

RPD = relative percent difference

C_1 = the larger of two observed values

C_2 = the smaller of two observed values

Completeness: Completeness refers to the number of analytically valid data points (accepted and reported values) collected from a measurement process compared to the total number of samples subjected to measurement. Percent completeness is calculated using the following equation:

Equation 1.3 % Completeness = (TDP-RDP)/TDP x 100

Where:

RDP = number of rejected and unreported results

TDP = number of total samples collected

The project completeness goal for completeness is greater than 90% for all samples, and 100% f confirmation samples.

Representativeness: Representativeness is a qualitative expression of the degree to which sample data accurately and precisely represent a characteristic of a population, a sampling point, or an environmental condition. Representativeness is maximized by ensuring that, for a given

project, the number, location of sampling points, the sample collection and analysis techniques are appropriate for the specific investigation, and that the sampling and analysis program will provide information that reflects "true" site conditions. Results for blind duplicate sample analysis are also used to evaluate representativeness.

Mass Balance and Mass Recovery: The surfactant recovery will be determined on a mass balance basis. The initial mass of surfactant or cosolvent injected will be determined by using the surfactant/cosolvent concentration injected multiplied by the volume of the surfactant/cosolvent solution injected. End surfactant/cosolvent masses will be calculated by summing volumes of effluent extracted multiplied by the corresponding surfactant/cosolvent concentrations. The difference in the injected and recovered mass will be compared to that predicted to be sorbed to the soil surface based on bench scale studies. Biodegradation is assumed to be negligible within the test cell due to the short residence time of the surfactant/cosolvent. The percent of mass recovered is therefore calculated using equation 1.4:

Equation 1.4 % Mass Recovered = 100% - [(IM - FM - Sorbed Mass)/IM] X 100

Sorbed Mass = ($\text{Soil}_{\text{mass, cell}} * K_d$)

Where: IM = Initial Mass = (Volume of Injected surfactant/cosolvent solution x Concentration of the surfactant)

FM = Final Mass = (Σ(Volume of Recovered Surfactant/cosolvent Solution x Concentration of the Surfactant/cosolvent))

$\text{Soil}_{\text{mass, cell}}$ (g) = Vol Soil (cm^3)

K_d = Grams Surfactant/Cosolvent per grams soil

Method-Detection Limits: The method detection limit (MDL) is the minimum analyte concentration that can be measured and reported with a 99 percent confidence that the concentration is greater than zero. The quantitation limit (QLs) represents the concentration of an analyte that can be routinely measured in the sample matrix with "reasonable" confidence in both identification and quantitation. QLs are verifiable by ensuring that the lowest non-zero calibration standard concentration is at or near the QL by using appropriate data analysis to ensure that the minimum detection concentration meets the 99 percent confidence levels as stated above. Samples detected below the QL will be appropriately flagged but will not negatively impact completeness. MDLs may be higher due to dilution requirements for analysis. MDLs will be evaluated in accordance with Appendix B Part 136 of the 40 Code of Federal Regulations (CFR) 136, 1984 ("Definition and procedures for the Determination of Method Detection Limit – Revision 1.1"). Method QLs will be determined for all onsite (field and laboratory) and offsite laboratory tests.

The soil MDLs will be higher than the groundwater MDLs due to the required field Method 5035 for sample preservation. The soil MDLs will be in the 100s ppb range and the groundwater will be in the 1s to 10s ppb range.

Comparability
Comparability is a qualitative parameter that expresses the confidence that one data set may be compared to another. Comparability of data is achieved through the use of standardized methods for sample collection and analysis, and the use of standardized units of measure. Data sets will be compared to assess the Study effectiveness (i.e. Pre-Partitioning tracer and Post-Partitioning tracer tests). Comparability will be necessary for Surbec data collected for the Study and not for existing investigation data.

5.0 ANALYTICAL PROCEDURES AND CALIBRATION

This section describes the laboratory procedures used for both physical and chemical methods. It discusses sample preparation and analytical procedures. This section does not include the field methods, as they are detailed in Appendix C.

A summary of analytical procedures are listed in Table A.3. There are no American Society for Testing and Materials (ASTM) or U.S. Environmental Protection Agency (EPA) standard methods for analysis of surfactants or contaminants in surfactant solutions; however, some of the methods are modifications of standard methods. When this is the case, the standard method is referenced. The modification of the methods for contaminant analysis when in the presence of surfactants is necessary because solubilization of a contaminant in micellar solution reduces its activity in water. Researchers at government facilities and several universities have developed effective methodologies for analysis of contaminants in surfactant solutions. Modified procedure developed at the University of Oklahoma for volatile contaminant analyses when surfactants are present in solution are given in Section 5.2.1. These methods will be utilized in the laboratory and the field, unless otherwise specified.

All methods for analysis are given here, however, once specific site(s), surfactants and cosolvents are selected, an addendum will be prepared, submitted for review and concurrence in letter report and attached to the approved work implementation plan (WIP).

1.5.1 Calibration Procedures
This section discusses general requirements for field equipment and laboratory instrument calibration and standards preparation. All requirements for calibration procedures and frequency for specific parameters are summarized in Table A.2. Instrument calibration is necessary for accurate sample quantitation, and establishes the dynamic range of an instrument. Criteria for calibration are specific to each method and instrument manufacturer. The following paragraphs outline the calibration procedures for the field equipment and laboratory instrumentation.

Data accuracy is dependent upon the accuracy of the standards used for instrument calibration. To ensure the highest quality standard, primary reference standards are obtained, if available, from the National Institute of Standards and Technology (NIST), EPA vendors, or other reliable commercial sources. When standards are received at the laboratory, the date received, supplier, lot number, purity, concentration, and expiration date are recorded in a standards log book. Vendor certification for the standards will be retained in the files.

Standards will be obtained either in their pure form or in stock or working standard solutions. Dilutions will be made from vendor standards. All standards will be given a standard identification number and the following information will be recorded in the standards logbook: source of the standard, the initial concentration of the standard, the final concentration of the standard, the volume of the standard that was diluted, the volume of the final solution, the solvent source and lot number used for standard preparation, and the preparer's initials. All standards will be validated prior to use.

Validation procedures for standards include a check for chromatographic purity and verification of the standard's concentration by comparing its response to a standard of the same analyte prepared at a different time or obtained from a different source. Reagents also are analyzed for purity; for example, every lot of dichloromethane (used for organic extraction) is prioritized to use in the laboratory. Standards are checked routinely for signs of compromise including deterioration (e.g. discoloration, formation of precipitates, and changes in concentration) or contamination and are discarded if deterioration is suspected or the expiration date has passed. Expiration dates are based on vendor recommendation, the analytical method, or internal research. Stock solutions for volatile organic compounds (VOC) are not to be held for more than 30 days. Fresh working calibration standards shall be prepared every week. Stock solutions for semi-volatile organic compounds shall not be held for more than 90 days. Dilutions below 1 part per million (ppm) shall not be held more than 30 days.

5.1.1 Laboratory Calibration

Analytical instruments will be calibrated using standards, discussed above, in accordance with the specified analytical methods and manufacturer's procedures. At a minimum, written calibration procedures include the equipment to be calibrated, the reference standards used for calibration, the calibration techniques, actions, acceptable performance tolerances, frequency of calibration, and calibration documentation format. Records of standard preparation and instrument calibration will be maintained. Instrument calibration will include daily checks using standards prepared independently of the calibration standards, and instrument response will be evaluated against established criteria. Calibration standards will cover a range of concentrations well above the detection limits and above the highest expected field sample concentration. The analysis logbook, maintained for each analytical instrument, will include, at a minimum, the date and time of calibration, the initials of the person performing the calibration, the calibrator reference number and concentration. Calibration procedures for specific instruments used for organic analyses are discussed in the following paragraphs.

Gas Chromatography/Mass Spectrometry (GC/MS). When GC/MS analysis of groundwater is required, the following procedure listed below will be followed.

Every 12 hours the instrument will be tuned with bromofluorobenzene (BFB) (according to the tuning criteria specified in the EPA Contract Laboratory Program Analytical Services [CLPAS]). After the instrument has met tuning criteria, it will then be calibrated for all target compounds.

Calibration standards at a minimum of five concentrations will be prepared by secondary dilution of stock standards. The compounds to be included in the calibration standards will be a function of the site specific NAPL composition (refer to Table A.1 for a list of potential analytes). As a

result, the calibration standards list cannot be identified until a site is selected and the NAPL constituents identified. This information will be included in the first letter report.

Each calibration solution, including internal standards and surrogates, will be introduced according to EPA Method 8260B for volatile compounds. A relative response factor (RF) will be calculated for each compound relative to the internal standard whose retention time is closest to the compound being measured. The RF is calculated as follows:

Equation 1.5 $RF = (A_x C_{is})/(A_{is} C_x)$

Where:
- RF = Area of characteristic ion for the compound being measured
- A_{is} = Area of characteristic ion for the specific internal standard
- A_x = Area of characteristic ion for the compound being measured
- C_{is} = Concentration of the specific internal standard
- C_x = Concentration of the compound being measured

The average relative response factor (RF_1) will be calculated for each compound using the values from the five-point calibration. A system performance check must be made before the calibration is accepted as valid.

The percent relative standard deviation (% RSD) for standards will be calculated from the RFs in the initial calibration and must meet specified criteria. The formula used to calculate %RSD is:

Equation 1.6 $$\%RSD = \frac{SD}{\bar{c}} X\ 100$$

Where:
- RSD = Relative standard deviation
- $\bar{c}$ = Mean of five initial RFs for a compound
- SD = Standard deviation of the RFs for a compound

$$SD = s = \sqrt{\frac{\sum_{i=1}^{n} x_i^2 - \frac{[\sum_{i=1}^{n} x_i]^2}{n}}{n-1}}$$

For every 12-hour shift, the GC/MS must be tuned by purging or injecting 4-BFB. Also, the initial calibration of the GC/MS will be checked by analyzing a calibration standard (usually the midlevel standard). If the minimum relative response factors for the standard compounds are not met, corrective action must be taken before samples are analyzed. The percent difference of relative response factor compared to the average relative response factor from the initial

calibration is calculated as follows:

Equation 1.7 $\% \text{ Difference} = (RF_1 - RF_c) / RF_1 \times 100$

Where: RF_1 =Average relative response factor from initial calibration

RF_c =Relative response factor from current calibration check standard.

If the percent difference criterion for each standard compound is met, the initial calibration is assumed to be valid. If the criterion is not met for any of the compounds, corrective action must be taken. A new five-point calibration must be generated if the source of the problem cannot be found and corrected.

The internal standard responses and retention times for each standard compound must be evaluated. If any internal standard retention time changes by more than 30 seconds from the last calibration check (12 hours), the system must be checked for malfunctions and corrected as necessary. If the extracted ion current profile area for any of the internal standards changes by a factor of two from the last daily calibration standard check, the system must be checked for malfunctions and corrections made as necessary. All samples analyzed during the time the system was malfunctioning must be reanalyzed. Details of modifications to the analytical method EPA 8260 to account for the presence of surfactant are identified in Section 5.2.1.

Gas Chromatography. A gas chromatograph (GC) will be used to analyze organic tracers used for the partitioning tracer tests. These analyses may be divided between the on-site Surbec Lab and the selected off-site laboratory, the University of Oklahoma lab. Refer to Section 5.3.2 for additional information regarding GC and tracer analysis.

High Pressure Liquid Chromatography (HPLC). HPLC will be used for surfactant analyses. Section 5.3.1 lists the various detectors that can be utilized depending on surfactant type. These analyses may be divided between the on-site Surbec Lab and the selected off-site laboratory, the University of Oklahoma lab.

Initial calibration consists of determining the linear range and establishing retention time windows. Detection limits will be established using the method detection limit study as defined in California Department of Water Resources, 1974. The calibration will be checked daily to ensure that the system remains within specifications. If the daily calibration check does not meet established criteria (refer to Table A.4), the system will be recalibrated. Calibration standards will be prepared according to the standard operating procedure for the method. For the SW846 8000 series methods, calibration standards will be prepared for each analyte of interest at five concentration levels. One of these standards will be slightly above the method detection limit. For verification of the quantification limit, spiked samples at the lowest detectable limit will be analyzed during instrument calibration. The other standards will bracket the concentration range expected in the environmental samples, but not exceed the working range of the detector. A reagent water blank will be run prior to calibration to show the absence of interferences. The calibration standards then will be introduced into the system and a calibration curve will be

generated for each analyte.

The response factor for each analyte at each concentration will be calculated as follows:

Equation 1.8 Response Factor (RF) = $\dfrac{\textit{Total Area of Peak}^{(a)}}{\textit{Mass Injected (in nanograms)}}$

[(a)]For multiresponse analytes, the area from at least five major peaks shall be used for quantitation.

Acceptance Criteria Linearity checks are based upon the correlation coefficient (r> .99) of the best fit line for the calibration data points, or on the percent relative standard deviation (% RSD) for response factors calculated for each analyte at each level over the working range. The correlation coefficient is calculated as:

Equation 1.9

$$r = \frac{n\Sigma(xy) - (\Sigma x)(\Sigma y)}{\sqrt{[n(\Sigma x^2) - (\Sigma x)^2][n(\Sigma y^2) - (\Sigma y)^2]}}$$

Where:
x = Calibration concentrations
y = Instrument response (peak area)
n = Number of calibration points (x,y data pairs).

5.1.2 Field Equipment Calibration

During the groundwater sampling program field equipment will be used to measure groundwater levels, pH, specific conductance, and temperature. The meters will be calibrated according to the procedures outlined below.

Water-Level Sounder
Electric water level sounders will be checked before the beginning of field activities by comparing the scale on the water level tape against an engineering measurement tape.

pH, Temperature, and Specific Conductivity Meter
A water quality instrument will be used for pH, temperature and specific conductivity measurement. The instrument will be calibrated daily prior to use according to the manufacturer's instructions. The meter will follow an automatic calibration routine in which a single standardizing solution, supplied by the manufacturer, is used to calibrate the meter for pH and specific conductivity. Periodically, the automatic calibration of the instrument will be checked manually using independent reference solutions including two pH buffers that bracket the expected pH (generally pH 7 and pH 10), a 1,000 µmhos/cm standard conductivity solution, and turbidity-free distilled water. The temperature probe will be checked periodically against a thermometer to confirm measurements.

Organic Vapor Meter
Organic vapor readings will be taken only for the purpose of monitoring the health and safety of the workers. Generally, if breathing air concentrations exceed 10 ppm respirators will be donned. Organic vapor detectors, including flame ionization detectors (FIDs) and photoionization detectors (PIDs), will be calibrated according to the manufacturer's instructions prior to daily use and any time that instrument drift is suspected. Calibration will be checked at the conclusion of each day of use in order to evaluate instrument performance. Instruments will not be adjusted before the final calibration check has been performed and recorded. Calibration procedures will be documented in the logbook or on the appropriate field form. Calibration gases that have a shelf life will not be used past the expiration date.

5.2 Sample Preparation

5.2.1 Contaminant in Surfactant Solution Sample Preparation

The existence of surfactants in aqueous samples can significantly reduce the volatility of the target VOCs from solution, thus affecting headspace volatilization methodologies. Also surfactants can foam during sparging in a headspace analysis. As a result, the analytical methodology (EPA 8260) will be modified slightly when surfactants are present in solution to account for this effect. Samples analyzed at the selected laboratories should utilize the same method for contaminant analysis. There are several possible methodologies that could be utilized for this purpose.

One potential methodology is a method developed at the University of Oklahoma for the analysis of contaminants in the surfactant/cosolvent solutions (see reference nos. 6 and 7 in Table A.3 of this section for peer-reviewed published procedures). An aliquot of the field sample is diluted with the 4 percent surfactant solution such that it is 10 percent by weight of the original sample (that is, a 0.2-gram sample aliquot is added to a headspace vial containing 1.8 grams of the 4 percent surfactant solution). The logic for the 4 percent solution is that it standardizes the surfactant concentration.

Due to the high potential for foaming during the sparging for GC/MS analysis, a heat source would be used to volatilize the sample into the carrier gas. To prevent foaming, the sample sparge tube (in the headspace analysis) should not penetrate the sample.

5.2.2 Contaminant and Tracer Sample Preparation

Preparation of these samples will be in accordance with EPA methods for volatiles analysis (EPA method 8260B) which require collection in 40-milliliter volatile organics analysis (VOA) vials and sealed without headspace.

5.3 Sample Analysis

For the analysis of VOCs in field samples containing surfactant, the analysis will be conducted using a GC/MS following a modified 8260 methodology.

5.3.1 Surfactant Analysis

Surfactant samples will be analyzed using a liquid chromatography system. Three in-line detectors will be installed for the analysis of different surfactants. Anionic steols will be analyzed by an Altech 320 conductivity detector and nonionic Tweens will be analyzed using an Altech Varex MKIII evaporative light-scattering detector. Vivian Star 4.5 Chromatography Workstation software will be used to record, analyze and store chromatograms.

5.3.2 Tracer/Cosolvent Analysis

Field samples containing organic tracers are typically analyzed using a gas chromatograph (GC) equipped with headspace auto-sampler and FID. Chromatography workstation software is used to record, analyze and store chromatograms from the GC.

For immediate analysis of the bromide tracer in the field, a Cole-Parmer Bromide Electrode will be utilized. The standards will be prepared and calibration curves are run at least daily. Single standards will be run hourly to ensure the probe is working correctly. Field samples containing fluorescein will be analyzed by a fluorometer. The standards will be prepared and calibration curves will be run at least daily. Single standards will be ran hourly to ensure the fluorometer is working correctly. This procedure will be used for both on-site and off-site analyses.

5.4 Quality Control

Quality control is demonstrated by documenting that there are no interferences from the analytical system, glassware, and/or surfactants. Equipment blanks will be carried through all stages of the sample preparation and measurement steps. For each analytical batch of up to 20 samples, a surfactant blank, a calibration standard and a calibration standard duplicate will be analyzed. The standards analyzed must be within plus or minus 10 percent of the calibration curve. Calibration standards will be composed of the investigated contaminants.

6.0 DATA REDUCTION, VALIDATION, AND REPORTING

This section generally describes procedures for reducing, validating, and reporting data. All data will be stored in electronic form in accordance with the specific laboratory policy on data storage. All information will be backed up electronically on either zip disks, CD ROM, or digital tape and stored for 3 years. Any modifications deemed necessary will need to be negotiated.

6.1 Data Reduction

The Project Manager or designated staff will be responsible for reducing the data obtained from on-site and off-site laboratories. The data will initially be tabulated to facilitate comparison and statistical analyses. All duplicates and blanks will be included in the tables, but will not be included in the comparisons and statistical analyses.

The purpose of the duplicates, spikes, and blanks is to be used as QC checks for the field and laboratory procedures (for example, "red flags"). Hence, anomalous duplicates, spikes, and

blanks results will be used to determine when data is questionable and not to be used in the comparisons or statistical analyses. Blanks will consist of trip blanks and field blanks as described in Section 7.1.

6.2 Data Validation and reporting

Quality assurance/quality control for laboratory generated data is reviewed by the Laboratory QC Manager to determine if the reported project data is acceptable for incorporation into the various project reports.

All laboratory data will be reviewed and evaluated in relation to data quality objectives established in this plan. A review of analytical data packages will be performed by the QC Manager and the Laboratory QC Manager.

Analytical results will also be reviewed by the Project Manager prior to being included in the project files and reported to the client. Should any anomalous or missing data appear in this documentation, the Project Manager will investigate the validity of the data in question, then draft a memo detailing the problem and proposed disposition of the data (accept, reject, use-as-is, etc.). The memo will be sent to the lab QC Manager for their review. Upon correction, the data will undergo a final review by a task separate QC Manager.

All project records will be reviewed for overall appearance, technical accuracy, and writing style prior to release to the client. The level of this review will be dependent upon the technical complexity of the report itself. In all cases, the report will be reviewed by the QC Manager.

The laboratory will archive all raw data/data packages associated with the analysis of project samples for a minimum of 5 years after project completion. This includes QA/QC standards, chromatograms, data notebooks, injection logs, instrument calibration and performance data, and any associated workbooks and calculations.

7.0 INTERNAL QUALITY CONTROL CHECKS

Quality control checks will be implemented daily throughout the performance of field activities. The QAPP and other required documentation will be available and maintained at the on-site laboratory. The main focus of the QC Manager will be to assess the field procedures, the laboratory data, and the results and conclusions drawn from this data. The assessment will be steered by the QA objectives stated in Section 1.1. A complete data assessment will consist of a step-by-step QC check from the collection of the data through the final data reporting.

7.1 Field QC Check Samples

The purpose of collecting duplicate samples is to check the laboratory and field procedures, and to evaluate the precision of the overall sampling and analysis program. The duplicate samples will be collected from locations with known contamination.

Duplicates

During a given scheduled sampling at each well, the duplicate sample will be collected immediately after the primary sample is collected. The duplicate will be assigned an identification to distinguish it from the primary sample collected at that location. As the duplicates will be submitted to the same laboratory, the identity of the duplicate will be distinguishable only by the sampler and not by the lab personnel. Based on these results, an objective assessment can be made concerning the lab and field procedures. Then an evaluation of the precision of the overall groundwater sampling and analysis program can be calculated. Duplicate samples will be collected at least weekly for off-site analysis. Daily duplicates will be collected during onsite analysis when the sample load is high (greater than 10 per day) to accurately assess the daily sampling variation and the daily laboratory operating procedures.

Blank Samples

Blank samples provide a check for cross-contamination during sample collection and shipment and in the laboratory. They are required when conducting water, sediment, and air sampling. Two types of blanks will be used to assess for potential cross-contamination during this project: trip blanks and field blanks.

One trip blank will be analyzed weekly by off-site labs. A triplicate blank sample (reagent grade water) will be shipped from the originating laboratory (off-site and on-site) to the facility and will then be returned with a sample batch to the laboratory for analysis. The blank will not be opened in the field and will remain in the cooler in which it was shipped from the laboratory. A triplicate blank is particularly relevant when volatile organic analyses are conducted as a check for cross-contamination during transport of the groundwater samples.

The second type of blank that will be used is the equipment blank. Equipment blanks are used to evaluate decontamination procedures. Weekly field blanks (reagent-grade water) will be prepared in the field during investigative work and daily during intensive sampling periods (for example, tracers, surfactant flood). Equipment blank samples will be obtained for the nested piezometer by pouring reagent-grade water into a clean, sampling bailer then filling a sample container in the same manner that would be used to collect a groundwater sample. Equipment blanks will be obtained from the wells by pumping reagent-grade water through the pump then filling a clean sample container in the same manner that is used to collect groundwater samples. This procedure is done in the field prior to sample collection at a selected location.

8.0 PERFORMANCE AND SYSTEM AUDITS

This section describes the QA audits that will monitor the system used to obtain measurements. These audits include technical systems audits and performance evaluation. A technical systems audit is a qualitative evaluation of all components of the measurement system, including technical personnel and QA management. This type of audit includes a careful evaluation of both field and laboratory QC procedures. The technical system audits will be performed before, or shortly after, measurement systems are operational, during the operation, and at the end of the operation. The audits will be performed by the Surbec Project/QC Manager, Mark Hasegawa. Copies of all reports summarizing auditing activities and corrective actions will be submitted to TtEMI as they occur and in the form of monthly reports and a final report.

After measurement systems are operational and begin generating data, performance evaluation audits will be conducted monthly to determine the bias of the total measurement system. Performance evaluation audits will consist of submitting performance evaluation samples to the laboratory, including duplicates and blanks.

Internal audits of data quality are retrospective evaluations of data and are required duties of the QA Manager. A representative portion of the results in an analytical report will be reviewed in detail daily by the QA Manager, starting with raw data and chromatograms, and then proceeding through the calculation of final results. Copies of all audit reports summarizing auditing activities and any corrective actions will be submitted to TtEMI for review.

9.0 CORRECTIVE ACTION

The QA Manager will be responsible for instituting and reporting all corrective action activities (Table A.2). The QA Program calls for corrective actions whenever quality control limits (for example, calibration acceptance criteria) or QA objectives (for example, precision, as determined by analyzing duplicate matrix spike samples) for a particular type of measurement are not met. The process will require corrective action if data generated from the laboratory lie outside the QA limitations associated with sampling and analysis for the parameters of interest. All corrective action — initiation, resolutions, and related actions — will begin immediately and will be documented on the Corrective Action Request Master Log. All corrective actions must be communicated to and concurred with TtEMI staff. A Corrective Action Form follows.

CORRECTIVE ACTION FORM

Surfactant Enhanced DNAPL Treatability Study, Alameda Point, Alameda, CA

Date: _____

Field Manager: _____

Project Activities Log (attach additional pages as required)

Time	*Description*

Non-Conformance Activity or Work

Time	*Description*

10.0 SAMPLING CHAIN-OF-CUSTODY, HANDLING, AND SHIPPING PROCEDURES

To ensure that samples are identified correctly and remain representative of the environment, the documentation and sample custody procedures specified in this section will be followed during sample collection and analysis. Standard sample documentation and custody procedures, as outlined below, will be used during each sampling event to maintain and document sample integrity during collection, transportation, storage, and analysis. The QA Officer 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. Individual on-site and off-site laboratory personnel will be responsible for maintaining sample custody and documentation from the time the samples are collected, through relinquishment to the lab, and to final sample disposition.

10.1 Sample Labels

Sample labels will be completed using indelible ink attached to sample containers at the time of sample collection. Any errors will be corrected by drawing a single line through the incorrect entry, entering the correct information, then initialing and dating the change.

10.2 Chain-of-Custody Procedures

Chain-of-custody (COC) procedures provide an accurate written record of the possession of each sample from the time of collection in the field through laboratory analysis. A sample is considered in custody if one of the following applies:

- It is in an authorized person's immediate possession
- It is in view of an authorized person after being in physical possession
- It is in a secure area after having been in physical possession of an authorized person
- It is in a designated secure area, restricted to authorized personnel only

The sample custody and documentation procedures will be initiated at the time of sample collection in the field. Sample collection details will be documented using Field Daily Sampling Log forms using indelible ink. Any errors will be corrected by drawing a single line through the incorrect entry, entering the correct information, then initialing and dating the change. Samples being shipped to an off-site laboratory will be documented using a Sample Submittal Form and, along with a completed COC Documentation Form, will be included with each sample cooler. Unused portions of the COC form will be crossed out and initialed. The sampler will retain a copy of the COC Documentation and the Sample Submittal forms. These forms will be signed, placed in a plastic bag, and taped to the inside of the shipping container used for sample transport. Custody seals will be placed in two locations across the cooler closure to ensure that any tampering is detectable. The date and initials of the sampler will be written on the custody seal. Signed airbills will serve as evidence of custody transfer between the field sampler and courier, and courier and laboratory. The sampler will retain and file copies of the COC record and the airbill after the samples are shipped. The samples are relinquished to the laboratory upon

arrival, and the laboratory personnel will then complete the COC.

A field sample lot number will be assigned to each sample cooler each day of sampling and will be recorded on the Field Daily Sampling Log. The field lot numbers are used to identify the field samples that are associated with specific quality control samples; that is, the field lot control number identifies the environmental samples and QC samples that were collected or submitted for analysis on the same day. The field lot numbers have four characters. The first character identifies whether there is an ambient conditions blank associated with the sample; the second character indicates whether there is an associated equipment blank; the third character indicates whether there is an associated triplicate blank; and the fourth character identifies the cooler that was used for sample shipping. For this demonstration, the first number will always be zero, because there will be no ambient condition samples. The next three numbers will be 0 to 9; that is, the first blank for the day is "1", the second is a "2" and so forth.

10.3 Laboratory Custody Procedures

Upon receipt of samples to off-site laboratories, the integrity of the shipping container will be checked by verifying that the custody seal is not broken. The cooler will be opened, and the temperature blank will be measured to determine the temperature inside the cooler. The sample containers will then be checked for breakage, leakage, damage, and the contents of the shipping container will be verified against the COC. Custody seal integrity, cooler temperature, and sample preservation will be documented.

10.4 Logbook Maintenance

A permanent logbook will be maintained in the sample control area of on-site and off-site laboratories to document the following:

- Date of sample receipt
- Sample accession number
- Number of samples
- Source of samples

All insufficiencies and/or discrepancies in sample logging will be immediately reported to the Laboratory Manager and the anomalies recorded in the logbook. The Laboratory Manager will either resolve the problem internally or contact Surbec's Project Manager for resolution. If the samples and documentation are acceptable, each sample container will be assigned a unique laboratory identification number to assist in tracking samples while they are in the custody of the laboratory. Other information that will be recorded includes date and time of sampling, sample description, due dates, and required analytical tests.

The samples will be transferred to the appropriate refrigerators. Separate refrigerators will be used for samples suspected to contain high levels of organic compounds and for samples for VOC analyses. The sample refrigerators will be kept at 4°C plus or minus 2°C; their temperatures will be measured daily with thermometers calibrated against NIST thermometers

and recorded. The cleanliness of refrigerators storing samples for VOC analyses will be monitored using refrigerator blanks.

Samples will be distributed for analysis by either a sample custodian or laboratory chemist. Sample tracking will be documented on the Sample Control Form. After all samples and documentation have been reviewed and appropriately annotated, the sample custodian will sign the logsheet. Any marks or notes made on the chain-of-custody document by the sample custodian will be clearly distinguishable from original field notations.

Shipping receipts will be stapled to the COC Documentation Form and stored in the project file. Samples will be placed in appropriate storage areas in the laboratory depending on storage requirements. The laboratory managers or their designee will be notified that the samples have arrived through the distribution of arrival notices. The sample custodian will log the samples delivered into the cold room in the Cold Room Sample Arrival Logbook. The cold room will be kept locked when not in use. Samples for metals analysis will be stored in a separate air-conditioned storage room located near the metals sample preparation area.

10.5 Sample Return and/or Disposal

All samples generated from the test site will be subjected to the appropriate testing procedures. Wastes generated off-site during the course of the testing processes will be stored in designated storage containers and disposed of by the laboratory as regulated according to all applicable federal, state and local regulations.

ATTACHMENT A

Standard Operating Procedure
Bench-Scale Surfactant Screening,
Tracer Testing, and
Analytical Procedures

1.0 Surfactant Bench-Scale Testing

Following are detailed standard operating procedures for the completion of bench-scale testing.

1.1 Contaminant Solubilization

The objective of this test is to quantify the solubilization potential of a range of surfactants and for the dense nonaqueous-phase liquid (DNAPL) from the subject site. Contaminant solubilization will be assessed in batch systems (40-milliliter EPA vials) by contacting an excess of the DNAPL with varying concentrations of the surfactants (ranging from concentrations of critical micelle concentration (CMC)/10 to concentrations of 20 times CMC concentrations) in site groundwater at the site temperature. At least 6 surfactant concentrations will be utilized, two below the CMC and four evenly spaced between the CMC and 20x the CMC on a solubilization versus surfactant concentration plot. Increasing DNAPL concentrations will be evidenced in the aqueous phase as the surfactant concentration increases (above the CMC for surfactants). The plot of aqueous DNAPL concentration versus surfactant concentration will be almost horizontal below the CMC and linear with a positive slope above the CMC. The linear portion of this region can be interpreted to determine the micellar-water partition coefficient of the DNAPL; increasing values of this partition coefficient indicate increased affinity of the contaminant for the surfactant micelles (and thus improved efficiency in the surfactant-enhanced remediation). Solubility as a function of cosolvent fraction will be measured and cosolvency powers will be determined using the log-linear cosolvency relationship. Aqueous DNAPL concentrations will be determined by High Performance Liquid Chromatography (HPLC) analysis.

1.2 Surfactant-DNAPL Phase Properties

The objective of this test is to evaluate the phase behavior of the surfactant (NAPL) system (may be simulated NAPL) in an effort to avoid significant reductions in the interfacial tension or unfavorable viscosities or densities which might result in unfavorable flow characteristics. Formation of middle-phase microemulsions (with ultra-low interfacial tension) is specific to the DNAPL composition and the groundwater system (temperature, surfactant system, ionic strength, etc.) and must thus be carefully examined to achieve success. Therefore, site-specific groundwater will be used.

DNAPL/surfactant or solution interfacial tensions will be measured for the selected surfactant systems. Samples will be prepared with 5 milliliters (ml) of DNAPL and 5 ml of surfactant

solution in 15-ml sample vials fitted with septa; the solutions will be equilibrated for 1 week with daily gentle mixing to assure equilibration. Interfacial tensions will be measured. Studies will be conducted in 10-ml glass pipettes flame-sealed to prevent volatilization losses. Five ml of DNAPL and 5-ml of aqueous solution will be added to the pipettes. The hydrophilic lipophilic balance (HLB) of the surfactant system will be varied (for example, one surfactant concentration will be held constant [for example, Aerosol OT] and the concentration of a second surfactant or a cosurfactant [hydrotrope; for example, SMDNS] or salinity or hardness will be varied). Visual inspection will monitor the phase behavior (surfactant in the oil versus water phase, appearance of a third phase-middle phase microemulsion). The phase diagram will plot phase behavior (Winsor Type I, II and III) as a function of varying the composition (HLB) and concentration of the surfactant system to produce a so-called three-parameter or phase optimization diagram. All systems exhibiting acceptable phase behavior will also be examined for viscosity and density. Systems with unfavorable viscosity or density will be modified or abandoned.

When adjusting surfactant systems towards a middle phase microemulsion pointwise solubility enhancements will be determined. Comparing solubility enhancement versus interfacial tension (IFT) as the system moves toward the Winsor Type III middle-phase micro emulsion will provide guidance as to what system to evaluate in column studies.

1.3 CMC Measurements

Because knowledge of the CMC of the surfactant facilitates conducting the remaining tasks, the first studies to be performed will be measurements of the CMC's of the surfactants at aquifer conditions. The first step in determining the CMC of a surfactant will be to use a dye test, using pinacyanol chloride as the dye, to estimate the CMC. Pinacyanol dye is violet in the absence of micelles but blue in the presence of micelles. A 10-ml sample of the surfactant at a concentration of 5 wt. % will be tested with a low concentration of the dye (initially solubilized in an ethanol solution). If the dye becomes blue, then the 5 wt. % solution is above the CMC; the solution is then diluted by factors of 10 (1 ml of surfactant to 9 ml of groundwater) until the solution becomes violet. The CMC of the surfactant is then approximately the average of the lowest concentration showing micelles and the highest concentration showing only monomers.

The final CMC of the surfactant is determined by surface tension measurements using an automated Wilhelmy plate tensiometer. The surface tensions of six surfactant concentrations are spaced so that 3 evenly divide the decade below the estimated CMC and three evenly divide the decade above the CMC when plotted on a surface tension versus log concentration plot. The break in the surface tension versus log concentration plot identifies the surfactant CMC. CMC measurements will be performed using site groundwater at the site groundwater temperature.

1.4 Surfactant Sorption

The objective of this test is to quantify the sorptive losses of the surfactants onto the soil from the test site. This will assess the negative impacts of surfactant losses due to sorption in the subsurface, and will assist in screening the surfactants for use at the site.

Surfactant sorption will be assessed in batch systems by contacting varying surfactant concentrations with a constant mass of soil from the site aquifer. Surbec Environmental will use six concentrations per surfactant, beginning with a feed concentration of 1.0 times CMC and

increasing in steps of two CMC units to a maximum concentration of 15 times CMC. The experiments will utilize 5 grams of soil with 25 ml of surfactant solution with equilibration times of at least 24 hours. Upon centrifugation for solids-liquid separation, aliquots of the supernatant will be analyzed for the equilibrium surfactant concentration. The mass of surfactant sorbed will be determined by mass balance (with appropriate controls to account for other losses). The resulting surfactant sorption isotherms (plots of mass of surfactant sorbed per mass of soil versus equilibrium surfactant concentration) will be analyzed for appropriate sorption parameters (for example, Langmuirian sorption coefficient and capacity terms).

1.5 Surfactant Precipitation

The objective of surfactant precipitation is to quantify the precipitation boundaries of the surfactants under investigation, whether the phase boundary is crossed due to ionic composition (ionic surfactants) or groundwater temperature (nonionic surfactants) of the system.

Precipitation (phase separation) assays will be conducted using 120-ml glass vials with 100 ml of solution in each vial. The ionic strength of the groundwater will be varied by addition of excess multivalent ions to assess precipitation of anionic surfactants; the groundwater temperature will be varied to assess phase separation of the nonionic surfactants. Ionic strength will be varied from 0.1 to 10.0 times the dominant monovalent and divalent cation concentrations present in the groundwater. Temperatures will be varied from 10°C below to 10°C above the mean groundwater temperature for aquifer. Only one set of samples will be mixed; the same set will be allowed to equilibrate at each target temperature. Surfactant concentrations will be varied from 0.1 to 25 times the CMC for assessing phase separation. Surfactant phase diagrams will be plotted by showing regions of phase separation for plots of surfactant concentration versus ionic strength at each temperature.

1.6 Contaminant Extraction-Column Studies

Surfactant and contaminant elution from the columns will be analyzed and plotted as breakthrough and elution curves. Mass balances of surfactant and contaminant will be conducted on the column runs and duplicates of certain column runs will be conducted; these measures will provide confidence as to the validity and reproducibility of the column results. Each column study will require 10 to 50 pore volumes to approach complete contaminant removal.

Glass liquid chromatography columns (2.5-centimeter diameter by 15-cm length) will be utilized for conducting column studies. The columns will be packed with core materials obtained from the subject site. Most likely the column will first be flushed with simulated DNAPL prior to flushing. A time-controlled fraction collector will be utilized to collect discrete samples for gas chromatograph (GC) or HPLC analysis. The surfactant/cosolvent concentration for each system will be selected based on predicted performance. The surfactant/cosolvent solutions will be prepared using native groundwater unless temperature measurements at the site indicate that a different temperature should be used. Hydraulic flow rates through the column will be determined prior to flushing the surfactant solution. When surfactant flushing begins, the following parameters will be monitored continually: flow, injection rate, and pressure drop. For each column test, a minimum of 7 influent and 15 effluent samples will be collected. The influent samples will be analyzed for concentrations of NAPL, surfactant/cosolvent, and selected cations (four samples only). IFT measurements will also be made. The effluent samples will be

analyzed for concentrations of dissolved TCE, select cations (four samples) and surfactant/cosolvent. Each effluent sample will be checked for free phase TCE, and IFT measurements will be made. Flushing will continue until an asymptotic level of removal is achieved.

At the conclusion of flushing, the columns will be dismantled to determine the concentrations of NAPL constituents and surfactant in soil. This information will be used to corroborate mass balances for the contaminant and surfactant.

1.7 Equilibrium Partitioning Airstripping Tests(optional)

The purpose of the batch equilibrium testing will be to determine the effects of surfactants on the partitioning of the NAPL components with air.

The surfactants selected for the final column soil flushing experiments will also be subjected to batch equilibrium partitioning experiments (surfactant-contaminant-air). Five samples of the surfactant/cosolvent solutions will be prepared at varying concentrations; if it is a surfactant, the concentrations will be 0, 0.5, 10, and 25 times the CMC. Excess NAPL (actual or simulated) solution will be added to each sample and mixed until saturation occurs. An air-to-water ratio of (volumetric; 2 to 5 ml of aqueous phase) 20:1 has been selected; this ratio should produce changes in the aqueous phase VOC concentrations over the range of surfactant concentrations used. Each stock solution will be analyzed prior to the test to determine pre-partitioning contaminant concentrations.

Vials will be prepared in triplicate for each surfactant concentration and sealed with Teflon-lined septum screw caps immediately after filling. Care will be taken to minimize agitation and turbulence during filling. The vials will then be allowed to equilibrate for 48 hours in darkness. The equilibrium contaminant concentrations in the aqueous phase will be determined by HPLC or other appropriate analysis. The concentration of contaminant in the vapor phase will be determined by an overall mass balance of the influent and effluent water stream.

The results of the batch equilibrium tests will be tabulated and summarized. The Lipe-Hasegawa model will be used to plot predicted partitioning results (Lipe et al., 1996). The results of the batch equilibrium tests will be used to validate the model for the site-specific NAPL.

1.8 Surfactant Re-concentration/Micellar Enhanced Ultrafiltration (MEUF)

The purpose of the MEUF testing is to determine the potential for economic recycling of the surfactant through membrane filtration.

Suitability of the surfactant chosen from the column tests will be determined by bench-scale ultrafiltration of solutions at 10 times the CMC. A volume of surfactant solution equal to 100 ml will be placed in a stirred batch cell designed to hold a sample of the ultrafiltration membrane. Air pressure will be applied to force the solution through the membrane. At least 20 percent of the solution will be forced through the membrane to assure equilibration of the membrane with the surfactant. Surfactant concentration in the permeate will be analyzed by HPLC. An acceptable permeate concentration should be at or below the CMC of the surfactant. Flux across the membranes will be measured across the largest molecular weight cut off (MWCO)

membrane giving a concentration near the CMC to allow calculation of the total membrane area needed for a scale-up.

1.9 Degradation Testing (optional)

Surfactant and contaminant degradation evaluation will be conducted by testing surfactants and/or cosolvents in site sediment groundwater samples. Over the years, the techniques for investigating the biodegradation of contaminants in the subsurface environments have been developed by us and embraced by the scientific community. The procedures for these tests will follow those included in the American Society for Microbiology's Manual of Environmental Microbiology (Suflita et al., 1997). All degradation testing will be supervised by Dr. Joe Suflita.

Sediments collected from the contaminated site will be sealed in the field (in ammunition boxes under nitrogen) and processed usually within 1 or 2 days. In order to determine the potential for aquifer microorganisms to biodegrade surfactants or chlorinated solvents, slurry incubations will set up under aerobic or select anaerobic conditions. Aquifer sediments samples will be opened in an anaerobic glove bag containing 5 percent Hydrogen (H_2) in Nitrogen (N_2) to ensure that subsamples for anaerobic incubations will not be exposed to O2 in the laboratory. Samples will be mixed in the anaerobic chamber to try to attain a representative homogeneous sample to add to aerobic and anaerobic incubation vessels.

Anaerobic incubations will be established by weighing 25 or 50 grams of aquifer sediment into 120- or 160-mL serum bottles. Anoxically prepared sterile mineral medium or site groundwater was then added to the microcosms (50 or 75 ml). Serum bottles will be sealed with sterile butyl rubber stoppers, or in the case of the volatile chlorinated solvents, with sterile composite stoppers (a butyl rubber stopper fused to a Teflon stopper). Microcosms will be sealed with aluminum crimps. Headspaces of the microcosms will be then exchanged with 20 percent CO2 in N2 and incubated at room temperature in the dark, or at the same temperature of the aquifer from which the sediments will be derived. Depending on which anaerobic electron-accepting process is to be studied, the mineral medium or groundwater is amended with nitrate for nitrate-reducing incubations, Fe(III) for iron-reducing conditions, sulfate for sulfate-reducing conditions, or without electron acceptor for methanogenic incubations.

Aerobic incubations will be established in Erlenmeyer flasks or serum bottles. Aquifer sediments will be asceptically weighed into incubation vessels (25 or 50 grams) and will be amended with site groundwater or sterile, aerobically prepared mineral medium (50 or 75 ml). Flasks or serum bottles for incubations with surfactants will be sealed with foam plugs, and serum bottles for chlorinated solvent incubations will be sealed with Teflon stoppers to prevent volatilization. Vessels will be incubated on a rotary shaker at room temperature or at the same temperature of the aquifer from which the sediments will be derived.

A known concentration of surfactant or chlorinated solvent will be added to each slurry from sterile, surfactant or chlorinated-solvent stock solutions. Stock solutions to be added to anaerobic incubations will be prepared anoxically. Surfactant- or chlorinated solvent-containing microcosms will be incubated alongside unamended substrate controls to account for background electron-accepting processes. Autoclaved controls containing substrates will be also established to account to abiotic losses [autoclaved three times for 60 minutes at 121°C and 15 pounds per

square inch (psi)]. All incubations will be set up in triplicate. The information determined from these studies will in turn be extremely valuable in deciding on the appropriate surfactant and ultimately in determining the fate of the contaminants. The incubation of aquifer slurries with contaminants can determine the fraction of contaminant mineralized and provide data needed for field studies.

Partitioning Tracer Testing Procedures

Objectives. Tracer tests will be performed prior to (pre-test) and subsequent to (post-test) the technology demonstration test. The objectives of these tests are to determine the total volume and the spatial distribution of NAPL within the flushed zone. During the test, a small volume of solution containing low concentrations of both conservative and partitioning tracers will be pumped through the cell. Chromatographic separation of the conservative and partitioning tracers will be reflected in concentration breakthrough curves (BTC) developed for the various sampling points in each cell. All tracer tests will be designed and conducted using procedures described by Pope et al. (1994) and Annable et al. (1995).

Tracers. Tracers will be chosen based on their partitioning behavior between water and NAPL from the test site. Other desirable tracer properties include 1) nontoxic, 2) nonhazardous, 3) nondegrading, 4) low volatility, 4) reasonable cost and availability, and 5) easily quantifiable in the presence of NAPL constituents. The impact of NAPL variability on the partitioning behavior of selected organic tracers will be evaluated by laboratory liquid-liquid partitioning tests. When possible, tracers will be selected from the following: ethanol, methanol, bromide, 2,2-dimethyl-3-pentanol, n-pentanol, 6-methyl-2-heptanol, 2,3-dimethyl-2-butanol, methylated hexanol, and methylated octanol.

Tracer Solution. The tracer solution will be developed by mixing a small volume (approximately 5 gallons) of the mixed alcohols with sufficient fresh tap water to yield the appropriate volume and concentration of tracer solution.

Sampling. Numerical simulations using a three-dimensional model will be run prior to each tracer test. These simulations will be based on measured hydraulic properties of the medium, and the partitioning characteristics of the tracers determined from laboratory studies. Sampling schedules will be developed from simulated BTCs. Each BTC will be defined by at least 20 data points for the sampling clusters and 20 to 30 points for the extraction wells. The distribution of these data points will be adequate to provide resolution of the entire BTC with minimal extrapolation. A minimum of one non-reactive and two reactive tracers will be used. Hydraulic gradients and flow rates will be continuously monitored and recorded during each test. To the extent possible, sample analysis will be conducted at the field site. All samples will be carefully labeled and stored in a manner to protect sample integrity. Sampling schedules may be modified during the tracer tests based on on-site measurement of tracer breakthrough.

General Procedures. The injection/extraction schedule for the tracer tests is as follows:

Days	Activities
0-0.5	Injection of 0.5 pore volume of fresh tap water and extraction of 0.5 pore volumes of groundwater. These activities will establish hydraulic equilibrium in the subsurface.
0.5-1	Injection of 500 to 1000 gallons total of tracer solution containing up to 100 milligrams per liter (mg/L) of various alcohols and 2,000 to 3,000 mg/L of bromide. Extraction will result in fluid with a composition similar to that of site groundwater.
1-6	Injection of 6 to 8 pore volumes of fresh tap water will follow tracer injection. The recovery wells will operate at a rate designed to ensure capture of injected tracers (expected duration of recovery well operation will be 8 to 10 days). The extracted fluid will initially show a composition similar to that of the site groundwater; the waste will then start to show increasing concentrations of the tracer constituents, followed by decreasing concentrations of the tracer constituents. Due to the low concentrations of constituents used in the input tracer solution, it is expected that the extracted fluid will contain extremely low concentrations of tracer constituents.

Data Analysis. Breakthrough curves for reactive tracers will be used to estimate the volume and spatial distribution of NAPL in each test cell. Up to three methods may be used to calculate the NAPL distribution. First, the integrated mass of NAPL in the swept volume will be calculated by the method of moments. Second, an inversion technique will be used with a solution to the one-dimensional convective-dispersive equation utilizing a method of superposition to account for spatial variability along the flow path. The third method will be an inversion technique. Calculations will be made for each of the sampling points and the extraction well. Estimated values of NAPL saturation will be stored electronically in a uniform format.

Moment Analysis. The method of moments may be used in combination with head measurements to determine the water-filled porosity and saturated hydraulic conductivity. These calculations will be made at each of the sampling locations and the extraction wells.

Miscellaneous. It is probable that the composition, as well as the volume of residual NAPL, will be altered during the technology demonstration tests; therefore, additional partitioning tests will be required to design post-extraction tracer tests. Tracer screening will be done using NAPL, which has been exposed to the appropriate extracting fluid under conditions similar to those present in the test cells. When possible, additional testing will be conducted on NAPL (or core material containing NAPL) taken from test cells following the technology demonstration tests. To the extent possible, the same tracers will be used in both the pre- and post-test tracer studies; however, if tracer partitioning behavior is substantially altered by in situ extraction, a different suite of tracers may be required.

Table A-1: List of Possible Analytes

Compound	Type
Trichloroethene (TCE)	Contaminant
Tetrachloroethene (PCE)	Contaminant
Methylene Chloride	Contaminant
Carbon Tetrachloride(CT)	Contaminant
cis-1,2-dichloroethene (1,2-DCE)	Contaminant
1,1-dichloroethene (1,1-DCE)	Contaminant
1,1-dichloroethane (1,1-DCA)	Contaminant
1,2-Dichloroethane (1,2-DCA)	Contaminant
1,1,1-Trichloroethane (1,1,1-TCA)	Contaminant
Vinyl Chloride	Contaminant
Total Petroleum Hydrocarbons	Contaminant
BTEX	Contaminant
Bromide	Tracer
Fluorescein	Tracer
Methanol	Tracer
Hexanol	Tracer
2,4-dimethyl-3-pentanol	Tracer
Ethanol	Tracer
Propanol	Tracer
2,2-dimethyl-3-pentanol	Tracer
n-pentanol	Tracer
6-methyl-2-heptanol	Tracer
2,3-dimethyl-2-butanol	Tracer
methylated hexanol	Tracer
methylated octanol	Tracer

BTEX-benzene, toluene, ethylbenzene, and xylenes

Table A-2: Summary of Calibration and Internal Quality Control Procedures

Analytical Method	Applicable Parameter	Quality Control Check	Minimum Frequency	Acceptance Criteria*	Corrective Action[a]
SW8260B	Volatile Organics	Check of mass spectral ion intensities using BFB	Once per 12-hour shift	Ion abundance criteria as described in method SW8260B	1) Reanalyze BFB 2) Adjust MS tune until analysis of BFB passes specifications
		Five-point calibration[g] (for all analytes)	Biannually or when daily calibration verification fails	1) SPCC average RF≥0.30 (≥0.25 for bromoform – SW8240); (≥0.10 for bromoform and ≥0.20 for 1,1,2,2-tetrachloroethane – SW8260) 2) RSD ≤30% for CCC RFs	Repeat concentrations not meeting acceptance criteria
		CCV[g,h]	Every 12 hours, prior to sample analysis	1) Same criteria for SPCCs as for initial calibration 2) CCC percent difference ≤ 25% from average RFs calculated following initial calibration	1) Repeat calibration verification 2) If still out, identify and correct problem 3) Reanalyze calibration verification; if still out, recalibrate
		Method blank	One per analytical batch	All analytes <QL	1) Investigate contamination source 2) Take and document appropriate corrective action 3) Repeat initial daily blank analysis or re-extract all global medium level soil samples prior to analysis 4) Repurge and reanalyze all samples processed with contaminated blank at no cost to Surbec unless analyte is not detected in associated 5) Flag sample results associated with method blank contamination

Analytical Method	Applicable Parameter	Quality Control Check	Minimum Frequency	Acceptance Criteria*	Corrective Action[a]
SW8260B		LCS (prepared with second source standard)	1 LCS per preparation batch or per 20 samples, whichever is more frequent	Recovery for all analytes within project limits	1) Reanalyze LCS 2) Identify and correct source of problem 3) If still out, reextract and reanalyze affected samples
		MS and MSD; level of spike must comply with SW846 criteria	1 MS/MSD[b] per every 20 project samples, or per preparation batch, whichever is more frequent	Recovery and RPD for all analytes within MS/MSD	1) Reanalyze MS unless obvious matrix interference or high sample concentration; if still out: 2) Check LCS 3) If LCS is in, flag data as matrix interference
		Surrogate spike	Every sample, spike, standard, and method blank	Recovery and RPD within project limits	1) Recalculate result; if still out: 2) Check instrument performance, if necessary 3) Reanalyze unless obvious matrix interference or high sample concentration; if still out: 4) Flag results if they do not meet criteria and document in report that steps 1 through 3 were performed
		IS and RT and responses check from calibration check standard	Every sample, spike, standard, and method blank	1) RT: Must be <30-second change from daily CCV 2) IS: Extracted ion area counts must be within a factor of 2 from the daily CCV	1) Inspect mass spectroscopy or GC for malfunctions 2) Take appropriate corrective actions 3) Reanalyze samples analyzed while system was malfunctioning
		MDL study	Once per year	MDLs established shall not exceed QLs	MDLs that exceed established criteria shall be submitted to Surbec for approval prior to any project samples

Analytical Method	Applicable Parameter	Quality Control Check	Minimum Frequency	Acceptance Criteria*	Corrective Action[a]
SW8020	Halogenated Volatile Organics & Volatile Aromatic Organics	Five-point calibration (for all analytes)	Biannually or when calibration verification fails	RSD <20% for RFs or r≥0.995 for linear regression	1) Identify and repeat analysis for outlying points 2) Recalculate RSD or r using valid points
		ICV/CCV	Daily, before sample analysis, after every 10 samples, and at the end of each batch	Recovery must meet criteria specified	1) Reanalyze ICV/CCV 2) If still out, identify and correct problem; reanalyze CCV 3) Recalibrate and reanalyze all samples since last valid CCV
		RT windows calculated for each analyte	One 72-hour study performed on each GC column and whenever a new column is installed	Per SW846 criteria	1) Perform maintenance Repeat test
		LCS	1 LCS per analytical batch or 1 per 20 samples, whichever is more frequent	Recovery within project limits	1) Reanalyze 2) Identify and correct problem If still out, reextract and reanalyze LCS and affected samples
		MS and MSD; level of spike must comply with SW846 requirements	1 MS/MSD[b] per every 20 project samples, or 1 MS/MSD per analytical batch (whichever is more frequent)	Recovery within LCS limits	1) Reanalyze MS unless obvious matrix interference or high sample concentration; if still out: 2) Check LCS If LCS is in, flag data as matrix interference
		Surrogate spike	Every sample spike, standard and reagent blank	Recovery for all surrogates within project limits	1) Recalculate result; if still out: 2) Check instrument performance and correct, if necessary 3) Reanalyze unless obvious matrix interference or high sample concentration; if still out: Flag results and report that steps 1 through 3 were performed

Analytical Method	Applicable Parameter	Quality Control Check	Minimum Frequency	Acceptance Criteria*	Corrective Action[a]
SW8020		Method blank	One per day/instrument	No analyte concentration >QL	1) Investigate contamination source 2) Take and document appropriate corrective action 3) Repurge and reanalyze all samples processed with a contaminated blank at no cost to Surbec unless analyte is not detected in associated sample 4) Flag sample results associated with reagent blank contamination
		Second-column confirmation, to meet EMR[d] requirements	100% for all positive results above the detection limit except noted common laboratory contaminants[e] (also see footnote "f")	Quantitative confirmation by a second GC column of dissimilar phase and retention characteristics within specified holding times	Resample and reanalyze at no cost to Surbec, even if first column analysis was conducted within holding times
		MDL study	Once per year	MDLs established shall not exceed QLs	MDLs that exceed established criteria shall be submitted to Surbec for approval prior to any project samples
SW8015	Total Petroleum Hydrocarbons -Volatiles	Five-point calibration (for all analytes)	When daily calibration verification fails	RSD of average RF <20%	1) Identify and repeat analysis for outlying points 2) Recalculate using valid points
		ICV/CCV	Daily, before sample analysis, after every 10 samples, and at the end of each batch for gasoline only	Response for all analytes within ± 20% of expected value	1) Reanalyze ICV/CCV 2) If still out, identify and correct problem; reanalyze CCV Recalibrate and reanalyze all samples since last valid CCV

Analytical Method	Applicable Parameter	Quality Control Check	Minimum Frequency	Acceptance Criteria*	Corrective Action[a]
SW8015		Method blank	One per analytical batch	No analyte concentration >QL	1) Investigate contamination source 2) Take and document appropriate corrective action 3) Reextract and reanalyze all samples processed with a contaminated blank at no cost to Surbec unless analyte is not detected in associated samples Flag sample results associated with reagent blank contamination
		LCS	1 LCS per analytical batch or 1 per 20 samples, whichever is more frequent	Recovery for all analytes within project limits	1) Reanalyze LCS 2) Identify and correct problem 3) If still out, reextract and reanalyze affected samples
		MS and MSD; level of spike must comply with SW846 criteria	1 MS/MSD[b] per every 20 project samples, or 1 MS/MSD per preparation batch, whichever is more frequent	Recovery and RPD for all analytes within MS/MSD	1) Reanalyze MS unless obvious matrix interference or high sample concentration; if still out: 2) Check LCS If LCS is in, flag data as matrix interference
		Surrogate spike	Every sample, spike, standard, and reagent blank	Recovery for all surrogates within project limits	1) Recalculate result; if still out: 2) Check instrument performance, take corrective action, if necessary 3) Reanalyze unless obvious matrix interference or high sample concentration; if still out: Flag results and document in report that steps 1 through 3 were performed
		Second-column confirmation, to meet EMR[d] requirements	For all detectable BTEX results in the absence of a gasoline pattern	Confirmation by a second GC column of dissimilar phase and retention characteristics within specified holding times is required	Resample and reanalyze at no cost to Surbec, even if first column analysis was conducted within holding times

Analytical Method	Applicable Parameter	Quality Control Check	Minimum Frequency	Acceptance Criteria*	Corrective Action[a]
SW8015		MDL study	Once per year	MDLs established shall not exceed QLs	MDLs that exceed established criteria shall be submitted to Surbec for approval prior to any project samples
160.1	Total Dissolved Solids	2-point balance calibration	Daily	±1.99 mg for 200 mg ±19.9 mg for 100 g	1) Recalibrate 2) If still out, repair balance and recalibrate
		Method blank	1 per 20 samples analyzed	<QL	
		LCS	1 LCS per preparation batch or per 20 samples, whichever is more frequent	Recovery within project limits	1) Reanalyze LCS 2) Identify and correct problem 3) If still out, reprepare and reanalyze affected samples
		Laboratory duplicate	1 per preparation batch or per 20 samples, whichever is more frequent	RPD within project limits	Report and describe
310.0	Alkalinity	Titrant standardization	After preparation and monthly	RPD <20%	1) Repeat standardization 2) Prepare new titrant
		LCS	1 per 10 samples	Recovery within project limits	1) Identify and correct problem 2) Reanalyze LCS 3) If still out, and reanalyze affected samples
		MS/MSD	1 per 10 samples	Recovery and RPD within project limits	1) Reanalyze MS; if still out: 2) Check LCS recoveries 3) If LCS recoveries are in, flag data as matrix interference
		MDL study	Once per year	MDLs established shall not exceed QLs	MDLs that exceed established criteria shall be submitted to Surbec for approval prior to any project sample analysis[d]

Analytical Method	Applicable Parameter	Quality Control Check	Minimum Frequency	Acceptance Criteria*	Corrective Action[a]
ASTM D422 (modified)	Particle size	Laboratory duplicate	1 per preparation batch or per 20 sample, whichever is more frequent	RPD ≤20%	1) If out, repeat measurement 2) If still out, flag data
SW846[1]	Moisture	Laboratory duplicate	1 per preparation batch or per 20 sample, whichever is more frequent	RPD ≤15%	1) If out, repeat measurement 2) If still out, flag data
SW9045C	pH	Laboratory duplicate Calibration check using buffer solution	Minimum 10% Field samples 1 per 10 samples analyzed	± 0.1 pH unit ± 0.05 pH unit	1) If out, repeat measurement 2) If still out, flag data Check with new buffers; if still out, repair meter
405.1	Biochemical Oxygen Demand	Laboratory duplicate	1 per 10 samples analyzed	RPD ≤20%[j]	1) If out, repeat measurement 2) If still out, flag data

[a] All corrective actions associated with this project work shall be documented and the records maintained by the laboratory, as specified in the EMR Handbook.
[b] MSD must be included if such a specific regulatory agency requirement exists for a project.
[c] Test methods for evaluating solid waste, U.S. EPA, January 1995.
[d] EMR Handbook, 1992
[e] Methylene chloride, acetone, and 2-butanone are considered to be common laboratory contaminants. Therefore, second-column confirmation is not required for the sole purpose of confirming the presence of any of these three analytes.
[f] For quarterly sampling, second column confirmation is not required if all detected compounds were confirmed at least once in the previous two quarters.
[g] SPCC =System Performance Check Compounds:1,1-dichloroethene, chloromethane, bromoform, chlorobenzene, 1,1,2,2-tetrachloroethane. CCC= Calibration Check Compounds: 1,1-dichloroethene, 1,2-dichloropropane, chloroform, ethylbenzene, toluene, and vinyl chloride.
[h] Only the CCCs/SPCCs are monitored in the CCV.
[i] Described in Method SW3550.
[j] No method specifications; limits to be used until data are available.

BFB = Bromofluorobenzene
BTEX = Benzene, toluene, ethylbenzene, and xylene
CCC = Calibration check compounds
CCV = Continuing calibration verification
CF = Calibration factor
EMR = Environmental Management Restoration Division
GC = Gas chromatograph
GFAA = Graphite furnace atomic absorption
ICV = Initial calibration verification
IS = Internal standard
LCS = Laboratory control sample
MDL = Method detection limit
MS = Matrix spike
MSA = Method of standard addition
MSD = Matrix spike duplicate
QL = Quantitation limit
r = Correlation coefficient
RF = Response factor
RPD = Relative Percent Difference
RSD = Relative standard deviation
RT = Retention time
SPCC = System performance check compounds

*Criteria is listed in Table A.3

Table A-3: Summary of On-site and Off-site Analytical Procedures*

ITEM	Sample Type	Analytical Method #	Method Title	Ref
VOC	Soil	SW8260B	Volatile Organic Compounds by GC/MS: Capillary Column Technique	4
VOC (pre and post test GW and discharge water)	Ground water	SW8260B	Volatile Organic Compounds by GC/MS: Capillary Column Technique	4
VOC (verification of field results at CEPA approved Lab)	Ground water	SW 8260B (Modified to Account for Surfactants)	Volatile Organic Compounds by GC/MS: Capillary Column Technique	4
VOC (UO analysis)	Ground water	Modified SW8015	GC with FID	5
VOC (onsite)	Ground water	Modified SW8015	GC with PID and Hall Detector	5
Surfactant	Ground water	See Section 8.5.1.1	HPLC	6,7
Organic tracers	Ground water	Modified SW 8015	GC with FID	5
Foc	Soil	Walkley-Black	Walkley- Black Method	8
Moisture Content	Soil	ASTM D2216	Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures	3
Specific Gravity	Soil	ASTM D854	Test Method for Specific Gravity of Soils	3
Bulk density	Soil	ASTM D2937	Test Method for Density of Soil in Place by the Drive-Cylinder Method	3
Sieve analysis	Soil	ASTM D422-63	Method for Particle Size Analysis of Soils	3
Cl-	Ground water	SW 325.3	Inorganics, Non-metallics	1
SO4-	Ground water	SW 375.4	Inorganics, Non-metallics	1
NO3-	Ground water	SW 353.3	Inorganics, Non-metallics	1
Ca 2+	Ground water	SW 215.1	Metals (Total and Dissolved) AAS, Direct Aspiration	1
Ca 2+	Soil	SW 7140	Atomic Absorption, (AA)	2
Mg 2+	Ground water	SW 242.1	Metals (Total, Dissolved, Atomic Absorption)	1
Mg 2+	Soil	SW 7450	Atomic Absorption	2
Na+	Ground water	SW 273.1	Metals (Total, Dissolved, Atomic Absorption)	1
Na+	Soil	SW7770	Atomic Absorption	2
BOD	Ground water	SW 405.1	Organics	1
Total Suspended Solids	Ground water	SW 160.2	Physical Properties	1
TDS	Ground water	SW 160.1	Physical Properties	1
PH	Ground water	SW 150.1	Physical Properties	1
Alkalinity	Ground water	SW 310.1	Inorganics, Non-Metallics	1
BTEX	Ground water	SW 8020	Aromatic Volatile Organics	1
BTEX	Soil	SW 8020	Aromatic Volatile Organics	1

* A copy of the procedure documentation will be maintained at the on-site laboratory.

Reference:

1. Methods for the Chemical Analysis of Water and Wastes. EPA-600/4-79-020. Revised March 1983. Environmental Monitoring Systems Laboratory. Cincinnati, Ohio, and Subsequent EPA-600/4 Technical Additions.

2. Testing Methods for Evaluating Solid Waste, Volumes IA-IC: Laboratory Manual, Physical/Chemical Methods and Volume II: Field Manual, Physical/Chemical Methods. SW-846. 3rd Edition. U.S. EPA Office of Solid Waste. Document Control No. 955-001-00000-1.

3. Annual Book of ASTM Standards. American Society of Testing and Materials, 1994.

4. Federal Register Part VII 40 CFR Part 136, Oct. 26, 1984.

5. Compilation of EPA's Sampling and Analysis Methods. 2nd Edition. Lewis Publishers, 1996.

6. Surfactant Remediation Field Demonstration Using a Vertical Circulation Well. Knox, R.C., Sabatini, D.A., Harwell, J.H., Brown, R. E., West, C.C., Blaha, F., Griffin, C. Groundwater, Vol. 35, No.6, Nov-Dec 1997.

7. Evaluation of Ethoxylated Alkylsulfate Surfactants for use in Subsurface Remediation. Rouse, J.D., Sabatini, D.A., Brown, R.E., Harwell, J.H. Water Environment Research, Vol. 68, No. 2, Mar-Apr 1996.

8. Part 2. Chemical and Microbiological Properties. In Method of Soil Analysis. American Society of Agronomy, Inc., Madison, WI. 1965. pp 1372-1376.

Table A-4: Quality Control Acceptance Criteria for General Chemistry and Miscellaneous Methods

Method	Analyte	Water				Soil			
		LCS % Rec	MS % Rec	MS/ MSD RPD	FD RPD	LCS % Rec	MS % Rec	MS/ MSD RPD	FD RPD
SW8015A	Benzene	62-128	62-128[b]	≤33	≤30	62-128	62-128[b]	≤33	≤50
	Toluene	62-129	61-137	≤32	≤30	62-129	61-129[b]	≤32	≤30
	Ethylbenzene	67-137	67-137[b]	≤31	≤30	67-137	67-137[b]	≤31	≤30
	Total xylenes	64-136	64-136[b]	≤30	≤30	64-136	64-136[b]	≤29	≤30

[a] No method specifications available.
[b] LCS criteria will be used to identify matrix effects.

Method	Analyte	Water				Soil (low)				Soil (medium)			
		LCS % Rec	MS % Rec[c]	MS/ MSD RPD	FD RPD	LCS % Rec	MS % Rec[c]	MS/ MSD RPD	FD RPD	LCS % Rec	MS % Rec[d]	MS/ MSD RPD	FD RPD
SW8020A	Benzene[d]	60-134	47-139	≤22	≤30	60-134[e]	21-188	≤9	≤50	33-134[f]	33-134[g]	≤27	≤50
	Toluene[d]	66-133	51-136	≤22	≤30	66-131	30-172	≤9	≤50	66-133	66-133[g]	≤9	≤50
	Ethylbenzene[d]	66-138	55-138	≤18	≤30	66-138	36-158	≤30	≤50	66-138	66-138	≤30	≤50
	Total xylenes[d]	63-141	63-141[g]	≤20	≤30	63-131	66-138	≤8	≤50	63-141	63-141[g]	≤8	≤50

[c] Based on historical MS/MSD data or historical LCS data.
[d] Must be included in matrix spikes.
[e] Water sample LCS limits used until soil limits are available.
[f] SW8010B limits.
[g] LCS criteria will be used to identify matrix effects.

Method	Analyte	Water[h]				Soil (low)			
		LCS % Rec	MS % Rec[i]	MS/ MSD RPD	FD RPD	LCS % Rec	MS % Rec	MS/ MSD RPD	FD RPD
SW8260B	Benzene[j]	75-132	75-132	≤10	≤30	67-141	60-141	≤18	≤50
	1,1-Dichloroethane[j]	59-139	59-139	≤23	≤30	62-134	62-134[i]	≤16	≤50
	1,2-Dichloroethane[j]	58-144	58-144	≤26	≤30	64-136	64-136[i]	≤20	≤50

Method	Analyte	Water[h]				Soil (low)			
		LCS % Rec	MS % Rec[l]	MS/ MSD RPD	FD RPD	LCS % Rec	MS % Rec	MS/ MSD RPD	FD RPD
SW8260B (cont'd)	1,1-Dichloroethene[j,k]	51-145	51-145	≤26	≤30	62-118	31-169	≤31	≤50
	cis-1,2-Dichloroethene[j]	50-150	50-150	≤30	≤30	50-150	50-150[i]	≤50	≤50
	Tetrachloroethene[j]	68-148	68-148	≤11	≤30	66-127	66-127[i]	≤14	≤50
	Toluene[j,k]	77-125	77-125	≤12	≤30	72-131	58-131	≤24	≤50
	1,1,1-Trichloroethane[j]	57-145	57-145	≤27	≤30	56-144	56-144[i]	≤26	≤50
	Trichloroethene[j,k]	75-120	75-120	≤11	≤30	71-149	50-149	≤26	≤50
	Vinyl chloride[j]	37-146	37-146	≤35	≤38	41-110	41-137	≤38	≤50
	BFB	84-115	84-119	NA	NA	65-123	65-123[i]	NA	NA

[h] 5 ml purge volume.
[i] LCS limits will be used to identify matrix effects.
[j] Minimum subset of analytes to be included in LCS.
[k] Minimum subset of analytes to be included in MS/MSD.
[l] No performance based specifications; limits to be used until data are available.

Method	Analyte	Water[m]				Soil (medium)			
		LCS % Rec	MS % Rec[n]	MS/ MSD RPD	FD RPD	LCS % Rec	MS % Rec[n]	MS/ MSD RPD	FD RPD
SW8260B	Benzene[o]	71-133	71-133	<14	<30	78-131	78-131	<6	<50
	1,1-Dichloroethane[o]	65-131	65-131	<19	<30	62-149	62-149	<8	<50
	1,2-Dichloroethane[o]	68-138	68-138	<12	<30	75-127	75-127	<5	<50
	1,1-Dichloroethene[o,p]	51-133	51-133	<23	<30	61-122	61-122	<11	<50
	cis-1,2-Dichloroethene[p]	66-144	66-144	<18	<30	54-126	54-126	<24	<50
	Tetrachloroethene[o]	62-125	62-125	<18	<30	68-147	68-147	<8	<50
	Toluene[o,p]	81-121	80-121	<14	<30	78-183	89-183	<12	<50
	1,1,1-Trichloroethane[o]	58-144	58-144	<21	<30	54-161	54-161	<7	<50
	Trichloroethene[o,p]	73-121	73-121	<13	<30	69-122	81-122	<7	<50
	Vinyl chloride[o]	14-161	27-161	<20	<30	52-127	52-127	<14	<50
	BFB	84-113	84-113	NA	NA	65-123	65-123	NA	NA

[m] 15 or 25 ml purge volume.
[n] LCS limits will be used to identify matrix effects.
[o] Minimum subset of analytes to be included in LCS.
[p] Minimum subset of analytes to be included in MS/MSD.

Method	Analyte	Water				Soil			
		LCS % Rec	MS % Rec	MS/ MSD RPD	RF RPD	LCS % Rec	MS % Rec	MS/ MSD RPD	FD RPD
	TOC-Walkley Black	NA	NA	NA	NA	76-110	38-142	≤29	≤50
E160.1	Total Dissolved Solids	80-120	75-125	≤20	≤30	NA	NA	NA	NA
E300.0	Anions	83-115[q]	66-133[q]	≤18	≤30	75-125	75-125[r]	NA	≤30
E310.1	Alkalinity	95-109	85-115[s]	≤20	≤30	NA	NA	NA	NA
E353[t]	Nitrate/Nitrite	85-115	85-115[r]	≤20	≤30	85-115	85-115[r]	≤30	≤50
E405.1	Biochemical Oxygen Demand	NA	NA	≤20	≤20	NA	NA	NA	NA
SW6010A	Calcium	80-125	59-125	≤30	≤30	75-125	34-128	≤52	≤100
	Magnesium	80-120	66-120	≤30	≤30	75-125	48-125	≤46	≤50

[q] Range of all analytes.
[r] LCS limits will be used to identify matrix effects.
[s] No method specifications; limits to be used until data are available.
[t] Precision evaluated by duplicate sample analysis.

FD = Field duplicate
LCS = Laboratory control sample
MS/MSD = Matrix spike/matrix spike duplicate
NA = Not applicable
Rec = Recovery
RF = Response Factor
RPD = Relative percent difference

APPENDIX B

HEALTH AND SAFETY

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Figure B.2 Health and Safety Plan Project Acceptance Form B-15

To complete a problem-free, injury-free and accident-free demonstration, Surbec will conduct all aspects of this Work Plan according to the Health and Safety Plan (HASP) presented in this section. This document is subtier to Surbec's corporate Health and Safety Plan. All HASP information will be subtier to 29 CFR and CCR Title 8; and 40 CFR and CCR Title 22. Surbec will bear the ultimate responsibility for implementing and adhering to all safety measures. All Surbec subcontractors are required to comply with this HASP.

1.1 Objectives

The objectives of the HASP are as follows:

- Assess potential site hazards before work
- Ensure that all personnel are aware of potential hazards
- Minimize or mitigate potential hazards
- Provide a means to protect personnel and report incidents
- Complete demonstration with zero reportable incidents

1.2 Health and Safety Organization and Key Personnel

Jeff Brammer will cordinate Site Health and Safety with all subcontractors. All subcontractors will be instructed with respect to site-specific health and safety issues and will be required to meet the criteria included in this document.

Surbec Project Manager	Mark Hasegawa	405-364-9726/405-640-9503
Surbec Site Health and Safety Officer	Jeff Brammer	405-826-2880
Surbec UO Health and Safety Officer	Bin Wu	
TtEMI Site Health and Safety Officer	Rafeal Lago	512-222-8258
TtEMI Navy Clean Program Health and Safety Officer	Conrad Sherman	

1.3 Hazard Assessment

Several potential hazards may be encountered during the course of the demonstration. These hazards are inherent to the scope of work and system operation described in this Work Plan. The identified potential hazards presented here are not intended as a complete list. We have a duty to recognize additional potential hazards throughout all phases of fieldwork. We have identified the following potential hazards.

1.3.1 Chemical Hazards

The evaluation of chemical hazards is based upon the knowledge of site background and anticipated risks posed by SESR. The chemical hazards associated with on site remediation activities include groundwater with VOCs, alcohols (2% to 50%), and surfactant (2% to 6%), which is to be used for enhanced solubilization. These chemicals will be handled using Level D personal protective equipment (refer to Section 1.4.1). The following paragraphs describe potential chemical hazards associated with SESR and the necessary precautions to be taken.

Liquid or Vapor Waste VOCs: The process liquid stream will contain VOCs. Site activities will involve sampling the feed and effluent streams for analysis. Major contaminants of concern

include: trichloroethene (TCE), tetrachloroethene (PCE), 1,2-dichloroethene (1,2-DCE), 1,1-dichloroethene (1,1-DCE), vinyl chloride, 1,1,1-trichloroethane (TCA), 1,2-dichloroethane (1,2-DCA), chloroethane, benzene, ethylbenzene, toluene, and xylenes. It is possible that other VOCs may exist in concentrations exceeding permissible exposure limits at certain pumping/sampling intervals. For this reason, safety precautions and procedures will be established by this HASP at a level of protection to guard against the possibility of exposure from such an occurrence. Workers will use appropriate personal protective equipment (PPE) when handling sample preservatives. Exposure to VOCs should be extremely low due to the slow rate of vaporization from the aqueous solution, short sampling time intervals during which vapors may escape, and the fact that the SESR treatment system will be outdoors where ventilation will significantly reduce exposure levels. Nonetheless, the safety precautions described in this HASP must be followed to prevent unnecessary exposure to contaminants.

Personnel may come in contact with groundwater or vapor contaminants at any time during the sampling, operation, and maintenance of the system. Precautions to prevent exposure to harmful levels of chemicals will include the usage of PPE. An organic vapor monitor (OVM) will be used during operations to record chemical vapor concentrations. Air-purifying respirators will be worn accordingly.

Only the Site Health and Safety Officer has the authority to downgrade or upgrade PPE. During operation of the system, personnel will follow these precautions:

- Avoid unnecessary contact with the contaminated groundwater or vapor.
- Wear appropriate PPE, such as inner and outer chemical resistant gloves, boots, apron, coveralls, splash goggles, or shield and air-purifying respirator with organic vapor/acid gas (OVA) filter cartridges, as required by this plan, when contact with liquid wastes can occur.
- Periodically check system integrity to prevent leaks or spills.
- Use an OVM at all times during sampling sessions to measure chemical vapor concentrations.

Methanol, Ethanol, Propanol, 2,2-Dimethyl-3-Pentanol, and Hexanol. One or all of these alcohols may be delivered to the site. Methanol will be used for contaminant extraction from soils in the field and laboratory. One of these alcohols may also be selected as a cosolvent for enhanced contaminant removal or as partitioning tracers.

Denatured alcohol may be fatal or cause blindness if swallowed in quantity. Other symptoms of exposure include headache, dizziness, nausea, and narcosis. Prolonged contact causes irritation to the skin and eyes. If contact with skin occurs, wash thoroughly with soap and water. If contact with eyes occurs, flush thoroughly with water for at least 15 minutes. If inhalation occurs, remove to fresh air. If accidental ingestion occurs, drink water and induce vomiting Denatured alcohol is flammable and should be kept away from heat and flames.

The following safety precautions are to be taken when one or more of these alcohols is being used:

1. Always wear chemical-resistant protective clothing, rubber gloves, goggles, and a face shield when working with alcohols. Contact lenses should not be worn when working with these chemicals. If vapor concentrations exceed the ceiling limit, Level C PPE will be worn.

2. Store alcohols away from heat, sparks, or direct flame. Label tanks:

POISON

DANGER

FLAMMABLE

3. When adding any of these alcohols to feed tanks or reservoirs, make sure the area is properly ventilated to prevent inhalation of vapors. Pour slowly to prevent agitation and splashing.

Test Kit Chemicals. Appropriate Level D PPE will be used when handling any test kit chemicals. Level D PPE will include eye protection, a laboratory coat, and chemical-resistant gloves. Care will be taken while handling acidic and basic chemicals; sodium bicarbonate will be available in the field as a neutralizing agent for use in the event of a splash or a spill. An eyewash and shower station will be available in the field laboratory.

Sample Preservatives. Hydrochloric acid (HCl) or sulfuric acid (H_2SO_4) will be used as chemical preservatives for water sample preservation. Both are strong acids and should be handled with care. These acids will be supplied in 1-liter bottles and will be stored in the demonstration laboratory trailer. Refer to the appropriate Material Safety Data Sheet (MSDS) for handling precautions and first aid response. Store acids in a dry place and prevent contact with moisture, bases, metals, and oxidizers. Acids will be labeled by the chemical supplier. Storage cabinets containing acids should be labeled as follows:

POISON

DANGER

CORROSIVE

Surfactants. Surfactants will be used for subsurface flushing activities. The surfactant will not be selected until the laboratory screening process is complete. MSDS data for several candidate surfactants are in Appendix F. The selected surfactant will be nontoxic and have Food and Drug Administration (FDA) food-grade or food-contact status.

1.3.1.1 First Aid

In the event of contact with the contaminants of concern listed above, emergency response personnel should be contacted immediately. Emergency response personnel should follow the

first aid procedures as outlined in the attached MSDSs (refer to Appendix F). For additional information, refer to the Surbec Health and Safety Plan.

1.3.2 Physical Hazards

Physical hazards are inherently present during project field activities. Common physical hazards include mechanical hazards, noise exposure associated with mechanical equipment use, slip-trip-fall hazards associated with the field environment, hazards associated with weather conditions, musculoskeletal injury resulting from lifting tasks, nuisance dusts associated with soil disturbance, fire and explosion hazards due to the refinery process chemicals, and explosion or electrical hazards from the contaminants present or underground pipes or lines that may be encountered during drilling and sampling activities. The typical physical hazards anticipated to be present on the site and the methods for preventing injury due to these hazards are described below.

1.3.2.1 Drill Rig Hazards, Overhead Hazards, and Heavy Equipment

Drill rig operations present a hydraulic system hazard; therefore, only personnel trained in drill rig use should be near the drill rig during operation. There will always be a minimum of two personnel present during drilling operations: one operator and one driller's helper. If the drill rig is operated on a sloped surface the "drill head" of the truck shall be positioned upgrade. The driller is responsible for inspecting the drill rig daily for safety purposes.

In addition to the drill rig, some heavy equipment may be necessary to install and remove the treatment system. Caution shall be used when working around heavy equipment because of obstructed views, loud noise, and other impediments. The operation of heavy equipment shall comply with 29 CFR 1926 and CCR Title 8, Construction Safety Orders. Every operator will be trained properly in the operation and maintenance of equipment. The equipment operators are responsible for daily verification that the equipment is safe to use. Proper safety practice will be observed near heavy equipment.

1.3.2.2 Noise

A noise hazard is presented from drilling equipment, airplanes, or other field activities. Hearing protection must be provided when noise levels are identified as exceeding 85 decibels (that is, whenever normal conversational speech cannot be heard) over an 8-hour period. Ear plugs and/or muffs will be worn at all times when personnel are within 25 feet of the drill rig. Hearing protection will also be worn in the vicinity of generators or any other equipment emitting loud noise. If hearing protection upgrades are deemed necessary by the site safety officer (SSO), they will be provided to personnel working in the noise hazard area. Refer to 29 CFR 1910.95 for additional information on noise exposure.

1.3.2.3 Slip-Trip-Fall Hazards

Slip-trip-fall hazards are common at most sites. While it is difficult to eliminate all slip-trip-fall hazards, risk of injury will be minimized by implementing safe work practices, utilizing proper foot wear, keeping the work area free from obstructions, and practicing good housekeeping.

In addition, the process piping for the extraction wells will connect to system components with aboveground piping. Well heads, piping, or other obstacles that may present tripping hazards will be marked conspicuously upon completion.

1.3.2.4 Lifting Hazards

Field operations often require the performance of laborious tasks. All employees must implement proper lifting procedures, such as keeping the load close to the body and using leg muscles instead of back muscles to perform lifting tasks. Additionally, employees shall not attempt to lift large, heavy, or awkwardly shaped objects without assistance.

1.3.2.5 Heat Stress

Care must be taken in order to avoid workers being overcome by heat stress due to the anticipated weather conditions and the added stress of the protective gear. All project tasks will be altered during times in which conditions significantly pose the threat for workers being exposed to heat stress.

Frequency of breaks will be based upon individual worker conditions and needs, as well as ambient air temperatures; breaks may be mandated by the SSO. Shade, cool water, and electrolyte solution will be provided at the site. Workers will be observed for potential problems prior to resuming work after breaks.

Monitoring Workers for Heat Stress. For workers wearing permeable clothing, follow recommendations for monitoring requirements and suggested work/rest schedules in the current American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values for Heat Stress. For workers wearing semipermeable or impermeable clothing, the ACGIH standard cannot be used. For those situations, workers should be monitored when the temperature in the work area is above 90°F (32°C). Monitor the following criteria:

- **Heart rate**. Count the radial pulse during a 30-second period as early as possible in the rest period. If the heart rate exceeds 100 beats per minute at the beginning of the rest period, shorten the next work cycle by one-third and keep the rest period the same. If the heart rate still exceeds 100 beats per minute at the next rest period, shorten the following work cycle by one-third.
- **Oral temperature**. Use a clinical thermometer (3 minutes under the tongue) or similar device to measure the oral temperature at the end of the work period (before drinking). If the oral temperature exceeds 99.6°F (37.6°C), shorten the next work cycle by one-third without changing the rest period. If the oral temperature still exceeds 99.6°F (37.6°C) at the beginning of the next rest period, shorten the following work cycle by one-third. Do not permit a worker to wear a semipermeable or impermeable garment when his/her oral temperature exceeds 100.6°F (38.1°C).
- **Body water loss, if possible**. Measure body weight on a scale accurate to ± 0.25 pounds at the beginning and end of each day to see if enough fluids are being taken to prevent dehydration. Weights should be taken while the employee is in minimal clothing. Body water loss should not exceed 1.5 percent of the total body weight in any given workday.

Initially, the frequency of physiological monitoring depends on the air temperature adjusted for solar radiation and the level of physical work. The length of the work cycle will be governed by the frequency of the required physiological monitoring. The suggested frequency of physiological monitoring for fit and acclimated workers is as follows.

Adjusted Temperature[1]	Normal Work Ensemble	Impermeable Ensemble
90°F (32.2°C) or Above	After each 45 minutes of work	After each 15 minutes of work
87.5-90°F (30.8-32.2°C)	After each 60 minutes of work	After each 30 minutes of work
82.5-87.5°F (28.1-30.8°C)	After each 90 minutes of work	After each 60 minutes of work
77.5-82.5°F (25.3-28.1°C)	After each 120 minutes of work	After each 90 minutes of work
72.5-77.5°F (22.5-25.3°C)	After each 150 minutes of work	After each 120 minutes of work

[1] Calculate the adjusted air temperature (t_{adj}) by using the following equation: $t_{adj.}$(°F) = t (°F) + [13 x (% sunshine)]. Measure air temperature (t) with a standard mercury-in-glass thermometer, with the bulb shielded from radiant heat. Estimate % sunshine by judging the fraction of time the sun is not covered by clouds thick enough to produce a shadow (100% sunshine - no cloud cover and a sharp, distinct shadow; 0% sunshine - no shadows).

Heat Stress Symptoms. Work activities in hot environments can result in heat rash, heat cramps, heat exhaustion, or even heat stroke. Heat rash may result from continuous exposure to hot or humid air. Heat cramps are caused by heavy sweating with inadequate electrolyte replacement. Signs and symptoms include muscle spasms and pain in the feet, hands, and abdomen.

Heat exhaustion occurs from increased stress on various body organs including inadequate blood circulation due to cardiovascular insufficiency or dehydration. Signs and symptoms include:

- Pale, cool, moist skin
- Heavy sweating
- Dizziness
- Nausea
- Fainting

Heat stroke is the most serious form of heat stress. Temperature regulation fails and the body temperature rises to critical levels. Immediate action must be taken to cool the body before serious injury and death occur. IMMEDIATE MEDICAL ATTENTION IS REQUIRED. Signs and symptoms are:

- Red, hot usually dry skin
- Lack of or reduced perspiration
- Nausea
- Dizziness and confusion
- Strong, rapid pulse
- Coma

1.3.2.6 Cold Stress

Preventive measures will be implemented during extreme cold conditions in order to prevent cold injury. Work will be altered in order to reflect these concerns during times in which conditions pose a significant threat for workers being exposed to cold stress. Workers unaccustomed to working under thermal stresses will be allowed to become acclimated.

Frequency of breaks will be based upon individual worker conditions and needs, as well as atmospheric conditions. A warm, protected break area will be provided. Consideration will be given to working in the warmer times of day (during sunshine conditions). Workers will be instructed to wear adequate layered clothing underneath personal protective clothing. Drinking water and electrolyte solution will be provided at site. Workers should self-monitor for signs and symptoms of cold stress. Special attention shall be placed on signs or symptoms of numbness in outer limbs and pale skin. Workers must report to the Site Safety Officer at the first sign of altered feeling of the skin so that warming measures can be taken.

Of special note for cold stress on the site is the wearing of Tyvek suits. Disposable clothing does not breathe; therefore, perspiration is not provided with the means of evaporation. During strenuous physical activity, clothes can become wet. Wet clothes combined with cold temperatures can lead to hypothermia. If the air temperature is less than 40°F and site personnel become wet, the person must change into dry clothes. The heated break area or a personal vehicle may be utilized as a change area.

Cold Stress Symptoms. If adequate clothing is not provided and time spent in cold areas is not reduced, work activities in cold environments can result in frostbite or hypothermia.

Frostbite is an injury resulting from exposure to cold. The extremities of the body (fingers and toes) are most often affected. SEEK MEDICAL ATTENTION IMMEDIATELY. The signs of frost bite are:

1. Skin turns white or grayish-yellow.
2. Pain is sometimes felt early, but subsides later. Often there is no pain.
3. The affected part feels intensely cold and numb.

Hypothermia is characterized by shivering, numbness, drowsiness, muscular weakness and a low internal body temperature when the body feels warm externally. Hypothermia can lead to unconsciousness and death. SEEK MEDICAL ATTENTION IMMEDIATELY.

1.3.2.7 Weather

During storms, rain may cause slippery surfaces. Lightning may also accompany storms creating an electrocution hazard during outdoor operations. To eliminate this hazard, weather conditions will be monitored and work suspended during electrical storms.

1.3.2.8 Underground Utilities

Facility civil engineering personnel will receive adequate notice to clear underground utilities before field personnel proceed with digging or drilling operations.

The estimated location of utility installations, such as sewer, telephone, fuel, electric, water lines, or any other underground installations, that reasonably may be expected to be encountered during the drilling investigation, shall be determined prior to beginning work at the site. The Alameda Point field team will issue a digging permit that contains provisions for utility marking and clearance. The approximate location of the underground installations shall be defined as a strip of land 2 feet on either side of underground installations.

1.3.2.9 Overhead Electrical Power Lines

Overhead power lines pose a danger of shock or electrocution if the power line is contacted or severed during site operations. Prior to conducting work in areas where overhead lines could be affected, the field team will notify the appropriate utility contact personnel. Information will be obtained regarding the line voltage and minimum separation distance required for work in the area. Crews will avoid overhead utilities by respecting advisable clearances during all field activities. Site 5 does not have overhead lines near the proposed study area.

1.3.2.10 Contact with Electricity

If mechanical equipment makes contact with electrical wires, it may or may not be insulated from the ground by the tires of the equipment. Under either circumstance, if the human body simultaneously comes in contact with the equipment and the ground, electrocution can result, causing death or serious injury. If the equipment makes contact with overhead or underground electrical lines, the following procedures shall be followed:

1. Personnel should not move or touch any part, particularly a metallic part, of the equipment. Anyone in the cab of the equipment should stay seated and not move, under most circumstances.
2. If it is determined that the equipment should be vacated, all personnel must jump clear and as far as possible from the equipment. Personnel must not step off -- but must jump off. Personnel should not hang on to any part of the equipment when jumping clear.
3. Personnel on the ground should stay away from the equipment; do not allow others to get near the truck or rig. Immediately assistance should be sought from local emergency personnel.

4. When an individual is injured and in contact with the equipment or with power lines, rescue should be attempted with extreme caution. If a rescue is attempted, a long, dry, unpainted piece of wood or a long, dry, clean rope should be used. Personnel should keep as far away from the victim as possible and not touch the victim until the victim is completely clear of the equipment or electrical lines.

1.3.2.11 Fall Protection

During the demonstration, minimal overhead work will be performed. If a ladder or other method of raising a worker above the ground becomes necessary, the situation will be assessed for use of proper safety equipment. If work is conducted at a height greater than 4 feet, a fall protection plan will be implemented.

1.3.2.12 Machinery/Mechanized Equipment

System operators will inspect the remediation equipment and maintain it for proper performance. They will perform maintenance on mechanized equipment only after proper lockout procedures.

1.4 Engineering Controls

To minimize the risk of accident or injury related to the potential hazards identified in Section 1.3, the following engineering controls will be implemented.

1.4.1 Personal Protective Equipment (PPE)

All personnel working on site will use a minimum of Level D protection. "Modified Level D" protection may be required when working with or around hazardous chemicals. "Modified Level D" protection includes Tyvek coveralls, chemical-resistant steel-toed boots, chemical-resistant gloves, and safety glasses. Workers will wear hard hats when working around all operating equipment and when overhead objects present a hazard.

PPE will be upgraded to Level C or C-modified upon notification of high airborne contaminant levels measured through site monitoring. Level C will include the use of a cartridge-equipped (MT/NIOSH-approved, MSA full-face respirator with MSA GM-H cartridge or equivalent) air-purifying respirator; chemical resistant apron (or Tyvek coveralls, depending on the specific activity); chemical-resistant gloves; splash goggles; hard hat (as necessary); and boots/shoes (leather or chemical resistant, steel-toe and shank).

1.4.2 Access Restriction

Temporary fencing or caution banners with signs will surround the test site, to block access by unauthorized personnel.

1.4.2.1 Description of Exclusion Zone

An exclusion zone will be established around the active work area for all tasks. Caution banners or safety fencing shall be used to delineate the exclusion zone during the demonstration unless the safety and health of non-project personnel can be assured.

1.4.2.2 Description of Decontamination Zone

A decontamination zone will be established adjacent to or near the exclusion zone. A decontamination "pad" will be constructed with visqueen and small berms for decontamination of drilling equipment (for example, augers, samplers).

1.4.2.3 Description of Procedures for Entering Exclusion and Decontamination Zones
All personnel must have received required training as specified in 29 CFR Part 1910, and undergo a daily briefing prior to their entering into the exclusion zone or decontamination zone. All personnel must be wearing the level of PPE as specified in the HASP prior to entering the exclusion zone or decontamination zone.

All smoking or other activities which may cause indirect ingestion of contaminants (that is, eating, drinking, or use of tobacco) will not be allowed inside of or within 100 feet of the exclusion zone or decontamination zone.

1.4.2.4 Description of Procedures for Exiting Exclusion Zone (Decontamination)

All exits from the exclusion zone must be made through the decontamination zone. Personnel will perform decontamination as outlined below.

Decontamination Procedure. Personnel will perform decontamination prior to removing PPE. Personnel who have not had direct contact with contaminated or potentially contaminated equipment, wastewater, or media will remove PPE and place disposable garments in a double-lined plastic garbage bag. All PPE will be temporarily stored in double-lined plastic garbage bags. Before disposal, all PPE will be made unfit for reuse (for example, arms and legs will be removed from Tyvek suits). When bags are full, the vapor in these bags will be monitored for contamination with field meters. In the absence of measurable contamination, the bags will be disposed of as solid waste in a waste receptacle on base. If contamination is measured above background (ambient air) levels, the PPE waste will be containerized and transferred as directed by the base for disposal. The SSO is responsible for monitoring decontamination procedures and determining their effectiveness. Potable water will be available on site for decontamination procedures. Personnel who have had contact with potentially contaminated equipment or media will perform the following process as necessary:

- Wash and remove exposed garments
- Rinse exposed equipment with Alconox and potable water
- Place disposable garments in double-lined garbage bag

All personnel must have an extra set of clothing on site in the event that their clothing becomes contaminated.

Respirators, if used, will be cleaned, air-dried, and placed in sealed plastic bags. Cartridges will be discarded after use. The decontamination water will be collected for disposal with the remaining liquid waste. Decontamination water and Alconox solution will be collected separately.

1.4.3 Electrical and Mechanical Lockouts

Electrical and/or mechanical lockouts will occur anytime during field activities if the need to repair or maintain the remediation equipment arises. Lockouts will include disabling the equipment by interrupting the power source and locking and tagging all movable or hazardous parts and power sources. Refer to the Surbec Health and Safety Plan for additional information on lockout/tagout procedures.

1.5 Safety Training

1.5.1 Personnel Training

The Superfund Amendments and Reauthorization Act (SARA) passed into law in 1986 requires that employers provide training for employees that are engaged in hazardous materials operations and site cleanups. 29 CFR and CCR Title 8 require employees to have 40 hours of initial training and 8 hours of annual refresher training. 29 CFR 1910.120 requires 40 hours of initial training and 8 hours of annual refresher training for workers at uncharacterized sites, including all workers involved in drilling and well sampling/testing operations. All other staff are required to have 24 hours of initial training and 8 hours of annual refresher training. Workers who are on site one time only or infrequently are not required to have any training provided they are continually escorted by trained individuals. Supervisors and managers are required to have 8 hours of specialized training unless they engage in any hazardous materials operations. All site personnel must meet these training requirements in addition to the site-specific training requirements prior to working on site. All employees must have received the required Occupational Safety and Health Administration (OSHA) training per 29 CFR 1910.120. Copies of records of employee training will be available on site. Refer to 29 CFR 1910.120 for additional information on requirements for personnel training.

Safety training, required of all personnel working on site, will include:

- 24-hour OSHA training, and 8-hour OSHA annual refresher
- Pre-entry site briefing
- Daily monitoring
- Physical and health effects of the hazardous chemicals
- How to lessen or prevent exposure to these hazardous chemicals through usage of control/work practices and PPE
- Emergency procedures to follow if they are exposed to chemicals
- Location of the MSDS file and hazardous chemicals list

All personnel will have current OSHA Hazardous Materials (HazMat) training, as required by 29 CFR 1910.120. The SSO will ensure that all personnel are trained properly and that records are maintained. Copies of MSDSs for all hazardous chemicals known or suspected on site will be maintained in the work area. MSDSs will be available to all on-site workers for review.

Pre-entry safety training will be conducted before any personnel begins fieldwork. At the completion of the training, each person will sign the Health and Safety Plan Acceptance Form. There may be instances where it is not practical to give every worker arriving at the site a

comprehensive safety briefing. If the worker will be at the site for less than 4 hours, the SSO will be responsible for supervising/escorting the worker while at the site. The worker will be listed in the field logbook as a "casual worker" and will not be required to sign a Health and Safety Plan Acceptance form.

1.5.2 Personnel Instruction

All Site personnel shall be instructed in basic hazard awareness by the SSO prior to daily work activities on the Site. This training will be augmented by crew briefings and site-specific task training. This training will cover safe operation of site equipment and lab safety in the on-site laboratory. Initial training will include:

- History of the site
- Chemical hazards
- Requirements for personal protection equipment, its effectiveness and its limitations
- Emergency procedures
- Decontamination procedures
- Personal hygiene and care
- General health and safety practices
- Physical hazards
- Outline of the day's work, potential hazards, and topic of the day

Information concerning the health and safety hazards of the contaminants at the Site shall be maintained at the Site by the SSO and shall be available to the employees for examination. Personnel shall be trained and cautioned to be aware of, and inform each other of, subjective symptoms of dizziness, uncoordination, or loss of equilibrium.

The SSO shall verify that employees have received training concerning the fitting, use, care, and limitations of respirators and other personal protection equipment. Verification of a qualitative respirator fit test shall also be made. Facial hair, which interferes with a satisfactory seal of the respirator to the face, will not be allowed on personnel required to wear respiratory protective equipment.

1.6 Site Monitoring

1.6.1 Operations

The treatment system will be closed, except for atmospheric discharge of air from the carbon canisters, the collection of contaminants in drums, and the collection of effluent water in a double-contained tank. Air monitoring will be performed in these locations routinely, using an organic vapor meter. If an extraction pipe breaks or other system breaches occur, the area will be evacuated and the system will be shut down until monitoring indicates the area is not hazardous. Otherwise, no field activities will be conducted in the hazardous area until the necessary repairs have been made.

1.6.2 Vapor Monitoring during Field Sampling

Initial air monitoring will be conducted by the SSO. After a period of several sampling episodes, the monitoring requirements will be reviewed on the basis of monitoring results and system use.

Workers will conduct activities that present exposure risks (such as sampling) in Level D PPE, unless monitoring indicates detections are approaching action levels. At this point, PPE will be upgraded or the activity will be rescheduled, as deemed appropriate by the SSO.

1.6.2.1 On site Air Quality Monitoring

Air monitoring shall be performed in the following manner. An organic vapor photoionization monitor (OVM) shall be used to quantify airborne concentrations of contaminants (total organics). Periodic readings shall be obtained in the work area. The airborne concentrations in meter units (mu) should be recorded in the field logbook. The OVM shall be pre- and post-calibrated daily. The results of daily calibration shall be recorded in the field logbook. Refer to the Operator's Manual for the OVM for calibration procedures.

1.7 Medical Surveillance Requirements

All personnel will have records of current medical surveillance physicals on file before starting work on site. Copies of these files will be maintained at the job site. No additional medical surveillance will be required unless warranted by exposures recorded during the demonstration period. Surbec will keep medical surveillance records.

1.8 Emergency Contacts And Medical Facilities

Surbec is responsible for health and safety while work is conducted at the site. The Surbec or other personnel responsible for health and safety are to summon the following emergency contacts in case of an incident.

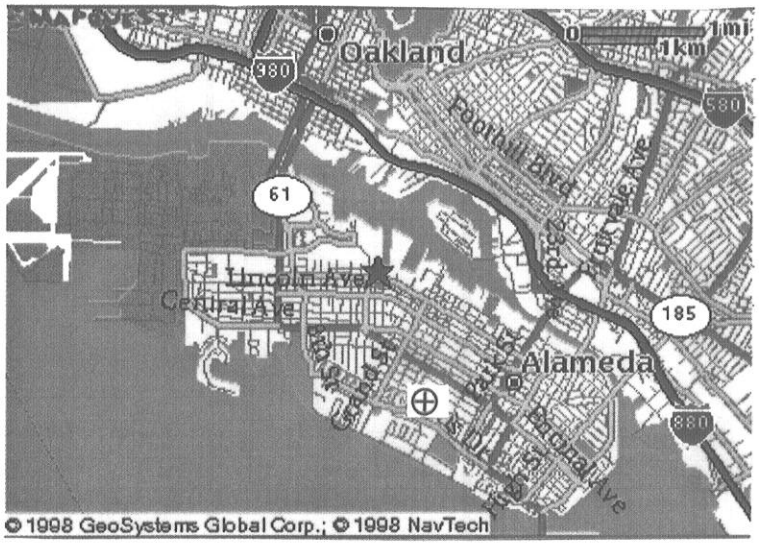
SSO	Jeff Brammer	405/826-2880
PM	Mark Hasegawa	405/364-9726

The medical facility to be used during an emergency is the Alameda Hospital located at 2070 Clinton Avenue in Alameda. The hospital telephone number is 510/522-3700. Directions from NAS Alameda to Alameda Hospital follow.

From Main gate:

- Drive straight onto Atlantic Avenue.
- From Atlantic Avenue heading east.
- Take Atlantic Avenue to Webster Street (CA Highway 61).
- Turn right on Webster heading south.
- Take Webster Street two blocks south to Buena Vista Avenue.
- Turn left on Buena Vista Avenue heading east.
- Follow Buena Vista Avenue for 1.7 miles to Willow Street.
- Turn right on Willow Street heading south.
- Follow Willow Street nine blocks south to Clinton Avenue.
- The hospital is at 2070 Clinton Avenue on the southeast corner of Clinton Avenue and Willow Street.

A hospital route map is located on Figure B.1.



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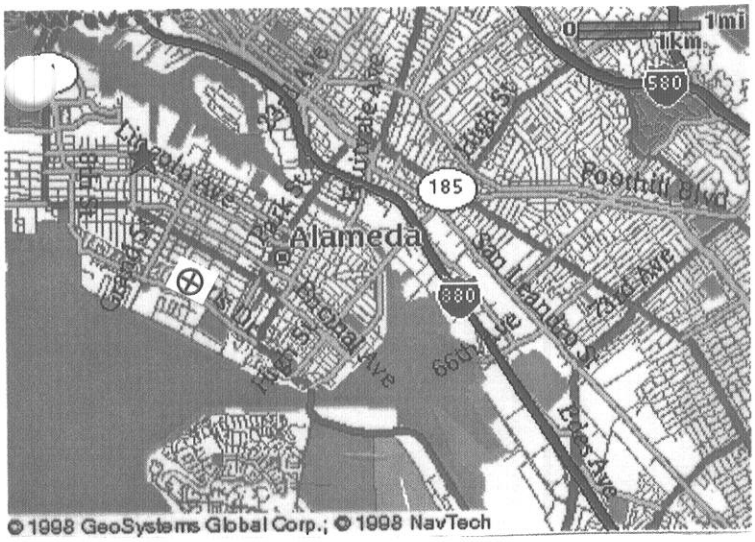

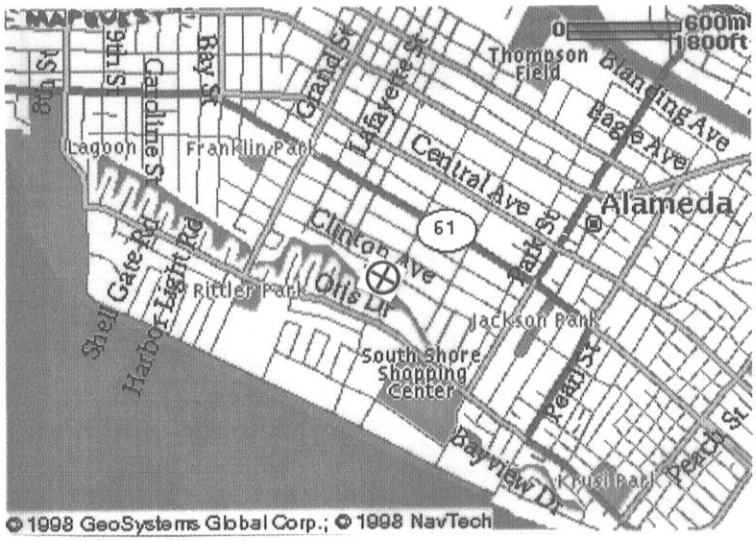

Legend:

⊕ Hospital Location

Figure B.1: Hospital Route Map

FIGURE B.2

HEALTH AND SAFETY PLAN PROJECT ACCEPTANCE FORM

INSTRUCTIONS: This form is to be completed by each person who works on the subject work site and returned to the Health and Safety Manager.

Job Number _____

Client/Project _____

Date _____

I represent that I have read and understand the contents of the above Plan and agree to perform my work in accordance with it.

NAME (PRINT)	SIGNATURE	COMPANY	DATE

APPENDIX C

SAMPLING AND ANALYSIS PLAN

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1.0 INTRODUCTION

A comprehensive and accurate performance evaluation of the demonstration depends on obtaining a complete, representative, and consistent data set chronicling the results of the demonstration. The data must characterize the original contaminant concentrations and distribution, the mass and rates of contaminant and surfactant/cosolvent removed, and the residual contamination and surfactant. The project sampling plan presented in this section specifies the general sampling locations and procedures for collecting soil and groundwater samples, the sample chain-of-custody procedures and the required packaging, labeling and shipping procedures.

Sampling activities to support the demonstration include the following main phases: System Well Installation, Laboratory Testing, Pre-demonstration Aquifer Testing: Push-pull Testing and Partitioning Tracer Testing, Surfactant/Cosolvent Flushing Operations, and Post-Partitioning Tracer Testing and Soil Sampling.

For each phase of sampling, the following information is specified within in this section:

- Sampling criteria and objectives
- Rationale for sample locations, number of samples, and analytical parameters
- Field methods and procedures
- Quality control

Field methods and procedures include sample collection methods, disposal methods, equipment decontamination, sample labeling, sample preservation, sample packaging and shipment and sample documentation. Standard operating procedures (SOP) documentation will be maintained at the on-site laboratory and at the University of Oklahoma laboratory. The selected off-site laboratory will be responsible for maintaining their own documentation that is consistent with procedures set forth in the WP. Where information regarding field methods and procedures or any other aspect of the sampling plan apply to both phases of sampling, sections are cross-referenced.

Section 1.1 details the sampling objectives to be followed for the sampling. Section 1.2 describes the sampling rationale for all phases of the demonstration, and Section 1.3 describes the specific locations, procedures and methods, and frequency of the sampling for the demonstration. Section 1.4 briefly summarizes the quality control (QC) sampling.

The goals of the listed procedures are to ensure that all information, data, and interpretations resulting from the soil/water sampling are technically sound, valid and properly documented. The implementation of procedures may change depending on the actual field conditions encountered during implementation. If changes to the soil/water sampling procedures are required, notification will be made as soon as possible of the change and work will not proceed until concurrence on the change has been received.

1.1 SITE SAMPLING OBJECTIVES

Site sampling objectives include any field investigations or activities performed before, during, and after the technology demonstration. The purpose of site sampling is to establish baseline conditions, confirm that test site groundwater contaminant concentrations meet the technology demonstration requirements, and evaluate the test progress and performance.

1.1.1 Sampling Objectives

The main sampling objectives are to assess contaminant concentrations in the soil and groundwater at the selected demonstration site and to assess the demonstration performance. Accurate contaminant concentrations obtained prior to, during, and at the completion of the project will allow for a comparison to the project objectives. Specific objectives of the sampling plan are listed below:

- To obtain accurate pre-test information (tracer tests) to accurately determine pre-existing nonaqueous-phase liquid (NAPL) concentrations in the subsurface
- To monitor performance of the SESR system in terms of its performance in removing target NAPLs (VOCs) from the subsurface
- To evaluate the aboveground treatment system for its ability to separate contaminant from surfactant for surfactant reuse
- To obtain accurate and representative influent/effluent water samples and flow data so that accurate performance mass balances can be calculated
- To obtain representative soil samples to accurately portray baseline VOC concentrations
- To obtain accurate surfactant analysis that will result in a realistic assessment of the usage and recovery rates for surfactants
- To obtain data that is useful for cost analysis and determination of the economic feasibility of using SESR at other sites

1.2 SAMPLING RATIONALE

The purpose of the sampling plan is to meet the project objectives. The samples will be split between the on-site laboratory (Surbec), the approved California laboratory (not yet selected) and the University of Oklahoma. The sampling locations and samples analysis distributions are documented in Table C-1. The sample ports and well locations are illustrated in Figure 4.4. As indicated in Table C-1 the sampling procedures have been broken down into five main sections:

- Demonstration Well Installation and laboratory testing
- Pre-demonstration Aquifer Testing: Partitioning tracer testing and Push-pull Testing
- Surfactant/cosolvent flushing
- Post-demonstration Partitioning tracer testing
- Demonstration Assessment Soil and Groundwater Sampling

Demonstration Well Installation
The demonstration setup requires the installation of four recovery wells, two injection wells, two hydraulic control wells, and four shallow monitor wells. During installation of the 12 wells, soil samples will be collected for field and laboratory analyses as described in Section 1.3.

Laboratory Testing
The purpose of the bench-scale laboratory testing is to determine the optimal system for surfactant/cosolvent flushing. Laboratory sampling procedures are outlined in the attached quality assurance project plan (QAPP) and documented in the references.

Pre-Partitioning Tracer Testing and Push-Pull
The purpose of sampling during this phase will be to quantify pre-test NAPL concentrations in the subsurface. The media to be sampled during this phase includes injection well groundwater and recovered and processed groundwater. The sample matrix and analyses are documented in Table C-1. The sampling frequencies for the tracer test (Table C-1) have been developed based on the duration of the test and the number of data points required to provide sufficient statistical analysis and a satisfactory level of confidence.

Surfactant/Cosolvent Flushing Operations
The purpose of the sampling during this phase will be to evaluate and adjust test conditions, evaluate surfactant recovery from the subsurface, evaluate the performance of the above ground treatment system and determine enhancement in contaminant recovery from the subsurface over baseline conditions. The media to be analyzed during this phase includes background (upgradient), perimeter (downgradient and cross gradient), and recovered and processed groundwater. Sample frequencies and locations are documented in Table C-1. Sample frequencies were established based on past test experience at Hill Air Force Base (AFB) and Tinker AFB, and current experience at McClellan AFB. For the duration of this test, sampling frequencies of every 8 hours (of the recovered groundwater and processed stream) will provide adequate testing data information.

Post-Partitioning Tracer Test
The purpose of sampling during this phase of the demonstration will be to quantify post-test contaminant concentrations. The media to be sampled during this phase includes groundwater and recovered groundwater. Sample matrix and analysis are documented in Table C-1. The sampling frequencies for the tracer test have been developed based on the duration of the test and the number of data points required providing sufficient statistical analysis and a satisfactory level of confidence (refer to the attached QAPP).

Demonstration Assessment Soil and Groundwater Sampling
Upon completion of the demonstration, soil samples will be collected at predetermined locations. The purpose of the soil sampling is to determine the effectiveness of the soil remediation from the surfactant flushing activities.

Groundwater samples will be collected from the recovery, injection, and hydraulic control wells three weeks after cessation of the pumping activities. The groundwater sampling results will also indicate the effectiveness of the surfactant flushing activities.

1.3 FIELD METHODS AND PROCEDURES

This section describes the field methods and procedures that will be used for drilling operations, groundwater sampling, aquifer characterization testing and Surfactant/Cosolvent Enhanced In Situ Flushing technology performance sampling. Field methods and procedures are provided for sample collection, disposal of contaminated materials, equipment decontamination, sample preservation, and sample packaging and shipment. Sample labeling and chain-of-custody procedures are described in the QAPP.

1.3.1 Drilling Activities

A total of 12 wells will be installed during this project. As these wells are completed, their specifications will be provided to the TtEMI Project Manager for official documentation. The drilling and well completion methodology will be consistent for all wells installed as part of this project. Locations for soil samples will vary depending on the contamination level with depth. Proposed well locations are shown on Figure 4.3. Shallow soil borings will not exceed 20 feet in depth and will be advanced using hollow-stem auger methods with continuous coring or split-spoon samplers (refer to the QAPP for alternative drilling methods).

Continuous Cores and Shelby Tube Sampling

The primary soil sampling methodology that will be used in the unconsolidated soils will be a continuous tube sampling system. This sampling method uses a 5.5-foot steel split-barrel sampling tube that is 2.5 to 4.0 inches in diameter. The sampler has a threaded cutting shoe, which mounts on the base of the sample tube, and a threaded retrieval head, which mounts onto the top of the sample tube. A sample retainer can be used in sandy or gravelly soils to improve recovery. The sampler is mounted within the lead hollow-stem auger flight and is adjusted so the cutting head or shoe is even with the auger cutting bits or extends to as much as 0.5-feet below the bit. The sampler is mounted on a drilling rod and is hydraulically pushed into the subsurface, but does not rotate as the auger is rotated. The hollow-stem augers are advanced in 5.0-foot increments. Once the augers have been advanced over the interval, the sampler is removed from the borehole (augers remain in position) and the sampling barrel is split open to expose the sample.

Shelby tube sampling may be employed in clay or silt soils where undisturbed soil samples are required for physical or chemical tests if continuous coring is not effective. The Shelby tube sampler (ASTM D-1 587-83) consists of a 3 in diameter thin wall (16 gauge) steel tube, 24 to 36 inches in length. The bottom of the tube or bit is sharpened so that the bevel is on the outside of the tube. The inside diameter of the bit is slightly less than that of the tube. The basic principle of operation is to hydraulically push or hammer the Shelby tube into the undisturbed soil in one continuous stroke without rotation. The tube is allowed to sit approximately 1 minute before sample removal to increase adhesion. The core is released by manually rotating to break off the core. The samples containing the soil should be carefully removed from the hole to minimize disturbance to the sample. Following sample removal, the sample will be measured, examined and described by the site geologist or geohydrologist. If undisturbed soil samples are obtained, the ends of the sample tube will be sealed to prevent loss of moisture.

Soil Vapor Sampling
If required, soil vapor headspace sampling will be conducted for the entire boring. The headspace samples will be collected in glass jars, covered with aluminum foil, and after a period of time pierced with an organic vapor monitor to record the vapor headspace concentrations. The headspace results will be used to assist in determining which sample(s) should be sent to the laboratory for volatile organics analyses as described in the QAPP.

Sample Collection Procedures
The sampling procedures common to undisturbed and disturbed sampling are described in this section. A breakdown of the procedures is listed as follows:

- Sample interval
- Sample identification
- Sample collection and management
- Soil packaging and handling
- Soil sample description and logging

Sample Interval
Sample cores will be taken across the entire depth of all borings. Each sample core will be examined and the geology logged according to the Unified Soil Classification System (ASTM D2488). Cores will be examined for visible signs of volatile organic compounds (VOC). Soil samples will only be obtained from beneath the water table. VOC samples from soils and duplicates will be preserved in methanol and will be taken from cores within the above-mentioned sample interval whenever VOC analysis are present. These samples will be sent to the appropriate laboratory for VOC analysis.

In order to characterize the subsurface soil characteristics in the flushed zone, sample cores will also be taken and sent to a geotechnical laboratory for analysis of frantion of organic carbon content (f_{oc}), bulk density, porosity, sieve analysis, and moisture content. The sample cores will be collected in shelby tubes with the ends sealed. They will be labeled, and placed in an appropriate container for shipment to the laboratory. Sample locations and frequency are identified in Table C-1.

In addition, cores will be taken during recovery/injection well installation and submitted to the University of Oklahoma (OU) for bench scale analysis. Cores will be obtained and screened as indicated above. Cores to be sent to UO will be from the targeted flushing zone and be representative of the target area. The cores will be collected from the locations indicated in Table C-1b.

Sample Identification
Each sample shall be identified according to its collection location. The sample will be labeled by the well/boring it was collected from, followed by the depth , as appropriate. As an example, a soil sample collected from the 24-foot depth during drilling and installation of Injection Well 1 would be labeled IW-1/24. A groundwater sample collected from Recovery Well 2 would be labeled RW-2. The sample identification will be well documented on the chain-of-custody form, in the field logbook, and on the sample jar.

Sample Collection and Management
Sample collection and management will comply with this Sampling and Analysis Plan (SAPP) and the QAPP. Soil samples will be collected for field headspace analyses and for laboratory analyses of volatiles by method 8260. The field samples will be composited over 2-to 2.5-foot increments from the soil cores collected in the continuous sample barrel or split spoons. The samples will be placed in glass jars and covered with aluminum foil. After a period of time, the foil will be pierced with an organic vapor monitor, and the headspace concentrations will be measured and recorded. Upon completion of the sample measurement, the sample will be disposed as outlined in this SAPP.

Selected soil samples will be collected for laboratory analyses of volatiles by method 8260. The samples will be collected and preserved according to established protocol for methanol preservation of samples for volatile organics. Soil sample jars, VOAs, will be pre-weighed in the laboratory and recorded; a measured amount of methanol will then be added, and the jar will be reweighed and sent to the field. A pre-determined amount of soil sample will be calculated based upon the amount of methanol in each jar. The soil sample will be collected with an open ended syringe and immediately extracted into the jar. The lid will be placed securely on the jar, and the sample information will be recorded in the logbook. The sample will be placed in a cooler with ice as required by the additional preservation protocols.

Sample Packaging and Handling
Samples to be sent to the laboratory for VOC analysis will be preserved in methanol as described in Method SW8260B. Selected samples will be split in order to conduct the various chemical or physical tests. All samples for the chemical tests will be placed in clean glass jars and properly labeled. Samples cores for physical tests and for bench scale screening purposes will be collected and sealed in shelby tubes before being labeled and placed in the appropriate shipping containers. All samples that will be analyzed will have a chain-of-custody form completed.

Soil Sample Description and Logging
All recovered samples will be described and logged by the site geologist upon collection. Description will include amount of core recovered; interval thickness; depth of lithology change; color according to the Munsel Color chart; grain-size distribution; macro-features and physical characteristics; mineralogy, soil and classification system (ASTM D2487 and D2488). Also documented on the drill logs will be documentation of odors and staining. The boring logs are the same as the ones used for the subsurface investigation.

Physical Testing of Soil Samples
Selected samples of the various lithological units encountered during test drilling will be subject to selected physical testing for soil characteristics important to site characterization and assessment. These physical tests will include the following methods:

- Particle size distribution (Sieve ASTM D-1140; Hydrometer ASTM D-2217)
- Visual classification (ASTM D-1587 and ASTM D-1588)
- F_{oc} (Walkley-Black Method)
- Porosity (density ASTM D-2216 and specific gravity ASTM D-854)
- Unified soil classification (ASTM D-2487)

- Soil moisture content (ASTM D-2216).

1.3.2 Groundwater Well Sampling

The groundwater sampling plan is outlined in Table C-1. All the sample locations have been identified in Table C-1. Groundwater samples will be utilized to quantify VOC and surfactant concentrations in the groundwater and will be critical in the evaluation of this technology.

All wells will be constructed and developed in accordance with the QAPP, and the groundwater sampling procedures will follow the guidelines set forth in this SAPP.

The general activities (not necessarily in order) that will occur during groundwater sampling are summarized as follows:

- Prearrangement of sample analytical requests with analytical testing laboratory
- Assembly and preparation of sampling equipment and supplies
- Groundwater sampling
- Well inspection
- Water level measurements
- Well depth measurement
- Measurement of any floating product in well
- Visual inspection of borehole water
- Calculation of purge volume
- Well bore evacuation
- Sampling
- Sample preservation and preparation
- On-site measurement of parameters
- Sample labeling
- Completion of sample records (field log book)
- Completion of chain-of-custody records
- Sample shipment

Equipment Assembly, Check and Calibration

Prior to the sampling event, all equipment to be used will be assembled and its operating condition verified, calibrated (if required), and properly cleaned (if required). In addition, all record-keeping materials will be prepared.

This activity will include verification that all equipment is in proper operating condition. Also, arrangements for repairs or replacements will be made for any inoperative equipment.

Prior to field use, where appropriate, equipment will be calibrated according to the manufacturer's specifications. This step applies to the equipment for making on-site measurements of pH, specific conductance, and water temperature.

Groundwater Sampling Procedures

Groundwater samples will be collected and submitted for three types of analysis: (1) VOC analysis, (2) inorganic analysis and (3) groundwater quality analysis. Samples will be collected

by filling the containers to a positive meniscus then tightly closing the container lids. Sample collection, labeling and chain-of-custody preparation will be consistent regardless of the analysis to be performed. However, sample quantities, holding times, and preservation will vary depending on the analysis to be performed. Whenever a commercial laboratory is utilized for the analysis, they may be required to provide sample containers (this includes UO). Surbec will supply the appropriate containers for all on-site analyses.

Special care will be exercised to prevent contamination of the groundwater and extracted samples during the sampling activities. The two primary ways in which such contamination can occur are through improper handling of a sample or through cross-contamination of the groundwater through insufficient cleaning of equipment between wells.

To prevent such contamination, all sampling equipment will be thoroughly cleaned before and between uses at different sampling locations. In addition, two further precautions will be followed:

- New disposable latex (or similar) gloves will be worn each time a different well is sampled
- Sample collection activities will proceed progressively from background to downgradient areas or from wells that are least contaminated to wells most contaminated.

Depending on the level of sampling activity, weekly or daily field blanks will be prepared to audit the quality of sample preparation.

The following paragraphs present procedures for the several activities that comprise groundwater sample acquisitions. These activities will be performed in the same order as presented below. Minor deviations from this procedure will be noted in the permanent sampling record.

Groundwater Level and Well Depth Measurement
Prior to the water level and well depth measurements, each well will be inspected thoroughly for signs of damage. Any damage or repairs needed to the well must be noted on the groundwater sampling record form or in the field logbook. Groundwater depth measurements will be conducted.

Immiscible Phase and Dense Phase Organic Measurement
If dense nonaqueous-phase liquid (DNAPL) phase is thought to be near the base of the well, its thickness must be measured and recorded. The presence of an organic layer precludes the exclusive use of electric (conductivity) sounders to establish an accurate static water level measurement. The electric sounders will not work properly in immiscible liquids.

The measurement of an immiscible layer requires the use of a specialized interface probe that distinguishes between organic liquids and water. The probe should be dropped to the bottom of the well to determine the thickness of DNAPL. The probe will beep continuously when NAPL is encountered and intermittently when water is encountered. Equipment calibration and decontamination will follow those procedures as outlined above. If the interface probe indicates

that DNAPL is present, a bottom discharge bailer will be dropped to the bottom of the well to confirm the presence of free phase DNAPL.

Visual Inspection of Well Water
All observations regarding immiscible phases, odor, or any other visual evidence of contamination will be recorded or in the field logbook.

Sample Extraction
A Grundfos® submersible pump will be used to purge groundwater from all wells during sampling. Disposable Teflon bailers, a peristaltic pump, Grundfos® pump, or another pump will be used to collect groundwater samples from all wells after purging. Prior to collection during purging, water parameter stabilization will be documented by monitoring parameters such as temperature, pH, and specific conductance. Each monitoring well will have dedicated sample tubing. Between uses, all pumps will be cleaned in accordance with decontamination procedures as documented in the QAPP. Care will be taken to prevent undue disturbance of water in the well when inserting the pump or bailer. The groundwater will be carefully poured down the inside of the sample bottle to prevent significant aeration of the sample. Excess water taken during sampling will be placed in a container for proper disposal.

On-site Parameter Measurement
The following measurements will be taken using field measurements. These parameters will be determined in each new well and at each major sampling event during the field demonstration. These parameters are:

- pH
- specific conductance
- temperature

These parameters will be measured in unfiltered, unpreserved, "fresh" water taken by the same technique as the samples taken for laboratory analyses. All on-site measurements will follow the procedures outlined in this SAPP. The measured values will be recorded in the field logbook.

Sampling Records
To provide complete documentation of sampling, detailed records will be maintained. These records will include the information listed below:

- Sample location (facility name)
- Sample identification (well number and/or sample number)
- Date and time of sampling
- Field observation of sample appearance and odor
- Weather conditions
- Sampler's identification
- Any other information which is significant

Groundwater sampling information will be recorded on a designated groundwater sampling record or in the field logbook.

1.3.3. General Sampling Procedures

Records Documentation During Aquifer Testing
Records will be maintained in logbooks, on laboratory and field forms for sampling events, and for daily activities as specified in the SAPP. The following forms (located at the end of this SAPP) may be used to record the data generated at the site:

- Field Daily Sampling Log
- Daily Field Logs
- Chain-of-Custody Documentation Form
- Drillers Log Summary
- Drilling Daily Field Report Form
- Lithologic Log
- Well Development Log
- Well Construction Details Form
- Data Validation Package Checklist

Site safety, field measurements, and site activities data will be kept in the field logbook. The permanent field logbook will be a bound book with consecutively numbered pages that will be suitable for submission as evidence in legal proceedings. The logbook will be used and maintained on a daily basis; all entries will be in permanent ink.

Sample Containers
Whenever applicable the analytical testing laboratory will provide clean containers and appropriate container lids with Teflon or aluminum liners for sample collection. All sample container lids will be sealed with tamperproof tape, and a label will be firmly attached to the side of the container (not the lid). The following information will be legibly and indelibly written on the label:

- Facility name
- Sample identification
- Sampling date
- Sampling time
- Sample collector's initials
- Preservatives used
- Type of sample
- Analysis to be performed

Sample containers shall be specific to the analysis to be performed on the sample.

Sample Preservation
Water samples will be properly prepared for transportation to the laboratory under refrigeration and chemical preservation, if necessary. Sample containers provided by the laboratory will have any necessary chemical preservatives added to the containers prior to being sealed and shipped. Sample containers provided by Surbec will be preserved in the field. While in the field, all

collected samples must be placed in ice-filled chests. Sample holding times and preservation requirements will be specified by the laboratory.

Sample Packaging and Shipment
The following packaging and labeling requirements for the sample materials are appropriate for shipping the sample to the testing laboratory:

- Preserve samples with ice and cool to 4°C
- Package sample so that is does not leak, spill, or vaporize
- Label package with sampler's name, address, and telephone number
- Laboratory's name, address, and telephone number
- Description of sample
- Quantity of sample
- Date of shipment
- Attach chain-of-custody forms inside shipment container

Disposal of Contaminated Samples
Soil cuttings will be placed immediately into roll-off containers stored near the demonstration site. Two trash containers will be used to store potentially contaminated personal protective equipment (PPE), such as the Tyvek and gloves, and for uncontaminated trash, such as the sand sacks and well plastic wrap.

All groundwater produced during implementation of the demonstration will be placed in designated tanks stored near the demonstration site.

Groundwater samples that are analyzed on site will be disposed of by placing them in the storage tanks containing recovered groundwater. Soil samples will be included with the drill cuttings. The external laboratories must dispose of the samples in accordance with state and federal regulations.

Wastes generated in the on-site laboratory will be segregated and containerized into separate waste streams to facilitate disposal by the base.

Equipment Decontamination
All sampling and test equipment that contacts the interior well casing will be thoroughly cleaned before being used in the field. This equipment includes water level tapes or probes, pumps, tubing, bailers, lifting line, test equipment for onsite use, and other equipment or portions thereof which are to be immersed. All equipment must be cleaned prior to use, unless carefully cleaned and wrapped for transport. The cleaning process is as follows:

- Clean with tap water and phosphate-free laboratory grade detergent using a brush, if necessary
- Rinse thoroughly with tap water
- Rinse thoroughly with distilled water

After sampling a well, the equipment used should be cleaned with phosphate-free laboratory grade detergent then rinsed thoroughly with distilled water, methanol, then hexane or cyclohexane. No metals contamination is anticipated; however, the decontamination protocol will be modified to include a 0.1 N nitric acid rinse if it is determined that metals analysis needs to be included in the sampling plan.

Any necessary deviation from these procedures will be documented in the permanent record of the sampling episode.

Sample Documentation
After samples have been obtained, chain-of-custody procedures will be followed to establish a written record concerning sample movement between the sampling site and the testing laboratory. Each shipping container will have a chain-of-custody form completed by the site sampling personnel packing the samples. The chain-of-custody form for each container will be completed in triplicate. One copy of this form will be maintained at the site, and the other two copies will be sealed in the container with the samples. One of the laboratory copies will become a part of the permanent record for the sample to be returned with the sample analyses.

1.4 QUALITY CONTROL SAMPLING

A detailed description of the QA program is presented in the QAPP. However, a summary of when duplicate and blank samples will be taken is included in Table C-1. In order to ensure sample quality, duplicate samples, triplicate blanks, and field blanks will be obtained throughout the project. As a rule of thumb, one duplicate sample will be taken per sampling day and submitted for analysis. Triplicate blanks will be taken once per sampling week. Field blanks will also be taken once per day.

Table C-1A: Sample Collection Summary

Activity	Sample type	# of Samples	Sample* Location	Volume of sample	Preservation	Constituents	Analytical Method	Location of Analysis
System Installation/ Pre-sampling	Soil	18	Soil borings	20 g	methanol	VOC	SW8260B	CAL-EPA-approved
	Soil	3	Soil borings	4"x12" core	Core Box; 4^0C	foc, BD, por. MC	ASTM	Standard Testing
	Soil	8	Soil borings	4"x12" core	Core Box; 4^0C	Bench work	NA	OU/Surbec
	GW	12	GW wells	45 ml	Zero HS;4^0C	VOC	SW8260B	CAL-EPA-approved
	GW	4	GW wells	5-gallons	Zero HS;4^0C	Bench work	NA	OU/Surbec
	GW	1	GW wells	1 liter	Zero HS;4^0C	Water quality	ASTM	
Aquifer testing	GW	11	Recovery wells	500 ml	Zero HS;4^0C	surfactant	NA	On-site/OU
	GW	12	Rec. GW	40 ml vial	Zero HS;4^0C	VOC	MOD 8260	CAL-EPA-approved
	GW	174	Recovery wells	500 ml	Zero HS;4^0C	tracers	NA	On-site/OU
	GW	80	Recovery wells	500 ml	Zero HS;4^0C	Bromide	Bromide Probe	Onsite
	GW	17	Rec. GW	40 ml vial	Zero HS;4^0C	VOC	MOD 8260	OU/Surbec
Surfactant flush	GW	179	rec. GW	40 ml vials	Zero HS;40C	Surfactant	NA	95% on-site, 5% off-site
	GW	179	rec. GW	40 ml vials	Zero HS;4^0C	VOCs	Mod 8260	95% on-site 5% off-site
	GW	10	rec. GW	40 ml vials	Zero HS;4^0C	Water quality	ASTM	
	Vapor	10	Ambient Air	Tedlar Bag	Zero HS;4^0C	VOCs		CAL-EPA-approved
Post Aquifer Test	GW	174	Recovery wells	500 ml	Zero HS;4^0C	tracers	NA	On-site/OU
	GW	80	Recovery wells	500 ml	Zero HS;4^0C	Bromide	Bromide Probe	On-site
	GW	13	Rec. GW	40 ml vial	Zero HS;4^0C	VOC	MOD 8260	CAL-EPA-approved
Post test Coring & Sampling	Soil	8	Soil borings	20 g	methanol	VOC	SW8260B	CAL-EPA-approved

GW-groundwater
g-gram
ml-milileter
VOC -volatile organic carbon

NA-not applicable
ASTM-American Society for Testing and Materials
OU-University of Oklahoma

Table C-1b Pre-sampling Plan

	Sample location	Soil			Groundwater		
		VOC Analysis	Geotechnical Analysis	Bench Testing	VOC Analysis	Bench Testing	BOD, TSS,TDS Alk.pH, Temp.
1	MW-1	1			1	1	
2	MW-2	1			1		
3	MW-3	1		1	1		
4	MW-4	1	1	1	1	1	
5	RW-1	2		1	1		
6	RW-2	2		1	1		
7	RW-3	2	1	1	1	1	
8	RW-4	2		1	1		
9	IW-1	2	1	1	1	1	
10	IW-2	2		1	1		1
11	IW-3	1					
12	IW-4	1					
	Duplicates 10%	0		NA	1	NA	
	Field Trip (1 per container)	0			1		
	Total	18	3	8	12	4	1

MW-monitoring well
RW-recovery well
IW-injection well
GW-groundwater
VOC-volatile organic carbon

Table C-1c Hydraulic Testing and Pre Partitioning Tracer Test

		Pump and Push Pull Test		PITT			
		Surfactant 0-6 days	VOC 0-6 days	Organic Tracer 0-3 days	4-6 days	Bromide 0-6 days	VOC 0-6 days
1	MW-1			3	3	1	1
2	MW-2			3	3	1	1
3	MW-3			3	3	1	1
4	MW-4			10	5	5	2
5	RW-1			20	10	18	2
6	RW-2			20	10	18	2
7	RW-3			20	10	18	2
8	RW-4			20	10	18	2
9	IW-1	8	8				
10	IW-2						
11	IW-3						
12	IW-4						
	Storage tank	2	2	3	3		2
	Composite GW						
	Duplicates 10%	1	2	10	5		1
	Field						
	Trip (1 per container)						1
	Total	11	12	112	62	80	17

MW-monitor well
RW-recovery well
IW-injection well
MPP-macro porous polymer
MEUF-micellar enhanced ultrafiltration
VOC-volatile organic carbon
BOD-biological oxygen demand
TSS-total suspended solids
Alk-alkalinity
TDS-total dissolved solids

Table C-2d System Operation

	Sample location	Surfactant Samples 0-5 Days	Surfactant Samples 6-10 Days	VOC Samples 0-5 Days	VOC Samples 6-10 Days	BOD, TSS, Alk.temp TDS. pH	Offgas VOC
1	MW-1	3	2	3	2		
2	MW-2	3	2	3	2		
3	MW-3	3	2	3	2		
4	MW-4	3	2	3	2		
5	S1(RW-1)	10	5	10	5		
6	S2(RW-2)	10	5	10	5		
7	S3(RW-3)	10	5	10	5		
8	S4(RW-4)	10	5	10	5		
9	IW-1						
10	IW-2						
11	IW-3						
12	IW-4						
	Process Sampling						
11	S5 (MPP influent)	5	5	10	5		
12	S6 (MPP effluent)	5	5	10	5		
13	S7(backup stripper)						
14	S8(backup stripper)						
15	S9(not sampled)						
16	S10 (MEUF Retentate)	10	5	5	5		
17	S11 (MEUF Permeate)	10	5	5	5		
18	S12						
19	S13 (reinjection solution)	10	5	10	5		
20	tankage	10	5	10	5	10	10
	Duplicates 5%	6	3	6	3		
	Field Trip (1 per container)	5	5	5	5		
	Total	113	66	113	66	10	10

MW-monitoring well
RW-recovery well
IW-injection well
MPP-macro porous polymer
MEUF-micellar enhanced ultrafiltration
VOC-volatile organic carbon
BOD-biological oxygen demand
TSS-total suspended solids
Alk-alkalinity
TDS-total dissolved solids

Table C-1e Post-Test Aquifer Sampling Summary

		PTT Organic Tracer 0-3 days	4-6 days	Bromide 0-6 days	VOC Day 6
1	MW-1	3	3	1	1
2	MW-2	3	3	1	1
3	MW-3	3	3	1	1
4	MW-4	10	5	5	1
5	RW-1	20	10	18	1
6	RW-2	20	10	18	1
7	RW-3	20	10	18	1
8	RW-4	20	10	18	1
9	IW-1				1
10	IW-2				1
11	IW-3				1
12	IW-4				1
	Storage tank	3	3		1
	Composite GW				
	Duplicates 10%	10	5		
	Field				
	Trip (1 per container)				
	Total	112	62	80	13

MW-monitoring well
RW-recovery well
IW-injection well
GW-groundwater
VOC-volatile organic carbon
PTT-partitioning tracer test

Table C-1f Post-Test Soil and Groundwater Sampling

	Sample location	Soil VOC Analysis
1	MW-1*	
2	MW-2*	
3	MW-3*	
4	MW-4	
5	RW-1*	
6	RW-2*	
7	RW-3*	
8	RW-4*	
9	IW-1*	
10	IW-2*	
11	IW-3	
12	IW-4	
13	SB-1	2
14	SB-2	2
15	SB-3	2
16	SB-4	2
	Duplicates 10% Field Trip (1 per container)	
	Total	8

* Soil boring to be placed approximately 4' within listed well towards the inside of the cell

MW-monitoring well
RW-recovery well
IW-injection well
SB-soil boring
VOC-volatile organic carbon

APPENDIX D

MODELING RESULTS

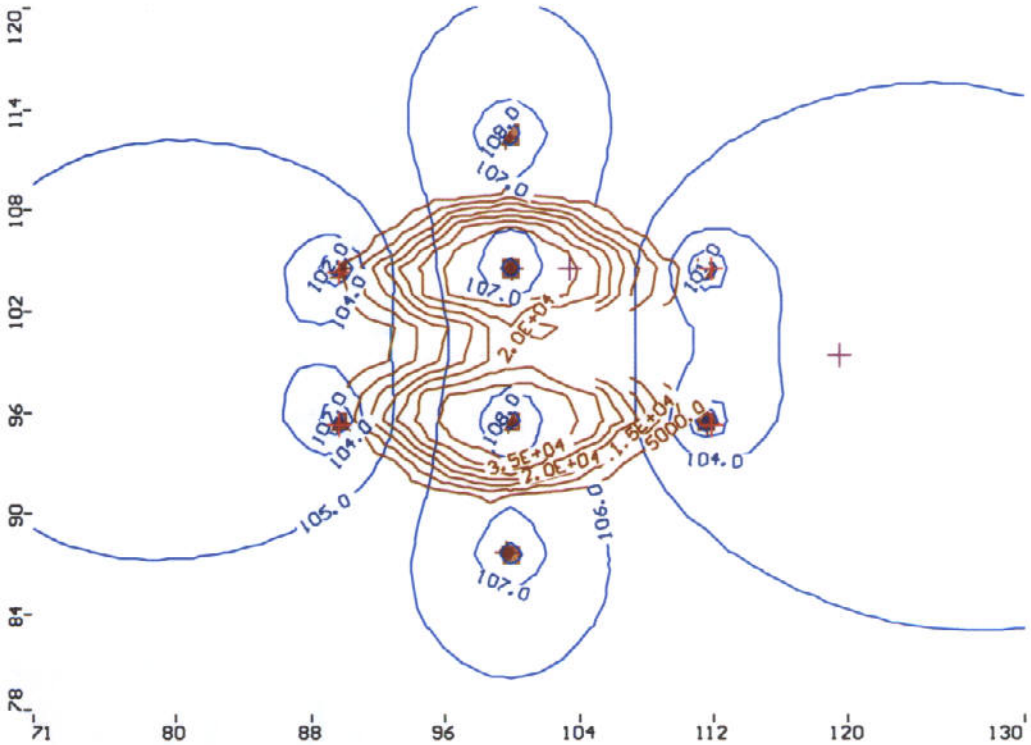


Figure D1: Plan view of surfactant distribution at elevation of 100 feet after 1 day of injection (Blue – water table and hydraulic head; Red – Surfactant concentration mg/l)

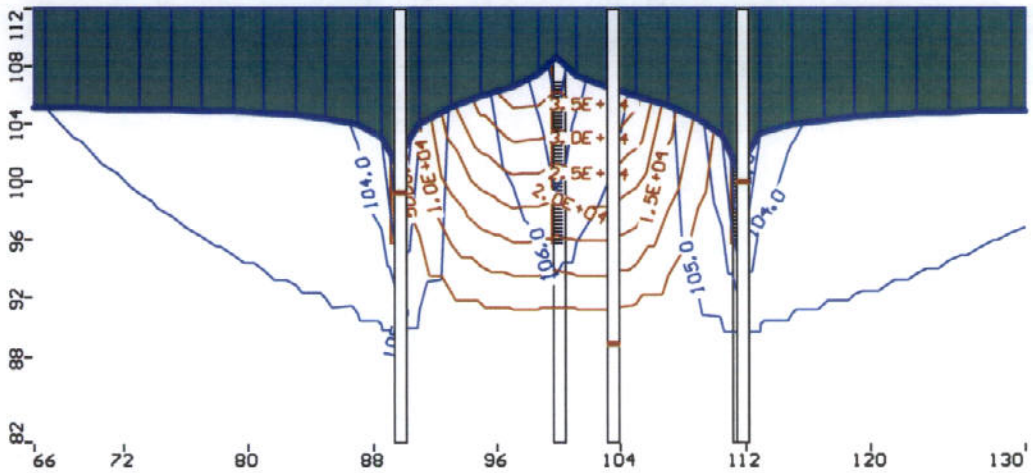


Figure D2: East-west cross-section through the north injection and recovery wells after 1 day of surfactant injection (Blue – water table and hydraulic head; Red – Surfactant concentration mg/l).

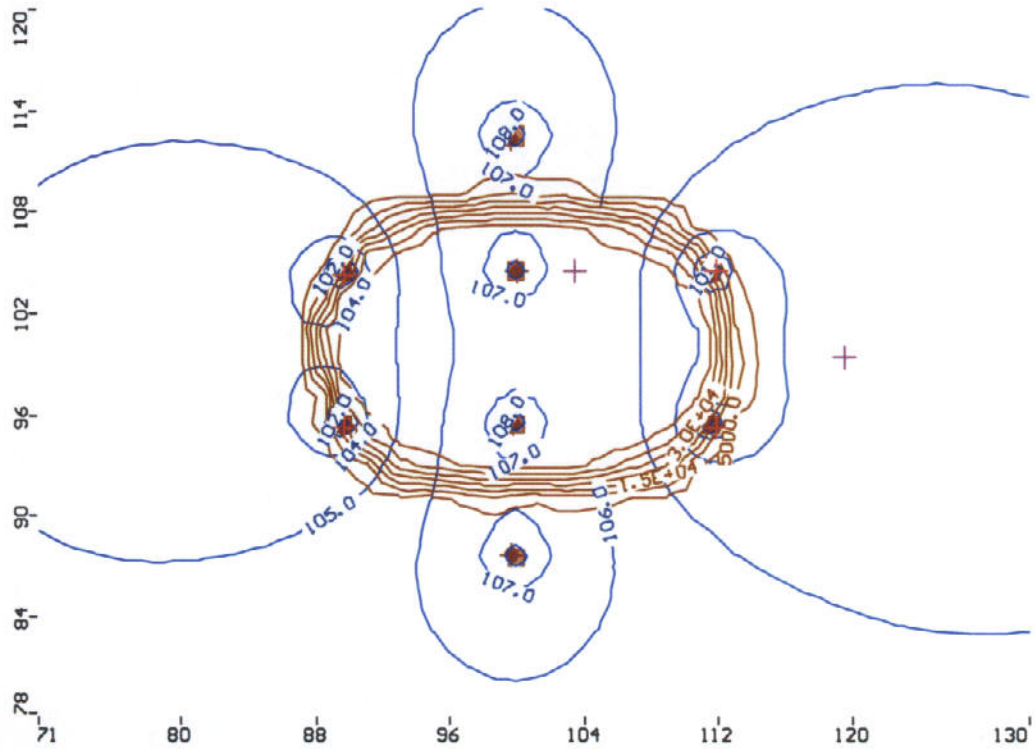


Figure D3: Plan View of Surfactant Distribution at elevation of 100 feet after 5 days of injection (Blue – water table and hydraulic head; Red – Surfactant concentration mg/l)

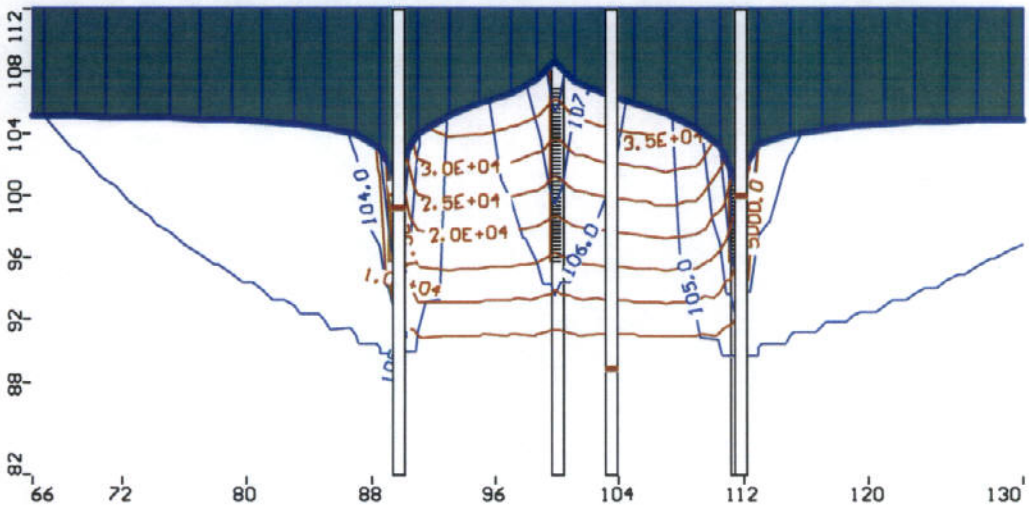


Figure D4: East-west cross-section through the north injection and recovery wells after 5 days of surfactant injection (Blue – water table and hydraulic head; Red – Surfactant concentration mg/l).

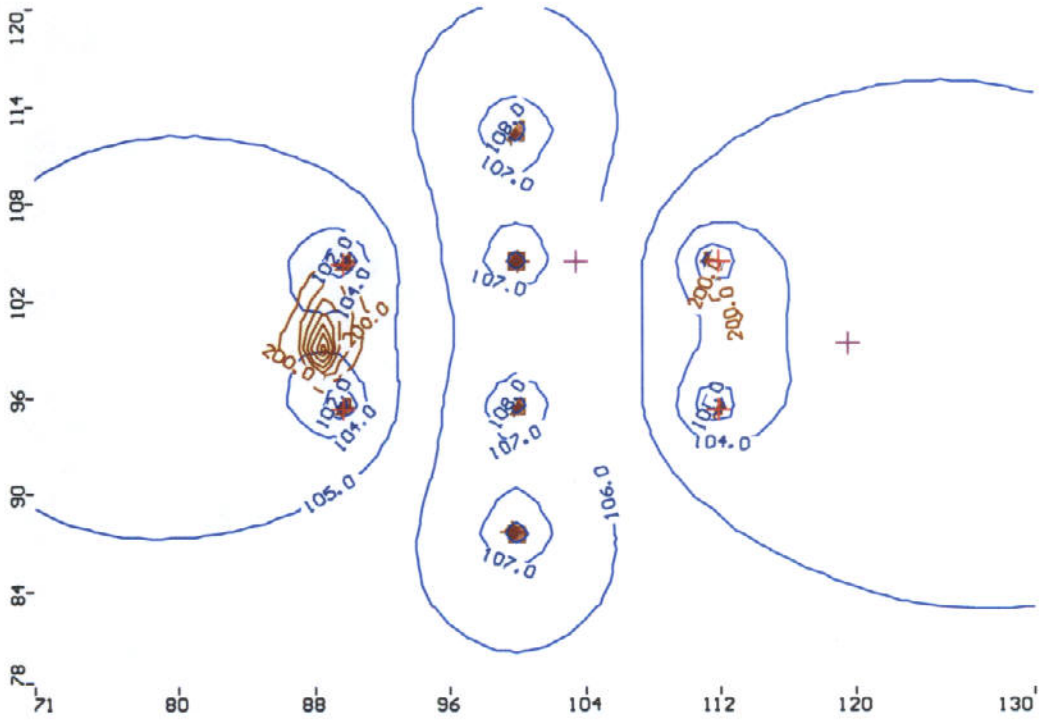
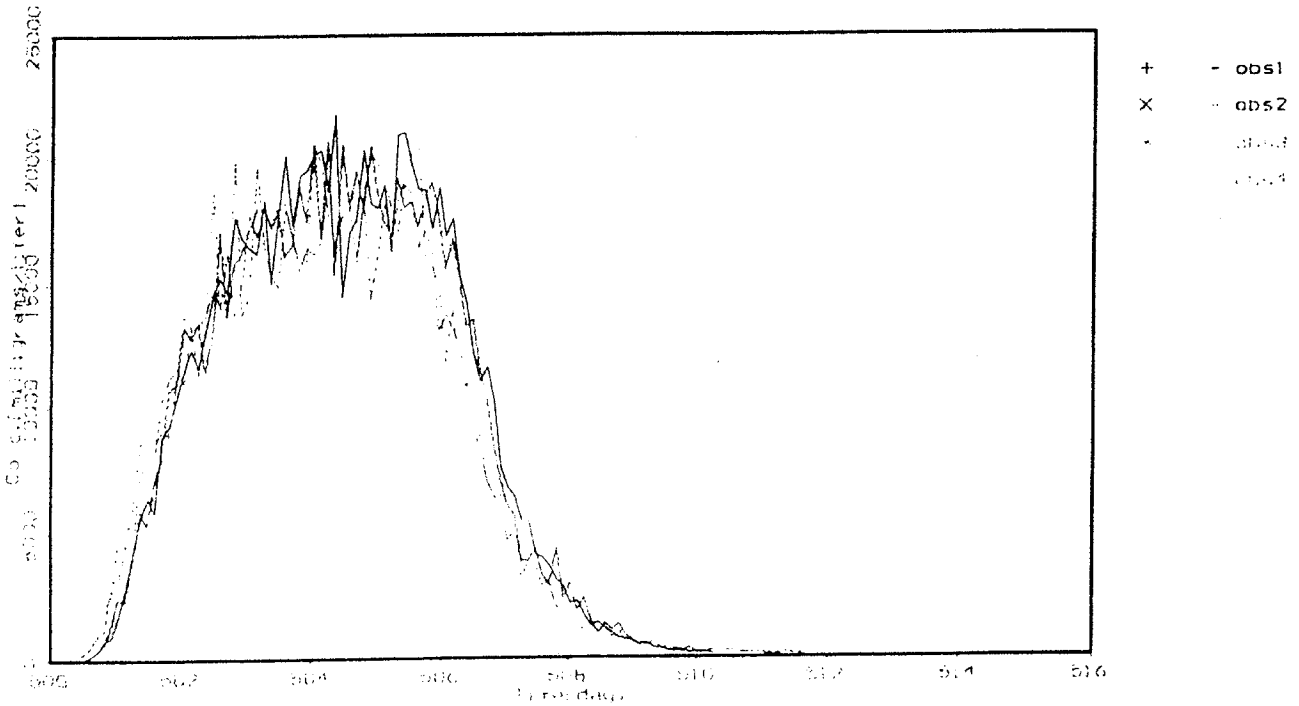


Figure D5: Plan View of surfactant distribution at elevation of 100 feet after 5 days of surfactant injection and 7 days of water flooding (Blue – water table and hydraulic head; Red – Surfactant concentration in mg/l).



OU Project: Alameda Point Description: BT in RW 1-4 (Shallow) Modeller: MAH 29 Dec 98	Visual MODFLOW v.2.7.1. (C) 1995-1997 Waterloo Hydrogeologic, Inc. NC: 103 NR: 104 NL: 2 Current Layer: 1

Table D1: Model Input Parameters

	Input Value	Reference
Hydraulic Conductivity	8 ft/d (fill) 0.001 ft/d (Bay Mud)	Slug test Data / Soil core analysis
Hydraulic Gradient	0.002 (from north to South)	Groundwater Sampling Events
Storage Coefficient (Sc)	0.0001	Freeze and Cherry, 1979
Specific yield	0.1	Freeze and Cherry, 1979
Bulk Density	48 kg/ ft3	Site 5 Geotechnical analysis
Porosity	0.35	Freeze and Cherry, 1979
Linear Sorption Coefficient (Surfactant)	0.0015 ft3/kg	Previous lab analysis
Dispersivity	0.5 ft	Distance/Peclet# = 10 ft / 20
Surface Elevation	112 ft	Site Investigation Survey Data
Depth to ground water	8 ft	Groundwater Sampling Events
Grid resolution	1 ft – 4 ft	Previous experience
Grid Size	200 ft x 200 ft	RFP

APPENDIX E

DESIGN DOCUMENTATION

MPP SYSTEMS
MPPE PROCESS DESCRIPTION
For
SURFACTANT-ENHANCED SUBSURFACE REMEDIATION

1.0 AKZO NOBEL AND MPP SYSTEMS

The Macro Porous Polymer – Extraction (MPPE) technology is a product of Akzo Nobel Research. Headquartered in Arnhem, The Netherlands, Akzo Nobel is a worldwide industrial organization with operations in more than 60 countries and over 70,000 employees. In addition to its core businesses of chemicals, coatings, pharmaceuticals, and fibers, the company focuses on the development of new products in major growth sectors that draw on its technological and marketing know-how. Akzo Nobel conducts an active environmental policy with respect to its products and processes. The technological and financial strengths of Akzo Nobel are an integral part of the MPPE product offering.

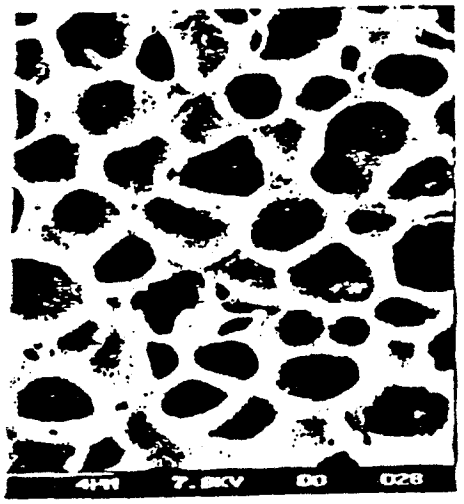
MPP Systems was established in 1994 to further develop and market the MPPE technology. MPP Systems is a unit of Akzo Nobel Business Development (ANBD), and has offices in The Netherlands, Germany, and the United States.

2.0 MPPE PROCESS DESCRIPTION

The Macro Porous Polymer-Extraction (MPPE) system of Akzo Nobel separates hydrocarbons from water by a unique and innovative liquid-liquid extraction process. A patented porous polymer developed by Akzo Nobel contains an extraction liquid within the pores. The macro porous polymer structure is shown in Figure 1. The polymer and the extraction liquid are both highly hydrophobic but organophilic, especially toward nonpolar compounds. Hydrocarbons, dissolved or dispersed in water, partition to the extraction liquid and remain in solution within the polymer pores. A strong attraction to the polymer coupled with an extremely low solubility in water serve to prevent partitioning of the extraction solvent to the water. Thus, a unidirectional extraction mass transfer is accomplished.

The MPPE material is applied in a packed column. The water/hydrocarbon (raffinate/solute) pass in plug flow through the column and the solute partitions to the solvent. Very high mass transfer efficiency is achieved as the declining concentration raffinate/solute front continuously meets fresh solvent in the polymer, the equivalent of many extractors in series.

ver time, the extraction solvent loads with hydrocarbon. Before the water reaches the aximum allowed effluent concentration, the MPPE is regenerated in-situ by stripping e hydrocarbons from the extraction solvent. Low pressure steam is introduced into the p of the column. As the polymer heats, the solute is vaporized from the solvent and asses out of the column with the steam. Again, the strong affinity of the solvent for the olymer, coupled this time with its very low vapor pressure, serve to keep the solvent in e polymer pores. The steam and solute are condensed together. Because the amount f steam required for stripping is very low, the concentration of solute in the condensate xceeds saturation, which leads to phase separation. The free-phase solute is available r beneficial reuse/recycle or disposal. High purity and low volume facilitate economical isposition of the recovered solute. The low-volume, solute-rich condensate is recycled the MPPE columns in a closed loop. Figure 2 is a flow diagram of the MPPE process.



gure 1. MPPE structure.

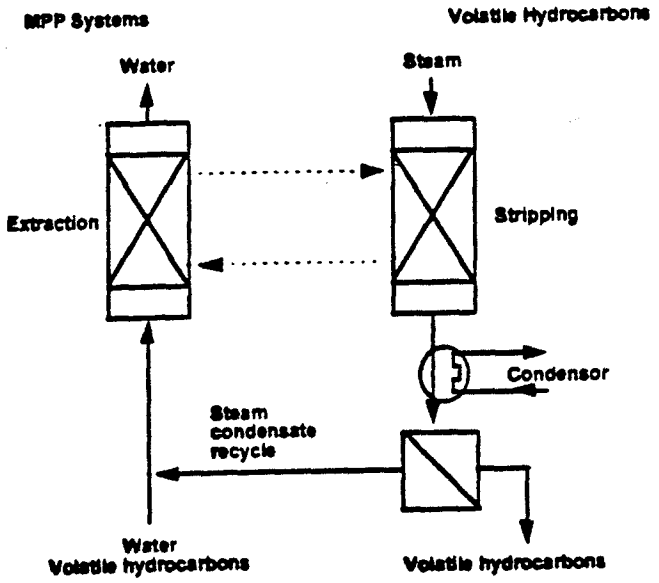


Figure 2. MPPE extraction/stripping system.

APPENDIX F – MSDS SHEETS

FINAL WORK IMPLEMENTATION PLAN FOR SURFACTANT ENHANCED DNAPL REMOVAL TREATABILITY STUDY

THE ABOVE IDENTIFIED ATTACHMENT HAS MISSING PAGES. IT COULD NOT BE DETERMINED WHETHER THESE PAGES ARE MISSING OR THE DOCUMENT WAS ISSUED WITHOUT THESE PAGES.

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 F

MSDS SHEETS

Product Information

DOWFAX* Surfactants

FDA Status of DOWFAX Surfactant Products

DOWFAX 3B2, DOWFAX C10L, DOWFAX 2A1, DOWFAX 2EP and DOWFAX 8390 solution surfactants, when used unmodified and according to good manufacturing practices for food contact applications, will comply with the U.S. Food, Drum and Cosmetic Act as amended under Food Additive Regulation 21 CFR 178.3400 (Emulsifiers and/or surface active agents). These products are described in the regulation as follows:

> "Sodium monoalkylphenoxyphenoxybenzenedisulfonate and sodium dialkylphenoxy-benzenedisulfonate mixtures containing not less than 70% of the monoalkylated product where the alkyl group is C_8 - C_{16}."

These products may be safely used as emulsifiers and/or surface active-agents in the manufacture of articles or components of articles intended for use in producing, manufacturing, packing, processing, preparing, treating, packaging, transporting or holding food subject to the provisions of this section.

No limitations are placed on the physical or chemical nature of the articles or components of articles to which the surfactants may be added. They include adhesives, resinous and polymeric coatings and coatings for paper and paperboard. Also, there is no limitation on the types of food with which the articles may come in contact or on the amount used. The quantity shall not, however, exceed that reasonably required to accomplish the intended technical effect. Thus, these surfactants may be used under a number of regulations including the following:

21CFR 175 105 - Adhesives.

21 CFR 175.300 - Resinous and Polymeric Coatings

21 CFR 176.170 - Components of Paper and Paperboard in Contact with Aqueous and Fatty Foods.

21 CFR 176.180 - Components of Paper and Paperboard in Contact with Dry Food

It is understood that the finished article must conform to appropriate regulations, but the surfactants listed do not impose any additional limitations

1510-015A
11/96

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Product Information

DOWFAX* Surfactants

North American Regulatory Status of DOWFAX Surfactants

	CAS Number(s)	TSCA (United States)	DSL (Canada)
DOWFAX 2A1	119345-04-9	Yes	Yes
DOWFAX 2A0	119345-03-8	Yes	Yes
DOWFAX 3B2	036445-71-3 070146-13-3	Yes	Yes
DOWFAX 3B0	070191-75-2 070191-74-1	Yes	No
DOWFAX 8390	065143-89-7 070191-76-3	Yes	Yes
DOWFAX C6L	147732-60-3	Yes	Yes

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Product Information

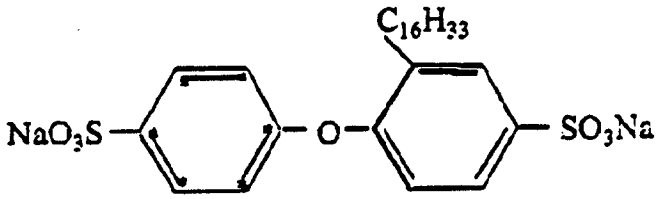
DOWFAX* Surfactants

Degradation of DOWFAX Surfactants

A study was under taken to determine the degradation products of DOWFAX surfactants. Two systems were examined, soil and activated sludge. Following is an overview of these studies

DOWFAX Chemistry

Due to analytical complexities associated with a reaction mixture, the degradation studies initially focused on a single isomer, the monoalkylated, disulfonated component with an alkyl chain of 16 carbons (C16 MADS).



Hypothetical Biodegradation Pathway

The choice of labeling the di-substituted ring is supported by the expected biodegradation pathway which is based on the known biodegradation pathway of linear alkyl benzene sulfonate.

Biodegradation is expected to be initiated on the terminal carbon of the linear alkyl group (omega oxidation). Degradation of the linear chain should proceed with consecutive two carbon losses (beta oxidation) to a carboxylic acid. Subsequent steps in the pathway are more speculative. One possible pathway would include opening of the tri-substituted ring followed by the degradation of the di-substituted ring. Thus, labeling of the di-substituted ring would allow the fate of the C16 MADS molecule to be studied until both aromatic rings are degraded.

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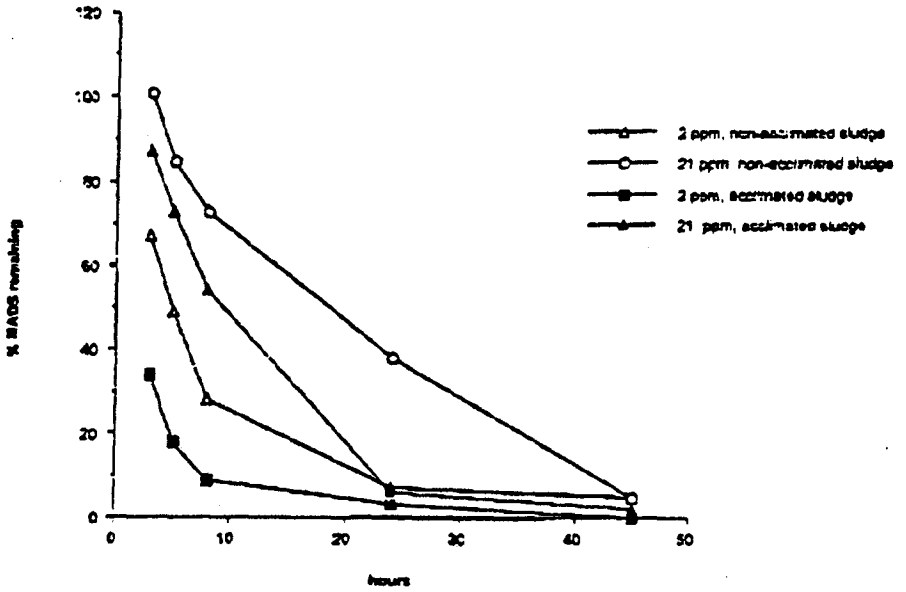
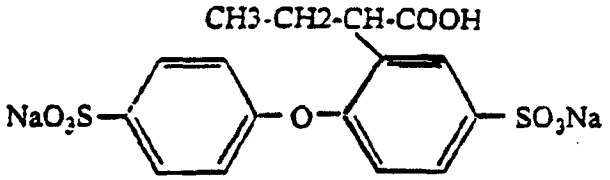
Degradation in Activated Sludge

A Soap and Detergent Association fill and draw design was used to study the degradation of the C16 MADS under both acclimated and non-acclimated conditions.

Municipal activated sludge (2500mg/L suspended solids) was acclimated to 20 ppm C16 MADS. Activated sludge not exposed to C16 MADS was maintained in a parellel system. Following acclimation, radiolabeled C16 MADS was introduced to each system. Primary degradation* is plotted below.



Less than 2% radio-labeled CO2 was collected. By analyzing the effluent, the major degradation product was identified as:



This degradation product supports the hypothesized degradation pathway

* Any chemical change to a compound that alters its properties so that it will no longer respond to an analytical procedure specific for the original compound.

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Degradation in Surface Soil

Standard microcosms were prepared with either aquifer solids (subsurface sandy loam) or a sandy loam surface soil and dosed with radio-labeled C16 MADS.

Soil	ppm MADS	95% primary degradation	mineralization* after 85 days
Subsurface sandy soil	1	10 days	<1%
Subsurface sandy soil	20	30 days	<1%
Sandy loam surface soil	1	4 days	29%
Sandy loam surface soil	20	4 days	12%

Significant mineralization was achieved in the sandy loam surface soil. The major degradation intermediate detected was similar to the product identified in the activated sludge study.

Degradation in the Zahn-Wellens Procedure (OECD 302B)

Once there was an understanding of the degradation of the radio-labeled C16 MADS, a standardized test method was employed to demonstrate mineralization of the commercial mixture (DOWFAX 8390 solution) compared to the synthesized component.

Upon dosing the test system, the surfactants were rapidly adsorbed onto the sludge. As degradation occurred, the intermediate was desorbed and found in the bulk solution. Desorption was confirmed, in a supplementary study with radio-labeled C16 MADS, by recovery of 100% of the radioactivity following filtration of the sludge after 9 days. Thus, removal of DOC (dissolved organic carbon) after 28 days was due to biodegradation, not adsorption.

After 28 days, the % removal (DOC) is:

- aniline (control) 98%
- LAS 81%
- C16 MADS 43%
- DOWFAX 8390 54%

Having achieved 54% DOC removal, DOWFAX 8390 may be classified as "inherently biodegradable"

* conversion of a compound to carbon dioxide, water and/or inorganic compounds, reported as % $^{14}CO_2$.

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Degradation Conclusions

- Primary biodegradation of C16 MADS occurs in a variety of aerobic environments (activated sludge, surface and subsurface soils). The degradation pathway is consistent with that of LAS

- Primary biodegradation of C16 MADS and DOWFAX 8390 surfactant in the Zahn-Wellens test allows them to be classified as inherently biodegradable.

- There are microorganisms in the soil capable of mineralizing the C16 MADS.

- The major degradation intermediate resulting from the degradation of DOWFAX 3B2 surfactant and DOWFAX C6L surfactant is consistent with that identified for the C16 MADS degradation.

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Acute Aquatic Toxicity of the Major Degradation Intermediate

The acuteaquatic toxicity of the major degradation intermediate was determined. Both rainbow trout and daphnid were evaluated under static conditions with replicate groups of 10 organisms.

Samples of activated sludge effluent were prepared in semi-continuous activated sludge (SCAS) units:

- Blank: Effluent from the SCAS unit

- Intermediate: Feed to the SCAS unit contained 20 ppm DOWFAX 8390; the effluent was confirmed to contain the previously identified major intermediate.

- DOWFAX 8390: Effluent from the SCAS unit was amended with DOWFAX 8390 surfactant at known concentrations.

	Species	Time	LC50	EC50
Blank	trout	96 hrs	>100%*	>100%
	daphnid	48 hrs	>100%	>100%
Intermediate	trout	96 hrs	>100%	>100%
	daphnid	48 hrs	>100%	>100%
DOWFAX 8390	trout	96 hrs	0.7mg/L	0.7mg/L
	daphnid	48 hrs	14.1mg/L	13.5mg/L

* Not toxic

Aquatic Toxicity Results

- The effluent had no effects on the rainbow trout or the daphnid.

- The biodegradation products from the activated sludge treatment of DOWFAX 8390 surfactant had no effects on rainbow trout or daphnid.

- The DOWFAX 8390 surfactant added directly to the effluent is toxic to fish, this is consistent with previous studies.

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Product Information

DOWFAX* Surfactants

Biodegradability of DOWFAX Surfactants

The DOWFAX surfactants have been evaluated using the semi-continuous activated sludge (SCAS) confirming test specified by the Soap and Detergent Association's (SDA) Subcommittee on Biodegradation Test Methods. The procedure involves the addition of surfactant at a nominal concentration of 20 mg/L to SCAS cylinders operated on a 24-hour fill and drain cycle. A 90% reduction in methylene blue active substance following 23 hours of aeration is required to classify an anionic surfactant as biodegradable according to this procedure.

For DOWFAX 3B2, DOWFAX C10L and DOWFAX 8390, a greater than 90% reduction occurred, allowing classification of these products as biodegradable under the conditions of the SCAS test. DOWFAX 2A1 and DOWFAX C6L did not achieved a greater than 90% reduction, so they are not considered biodegradable under this procedure.

DOWFAX 2A1, which does not pass the SCAS test for biodegradability, is biologically transformed during the SCAS procedure. The effluent of the SCAS unit, containing metabolites of DOWFAX 2A1, did not show any significant toxicity to fathead minnows (Phmephales promelas Rafinesque) in 96 hours or to the water flea (Daphnia magna Straus) in 48 hours.

To date, only DOWFAX 8390 solution was been tested under the guidelines of OECD 302B, the Zahn-Wellens procedure. DOWFAX 8390 solution may be classified as "inherently biodegradable" in accordance with this procedure

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Product Information

DOWFAX* Surfactants

Aquatic Toxicity

Surfactant	Species	Toxicity*	Test
DOWFAX Hydrotrope	Daphnia magna	S	48 hour, static acute
	Fathead minnow	S	96 hour, static acute
DOWFAX 3B2	Daphnia magna	M	48 hour, static acute
	Fathead minnow	M	96 hour, flow-thru acute
	Rainbow trout	M	96 hour, static acute
	Bluegill	M	96 hour, static acute
DOWFAX 2A1	Daphnia magna	M	48 hour, static acute
	Fathead minnow	M	96 hour, flow-thru acute
	Rainbow trout	M	96 hour, static acute
	Bluegill	M	96 hour, static acute
	Ceriodaphnia	M	48 hours, 3 brood
DOWFAX Detergent	Daphnia magna	S	48 hour, static acute
	Rainbow trout	H	96 hour, static acute
LAS, sodium salt	Fathead minnow	M	48 hour, static acute
	Bluegill	M	96 hour, static acute
Sodium lauryl sulfate	Bluegill	M	96 hour, static acute
	Daphnia magna	M	48 hour, static acute
	Fathead minnow	M	48 hour, static acute
Nonylphenol ethoxylate (10 mole EO)	Rainbow trout	M	96 hour, static acute
alpha olefin sulfonate (C14 -16)	Rainbow trout	M	96 hour, static acute

* Toxicity is reported in accordance with the categorization system used by the U.S. EPA**:
  - VH = very highly toxic, <0.1 ppm
  - H = highly toxic, >0.1 and <1 ppm
  - M = moderately toxic, >1 and <10 ppm
  - S = slightly toxic, >10 and < 100 ppm
  - PN = practically non-toxic, >100 ppm

** PB86-129277 EPA 540/9-85-006 Hazard Evaluation Division Standard Evaluation Procedure prepared by E. Zucker.

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Stepan

Product Bulletin

Product Name	**STEOL® CS-130**
Chemical Structure	$CH_3(CH_2)_{10}CH_2(OCH_2CH_2)OSO_3Na$
CAS Registry Number	15826-16-1
INCI Name	Sodium Laureth Sulfate

Applications

STEOL CS-130 is a sodium lauryl ether sulfate derived from fatty alcohols, ethoxylated to an average of one mole, and sulfated via Stepan's continuous SO_3 process. The consistent, high purity product made possible by this continuous sulfation process will afford excellent reproducibility in STEOL CS-130 based formulas.

STEOL CS-130 offers the formulator improved mildness over sodium lauryl sulfate, without sacrificing critical performance attributes such as foaming and viscosity response. Its low skin irritation properties make it useful for mild cleansing products, as well as, baby products.

STEOL CS-130 is an ideal surfactant for use in shampoos, bath products and hand soaps offering excellent viscosity response, foam properties, and skin compatibility.

The viscosity of products based on STEOL CS-130 can be enhanced through the incorporation of amides or betaines which will also serve to improve foam stability. By adjusting the amount of additive, products exhibiting the desired physical attributes are readily developed. Since STEOL CS-130 is compatible with commonly used opacifying and pearlizing agents, the formulator is afforded flexibility in developing products having the desired physical appearance.

Typical Properties

Appearance @ 25°C	Clear liquid
Actives, % (MW 346)	25.3
Unsulfated Material, %	0.9
Sodium Chloride %	0.11
Sodium Sulfate, %	0.20
pH, 10% aqueous	8.0
Color, %T @ 420 nm	97
Viscosity, cps @ 25°C	136
Viscosity, cps @ 60°C	13
Cloud Point (as is), °C (°F)	5 (41)
Freeze Point, °C (°F)	5 (41)
Pour Point, °C (°F)	8 (46)
Flash Point (PMCC), °C (°F)	>94 (>201)
Critical Micelle Concentration, g/L	2.9
Density, g/ml (lbs/U.S. gal)	1.04 (8.7)
RVOC, U.S. EPA, %	0

Biodegradability

Product is readily biodegradable. Additional information is available upon request.

Toxicity

STEOL CS-130 is practically non-toxic orally (LD_{50} is >5 g/kg) and causes mild to moderate skin and moderate eye irritation at 10% active.

STEOL® is a registered trademark of Stepan Company.

Storage & Handling

Normal safety precautions (i.e. gloves and safety goggles) should be employed when handling STEOL CS-130. Contact with the eyes and prolonged contact with the skin should be avoided.

It is recommended that STEOL CS-130 be stored in sealed containers at temperatures above 45°F (7°C). Avoid overheating or freezing. If material is frozen, mild heat and agitation are recommended to ensure the material is homogeneous before use.

Bulk Storage Information: Tanks made of 316 stainless steel or fiberglass with an Atlac 382 corrosion liner are recommended. Positive displacement gear pumps and piping should be 316 stainless steel. Recommended storage for bulk tanks is 90-100°F (32-38°C).

Standard Packaging: STEOL CS-130 is available in bulk and in 55 gallon drums (net weight 450 lb/204 kg).

Clearances

STEOL CS-130 is listed in Japan (MITI 2-1682), Canada (DSL 15826-16-1), Australia (AICS 15826-16-1), and Europe (EINECS 239-925-1).

STEOL CS-130 is available as Kosher Certified.

Additional Safety Information

A Material Safety Data Sheet is available upon request.

For Additional Assistance

For applications or product handling assistance, call our Technical Service Department at 1-800-745-7837.
For ordering assistance, call our Customer Service Department at 1-800-457-7673.

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Northfield, Illinois 60093
Telephone (847) 445-7500

Responsible Care®

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Technical Information | **Stepan**

Stepan Company

Northfield, Illinois 60093
Telephone 847 446 7500

BIODEGRADATION OF ALKYL ETHER SULFATES

Applicable Stepan Products:

ALPHA FOAMER®	POLYSTEP® B-20	STEOL® CS-270
CEDEPAL® FA-406	POLYSTEP® B-22	STEOL® CS-330
CEDEPAL® FS-406	POLYSTEP® B-23	STEOL® CS-370
CEDEPAL® TD-403	STEOL® 4N	STEOL® CS-370-25
CEDEPAL® TD-407	STEOL® CA-130	STEOL® CS-460
CEDEPAL® TDS-484LD	STEOL® CA-230	STEPOSOL® CA-207
POLYSTEP® B-11	STEOL® CA-460	STEPOSOL® CA-319
POLYSTEP® B-12	STEOL® CS-130	STEPOSOL® CA-406H
POLYSTEP® B-19	STEOL® CS-230	

Biodegradation:

Alkyl ether sulfates (AES) are frequently used in liquid detergent products such as dishwashing, hair shampoo, bubble bath and shower/bath type products. It has been reported that over 500 million pounds of AES are produced and used annually in the United States.

Numerous laboratory studies have shown that the linear forms of AES, found in the Stepan surfactants identified above, biodegrade quite readily under both aerobic and anaerobic conditions. Primary biodegradation of C_{12} ether sulfates in river die-away studies has been found to reach 90-100% within 1 to 5 days. Ultimate biodegradation of C_{12} to C_{18} ether sulfates has been shown to reach 100% in 28 to 55 days in both oxygen demand and CO_2 evolution studies. OECD (Organization for Economic Cooperation and Development) Closed Bottle and Sturm tests have been performed on various AES compounds by a number of researchers. Biodegradation rates reaching 100% have been reported. The Stepan AES products identified above are considered to be readily biodegradable by OECD standards.

Field studies have shown that removal of AES compounds during routine sewage treatment processes is extensive. AES removal rates of 98-100% have been reported.

References:

* Arthur D. Little, Inc., "Environmental and Human Safety of Major Surfactants, Volume 1. Anionic Surfactants, Part 2. Alcohol Ethoxy Sulfates, Final Report to the Soap and Detergent Association, February, 1991.
* Painter, H.A., "Alkyl Ether Sulfates", The Handbook of Environmental Chemistry, Vol 3, Part F: Anthropogenic Compounds, 1992, pp. 58-68.

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Use this MSDS for enclosed experimental surfactant

EXPERIMENTAL PRODUCT FOR DEVELOPMENTAL USE

VISTA

Vista Chemical Company
P.O. Box 19029
Houston, TX 77224

MATERIAL SAFETY DATA SHEET

1. PRODUCT IDENTIFICATION

MANUFACTURER'S NAME	VISTA CHEMICAL COMPANY
ADDRESS	12025 Vista Parke Dr. Austin, TX 78729
TRADE NAME	ALFONIC 6/10-10/50 Alcohol Ether Sulfate (Aqueous Solution)
SYNONYMS	Alcohol Ether Sulfate (Sodium or Ammonia Salt)
CAS NUMBER	68037-05-8 (Ammonia) or 68037-06-9 (Sodium)
REGULAR TELEPHONE NO. 512-331-2500	EMERGENCY TELEPHONE NO. 318-494-5142

2. HAZARDOUS INGREDIENTS

MATERIAL OR COMPONENT	%	HAZARD DATA
None		Non-Hazardous

3. PHYSICAL DATA

BOILING POINT (°F)	≈210°F	SPECIFIC GRAVITY (H_2O =1)	≈1.1
VAPOR PRESSURE (mm Hg.)	49 @ 100°F	MELTING POINT	Unknown
SOLUBILITY IN WATER	Soluble	VAPOR DENSITY	Unknown
APPEARANCE AND ODOR	White to pale yellow liquid/thick liquid. Sweet odor.		

4. FIRE AND EXPLOSION DATA

FLASH POINT (TEST METHOD)	>210°F (COC)		AUTOIGNITION TEMPERATURE	Unknown	
FLAMMABLE LIMITS IN AIR % BY VOL	LOWER	Unknown	UPPER	Unknown	

EXTINGUISHING MEDIA	Water spray; carbon dioxide; dry chemical; alcohol-approved foam.
SPECIAL FIRE FIGHTING PROCEDURES	Cool exposed equipment with water spray. Self-contained breathing apparatus should be worn if fighting fires in confined areas.
UNUSUAL FIRE AND EXPLOSION	None expected.

5. HEALTH HAZARD INFORMATION

FIRST AID

EYES: Flush eyes with large amounts of water for at least 15 minutes. If irritation persists, seek medical aid.

SKIN: Flush with water, then wash affected area with mild soap and water. If irritation persists, seek medical aid.

INHALATION: Remove to fresh air. If breathing has stopped, administer artificial respiration or oxygen. Seek medical aid.

INGESTION: DO NOT INDUCE VOMITING. If large amounts are ingested, gastric lavage with large amounts of water or 5 percent sodium bicarbonate by qualified persons. SEEK MEDICAL AID.

NATURE OF HAZARD

EYES: Irritation may occur with exposure to concentrated vapors. Liquid is contact irritant. May cause corneal inflammation.

SKIN: Repeated or prolonged contact can cause reddening of the skin, scaling, and dermatitis.

INHALATION: Irritation of the nose and throat, dizziness, and headache.

INGESTION: Depression of central nervous system.

EFFECTS OF OVEREXPOSURE:

ACUTE OVEREXPOSURE: Irritation nose, eyes, and throat, dizziness and headache.

CHRONIC OVEREXPOSURE: Depression of central nervous system.

THRESHOLD LIMIT VALUE (TLV)

None established.

TOXICITY DATA

This is an experimental product and has not be specifically tested. Data for similar alcohol ether sulfate is given below:

SKIN CONTACT:	Acute Dermal LC_{50}, Rabbits: 2.5 g/kg. Skin Irritation Index, Rabbits: 4.2 (Max. possible score is 8.0)
EYE CONTACT:	Eye Irritation Index in Rabbits unwashed: 48 (48 hrs. after exposure) (Max. possible score is 110). Permanent eye damage occured.
INHALATION:	No data available.
INGESTION:	Acute Oral LD_{50}, Rat: 6.5 g/kg

6. REACTIVITY DATA

CONDITIONS CONTRIBUTING TO INSTABILITY

High temperatures.

INCOMPATIBILITY

With strong oxidizing agents, Corrosive to steel, copper, and nickel.

HAZARDOUS DECOMPOSITION PRODUCTS

None

CONDITIONS CONTRIBUTING TO HAZARDOUS POLYMERIZATION

Should not occur.

7. SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED

Eliminate all sources of ignition. Evacuate the area. Contain the spill if possible.

NEUTRALIZING CHEMICALS

Not applicable

WASTE DISPOSAL METHOD

Material should be picked up and incinerated in accordance with federal, state, and local regulations.

8. SPECIAL PROTECTION INFORMATION

VENTILATION REQUIREMENTS

Mechanical ventilation is recommended if handling material in an enclosed space.

SPECIFIC PERSONAL PROTECTIVE EQUIPMENT

RESPIRATORY (SPECIFY IN DETAIL): If inhalation hazard is encountered, NIOSH approved organic vapor respirators or air-supplied equipment dependent on concentration.

EYE: Chemical goggles or full-face shield to protect from splash.

GLOVES: Rubber or other impervious material to avoid repeated or prolonged skin contact.

OTHER CLOTHING AND EQUIPMENT: Other impervious clothing as needed to avoid repeated or prolonged skin contact.

SPECIAL PRECAUTIONS

HAZARD CLASSIFICATION INFORMATION

IMO HAZARD CLASS AND NUMBER Not applicable	US DOT HAZARD CLASS Not applicable
UN NUMBER Not applicable	US DOT IDENTIFICATION NUMBER Not applicable

TRANSPORTATION AND STORAGE

USUAL SHIPPING CONTAINERS Drums Sample containers	ELECTROSTATIC ACCUMULATION HAZARD None
	STORAGE/TRANSPORT PRESSURE Ambient
STORAGE TRANSPORT TEMPERATURE Ambient	LOADING/UNLOADING TEMPERATURE Ambient
	VISCOSITY AT LOADING/ UNLOADING TEMPERATURE Unknown

HANDLING AND STORAGE MATERIALS AND COATINGS

SUITABLE	UNSUITABLE
Stainless steel Fiber drums Polyethylene containers Polyethylene lined containers	Steel Copper Nickel

THE ABOVE DATA IS BASED ON TESTS AND EXPERIENCE WHICH VISTA BELIEVES RELIABLE AND ARE SUPPLIED FOR INFORMATIONAL PURPOSES ONLY. VISTA DISCLAIMS ANY LIABILITY FOR DAMAGE OR INJURY WHICH RESULTS FROM THE USE OF THE ABOVE DATA AND NOTHING CONTAINED THEREIN SHALL CONSTITUTE A GUARANTEE, WARRANTY (INCLUDING WARRANTY OF MERCHANTABILITY) OR REPRESENTATION (INCLUDING FREEDOM FROM PATENT LIABILITY) BY VISTA WITH RESPECT TO THE DATA, THE PRODUCT DESCRIBED, OR THEIR USE FOR ANY SPECIFIC PURPOSE, EVEN IF THAT PURPOSE IS KNOWN TO VISTA.

9. SPECIAL PRECAUTIONS

HAZARD CLASSIFICATION INFORMATION

IMO HAZARD CLASS AND NUMBER Not applicable	US DOT HAZARD CLASS Not applicable
UN NUMBER Not applicable	US DOT IDENTIFICATION NUMBER Not applicable

TRANSPORTATION AND STORAGE

USUAL SHIPPING CONTAINERS Drums Sample containers	ELECTROSTATIC ACCUMULATION HAZARD None
	STORAGE/TRANSPORT PRESSURE Ambient
STORAGE TRANSPORT TEMPERATURE Ambient	LOADING/UNLOADING TEMPERATURE Ambient
	VISCOSITY AT LOADING/ UNLOADING TEMPERATURE Unknown

HANDLING AND STORAGE MATERIALS AND COATINGS

SUITABLE	UNSUITABLE
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1 CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

Material Name:
TWEEN® 80

ICI Americas Inc.
P.O. Box 15391
Wilmington, Delaware 19850
ICI Operator (24 hr.): (302) 887-3000
Medical Emergency (24 hr.): (800) 228-5635, Ext. 181
Chemical Emergency (24 hr.) - Involving Transportation
Spills, Leaks, Fires, or Accidents: (800) 424-9300

2 COMPOSITION/INFORMATION ON INGREDIENTS

Ingredients	CAS Number	Percent	OSHA PEL
POLYOXYETHYLENE (20) SORBITAN MONOOLEATE	9005-65-6	90 - 100%	Not listed.

Values are not product specifications.

3 HAZARDS IDENTIFICATION

General:
Limited toxicity data are available on this specific product; this health hazard assessment is based on the results of screening tests.

Emergency Overview:
Appearance: Yellow to amber oily liquid
NO HAZARDS ARE KNOWN TO BE ASSOCIATED WITH EXPOSURES TO THIS PRODUCT.

Routes of exposure: Eye contact; Skin contact; Inhalation

Symptoms of Overexposure (Acute & Chronic):
Eye contact:
No irritation is likely to develop following contact with human eyes.

Skin contact:
No irritation is likely to develop following contact with human skin.
This product will probably not be absorbed through human skin.

Inhalation:
No irritation is expected to be associated with inhalation of this material.

3 HAZARDS IDENTIFICATION (Cont.)

No toxic effects are known to be associated with inhalation of this material.

Ingestion:
This material is not likely to cause irritation upon ingestion.
No toxic effects are expected following ingestion of this product.

4 FIRST AID MEASURES

Eyes:
Immediately flush with plenty of water for at least 15 minutes. If redness, itching, or a burning sensation develops, have eyes examined and treated by medical personnel.

Skin:
Wash material off of the skin with plenty of soap and water. If redness, itching, or a burning sensation develops, get medical attention.

Ingestion:
DO NOT INDUCE VOMITING. Give one or two glasses of water to drink and refer to medical personnel or take direction from either a physician or a poison control center. Never give anything by mouth to an unconscious person.

Inhalation:
Remove victim to fresh air. If a cough or other respiratory symptoms develop, consult medical personnel.

5 FIRE FIGHTING MEASURES

Flashpoint and method: Above 300 F, 148.9 C (C.O.C.)
Autoignition temperature: No data.
Flammable limits (LEL/UEL): No data.

Extinguishing media:
Water fog, alcohol foam, carbon dioxide, dry chemical, halogenated agents.

Special fire-fighting protective equipment:
Self-contained breathing apparatus with full facepiece and protective clothing.

Unusual fire and explosion hazards:
None known.

Explosion data:
Sensitivity to mechanical impact: Not applicable

5 FIRE FIGHTING MEASURES (Cont.)

Sensitivity to static discharge: Not applicable

6 ACCIDENTAL RELEASE MEASURES

Refer to Section 8 for proper personal protective equipment.

Steps to be taken in case material is released or spilled:
Soak up material with absorbent and shovel into a chemical waste container.
Wash residue from spill area with water and flush to a sewer serviced by a permitted wastewater treatment facility.

7 HANDLING AND STORAGE

Storage requirements: 50-90 deg F in original closed container.

Cautions to take during handling and storage:
Do not use this product in formulations intended for parenteral administration unless the final formulation has been tested thoroughly and is safe for its intended use.

8 EXPOSURE CONTROLS/PERSONAL PROTECTION

Exposure limits:
No ACGIH TLV or OSHA PEL assigned. Minimize exposure in accordance with good hygiene practice.

Engineering controls:
Use ventilation adequate to maintain safe levels.

Eye protection:
Safety glasses with side shields.

Protective clothing:
Impervious gloves.

Respiratory protection:
Not normally needed if controls are adequate.

Other protective equipment:
Eyewash station in work area.

8 EXPOSURE CONTROLS/PERSONAL PROTECTION (Cont.)

9 PHYSICAL AND CHEMICAL PROPERTIES

Appearance & odor: Yellow to amber oily liquid
Odor threshold: No data
Boiling point: Above 212 F, 100 C
Melting point: No data
Vapor pressure (mm Hg at 20° C): <1.0
Vapor density (air = 1): Not applicable
Solubility in water: Soluble
pH: Neutral
Specific gravity: 1.07
% Volatile by volume: Negligible
Cloud point: No data
Viscosity: No data
Partition Coefficient: No data
Coefficient of water/oil distribution: No data
Freezing point: No data

10 STABILITY AND REACTIVITY

Stability:
Stable under normal conditions.

Incompatibility:
Oxidizing agents.

Conditions to avoid:
None known.

Hazardous decomposition products:
Combustion products: Carbon dioxide, carbon monoxide.

Hazardous polymerization:
Will not occur.

11 TOXICOLOGICAL INFORMATION

The toxicity data listed below are based on the results of screening tests on this specific product.

Eye contact: This material was practically nonirritating in rabbit eye irritation studies. No irritation is expected following human eye contact.

11 TOXICOLOGICAL INFORMATION (Cont.)

Skin contact: This material was slightly irritating following a 24-hour exposure to rabbit skin. This material was nonirritating and nonsensitizing in human patch tests.

Acute oral toxicity: The oral LD50 is greater than 15 g/kg. This material is classified as "relatively harmless" by ingestion.

Carcinogenicity: This material is not listed as a carcinogen by OSHA, IARC, and NTP.

Reproductive toxicity/Teratogenicity: No available information.

Mutagenicity: No available information.

Other effects of overexposure: Numerous long-term feeding studies have been conducted on a variety of animal species. Animals have been fed polysorbates at dietary levels of up to 25%, for periods of up to two years, and in some cases, over multiple generations. After reviewing many of these studies, the FAO/WHO Committee on Food Additives concluded that polysorbates cause no toxicological effects at a level of five percent in the daily diet of test animals. The most notable effect observed at higher doses is diarrhea, an expected, non-specific physiological effect associated with having large quantities of a relatively slowly absorbed material in the gut.

Toxicologically synergistic products: None known.

12 ECOLOGICAL INFORMATION

The ecological information listed below is based on the results of screening tests.

Persistence and degradation: This product is biodegradable in water.

T city: Not harmful to aquatic organisms.

12 ECOLOGICAL INFORMATION (Cont.)

Effects on effluent treatment: Unlikely to have any significant effects on effluent treatment.

13 DISPOSAL CONSIDERATIONS

Disposal method:
Discarded product is not a hazardous waste under RCRA, 40 CFR 261.

Container disposal:
Puncture or otherwise destroy empty container before disposal.

14 TRANSPORT INFORMATION

Department of Transportation:
Not regulated.

DOT (Transporation of Dangerous Goods):
Not regulated.

15 REGULATORY INFORMATION

TSCA (Toxic Substances Control Act) Regulations, 40 CFR 710:
All ingredients are on the TSCA Chemical Substance Inventory.

DSL (Canadian Domestic Substances List):
All ingredients are listed on the Canadian DSL.

OSHA Hazard Communication Standard, 29 CFR 1910.1200, Hazard Summary:
Physical Hazards: None.
Health Hazards: None

HMIS Classification:
Noncontrolled (Nonhazardous).

CERCLA and SARA Regulations (40 CFR 355, 370, and 372):
This material contains the following chemicals subject to the reporting requirements of SARA 313:
**** NO SARA 313 CHEMICALS FOR THIS CHEMICAL ****

SARA 311/312 Hazard Categories:

Immediate: NO
Delayed: NO

15 REGULATORY INFORMATION (Cont.)

Fire: NO
Pressure: NO
Reactivity: NO

State Regulations:
California Proposition 65: WARNING. This product can contain chemicals known to the State of California to cause cancer and birth defects or other reproductive harm.

16 OTHER INFORMATION

We assigned NFPA ratings and HMIS ratings to this product based on the hazards of its ingredient(s). Because the customer is most aware of the application of the product, he must ensure that the proper personal protective equipment (PPE) is provided consistent with information contained in the product MSDS.*

HMIS Information
Health 0
Flammability 1
Reactivity 0

NFPA Information
Health 0
Flammability 1
Reactivity 0

This information is intended solely for the use of individuals trained in he particular hazard rating system.

his Material Safety Data Sheet was prepared by ICI Surfactants' Regulatory ervices Department.
ate: 09/30/97

The information herein is given in good faith
but no warranty, expressed or implied, is made.

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ICI Surfactants
Regulatory Services
Tel: (800) 822-8215
Fax: (302) 887-2454

Material Safety Data Sheet

Dow Chemical U.S.A.* Midland, MI 48674 Emergency Phone: 517-636-4400

Product code: 05802

Product Name: DOWFAX (R) 8390 SOLUTION SURFACTANT

Effective Date: 01/17/91 Date Printed: 08/31/91 MSDS:001177

1. INGREDIENTS: (% w/w, unless otherwise noted)

Disodium hexadecyldiphenyloxide disulfonate, and	CAS# 065143-89-7	
Disodium dihexadecyldiphenyloxide disulfonate	CAS# 070191-76-3	40% Max.
Water	CAS# 007732-18-5	Balance
Sodium sulfate	CAS# 007757-82-6	3% Max.
Sodium chloride	CAS# 007647-14-5	3% Max.
Methylene chloride	CAS# 000075-09-2	2% Max.

This document is prepared pursuant to the OSHA Hazard Communication Standard (29 CFR 1910.1200). In addition, other substances not 'Hazardous' per this OSHA Standard may be listed. Where proprietary ingredient shows, the identity may be made available as provided in this standard.

2. PHYSICAL DATA:

BOILING POINT: 100C, 212F
VAP PRESS: 82.7 mmHg @ 20C, 68F
VAP DENSITY: No data available.
SOL. IN WATER: Completely miscible.
SP. GRAVITY: 1.138 @ 25C
APPEARANCE: Light brown liquid (aqueous solution).
ODOR: Disinfectant-type.

3. FIRE AND EXPLOSION HAZARD DATA:

FLASH POINT: Flame extinguished; none to boiling.
METHOD USED: Closed cup; open cup.

FLAMMABLE LIMITS
LFL: Not applicable.
UFL: Not applicable.

EXTINGUISHING MEDIA: The organic portion may burn once the water is evaporated. In such case, use water for extinguishing media.

FIRE & EXPLOSION HAZARDS: None known.

(Continued on page 2 , over)
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3. FIRE AND EXPLOSION HAZARD DATA: (CONTINUED)

FIRE-FIGHTING EQUIPMENT: Wear positive-pressure, self-contained breathing apparatus.

4. REACTIVITY DATA:

STABILITY: (CONDITIONS TO AVOID) Stable at ambient temperatures.

INCOMPATIBILITY: (SPECIFIC MATERIALS TO AVOID) Acids.

HAZARDOUS DECOMPOSITION PRODUCTS: Sulfur dioxide.

HAZARDOUS POLYMERIZATION: Will not occur.

5. ENVIRONMENTAL AND DISPOSAL INFORMATION:

ACTION TO TAKE FOR SPILLS/LEAKS: Soak up with suitable absorbent. Avoid release into natural waters or public water supply.

DISPOSAL METHOD: Dispose of according to local, state, and federal regulations. Incineration is preferred.

6. HEALTH HAZARD DATA:

EYE: May cause moderate irritation with corneal injury. Dusts may irritate eyes. In animals, irritation and corneal injury healed within 14 days.

SKIN CONTACT: Prolonged or repeated exposure may cause skin irritation. Animal tests indicate some potential for allergic skin reaction to undiluted or higher concentrations but not to lower concentrations representing exaggerated use conditions. No allergic skin reactions were noted in humans exposed to a structurally-related surfactant at concentrations representing exaggerated conditions.

SKIN ABSORPTION: A single prolonged skin exposure is not likely to result in the material being absorbed through skin in harmful amounts. The dermal LD50 in rats is >2000 mg/kg.

INGESTION: Single dose oral toxicity is low. The oral LD50 for male and female rats is >5000 mg/kg. Small amounts swallowed incidential to normal handling operations are not likely to cause injury; swallowing amounts larger than that may cause injury.

(Continued on page 3)
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6. HEALTH HAZARD DATA: (CONTINUED)

INHALATION: Excessive exposure may cause irritation to upper respiratory tract. Contains methylene chloride, a chemical which has anesthetic properties when encountered in high concentrations. Methylene chloride also causes carboxyhemoglobinemia, a condition which impairs the blood's ability to transport oxygen.

SYSTEMIC & OTHER EFFECTS: Excessive exposure may cause liver and kidney effects. Did not cause cancer in long-term animal studies (product similar to active ingredients). This mixture contains methylene chloride which is listed as a potential carcinogen for hazard communication purposes under OSHA Standard 29 CFR 1910.1200 by IARC and NTP. Methylene chloride has been shown to increase the rate of spontaneously occurring malignant tumors in the B6C3F1 mouse and benign tumors in laboratory rats. Other animal studies, as well as several human epidemiology studies, failed to show a tumorigenic response. Methylene chloride is not believed to pose a measurable carcinogenic risk to man when handled as recommended. Methylene chloride does not cause birth defects and does not interfere with reproduction, judging from animal studies; however, it has been shown to cause some toxicity to the fetus but only at doses which caused toxic effects to the mother. Results of in vitro ('test tube') mutagenicity tests have been negative. (active ingredients) Has been shown to have mutagenic activity in bacteria (methylene chloride). Negative or equivocal results have been obtained in mutagenicity tests of methylene chloride using mammalian cells or animals.

7. FIRST AID:

EYES: Irrigate with flowing water immediately and continuously for 15 minutes. Consult medical personnel.

SKIN: Wash off in flowing water or shower.

INGESTION: Induce vomiting if large amounts are ingested. Consult medicial personnel.

INHALATION: Remove to fresh air if effects occur. Consult a physician.

NOTE TO PHYSICIAN: No specific antidote. Supportive care. Treatment based on judgment of the physician in response to reactions of the patient. If burn is present, treat as any

(Continued on page 4 , over)
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7. FIRST AID: (CONTINUED)

thermal burn, after decontamination.

8. HANDLING PRECAUTIONS:

EXPOSURE GUIDELINE(S): None established for active ingredient. ACGIH TLV is 50 ppm for methylene chloride. OSHA PEL is 500 ppm TWA, 1000 ceiling, 2000 peak for methylene chloride.

VENTILATION: Lethal concentrations may exist in areas with poor ventilation.

RESPIRATORY PROTECTION: For most conditions, no respiratory protection should be needed; however, in misty atomspheres, use an approved mist respirator.

SKIN PROTECTION: For brief contact, no precautions other than clean body-covering clothing should be needed. When prolonged or frequently repeated contact could occur, use protective clothing impervious to this material. Selection of specific items such as gloves, boots, apron or full-body suit will depend on operation.

EYE PROTECTION: Chemical workers goggles.

9. ADDITIONAL INFORMATION:

SPECIAL PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: Avoid eye contact. Avoid breathing mists if generated. Avoid trapping material under clothing.

MSDS STATUS: Revised sections 6-8.

REGULATORY INFORMATION: (Not meant to be all-inclusive--selected regulations represented.)

NOTICE: The information herein is presented in good faith and believed to be accurate as of the effective date shown above. However, no warranty, express or implied, is given. Regulatory requirements are subject to change and may differ from one location to another; it is the buyer's responsibility to ensure that its activities comply with federal, state or provincial, and local laws. The following specific information is made for the purpose of complying with numerous federal, state or provincial, and local laws and regulations. See MSD Sheet for health and safety information.

U.S. REGULATIONS

SARA 313 INFORMATION: This product contains the following substances subject to the reporting requirements of Section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 and 40 CFR Part 372:

CHEMICAL NAME	CAS NUMBER	CONCENTRATION
DICHLOROMETHANE (METHYLENE CHLORIDE)	000075-09-2	<2 %

SARA HAZARD CATEGORY: This product has been reviewed according to the EPA "Hazard Categories" promulgated under Sections 311 and 312 of the Superfund Amendment and Reauthorization Act of 1986 (SARA Title III) and is considered, under applicable definitions, to meet the following categories:

An immediate health hazard
A delayed health hazard
Hazard categories are listed solely to assist with federal reporting under Title III. They are not intended and are not appropriate for evaluating safe product handling and use. To review health and safety information, refer to the body of this material safety data sheet.

CANADIAN REGULATIONS

The Workplace Hazardous Materials Information System (W.H.M.I.S.) Classification for this product is:

D1B
D2A
D2B

(Continued on page R-2 , over)
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REGULATORY INFORMATION (CONTINUED)

The Transportation of Dangerous Goods Act (T.D.G.A.) classification for this product is:

Not regulated

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The Information Herein Is Given In Good Faith, But No Warranty, Express Or Implied, Is Made. Consult The Dow Chemical Company For Further Information.

* An Operating Unit of The Dow Chemical Company

CYTEC

MATERIAL SAFETY DATA

MSDS No: 0043
CAS No: 002373-38-8
Date: 07/01/97
Supersedes: 01/28/97

1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

PRODUCT NAME: **AEROSOL® MA 80% Surfactant**

SYNONYMS: Sodium dihexyl sulfosuccinate in mixture of ethanol and water

CHEMICAL FAMILY: Ester

MOLECULAR FORMULA: C16H29O7NaS (active ingredient)

MOLECULAR WGT: 388; (Active ingredient)

CYTEC INDUSTRIES INC., FIVE GARRET MOUNTAIN PLAZA, WEST PATERSON, NEW JERSEY 07424, USA
For Product Information call 1-800/652-6013. Outside the USA and Canada call 973/357-3193.
EMERGENCY PHONE: For emergency involving spill, leak, fire, exposure or accident call CHEMTREC: 1-800/424-9300. Outside the USA and Canada call 703/527-3887.

2. COMPOSITION/INFORMATION ON INGREDIENTS

OSHA REGULATED COMPONENTS

COMPONENT	CAS. NO.	%	TWA/CEILING	REFERENCE
Sodium di(1,3-dimethylbutyl)sulfosuccinate	002373-38-8	~78-80	not established	
Methyl isobutyl carbinol	000108-11-2	<1.0	25 ppm (skin) 40 ppm STEL	OSHA/ACGIH
Ethanol	000064-17-5	~5.0	1000 ppm	OSHA/ACGIH

3. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

APPEARANCE AND ODOR: Clear, viscous liquid; pleasant, fruity odor

STATEMENTS OF HAZARD:
WARNING! FLAMMABLE LIQUID AND VAPOR
CAUSES EYE AND SKIN IRRITATION

CHRONIC HAZARD WARNING:
REPRODUCTIVE HAZARD - CONTAINS ETHANOL WHICH MAY CAUSE BIRTH DEFECTS OR OTHER ADVERSE EFFECTS ON PREGNANCY.
Risk of effects depends on duration and level of exposure.

POTENTIAL HEALTH EFFECTS

EFFECTS OF OVEREXPOSURE:
Acute oral (rat) and acute dermal (rabbit) LD50 values are approximately 1.75 g/kg and 5.0 g/kg, respectively. Marked eye and skin irritation were produced during primary irritation studies with rabbits. The 4-hour inhalation LC50 is greater than 20 mg/L.
Direct contact with this material may cause moderate eye and skin irritation.
Refer to Section 11 for toxicology information on the OSHA regulated components of this product.

4. FIRST AID MEASURES

In case of skin contact, remove contaminated clothing without delay. Flush skin thoroughly with water. Do not reuse clothing without laundering.

In case of eye contact, immediately irrigate with plenty of water for 15 minutes. Obtain medical attention if irritation persists.
Material is not expected to be harmful if inhaled. If inhaled, remove to fresh air.

5. FIRE FIGHTING MEASURES

FLAMMABLE PROPERTIES

FLASH POINT: 97 F; 36 C
METHOD: Pensky-Martens Closed Cup

FLAMMABLE LIMITS
(% BY VOL): Not available

AUTOIGNITION TEMP: Not available

DECOMPOSITION TEMP: Not available

EXTINGUISHING MEDIA AND FIRE FIGHTING INSTRUCTIONS

Use water spray, alcohol foam, carbon dioxide or dry chemical to extinguish fires. Water stream may be ineffective. Use water to keep containers cool. Wear self-contained positive pressure breathing apparatus and full firefighting protective clothing. See Section 8 (Exposure Controls/Personal Protection) for special protective clothing.

6. ACCIDENTAL RELEASE MEASURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED

Remove sources of ignition.
Where exposure level is not known, wear NIOSH approved, positive pressure, self-contained respirator. Where exposure level is known, wear NIOSH approved respirator suitable for level of exposure. In addition to the protective clothing/equipment in Section 8 (Exposure Controls/Personal Protection), wear impervious boots. Cover spills with some inert absorbent material; sweep up and place in a waste disposal container. Flush area with water.

7. HANDLING AND STORAGE

Keep away from heat, sparks, and flame. Avoid contact with eyes, skin, and clothing. Keep container closed. Use with adequate ventilation. Wash thoroughly after handling.

Areas containing this material should have fire-safe practices and electrical equipment in accordance with Electrical and Fire Protection codes (NFPA-30) governing Class I Flammable Liquids.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

ENGINEERING CONTROLS AND PERSONAL PROTECTIVE EQUIPMENT (PPE)

Where this material is not used in a closed system, good enclosure and local exhaust ventilation should be provided to control exposure. Food, beverages, and tobacco products should not be carried, stored, or consumed where this material is in use. Before eating, drinking, or smoking, wash face and hands with soap and water. Avoid skin contact. Protective clothing such as impervious gloves, apron, workpants, long sleeve work shirt, or disposable coveralls are recommended to prevent skin contact. For operations where eye or face contact can occur, wear eye protection such as chemical splash proof goggles or face shield. Eyewash equipment and safety shower should be provided in areas of potential exposure. Where exposures are below the Permissible Exposure Limit (PEL), no respiratory protection is required. Where exposures exceed the PEL use respirator approved by NIOSH for the material and level of exposure. See "GUIDE TO INDUSTRIAL RESPIRATORY PROTECTION" (NIOSH). Since this material contains a component with a skin notation with its PEL as shown in the regulated components section, additional skin protection such as a protective suit may be required.

Shower after completion of workshift. Launder work clothing at end of workshift prior to reuse. Store street clothing separately from work clothing and protective equipment. Work clothing and shoes must not be taken home.

9. PHYSICAL AND CHEMICAL PROPERTIES

APPEARANCE AND ODOR: Clear, viscous liquid; pleasant, fruity odor

BOILING POINT: 173 F; 78 C; (value for ethanol/water)

MELTING POINT: Not available

VAPOR PRESSURE: Not available

SPECIFIC GRAVITY: 1.13

VAPOR DENSITY: Not available

% VOLATILE (BY WT): 20

pH: Not available

SATURATION IN AIR (% BY VOL): Not available

EVAPORATION RATE: Not available

SOLUBILITY IN WATER: Complete

10. STABILITY AND REACTIVITY

STABILITY: Stable
CONDITIONS TO AVOID: None known

POLYMERIZATION: Will Not Occur
CONDITIONS TO AVOID: None known

INCOMPATIBLE MATERIALS: Strong acids and alkalies promote degradation by hydrolysis; strong oxidizing agents.

HAZARDOUS DECOMPOSITION PRODUCTS: Thermal decomposition or combustion may produce carbon monoxide, carbon dioxide and/or oxides of sulfur

11. TOXICOLOGICAL INFORMATION

Toxicological information for the product is found under Section 3. HAZARDS IDENTIFICATION. Toxicological information on the OSHA regulated components of this product is as follows:

Sodium di(1,3-dimethylbutyl)sulfosuccinate has acute oral (rat) and dermal (rabbit) LD50 values of greater than 1750 mg/kg and 5 ml/kg, respectively. Direct contact with this material may cause moderate to severe eye and skin irritation. This material is not expected to cause allergic skin reaction based tests in guinea pigs.

Methyl isobutyl carbinol has acute oral (rat) and dermal (rabbit) LD50 values of 2.6 g/kg and 3.6 g/kg, respectively. Methyl isobutyl carbinol has an acute 4-hour inhalation LC50 (rat) >2000 ppm (8.34 mg/L). Acute overexposure to methyl isobutyl carbinol vapor causes mucous membrane irritation and severe eye irritation. Direct contact with methyl isobutyl carbinol causes mild skin irritation.

Ethanol has acute oral (rat) and dermal (rabbit) LD50 values of 7060 mg/kg and 20,000 mg/kg, respectively. The 10-hour inhalation LC50 for ethanol in rats is 20,000 ppm (94.05 mg/L/4hr). Ethanol is a potent teratogen associated with abnormal fetal formation, growth retardation, neurological damage, and behavioral alterations in children with fetal alcohol syndrome. In a dominant lethal assay, male mice treated with ethanol over a three day period showed significant decrease in average litter size along with increased incidence of dead implants

12. ECOLOGICAL INFORMATION

LC50

BLUEGILL, 96 HOUR: > 1000 mg/L

TROUT 96 HOUR: 1200 mg/L

BOD

28 Day: 16.7 %

OCTANOL/H_2O PARTITION COEF.: Not available

13. DISPOSAL CONSIDERATIONS

The information on RCRA waste classification and disposal methodology provided below applies only to the Cytec product, as supplied. If the material has been altered or contaminated, or it has exceeded its recommended shelf life, the guidance may be inapplicable. Hazardous waste classification under federal regulations (40 CFR Part 261 et seq) is dependent upon whether a material is a RCRA "listed hazardous waste" or has any of the four RCRA "hazardous waste characteristics." Refer to 40 CFR Part 261.33 to determine if a given material to be disposed of is a RCRA "listed hazardous waste"; information contained in Section 15 of this MSDS is not intended to indicated if the product is a "listed hazardous waste." RCRA Hazardous Waste Characteristic. There are four characteristics defined in 40 CFR Section 261.21-61.24: Ignitability, Corrosivity, Reactivity, and Toxicity. To determine Ignitability, see Section 5 of this MSDS (flash point). For Corrosivity, see Sections 9 and 14 (pH and DOT corrosivity). For Reactivity, see Section 10 (incompatible materials). For Toxicity, see Section 2 (composition). Federal regulations are subject to change. State and local requirements, which may differ from or be more stringent than the federal regulations, may also apply to the classification of the material if it is to be disposed. Cytec encourages the recycle, recovery and reuse of materials, where permitted, as an alternate to disposal as a waste. Cytec recommends that organic materials classified as RCRA hazardous wastes be disposed of by thermal treatment or incineration at EPA approved facilities. Cytec has provided the foregoing for information only; the person generating the waste is responsible for determining the waste classification and disposal method.

14. TRANSPORT INFORMATION

This section provides basic shipping classification information. Refer to appropriate transportation regulations for specific requirements.

	D.O.T. SHIPPING INFORMATION	IMO SHIPPING INFORMATION
SHIPPING NAME:	FLAMMABLE LIQUID, N.O.S.	FLAMMABLE LIQUID, N.O.S.
HAZARD CLASS/ PACKING GROUP:	3 III	3.3 III
UN NUMBER:	UN1993	1993
IMDG PAGE:	Not Applicable	3345
D.O.T. HAZARDOUS SUBSTANCES:	(PRODUCT REPORTABLE QUANTITY) Not Applicable	Not Applicable
TRANSPORT LABEL REQUIRED:	Flammable Liquid	Flammable Liquid

	ICAO/IATA	TRANSPORT CANADA
SHIPPING NAME:	FLAMMABLE LIQUID, N.O.S.	FLAMMABLE LIQUID, N.O.S.
HAZARD CLASS:	3	3
SUBSIDIARY CLASS:	—	—
UN / ID NUMBER:	1993	1993

PACKING GROUP:	III	III
TRANSPORT LABEL REQUIRED:	Flammable Liquid	Flammable Liquid
PACKING INSTR:	PASSENGER 309 CARGO 310	Not Applicable
MAX NET QTY:	PASSENGER 60L CARGO 220L	Not Applicable

ADDITIONAL TRANSPORT INFORMATION

TECHNICAL NAME (N.O.S.): (Contains ethanol)

15. REGULATORY INFORMATION

INVENTORY INFORMATION

US TSCA: This product is manufactured in compliance with all provisions of the Toxic Substances Control Act, 15 U.S.C. 2601 et. seq.

CANADA DSL: Components of this product have been reported to Environment Canada in accordance with subsection 25 of the Canadian Environmental Protection Act and are included on the Domestic Substances List.

EEC EINECS: All components of this product are included in the European Inventory of Existing Chemical Substances (EINECS) in compliance with Council Directive 67/548/EEC and its amendments.

OTHER ENVIRONMENTAL INFORMATION The following components of this product may be subject to reporting requirements pursuant to Section 313 of CERCLA (40 CFR 372), Section 12(b) of TSCA, or may be subject to release reporting requirements (40 CFR 307, 40 CFR 311, etc.) See Section 13 for information on waste classification and waste disposal of this product.

COMPONENT	CAS. NO.	%	TPQ(lbs)	RQ(lbs)	S313	TSCA 12B
This product does not contain any components regulated under these sections of the EPA						

PRODUCT CLASSIFICATION UNDER SECTION 311 OF SARA				
ACUTE (Y)	CHRONIC (Y)	FIRE (Y)	REACTIVE (N)	PRESSURE (N)

16. OTHER INFORMATION

NFPA HAZARD RATING (National Fire Protection Association)

Fire 3
Health 2 0 Reactivity
—
Special

FIRE: Liquids and solids that can be ignited under almost all ambient temperature conditions.

HEALTH: Materials which on intense or continued exposure could cause temporary incapacitation or possible residual injury unless prompt medical treatment is given

REACTIVITY: Materials which in themselves are normally stable, even under fire exposure conditions, and which are not reactive with water.

REASON FOR ISSUE:

Area Code Change

Larry R. Johnson, DVM, PhD, DABT

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MATERIAL SAFETY DATA SHEET

DDUCT NUMBER: 123117 PRODUCT NAME: STEOL CS-330

STEPAN COMPANY
NORTHFIELD, IL. 60093
(847) 446-7500

EMERGENCY INFORMATION
MEDICAL: 1-800-228-5635
CHEMTREC: 1-800-424-9300

SECTION I: GENERAL INFORMATION

RODUCT NUMBER: 123117 PRODUCT NAME: STEOL CS-330
PRODUCT CLASS: ALCOHOL ETHOXY SULFATE
PRECAUTIONS: CAUSES IRRITATION.
REFER TO BILL OF LADING OR CONTAINER LABEL FOR DOT OR OTHER TRANSPORTATION HAZARD CLASSIFICATION, IF ANY.

SECTION II: HAZARDOUS INGREDIENTS

INGREDIENT (CAS #)	OSHA PEL (PPM)	ACGIH TLV (PPM)	OTHER

NO INGREDIENTS IDENTIFIED BY OSHA AS HAZARDOUS ARE KNOWN TO BE PRESENT, OR THE INGREDIENTS PRESENT ARE BELOW LEVELS SPECIFIED AS HAZARDOUS BY OSHA (29 CFR 1910.1200).

NE = NOT ESTABLISHED.
NL = NOT LISTED.
(C) = IDENTIFIED AS A CARCINOGEN BY OSHA, IARC, OR NTP.

SECTION III: PHYSICAL/CHEMICAL DATA

BOILING POINT:

(CONTINUED)

OVER 212 DEG F. (100 DEG C.).
% VOLATILE BY WEIGHT:
68%
EVAPORATION RATE: ESTIMATED SLOWER THAN ETHYL ETHER.

VAPOR DENSITY: ESTIMATED LIGHTER THAN AIR.
VAPOR PRESSURE (MM HG):
NOT DETERMINED OR UNKNOWN.
WEIGHT PER GALLON:
8.6 LBS.

SECTION IV: FIRE AND EXPLOSION DATA

FLASH POINT: NOT APPLICABLE (WATER SOLUTION).
EXPLOSIVE LIMITS:
LOWER: NOT APPLICABLE. UPPER: NOT APPLICABLE.
EXTINGUISHING MEDIA: NON FLAMMABLE, WATER SOLUTION
SPECIAL FIRE FIGHTING PROCEDURES: SELF-CONTAINED POSITIVE PRESSURE BREATHING APPARATUS AND PROTECTIVE CLOTHING SHOULD BE WORN IN FIGHTING FIRES INVOLVING CHEMICALS.
UNUSUAL FIRE AND EXPLOSION HAZARDS: NONE KNOWN.

SECTION V: REACTIVITY DATA

STABILITY: STABLE
HAZARDOUS POLYMERIZATION: WILL NOT OCCUR
INCOMPATABILITY (MATERIALS TO AVOID):
STRONG OXIDIZING AGENTS
STRONG ACID.
HAZARDOUS DECOMPOSITION PRODUCTS:
SULFUR DIOXIDE AND HYDROGEN SULFIDE.

SECTION VI: HEALTH HAZARD DATA

EFFECTS OF OVEREXPOSURE/EMERGENCY AND FIRST AID PROCEDURES

(CONTINUED)

EYES: CONTACT WITH EYES IS PAINFUL AND IRRITATING.
FLUSH EYES IMMEDIATELY WITH PLENTY OF WATER FOR AT LEAST 15 MINUTES.

SKIN: PROLONGED OR REPEATED CONTACT WITH SKIN CAUSES IRRITATION.
WASH OFF SKIN WITH WATER. REMOVE CONTAMINATED CLOTHING AND CLEAN BEFORE REUSE.

INHALATION: MIST CAUSED BY MANUFACTURING OPERATIONS IRRITATES NASAL PASSAGES.
IF VAPORS OR MIST CAUSE IRRITATION OR DISTRESS, REMOVE TO FRESH AIR.
GIVE OXYGEN OR APPLY ARTIFICIAL RESPIRATION, IF NEEDED.

INGESTION: IF SWALLOWED, CONSULT A PHYSICIAN IMMEDIATELY.

CHRONIC EFFECTS AND MEDICAL CONDITIONS AGGRAVATED BY OVEREXPOSURE:
CHRONIC EFFECTS AND MEDICAL CONDITIONS AGGRAVATED BY OVER-EXPOSURE TO THIS PRODUCT HAVE NOT BEEN ESTABLISHED. UNNECESSARY EXPOSURE TO THIS PRODUCT OR ANY CHEMICAL SHOULD BE AVOIDED.

IF ANY SYMPTOMS PERSIST, CONSULT A PHYSICIAN.

CARCINOGEN: THIS PRODUCT IS NOT CONSIDERED A CARCINOGEN BY OSHA, NTP, OR IARC.

THRESHOLD LIMIT VALUE:
NOTE: THIS PRODUCT MAY CONTAIN 1,4-DIOXANE AS A BY-PRODUCT, WHICH CAN BE ABSORBED BY INHALATION AND THROUGH THE SKIN. PLEASE BE ADVISED THAT 1,4-DIOXANE IS A CANCER-SUSPECT AGENT AND CAN CAUSE LIVER AND KIDNEY INJURY WITH OVER-EXPOSURE.

****
FOR ADDITIONAL MEDICAL INFORMATION, CALL 1-800-228-5635
****

SECTION VII: SPILL, LEAK, AND DISPOSAL PROCEDURES

CONTAIN ALL SPILLS AND LEAKS TO PREVENT DISCHARGE INTO THE ENVIRONMENT.
VENTILATE AREA.

SMALL SPILLS: SOAK UP WITH ABSORBANT, SHOVEL INTO WASTE CONTAINER, FLUSH AREA WITH WATER.

LARGE SPILLS: RECOVER LIQUID FOR REPROCESSING OR DISPOSAL.

(CONTINUED)

WASTE DISPOSAL: RECOVER MATERIAL OR DISPOSE (INCINERATION IS PREFERRED) IN ACCORDANCE WITH ALL APPLICABLE FEDERAL, STATE, AND LOCAL REGULATIONS. MATERIAL COLLECTED WITH ABSORBANT MAY BE DISPOSED IN A PERMITTED LANDFILL IN ACCORDANCE WITH FEDERAL, STATE, AND LOCAL REGULATIONS. EMPTY CONTAINER MAY RETAIN VAPOR OR PRODUCT RESIDUE. OBSERVE ALL LABELED SAFEGUARDS UNTIL CONTAINER IS CLEANED, RECONDITIONED, OR DESTROYED.

SECTION VIII: PROTECTIVE MEASURES

EYE PROTECTION: WEAR FULL FACE SHIELD OR GOGGLES WHEN HANDLING.
PROTECTIVE GLOVES: USE IMPERVIOUS GLOVES.
RESPIRATORY PROTECTION:
IF VAPORS ARE PRESENT, USE NIOSH OR MSHA APPROVED RESPIRATOR FOR ORGANIC VAPORS, AIR-LINE RESPIRATOR, OR A SELF-CONTAINED BREATHING APPARATUS.
VENTILATION:
USE ADEQUATE VENTILATION.

OTHER PROTECTIVE EQUIPMENT:
WEAR PROTECTIVE CLOTHING TO PREVENT REPEATED OR PROLONGED CONTACT.
EYE WASH STATION AND SAFETY SHOWER SHOULD BE NEAR WORK AREA.

SECTION IX: SPECIAL PRECAUTIONS

HANDLING AND STORAGE:
AVOID OVERHEATING OR FREEZING.
OTHER PRECAUTIONS:
SPILLED MATERIAL IS SLIPPERY. WASH THOROUGHLY AFTER HANDLING. IF INGESTED, CALL A PHYSICIAN.

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(CONTINUED)

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****
****

(R) REGISTERED TRADEMARK OR APPLICATION PENDING.

pan

heim Plant

Pat[illegible]et

[illegible]2803

[illegible]32

491-8539

Stepan Company

☐ Fieldsboro Plant
Bordentown, N.J. 08505
(609) 298-1222
(FAX) 609-298-7950

☐ Maywood Plant
100 West Hunter Avenue
Maywood, N.J. 07607
(201) 845-3030
(FAX) 201-845-6754

☒ Sample Room
☐ Millsdale Works
☐ Pilot Plant
Elwood, Illinois 60421
(815) 727-4944
(FAX) 815-774-5393

☐ Winder Plant
951 Bankhead Hwy.
Winder, GA 30680-0951
(770) 867-7471
(FAX) 770-867-5300

☐ Northfield
Corporate Offices
Research & Development
Northfield, IL 60093
(847) 446-7500
(FAX) 847-501-2100

2311

CERTIFICATE OF ANALYSIS / CERTIFICATE OF COMPLIANCE

Customer Sample	Date 1/7/98	Spec CB056	Spec Maint. Date	Qty
	Lead #	S/O #	Lot # 831841	
	Tlr #		T/C # F80107-91	
	Cust. PO #		Rel #	

STEPAN'S: STEOL CS-330

117-D ACTIVES (EQ. WT. 422)	27.5-29.5%	27.99
120-0 UNSULFATED ALCOHOL	0.4-1.4%	0.89
119-0 SODIUM CHLORIDE	0.4% MAX	0.01
098-F SODIUM SULFATE	0.6% MAX	0.20
058-0 PH (10% AQUEOUS)	6.5-8.5	8.18
[illegible] FORMALDEHYDE, PPM	400 PPM MIN	610
[illegible]6-F COLOR, %T @ 420MU (10 MM I.D. TUBE)	90% MIN	95
110-0 APPEARANCE @ 25C	CLEAR, F.F.M.	PASS
150-0 BUFFER, AS NA HCO3	RECORD	0.25
024-0 VISCOSITY @ 25C	800 CPS MAX	64
039-0 CLOUD POINT (QUICK COOL)	5C MAX	0

DEDICATED TO CONTINUOUS IMPROVEMENT THROUGH SQC & SPC

[illegible] product is not designated as having USP, NF or FDA cosmetic pharmaceutical, or food grade status unless [illegible]ecifically so stated in product name herein or in other documentation provided by Stepan Company
[illegible]IS ANALYSIS IS NOT TO BE CONSTRUED AS A WARRANTY, EXPRESSED OR IMPLIED. The preceding data is [illegible]

Very truly yours
STEPAN COMPANY

SIGMA-ALDRICH

ATTN: SAFETY DIRECTOR
UNIV OF OKLAHOMA
TRACY CARTER
405-325-4217

EMERGENCY PHONE 1-414-273-3850
PO BOX 355 MILWAUKEE, WI 52301
DATE 10/22/98
CUST#: 370851
PO#:

MATERIAL SAFETY DATA SHEET

SECTION 1. CHEMICAL IDENTIFICATION

CATALOG #: 23922-4
NAME: CALCIUM CHLORIDE, -4+30 MESH, TECH.

SECTION 2. COMPOSITION/INFORMATION ON INGREDIENTS

CAS #: 10043-52-4
MF: CACL2
EINECS NO: 233-140-8

SYNONYMS
CALPLUS * CALTAC * DOWFLAKE * LIQUIDOW * PELADOW * SNOMELT * SUPERFLAKE ANHYDROUS *

SECTION 3. HAZARDS IDENTIFICATION

LABEL PRECAUTIONARY STATEMENTS
HARMFUL
HARMFUL IF SWALLOWED.
IRRITATING TO EYES, RESPIRATORY SYSTEM AND SKIN.
IN CASE OF CONTACT WITH EYES, RINSE IMMEDIATELY WITH PLENTY OF WATER AND SEEK MEDICAL ADVICE.
WEAR SUITABLE GLOVES AND EYE/FACE PROTECTION.
HYGROSCOPIC
KEEP TIGHTLY CLOSED.
HANDLE AND STORE UNDER ARGON.

SECTION 4. FIRST-AID MEASURES

IN CASE OF CONTACT, IMMEDIATELY FLUSH EYES OR SKIN WITH COPIOUS AMOUNTS OF WATER FOR AT LEAST 15 MINUTES WHILE REMOVING CONTAMINATED CLOTHING AND SHOES.
IF INHALED, REMOVE TO FRESH AIR. IF NOT BREATHING GIVE ARTIFICIAL RESPIRATION. IF BREATHING IS DIFFICULT, GIVE OXYGEN.
IF SWALLOWED, WASH OUT MOUTH WITH WATER PROVIDED PERSON IS CONSCIOUS.
CALL A PHYSICIAN.
WASH CONTAMINATED CLOTHING BEFORE REUSE.

SECTION 5. FIRE FIGHTING MEASURES

EXTINGUISHING MEDIA
UNCOMBUSTIBLE.
USE EXTINGUISHING MEDIA APPROPRIATE TO SURROUNDING FIRE CONDITIONS.

SPECIAL FIREFIGHTING PROCEDURES

CONTINUED ON NEXT PAGE

GMA-ALDRICH

CUST#: 370851

MATERIAL SAFETY DATA SHEET

CATALOG #: 23922-4
NAME: CALCIUM CHLORIDE, -4+30 MESH, TECH.

WEAR SELF-CONTAINED BREATHING APPARATUS AND PROTECTIVE CLOTHING TO PREVENT CONTACT WITH SKIN AND EYES.

UNUSUAL FIRE AND EXPLOSIONS HAZARDS
EMITS TOXIC FUMES UNDER FIRE CONDITIONS.

CTION 6. - - - - - - - - - ACCIDENTAL RELEASE MEASURES- - - - - - - - -

WEAR SELF-CONTAINED BREATHING APPARATUS, RUBBER BOOTS AND HEAVY RUBBER GLOVES.
SWEEP UP, PLACE IN A BAG AND HOLD FOR WASTE DISPOSAL.
AVOID RAISING DUST.
VENTILATE AREA AND WASH SPILL SITE AFTER MATERIAL PICKUP IS COMPLETE.

CTION 7. - - - - - - - - - - - HANDLING AND STORAGE- - - - - - - - - - -

REFER TO SECTION 8.

CTION 8. - - - - - - - EXPOSURE CONTROLS/PERSONAL PROTECTION- - - - - -

WEAR APPROPRIATE NIOSH/MSHA-APPROVED RESPIRATOR, CHEMICAL-RESISTANT GLOVES, SAFETY GOGGLES, OTHER PROTECTIVE CLOTHING.
SAFETY SHOWER AND EYE BATH.
MECHANICAL EXHAUST REQUIRED.
DO NOT BREATHE DUST.
AVOID CONTACT WITH EYES, SKIN AND CLOTHING.
AVOID PROLONGED OR REPEATED EXPOSURE.
WASH THOROUGHLY AFTER HANDLING.
HARMFUL SOLID.
IRRITANT.
KEEP TIGHTLY CLOSED.
STORE IN A COOL DRY PLACE.

CTION 9. - - - - - - - - PHYSICAL AND CHEMICAL PROPERTIES - - - - - - -

APPEARANCE AND ODOR
WHITE BEADS

PHYSICAL PROPERTIES
MELTING POINT: 782 C
VAPOR PRESSURE: 0.01MM 20 C
SPECIFIC GRAVITY: 2.150

CTION 10. - - - - - - - - - -STABILITY AND REACTIVITY - - - - - - - - -

STABILITY
STABLE.

COMPATIBILITIES

CONTINUED ON NEXT PAGE

SIGMA-ALDRICH

CUST#: 370851

MATERIAL SAFETY DATA SHEET

CATALOG #: 23922-4
NAME: CALCIUM CHLORIDE, -4+30 MESH, TECH.

STRONG ACIDS
WATER
ZINC
METHYL VINYL ETHER
CALCIUM CHLORIDE IS ATTACKED BY BROMINE TRIFLUORIDE.
REACTS VIOLENTLY WITH:
BORON OXIDES.
CALCIUM OXIDE

HAZARDOUS COMBUSTION OR DECOMPOSITION PRODUCTS
TOXIC FUMES OF:
HYDROGEN CHLORIDE GAS

HAZARDOUS POLYMERIZATION
WILL NOT OCCUR.

SECTION 11. - - - - - - - - - - TOXICOLOGICAL INFORMATION - - - - - - - -

ACUTE EFFECTS
HARMFUL IF SWALLOWED.
MAY BE HARMFUL IF INHALED.
MAY BE HARMFUL IF ABSORBED THROUGH THE SKIN.
CAUSES EYE AND SKIN IRRITATION.
MATERIAL IS IRRITATING TO MUCOUS MEMBRANES AND UPPER RESPIRATORY TRACT.
TO THE BEST OF OUR KNOWLEDGE, THE CHEMICAL, PHYSICAL, AND TOXICOLOGICAL PROPERTIES HAVE NOT BEEN THOROUGHLY INVESTIGATED.

RTECS #: EV9800000
CALCIUM CHLORIDE

TOXICITY DATA

ORL-RAT LD50:1 GM/KG	CNJMAQ 12,216,1948
IPR-RAT LD50:264 MG/KG	DYYAAZ 14,963,1977
SCU-RAT LD50:2630 MG/KG	DYYAAZ 14,963,1977
IMS-RAT LD50:25 MG/KG	EMSUAB 4,223,1946
ORL-MUS LD50:1940 MG/KG	DYYAAZ 14,963,1977
IPR-MUS LD50:210 MG/KG	GTPZAB 34(5),51,1990
SCU-MUS LD50:823 MG/KG	DYYAAZ 14,963,1977
IVN-MUS LD50:42 MG/KG	TXAPA9 22,150,1972

TARGET ORGAN DATA
BEHAVIORAL (SOMNOLENCE)
BEHAVIORAL (CONVULSIONS OR EFFECT ON SEIZURE THRESHOLD)
BEHAVIORAL (CHANGE IN MOTOR ACTIVITY)
SKIN AND APPENDAGES (AFTER SYSTEMIC EXPOSURE: DERMATITIS, OTHER)
NUTRITIONAL AND GROSS METABOLIC (CHANGES IN: CA)
RTECS SELECTED REGISTRY OF TOXIC EFFECTS OF CHEMICAL SUBSTANCES

CONTINUED ON NEXT PAGE

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CUST#: 370851

MATERIAL SAFETY DATA SHEET

CATALOG #: 23922-4
NAME: CALCIUM CHLORIDE, -4+30 MESH, TECH.

(RTECS) DATA IS PRESENTED HERE. SEE ACTUAL ENTRY IN RTECS FOR COMPLETE INFORMATION.

CTION 12. - - - - - - - - - - ECOLOGICAL INFORMATION - - - - - - - - - - -

DATA NOT YET AVAILABLE.

CTION 13. - - - - - - - - - - DISPOSAL CONSIDERATIONS - - - - - - - - - -

DISSOLVE OR MIX THE MATERIAL WITH A COMBUSTIBLE SOLVENT AND BURN IN A CHEMICAL INCINERATOR EQUIPPED WITH AN AFTERBURNER AND SCRUBBER. OBSERVE ALL FEDERAL, STATE AND LOCAL ENVIRONMENTAL REGULATIONS.

N 14. - - - - - - - - - - - TRANSPORT INFORMATION - - - - - - - - - -

CONTACT ALDRICH CHEMICAL COMPANY FOR TRANSPORTATION INFORMATION.

CTION 15. - - - - - - - - - - REGULATORY INFORMATION - - - - - - - - - -

EUROPEAN INFORMATION
EC INDEX NO: 017-013-00-2
HARMFUL
R 36
IRRITATING TO EYES.
S 22
DO NOT BREATHE DUST.
S 24
AVOID CONTACT WITH SKIN.

REVIEWS, STANDARDS, AND REGULATIONS

DEL=MAK
EPA FIFRA 1988 PESTICIDE SUBJECT TO REGISTRATION OR RE-REGISTRATION
FEREAC 54,7740,1989
NOHS 1974: HZD 15720; NIS 87; TNF 7996; NDS 79; TNE 110691
NOES 1983: HZD 15720; NIS 116; TNF 15168; NDS 113; TNE 354620; TFE 117433
EPA GENETOX PROGRAM 1988, NEGATIVE: CELL TRANSFORM.-SA7/SHE
EPA TSCA SECTION 8(B) CHEMICAL INVENTORY
EPA TSCA SECTION 8(D) UNPUBLISHED HEALTH/SAFETY STUDIES
EPA TSCA TEST SUBMISSION (TSCATS) DATA BASE, JUNE 1998

CTION 16. - - - - - - - - - - OTHER INFORMATION- - - - - - - - - - - -

THE ABOVE INFORMATION IS BELIEVED TO BE CORRECT BUT DOES NOT PURPORT TO BE ALL INCLUSIVE AND SHALL BE USED ONLY AS A GUIDE. ALDRICH SHALL NOT BE LD LIABLE FOR ANY DAMAGE RESULTING FROM HANDLING OR FROM CONTACT WITH E ABOVE PRODUCT. SEE REVERSE SIDE OF INVOICE OR PACKING SLIP FOR

CONTINUED ON NEXT PAGE

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CUST#: 370851

MATERIAL SAFETY DATA SHEET

CATALOG #: 23922-6
NAME: CALCIUM CHLORIDE, -4+30 MESH, TECH.

ADDITIONAL TERMS AND CONDITIONS OF SALE.

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SIGMA-ALDRICH

ATTN: SAFETY DIRECTOR
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405-325-4217

EMERGENCY PHONE 1-414-273-3850
PO BOX 355 MILWAUKEE, WI 53201
DATE 10/22/98
CUST#: 370851
PO#:

MATERIAL SAFETY DATA SHEET

SECTION 1. - - - - - - - - - - CHEMICAL IDENTIFICATION- - - - - - - - - -

CATALOG #: 36280-8
NAME: ETHYL ALCOHOL, REAGENT, DENATURED

SECTION 2. - - - - - - COMPOSITION/INFORMATION ON INGREDIENTS - - - - - -

CAS #: 64-17-5
MF: C2H6O
EC NO: 200-578-6

ADDITIONAL INFORMATION
CONTAINS METHYL ALCOHOL, CHEMICAL ABSTRACTS REGISTRY NUMBER 67-56-1.
CONTAINS 2-PROPANOL (ISOPROPYL ALCOHOL), CHEMICAL ABSTRACTS REGISTRY NUMBER 67-63-0.

RTECS DATA AND SYNONYMS SUPPLIED ARE FOR THE MOST ABUNDANT HAZARDOUS COMPONENT OF THIS PRODUCT.

SYNONYMS
ABSOLUTE ETHANOL * AETHANOL (GERMAN) * AETHYLALKOHOL (GERMAN) * ALCOHOL * ALCOHOL, ANHYDROUS * ALCOHOL DEHYDRATED * ALCOOL ETHYLIQUE (FRENCH) * ALCOOL ETILICO (ITALIAN) * ALGRAIN * ALKOHOL (GERMAN) * ALKOHOLU ETYLOWEGO (POLISH) * ANHYDROL * COLOGNE SPIRIT * ETANOLO (ITALIAN) * ETHANOL (ACGIH:OSHA) * ETHYL ALCOHOL (DOT:OSHA) * ETHYL ALCOHOL ANHYDROUS * ETHYL HYDRATE * ETHYL HYDROXIDE * ETYLOWY ALKOHOL (POLISH) * FERMENTATION ALCOHOL * GRAIN ALCOHOL * JAYSOL * JAYSOL S * METHYLCARBINOL * MOLASSES ALCOHOL * NCI-C03134 * POTATO ALCOHOL * SD ALCOHOL 23-HYDROGEN * SPIRITS OF WINE * SPIRT * TECSOL *

SECTION 3. - - - - - - - - - - HAZARDS IDENTIFICATION - - - - - - - - -

LABEL PRECAUTIONARY STATEMENTS
FLAMMABLE (USA)
HIGHLY FLAMMABLE (EU)
HARMFUL
HARMFUL BY INHALATION AND IF SWALLOWED.
IRRITATING TO EYES, RESPIRATORY SYSTEM AND SKIN.
TARGET ORGAN(S):
NERVES
EYES
KEEP CONTAINER TIGHTLY CLOSED.
KEEP AWAY FROM SOURCES OF IGNITION - NO SMOKING.
AVOID CONTACT WITH SKIN.
IN CASE OF ACCIDENT OR IF YOU FEEL UNWELL, SEEK MEDICAL ADVICE

CONTINUED ON NEXT PAGE

We are committed to the success of our customers through science, technology and service.

MA Aldrich Fluka SUPELCO SIGMA SAF SIGMA-ALDRICH RESEARCH

SIGMA-ALDRICH

CUST#: 370851

MATERIAL SAFETY DATA SHEET

CATALOG #: 36280-B
NAME: ETHYL ALCOHOL, REAGENT, DENATURED

IMMEDIATELY (SHOW THE LABEL WHERE POSSIBLE).
HYGROSCOPIC
KEEP TIGHTLY CLOSED.
HANDLE AND STORE UNDER NITROGEN.

CTION 4. - - - - - - - - - - - FIRST-AID MEASURES- - - - - - - - - - -

IN CASE OF CONTACT, IMMEDIATELY FLUSH EYES OR SKIN WITH COPIOUS AMOUNTS OF WATER FOR AT LEAST 15 MINUTES WHILE REMOVING CONTAMINATED CLOTHING AND SHOES.
ASSURE ADEQUATE FLUSHING OF THE EYES BY SEPARATING THE EYELIDS WITH FINGERS.
IF INHALED, REMOVE TO FRESH AIR. IF NOT BREATHING GIVE ARTIFICIAL RESPIRATION. IF BREATHING IS DIFFICULT, GIVE OXYGEN.
IF SWALLOWED, WASH OUT MOUTH WITH WATER PROVIDED PERSON IS CONSCIOUS.
CALL A PHYSICIAN.
WASH CONTAMINATED CLOTHING BEFORE REUSE.

CTION 5. - - - - - - - - - - FIRE FIGHTING MEASURES - - - - - - - - - -

EXTINGUISHING MEDIA
CARBON DIOXIDE, DRY CHEMICAL POWDER OR APPROPRIATE FOAM.

SPECIAL FIREFIGHTING PROCEDURES
WEAR SELF-CONTAINED BREATHING APPARATUS AND PROTECTIVE CLOTHING TO PREVENT CONTACT WITH SKIN AND EYES.
USE WATER SPRAY TO COOL FIRE-EXPOSED CONTAINERS.
FLAMMABLE LIQUID.

UNUSUAL FIRE AND EXPLOSIONS HAZARDS
EMITS TOXIC FUMES UNDER FIRE CONDITIONS.
VAPOR MAY TRAVEL CONSIDERABLE DISTANCE TO SOURCE OF IGNITION AND FLASH BACK.
CONTAINER EXPLOSION MAY OCCUR UNDER FIRE CONDITIONS.

CTION 6. - - - - - - - - - ACCIDENTAL RELEASE MEASURES- - - - - - - - -

SHUT OFF ALL SOURCES OF IGNITION.
EVACUATE AREA.
WEAR SELF-CONTAINED BREATHING APPARATUS, RUBBER BOOTS AND HEAVY RUBBER GLOVES.
ABSORB ON SAND OR VERMICULITE AND PLACE IN CLOSED CONTAINERS FOR DISPOSAL.
USE NONSPARKING TOOLS.
VENTILATE AREA AND WASH SPILL SITE AFTER MATERIAL PICKUP IS COMPLETE.

CTION 7. - - - - - - - - - - - HANDLING AND STORAGE- - - - - - - - - - -

REFER TO SECTION 8.

CONTINUED ON NEXT PAGE

SIGMA-ALDRICH

CUST#: 370851

MATERIAL SAFETY DATA SHEET

CATALOG #: 36280-B
NAME: ETHYL ALCOHOL, REAGENT, DENATURED

CTION 8. - - - - - - - EXPOSURE CONTROLS/PERSONAL PROTECTION- - - - - -

WEAR APPROPRIATE NIOSH/MSHA-APPROVED RESPIRATOR, CHEMICAL-RESISTANT
GLOVES, SAFETY GOGGLES, OTHER PROTECTIVE CLOTHING.
USE ONLY IN A CHEMICAL FUME HOOD.
SAFETY SHOWER AND EYE BATH.
DO NOT BREATHE VAPOR.
DO NOT GET IN EYES, ON SKIN, ON CLOTHING.
AVOID PROLONGED OR REPEATED EXPOSURE.
WASH THOROUGHLY AFTER HANDLING.
HARMFUL LIQUID.
IRRITANT.
KEEP TIGHTLY CLOSED.
KEEP AWAY FROM HEAT, SPARKS, AND OPEN FLAME.
STORE IN A COOL DRY PLACE.

SECTION 9. - - - - - - - - PHYSICAL AND CHEMICAL PROPERTIES - - - - - - -

APPEARANCE AND ODOR
COLORLESS LIQUID

PHYSICAL PROPERTIES
BOILING POINT: 78 C
MELTING POINT: -130 C
FLASHPOINT 48 F 8C

EXPLOSION LIMITS IN AIR:
UPPER 19% 60 C
LOWER 3.3%
AUTOIGNITION TEMPERATURE: 793 F 422C
VAPOR PRESSURE: 40MM 19 C
SPECIFIC GRAVITY: 0.785
VAPOR DENSITY: 1.59

SECTION 10. - - - - - - - - - -STABILITY AND REACTIVITY - - - - - - - - -

STABILITY
STABLE.

INCOMPATIBILITIES
OXIDIZING AGENTS
PEROXIDES
ACIDS
ACID CHLORIDES
ACID ANHYDRIDES
ALKALI METALS
AMMONIA

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SIGMA-ALDRICH

CUST#: 370851

MATERIAL SAFETY DATA SHEET

CATALOG #: 36280-8
NAME: ETHYL ALCOHOL, REAGENT, DENATURED

PROTECT FROM MOISTURE.

HAZARDOUS COMBUSTION OR DECOMPOSITION PRODUCTS
TOXIC FUMES OF:
CARBON MONOXIDE, CARBON DIOXIDE

HAZARDOUS POLYMERIZATION
WILL NOT OCCUR.

CTION 11. - - - - - - - - - - TOXICOLOGICAL INFORMATION - - - - - - - -

ACUTE EFFECTS
HARMFUL IF INHALED OR SWALLOWED.
MAY BE HARMFUL IF ABSORBED THROUGH THE SKIN.
VAPOR OR MIST IS IRRITATING TO THE EYES, MUCOUS MEMBRANES AND UPPER RESPIRATORY TRACT.
CAUSES SKIN IRRITATION.
CAN CAUSE CNS DEPRESSION.
EXPOSURE CAN CAUSE:
GASTROINTESTINAL DISTURBANCES
NAUSEA, DIZZINESS AND HEADACHE
NARCOTIC EFFECT
PROLONGED OR REPEATED EXPOSURE TO SKIN CAUSES DEFATTING AND DERMATITIS.
MAY CAUSE CONVULSIONS.

CHRONIC EFFECTS
TARGET ORGAN(S):
NERVES
EYES
LIVER
KIDNEYS
HEART
CARDIOVASCULAR SYSTEM
G.I. SYSTEM
TO THE BEST OF OUR KNOWLEDGE, THE CHEMICAL, PHYSICAL, AND TOXICOLOGICAL PROPERTIES HAVE NOT BEEN THOROUGHLY INVESTIGATED.

ACUTE EFFECTS
HARMFUL IF INHALED OR SWALLOWED.

TECS #: KQ6300000
ETHYL ALCOHOL

IRRITATION DATA
SKIN -RBT 400 MG OPEN MLD
-RBT 20 MG/24H MOD
-RBT 500 MG SEV

UCDS** 7/22/1970
85JCAE -,189,1986
AJOPAA 29,1363,1945

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MATERIAL SAFETY DATA SHEET

CATALOG #: 36280-B
NAME: ETHYL ALCOHOL, REAGENT, DENATURED

EYE-RBT 500 MG/24H MLD	85JCAE -,189,1986
EYE-RBT 100 MG/4S RINSE MOD	FCTOD7 20,573,1982

TOXICITY DATA

ORL-CHD LDLO:2 GM/KG	ATXKA8 17,183,1958
ORL-HMN LDLO:1400 MG/KG	NPIRI* 1,44,1974
SCU-INF LDLO:19440 MG/KG	AJCPAI 5,456,1935
ORL-RAT LD50:7060 MG/KG	TXAPA9 16,718,1970
IHL-RAT LC50:20000 PPM/10H	NPIRI* 1,44,1974
IPR-RAT LD50:3600 UG/KG	PHMGBN 2,27,1969
IVN-RAT LD50:1440 MG/KG	TXAPA9 18,60,1971
IAT-RAT LD50:11 MG/KG	TXAPA9 18,60,1971
ORL-MUS LD50:3450 MG/KG	GISAAA 32(3),31,1967
[illegible]-MUS LC50:39 GM/M3/4H	GTPZAB 26(8),53,1982
[illegible]-MUS LD50:528 MG/KG	STRAAA 127,245,1965
SCU-MUS LD50:8285 MG/KG	FADNAU 48A,99,1970
IVN-MUS LD50:1973 MG/KG	MBTXAC 1,128,1955
ORL-RBT LD50:6300 MG/KG	MBTXAC 1,130,1955
IPR-RBT LD50:963 MG/KG	EVHPAZ 61,321,1985
IVN-RBT LD50:2374 MG/KG	EVHPAZ 61,321,1985
ORL-GPG LD50:5560 MG/KG	JIHTAB 23,259,1941
IPR-GPG LD50:3414 MG/KG	EVHPAZ 61,321,1985
IPR-HAM LD50:5068 MG/KG	EVHPAZ 61,321,1985
IPR-HAM LD50:4300 MG/KG	TXAPA9 13,358,1968

TARGET ORGAN DATA
BEHAVIORAL (SLEEP)
BEHAVIORAL (CHANGE IN MOTOR ACTIVITY)
BEHAVIORAL (ATAXIA)
BEHAVIORAL (ANTIPSYCHOTIC)
BEHAVIORAL (HEADACHE)
BEHAVIORAL (CHANGE IN PSYCHOPHYSIOLOGICAL TESTS)
LUNGS, THORAX OR RESPIRATION (CHRONIC PULMONARY EDEMA OR CONGESTION)
LUNGS, THORAX OR RESPIRATION (DYSPNAE)
LUNGS, THORAX OR RESPIRATION (OTHER CHANGES)
GASTROINTESTINAL (ALTERATION IN GASTRIC SECRETION)
GASTROINTESTINAL (HYPERMOTILITY, DIARRHEA)
GASTROINTESTINAL (NAUSEA OR VOMITING)
GASTROINTESTINAL (OTHER CHANGES)
LIVER (FATTY LIVER DEGENERATION)
LIVER (TUMORS)
BLOOD (OTHER CHANGES)
BLOOD (LYMPHOMA INCLUDING HODGKIN'S DISEASE)
PATERNAL EFFECTS (TESTES, EPIDIDYMIS, SPERM DUCT)
EFFECTS ON FERTILITY (FEMALE FERTILITY INDEX)
EFFECTS ON FERTILITY (MALE FERTILITY INDEX)
EFFECTS ON FERTILITY (POST-IMPLANTATION MORTALITY)
EFFECTS ON FERTILITY (OTHER MEASURES OF FERTILITY)

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MATERIAL SAFETY DATA SHEET

CATALOG #: 36280-B
NAME: ETHYL ALCOHOL, REAGENT, DENATURED

EFFECTS ON EMBRYO OR FETUS (EXTRA EMBRYONIC STRUCTURES)
EFFECTS ON EMBRYO OR FETUS (CYTOLOGICAL CHANGES)
EFFECTS ON EMBRYO OR FETUS (FETOTOXICITY)
EFFECTS ON EMBRYO OR FETUS (FETAL DEATH)
EFFECTS ON EMBRYO OR FETUS (OTHER EFFECTS TO EMBYRO OR FETUS)
SPECIFIC DEVELOPMENTAL ABNORMALITIES (EYE, EAR)
SPECIFIC DEVELOPMENTAL ABNORMALITIES (CRANIOFACIAL)
SPECIFIC DEVELOPMENTAL ABNORMALITIES (MUSCULOSKELETAL SYSTEM)
SPECIFIC DEVELOPMENTAL ABNORMALITIES (RESPIRATORY SYSTEM)
EFFECTS ON NEWBORN (GROWTH STATISTICS)
TUMORIGENIC (EQUIVOCAL TUMORIGENIC AGENT BY RTECS CRITERIA)
ONLY SELECTED REGISTRY OF TOXIC EFFECTS OF CHEMICAL SUBSTANCES (RTECS) DATA IS PRESENTED HERE. SEE ACTUAL ENTRY IN RTECS FOR COMPLETE INFORMATION.

SECTION 12. - - - - - - - - - - ECOLOGICAL INFORMATION - - - - - - - - - -

DATA NOT YET AVAILABLE.

SECTION 13. - - - - - - - - - - DISPOSAL CONSIDERATIONS - - - - - - - - -

BURN IN A CHEMICAL INCINERATOR EQUIPPED WITH AN AFTERBURNER AND SCRUBBER BUT EXERT EXTRA CARE IN IGNITING AS THIS MATERIAL IS HIGHLY FLAMMABLE.
OBSERVE ALL FEDERAL, STATE AND LOCAL ENVIRONMENTAL REGULATIONS.

SECTION 14. - - - - - - - - - - TRANSPORT INFORMATION - - - - - - - - -

CONTACT ALDRICH CHEMICAL COMPANY FOR TRANSPORTATION INFORMATION.

SECTION 15. - - - - - - - - - - REGULATORY INFORMATION - - - - - - - - - -

EUROPEAN INFORMATION
EC INDEX NO: 603-002-00-5
HIGHLY FLAMMABLE
HARMFUL
R 11
HIGHLY FLAMMABLE.
R 20/22
HARMFUL BY INHALATION AND IF SWALLOWED.
S 7
KEEP CONTAINER TIGHTLY CLOSED.
S 16
KEEP AWAY FROM SOURCES OF IGNITION - NO SMOKING.
S 24
AVOID CONTACT WITH SKIN.
S 7
IN CASE OF ACCIDENT OR IF YOU FEEL UNWELL, SEEK MEDICAL ADVICE

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SIGMA-ALDRICH

CUST#: 370851

MATERIAL SAFETY DATA SHEET

CATALOG #: 22351-4
NAME: SODIUM CHLORIDE, 99+%, A.C.S. REAGENT

THE ABOVE INFORMATION IS BELIEVED TO BE CORRECT BUT DOES NOT PURPORT TO BE ALL INCLUSIVE AND SHALL BE USED ONLY AS A GUIDE. ALDRICH SHALL NOT BE HELD LIABLE FOR ANY DAMAGE RESULTING FROM HANDLING OR FROM CONTACT WITH THE ABOVE PRODUCT. SEE REVERSE SIDE OF INVOICE OR PACKING SLIP FOR ADDITIONAL TERMS AND CONDITIONS OF SALE.

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MATERIAL SAFETY DATA SHEETS

Genium Publishing Corporation
One Genium Plaza
Schenectady, NY 12304-4690 USA
(518) 377-8854

Material Safety Data Sheets Collection:

Sheet No. 683
Polychlorinated Biphenyls (PCBs)

Issued: 11/88 Revision: A, 9/92

Section 1. Material Identification

R 1
I 4
S 3*
K 1
* Skin absorption

NFPA
1
2 0
–

HMIS
H 2‡
F 1
R 0
PPE†
† Sec. 8
‡ Chronic Effects

Polychlorinated Biphenyls [$C_{12}H_{10-n}Cl_n$ (n=3, 4, 5)] Description: A class of nonpolar chlorinated hydrocarbons with a biphenyl nucleus (two benzene nuclei connected by a single C-C bond) in which any or all of the hydrogen atoms have been replaced by chlorine. Commercial PCBs are mixtures of chlorinated biphenyl isomers with varying degrees of chlorination. Prepared industrially by the chlorination of biphenyl with anhydrous chlorine in the presence of a catalyst such as ferric chloride or iron filings. Except for limited research and development applications, PCBs have not been produced in the US since 1977. When large quantities of PCBs were manufactured in the US, they were marketed under the tradename Aroclor (Monsanto) and were characterized by four digit numbers. The first two digits indicating biphenyls (12), triphenyls (54), or both (25, 44); the last two digits indicating the weight percent of chlorine. PCBs' thermal stability, nonflammability, and high dielectric capability made them very useful in electrical equipment. Formerly used as additives in hydraulic fluids, heat transfer systems, lubricants, cutting oils, printer's ink, fire retardants, asphalt, brake linings, automobile body sealants, plasticizers, adhesives, synthetic rubber, floor tile, wax extenders, dedusting agents, pesticide extenders, and carbonless reproducing paper. PCBs are still used in certain existing electrical capacitors and transformers that require enhanced electrical protection to avoid heating from sustained electric faults.

Other Designations: CAS No. 1336-36-3, Aroclor, Clophen, Chlorextol, chlorinated biphenyls, chlorinated diphenyl, chlorinated diphenylene, chloro biphenyl, chloro-1,1-biphenyl, Dykanol, Fenclor, Inertecn, Kaneclor, Montar, Noflamol, Phenoclor, Pyralene, Pyranol, Santotherm, Sovol, Therminol FR-1

Cautions: PCBs are potent liver toxins that may be absorbed through skin. Potentially, chronic or delayed toxicity is significant because PCBs accumulate in fatty tissue and may reasonably be anticipated to be carcinogens. PCBs are a bioaccumulative environmental hazard. When burned, decomposition products may be more hazardous than the PCBs.

Section 2. Ingredients and Occupational Exposure Limits

PCBs, contain various levels of polychlorinated dibenzofurans and chlorinated naphthalenes as contaminants

1991 OSHA PELs, Skin
8-hr TWA (Chlorodiphenyl, 42% chlorine): 1 mg/m³
8-hr TWA (Chlorodiphenyl, 54% chlorine): 0.5 mg/m³

1990 DFG (Germany) MAK, Danger of Cutaneous Absorption
TWA (Chlorodiphenyl, 42% chlorine): 0.1 ppm (1 mg/m³)
Category III: Substances with systemic effects, onset of effect > 2 hr., half-life > shift length (strongly cumulative)
Short-term Level: 1 ppm, 30 min., average value, 1 per shift
TWA (Chlorodiphenyl, 54% chlorine): 0.05 ppm (0.5 mg/m³)
Category III: (see above)
Short-term Level: 0.5 ppm, 30 min., average value, 1 per shift

1985-86 Toxicity Data*
Rat, oral, TD: 1250 mg/kg administered intermittently for 25 weeks produced liver tumors.
Mammal, oral, TD_{Lo}: 325 mg/kg administered to female for 30 days prior to mating and from the 1st to the 36th day of gestation produced effects on newborn (stillbirth; live birth index; viability index).

1990 NIOSH REL
TWA (Chlorodiphenyl, 42% chlorine): 0.001 mg/m³
TWA (Chlorodiphenyl, 54% chlorine): 0.001 mg/m³

1992-93 ACGIH TLVs, Skin *
TWA (Chlorodiphenyl, 42% chlorine): 1 mg/m³
TWA (Chlorodiphenyl, 54% chlorine): 0.5 mg/m³

* These guidelines offer reasonably good protection against systemic intoxication, but may not guarantee that chloroacne won't occur.
† See NIOSH, *RTECS* (TQ1350000), for additional reproductive, tumorigenic, and toxicity data.

Section 3. Physical Data*

Boiling Point: 644-707 °F (340-375 °C)
Melting Point: 42%: -2.2 °F (-19°C); 54%: 14 °F (-10 °C)
Vapor Pressure: 1 mm Hg at 100 °F (38 °C); 10^{-6} to 10^{-3} mm at 20 °C
Molecular Weight: 188.7 to 398.5

Specific Gravity: 1.3 to 1.8 at 20 °C
Water Solubility: Low solubility (0.007 to 5.9 mg/L)
Other Solubilities: Most common organic solvents, oils, and fats; slightly soluble in glycerol and glycols.

Appearance and Odor: PCBs vary from mobile oily liquids to white crystalline solids and hard non-crystalline resins, depending upon chlorine content.

* Physical and chemical properties vary widely according to degree and to the position of chlorination.

Section 4. Fire and Explosion Data

Flash Point: 286-385 °F (141-196 °C) OC*	Autoignition Temperature: 464 °F (240 °C)	LEL: None reported	UEL: None reported

Extinguishing Media: Use extinguishing media suitable to the surrounding fire. Use dry chemical, foam, carbon dioxide (CO_2), or water spray. Water spray may be ineffective. Use water spray to cool fire-exposed containers or transformers. Do not scatter PCBs with high-pressure water streams. Unusual Fire or Explosion Hazards: Combustion products (hydrogen chloride, phosgene, polychlorinated dibenzofurans, and furans) are more hazardous than the PCBs themselves. Special Fire-fighting Procedures: Because fire may produce toxic thermal decomposition products, wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in pressure-demand or positive-pressure mode. Approach fire from upwind to avoid highly toxic decomposition products. Structural firefighter's protective clothing will provide *limited* protection. Do not release runoff from fire control methods to sewers or waterways. Dike for later disposal.

* Flash points shown are a range for various PCBs. Some forms do not have flash points.

Section 5. Reactivity Data

Stability/Polymerization: PCBs are very stable materials but are subject to photodechlorination when exposed to sunlight or UV (spectral region above 290 nanometers). Hazardous polymerization cannot occur. Chemical Incompatibilities: PCBs are chemically inert and resistant to oxidation, acids, and bases. Conditions to Avoid: Avoid heat and ignition sources.
Hazardous Products of Decomposition: Thermal oxidative decomposition [1112-1202 °F (600-650 °C)] of PCBs can produce highly toxic derivatives, including polychlorinated dibenzo-para-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), hydrogen chloride, phosgene and other irritants.

Section 6. Health Hazard Data

Carcinogenicity: The IARC,[104] and NTP[109] list PCBs as an IARC probable carcinogen (overall evaluation is 2A; limited human data; sufficient animal data) and NTP anticipated carcinogen, respectively. **Summary of Risks:** PCBs are potent liver toxins that can be absorbed through skin in toxic amounts without immediate pain or irritation. PCBs have low acute toxicity, but can accumulate in fatty tissue and severe effects may develop later. Generally, toxicity increases with a higher chlorine content; PCB-oxides are more toxic. The toxic action on the liver also increases with simultaneous exposure to other liver toxins, e.g. chlorinated solvents, alcohol, and certain drugs. Pathological pregnancies (abnormal pigmentations, abortions, stillbirths, and underweight births) have been associated with increased PCB serum levels in mothers; PCBs can be passed in breast milk. PCBs can affect the reproductive system of adults. **Medical Conditions Aggravated by Long-Term Exposure:** Skin, liver, and respiratory disease. **Target Organs:** Skin, liver, eyes, mucous membranes, and respiratory tract. **Primary Entry Routes:** Inhalation, dermal contact, ingestion. **Acute Effects:** Exposure to PCB vapor or mist is severely irritating to the skin, eyes, nose, throat, and upper respiratory tract. Intense acute exposure to high concentrations may result in eye, lung, and liver injury. Systemic effects include nausea, vomiting, increased blood pressure, fatigue, weight loss, jaundice, edema and abdominal pain. Cognitive, neurobehavior and psychomotor impairment and memory loss have also been seen after acute exposure. **Chronic Effects:** Repeated exposure to PCBs can cause chloroacne; redness, swelling, dryness, thickening and darkening of the skin and nails; swelling and burning of the eyes, and excessive eye discharge; distinctive hair follicles; gastrointestinal disturbances; neurological symptoms including headache, dizziness, depression, nervousness, numbness of the extremities, and joint and muscle pain; liver enlargement; menstrual changes in women; and chronic bronchitis. Cancer, primarily liver, is also a possible result of exposure, but data is inconclusive.

FIRST AID **Eyes:** *Do not* allow victim to rub or keep eyes tightly shut. Rinsing eyes with medical oil (olive, mineral) initially may remove PCB and halt irritation better than water rinsing alone. Gently lift eyelids and flush immediately and continuously with flooding amounts of water until transported to an emergency medical facility. Consult a physician immediately. **Skin:** *Quickly* remove contaminated clothing. Rinse with flooding amounts of water for at least 15 min. Wash exposed area with soap and water. *Multiple soap and water washings are necessary.* Avoid the use of organic solvents to clean the skin. For reddened or blistered skin, consult a physician. **Inhalation:** Remove exposed person to fresh air and support breathing as needed. **Ingestion:** In most cases, accidental PCB ingestion will not be recognized until long after vomiting would be of any value. Never give anything by mouth to an unconscious or convulsing person. Vomiting of the pure substance may cause aspiration. Consult a physician. **Note to Physicians:** Monitor patients for increased hepatic enzymes, chloroacne, and eye, gastrointestinal, and neurologic symptoms listed above. Diagnostic tests include blood levels of PCBs and altered liver enzymes.

Section 7. Spill, Leak, and Disposal Procedures

Spill/Leak: Notify safety personnel, evacuate all unnecessary personnel, provide adequate ventilation, and isolate hazard area. Cleanup personnel should protect against vapor inhalation and skin or eye contact. For small spills, take up with sand or other noncombustible material and place into containers for later disposal. For larger spills, dike far ahead of spill to contain for later disposal. Follow applicable OSHA regulations (29 CFR 1910.120). **Environmental Transport:** PCBs have been shown to bio-concentrate significantly in aquatic organisms. **Ecotoxicity:** Bluegill, TLm: 0.278 ppm/96 hr. Mallard Duck, LD_{50}: 2000 ppm. **Environmental Degradation:** In general, the persistence of PCBs increases with an increase degree of chlorination. **Soil Absorption/Mobility:** PCBs are tightly absorbed in soil and generally do not leach significantly in most aqueous soil systems. However, in the presence of organic solvents, PCBs may leach rapidly through the soil. Volatilization of PCBs from soil may be slow, but over time may be significant. **Disposal:** Approved PCB disposal methods include: incineration with scrubbing, high-efficiency boilers, landfills, and EPA-approved alternative disposal methods. Each disposal method has various criteria. Contact your supplier or a licensed contractor for detailed recommendations. Follow applicable Federal, state, and local regulations.

Designations

RCRA Hazardous Waste (40 CFR 261.33): Not listed
SARA Extremely Hazardous Substance (40 CFR 355): Not listed
Listed as a SARA Toxic Chemical (40 CFR 372.65)
Listed as a CERCLA Hazardous Substance* (40 CFR 302.4): Final Reportable Quantity (RQ), 1 lb (0.454 kg) [* per CWA, Sec. 311(b)(4) and 307(a)]

OSHA Designations

Listed as an Air Contaminant (29 CFR 1910.1000, Table Z-1-A)

Section 8. Special Protection Data

Goggles: Wear protective eyeglasses or chemical safety goggles, per OSHA eye- and face-protection regulations (29 CFR 1910.133). Because contact lens use in industry is controversial, establish your own policy. **Respirator:** Seek professional advice prior to respirator selection and use. Follow OSHA respirator regulations (29 CFR 1910.134) and, if necessary, wear a MSHA/NIOSH-approved respirator. Select respirator based on its suitability to provide adequate worker protection for given working conditions, level of airborne contamination, and presence of sufficient oxygen. Minimum respiratory protection should include a combination dust-fume-mist and organic vapor cartridge or canister or air-supplied, depending upon the situation. For emergency or nonroutine operations (cleaning spills, reactor vessels, or storage tanks), wear an SCBA. *Warning! Air-purifying respirators do not protect workers in oxygen-deficient atmospheres.* If respirators are used, OSHA requires a written respiratory protection program that includes at least: medical certification, training, fit-testing, periodic environmental monitoring, maintenance, inspection, cleaning, and convenient, sanitary storage areas. **Other:** Wear chemically protective gloves, boots, aprons, and gauntlets to prevent all skin contact. Butyl rubber, neoprene, Teflon, and fluorocarbon rubber have break through times greater than 8 hrs. **Ventilation:** Provide general and local exhaust ventilation systems to maintain airborne concentrations below the OSHA PEL (Sec. 2). Local exhaust ventilation is preferred because it prevents contaminant dispersion into the work area by controlling it at its source.[103] **Safety Stations:** Make available in the work area emergency eyewash stations, safety/quick-drench showers, and washing facilities. **Contaminated Equipment:** Separate contaminated work clothes from street clothes and launder before reuse. Segregate contaminated clothing in such a manner so that there is no direct contact by laundry personnel. Implement quality assurance to ascertain the completeness of the cleaning procedures. Remove this material from your shoes and clean PPE. **Comments:** Never eat, drink, or smoke in work areas. Practice good personal hygiene after using this material, especially before eating, drinking, smoking, using the toilet, or applying cosmetics.

Section 9. Special Precautions and Comments

Storage Requirements: Store in a closed, labelled, container in a ventilated area with appropriate air pollution control equipment. **Engineering Controls:** To reduce potential health hazards, use sufficient dilution or local exhaust ventilation to control airborne contaminants and to maintain concentrations at the lowest practical level. **Administrative Controls:** Inform employees of the adverse health effects associated with PCBs. Limit access to PCB work areas to authorized personnel. Consider preplacement and periodic medical examinations with emphasis on the skin, liver, lung, and reproductive system. Monitor PCB blood levels. Consider possible effects on the fetus. Keep medical records for the entire length of employment and for the following 30 yrs.

Transportation Data (49 CFR 172.101)

Shipping Name: Polychlorinated biphenyls
Hazard Class: 9
No.: UN2315
DOT Packing Group: II
DOT Label: CLASS 9
Special Provisions (172.102): 9, N81

Packaging Authorizations
a) Exceptions: 173.155
b) Non-bulk Packaging: 173.202
c) Bulk Packaging: 173.241

Quantity Limitations
a) Passenger Aircraft or Railcar: 100 L
b) Cargo Aircraft Only: 220 L

Vessel Stowage Requirements
a) Vessel Stowage: A
b) Other: 34

MSDS Collection References: 26, 73, 89, 100, 101, 103, 124, 126, 127, 132, 133, 136, 163, 164, 168, 169, 174, 175, 180
Prepared by: MJ Wurth, BS; Industrial Hygiene Review: PA Roy MPH, CIH; Medical Review: AC Darlington, MD

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Material Safety Data Sheet

From Genium's Reference Collection
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GENIUM PUBLISHING CORP.

No. 624

NAPHTHALENE

Issued: November 1987

SECTION 1. MATERIAL IDENTIFICATION

24

Material Name: NAPHTHALENE

Description (Origin/Uses): Used as a moth repellant and in many industrial processes.

Other Designations: Naphthalin; Naphthene; Tar Camphor; $C_{10}H_8$; NIOSH *RTECS* No. QJ0525000; CAS No. 0091-20-3

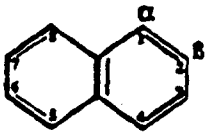
Manufacturer: Contact your supplier or distributor. Consult the latest edition of the *Chemicalweek Buyer's Guide* (Genium ref. 73) for a list of suppliers.

HMIS
H 2
F 2
R 0
PPG*
*See sect. 8

R 1
I 4
S 1
K 2

SECTION 2. INGREDIENTS AND HAZARDS

	%	EXPOSURE LIMITS
Naphthalene, CAS No. 0091-20-3	ca 100	IDLH* Level: 500 ppm ACGIH TLVs, 1987-88 TLV-TWA: 10 ppm, 50 mg/m³ OSHA PEL 8-Hr TWA: 10 ppm, 50 mg/m³ Toxicity Data** Child, Oral, LD_{Lo}: 100 mg/kg Man, Unknown, LD_{Lo}: 74 mg/kg Rat, Oral, LD_{50}: 1250 mg/kg



*Immediately dangerous to life and health
**See NIOSH *RTECS* for additional data with references to irritative, mutagenic, reproductive, and tumorigenic effects.

SECTION 3. PHYSICAL DATA

Boiling Point: 424°F (218°C)
Vapor Density (Air = 1): 4.4
Vapor Pressure: 0.087 Torr at 77°F (25°C)
Water Solubility: Insoluble
Specific Gravity (H_2O = 1): 1.162 at 68°F (20°C)
Melting Point: 176°F (80°C)
Molecular Weight: 128 Grams/Mole
% Volatile by Volume: ca 100

Appearance and Odor: White crystalline flakes; strong coal tar odor.

SECTION 4. FIRE AND EXPLOSION DATA

Flash Point and Method	Autoignition Temperature	Flammability Limits in Air	LOWER	UPPER
174°F (79°C) OC; 190°F (88°C) CC	979°F (526°C)	% by Volume	0.9	5.9

Extinguishing Media: Use water spray, dry chemical, or carbon dioxide to fight fires involving naphthalene. **Caution:** Foam or direct water spray applied to molten naphthalene may cause extensive foaming.

Unusual Fire or Explosion Hazards: Naphthalene is a volatile solid that gives off flammable vapor when heated (as in fire situations). This vapor is much denser than air and will collect in enclosed or low-lying areas like sumps. In these areas an explosive air-vapor mixture may form, and extra caution is required to prevent any ignition sources from starting an explosion or fire.

Special Fire-fighting Procedures: Wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in the pressure-demand or positive-pressure mode.

SECTION 5. REACTIVITY DATA

Naphthalene is stable in closed containers at room temperature under normal storage and handling conditions. It does not undergo hazardous polymerization.

Chemical Incompatibilities: Naphthalene is incompatible with strong oxidizing agents, chromic anhydride, and mixtures of aluminum trichloride and benzoyl chloride.

Conditions to Avoid: Ignition sources like open flame, unprotected heaters, excessive heat, lighted tobacco products, and electric sparks must not occur in work areas where naphthalene vapor may become concentrated.

Hazardous Products of Decomposition: Toxic gases like carbon monoxide are produced during fire conditions. Irritating, flammable vapor forms below the melting point because even solid naphthalene has a significant vapor pressure.

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SECTION 6. HEALTH HAZARD INFORMATION

Naphthalene is not listed as a carcinogen by the NTP, IARC, or OSHA.
Summary of Risks: Renal shutdown (kidney failure), hemolytic effects (breakdown of red blood cells), hematuria (blood in the urine), oliguria (low volume of urine), jaundice, eye damage, and depression of the central nervous system (CNS) are the primary health concerns associated with exposure to naphthalene. The ACGIH TLVs in section 2 are set to prevent eye damage. These recommended exposure limits may not be low enough to prevent blood changes in genetically hypersensitive individuals.
Medical Conditions Aggravated by Long-Term Exposure: Diseases of the blood, liver, and kidneys. Administer medical exams emphasizing these organs. **Target Organs:** Eyes, skin, kidneys, liver, blood (red blood cell effects), and CNS.
Primary Entry: Inhalation, skin contact. **Acute Effects:** Inhalation of naphthalene vapor causes excitement, confusion, headache, nausea, and loss of appetite. **Chronic Effects:** Increased incidence of cataracts.
FIRST AID
Eye Contact: Immediately flush eyes, including under the eyelids, gently but thoroughly with plenty of running water for at least 15 minutes to remove particles.
Skin Contact: Immediately wash the affected area with soap and water.
Inhalation: Remove victim to fresh air; restore and/or support his breathing as needed.
Ingestion: Call a poison control center. Never give anything by mouth to someone who is unconscious or convulsing. Administer a gastric lavage followed by saline catharsis. Monitor blood and electrolytic balance. Other sources recommend giving the victim several glasses of water to drink.

GET MEDICAL HELP (IN PLANT, PARAMEDIC, COMMUNITY) FOR ALL EXPOSURES. Seek prompt medical assistance for further treatment, observation, and support after first aid.

SECTION 7. SPILL, LEAK, AND DISPOSAL PROCEDURES

Spill/Leak: Notify safety personnel, provide ventilation, and eliminate all ignition sources immediately. Cleanup personnel need protection against contact and inhalation of vapor (see sect. 8). Contain large spills and collect waste. Use nonsparking tools to place naphthalene into closable containers for disposal. Keep waste out of sewers, watersheds, and waterways.
Waste Disposal: Consider reclamation, recycling, or destruction rather than disposal in a landfill. Contact your supplier or a licensed contractor for detailed recommendations. Follow Federal, state, and local regulations.

OSHA Designations
Air Contaminant (29 CFR 1910.1000, Subpart Z)
EPA Designations (40 CFR 302.4)
RCRA Hazardous Waste, No. U165
CERCLA Hazardous Substance, Reportable Quantity: 100 lbs (45.4 kg)

SECTION 8. SPECIAL PROTECTION INFORMATION

Goggles: Always wear protective eyeglasses or chemical safety goggles. Follow the eye- and face-protection guidelines of 29 CFR 1910.133. **Respirator:** Use a NIOSH-approved respirator per the *NIOSH Pocket Guide to Chemical Hazards* (Genium ref. 88) for the maximum-use concentrations and/or the exposure limits cited in section 2. Respirator usage must be in accordance with the OSHA regulations of 29 CFR 1910.134. IDLH or unknown concentrations require an SCBA with a full facepiece operated in the pressure-demand or positive-pressure mode. **Warning:** Air-purifying respirators will *not* protect workers in oxygen-deficient atmospheres.
Other Equipment: Wear impervious gloves, boots, aprons, gauntlets, etc., as required by the specific work environment to prevent skin contact. **Ventilation:** Install and operate general and local maximum explosion-proof ventilation systems of sufficient power to maintain airborne levels of naphthalene below the OSHA PEL standard cited in section 2. **Safety Stations:** Make eyewash stations, washing facilities, and safety showers available in areas of use and handling. **Contaminated Equipment:** Contact lenses pose a special hazard; soft lenses may absorb irritants, and all lenses concentrate them. Do *not* wear contact lenses in any work area. Remove and launder contaminated clothing before wearing it again; clean this material from shoes and equipment.
Comments: Practice good personal hygiene; always wash thoroughly after using this material. Keep this material off of your clothing and equipment. Avoid transferring this material from hands to mouth while eating, drinking, or smoking. Do *not* smoke, eat, or drink in any immediate work area. Avoid inhalation of vapor!

SECTION 9. SPECIAL PRECAUTIONS AND COMMENTS

Storage Segregation: Store naphthalene in a cool, dry, well-ventilated area away from chemical incompatibles (see sect. 5).
Special Handling/Storage: Protect containers from physical damage. All bulk storage facilities must be built with an explosion-proof design. All containers used in shipping/transferring operations must be electrically grounded to prevent static sparks. Use monitoring equipment to measure the extent of vapor present in any storage facility containing naphthalene because of potential fire and explosion hazards.
Comments: All operations with naphthalene must be done carefully to prevent accidental ignition of its flammable/explosive vapor. If the weather is warm, more naphthalene vapor forms and the potential for explosion increases. Do *not* smoke in any use or storage area!
Transportation Data (49 CFR 172.101-2)

DOT Shipping Name: Naphthalene	**DOT ID No.** UN1334
DOT Hazard Class: ORM-A	**IMO Label:** Flammable Solid
IMO Class: 4.1	**DOT Label:** None

References: 1, 2, 12, 73, 84-94, 103. PJI

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Indust. Hygiene/Safety
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Material Safety Data Sheets Collection:

Sheet No. 514
p-Dichlorobenzene

Issued: 10/83 Revision: A, 11/90

Section 1. Material Identification

p-Dichlorobenzene ($C_6H_4Cl_2$) Description: Derived by chlorinating monochlorobenzene. Used as a general insecticide; a moth repellent; a germicide; a chemical intermediate in the production of polyphenylene sulfide; a plastic used in the electrical and electronics industries; a space deodorant in products such as room deodorizers, urinal and toilet bowl blocks, and diaper pail deodorizers; and in producing 1,2,4 trichlorobenzene.

Other Designations: CAS No. 0106-46-7, 1,4-dichlorobenzene, dichlorocide, Evola,* NCI-c 54955, Paracide,* Paracrystals, Paradi,* paradichlorobenzol, Paramoth,* *p*-chlorophenyl chloride, PDB,* Santochlor.*

Manufacturer: Contact your supplier or distributor. Consult the latest *Chemicalweek Buyers' Guide*™ for a suppliers list.

Cautions: *p*-Dichlorobenzene vapor is an eye and upper respiratory tract irritant. *It is toxic to the liver*. Prolonged exposure to high concentrations may cause weakness, dizziness, and weight loss. Flammable when exposed to heat, flame, or oxidizers.

R	1
I	3
S	1
K	2

NFPA: 2 / 2 / 0 / -

HMIS
H 2
F 2
R 0
PPG*
* Sec. 8

Section 2. Ingredients and Occupational Exposure Limits

p-Dichlorobenzene, ca 100%

1989 OSHA PELs
8-hr TWA: 75 ppm, 450 mg/m³
15-min STEL: 110 ppm, 675 mg/m³

1990-91 ACGIH TLVs
TWA: 75 ppm, 451 mg/m³
STEL: 110 ppm, 661 mg/m³

1988 NIOSH REL
None established

1985-86 Toxicity Data*
Human, oral, TD_{Lo}: 300 mg/kg produced sense organs and special senses (other eye effects); lungs, thorax, or respiration (other changes); and gastrointestinal (hypermotility, diarrhea) effects
Human, eye: 80 ppm

1987 IDLH Level
1000 ppm

* See NIOSH, *RTECS* (CZ4550000), for additional irritative, mutative, reproductive, and toxicity data.

Section 3. Physical Data

Boiling Point: 345 °F (174 °C) at 760 mm Hg
Melting Point: 127.6 °F (53.1 °C)
Vapor Pressure: 10 mm Hg at 130.6 °F (54.8 °C)
Vapor Density (Air = 1): 5.08
Molecular Weight: 147.01
Specific Gravity: 1.248 at 131 °F (55 °C)
Water Solubility: Insoluble

Appearance and Odor: Volatile, white crystals with a distinctive mothball-like odor that becomes very strong at concentrations between 30 and 60 ppm. At concentrations of 80 to 160 ppm, vapors are painful to the eyes and nose. Odors and irritating effects are good warnings against overexposure to *p*-dichlorobenzene; however, individuals may develop tolerance to high concentrations.

Section 4. Fire and Explosion Data

Flash Point: 150 °F (66 °C), CC	Autoignition Temperature: None reported	LEL: 1.7% v/v	UEL: None reported

Extinguishing Media: Use dry chemical, carbon dioxide, alcohol foam, or water spray. Use water spray to cool fire-exposed container, to disperse vapors, or to blanket a pool fire.

Unusual Fire or Explosion Hazards: Explosive and toxic mixtures may form in air when this material is heated, such as in a fire.

Special Fire-fighting Procedures: Since fire may produce toxic fumes, wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in the pressure-demand or positive-pressure mode and full protective clothing. Thoroughly decontaminate firefighting equipment after use. Be aware of runoff from fire control methods. Do not release to sewers or waterways.

Section 5. Reactivity Data

Stability/Polymerization: *p*-Dichlorobenzene is stable at room temperature in closed containers under normal storage and handling conditions. Hazardous polymerization cannot occur.

Chemical Incompatibilities: *p*-Dichlorobenzene is incompatible with strong oxidizers and oxidizing agents.

Conditions to Avoid: Avoid incompatibilities and heat or ignition sources.

Hazardous Products of Decomposition: Thermal oxidative decomposition of *p*-dichlorobenzene includes carbon monoxide, chlorides, and chlorine.

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Material Safety Data Sheets Collection:

Sheet No. 358
o-Dichlorobenzene

Issued: 11/77 Revision: C, 8/90

Section 1. Material Identification

o-Dichlorobenzene ($C_6H_4Cl_2$) Description: Prepared by the chlorination of benzene or monochlorobenzene in the presence of a catalyst. Used as a solvent for waxes, gums, tars, resins, oils, and asphalts; an insecticide for locust borers and termites; a degreasing agent for metals, leather, and wool; an intermediate in manufacturing dyes; an ingredient of metal polishes; an industrial odor control; a heat transfer medium; and in removing sulfur from illuminating gas.
Other Designations: CAS No. 0095-50-1, DCB, 1,2-dichlorobenzene, orthodichlorobenzene.
Manufacturer: Contact your supplier or distributor. Consult the latest *Chemicalweek Buyers' Guide*(TM) for a suppliers list.

R 1
I 3
S 2*
K 2
* Skin absorption

NFPA
2 2 0

HMIS
H 2
F 2
R 0
PPG*
* Sec. 8

Caution: *o*-Dichlorobenzene is a local irritant, a strong central nervous system (CNS) depressant, and a liver and kidney poison.

Section 2. Ingredients and Occupational Exposure Limits

o-Dichlorobenzene*

1989 OSHA PEL
15-min STEL (ceiling): 50 ppm, 300 mg/m³

1989-90 ACGIH
TLV-STEL (ceiling): 50 ppm, 301 mg/m³

1985-86 Toxicity Data†
Rat, inhalation, LC_{Lo}: 821 ppm inhaled over 7 hr produces changes in behavior (general anesthetic), liver (hepatitis: hepatocellular necrosis, zonal) and sense organs, and special senses (tearing)
Rat, oral, LD_{50}: 500 mg/kg; toxic effects not yet reviewed
Rabbit, eye: 100 mg/30-s rinse produces mild irritation

1987 IDLH Level
1700 ppm

1988 NIOSH REL
None established

* This material may contain some impurities. It is at least 85% *o*-dichlorobenzene, but may contain varying percentages of *para*- and *meta*-dichlorobenzene.
† See NIOSH, *RTECS* (CZ4500000), for additional irritative, mutative, reproductive, and toxicity data.

Section 3. Physical Data

Boiling Point: 356.9 °F (180.5 °C) at 760 mm Hg
Melting Point: 1.4 °F (-17 °C)
Vapor Pressure: 1.47 mm Hg at 25 °C
Vapor Density (Air = 1): 5.05

Molecular Weight: 147.01
Specific Gravity 20°C/4°C: 1.3059
Water Solubility: Practically insoluble (137 mg/liter at 25°C)

% Volatile by Volume: ca 100
Evaporation Rate (BuAc = 1): <1

Appearance and Odor: A colorless liquid with a disagreeable, aromatic odor. The high and low odor thresholds are 300 and 12 mg/m³; *o*-dichlorobenzene is irritating at 150 mg/m³. The odor is perceptible at 2 to 4 ppm.

Section 4. Fire and Explosion Data

Flash Point: 151 °F (66 °C), CC	Autoignition Temperature: 1198 °F (648 °C)	LEL: 2.2% v/v	UEL: 9.2% v/v

Extinguishing Media: Extinguish fires involving this combustible material with water spray, dry chemical, foam, or carbon dioxide.
Unusual Fire or Explosion Hazards: Under normal working conditions, *o*-dichlorobenzene should not pose a fire hazard because of its high flash point. However, explosive mixtures may form if this material is heated or in a fire situation.
Special Fire-fighting Procedures: Since fire may produce toxic fumes, wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in the pressure-demand or positive-pressure mode and a fully encapsulating suit. Use water to cool fire-exposed containers, to flush spill away from exposures, and to protect workers attempting to stop a leak. Be aware of runoff from fire control methods. Do not release to sewers or waterways.

Section 5. Reactivity Data

Stability/Polymerization: *o*-Dichlorobenzene is stable at room temperature in closed containers under normal storage and handling conditions. Hazardous polymerization cannot occur.
Chemical Incompatibilities: This material can react vigorously with oxidizing materials. If *o*-dichlorobenzene is stored in sealed aluminum containers, a slow reaction with the aluminum could lead to an explosion.
Conditions to Avoid: Avoid heat and hot surfaces.
Hazardous Products of Decomposition: Thermal oxidative decomposition of *o*-dichlorobenzene can emit toxic fumes of chlorine (Cl^-).

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Section 6. Health Hazard Data

Carcinogenicity: *p*-Dichlorobenzene is an NTP anticipated human carcinogen and an IARC possible human carcinogen (Group 2B) with inadequate human evidence and sufficient animal evidence.
Summary of Risks: This material has a relatively low level of acute or chronic toxicity. It may be irritating to eyes, nose, upper airways, and [illegible]nal tract upon inhalation or ingestion. Limited case reports link acute exposure to hemolytic anemia, jaundice, methemglobinemia, granulo[illegible] of the lung, liver atrophy, toxic hepatitis, kidney injury, and allergic pigmentation and purpura (tiny hemorrhages) of the skin. Occupational studies of PDB-exposed workers reveal none of the blood abnormalities noted with similar substances. Vapors may produce painful irritation of the eyes at 50 to 80 ppm and severe discomfort at 160 ppm.
Medical Conditions Aggravated by Long-Term Exposure: Individuals with liver disease should not be exposed to *p*-dichlorobenzene.
Target Organs: Liver, respiratory system, eyes, kidneys, and skin.
Primary Entry Routes: Inhalation and dermal contact.
Acute Effects: Acute exposures to PDB vapor may be irritating to mucous membranes of the eyes and upper respiratory tract. Ingestion of the solid resulted in toxicity to a 3-year old child, with hemolytic anemia, jaundice, and methemglobinemia. Nausea, vomiting, and diarrhea are seen in other cases. Prolonged skin exposure may cause skin irritation.
Chronic Effects: Limited case studies show chronic toxicity with exposure to PDB. Chronic ingestion is linked to anemia, leukemia, and kidney damage. In one case, chemical dependence was noted with signs of withdrawal when ingestion stopped. Chronic vapor exposure is suggested in cases of lung granulomatosis, liver abnormalities, kidney damage, anemia, other blood cell abnormalities, and cataract formation.
FIRST AID
Eyes: Gently lift the eyelids and flush immediately and continuously with flooding amounts of water until transported to an emergency medical facility. Consult a physician immediately.
Skin: *Quickly* remove contaminated clothing. Rinse with flooding amounts of water for at least 15 min. For reddened or blistered skin, consult a physician. Wash affected area with soap and water.
Inhalation: Remove exposed person to fresh air and support breathing as needed.
Ingestion: Never give anything by mouth to an unconscious or convulsing person. If ingested, have that conscious person drink 1 to 2 glasses of water, then induce vomiting. Consult a physician.
After first aid, get appropriate in-plant, paramedic, or community medical support.
Note to Physicians: Urinary excretion of 2,5-dichlorophenol, a metabolite of *p*-dichlorobenzene, may be useful as an index of exposure.

Section 7. Spill, Leak, and Disposal Procedures

Spill/Leak: Notify safety personnel, evacuate all unnecessary personnel, and remove or extinguish all heat and ignition sources. Cleanup personnel should protect against vapor inhalation and skin or eye contact. For liquid spills, take up spilled material with noncombustible absorbent material and place into clean metal containers for disposal. For large liquid spills, dike far ahead of spill to contain liquid. For dry spills, shovel spilled material into clean metal containers for disposal. Runoff to sewers or waterways may create health and explosion hazards. (96-hr LC_{50}, fathead minnow: 4.2 to 30 mg/l, moderately toxic.) Pesticide wastes are toxic. Follow applicable EPA and OSHA regulations (29 CFR 1910.120).
Disposal: Contact your supplier or a licensed contractor for detailed recommendations. Follow applicable Federal, state, and local regulations.
EPA Designations
Listed as a RCRA Hazardous Waste (40 CFR 261.33), Hazardous Waste No. U072
Listed as a CERCLA Hazardous Substance* (40 CFR 302.4), Reportable Quantity (RQ): 100 lb (45.4 kg) [* per Clean Water Act, Sec. 311(b)(4), [illegible] 307(a), and per RCRA, Sec. 3001]
[illegible] Extremely Hazardous Substance (40 CFR 355): Not listed
[illegible]ed as a SARA Toxic Chemical (40 CFR 372.65)
OSHA Designations
Listed as an Air Contaminant (29 CFR 1910.1000, Table Z-1-A)

Section 8. Special Protection Data

Goggles: Wear protective eyeglasses or chemical safety goggles, per OSHA eye- and face-protection regulations (29 CFR 1910.133).
Respirator: Seek professional advice prior to respirator selection and use. Follow OSHA respirator regulations (29 CFR 1910.134) and, if necessary, wear a NIOSH-approved respirator. A gas mask with organic vapor canister and dust filter is suitable to 1000 ppm. For emergency or nonroutine operations (cleaning spills, reactor vessels, or storage tanks), wear an SCBA. *Warning! Air-purifying respirators do not protect workers in oxygen-deficient atmospheres.*
Other: Wear impervious gloves, boots, aprons, and gauntlets to prevent prolonged or repeated skin contact. Neoprene gloves are recommended.
Ventilation: Provide general and local explosion-proof ventilation systems to maintain airborne concentrations below OSHA PELs and ACGIH TLVs (Sec. 2). Local exhaust ventilation is preferred since it prevents contaminant dispersion into the work area by controlling it at its source.[107]
Safety Stations: Make available in the work area emergency eyewash stations, safety/quick-drench showers, and washing facilities.
Contaminated Equipment: Never wear contact lenses in the work area: soft lenses may absorb, and all lenses concentrate, irritants. Remove this material from your shoes and equipment. Launder contaminated clothing before wearing.
Comments: Never eat, drink, or smoke in work areas. Practice good personal hygiene after using this material, especially before eating, drinking, smoking, using the toilet, or applying cosmetics.

Section 9. Special Precautions and Comments

Storage Requirements: Store in tightly closed containers in a cool, dry, well-ventilated area away from all heat and ignition sources and oxidizing agents. *p*-Dichlorobenzene melts at 127 °F (53 °C). Protect containers against physical damage.
Engineering Controls: Avoid dust or vapor inhalation and eye and skin contact (especially when heated). Institute a respiratory protection program that includes regular training, maintenance, inspection, and evaluation. Practice good personal hygiene and housekeeping procedures.
Other Precautions: Provide preplacement and annual physical examinations that emphasize the liver (liver function tests), upper respiratory tract, and eyes.

Transportation Data (49 CFR 172.101, .102)

DOT Shipping Name: Dichlorobenzene, para, solid
DOT Hazard Class: ORM-A
ID No.: UN1592
DOT Label: None
Packaging Exceptions: 173.505
Packaging Requirements: 173.510

IMO Shipping Name: *p*-Dichlorobenzene
IMO Hazard Class: 6.1
ID No.: UN1592
IMO Label: St. Andrews Cross
IMDG Packaging Group: III

MSDS Collection References: 1-7, 9, 10, 12, 14, 16, 23, 26, 31, 34, 38, 43, 48, 73, 84, 85, 89, 100, 101, 103, 124, 126, 127, 132, 133, 136, 138, 139, 140, 142, 143, 146, 148
Prepared by: MJ Allison, BS; **Industrial Hygiene Review:** DJ Wilson, CIH; **Medical Review:** W Silverman, MD; **Edited by:** JR Stuart, MS

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Material Safety Data Sheets Collection:

Sheet No. 316
Benzene

Issued: 11/78 Revision: E, 8/90

Section 1. Material Identification

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Benzene (C_6H_6) Description: Derived by fractional distillation of coal tar, hydrodealkylation of toluene or pyrolysis of gasoline, catalytic reforming of petroleum, and transalkylation of toluene by disproportionation reaction. Used as a fuel; a chemical reagent; a solvent for a large number of materials such as paints, plastics, rubber, inks, oils, and fats; in manufacturing phenol, ethylbenzene (for styrene monomer), nitrobenzene (for aniline), dodecylbenzene (for detergents), cyclohexane (for nylon), chlorobenzene, diphenyl, benzene hexachloride, maleic anhydride, benzene-sulfonic acid, artificial leather, linoleum, oil cloth, varnishes, and lacquers; for printing and lithography; in dry cleaning; in adhesives and coatings; for extraction and rectification; as a degreasing agent; in the tire industry; and in shoe factories. Benzene has been banned as an ingredient in products intended for household use and is no longer used in pesticides.
Other Designations: CAS No. 0071-43-2, benzol, carbon oil, coal naphtha, cyclohexatriene, mineral naphtha, nitration benzene, phene, phenyl hydride, pyrobenzol.
Manufacturer: Contact your supplier or distributor. Consult the latest *Chemicalweek Buyers' Guide*[73] for a suppliers list.

R	1
I	4
S	2*
K	4

*Skin absorption

NFPA: 3 / 2 / 0 / -

HMIS
H 3
F 3
R 0
PPG†
† Sec. 8

Cautions: Benzene is a confirmed *human carcinogen* by the IARC. *Chronic low-level exposure may cause cancer (leukemia) and bone marrow damage, with injury to blood-forming tissue.* It is also a dangerous fire hazard when exposed to heat or flame.

Section 2. Ingredients and Occupational Exposure Limits

Benzene, ca 100%*

1989 OSHA PELs
(29 CFR 1910.1000, Table Z-1-A)
8-hr TWA: 1 ppm, 3 mg/m³
15-min STEL: 5 ppm, 15 mg/m³

(29 CFR 1910.1000, Table Z-2)
8-hr TWA: 10 ppm
Acceptable Ceiling Concentration: 25 ppm
Acceptable Maximum Peak: 50 ppm (10 min)†

1989-90 ACGIH
TLV-TWA: 10 ppm, 32 mg/m³

1988 NIOSH RELs
TWA: 0.1 ppm, 0.3 mg/m³
Ceiling: 1 ppm, 3 mg/m³

1985-86 Toxicity Data‡
Man, oral, LD_{Lo}: 50 mg/kg; no toxic effect noted
Man, inhalation, TC_{Lo}: 150 ppm inhaled intermittently over 1 yr in a number of discrete, separate doses affects the blood (other changes) and nutritional and gross metabolism (body temperature increase)
Rabbit, eye: 2 mg administered over 24 hr produces severe irritation

* OSHA 29 CFR 1910.1000, Subpart Z, states that the final benzene standard in 29 CFR 1910.1028 applies to all occupational exposures to benzene except in some subsegments of industry where exposures are consistently under the action level (i.e., distribution and sale of fuels, sealed containers and pipelines, coke production, oil and gas drilling and production, natural gas processing, and the percentage exclusion for liquid mixtures); for the excepted subsegments, the benzene limits in Table Z-2 apply.
† Acceptable maximum peak above the acceptable ceiling concentration for an 8-hr shift.
‡ See NIOSH, *RTECS* (CY1400000), for additional irritative, mutative, reproductive, tumorigenic, and toxicity data.

Section 3. Physical Data

Boiling Point: 176 °F (80 °C)
Melting Point: 42 °F (5.5 °C)
Vapor Pressure: 100 mm Hg at 79 °F (26.1 °C)
Vapor Density (Air = 1): 2.7
Evaporation Rate (Ether = 1): 2.8

Molecular Weight: 78.11
Specific Gravity (15 °C/4 °C): 0.8787
Water Solubility: Slightly (0.180 g/100 g of H_2O at 25 °C)
% Volatile by Volume: 100
Viscosity: 0.6468 mPa at 20 °C

Appearance and Odor: A colorless liquid with a characteristic sweet, aromatic odor. The odor recognition threshold (100% of panel) is approximately 5 ppm (unfatigued) in air. Odor *is not* an adequate warning of hazard.

Section 4. Fire and Explosion Data

Flash Point: 12 °F (-11.1 °C), CC	Autoignition Temperature: 928 °F (498 °C)	LEL: 1.3% v/v	UEL: 7.1% v/v

Extinguishing Media: Use dry chemical, foam, or carbon dioxide to extinguish benzene fires. Water may be ineffective as an extinguishing agent since it can scatter and spread the fire. Use water spray to cool fire-exposed containers, flush spills away from exposures, disperse benzene vapor, and protect personnel attempting to stop an unignited benzene leak.
Unusual Fire or Explosion Hazards: Benzene is a Class 1B flammable liquid. A concentration exceeding 3250 ppm is considered a potential fire explosion hazard. Benzene vapor is heavier than air and can collect in low lying areas or travel to an ignition source and flash back. Explosive and flammable benzene vapor-air mixtures can easily form at room temperature. Eliminate all ignition sources where benzene is used, handled, or stored.
Special Fire-fighting Procedures: Isolate hazard area and deny entry. Since fire may produce toxic fumes, wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in the pressure-demand or positive-pressure mode and full protective equipment. Structural firefighter's protective clothing provides limited protection. Stay out of low areas. Be aware of runoff from fire control methods. Do not release to sewers or waterways. Runoff to sewer can create pollution, fire, and explosion hazard.

Section 5. Reactivity Data

Stability/Polymerization: Benzene is stable at room temperature in closed containers under normal storage and handling conditions. Hazardous polymerization cannot occur.
Chemical Incompatibilities: Benzene explodes on contact with diborane, permanganic acid, bromine pentafluoride, peroxodisulfuric acid, and peroxomonosulfuric acid. It ignites on contact with dioxygen difluoride, dioxygenyl tetrafluoroborate, iodine heptafluoride, and sodium peroxide + water. Benzene forms sensitive, explosive mixture with iodine pentafluoride, ozone, liquid oxygen, silver perchlorate, nitryl perchlorate, nitric acid, and arsenic pentafluoride + potassium methoxide (explodes above 30 °C). A vigorous or incandescent reaction occurs with bromine trifluoride, uranium hexafluoride, and hydrogen + Raney nickel [above 410 °F (210 °C)]. Benzene is incompatible with oxidizing materials.
Conditions to Avoid: Avoid heat and ignition sources.
Hazardous Products of Decomposition: Thermal oxidative decomposition of benzene can produce toxic gases and vapors such as carbon monoxide.

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Section 6. Health Hazard Data

Carcinogenicity: The ACGIH, OSHA, and IARC list benzene as, respectively, a suspected human carcinogen, a cancer hazard, and, based on sufficient human and animal evidence, a human carcinogen (Group 1).
Summary of Risks: Prolonged skin contact or excessive inhalation of benzene vapor may cause headache, weakness, appetite loss, and fatigue. The most important health hazards are cancer (leukemia) and bone marrow damage with injury to blood-forming tissue from chronic low-level exposure. Higher level exposures may irritate the respiratory tract and cause central nervous system (CNS) depression.
Medical Conditions Aggravated by Long-Term Exposure: Exposure may worsen ailments of the heart, lungs, liver, kidneys, blood, and CNS.
Target Organs: Blood, central nervous system, bone marrow, eyes, upper respiratory tract, and skin.
Primary Entry Routes: Inhalation, skin contact.
Acute Effects: Symptoms of acute overexposure include irritation of the eyes, nose, and respiratory tract, breathlessness, euphoria, nausea, drowsiness, headache, dizziness, and intoxication. Severe exposure may lead to convulsions and unconsciousness. Skin contact may cause a drying rash (dermatitis).
Chronic Effects: Long-term chronic exposure may result in many blood disorders ranging from aplastic anemia (an inability to form blood cells) to leukemia.
FIRST AID
Eyes: Gently lift the eyelids and flush immediately and continuously with flooding amounts of water until transported to an emergency medical facility. Consult a physician immediately.
Skin: *Quickly* remove contaminated clothing. Immediately rinse with flooding amounts of water for at least 15 min. For reddened or blistered skin, consult a physician. Wash affected area with soap and water.
Inhalation: Remove exposed person to fresh air. Emergency personnel should protect against inhalation exposure. Provide CPR to support breathing or circulation as necessary. Keep awake and transport to a medical facility.
Ingestion: Never give anything by mouth to an unconscious or convulsing person. If ingested, *do not induce vomiting* since aspiration may be fatal. Call a physician immediately.
After first aid, get appropriate in-plant, paramedic, or community medical support.
Physician's Note: Evaluate chronic exposure with a CBC, peripheral smear, and reticulocyte count for signs of myelotoxicity. Follow up any early indicators of leukemia with a bone marrow biopsy. Urinary phenol conjugates may be used for biological monitoring of recent exposure. Acute management is primarily supportive for CNS depression.

Section 7. Spill, Leak, and Disposal Procedures

Spill/Leak: *Design and practice a benzene spill control and countermeasure plan (SCCP).* Notify safety personnel, evacuate all unnecessary personnel, eliminate all heat and ignition sources, and provide adequate ventilation. Cleanup personnel should protect against vapor inhalation, eye contact, and skin absorption. Absorb as much benzene as possible with an inert, noncombustible material. For large spills, dike far ahead of spill and contain liquid. Use nonsparking tools to place waste liquid or absorbent into closable containers for disposal. Keep waste out of confined spaces such as sewers, waterbeds, and waterways because of explosion danger. Follow applicable OSHA regulations (29 CFR 1910.120).
Disposal: Contact your supplier or a licensed contractor for detailed recommendations. Follow applicable Federal, state, and local regulations.
EPA Designations
Listed as a RCRA Hazardous Waste (40 CFR 261.33), Hazardous Waste No. U019
Listed as a CERCLA Hazardous Substance* (40 CFR 302.4), Reportable Quantity (RQ): 1000 lb (454 kg) [* per Clean Water Act, Sec. 307 (a), 311 (b)(4), 112; and per RCRA, Sec. 3001]
SARA Extremely Hazardous Substance (40 CFR 355): Not listed
Listed as SARA Toxic Chemical (40 CFR 372.65)
OSHA Designations
Listed as an Air Contaminant (29 CFR 1910.1000, Tables Z-1-A and Z-2)

Section 8. Special Protection Data

Goggles: Wear protective eyeglasses or chemical safety goggles, per OSHA eye- and face-protection regulations (29 CFR 1910.133).
Respirator: Seek professional advice prior to respirator selection and use. Follow OSHA respirator regulations (29 CFR 1910.134) and, if necessary, wear a NIOSH-approved respirator. For emergency or nonroutine operations (cleaning spills, reactor vessels, or storage tanks), wear an SCBA. *Warning! Air-purifying respirators do not protect workers in oxygen-deficient atmospheres.*
Other: Wear impervious gloves, boots, aprons, and gauntlets to prevent skin contact.
Ventilation: Provide general and local explosion-proof ventilation systems to maintain airborne concentrations at least below the OSHA PELs (Sec. 2). Local exhaust ventilation is preferred since it prevents contaminant dispersion into the work area by controlling it at its source.[NIO]
Safety Stations: Make available in the work area emergency eyewash stations, safety/quick-drench showers, and washing facilities.
Contaminated Equipment: Never wear contact lenses in the work area: soft lenses may absorb, and all lenses concentrate, irritants. Remove this material from your shoes and equipment. Launder contaminated clothing before wearing.
Comments: Never eat, drink, or smoke in work areas. Practice good personal hygiene after using this material, especially before eating, drinking, smoking, using the toilet, or applying cosmetics.

Section 9. Special Precautions and Comments

Storage Requirements: Store in tightly closed containers in a cool, dry, well-ventilated area away from all heat and ignition sources and incompatible materials. *Caution! Benzene vapor may form explosive mixtures in air.* To prevent static sparks, electrically ground and bond all containers and equipment used in shipping, receiving, or transferring operations in production and storage areas. When opening or closing benzene containers, use nonsparking tools. Keep fire extinguishers readily available.
Engineering Controls: Because OSHA specifically regulates benzene (29 CFR 1910.1028), educate workers about its potential hazards and dangers. Minimize all possible exposures to carcinogens. If possible, substitute less toxic solvents for benzene; use this material with extreme caution and only if absolutely essential. Avoid vapor inhalation and skin and eye contact. Use only with adequate ventilation and appropriate personal protective gear. Institute a respiratory protection program that includes regular training, maintenance, inspection, and evaluation. Designate regulated areas of benzene use (see legend in the box below) and label benzene containers with "DANGER, CONTAINS BENZENE, CANCER HAZARD."
Other Precautions: Provide preplacement and periodic medical examinations with emphasis on a history of blood disease or previous exposure.

Transportation Data (49 CFR 172.101, .102)

DOT Shipping Name: Benzene (*benzol*)
DOT Hazard Class: Flammable liquid
ID No.: UN1114
DOT Label: Flammable liquid
DOT Packaging Exceptions: 173.118
DOT Packaging Requirements: 173.119

IMO Shipping Name: Benzene
IMO Hazard Class: 3.2
ID No.: UN1114
IMO Label: Flammable liquid
IMDG Packaging Group: II

DANGER
BENZENE
CANCER HAZARD
FLAMMABLE–NO SMOKING
AUTHORIZED PERSONNEL ONLY
RESPIRATOR REQUIRED

MSDS Collection References: 1, 2, 12, 26, 73, 84-94, 100, 101, 103, 109, 124, 126, 127, 132, 134, 136, 138, 139, 143
Prepared by: MJ Allison, BS; **Industrial Hygiene Review:** DJ Wilson, CIH; **Medical Review:** MJ Upfal, MD, MPH; **Edited by:** JR Stuart, MS

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Material Safety Data Sheets Collection:

Sheet No. 409
Cresol (Mixed Isomers)

Issued: 12/78 Revision: B, 3/92

Section 1. Material Identification

Cresol, *mixed isomers* ($CH_3C_6H_4OH$) Description: Derived from coal tar or petroleum. Cresol is marketed by individual isomer and as pure or crude cresol. Pure cresol is a mixture of *ortho*, *meta*, and *para* isomers. Crude cresol (commercial cresol) is prepared by distilling "grey phenic acid" at 356 to 401 °F (180 to 205 °C) and is comprised of 20% *ortho*, 40% *meta*, and 30% *para* isomers, plus small amounts of phenol and xylenols. Each isomer can be prepared synthetically by diazotization of the specific corresponding toluidine. Used in manufacturing synthetic resins, explosives, photographic developers, petroleum, paint, disinfectants, and fumigants; as an ore flotation agent; and in the agriculture industry for herbicides and insecticides.
Other Designations: CAS No. 1319-77-3, Bacillol, cresylic acid, Tekresol, tricresol.
Manufacturer: Contact your supplier or distributor. Consult latest *Chemical Week Buyers' Guide*(73) for a suppliers list.

Caution: Cresol is severely irritating to mucous membranes, eyes, and skin. Depending on the cresol concentration, extent of exposure, and amount of skin exposed, toxicity may be slight (irritation) or severe (permanent injury or death).

R 1
I 4
S 3*
K 2
* Skin absorption

NFPA
2 / 3 / 0 / —

HMIS
H 3
F 2
R 0
PPG†
† Sec. 8

Section 2. Ingredients and Occupational Exposure Limits

Cresol (*mixed isomers*) National Formulary (NF) grade contains < 5% phenol

1990 OSHA PEL (Skin)
8-hr TWA: 5 ppm (22 mg/m³)

1990 NIOSH REL
TWA: 5 ppm (22 mg/m³)

1990 IDLH Level
250 ppm

1991-92 ACGIH TLV (Skin)
TWA: 5 ppm (22 mg/m³)

1990 DFG (Germany) MAK
TWA: 5 ppm (22 mg/m³) (H)*
Peak Exposure Limit: 10 ppm, 5 min, momentary value/8 per shift

1985-86 Toxicity Data†
Rat, oral, LD_{50}: 1454 mg/kg; toxic effects not yet reviewed
Mouse, inhalation, LC_{50}: 179 mg/m³/2 hr; no toxic effects noted (*o*-)
Rabbit, eye: 103 mg produced severe irritation (*p*-)
Rabbit, skin: 517 mg applied for 24 hr produced severe irritation (*m*-)
Rabbit, skin, LD_{50}: 2000 mg/kg; toxic effects not yet reviewed

* Danger of cutaneous absorption.
† See NIOSH, *RTECS* (GO5950000), for additional toxicity data. For data on specific isomers, see *RTECS* (GO6125000, *meta*; GO6300000, *ortho*; and GO6475000, *para*).

Section 3. Physical Data

Boiling Point Range: 375.8 to 397.4 °F (191 to 203 °C)
Melting Point Range: 51.8 to 95 °F (11 to 35 °C)
Vapor Pressure: 0.25 (*ortho*), 0.15 (*meta*), 0.11 (*para*) mm Hg at 68 °F (20 °C)
Vapor Density (air = 1): 3.72
pH: Saturated solutions are neutral or slightly acidic to litmus
Viscosity: 4.49 to 7.0 cP at 104 °F (40 °C)

Molecular Weight: 108.13
Specific Gravity: 1.030 to 1.038 at 77 °F (25 °C)
Water Solubility: Soluble, 1%
Other Solubilities: Soluble in alcohol, ether, dilute alkalies, glycol and vegetable oils
Refraction Index: 1.5353 at 75.2 °F (24 °C)
Odor Threshold: Low, 0.012 mg/m³; high, 22 mg/m³

Appearance and Odor: Colorless, yellow, or pinkish liquid turning brown on exposure to air or light with a phenolic odor and pungent taste.

Section 4. Fire and Explosion Data

Flash Point: 178 °F (81.11 °C, *ortho*), 187 °F (86.11 °C, *meta* and *para*), CC	Autoignition Temperature: 1110 °F (559 °C, *ortho*), 1038 °F (558 °C, *meta* and *para*)	LEL: 1.4% (*ortho*), 1.1% (*meta* and *para*) at 302 °F (150 °C)	UEL: None reported

Extinguishing Media: While cresol does not ignite easily, it burns. For small fires, use dry chemical, carbon dioxide (CO_2), water spray, or regular foam. For large fires, use water spray, fog, or regular foam. Do not scatter material with more water than is necessary to put out fire.
Unusual Fire or Explosion Hazards: Container may explode in heat of fire.
Special Fire-fighting Procedures: Since fire may produce toxic thermal decomposition products, wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in pressure-demand or positive-pressure mode. Structural firefighters' protective clothing is ineffective for fires involving cresol. Use clothing the manufacturer recommends specifically for use with cresol. If possible without risk, remove container from fire area. Fight fire from maximum distance. Stay away from ends of tanks. Be aware of runoff from fire control methods. Do not release to sewers or waterways.

Section 5. Reactivity Data

Stability/Polymerization: Cresol is stable at room temperature in closed containers under normal storage and handling conditions. Hazardous polymerization cannot occur.
Chemical Incompatibilities: Cresol reacts with oxidizing materials and causes a temperature and pressure increase with chlorosulfonic acid, nitric acid, and oleum.
Conditions to Avoid: Ignition sources and contact with incompatibles.
Hazardous Products of Decomposition: Thermal oxidative decomposition of cresol can produce carbon dioxide (CO_2) and toxic cresol fumes.

Section 6. Health Hazard Data

Carcinogenicity: The IARC,(164) NTP,(162) and OSHA(166) do not list cresol as a carcinogen. Summary of Risks: Cresol is corrosive to eyes, skin, and mucous membranes. Degree of toxicity depends on the cresol concentration involved, amount of surface area exposed, and duration of exposure. Ingestion is corrosive to the digestive tract's mucous membranes and can pose serious problems if not treated promptly. Because cresol has a low vapor pressure, it is not volatile enough under normal conditions to present an inhalation hazard. If heated, vapor inhalation is likely. Severe chemical burns and dermatitis are the main hazards in industry. Note that cresol's *ortho* and *para* isomers (if used individually) are in crystal form and thus are a dust inhalation hazard. By all routes of exposure, cresol produces toxic symptoms similar to phenol's. Medical Conditions Aggravated by Long-Term Exposure: Skin diseases. Target Organs: Eyes, skin, central nervous system (CNS), liver and kidney. Primary Entry Routes: Skin and eye contact/absorption. Acute Effects: Cresol is absorbed through skin, open wounds, and the mucous membranes of the respiratory and digestive tracts. The rate at which skin absorbs cresol depends more on the size of exposure area than on the concentration of material applied. Cresol is corrosive to the skin causing smarting; tingling; redness; swelling; burns that may be very painful and become white and wrinkled with softening that may become gangrenous; blisters; possible shock as a result

Continue on next page

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Section 6. Health Hazard Data, *continued*

of pain; and, in severe cases of absorption, coma and death. Contact with eyes may cause stinging, and burning, watering of eyes, redness and swelling of corneal opaqueness causing blurred vision and possible loss of sight. In rare cases, a pigment disorder called ochronosis occurs characterized by ...ning of skin, conjunctiva, and cartilage of the nose and ears. Ingestion leads to burning of lips, mouth, and throat, pain in swallowing, ulceration of mucous membranes of the mouth, color change of the tongue (white), thirst, throat swelling, cramps, nausea and vomiting (sometimes of coffee grounds-like material due to digestive hemorrhage). In severe cases symptoms might progress to shock, convulsions, coma, and death. If vapor inhalation occurs, symptoms include irritation of mucous membranes of nose, eyes, and mouth, watering of eyes, sneezing, coughing, difficulty breathing, headache, nausea, muscle weakness, and possible pulmonary edema. In most cases of exposure, if death occurs, it is usually caused by respiratory failure. Chronic Effects: Repeated exposure to cresol may cause digestive disturbances, liver, kidney, spleen and pancreatic damage, and skin eruptions or dermatitis. Some people can become allergic or hypersensitive to cresol.

FIRST AID: *Emergency personnel should protect against contamination.*

Eyes: Gently lift eyelids and flush immediately and continuously with flooding amounts of water until transported to an emergency medical facility. *Do not* allow victim to rub or keep eyes tightly shut. Consult a physician immediately. Skin: *Quickly* remove contaminated clothing to prevent burns. Rinse with flooding amounts of water for at least 15 min. If clothing is stuck to skin after flushing with water, *do not* remove! Thoroughly wash exposed area with soap and water. For reddened or blistered skin, consult a physician. Inhalation: Remove exposed person to fresh air and support breathing as needed. Ingestion: Never give anything by mouth to an unconscious or convulsing person. Contact a poison control center. Unless the poison control center advises otherwise, have that *conscious and alert* person drink 1 to 2 glasses of water, then induce vomiting with 2 tablespoons of Ipecac (adult dose). After patient vomits, give activated charcoal in 8 oz. of water to drink. After first aid, get appropriate in-plant, paramedic, or community medical support.

Note to Physicians: Since effects may be delayed, keep victim under observation. Irrigate eyes and wash skin with a mixture of polyethylene glycol 300 and industrial methylated spirits (PEG 300/IMS, 2:1 by volume). Recommended treatment for ingestion is repeated gastric lavage with large quantities of olive oil.

Section 7. Spill, Leak, and Disposal Procedures

Spill/Leak: Immediately notify safety personnel, isolate and ventilate area (with fixed or portable fan systems for cross-ventilation), deny entry, and stay upwind. Shut off all ignition sources. Spilled liquid can be neutralized with crushed limestone or soda ash. Take up small spills with earth, sand, vermiculite or other absorbent, noncombustible material and place into suitable containers. For large spills, dike far ahead of liquid for later disposal or reclamation. For water spills, you may need to trap cresol at the bottom with sandbag barriers, apply activated charcoal, and then remove trapped material with dredges or lifts. Follow applicable OSHA regulations (29 CFR 1910.120).

Environmental Degradation: When released into the atmosphere, cresol degrades by reacting with photochemically produced hydroxyl radicals during the day (half-life = 8 to 10 hr), and with nitrate radicals at night (half-life = 2 to 5 min). Cresol biodegrades in eutrophic (nutrient-rich) waters.

Ecotoxicity Values: Blue gill, TL_{50}, 24 mg/L/96 hr (fresh water); shrimp, TL_{50}, 10 to 100 ppm/48 hr (saltwater).

Soil Absorption/Mobility: Cresol is mobile in soil but biodegradation is probable. Cresols probably leach due to water solubility.

Disposal: Contact your supplier or a licensed contractor for detailed recommendations. Follow applicable Federal, state, and local regulations.

EPA Designations

...sted as a RCRA Hazardous Waste (40 CFR 261.33): No. U052*

...d as a CERCLA Hazardous Substance† (40 CFR 302.4): Reportable ...antity (RQ), 1000 lb (454 kg) [† per RCRA, Sec. 3001 and CWA, Sec. 311(b)(4)]

...d (*o-cresol only*) as a SARA Extremely Hazardous Substance (40 CFR 355)

Listed as a SARA Toxic Chemical (40 CFR 372.65)

OSHA Designations

Listed as an Air Contaminant (29 CFR 1910.1000, Table Z-1-A)

* When a spent solvent and classified as a hazardous waste from nonspecific sources, cresol has Hazardous Waste No. F004.

Section 8. Special Protection Data

Goggles: Wear protective eyeglasses or chemical safety goggles or faceshields to protect against droplets or spray, per OSHA eye- and face-protection regulations (29 CFR 1910.133). Because contact lens use in industry is controversial, establish your own policy.

Respirator: Seek professional advice prior to respirator selection and use. Follow OSHA respirator regulations (29 CFR 1910.134) and, if necessary, wear a MSHA/NIOSH-approved respirator. Select respirator based on its suitability to provide adequate worker protection for given working conditions, level of airborne contamination, and presence of sufficient oxygen. At 50 to 500 ppm use a full face gas mask. For emergency or nonroutine operations (cleaning spills, reactor vessels, or storage tanks), wear an SCBA. *Warning! Air-purifying respirators do not protect workers in oxygen-deficient atmospheres.* If respirators are used, OSHA requires a respiratory protection program that includes: training, fit-testing, periodic environmental monitoring, maintenance, inspection, cleaning, and convenient, sanitary storage areas.

Other: Wear chemically protective gloves, boots, aprons, and gauntlets to prevent all skin contact. Rubber is suggested as a material suitable for protection against cresol.

Ventilation: Provide general and local exhaust ventilation systems to maintain airborne concentrations below the OSHA PEL (Sec. 2). Local exhaust ventilation is preferred because it prevents contaminant dispersion into the work area by controlling it at its source.[100]

Safety Stations: Make available in the work area emergency eyewash stations, safety/quick-drench showers, and washing facilities.

Contaminated Equipment: Separate contaminated work clothes from street clothes. Launder contaminated work clothing before wearing. Remove this material from your shoes and clean personal protective equipment.

Comments: Never eat, drink, or smoke in work areas. Practice good personal hygiene after using this material, especially before eating, drinking, smoking, using the toilet, or applying cosmetics.

Section 9. Special Precautions and Comments

Storage Requirements: Prevent physical damage to containers. Store in properly labelled (with trade name) iron or steel containers in cool, dry, well-ventilated location. Protect from light and keep away from incompatibles (Sec. 5). Outside or detached storage is preferred. To prevent static sparks, electrically ground and bond all equipment used in cresol manufacture, use, and storage.

Engineering Controls: To reduce potential health hazards, use sufficient dilution or local exhaust ventilation to control airborne contaminants and to maintain concentrations at the lowest practical level.

Administrative Controls: Consider preplacement and periodic examinations of exposed workers that emphasize skin, kidney, liver, and respiratory system.

Transportation Data (49 CFR 172.101, .102)

Shipping Name: Cresol
Hazard Class: Corrosive material
...: UN2076
...T Label: Corrosive
DOT Packaging Exceptions: 173.244
DOT Packaging Requirements: 173.245

IMO Shipping Name: Cresols (*o-*, *m-*, *p-*)
IMO Hazard Class: 6.1
ID No.: UN2076
IMO Label: Poison
IMDG Packaging Group: II

MSDS Collection References: 26, 38, 73, 89, 100, 101, 103, 124, 126, 127, 132, 133, 136, 140, 153, 159, 162, 163, 164

Prepared by: M Gannon, BA; Industrial Hygiene Review: PA Roy, MPH, CIH; Medical Review: AC Darlington, MPH, MD; Edited by: JR Stuart, MS

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Material Safety Data Sheet Collection

Methylene Chloride **MSDS No. 310**

Date of Preparation: 11/77 Revision: G, 6/94

Section 1 - Chemical Product and Company Identification

44

Product/Chemical Name: Methylene Chloride
Chemical Formula: CH_2Cl_2
CAS No.: 75-09-2
Synonyms: DCM, dichloromethane, Freon 30, methylene bichloride, methylene dichloride, NCI-C50102, Solmethine
Derivation: Produced by chlorination of methane.
General Use: Used as a solvent for cellulose acetate, adhesives, food processing, and pharmaceuticals; in degreasing and cleaning fluids, paint and varnish removers, decaffeination of coffee, in propellant mixtures for aerosols; as a blowing agent in foams, dewaxing agent, component of fire extinguishing compound, chemical intermediate, low temperature heat-transfer medium, and as a fumigant. Formerly used as an anesthetic.
Vendors: Consult the latest *Chemical Week Buyers' Guide.* (73)

Section 2 - Composition / Information on Ingredients

Methylene chloride, ca < 100 % vol
Trace Impurities: Stabilizers may be added such as: amines, 4-cresol, hydroquinone, methanol, 2-methyl-2-ene, 1-naphthol, nitromethane + 1,4-dioxane, phenol, resorcinol, and thymol.

OSHA PELs
8-hr TWA: 500 ppm*
Ceiling: 1000 ppm (2000 ppm 5 min. peak in any 2 hr period)

ACGIH TLV
TWA: 50 ppm (174 mg/m^3)

NIOSH REL
Carcinogen; lowest feasible concentration.

IDLH Level
Ca [5000 ppm]

DFG (Germany) MAK
TWA: 100 ppm (360 mg/m^3)
Category II: Substances with systemic effects
Onset of Effect: < 2 hr
Half-life: 2 hr to shift length

Peak Exposure Limit:
500 ppm, 30 min. average value, 2/shift

*Proposed change to: 25 ppm (TWA); 125 ppm (STEL)

Section 3 - Hazards Identification

☆☆☆☆☆ Emergency Overview ☆☆☆☆☆

Methylene chloride is a colorless, volatile liquid with a sweet odor. It is irritating to the eyes, skin, and respiratory tract. At high concentrations it can cause narcosis (unconsciousness). Methylene chloride is metabolized to carbon monoxide in the body which contributes to much of its toxicity. It can form flammable mixtures with air (forming toxic phosgene when burned) and becomes explosive when mixed with oxygen.

Wilson Risk Scale
R 1
I 3
S 2*
K 1
*Skin absorption

HMIS
H 2*
F 1
R 0
*Chronic Effects
PPE†
†Sec. 8

Potential Health Effects

Primary Entry Routes: Inhalation, skin and eye contact.
Target Organs: Eyes, skin, central nervous system (CNS), cardiovascular system (CVS), blood.
Acute Effects
Inhalation: Symptoms include headache, giddiness, irritability, nausea, stupor, numbness and tingling of limbs, fatigue, anemia and polymorphonuclear leukocytosis, digestive disturbances, and neurasthenic disorders (emotional and psychic disorders characterized by easy fatigue, lack of motivation, feelings of inadequacy, and psychosomatic symptoms). Many symptoms are attributed to the metabolism of methylene chloride to carbon monoxide in the body. The carbon monoxide forms carboxyhemoglobin in the blood, which unlike hemoglobin, does not have the ability to carry oxygen. This lack of oxygen leads to CNS and CVS problems. However, CNS effects *have* been seen in persons without a significantly elevated blood carbon monoxide level.
Eye: Exposure to vapors produces irritation, tearing, and conjunctivitis. Direct contact with the liquid causes severe pain, but permanent damage does not occur.
Skin: Contact is irritating and can be painful (burns) if confined to skin (i.e. trapped under gloves or clothing). Methylene chloride can be absorbed through the skin to cause systemic effects.
Ingestion: Expected to cause gastrointestinal irritation, nausea, vomiting, and systemic effects (see inhalation).
Carcinogenicity: IARC (Class 2B, possibly carcinogenic to humans with limited human and sufficient animal evidence), NTP (Class 2, reasonably anticipated to be a carcinogen with limited human and sufficient animal evidence), ACGIH (TLV-A2, suspected human carcinogen as agent is carcinogenic in animals at dose levels considered relevant to worker exposure but insufficient epidemiological studies are available to confirm an increased cancer risk), NIOSH (Class X, carcinogen defined without further categorization), EPA (Class B2, sufficient evidence from animal studies and inadequate or no data from epidemiologic studies), and DFG (MAK B, justifiably suspected of having carcinogenic potential).
Medical Conditions Aggravated by Long-Term Exposure: Skin and cardiovascular disorders.

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Chronic Effects: Repeated skin contact can cause dermatitis. Liver disease has been reported. *Case Reports*: 1 yr exposure caused toxic encephalopathy (toxicity of the brain) with audio and visual delusions and hallucinations; 3 yr exposure to 300 to 1000 ppm caused memory loss, intellectual impairment, and balance disturbances.

Other: Methylene chloride will cross the placenta. The estimated lethal dose is 0.5 to 5 mL/kg. Although methylene chloride has a distinct sweetish odor, it is not recognized at levels low enough to protect from overexposure.

Section 4 - First Aid Measures

Inhalation: Remove exposed person to fresh air, administer 100% humidified, supplemental oxygen and support breathing.

Eye Contact: *Do not* allow victim to rub or keep eyes tightly shut. Gently lift eyelids and flush immediately and continuously with flooding amounts of water for at least 15 min. Consult an ophthalmologist if pain or irritation persist.

Skin Contact: *Quickly* remove contaminated clothing. Rinse with flooding amounts of water for at least 15 min. Wash exposed area with soap and water. For reddened or blistered skin, consult a physician.

Ingestion: Never give anything by mouth to an unconscious or convulsing person. Contact a poison control center. Unless the poison control center advises otherwise, have the *conscious and alert* person drink 1 to 2 glasses of water, then induce vomiting with Ipecac syrup. If vomiting does not occur, the decision to perform gastric lavage should be made.

After first aid, get appropriate in-plant, paramedic, or community medical support.

Note to Physicians: Lethal blood level = 280 mg/L. Biological monitoring: carbon monoxide in expired air (nonsmokers only). Recently, methylene chloride concentrations in urine have been found to correlate well to concentrations in air.

Section 5 - Fire-Fighting Measures

NFPA

Flash Point: Methylene chloride does not have a flash point by standard tests. However, it does form flammable mixtures with air.

Autoignition Temperature: 1033 °F (556 °C)

LFL: 12% v/v

UFL: 19% v/v

LEL: 15.5% (in oxygen)

UEL: 66.4% (in oxygen)

Extinguishing Media: For small fires, use dry chemical or carbon dioxide. For large fires, use water spray, fog, or regular foam.

Unusual Fire or Explosion Hazards: Creates an explosion hazard if allowed to enter a confined space. Container may explode in heat of fire.

Hazardous Combustion Products: Hydrogen chloride, carbon monoxide and phosgene.

Fire-Fighting Instructions: Apply cooling water to sides of tanks until well after fire is out. Stay away from ends of tanks. Do not release runoff from fire control methods to sewers or waterways.

Fire-Fighting Equipment: Because fire may produce toxic thermal decomposition products, wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in pressure-demand or positive-pressure mode. Structural firefighters' protective clothing provides only limited protection.

Section 6 - Accidental Release Measures

Spill /Leak Procedures: Notify safety personnel, isolate and ventilate area, deny entry, and stay upwind. Shut off ignition sources. Cleanup personnel need to protect against inhalation and skin/eye contact.

Small Spills: Take up with earth, sand, vermiculite, or other absorbent, noncombustible material.

Large Spills

Containment: Dike far ahead of spill for later reclamation or disposal. Do not release into sewers or waterways.

Cleanup: Damp mop any residue.

Regulatory Requirements: Follow applicable OSHA regulations (29 CFR 1910.120).

Section 7 - Handling and Storage

Handling Precautions: Do not use near ignition sources. Wear appropriate PPE. Do not use plastic or rubber hose for unloading trucks or tank cars unless the materials have been tested and approved for methylene chloride service.

Storage Requirements: Store in a cool, dry, well-ventilated area away from heat, ignition sources, and incompatibles (Sec. 10). To minimize decomposition, all storage containers should be galvanized or lined with a phenolic coating. Indoor storage tanks should have vents piped outdoors to prevent vapors from escaping into work areas. Prevent moisture from entering tanks.

Section 8 - Exposure Controls / Personal Protection

Engineering Controls: Do not use closed circuit rebreathing systems employing soda lime or other carbon dioxide absorber because of formation of toxic compounds capable of producing cranial nerve paralysis. To prevent static sparks, electrically ground and bond all equipment used with and around methylene chloride.

Ventilation: Provide general or local exhaust ventilation systems to maintain airborne levels below OSHA PELs (Sec. 2). Local exhaust ventilation is preferred because it prevents contaminant dispersion into the work area by controlling it at its source.(103)

Administrative Controls: Consider preplacement and periodic medical exams of exposed workers with emphasis on skin, liver, CNS, CVS, and blood. A complete blood count should be performed and carboxyhemoglobin levels should be determined

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periodically. Any level above 5% should prompt investigation of employee and workplace to determine the cause (smokers will already have an increased level of carboxyhemoglobin and are at increased risk). Use less hazardous solvents where possible.

Respiratory Protection: Seek professional advice prior to respirator selection and use. Follow OSHA respirator regulations (29 CFR 1910.134) and, if necessary, wear a MSHA/NIOSH-approved respirator. For any detectable concentration, use any SCBA or supplied-air respirator (with auxiliary SCBA) with a full facepiece and operated in pressure demand or other positive-pressure mode. For emergency or nonroutine operations (cleaning spills, reactor vessels, or storage tanks), wear an SCBA. *Warning! Air-purifying respirators do not protect workers in oxygen-deficient atmospheres.* If respirators are used, OSHA requires a written respiratory protection program that includes at least: medical certification, training, fit-testing, periodic environmental monitoring, maintenance, inspection, cleaning, and convenient, sanitary storage areas.

Protective Clothing/Equipment: Wear chemically protective gloves, boots, aprons, and gauntlets to prevent prolonged or repeated skin contact. Polyvinyl alcohol and Viton laminated with Neoprene are suitable materials for PPE. Natural rubber, synthetic rubbers, and polyvinyl chloride *do not* provide protection against methylene chloride. Wear protective eyeglasses or chemical safety goggles, per OSHA eye- and face-protection regulations (29 CFR 1910.133). Contact lenses are not eye protective devices. Appropriate eye protection must be worn instead of, or in conjunction with contact lenses.

Safety Stations: Make emergency eyewash stations, safety/quick-drench showers, and washing facilities available in work area.

Contaminated Equipment: Separate contaminated work clothes from street clothes. Launder before reuse. Remove methylene chloride from your shoes and clean personal protective equipment.

Comments: Never eat, drink, or smoke in work areas. Practice good personal hygiene after using methylene chloride, especially before eating, drinking, smoking, using the toilet, or applying cosmetics.

Section 9 - Physical and Chemical Properties

Physical State: Liquid
Appearance and Odor: Colorless; volatile with a sweet odor.
Odor Threshold: 205 to 307 ppm
Vapor Pressure: 350 mm Hg at 68 °F (20 °C); 440 mm Hg at 77 °F (25 °C)
Saturated Vapor Density (Air = 1.2 kg/m^3, 0.075 lb/ft^3): 2.256 kg/m^3 or 0.141 lb/ft^3
Formula Weight: 84.9
Specific Gravity (H_2O=1, at 4 °C): 1.33 at 15 °C
Water Solubility: 2%
Octanol/Water Partition Coefficient: log Kow = 1.25
Other Solubilities: Soluble in alcohol, acetone, chloroform, carbon tetrachloride, ether, and dimethylformamide.
Boiling Point: 104 °F (40 °C)
Freezing Point: -142 °F (-97 °C)
Viscosity: 0.430 cP at 68 °F (20 °C)
Refractive Index: 1.4244 at 68 °F (20 °C/D)
Surface Tension: 0.5 to 2.3 g/L (*in oxygen*)
Bulk Density: 11.07 lb/gal at 68 °F (20 °C)
Ionization Potential: 11.32 eV
Critical Temperature: 473 °F (245 °C)
Critical Pressure: 60.9 atm

Section 10 - Stability and Reactivity

Stability: Methylene chloride is stable at room temperature in closed containers under normal storage and handling conditions. Tends to carbonize when vapor contacts steel or metal chlorides at high temperatures 572 to 842 °F (300 to 450 °C).

Polymerization: Hazardous polymerization does not occur.

Chemical Incompatibilities: Include aluminum, lithium, sodium, aluminum bromide, azides, dimethyl sulfoxide + perchloric acid, N-methyl-N-nitrosourea + potassium hydroxide, sodium-potassium alloy, potassium *t*-butoxide, dinitrogen pentoxide, dinitrogen tetraoxide, nitric acid, and oxidizers. Methylene chloride will attack some forms of plastic, rubber, and coatings. Corrodes iron, some stainless steel, copper, and nickel.

Conditions to Avoid: Exposure to heat, ignition sources, and incompatibles.

Hazardous Decomposition Products: Hydrogen chloride, carbon monoxide and phosgene.

Section 11- Toxicological Information

Toxicity Data:*

Eye Effects:
Rabbit, eye: 162 mg caused moderate irritation.
Skin Effects:
Rabbit, skin: 810 mg/24 hr caused severe irritation.
Carcinogenicity:
Rat, inhalation: 3500 ppm/2 yr (intermittently) caused endocrine tumors.
Mutagenicity:
Rat, oral: 1275 mg/kg caused DNA damage.
Human, fibroblast: 5000 ppm/1 hr (continuously) caused DNA inhibition.

Acute Inhalation Effects:
Human, inhalation, TC_{Lo}: 500 ppm/1 yr (intermittently) caused altered sleep time, somnolence, and change in heart rate.
Human, inhalation, TC_{Lo}: 500 ppm/8 hr caused euphoria.
Acute Oral Effects:
Human, oral, LD_{Lo}: 357 mg/kg caused somnolence, paresthesia, and convulsions or effect on seizure threshold.
Rat, oral, LD_{50}: 1600 mg/kg
Multiple Dose Toxicity Data:
Rat, inhalation: 8400 ppm/6 hr/13 weeks (intermittently) caused changes in liver weight.

* See NIOSH, *RTECS* (PA8050000), for additional toxicity data.

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Section 12 - Ecological Information

Ecotoxicity: *Pimephales promelas* (fathead minnow), LC_{50} = 193 mg/L/96 hr; *Lepomis macrochirus* (bluegill), LC_{50} = 230 mg/L/24 hr; *Poecilia reticulata* (guppies), LC_{50} = 294 ppm/14 days. Cytotoxic to plants.

Environmental Degradation: In air, methylene chloride degrades by reaction with photochemically-produced hydroxyl radicals (half-life = a few months) but does not undergo *direct* photolysis. Degradation products include carbon monoxide, carbon dioxide, and phosgene. In water, it is removed primarily by evaporation (est. half-life = 3 to 5.6 hr under moderate mixing conditions). Some may biodegrade but it is not expected to adsorb to sediment or bioconcentrate. If released to soil most methylene chloride will rapidly evaporate. Some may leach through soil. Methylene chloride will adsorb to peat moss but not to sand.

Section 13 - Disposal Considerations

Disposal: Pour on sand or earth at a safe distance/location from occupied areas and allow to evaporate (most is transformed to carbon monoxide). A good candidate for liquid injection, rotary kiln, or fluidized bed incineration. Investigate biodegradation: methylene chloride is reported to completely biodegrade under aerobic conditions with sewage seed or activated sludge between 6 hrs. and 7 days. Contact your supplier or a licensed contractor for detailed recommendations. Follow applicable Federal, state, and local regulations.

Section 14 - Transport Information

DOT Transportation Data (49 CFR 172.101):

Shipping Name: Dichloromethane
Shipping Symbols: –
Hazard Class: 6.1
ID No.: UN1593
Packing Group: III
Label: Keep away from food
Special Provisions (172.102): N36, T13

Packaging Authorizations
a) Exceptions: 173.153
b) Non-bulk Packaging: 173.203
c) Bulk Packaging: 173.241

Quantity Limitations
a) Passenger, Aircraft, or Railcar: 60 L
b) Cargo Aircraft Only: 220 L

Vessel Stowage Requirements
a) Vessel Stowage: A
b) Other: –

Section 15 - Regulatory Information

EPA Regulations:
Listed as a RCRA Hazardous Waste Number (40 CFR 261.33): U080
Listed as a CERCLA Hazardous Substance (40 CFR 302.4) per RCRA, Sec. 3001 and CWA, Sec. 307(a)
CERCLA Reportable Quantity (RQ), 1000 lb (454 kg)
Listed as a SARA Toxic Chemical (40 CFR 372.65)
SARA EHS (Extremely Hazardous Substance) (40 CFR 355): Not listed
OSHA Regulations:
Listed as an Air Contaminant (29 CFR 1910.1000, Table Z-1, Z-1-A)

Section 16 - Other Information

References: 1, 8, 73, 103, 124, 132, 136, 148, 149, 153, 159, 187, 190, 192, 194, 195

Prepared By ..... M Gannon, BA
Industrial Hygiene Review ..... S Gilson, CIH
Medical Review ..... J Brent, MD, PhD

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Section 1. Material Identification

Perchloroethylene (C_2Cl_4) Description: By chlorination of hydrocarbons and pyrolysis of the carbon tetrachloride that is formed, or by catalytic oxidation of 1,1,2,2-tetrachloroethane. Used in dry cleaning and textile processing, metal degreasing, insulating fluid and cooling gas in electrical transformers, production of adhesives, aerosols, paints, and coatings; as a chemical intermediate, a solvent for various applications, extractant for pharmaceuticals, a pesticide intermediate, and an antihelminthic (parasitic worm removal) agent in veterinary medicine.
Other Designations: CAS No. 127-18-4, Ankilostin, carbon dichloride, Didakene, ethylene tetrachloride, Perchlor, Perclene, Perk, Tetracap, tetrachloroethylene.
Manufacturer: Contact your supplier or distributor. Consult latest *Chemical Week Buyers' Guide*[73] for a suppliers list.

R 1
I 3
S 2*
K 0
* Skin absorption

NFPA
0
2 0
-

HMIS
H 2†
F 0
R 0
PPE‡
† Chronic effects
‡ Sec. 8

Cautions: Perchloroethylene is a central nervous system depressant, causes liver and kidney damage (from acute or chronic exposures), and is considered an IARC Class 2B carcinogen (animal sufficient evidence, human inadequate data).

Section 2. Ingredients and Occupational Exposure Limits

Perchloroethylene, < 99%. Impurities include a small amount of amine or phenolic stabilizers.

1991 OSHA PEL
8-hr TWA: 25 ppm (170 mg/m³)

1990 IDLH Level
500 ppm

1990 NIOSH REL
NIOSH-X Carcinogen
Limit of Quantitation: 0.4 ppm

1992-93 ACGIH TLVs
TWA: 50 ppm (339 mg/m³)
STEL: 200 ppm (1357 mg/m³)

1990 DFG (Germany) MAK
TWA: 50 ppm (345 mg/m³)
Category II: substances with systemic effects
Half-life: < 2 hr
Peak Exposure Limit: 100 ppm, 30 min average value, 4/shift

1985-86 Toxicity Data*
Man, inhalation, TC_{Lo}: 280 ppm/2 hr caused conjunctival irritation and anesthesia.
Human, lung: 100 mg/L caused unscheduled DNA synthesis.
Rat, oral, LD_{50}: 3005 mg/kg; caused somnolence, tremor, and ataxia.
Rat, inhalation, TC_{Lo}: 200 ppm/6 hr given intermittently over 2 years produced leukemia and testicular tumors.
Rabbit, eye: 162 mg caused mild irritation.
Rabbit, skin: 810 mg/24 hr caused severe irritation.

* See NIOSH, *RTECS* (KX3850000), for additional irritation, mutation, reproductive, tumorigenic, & toxicity data.

Section 3. Physical Data

Boiling Point: 250 °F (121.2 °C)
Freezing Point: -8 °F (-23.35 °C)
Vapor Pressure: 13 mm Hg at 68 °F (20 °C)
Surface Tension: 31.74 dyne/cm at 68 °F (20 °C)
Viscosity: 0.84 cP at 77 °F (25 °C)
Refraction Index: 1.50534 at 68 °F (20 °C)
Molecular Weight: 165.82

Density: 1.6311 at 59 °F (15/4 °C)
Water Solubility: 0.02% at 77 °F (25 °C)
Other Solubilities: Miscible with alcohol, ether, benzene, chloroform, and oils.
Odor Threshold: 47 to 71 ppm (poor warning properties since olfactory fatigue is probable)
Evaporation Rate: 0.15 gal/ft²/day at 77 °F (25 °C)
Saturated Vapor Density (Air = 0.075 lb/ft³ or 1.2 kg/m³): 0.081 lb/ft³ or 1.296 kg/m³

Appearance and Odor: Colorless liquid with an ether-like odor.

Section 4. Fire and Explosion Data

Flash Point: Nonflammable	Autoignition Temperature: Nonflammable	LEL: None reported	UEL: None reported

Extinguishing Media: For small fires, use dry chemical, carbon dioxide (CO_2). For large fires, use water spray, fog, or regular foam.
Unusual Fire or Explosion Hazards: Vapors are heavier than air and collect in low-lying areas.
Special Fire-fighting Procedures: Because fire may produce toxic thermal decomposition products, wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in pressure-demand or positive-pressure mode. Apply cooling water to sides of container until well after fire is out. Stay away from ends of tanks. Do not release runoff from fire control methods to sewers or waterways.

Section 5. Reactivity Data

Stability/Polymerization: Perchloroethylene is stable up to 932 °F (500 °C) in the absence of catalysts, moisture, and oxygen but deteriorates rapidly in warm, moist climates. It is slowly decomposed by light. Amine or phenolic stabilizers are usually added. Hazardous polymerization cannot occur. Chemical Incompatibilities: Slowly (faster in presence of water) corrodes aluminum, iron, and zinc. It is incompatible with chemically active metals (i.e., barium, beryllium, and lithium (explodes with lithium shavings), strong oxidizers, sodium hydroxide, caustic soda, potash, and nitric acid. Perchloroethylene forms an explosive mixture with dinitrogen tetraoxide and reacts with activated charcoal at 392 °F (200 °C) to yield hexachloroethane and hexachlorobenzene. Conditions to Avoid: Contact with moisture and incompatibles.
Hazardous Products of Decomposition: Thermal oxidative decomposition of perchloroethylene can produce carbon dioxide and toxic chlorine, hydrogen chloride, and phosgene gas (also produced by contact with UV light).

Section 6. Health Hazard Data

Carcinogenicity: Perchloroethylene is listed as a carcinogen by The IARC (Group 2B, animal sufficient evidence, human inadequate data),[164] NTP (Class 2, reasonably anticipated as a carcinogen, with limited human evidence and sufficient animal evidence),[169] NIOSH (Class-X, carcinogen defined with no further explanation),[164] and DFG (MAK-B, justifiably suspected of having carcinogenic potential)[164]. There is some controversy regarding human carcinogenicity because even though there is an increased number of cancers of the skin, colon, lung, urogenital tract, and lympho-sarcomas; the dry cleaning workers studied were also exposed to other chemicals. Summary of Risks: Perchloroethylene is stored in the fatty tissue and slowly metabolized with the loss of chlorine. The half-life of its urinary metabolite (trichloroacetic acid) is 144 hours. Perchloroethylene exerts the majority of its toxicity on the central nervous system causing symptoms ranging from light-headedness and slight 'inebriation' to unconsciousness. Liver damage is possible after severe acute or minor long-term exposure. It has a synergistic effect with toluene.

Continue on next page

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Section 6. Health Hazard Data, *continued*

Medical Conditions Aggravated by Long-Term Exposure: Nervous, liver, kidney, or skin disorders. **Target Organs:** Liver, kidney, eyes, upper respiratory tract, skin, and central nervous system. **Primary Entry Routes:** Inhalation and skin and eye contact. **Acute Effects:** Exposure to high levels can cause liver damage which may take several weeks to develop. Vapor exposure can cause slight smarting of the eyes and throat (in high concentrations). In human studies, exposure to 2000 ppm/5 min caused mild CNS depression; 600 ppm/10 min caused numbness around the mouth, dizziness, and incoordination; 100 ppm/7 hr caused mild eye, nose, and throat irritation, flushing of the face and neck, headache, somnolence, and slurred speech. Skin contact may produce dermatitis because of perchloroethylene's defatting action (more common after repeated exposure). Direct eye contact causes tearing and burning but no permanent damage. Ingestion is rare but can cause irritation of the lips, mouth and gastrointestinal tract, irregular heartbeat, nausea & vomiting, diarrhea (possibly blood stained), drowsiness, unconsciousness, and risk of pulmonary edema (fluid in lungs). **Chronic Effects:** Prolonged exposure can cause impaired memory, extremity (hands, feet) weakness, peripheral neuropathies, impaired vision, muscle cramps, liver damage (fatty degeneration, necrosis, yellow jaundice, and dark urine) and kidney damage (oliguric uremia, conjestion and granular swelling).

FIRST AID ***Rescuers must not enter areas with potentially high perchloroethylene levels without a self-contained breathing apparatus.*** **Eyes:** *Do not* allow victim to rub or keep eyes tightly shut. Gently lift eyelids and flush immediately and continuously with flooding amounts of water until transported to an emergency medical facility. Consult a physician immediately. **Skin:** *Quickly* remove contaminated clothing. Rinse with flooding amounts of water for at least 15 min. Wash exposed area with soap and water. For reddened or blistered skin, consult a physician. **Inhalation:** Remove exposed person to fresh air and support breathing as needed. *Never administer adrenalin!* **Ingestion:** Never give anything by mouth to an unconscious or convulsing person. Contact a poison control center and unless otherwise advised, have that *conscious and alert* person drink 1 to 2 glasses of water, then induce vomiting. Be sure victim's head is positioned to avoid aspiration of vomitus into the lungs. **Note to Physicians:** Monitor level of consciousness, EEG (abnormalaties may indicate chronic toxicity), blood enzyme levels (for 2 to 3 wk after exposure), EKG, adequacy of respirations & oxygenation, and liver and kidney function. *BEIs:* C_2Cl_4 in expired air (10 ppm), sample prior to last shift of work week; C_2Cl_4 in blood (1 mg/L), sample prior to last shift of work week; trichloroacetic acid in urine (7 mg/L), sample at end of workweek.

Section 7. Spill, Leak, and Disposal Procedures

Spill/Leak: Notify safety personnel, isolate and ventilate area, deny entry, and stay upwind. Shut off ignition sources (although noncombustible, it forms toxic vapors from thermal decomposition). For small spills, take up with earth, sand, vermicalite, or other absorbent, noncombustible material and place in suitable containers for later disposal. For large spills, dike far ahead of spill and await reclamation or disposal. Report any release in excess of 1 lb. Follow applicable OSHA regulations (29 CFR 1910.120). **Environmental Transport:** If released to soil, perchloroethylene evaporates and some leaches to groundwater. It may absorb slightly to soils with heavy organic matter. Biodegradation may be important in anaerobic soils. In water, it is subject to rapid volatilization with an estimated half-life from <1 day to several weeks. In air, it exists mainly in the vapor-phase and is subject to photooxidation with a half-life of 30 minutes to 2 months. **Ecotoxicity Values:** Guppy (*Poecilia reticulata*), LC_{50} = 18 ppm/7 days; fathead minnow (*Pimephales promelas*), LC_{50} = 18.4 mg/L/96 hr, flow through bioassy. **Disposal:** Consider recovery by distillation. A potential candidate for rotary kiln incineration at 1508 to 2912 °F (820 to 1600 °C) or fluidized bed incineration at 842 to 1796 °F (450 to 980 °C). Contact your supplier or a licensed contractor for detailed recommendations. Follow applicable Federal, state, and local regulations.

EPA Designations
Listed as a RCRA Hazardous Waste (40 CFR 261.33): No. U210
Listed as a CERCLA Hazardous Substance* (40 CFR 302.4): Final Reportable Quantity (RQ), 100 lb (45.4 kg) [* per CWA Sec. 307 (a)]
SARA Extremely Hazardous Substance (40 CFR 355), TPQ: Not listed
Listed as a SARA Toxic Chemical (40 CFR 372.65)

OSHA Designations
Listed as an Air Contaminant (29 CFR 1910.1000, Table Z-1-A)

Section 8. Special Protection Data

Goggles: Wear a faceshield (8 inch minimum) per OSHA eye- and face-protection regulations (29 CFR 1910.133). Because contact lens use in industry is controversial, establish your own policy. **Respirator:** Seek professional advice prior to respirator selection and use. Follow OSHA respirator regulations (29 CFR 1910.134) and, if necessary, wear a MSHA/NIOSH-approved respirator. For any detectable concentration, use a supplied-air respirator or SCBA with a full facepiece operated in pressure demand or other positive-pressure mode. For emergency or nonroutine operations (cleaning spills, reactor vessels, or storage tanks), wear an SCBA. *Warning! Air-purifying respirators do not protect workers in oxygen-deficient atmospheres.* If respirators are used, OSHA requires a respiratory protection program that includes at least: medical certification, training, fit-testing, periodic environmental monitoring, maintenance, inspection, cleaning, and convenient, sanitary storage areas. **Other:** Wear chemically protective gloves, boots, aprons, and gauntlets made of butyl rubber, Neoprene, or Viton to prevent skin contact. **Ventilation:** Provide general and local exhaust ventilation systems to maintain airborne concentrations below the OSHA PEL (Sec. 2). Local exhaust ventilation is preferred because it prevents contaminant dispersion into the work area by controlling it at its source.[105] **Safety Stations:** Make available in the work area emergency eyewash stations, safety/quick-drench showers, and washing facilities. **Contaminated Equipment:** Separate contaminated work clothes from street clothes and launder before reuse. Remove this material from your shoes and clean personal protective equipment. **Comments:** Never eat, drink, or smoke in work areas. Practice good personal hygiene after using this material, especially before eating, drinking, smoking, using the toilet, or applying cosmetics.

Section 9. Special Precautions and Comments

Storage Requirements: Prevent physical damage to containers. Store in a cool, dry, well-ventilated area away from sunlight, and incompatibles. Do not store sludge from vapor degreasers in tightly-sealed containers and keep outside until disposal is arranged. **Engineering Controls:** To reduce potential health hazards, use sufficient dilution or local exhaust ventilation to control airborne contaminants and to maintain concentrations at the lowest practical level. Check stabilizer levels frequently and ventilation equipment (air velocity, static pressure, air valve) at least every 3 months. Install an air dryer in ventlines to storage tanks to prevent moisture from rusting and weakening the tank and contaminating or discoloring its contents. Purge all tanks before entering for repairs or cleanup. Build a dike around storage tanks capable of containing all the liquid. Ground tanks to prevent static electricity. **Administrative Controls:** Consider preplacement and periodic medical exams of exposed workers that emphasize liver, kidney, and nervous system function, and the skin. Alcoholism may be a predisposing factor.

Transportation Data (49 CFR 172.101)

DOT Shipping Name: Tetrachloroethylene
Hazard Class: 6.1
No.: UN1897
DOT Packing Group: III
DOT Label: Keep away from food
Special Provisions (172.102): N36, T1

Packaging Authorizations
a) Exceptions: 173.153
b) Non-bulk Packaging: 173.203
c) Bulk Packaging: 173.241

Quantity Limitations
a) Passenger Aircraft or Railcar: 60 L
b) Cargo Aircraft Only: 220 L

Vessel Stowage Requirements
a) Vessel Stowage: A
b) Other: 40

MSDS Collection References: 26, 73, 100, 101, 103, 124, 126, 127, 132, 133, 140, 148, 149, 153, 159, 163, 164, 167, 168, 171, 174, 175, 176, 180.
Prepared by: M Gannon, BA; Industrial Hygiene Review: D Wilson, CIH; Medical Review: W Silverman, MD

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Material Safety Data Sheets Collection:

Sheet No. 311
Methyl Chloroform

Issued: 11/75 Revision: F, 3/92 Errata: 6/92

Section 1. Material Identification

38

Methyl Chloroform ($C_2H_3Cl_3$) Description: Derived by catalytic addition of hydrogen chloride to 1,1-dichloroethylene or by re-fluxing chlorine monoxide with carbon tetrachloride and chloroethane. Available in technical and solvent grades which differ only in the amount of stabilizer added to prevent metal parts corrosion. Used as a solvent for oils, waxes, tars, cleaning precision instruments, and pesticides; as a component of inks and drain cleaners; in degreasing metals, and textile processing. In recent years, methyl chloroform has found widespread use as a substitute for carbon tetrachloride.

R	1	
I	2	
S	2*	
K	1	

Genium: 1, 2, 1, —

Other Designations: CAS No. 71-55-6, α-trichloroethane; Inhibisol; 1,1,1-trichloroethane; Strobane.
Manufacturer: Contact your supplier or distributor. Consult latest *Chemical Week Buyers' Guide*[72] for a suppliers list.
Cautions: Methyl chloroform is a skin, eye, and respiratory tract irritant and can become narcotic with an anesthetic effect at high concentrations.
* Data on skin absorption via methyl chloroform is conflicting.[133] Some studies show definite absorption where others don't.

HMIS
H 2
F 1
R 1
PPG*
* Sec. 8

Section 2. Ingredients and Occupational Exposure Limits

Methyl chloroform, ca 92 to 97%*

1990 OSHA PELs
8-hr TWA: 350 ppm (1900 mg/m³)
15-min STEL: 450 ppm (2450 mg/m³)

1990 IDLH Level
1000 ppm

1990 NIOSH REL
15-min Ceiling: 350 ppm (1900 mg/m³)

1991-92 ACGIH TLVs
TWA: 350 ppm (1910 mg/m³)
STEL: 450 ppm (2460 mg/m³)

1990 DFG (Germany) MAKs
TWA: 200 ppm (1080 mg/m³)
Half-life: 2 hr to shift length
Peak Exposure Limit: 1000 ppm/30 min (average value)/2 per shift

1985-86 Toxicity Data†
Human, oral, TD_{Lo}: 670 mg/kg produced diarrhea, nausea, and vomiting
Human, inhalation, LC_{Lo}: 27 g/m³/10 min; toxic effects not yet reviewed
Man, eye: 450 ppm/8 hr produced irritation
Rat, inhalation, TC_{Lo}: 2100 ppm/24 hr for 14 days prior to mating and from 1 to 20 days of pregnancy produced specific developmental abnormalities of the musculoskeletal system

* Methyl chloroform usually contains inhibitors (3 to 8%) to prevent corrosion of aluminum and some other metals. Typical inhibitors are nitromethane, butylene oxide, secondary butyl alcohols, ketones, and glycol diesters.
† See NIOSH, *RTECS* (KJ2975000), for additional irritation, mutation, reproductive, and toxicity data.

Section 3. Physical Data

Boiling Point: 165 °F (75 °C)
Freezing Point: -22 °F (-30 °C)
Vapor Pressure: 100 mm Hg at 68 °F (20 °C)
Vapor Density (air = 1): 4.55
Corrosivity: Readily corrodes aluminum and its alloys
Refraction Index: 1.43765 at 69.8 °F (21 °C)
Viscosity: 0.858 cP at 68 °F (20 °C)
Molecular Weight: 133.42
Density: 1.3376 at 68/39.8 °F (20/4 °C)
Water Solubility: Insoluble
Other Solubilities: Soluble in acetone, alcohol, ether, benzene, carbon tetrachloride, and carbon disulfide
% in Saturated Air: 16.7% at 77 °F (25 °C)
Relative Evaporation Rate (butyl acetate = 1): 12.8
Appearance and Odor: Colorless liquid with a sweetish, chloroform-like odor. The odor threshold is 44 ppm.

Section 4. Fire and Explosion Data

Flash Point: None (in conventional CC tests)	Autoignition Temperature: 932 °F (500 °C)	LEL: 7% v/v	UEL: 16% v/v

Extinguishing Media: *Noncombustible liquid* whose *vapor* burns in the presence of excess oxygen or a strong ignition source. For small fires, use dry chemical or carbon dioxide (CO_2). For large fires use fog or regular foam. If these materials are unavailable, a water spray may be used but be aware that water reacts slowly with methyl chloroform to release hydrochloric acid.
Unusual Fire or Explosion Hazards: Vapors are heavier than air and may travel to a strong ignition source and flash back. Air/vapor mixtures may explode when heated. Container may explode in heat of fire. Exposure to open flames or arc welding can produce hydrogen chloride and phosgene.
Special Fire-fighting Procedures: Methyl chloroform's burning rate is 2.9 mm/min. Since fire may produce toxic thermal decomposition products, wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in pressure-demand or positive-pressure mode. Structural firefighters' protective clothing provides limited protection. Wear clothing specifically recommended by the manufacturer for use in fires involving methyl chloroform. Apply cooling water to container sides until after fire is extinguished. Stay away from ends of tanks. Isolate area for 1/2 mile if fire involves tank, truck, or rail car. Be aware of runoff from fire control methods. Do not release to sewers or waterways.

Section 5. Reactivity Data

Stability/Polymerization: Methyl chloroform is stable at room temperature in closed containers under normal storage and handling conditions. Hazardous polymerization can occur in contact with aluminum trichloride.
Chemical Incompatibilities: Methyl chloroform is incompatible with sodium hydroxide, nitrogen tetroxide, oxygen (liquid or gas), strong oxidizers, and chemically active metals like aluminum, zinc, and magnesium powders; reacts violently with caustics to form dichloroacetylene; reacts slowly with water to form hydrochloric acid; forms shock sensitive mixtures with potassium; and polymerizes in contact with aluminum trichloride.
Conditions to Avoid: Exposure to moisture, strong ignition sources, and arc-welding units, and contact with incompatibles.
Hazardous Products of Decomposition: Thermal oxidative decomposition (temperatures >500 °F, contact with hot metals, or under UV rays) of methyl chloroform can produce carbon dioxide (CO_2) and toxic dichloroacetylene, hydrogen chloride, and phosgene gases.

Section 6. Health Hazard Data

Carcinogenicity: The IARC (Class 3, inadequate evidence),[164] NTP,[142] and OSHA[164] do not list methyl chloroform as a carcinogen.
Summary of Risks: Methyl chloroform is considered one of the least toxic of the liquid chlorinated hydrocarbons. It is irritating to eyes, skin, and respiratory tract. Although low in systemic toxicity, methyl chloroform is an anesthetic capable of causing death at high concentrations (>15,000 ppm), generally in poorly ventilated, enclosed areas. Quick and complete recovery is observed after prompt removal of unconscious persons from area of exposure. Like many other solvents, methyl chloroform sensitizes the heart to epinephrine (blood pressure-raising hormone) and may induce cardiac arrhythmias and arrest.
Medical Conditions Aggravated by Long-Term Exposure: None reported.
Target Organs: Skin, eyes, central nervous (CNS) and cardiovascular (CVS) systems.

Continue on next page

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Section 6. Health Hazard Data, *continued*

Primary Entry Routes: Inhalation, skin contact. **Acute Effects:** Methyl chloroform defats the skin causing irritation, redness, dryness, and scaling. Contact with eyes produces irritation and mild conjunctivitis. Vapor inhalation can cause headache, dizziness, equilibrium disturbances, and in high concentrations may lead to CNS depression, unconsciousness, and coma. During a 60-min exposure period these effects are observed: 100 ppm is the observed odor threshold, at 500 ppm there is obvious odor and decreased reaction time, 1000 ppm causes slight equilibrium loss, at 5000 ppm there is definite incoordination, and 20,000 ppm produces surgical strength anesthesia with possible death. Mild liver and kidney dysfunction may occur after CNS depression recovery. Although unlikely, if ingestion occurs, symptoms include nausea, vomiting, diarrhea, and possible esophageal burns. The acute lethal human dose is ~500 to 5000 mg/kg. **Chronic Effects:** None reported.

FIRST AID

Eyes: Gently lift eyelids and flush immediately and continuously with flooding amounts of water until transported to an emergency medical facility. *Do not* allow victim to rub or keep eyes tightly shut. Consult a physician immediately. **Skin:** *Quickly* remove contaminated clothing. Rinse with flooding amounts of water for at least 15 min. Wash exposed area with soap and water. For reddened or blistered skin, consult a physician. **Inhalation:** Remove exposed person to fresh air and support breathing as needed. **Ingestion:** Never give anything by mouth to an unconscious or convulsing person. Contact a poison control center, and unless otherwise advised, have that *conscious and alert* person drink 1 to 2 glasses of water to dilute. When deciding whether to induce vomiting, carefully consider amount ingested, time since ingestion, and availability of medical help. If large amounts are recently ingested (absorption into the body is not yet likely to have occurred), and medical help or transportation to a medical facility is not readily available, induce vomiting. Otherwise, vomiting is not recommended since aspiration of vomitus can produce chemical pneumonitis. **Note to Physicians:** Do not use adrenaline or sympathomimetic amines in treatment because of the increased cardiac sensitivity involved.

Section 7. Spill, Leak, and Disposal Procedures

Spill/Leak: Immediately notify safety personnel, isolate area, deny entry, and stay upwind. Shut off all ignition sources. If possible without risk, shut off leak. Cleanup personnel should wear fully encapsulating vapor-protective clothing. For small spills, take up with earth, sand, vermiculite, or other absorbent, noncombustible material. Using nonsparking tools, place in suitable containers for disposal or reclamation. For large spills, dike far ahead of liquid spill for later disposal or reclamation. Report any release in excess of 1000 lb. Follow applicable OSHA regulations (29 CFR 1910.120).
Environmental Transport: In water, methyl chloroform's half-life is hours to weeks depending on wind and mixing conditions. It is very persistent in groundwater. On land it volatilizes due to its high vapor pressure and leaches extensively. When released to the atmosphere, methyl chloroform can be transported long distances and returned to earth via rain. It is slowly degraded by reaction with hydroxyl radicals and has a half-life of 6 months to 25 years. The Natural Resources Defenses Council reported recently that methyl chloroform depletes ozone.
Ecotoxicity Values: *Pimephales promelas* (fathead minnow), LC_{50}: 52.8 mg/L/96 hr; *Poecilia reticulata* (guppy), LC_{50}: 133 ppm/7 day.
Disposal: Contact your supplier or a licensed contractor for detailed recommendations. Follow applicable Federal, state, and local regulations.

EPA Designations
Listed as a RCRA Hazardous Waste (40 CFR 261.33): No. U226
Listed as a CERCLA Hazardous Substance* (40 CFR 302.4): Reportable Quantity (RQ), 1000 lb (454 kg) [* per RCRA, Sec. 3001, CWA, Sec. 307(a), and CAA, Sec. 112]
SARA Extremely Hazardous Substance (40 CFR 355): Not listed
Listed as a SARA Toxic Chemical (40 CFR 372.65)

OSHA Designations
Listed as an Air Contaminant (29 CFR 1910.1000, Table Z-1-A)

Section 8. Special Protection Data

Goggles: Wear splash-proof, protective chemical safety goggles or faceshields, per OSHA eye- and face-protection regulations (29 CFR 1910.133). Because contact lens use in industry is controversial, establish your own policy.
Respirator: Seek professional advice prior to respirator selection and use. Follow OSHA respirator regulations (29 CFR 1910.134) and, if necessary, wear a MSHA/NIOSH-approved respirator. Select respirator based on its suitability to provide adequate worker protection for given working conditions, level of airborne contamination, and presence of sufficient oxygen. For emergency or nonroutine operations (cleaning spills, reactor vessels, or storage tanks), wear an SCBA. *Warning! Air-purifying respirators do not protect workers in oxygen-deficient atmospheres.* If respirators are used, OSHA requires a respiratory protection program that includes at least: training, fit-testing, periodic environmental monitoring, maintenance, inspection, cleaning, and convenient, sanitary storage areas.
Other: Wear chemically protective gloves, boots, aprons, and gauntlets to prevent repeated or prolonged skin contact. Viton and butyl rubber [with breakthrough times (BTs) of >8 hr and 4 to 7.9 hr, respectively] are recommended materials for protective gear. *Do not use* neoprene, polyvinyl chloride (PVC), natural rubber, or polyethylene because these materials have a BT of <1 hr.
Ventilation: Provide general and local exhaust (in some cases, explosion-proof) ventilation systems to maintain airborne concentrations below OSHA PELs (Sec. 2). Local exhaust ventilation is preferred since it prevents contaminant dispersion into work area by controlling it at its source.[103]
Safety Stations: Make available in the work area emergency eyewash stations, safety/quick-drench showers, and washing facilities.
Contaminated Equipment: Separate contaminated work clothes from street clothes. Launder contaminated work clothing before wearing. Remove this material from your shoes and clean personal protective equipment.
Comments: Never eat, drink, or smoke in work areas. Practice good personal hygiene after using this material, especially before eating, drinking, smoking, using the toilet, or applying cosmetics.

Section 9. Special Precautions and Comments

Storage Requirements: Prevent physical damage to containers. Store in cool, dry, well-ventilated (use pressure-vacuum ventilation) area away from ignition sources, arc-welding operations, and incompatibles (Sec. 5). Regularly monitor inhibitor levels. *Do not* store in aluminum containers or use pressure-spraying equipment when methyl chloroform is involved.
Engineering Controls: To reduce potential health hazards, use sufficient dilution or local exhaust ventilation to control airborne contaminants and to maintain concentrations at the lowest practical level. To prevent static sparks, electrically ground and bond all equipment used in methyl chloroform manufacturing, use, storage, transfer, and shipping.
Administrative Controls: Consider preplacement and periodic medical exams of exposed workers that emphasize CNS, CVS, liver and skin.

Transportation Data (49 CFR 172.101, .102)

DOT Shipping Name: 1,1,1-Trichloroethane
DOT Hazard Class: ORM-A
ID No.: UN2831
DOT Label: None
DOT Packaging Exceptions: 173.505
DOT Packaging Requirements: 173.605

IMO Shipping Name: 1,1,1-Trichloroethane
IMO Hazard Class: 6.1
ID No.: UN2831
IMO Label: St. Andrews Cross
IMDG Packaging Group: III

MSDS Collection References: 26, 38, 73, 89, 100, 101, 103, 124, 126, 127, 132, 133, 136, 148, 153, 159, 162, 163, 164
Prepared by: M Gannon, BA; Industrial Hygiene Review: D Wilson, CIH; Medical Review: AC Darlington, MPH, MD; Edited by: JR Stuart, MS

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Material Safety Data Sheets Collection:

Sheet No. 315
Chloroform

Issued: 11/77 **Revision: D, 9/92**

Section 1. Material Identification

39

Chloroform ($CHCl_3$) Description: Derived by chlorination of methane, hydrochlorination of methanol, or reaction of chlorinated lime with acetone, acetaldehyde, or ethanol. Purified by extraction with concentrated sulfuric acid and rectification. Used in the manufacture of fluorocarbons (mainly FC-22) for refrigerants, in plastics, photographic processing, fire extinguishers, insecticides, and dry cleaning; as a solvent for fats, oils, waxes, rubbers, alkaloids, Gutta-Percha, and resins. Used as an anesthetic since 1847 but abandoned within the last few decades because of cardiac arrest during surgery and delayed death due to liver injury.

Other Designations: CAS No. 67-66-3, Freon-20, methane trichloride, methenyl chloride, R-20 (refrigerant), trichloroform, trichloromethane, TCM. Improperly called 'formyl chloride.'

Manufacturer: Contact your supplier or distributor. Consult latest *Chemical Week Buyers' Guide*[73] for a suppliers list.

Cautions: Chloroform is considered one of the most dangerous and volatile chlorinated hydrocarbons. It is a central nervous system (CNS) and cardiac depressant, an eye, skin, and respiratory tract irritant, and causes liver and kidney damage from acute and chronic exposure.

NFPA
R 1
I 3
S 2*
K 2
* Skin absorption

HMIS
H 3†
F 0
R 0
PPE‡
† Chronic effects
‡ Sec. 8

Section 2. Ingredients and Occupational Exposure Limits

Chloroform, ca 99%. Usually contains 0.75% ethanol as a stabilizer. Impurities include bromodichloromethane, vinylidene, and diethyl carbonate.

1991 OSHA PEL
8-hr TWA: 2 ppm (9.78 mg/m³)

1990 IDLH Level
1000 ppm

1990 NIOSH REL
60 min STEL: 2 ppm (9.78 mg/m³)

1992-93 ACGIH TLV
TWA: 10 ppm (49 mg/m³)

1990 DFG (Germany) MAK
TWA: 10 ppm (50 mg/m³)
Category II: Substances with systemic effects. Half-life = 2 hr
Peak Exposure Limit: 20 ppm, 30 min average value, 4/shift

1985-86 Toxicity Data*
Human, inhalation, TC_{Lo}: 10 mg/m³/1 year caused anorexia, nausea, and vomiting.
Rat, oral, TD_{Lo}: 13832 mg/kg given continuously for 2 years caused leukemia.
Rat, oral, LD_{50}: 908 mg/kg caused weight loss or decreased weight gain.
Rat, inhalation, TC_{Lo}: 30 ppm/7 hr administered from the 6 to 15 day of pregnancy caused fetotoxicity or developmental abnormalities of the musculoskeletal system.
Rabbit, eye: 20 mg/24 hr caused moderate irritation.

* See NIOSH, *RTECS* (PS9100000), for additional irritation, mutation, reproductive, tumorigenic, and toxicity data.

Section 3. Physical Data

Boiling Point: 143 °F (62 °C)
Freezing Point: -82 °F (-63.5 °C)
Molecular Weight: 119.39
Viscosity: 5.63 mP at 68 °F (20 °C)
Relative Evaporation Rate (BuAc=1): 11.6
Surface Tension: 27.1 dyne/cm at 68 °F (20 °C)
Refraction Index: 1.4422 at 77 °F (25 °C)
Density: 1.49845 at 59 °F (15 °C)
Water Solubility: Nearly insoluble; 0.5% at 77 °F (25 °C)
Other Solubilities: Soluble in ethanol, ethyl ether, benzene, acetone, carbon disulfide, and carbon tetrachloride.
Odor Threshold: 85 to 307 ppm (*range from combined sources*)
Vapor Pressure: 160 mm Hg at 68 °F (20 °C); 200 mm Hg at 77 °F (25 °C)
Saturated Vapor Density (Air = 0.075 lb/ft³ or 1.2 kg/m³): 0.136 lb/ft³ or 2.183 kg/m³

Appearance and Odor: Colorless, volatile liquid with a heavy, ethereal odor.

Section 4. Fire and Explosion Data

Flash Point: Nonflammable	Autoignition Temperature: Nonflammble	LEL: None reported	UEL: None reported

Extinguishing Media: Nonflammable from standard tests in air but will burn on prolonged exposure to flame or high temperature. To fight fire, use extinguishing agents suitable for surrounding fire. *Do not* scatter material with a high-pressure water stream. **Unusual Fire or Explosion Hazards:** Container may explode in heat of fire. **Special Fire-fighting Procedures:** Because fire may produce toxic thermal decomposition products, wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in pressure-demand or positive-pressure mode. Structural firefighters' protective clothing is *not* effective. Stay away from ends of tanks. Do not release runoff from fire control methods to sewers or waterways.

Section 5. Reactivity Data

Stability/Polymerization: Chloroform is stable at room temperature in closed containers under normal storage and handling conditions. Hazardous polymerization cannot occur. It's pH decreases on prolonged exposure to air and light due to hydrochloric acid (HCl) formation. The recommended shelf-life is 2 months for full containers and 2 weeks for partially full containers. **Chemical Incompatibilities:** Incompatible with acetone, alkalis, aluminum, disilane, lithium, magnesium, dinitrogen dioxide, nitrogen tetroxide, perchloric acid, phosphorus pentoxide, potassium, potassium hydroxide, methyl alcohol, potassium *tert*-butoxide, sodium, sodium hydroxide, sodium methylate, sodium-potassium alloy, triisopropylphosphine, calcium hydroxide, and fluorine and any strong oxidizers. **Conditions to Avoid:** Exposure to light, prolonged heat, and incompatibles. **Hazardous Products of Decomposition:** Thermal oxidative decomposition of $CHCl_3$ can produce carbon dioxide and toxic chlorine, HCl, and phosgene gas. $CHCl_3$ decomposes at 437 °F to formic acid, carbon monoxide, and HCl on prolonged heating with water.

Section 6. Health Hazard Data

Carcinogenicity: Chloroform is considered a carcinogen by the IARC (Class-2B, possibly carcinogenic in humans with limited human and sufficient animal evidence),[166] NTP (Class 2, reasonably anticipated to be a carcinogen, limited human and sufficient animal evidence),[167] and NIOSH (Class X, carcinogen defined with no further categorization),[168] DFG (MAK-B, justifiably suspected of having carcinogenic potential),[163] and ACGIH (Class A2, suspected human carcinogen based on limited epidemiologic evidence or demonstration)[163]. Carcinogenicity tends to be organ specific primarily to the liver and kidneys. **Summary of Risks:** Chloroform is a CNS depressant, eye, skin, and respiratory tract irritant, and causes damage to the liver and kidneys. Symptoms range from dizziness to cardiac arrythmias resulting in death. Chloroforms' toxicity is due to its easy lipid solubility. Avoid exposure during pregnancy because $CHCl_3$ diffuses readily across the placenta. Alcoholics seem to be affected sooner and more severely than others from chloroform exposure (alcohol may already have damaged the liver). Ethanol, polybrominated biphenols, steroids, and ketones potentiate chloroform's toxicity.

Continue on next page

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ction 6. Health Hazard Data

get Organs: Liver, kidney, heart, eyes, skin. **Primary Entry Routes:** Inhalation, ingestion, skin contact/absorption. **Medical Conditions** vated by Long-Term Exposure: Alcoholism, liver, kidney, or nervous system disorders. **Acute Effects:** Vapor inhalation causes varying d of CNS depression depending on concentration and exposure length. Symptoms include headache, nausea, dizziness, drunkenness, progressive ess, vomiting, thirst, delirium, and disorientation. Exposure to 14,000 to 16,000 ppm has caused rapid unconsciousness. Severe acute exposures ca. amage the liver and kidney (damage is usually not observed for 24 to 48 hr post exposure), respiratory failure, severe cardiac arrythmias (reason for discontinuation of use as an anesthetic), and death. Apparent recovery from heavy exposures may result in delayed death due to liver or kidney failure. Death usually occurs 4 to 5 days post exposure and autopsy shows massive liver necrosis. Vapors cause eye irritation and spasmodic winking. Direct eye contact with the liquid causes immediate burning pain and possible corneal epithelium damage. Skin contact with the liquid produces burning pain, erythema, and vesiculation due to defatting of the skin. Ingestion can cause gastrointestinal irritation, irregular heartbeat, nausea and vomiting, diarrhea (possibly blood-stained), drowsiness, unconsciousness, and state of shock. **Chronic Effects:** Prolonged inhalation of chloroform vapors causes fatigue, digestive disturbances, frequent and burning urination, mental dullness, and CNS and peripheral neuropathies. Liver (fatty degeneration and enlargement with hepatitis seen in dogs) and kidney damage may also occur.

FIRST AID Eyes: *Do not* allow victim to rub or keep eyes tightly shut. Gently lift eyelids and flush immediately and continuously with flooding amounts of water until transported to an emergency medical facility. Consult a physician immediately. Skin: *Quickly* remove contaminated clothing. Rinse with flooding amounts of water for at least 15 min. Wash exposed area with soap and water. Inhalation: Remove exposed person to fresh air and support breathing as needed. Ingestion: Never give anything by mouth to an unconscious or convulsing person. Contact a poison control center and unless otherwise advised, have that *conscious and alert* person drink 1 to 2 glasses of water, to dilute. *Do not* induce vomiting because victim may become obtunded. Gastric lavage may be indicated if patient is comatose or at risk of convulsing. Note to Physicians: Because effects may be delayed (especially kidney and liver problems), keep victim under observation for 24 to 48 hr. Administration of fluids may help to prevent kidney failure. Obtain blood glucose, urinalysis, liver function tests, chest x-ray, and monitor cardiac function and fluid/electrolyte status. Monitor liver and kidney function for 4 to 5 days after exposure. Disulfiram, its metabolites, and a high carbohydrate diet appear to protect somewhat against chloroform toxicity. *Do not give adrenalin!* Tests may show increased bilirubin, ketosis, lowered blood prothrombin, and fibrogen.

Section 7. Spill, Leak, and Disposal Procedures

Spill/Leak: Notify safety personnel, isolate and ventilate area, deny entry, and stay upwind. If possible without risk, move container from spill area. Cleanup personnel should wear fully encapsulating vapor-protective clothing. For small spills, take up with earth, sand, vermiculite, or other absorbent, noncombustible material and place in suitable containers for disposal. For large spills, dike far ahead of spill and contain for later disposal or reclamation. Spills in water may need to be trapped at the bottom with sand bag barriers and treated with activated carbon and removed by suction hoses, mechanical lifts, and dredges. Follow applicable OSHA regulations (29 CFR 1910.120). **Ecotoxicity Values:** Rainbow Trout (*Salmo gairdneri*), LC_{50} = 2030 µg/L; bluegill (*Lepomis macrochirus*), LC_{50} = 100,000 µg/L/96 hr; largemouth bass (*Micropterus salmoides*) LC_{50} = 51 ppm/96 hr. **Environmental Degradation:** If released to land, most chloroform evaporates rapidly (due to high vapor pressure) while some may leach to groundwater where it remains for a long time on the bottom. If released to water, chloroform evaporates rapidly with estimated half-lifes of r (river), 40 hr (pond), 9 to 10 days (lake). In air, chloroform photodegrades with a half-life of 80 days. It can be transported long distances and y return to earth via rain. **Disposal:** Reclamation is possible through distillation or steam stripping. Chloroform is a candidate for liquid , rotary kiln, or fluidized bed incineration with an acid scrubber. Contact your supplier or a licensed contractor for detailed recommenda- ollow applicable Federal, state, and local regulations.

EPA Designations
Listed as a RCRA Hazardous Waste (40 CFR 261.33): No. U044
Listed as a SARA Extremely Hazardous Substance (40 CFR 355), TPQ: 10,000 lb
Listed as a SARA Toxic Chemical (40 CFR 372.65)
Listed as a CERCLA Hazardous Substance* (40 CFR 302.4): Final Reportable Quantity (RQ), 10 lb (4.54 kg) [* per RCRA, Sec. 3001; CWA, Sec. 311(b)(4), & CWA Sec. 307(a)]

OSHA Designations
Listed as an Air Contaminant (29 CFR 1910.1000, Table Z-1-A)

Section 8. Special Protection Data

Goggles: Wear chemical safety goggles for concentrations of 5 ppm to 2% and a full facepiece for levels above 2%, per OSHA eye- and face-protection regulations (29 CFR 1910.133). Because contact lens use in industry is controversial, establish your own policy. **Respirator:** Seek professional advice prior to respirator selection and use. Follow OSHA respirator regulations (29 CFR 1910.134) and, if necessary, wear a MSHA/NIOSH-approved respirator. For any detectable concentration use a supplied-air respirator or SCBA with a full facepiece and operated in pressure-demand or other positive pressure mode. For emergency or nonroutine operations (cleaning spills, reactor vessels, or storage tanks), wear an SCBA. *Warning! Air-purifying respirators do not protect workers in oxygen-deficient atmospheres.* If respirators are used, OSHA requires a written respiratory protection program that includes at least: medical certification, training, fit-testing, periodic environmental monitoring, maintenance, inspection, cleaning, and convenient, sanitary storage areas. **Other:** Wear chemically protective gloves, boots, aprons, and gauntlets made of polyvinyl alcohol or Viton (breakthrough times > 1 hr) to prevent skin contact. **Ventilation:** Provide general and local exhaust ventilation systems to maintain airborne concentrations below the OSHA PEL (Sec. 2). Local exhaust ventilation is preferred because it prevents contaminant dispersion into the work area by controlling it at its source.[103] **Safety Stations:** Make available in the work area emergency eyewash stations, safety/quick-drench showers, and washing facilities. **Contaminated Equipment:** Separate contaminated work clothes from street clothes and launder before reuse. Remove this material from your shoes and clean personal protective equipment. **Comments:** Never eat, drink, or smoke in work areas. Practice good personal hygiene after using this material, especially before eating, drinking, smoking, using the toilet, or applying cosmetics.

Section 9. Special Precautions and Comments

Storage Requirements: Prevent physical damage to containers. Store in lead-lined or mild steel containers of all-welded construction in a cool (< 30 °C), dry, well-ventilated area away from direct light and incompatibles. **Engineering Controls:** To reduce potential health hazards, use sufficient dilution or local exhaust ventilation to control airborne contaminants and to maintain concentrations at the lowest practical level. Isolate operations involving chloroform. **Administrative Controls:** It is suggested that chloroform use for extractions in labs should be avoided and replaced because of its toxicity and carcinogenic potential. Consider preplacement and periodic medical exams of exposed workers.

Transportation Data (49 CFR 172.101)

pping Name: Chloroform
zard Class: 6.1
D No.: UN1888
DOT Packing Group: II
DOT Label: Poison
pecial Provisions (172.102): N36, T14

Packaging Authorizations
a) Exceptions: None
b) Nonbulk Packaging: 173.202
c) Bulk Packaging: 173.243

Quantity Limitations
a) Passenger Aircraft or Railcar: 5L
b) Cargo Aircraft Only: 60L

Vessel Stowage Requirements
a) Vessel Stowage: A
b) Other: 40

SDS Collection References: 26, 73, 100, 101, 103, 124, 126, 127, 132, 133, 136, 139, 140, 148, 153, 159, 163, 164, 167, 168, 169, 171, 174, 175, 176, 180.
Prepared by: M Gannon, BA; Industrial Hygiene Review: PA Roy, MPH, CIH; Medical Review: W Silverman, MD

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Material Safety Data Sheets Collection:

Sheet No. 410
Carbon Tetrachloride

Issued: 12/80 Revision: B, 4/90

Section 1. Material Identification

31

Carbon Tetrachloride Description: A chlorinated hydrocarbon derived from interacting carbon disulfide and chlorine in the presence of iron, or chlorination of methane or higher hydrocarbons at 482 °F/250 °C to 752 °F/400 °C. Carbon tetrachloride is treated with caustic alkali solution to remove sulfur chloride. Its primary use is in manufacturing flurocarbon propellants. It is also used in producing of semiconductors, chlorinating organic compounds, metal degreasing, refrigerants; as a solvent for oils, fats, rezins, rubber waxes, lacquers, and varnishes; and as an agricultural fumigant. This material was widely used in the dry-cleaning industry.

Other Designations: CAS No. 0056-23-5; CCl_4; carbon chloride; carbon tet; methane tetrachloride; perchloromethane; tetrachlorocarbon; tetrachloromethane.

Manufacturer: Contact your supplier or distributor. Consult the latest *Chemicalweek Buyers' Guide*(TM) for a suppliers list.

R 1
I 4
S 2*
K 0
*Skin absorption

NFPA
0
3 0
-

HMIS
H 3
F 0
R 0
PPG†
† Sec. 8

Section 2. Ingredients and Occupational Exposure Limits

Carbon tetrachloride, ca 100%

OSHA PEL
8-hr TWA: 2 ppm, 12.6 mg/m³

ACGIH TLV (Skin), 1989-90
TLV-TWA: 5 ppm, 31 mg/m³

NIOSH REL, 1987
60-min ceiling: 2 ppm, 12.6 mg/m³

Toxicity Data*
Rat, oral, LD_{50}: 2800 mg/kg; toxic effects not yet reviewed
Rat, inhalation, LC_{50}: 8000 ppm over 4 hr; no toxic effect noted
Human, inhalation, TC_{Lo}: 20 ppm inhaled produces gastrointestinal effects (nausea or vomiting)

* See NIOSH, *RTECS* (FG4900000), for additional irritative, mutative, tumorigenic, and toxicity data.

Section 3. Physical Data

Boiling Point: 169.77 °F/76.54 °C
Melting Point: -9.4 °F/-23 °C
Vapor Pressure: 91.3 mm Hg at 68 °F/20 °C
Vapor Density (Air = 1): 5.32
Molecular Weight: 153.84 g/mol
Specific Gravity (H_2O = 1 at 39 °F/4 °C): 1.5940 at 68 °F/20 °C
Water Solubility: Very slightly soluble (800 mg/l at 68 °F/20 °C)
Evaporation Rate (Butyl Acetate = 1): 12.8

Appearance and Odor: A colorless liquid with a heavy ethereal odor. The high and low odor thresholds are, respectively, 128.4 and 60 mg/m³. Odor is not an adequate warning sign to prevent overexposure.

Section 4. Fire and Explosion Data

Flash Point: None reported	Autoignition Temperature: None reported	LEL: None reported	UEL: None reported

Extinguishing Media: Carbon tetrachloride is nonflammable and will not support combustion. Use extinguishing media appropriate to the surrounding fire. This material was previously used as an extinguishing medium in portable fire extinguishers, but its toxicity and fire decomposition products lead to its replacement with "safer" extinguishing media.

Unusual Fire or Explosion Hazards: Carbon tetrachloride can react violently with hot or burning metals such as aluminum and magnesium.

Special Fire-fighting Procedures: Since fire may produce toxic fumes, wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in the pressure-demand or positive-pressure mode and fully encapsulating suit. Use water spray to cool fire-exposed containers. Be aware of runoff from fire control methods. Do not release to sewers or waterways.

Section 5. Reactivity Data

Stability/Polymerization: Carbon tetrachloride is stable at room temperature in closed containers under normal storage and handling conditions. Hazardous polymerization cannot occur.

Chemical Incompatibilities: Carbon tetrachloride reacts violently with fluorine gas, alkali metals, and aluminum (see reference 126 for specific incompatibilities).

Conditions to Avoid: This material has caused explosions when used as a fire extinguisher on wax fires and uranium fires. It may also form toxic phosgene when used to put out electrical fires.

Hazardous Products of Decomposition: Thermal oxidative decomposition of carbon tetrachloride can produce toxic phosgene and hydrogen chloride.

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Section 6. Health Hazard Data

Carcinogenicity: The NTP, IARC, and ACGIH list carbon tetrachloride as an anticipated human carcinogen, a possible human carcinogen, and a suspected human carcinogen, respectively.

ummary of Risks: Carbon tetrachloride is highly toxic and irritating by inhalation, ingestion (mean lethal dose is 5 to 10 ml), and skin absorption. Alcohol's synergistic effects markedly increase CCl_4's toxicity. Excessive exposure may result in central nervous system depression, cardiac arrhythmias, and gastrointestinal symptoms. In humans the majority of fatalities have been the result of renal injury with secondary cardiac failure. Kidney and liver damage can occur from severe acute or chronic exposure. Human liver damage occurs more often after ingestion of the liquid than after the inhalation of the vapor. However, after a 30 min to 1 hr exposure to concentrations of 1000 to 2000 ppm, humans have died from acute renal damage.

Medical Conditions Aggravated by Long-Term Exposure: Prolonged recovery and permanent disability of the liver, kidney, and lungs are possible.

Target Organs: Central nervous system, eyes, skin, liver, kidneys, lungs.

Primary Entry Routes: Inhalation, percutaneous (through the skin).

Acute Effects: Acute exposure symptoms include eye, nose, skin, and throat irritation; cough, dyspnea, cyanosis, cardiac arrhythmias, headaches, dizziness, mental confusion, nausea, vomiting, abdominal pain, and diarrhea. Jaundice and abnormal liver enlargement accompanied by oliguria (reduced excretion of urine), proteinuria (protein in urine), and hematuria (blood in urine) may occur even after several days delay.

Chronic Effects: Chronic exposure symptoms include defatting dermatitis, headaches, dizziness, mental confusion, apathy, anorexia, nausea, vomiting, abdominal pain, weight loss, narrowing of visual field, optic nerve damage with possible blindness, hearing loss, and renal and hepatic decompensation (loss of these organs' ability to correct dysfunction). Chronic exposure may result in the development of aplastic anemia.

FIRST AID

Eyes: Flush immediately, including under the eyelids, gently but thoroughly with flooding amounts of running water for at least 15 min.

Skin: *Quickly* remove contaminated clothing. After rinsing affected skin with flooding amounts of water, wash it with soap and water.

Inhalation: Remove exposed person to fresh air and support breathing as needed.

Ingestion: Never give anything by mouth to an unconscious or convulsing person. Give one to two glasses of water to dilute and induce vomiting, unless the person shows evidence of decreasing mental functioning and awareness.

After first aid, get appropriate in-plant, paramedic, or community medical support.

Physician's Note: To minimize hepatorenal damage, consider intravenous acetylcysteine. Hyperbaric oxygen is also utilized for significant exposures. Dialysis has also been suggested in severe cases. Give cardiorespiratory support as indicated and carefully monitor fluid and electrolytes. Closely monitor hepatic and renal functions. Avoid epinephrine because of myocardial sensitization and potential for inducing ventricular arrhythymias.

Section 7. Spill, Leak, and Disposal Procedures

Spill/Leak: Notify safety personnel, evacuate area, and provide maximum exhaust ventilation. Cleanup personnel should protect against inhalation and skin and eye contact. Small spills can be absorbed on paper or some noncombustible, inert ingredient and allowed to evaporate in a hood. For large spills, dike far ahead to contain spill for disposal. Prevent release of CCl_4 to surface water or sewers. Follow applicable OSHA regulations (29 CFR 1910.120).

Disposal: Contact your supplier or a licensed contractor for detailed recommendations. Follow applicable Federal, state, and local regulations.

EPA Designations
Listed as a RCRA Hazardous Waste (40 CFR 261.33)
SARA Extremely Hazardous Substance (40 CFR 355): Not listed
sted as a SARA Toxic Chemical (40 CFR 372.65)
sted as a CERCLA Hazardous Substance* (40 CFR 302.4), Reportable Quantity (RQ): 5000 lb (2270 kg) [* per RCRA, Sec. 3001, per Clean Water Act, Sec. 307(a), 311 (b)(4)]

OSHA Designations
Listed as an Air Contaminant (29 CFR 1910.1000, Table Z-2)

Section 8. Special Protection Data

Goggles: Wear protective eyeglasses or chemical safety goggles, per OSHA eye- and face-protection regulations (29 CFR 1910.133).

Respirator: Follow OSHA respirator regulations (29 CFR 1910.134) and, if necessary, wear a NIOSH-approved respirator. For emergency or nonroutine operations (cleaning spills, reactor vessels, or storage tanks), wear an SCBA.

Warning: Air-purifying respirators do *not* protect workers in oxygen-deficient atmospheres.

Other: Wear impervious gloves, boots, aprons, and gauntlets to prevent skin contact. Polyvinyl alcohol protective gear is recommended.

Ventilation: Provide general and local explosion-proof ventilation systems to maintain airborne concentrations below the OSHA PEL, ACGIH TLV, and NIOSH REL (Sec. 2). Local exhaust ventilation is preferred since it prevents contaminant dispersion into the work area by controlling it at its source.[102]

Safety Stations: Make available in the work area emergency eyewash stations, safety/quick-drench showers, and washing facilities.

Contaminated Equipment: Never wear contact lenses in the work area: soft lenses may absorb, and all lenses concentrate, irritants. Remove this material from your shoes and equipment. Launder contaminated clothing before wearing.

Comments: Never eat, drink, or smoke in work areas. Practice good personal hygiene after using this material, especially before eating, drinking, smoking, using the toilet, or applying cosmetics.

Section 9. Special Precautions and Comments

Storage Requirements: Store in tightly closed container in a cool, dry, well-ventilated, low fire-risk area away from incompatible materials (Sec. 5), direct sunlight, and heat. Prevent exposure of vapors to high temperature to prevent decomposition to toxic and corrosive gases and vapors.

Engineering Controls: Avoid vapor inhalation and skin or eye contact. Use only with adequate ventilation and appropriate personal protective gear. Monitor vapor levels and institute a respiratory protection program which includes training, maintenance, inspection, and evaluation.

Practice good personal hygiene procedures. When possible, substitute a less hazardous solvent for CCl_4. Provide preplacement and biannual medical exams, including studies of liver and kidney function. Prevent exposing individuals with liver, kidney, or central nervous system diseases, or alcoholism. Alcohol's synergistic effects markedly increase CCl_4's toxicity.

Transportation Data (49 CFR 172.101, .102)

DOT Shipping Name: Carbon tetrachloride
DOT Hazard Class: ORM-A
ID No.: UN1846
DOT Label: None
DOT Packaging Requirements: 173.620
DOT Packaging Exceptions: 173.505

IMO Shipping Name: Carbon tetrachloride
IMO Hazard Class: 6.1
IMO Label: Poison
IMDG Packaging Group: II
ID No.: UN1846

MSDS Collection References: 7, 26, 38, 53, 73, 84, 85, 88, 89, 100, 103, 109, 124, 126, 127, 129, 130, 131, 134, 136, 137

Prepared by: MJ Allison, BS; Industrial Hygiene Review: DJ Wilson, CIH; Medical Review: MJ Hardies, MD

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Section 1. Material Identification

Trichloroethylene (C_2HCl_3) Description: Derived by treating tetrachloroethane with lime or other alkali in the presence of water, or by thermal decomposition of tetrachloroethane followed by steam distillation. Stabilizers such as epichlorohydrin, isobutanol, carbon tetrachloride, chloroform, benzene, or pentanol-2-triethanolamine are then added. Used as a degreasing solvent in electronics and dry cleaning, a chemical intermediate, a refrigerant and heat-exchange liquid, and a diluent in paint and adhesives; in oil, fat, and wax extraction and in aerospace operations (flushing liquid oxygen). Formerly used as a fumigant (food) and anesthetic (replaced due to its hazardous decomposition in closed-circuit apparatus).
Other Designations: CAS No. 79-01-6; acetylene trichloride; Algylen; Anamenth; Benzinol; Cecolene; Chlorylen; Dow-Tri; ethylene trichloride; Germalgene; Narcogen; Triasol; trichloroethene; TCE; 1,1,3-trichloroethylene.
Manufacturer: Contact your supplier or distributor. Consult latest *Chemical Week Buyers' Guide*[73] for a suppliers list.

R 1
I 2
S 2*
K 3
* Skin absorption

NFPA: 2 / 2 / 0 / -

HMIS
H 2†
F 2
R 0
PPE‡
† Chronic Effects
‡ Sec. 8

Cautions: TCE is irritating and toxic to the central nervous system (CNS). Inhalation of high concentrations have lead to death due to ventricular fibrillation. Chronic exposure may lead to heart, liver, and kidney damage. The liquid is absorbed through the skin. Although it has a relatively low flash point, TCE burns with difficulty.

Section 2. Ingredients and Occupational Exposure Limits

Trichloroethylene, < 100% [contains stabilizers (Sec. 1)].

1991 OSHA PELs
8-hr TWA: 50 ppm (270 mg/m³)
15-min STEL: 200 ppm (1080 mg/m³)

1990 IDLH Level
1000 ppm

1990 NIOSH REL
10-hr TWA: 25 ppm (~135 mg/m³)

1992-93 ACGIH TLVs
TWA: 50 ppm (269 mg/m³)
STEL: 200 ppm (1070 mg/m³)

1990 DFG (Germany) MAK
Ceiling: 50 ppm (270 mg/m³)
Category II: Substances with systemic effects
Half-life: 2 hr to shift length
Peak Exposure Limit: 250 ppm, 30 min average value; 2 peaks/shift

1985-86 Toxicity Data*
Human, inhalation, TC_{Lo}: 160 ppm/83 min caused hallucinations and distorted perceptions.
Human, lymphocyte: 5 mL/L caused DNA inhibition.
Rabbit, skin: 500 mg/24 hr caused severe irritation.
Rabbit, eye: 20 mg/24 hr caused moderate irritation.
Mouse, oral, TD_{Lo}: 455 mg/kg administered intermittently for 78 weeks produced liver tumors.

* See NIOSH, *RTECS* (KX4550000), for additional irritation, mutation, reproductive, tumorigenic and toxicity data.

Section 3. Physical Data

Boiling Point: 189 °F (87 °C)
Freezing Point: -121 °F (-85 °C)
Viscosity: 0.0055 Poise at 77 °F (25 °C)
Molecular Weight: 131.38
Density: 1.4649 at 20/4 °C
Refraction Index: 1.477 at 68 °F (20 °C/D)
Odor Threshold: 82 to 108 ppm (*not an effective warning*)

Vapor Pressure: 58 mm Hg at 68 °F (20 °C); 100 mm Hg at 32 °F (0 °C)
Saturated Vapor Density (Air = 0.075 lbs/ft³; 1.2 kg/m³): 0.0956 lbs/ft³; 1.53 kg/m³
Water Solubility: Very slightly soluble; 0.1% at 77 °F (25 °C)
Other Solubilities: Highly soluble in organic solvents (alcohol, acetone, ether, carbon tetrachloride, & chloroform) and lipids.
Surface Tension: 29.3 dyne/cm

Appearance and Odor: Clear, colorless (sometimes dyed blue), mobile liquid with a sweet chloroform odor.

Section 4. Fire and Explosion Data

Flash Point: 90 °F (32 °C) CC	Autoignition Temperature: 788 °F (420 °C)	LEL: 8% (25 °C); 12.5% (100 °C)	UEL: 10% (25 °C); 90% (100 °C)

Extinguishing Media: A Class 1C Flammable Liquid. Although it has a flash point of 90 °F, TCE burns with difficulty. For small fires, use dry chemical, carbon dioxide, water spray, or regular foam. For large fires, use water spray, fog, or regular foam. Unusual Fire or Explosion Hazards: Vapor/air mixtures may explode when ignited. Container may explode in heat of fire. Special Fire-fighting Procedures: Because fire may produce toxic thermal decomposition products, wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in pressure-demand or positive-pressure mode. Structural firefighters' protective clothing provides only limited protection against TCE. Apply cooling water to sides of container until well after fire is out. Stay away from ends of tanks. Do not release runoff from fire control methods to sewers or waterways.

Section 5. Reactivity Data

Stability/Polymerization: TCE slowly decomposes in the presence of light and moisture to form corrosive hydrochloric acid. Hazardous polymerization cannot occur. Chemical Incompatibilities: Include alkalis (sodium hydroxide), chemically active metals (aluminum, beryllium, lithium, magnesium, sodium, potassium, and titanium), epoxides, and oxidants (nitrogen tetraoxide, perchloric acid). Contact with 1-chloro-2,3-epoxy propane or the mono and di 2,3-epoxypropyl ethers of 1,4-butanediol + 2,2-bis-4(2',3'-epoxypropoxy)-phenylpropane can, in the presence of catalytic quantities of halide ions, cause dehydrochlorination of TCE to explosive dichloroacetylene. Conditions to Avoid: Exposure to light, moisture, ignition sources, and incompatibles. Hazardous Products of Decomposition: Thermal oxidative decomposition of TCE (above 300 °C) or exposure to ultraviolet light can produce carbon dioxide (CO_2) and toxic dichloro acetylene (explosive), chlorine, hydrogen chloride, and phosgene gas.

Section 6. Health Hazard Data

Carcinogenicity: The following agencies have rated TCE's carcinogenicity: IARC (Class 3, limited animal evidence & insufficient human data), Germany MAK (Class B, justifiably suspected of having carcinogenic potential), & NIOSH (Class X, carcinogen defined with no further categorization). Summary of Risks: TCE vapor is irritating to the eyes, nose, and respiratory tract and inhalation of high concentrations can lead to severe CNS effects such as unconsciousness, ventricular arrythmias, and death due to cardiac arrest. Mild liver dysfunction was also seen at levels high enough to produce CNS effects. Contact with the liquid is irritating to the skin and can lead to dermatitis by defatting the skin. Chronic toxicity is observed in the victims increasing intolerance to alcohol characterized by 'degreasers flush', a transient redness of the face, trunk, and arms. The euphoric effect of TCE has led to craving, and habitual sniffing of its vapors.

Continue on next page

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Section 6. Health Hazard Data, *Continued*

TCE crosses the placental barrier and thus exposes the fetus (any effects are yet unknown). There are increased reports of menstrual disorders in women workers and decreased libido in males at exposures high enough to cause CNS effects. TCE is eliminated unchanged in expired air and as metabolites (trichloroacetic acid & trichloroethanol) in blood and urine. **Medical Conditions Aggravated by Long-Term Exposure:** Disorders of nervous system, skin, heart, liver, and kidney. **Target Organs:** Respiratory, central & peripheral nervous, and cardiovascular (heart) systems, liver, kidney, and skin. **Primary Entry Routes:** Inhalation, skin and eye contact, and ingestion (rarely). **Acute Effects:** Vapor inhalation can cause eye, nose, and throat irritation, nausea, blurred vision, overexcitement, headache, drunkenness, memory loss, irregular heartbeat (resulting in sudden death), unconsciousness, and death due to cardiac failure. Skin contact with the liquid can cause dryness and cracking and prolonged exposure (generally if the victim is unconscious) can cause blistering. Eye contact can cause irritation and watering, with corneal epithelium injury in some cases. Ingestion of the liquid can cause lip, mouth, and gastrointestinal irritation, irregular heartbeat, nausea and vomiting, diarrhea (possibly blood-stained), drowsiness, and risk of pulmonary edema (fluid in lungs). **Chronic Effects:** Effects may persist for several weeks or months after repeated exposure. Symptoms include giddiness, irritability, headache, digestive disturbances, mental confusion, intolerance to alcohol (degreasers flush), altered color perception, loss or impairment of sense of smell, double vision, and peripheral nervous system function impairment including persistent neuritis, temporary loss of sense of touch, and paralysis of the fingers from direct contact with TCE liquid.
FIRST AID Eyes: *Do not* allow victim to rub or keep eyes tightly shut. Gently lift eyelids and flush immediately and continuously with flooding amounts of water until transported to an emergency medical facility. Consult a physician immediately. **Skin:** *Quickly* remove contaminated clothing. Rinse with flooding amounts of water for at least 15 min. Wash exposed area with soap and water. **Inhalation:** Remove exposed person to fresh air and support breathing as needed. **Ingestion:** Never give anything by mouth to an unconscious or convulsing person. Contact a poison control center and unless otherwise advised, have that *conscious and alert* person drink 1 to 2 glasses of water, then induce vomiting. Do not give milk, as its fat content (TCE is lipid soluble) may inhance gastrointestinal absorption of TCE. **Note to Physicians:** TCE elimination seems to be triphasic with half lives at 20 min, 3 hr, and 30 hr. Some success is seen in treating patients with propranolol, atropine, and disulfiram. Monitor urine and blood (lethal level = 3 to 110 µg/mL) metabolites. BEI = 100 mg/g creatinine (trichloroacetic acid) in urine, *sample at end of workweek.* BEI = 4 mg/L (trichloroethanol) in blood, *sample at end of shift at end of the workweek.* These tests are not 100% accurate indicators of exposure; monitor TCE in expired air as a confirmatory test.

Section 7. Spill, Leak, and Disposal Procedures

Spill/Leak: Immediately notify safety personnel, isolate and ventilate area, deny entry, and stay upwind. Shut off all ignition sources. For small spills, take up with earth, sand, vermiculite, or other absorbent, noncombustible material and place in suitable container for later disposal. For large spills, flush to containment area where density stratification will form a bottom TCE layer which can be pumped and containerized. Report any release in excess of 1000 lbs. Follow applicable OSHA regulations (29 CFR 1910.120). **Ecotoxicity Values:** Bluegill sunfish, LC_{50} = 44,700 µg/L/96 hr; fathead minnow (*Pimephales promelas*), LC_{50} = 40.7 mg/L/96 hr. **Environmental Degradation:** In air, TCE is photooxidized with a half-life of 5 days and reported to form phosgene, dichloroacetyl chloride, and formyl chloride. In water it evaporates rapidly in minutes to hours. TCE rapidly evaporates and may leach since it does not absorb to sediment. **Soil Absorption/Mobility:** TCE has a Log K_{oc} of 2, indicating high soil mobility. **Disposal:** Waste TCE can be poured on dry sand and allowed to vaporize in isolated location, purified by distillation, or returned to supplier. A potential candidate for rotary kiln incineration at 1508 to 2912 °F (820 to 1600 °C) with an acid scrubber to remove halo acids. Contact your supplier or a licensed contractor for detailed recommendations. Follow applicable Federal, state, and local regulations.

Designations
Extremely Hazardous Substance (40 CFR 355): Not listed
Listed as a SARA Toxic Chemical (40 CFR 372.65)
Listed as a RCRA Hazardous Waste (40 CFR 261.33 & 261.31): No. U228 & F002 (*spent solvent*)
Listed as a CERCLA Hazardous Substance* (40 CFR 302.4): Final Reportable Quantity (RQ), 100 lb (45.4 kg) [* per RCRA, Sec. 3001, CWA Sec. 311 (b)(4), & CWA Sec. 307 (a)]

OSHA Designations
Listed as an Air Contaminant (29 CFR 1910.1000, Table Z-1-A)

Section 8. Special Protection Data

Goggles: Wear chemical safety goggles (cup-type or rubber framed, equipped with impact-resistant glass), per OSHA eye- and face-protection regulations (29 CFR 1910.133). Because contact lens use in industry is controversial, establish your own policy. **Respirator:** Seek professional advice prior to respirator selection and use. Follow OSHA respirator regulations (29 CFR 1910.134) and, if necessary, wear a MSHA/NIOSH-approved respirator. At any detectable concentration, wear a SCBA with a full facepiece operated in pressure demand or other positive pressure mode. For emergency or nonroutine operations (cleaning spills, reactor vessels, or storage tanks), wear an SCBA. *Warning! Air-purifying respirators do not protect workers in oxygen-deficient atmospheres.* If respirators are used, OSHA requires a respiratory protection program that includes at least: medical certification, training, fit-testing, periodic environmental monitoring, maintenance, inspection, cleaning, and convenient, sanitary storage areas. **Other:** Wear chemically protective gloves, boots, aprons, and gauntlets made from Viton or Neoprene to prevent skin contact. *Do not* use natural rubber or polyvinyl chloride (PVC). **Ventilation:** Provide general and local exhaust ventilation systems to maintain airborne concentrations below OSHA PELs (Sec. 2). Local exhaust ventilation is preferred because it prevents contaminant dispersion into the work area by controlling it at its source.[103] **Safety Stations:** Make available in the work area emergency eyewash stations, safety/quick-drench showers, and washing facilities. **Contaminated Equipment:** Separate contaminated work clothes from street clothes and launder before reuse. Remove this material from your shoes and clean personal protective equipment. **Comments:** Never eat, drink, or smoke in work areas. Practice good personal hygiene especially before eating, drinking, smoking, using the toilet, or applying cosmetics.

Section 9. Special Precautions and Comments

Storage Requirements: Prevent physical damage to containers. Store in steel drums, in a cool, dry, well-ventilated area away from sunlight, heat, ignition sources, and incompatibles (Sec. 5). Store large quantities in galvanized iron, black iron, or steel containers; small amounts in dark (amber) colored glass bottles. **Engineering Controls:** To reduce potential health hazards, use sufficient dilution or local exhaust ventilation to control airborne contaminants and to maintain concentrations at the lowest practical level. Design processes so that the operator is not directly exposed to the solvent or its vapor. Do not use open electric heaters, high-temperature processes, arc-welding or open flames in TCE atmospheres. **Administrative Controls:** Consider preplacement and periodic medical exams of exposed workers with emphasis on skin, respiratory, cardiac, central and peripheral nervous systems, and liver and kidney function. Employ air and biological monitoring (BEIs). Instruct employees on safe handling of TCE.

Transportation Data (49 CFR 172.101)

Shipping Name: Trichloroethylene
Hazard Class: 6.1
ID No.: UN1710
DOT Packing Group: III
DOT Label: Keep Away From Food
DOT Special Provisions (172.102): N36, T1

Packaging Authorizations
a) Exceptions: 173.153
b) Non-bulk Packaging: 173.203
c) Bulk Packaging: 173.241

Quantity Limitations
a) Passenger Aircraft or Railcar: 60L
b) Cargo Aircraft Only: 220L

Vessel Stowage Requirements
a) Vessel Stowage: A
b) Other: 40

MSDS Collection References: 26, 73, 100, 101, 103, 124, 126, 127, 132, 133, 136, 139, 140, 148, 149, 153, 159, 163, 164, 167, 168, 171, 174, 175, 176, 180.
Prepared by: M Gannon, BA; Industrial Hygiene Review: D Wilson, CIH; Medical Review: AC Darlington, MD

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Material Safety Data Sheets Collection:

Sheet No. 382
Vinyl Chloride

Issued: 7/78 Revision: C, 9/92

Section 1. Material Identification

Vinyl Chloride (C_2H_3Cl) Description: Derived from ethylene dichloride and alcoholic potassium, by reaction of acetylene and hydrogen chloride (as gas or liquids), or by oxychlorination where ethylene reacts with hydrochloric acid and oxygen. Inhibitors such as butyl catechol, hydroquinone, or phenol are added to prevent polymerization. Used in the plastics industry for the production of polyvinyl chloride resins, in organic synthesis and formerly as a refrigerant, extraction solvent, and propellant (banned in 1974 because of its carcinogenic activity).
Other Designations: CAS No. 75-01-4, chloroethylene, chloroethene, ethylene monochloride, Trovidur, VC, VCM.
Manufacturer: Contact your supplier or distributor. Consult latest *Chemical Week Buyers' Guide*[73] for a suppliers list.

Cautions: Vinyl chloride is a confirmed human carcinogen. Vapor inhalation leads to central nervous system (CNS) depression. The liquid can cause frostbite. It is a flammable gas at room temperature and polymerizes on exposure to air or sunlight. Avoid exposure to VC through engineering controls and wearing PPE

NFPA
R 2
I 4
S 4
K 4

HMIS
H 3*
F 4
R 2
PPE - Sec. 8
* Chronic effects

Section 2. Ingredients and Occupational Exposure Limits

Vinyl Chloride, ca 98 to 99%. Impurities include water, acetaldehyde, hydrogen chloride, hydrogen peroxide, methyl chloride, butane, 1,3-butadiene, chlorophene, diacetylene, vinyl acetylene, and propine.

1991 OSHA PELs
8-hr TWA: 1 ppm
Ceiling: 5 ppm; OSHA-X

1990 NIOSH REL
NIOSH-X

1992-93 ACGIH TLV
TWA: 5 ppm (13 mg/m³)
TLV-A1

1990 DFG (Germany) TRK*
Existing Installations: 3 ppm
MAK-A1

1985-86 Toxicity Data†
Man, inhalation, TC_{Lo}: Intermittent exposure to 200 ppm for 14 yr caused liver tumors.
Man, inhalation, TC_{Lo}: 30 mg/m³/5 yr caused spermatogenesis.
Human, inhalation, TC: Continuous exposure to 300 mg/m³ for an undetermined number of weeks caused blood tumors.
Rat, oral, LD_{50}: 500 mg/kg; toxic effects not yet reviewed

* TRK (technical exposure limit) is used in place of MAK when a material is a carcinogen. Unlike an MAK below which no adverse effects are expected, the TRK is a limit set below which adverse effects may still occur. This is based on the theory that 1 molecule of a carcinogenic substance may still produce a tumor. The TRK is set to allow for an acceptable risk (for example, 1 tumor in 1 million persons may be an acceptable risk).
† See NIOSH, *RTECS* (KU9625000), for additional mutation, reproductive, tumorigenic, and toxicity data.

Section 3. Physical Data

Boiling Point: 7 °F (-13.9 °C)
Freezing Point: -245 °F (-159.7 °C)
Molecular Weight: 62.5
Specific Gravity: 0.9106 at 68 °F (20 °C)
Ionization Potential: 9.99 eV
Refraction Index: 1.370 at 20 °C/D
Surface Tension: 23.1 dyne/cm at -4 °F (-20 °C)
Odor Threshold: 2000 to 5000 ppm*
Vapor Density (Air = 1): 2.155

Water Solubility: Slightly soluble, 0.1% at 77 °F (25 °C)
Other Solubilities: alcohol, benzene, carbon tetrachloride, ether, hydrocarbon and oils.
Vapor Pressure: 2530 mm Hg at 68 °F (20 °C), 400 mm Hg at -18.4 °F (-28 °C)
Critical Temperature: 304.7 °F (151.5 °C)
Critical Pressure: 56.8 atm
Viscosity: 0.01072 cP at 68 °F (20 °C), *gas*; 0.28 cP at -4 °F (-20 °C), *liquid*
Appearance and Odor: A gas at room temperature. Usually found as a compressed/cooled liquid. The colorless liquid forms a vapor with a pleasant ethereal odor.

*The actual vapor concentration that can be detected by humans has not been adequately determined and varies from one individual to another, from impurities, and probably from exposure duration. The odor threshold is not an accurate warning of exposure.

Section 4. Fire and Explosion Data

Flash Point: -108.4 °F (-78 °C) OC	Autoignition Temperature: 882 °F (472 °C)	LEL: 3.6% v/v	UEL: 33% v/v

Extinguishing Media: For small fires, use dry chemical or carbon dioxide. For large fires, use water spray, fog, or regular foam. Unusual Fire or Explosion Hazards: Large fires can be practically inextinguishable. Vapors may travel to an ignition source and flash back. VC may polymerize in cylinders or tank cars and explode in heat of fire. Vapors pose an explosion hazard indoors, outdoors, and in sewers. VC decomposes in fire to hydrogen chloride, carbon monoxide, carbon dioxide, and phosgene. Burning rate = 4.3 mm/min. Special Fire-fighting Procedures: Because fire may produce toxic thermal decomposition products, wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in pressure-demand or positive-pressure mode. Stop gas leak if possible. Let tank, tank car, or tank truck burn unless leak can be stopped. For massive fire in cargo area, use monitor nozzles or unmanned hose holders; if this is impossible, withdraw from area and let fire burn. Withdraw immediately if you hear a rising sound from venting safety device or notice any tank discoloration due to fire. *Do not* release runoff from fire control methods to sewers or waterways.

Section 5. Reactivity Data

Stability/Polymerization: Long term exposure to air may result in formation of peroxides which initiates explosive polymerization of the chloride. VC can polymerize on exposure to light or in presence of a catalyst. Chemical Incompatibilities: VC can explode on contact with oxide of nitrogen, may liberate hydrogen chloride on exposure to strong alkalies, and is incompatible with copper, oxidizers, aluminum, and peroxides. In the presence of moisture, VC attacks iron and steel. Conditions to Avoid: Exposure to sunlight, air, heat, and incompatibles. Hazardous Products of Decomposition: Thermal oxidative decomposition of vinyl chloride can produce carbon oxides, and chloride gas.

Section 6. Health Hazard Data

Carcinogenicity: Vinyl chloride is listed as a carcinogen by the IARC (Class 1, *sufficient human evidence*),[164] NTP (Class 1, *sufficient human evidence*),[169] NIOSH (Class X, *carcinogen defined without further categorization*),[163] ACGIH (TLV-A1, *confirmed human carcinogen*),[163] DFG (MAK-A1, *capable of inducing malignant tumors in humans*),[163] and OSHA (Class X, *carcinogen defined without further categorization*).[164] Liver tumors (angiosarcomas) are confirmed from VC exposure. Other tumors of the CNS, respiratory system, blood, and lymphatic system have occurred from exposure to the polyvinyl chloride manufacture process but VC itself may not be the causative agent. Summary of Risks: Vapor inhalation causes varying degrees of CNS depression with noticeable anesthetic effects at levels of 1% (10,000 ppm). Studies have shown loss of libido and sperm in men exposed to VC and in Russian studies, 77% of exposed women experienced ovarian dysfunction, benign uterine growths, and prolapsed genital organs. However, no teratogenic effects have been seen in offspring of exposed workers.

Continue on next page

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Section 6. Health Hazard Data, *continued*

pears that metabolism is necessary before many of VC's toxic effects occur. Some vinyl chloride is exhaled unchanged but most is metabolized to monoacetaldehyde. Skin absorption may occur if liquid is confined on skin but absorbed amount would be small. It is possible that the phenol inhibitor absorbed as well. The compressed liquid can cause frostbite. Vapors are severely irritating to the eyes. Chronic exposure can cause cancer and a syndromes known as *vinyl chloride disease*. **Medical Conditions Aggravated by Long-Term Exposure:** Liver, cardiac, pulmonary, and connective tissue disorders. **Target Organs:** Liver, CNS, respiratory and lymphatic systems, bone, and connective tissue of the skin. **Primary Entry Routes:** Inhalation, skin/eye contact. **Acute Effects:** CNS effects include fatigue, headache, vertigo, ataxia, euphoria, visual disturbances, dulling of auditory cues, numbness and tingling in the extremities, narcosis, unconsciousness, and death due to respiratory failure. Respiratory problems include dyspnea, asthma, and pneumonoconiosis. **Chronic Effects:** Repeated exposure has lead to liver cancer; confirmed because of the otherwise rarity of its type (angiosarcoma). Tumors in other organs have occurred in the polyvinyl chloride industry but agents other than VC may be responsible; authorities are still debating this issue. A triad of other effects are associated with VC exposure. Acro-osteolysis is associated with hand cleaning of polymerization vessels and characterized by dissolution of bone in the hands, especially when associated with resorption. Raynaud's Phenomenon is a vascular disorder marked by recurrent spasm of the capillaries and especially those of the fingers and toes on exposure to cold. This is usually accompanied by pain and in severe cases may progress to local gangrene. Sclerodermatous skin changes (affecting the dorsal hands and distal forearms) are seen and described as a slowly progressive disease marked by deposition of fibrous connective tissue in the skin. The skin becomes thickened and raised nodules appear. Arthralgias (pain in one or more joints) and blood changes with decreased platelet number and capillary abnormalities may also occur.
FIRST AID Eyes: *Do not* allow victim to rub or keep eyes tightly shut. Gently lift eyelids and flush immediately and continuously with flooding amounts of water until transported to an emergency medical facility. Consult a physician immediately. Skin: *Quickly* remove contaminated clothing. Rinse with flooding amounts of water for at least 15 min. Wash exposed area with soap and water. For reddened or blistered skin, consult a physician. For frostbite, immerse affected area in 107.6 °F (42 °C) water until completely rewarmed. *Do not* use dry heat. **Inhalation:** Remove exposed person to fresh air and support breathing as needed. **Ingestion:** Unlikely! VC is a gas above 7 °F (-14°C). **Note to Physicians:** Endotracheal intubation may be required if significant CNS or respiratory depression occur. Diagnostic test: thiodiglycolic acid in urine (normally < 2 mg/g creatinine).

Section 7. Spill, Leak, and Disposal Procedures

Spill/Leak: Notify safety personnel, isolate and ventilate area, deny entry, and stay upwind. If possible without risk, stop gas flow. Shut off ignition sources. Report any release > 1 lb. Follow applicable OSHA regulations (29 CFR 1910.120). **Environmental Transport:** VC reacts with hydroxyl radicals in the trophosphere with a half-life of 1.2 days. The half-life = a few hr in photochemical smog. Reaction products in the air include chloroacetaldehyde, hydrogen chloride, chloroethylene, epoxide, formaldehyde, formyl chloride, formic acid, and carbon monoxide. In soil, VC rapidly volatilizes. What does not evaporate will be highly mobile and may leach into groundwater. In water, VC is not expected to hydrolyze, bioconcentrate, or absorb to sediment. It will rapidly volatilize with an estimated half-life of 0.805 hr for evaporation from a river 1 meter deep with a current of 3 meter/sec and a wind velocity of 3 meter/sec. In waters containing photosensitizers such as humic acid, photodegradation will be rapid. **Soil Absorption/Mobility:** From an estimated solubility of 2,700 ppm, a Koc of 56 is established for VC which indicates high soil mobility and potential to leach into groundwater. **Disposal:** Dilute any waste compressed liquid to a 1% solution and remove phenol inhibitor as sodium. Pour onto vermiculite, sodium bicarbonate, or a sand & soda ash mixture (90/10). Add slaked lime if fluoride is present. Mix in paper boxes, place in incinerator, cover with scrap wood and paper, and ignite with excelsior train. Another method is to dissolve waste in a flammable solvent and spray in incinerator firebox equipped with an afterburner and alkali scrubber. Contact your supplier or a licensed contractor for detailed recommendations. Follow applicable Federal, state, and local regulations.

signations
a RCRA Hazardous Waste (40 CFR 261.33): No. U043
SARA Extremely Hazardous Substance (40 CFR 355), TPQ: Not listed
Listed as a SARA Toxic Chemical (40 CFR 372.65)
Listed as a CERCLA Hazardous Substance* (40 CFR 302.4): Final Reportable Quantity (RQ), 1 lb (0.454 kg) [* per CWA, Sec. 307 (a); CAA, Sec. 112, & RCRA, Sec. 3001]

OSHA Designations
Listed as an Air Contaminant (29 CFR 1910.1000, Table Z-1-A)

Section 8. Special Protection Data

Goggles: Wear protective eyeglasses or chemical safety goggles, per OSHA eye- and face-protection regulations (29 CFR 1910.133). Because contact lens use in industry is controversial, establish your own policy. **Respirator:** Seek professional advice prior to respirator selection and use. Follow OSHA (29 CFR 1910.134) and, if necessary, wear a MSHA/NIOSH-approved respirator. According to NIOSH[145], for any detectable concentration use a SCBA or supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure mode. See 29 CFR 1910.1017 for detailed OSHA respirator recommendations. For emergency or nonroutine operations (cleaning spills, reactor vessels, or storage tanks), wear an SCBA. *Warning! Air-purifying respirators do not protect workers in oxygen-deficient atmospheres.* If respirators are used, OSHA requires a written respiratory protection program that includes at least: medical certification, training, fit-testing, periodic environmental monitoring, maintenance, inspection, cleaning, and convenient, sanitary storage areas. **Other:** Wear chemically protective gloves, boots, aprons, and gauntlets made of Viton or chlorinated polyethylene to prevent skin contact. **Ventilation:** Provide general and local exhaust ventilation systems to maintain airborne concentrations below the OSHA PEL's (Sec. 2). Local exhaust ventilation is preferred because it prevents contaminant dispersion into the work area by controlling it at its source.[103] **Safety Stations:** Make available in the work area emergency eyewash stations, safety/quick-drench showers, and washing facilities. **Contaminated Equipment:** Separate work clothes from street clothes, launder before reuse and clean PPE. **Comments:** Never eat, drink, or smoke in work areas. Practice good personal hygiene after using this material, especially before eating, drinking, smoking, using the toilet, or applying cosmetics.

Section 9. Special Precautions and Comments

Storage Requirements: Store in a cool, dry, well-ventilated area in clearly labeled containers. Outside or detached storage is preferred. Large amounts should be stored in steel containers under pressure. Keep separate from incompatibles (Sec. 5). Venting, under pressure should be safety relief. At atm, venting should be pressure vacuum. Regularly monitor inhibitor levels. To avoid static sparks, electrically ground and bond all equipment used with VC. Avoid open flames, spark formation and electric discharges around VC. **Engineering Controls:** To reduce potential health hazards, use sufficient dilution or local exhaust ventilation to control airborne contaminants and to maintain concentrations at the lowest practical level. Install Class 1, Group D electrical equipment. **Administrative Controls:** Inform VC exposed personnel of hazards associated with its use. Preplacement and periodic medical exams of workers exposed above the action level is mandatory under OSHA 29 CFR (1910.1017). Monitor for liver cancer, scleroderma, pneumonitis, clotting abnormalities, and acro-osteolysis.

Transportation Data (49 CFR 172.101)

DOT Shipping Name: Vinyl Chloride
Hazard Class: 2.1
UN1086
Packing Group: --
DOT Label: Flammable Gas
Special Provisions (172.102): B44

Packaging Authorizations
a) Exceptions: 173.306
b) Non-bulk Packaging: 173.304
c) Bulk Packaging: 173.314 & 173.315

Quantity Limitations
a) Passenger Aircraft or Railcar: Forbidden
b) Cargo Aircraft Only: 150 kg

Vessel Stowage Requirements
a) Vessel Stowage: B
b) Other: 40

MSDS Collection References: 26, 73, 100, 101, 103, 124, 126, 127, 132, 133, 136, 140, 148, 149, 153, 159, 162, 163, 164, 167, 168, 171, 174, 175
Prepared by: M Gannon, BA; Industrial Hygiene Review: PA Roy, MPH, CIH; Medical Review: AC Darlington, MPH, MD

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Material Safety Data Sheets Collection:

Sheet No. 830
1,1-Dichloroethane

Issued: 6/92

Section 1. Material Identification

38

1,1-Dichloroethane (CH_3CHCL_2) Description: Derived by various methods; by direct chlorination of ethane, as a side product of chloral manufacture, by treating ethylene and chlorine with calcium chloride, by action of phosphorus chloride on acetaldehyde, and the reaction of hydrogen chloride and vinyl chloride at 20 to 55 °C in the presence of an aluminum, ferric, or zinc chloride catalyst. Found as an air contaminant in submarines and space craft. Its largest industrial use is in the production of 1,1,1-trichloroethane. Also used as a cleansing agent, degreaser, solvent for plastics, oils, and fats, grain fumigant, chemical intermediate; in insecticide sprays, rubber cementing, fabric spreading, paint and varnish removers, in ore flotation, vinyl chloride production, and as a coupling agent in anti-knock gasoline. Formerly used as an anesthetic.
Other Designations: CAS No. 75-34-3; assymetrical dichloroethane; chlorinated hydrochloric ether; ethylidene chloride; ethylidene dichloride.
Manufacturer: Contact your supplier or distributor. Consult latest *Chemical Week Buyers' Guide*[73] for a suppliers list.
Cautions: 1,1-Dichloroethane is volatile and highly flammable. It is irritating to the eyes and respiratory tract and inhalation of high concentrations causes an anesthetic effect.

R	1
I	3
S	2
K	4

NFPA: 3 / 2 / 0 / –

HMIS
H 2
F 3
R 0
PPG*
* Sec. 8

Section 2. Ingredients and Occupational Exposure Limits

1,1-Dichloroethane, reagent grade (99.7%). Impurities consist of ethyl chloride (0.02%), trichloroethylene (0.08%), butylene oxide (0.08%), ethylene dichloride (0.01%), and unknown (0.14%).

1991 OSHA PEL
8-hr TWA: 100 ppm (400 mg/m³)

1990 IDLH Level
4000 ppm

1990 NIOSH REL
8-hr TWA: 100 ppm (400 mg/m³)

1991-92 ACGIH TLVs*
TWA: 200 ppm (810 mg/m³)
STEL: 250 ppm (1010 mg/m³)

1990 DFG (Germany) MAK
100 ppm (400 mg/m³)
Half-life: < 2hr
Peak Exposure Limit: 200 ppm/30 min. average value/maximum of 4 peaks per shift

1985-86 Toxicity Data†
Mouse, oral, TD_{Lo}: 185 g/kg administered intermittently for 78 wk produced uterine tumors.
Rat, oral, LD_{50}: 725 mg/kg; toxic effects not yet reviewed.‡
Rat, inhalation, TC_{Lo}: 6000 ppm/7 hr administered during 6 to 15 days of pregnancy caused developmental abnormalities of the musculoskeletal system.

* Notice of intended change to 100 ppm/405 mg/m³.
†See NIOSH, *RTECS* (KI0175000), for additional reproductive, tumorigenic and toxicity data.
‡ Considered a possible error since subsequent studies at higher concentrations failed to produce comparative results.[133]

Section 3. Physical Data

Boiling Point: 135 °F (57.3 °C)
Melting Point: -143 °F (-96.98 °C)
Vapor Pressure: 230 mm Hg at 77 °F (25 °C)
Saturated Vapor Density (air = 1.2 kg/m³ or 0.075 lbs/ft³): 2.076 kg/m³ or 0.129 lbs/ft³
Refraction Index: 1.4166 at 68 °F (20 °C)
Surface Tension: 24.75 dyne/cm at 68 °F (20 °C)

Molecular Weight: 98.97
Specific Gravity: 1.174 at 68 °F (20/4 °C)
Water Solubility: Slightly, 0.5%
Other Solubilities: Very soluble in alcohol and ether, soluble in acetone, benzene, and fixed and volatile oils.
Relative Evaporation Rate (BuAc=1): 11.6
Odor Threshold: 49 to 1359 ppm; odor is not sufficient to warn against overexposure

Appearance and Odor: Colorless, mobile, oily liquid with a chloroform odor and a saccharin taste.

Section 4. Fire and Explosion Data

Flash Point: 17 °F (-8.33 °C) CC*	Autoignition Temperature: 856 °F (493 °C)	LEL: 5.6% v/v	UEL: 11.4% v/v

Extinguishing Media: A Class 1B Flammable Liquid. For small fires, use dry chemical, carbon dioxide (CO_2), or "alcohol-resistant" foam. For large fires, use fog or "alcohol-resistant" foam. Water may be ineffective unless used as a "blanket".
Unusual Fire or Explosion Hazards: Vapors may travel to an ignition source and flash back. Container may explode in heat of fire.
Special Fire-fighting Procedures: Because fire may produce toxic thermal decomposition products, wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in pressure-demand or positive-pressure mode. Structural firefighter's protective clothing will provide only limited protection. If possible without risk, move container from fire area. Apply cooling water to sides of containers until well after fire is out. Stay away from ends of tanks. For massive fire in cargo area, use monitor nozzles or unmanned hose holders; if this is impossible, withdraw from area and let fire burn. Withdraw immediately if you hear a rising sound from venting safety device or notice any tank discoloration due to fire. Do not release runoff from fire control methods to sewers (explosion) or waterways.
* 22 °F (-5.5 °C), OC[148]

Section 5. Reactivity Data

Stability/Polymerization: 1,1-Dichloroethane is stable at room temperature in closed containers under normal storage and handling conditions. Hazardous polymerization cannot occur.
Chemical Incompatibilities: Incompatible with strong oxidizers and forms acetaldehyde in contact with caustics. 1,1-Dichloroethane will attack some forms of plastics, rubber, and coatings.
Conditions to Avoid: Exposure to heat and ignition sources and contact with incompatibles.
Hazardous Products of Decomposition: Thermal oxidative decomposition of 1,1-dichloroethane can produce carbon dioxide (CO_2), irritating hydrogen chloride (HCl) and toxic phosgene ($COCL_2$) fumes.

Section 6. Health Hazard Data

Carcinogenicity: The IARC,[164] NTP,[169] and OSHA[164] do not list 1,1-dichloroethane as a carcinogen. However, the National Cancer Institute has recommended caution due to analogy to other chloroethanes such as 1,2-dichlorothane which are shown to cause cancer in animals.
Summary of Risks: 1,1-Dichloroethane is irritating to the eyes and respiratory system. It causes varying degrees of central nervous system (CNS) disturbance depending on the concentration and duration of exposure. Liver and kidney toxicity is controversial.

Continue on next page

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Section 6. Health Hazard Data, *continued*

Some sources report that severe, acute exposures can cause damage, some quote recent detailed chronic studies which indicate little capacity for damage; still others refute the possibility of acute damage even from very high exposures. In reviewing the data it appears likely that chronic exposure will not cause kidney or liver damage but acute exposures to high concentrations may. There is definite evidence that 1,1-dichloroethane produces liver damage in monkeys, dogs, and rats when exposed to 98 ppm/90 days. It is also unclear whether or not 1,1-dichloroethane is absorbed through the skin. There are reports of absorption (although not in toxic amounts) and others claiming there is no absorption. Given this controversial data it is best to take precautions as if skin absorption, and liver and kidney damage were proven to occur. **Medical Conditions Aggravated by Long-term Exposure:** Chronic respiratory and skin disease, neurological damage, and liver or kidney disorders. **Target Organs:** Skin, CNS, liver, kidney. **Primary Entry Routes:** Inhalation and skin contact. **Acute Effects:** Inhalation symptoms include eye, nose, and throat irritation, headache, dizziness, coughing, staggering, disturbed vision, irregular heartbeat (can result in sudden death), unconsciousness, narcosis, coma, and death due to cardiac or respiratory failure. There is the risk of pulmonary edema (fluid in lungs). Skin contact is irritating and causes defatting, redness and swelling. Vapor contact with the eyes causes irritation, watering eyes and lid inflammation. Splashes to the eyes produces a burning sensation, watering, and lid inflammation. **Chronic Effects:** Repeated skin contact can cause a rash and scaliness. Repeated inhalation may have neurological effects.

FIRST AID. *Emergency personnel should protect against contamination.*

Eyes: Gently lift eyelids and flush immediately and continuously with flooding amounts of water until transported to an emergency medical facility. Do *not* allow victim to rub or keep eyes tightly shut. Immediately consult an ophthamlologist. **Skin:** 1,1-Dichloroethane vaporizes easily and poses an inhalation hazard as well. *Quickly and carefully* remove contaminated clothing; *1,1-dichloroethane is flammable!* Rinse with flooding amounts of water for at least 15 min. Wash exposed area with soap and water. For reddened or blistered skin, consult a physician. **Inhalation:** Remove exposed person to fresh air and support breathing as needed. **Ingestion:** Never give anything by mouth to an unconscious or convulsing person. Contact a poison control center. Unless the poison control center advises otherwise, have that *conscious and alert* person drink 1 to 2 glasses of water, then induce vomiting. After vomiting, give 2 tbsp activated charcoal in 8 oz water to drink.

After first aid, get appropriate in-plant, paramedic, or community medical support.

Note to Physicians: Proper ventilation is the main treatment for acute exposure. Be prepared to support respiration if needed. Monitor liver function studies, urine analysis, and creatinine with acute and chronic exposure.

Section 7. Spill, Leak, and Disposal Procedures

Spill/Leak: Immediately notify safety personnel, isolate and ventilate area, deny entry, and stay upwind. Shut off ignition sources. Cleanup personnel should protect against inhalation and skin contact. For small spills, take up with earth, sand, vermiculite, or other absorbent, noncombustible material and using nonsparking tools, place in a suitable container. For large spills, dike far ahead of liquid spill for disposal or reclamation. Do not allow 1,1-dichloroethane to enter confined areas such as a sewer because of potential explosion. Follow applicable OSHA regulations (29 CFR 1910.120). **Environmental Degradation:** In soil, 1,1-dichloroethane volatilizes rapidly but may leach into groundwater. In water it will volatilize from a pond, lake, or river with a half-life of 6 to 9 days, 5 to 8 days, and 24 to 32 hr, respectively. In the atmosphere it will degrade by reaction with photochemically produced hydroxyl radicals with a 62 day half-life. It may also be carried back to soil via rain.

Ecotoxicity Values: *Artemia salina*, brine shrimp, TLm 320 mg/L/24 hr; *Lagodon rhomboides*, pinperch, TLm 160 mg/L/24 hr; *Poecilia reticulata*, guppies, LC_{50} 202 ppm/7 days.

Disposal: Contact your supplier or a licensed contractor for detailed recommendations. Follow applicable Federal, state, and local regulations.

EPA Designations
SARA Extremely Hazardous Substance (40 CFR 355): Not listed
SARA Toxic Chemical (40 CFR 372.65): Not listed
Listed as a RCRA Hazardous Waste (40 CFR 261.33): No. U076
Listed as a CERCLA Hazardous Substance* (40 CFR 302.4): Final Reportable Quantity (RQ), 1000 lb (454 kg)
[* per RCRA, Sec. 3001 & CWA, Sec. 307(a)]

OSHA Designations Listed as an Air Contaminant (29 CFR 1910.1000, Table Z-1-A)

Section 8. Special Protection Data

Goggles: Wear protective eyeglasses or chemical safety goggles, per OSHA eye- and face-protection regulations (29 CFR 1910.133). Because contact lens use in industry is controversial, establish your own policy. **Respirator:** Seek professional advice prior to respirator selection and use. Follow OSHA respirator regulations (29 CFR 1910.134) and, if necessary, wear a NIOSH/MSHA-approved respirator. For < 1000 ppm, use any supplied-air respirator or SCBA. For < 2500 ppm, use any supplied-air respirator operated in a continuous flow mode. For < 4000 ppm, use any supplied-air respirator or SCBA with a full facepiece. For emergency or nonroutine operations (cleaning spills, reactor vessels, or storage tanks), wear an SCBA. *Warning! Air-purifying respirators do not protect workers in oxygen-deficient atmospheres.* If respirators are used, OSHA requires a respiratory protection program that includes at least: training, fit-testing, periodic environmental monitoring, maintenance, inspection, cleaning, and convenient, sanitary storage areas. **Other:** Wear chemically protective gloves, boots, aprons, and gauntlets to prevent repeated or prolonged skin contact. Polyvinyl alcohol is recommended as suitable material for PPG. **Ventilation:** Provide general and local exhaust ventilation systems to maintain airborne concentrations below the OSHA PEL (Sec. 2). Local exhaust ventilation is preferred because it prevents contaminant dispersion into the work area by controlling it at its source.[103] **Safety Stations:** Make available in the work area emergency eyewash stations, safety/quick-drench showers, and washing facilities. **Contaminated Equipment:** Separate contaminated work clothes from street clothes and launder before reuse. Thoroughly decontaminate personal protective equipment. **Comments:** Never eat, drink, or smoke in work areas. Practice good personal hygiene after using this material, especially before eating, drinking, smoking, using the toilet, or applying cosmetics.

Section 9. Special Precautions and Comments

Storage Requirements: Prevent physical damage to containers. Store in a cool, dry, well-ventilated area away from ignition sources and incompatibles (Sec. 5). Label containers to indicate the contents' high flammability. Periodically inspect containers for cracks and leaks. To prevent static sparks, electrically ground and bond all equipment used in 1,1-dichloroethane manufacture, use, storage, transfer, and shipping.

Engineering Controls: To reduce potential health hazards, use sufficient dilution or local exhaust ventilation to control airborne contaminants and to maintain concentrations at the lowest practical level.

Administrative Controls: Consider preplacement and periodic medical exams of exposed workers emphasizing the skin, CNS, liver, and kidney. Educate workers about the hazards of 1,1-dichloroethane and the necessary precautions to reduce or prevent exposure.

Transportation Data (49 CFR 172.102)

IMO Shipping Name: 1,1-Dichloroethane
IMO Hazard Class: 3.2
ID No.: UN2362
IMO Label: Flammable Liquid
IMDG Packaging Group: II

MSDS Collection **References:** 73, 89, 101, 103, 126, 127, 131, 132, 133, 136, 140, 148, 149, 153, 159, 162, 163, 164, 167, 168, 171
Prepared by: M Gannon, BA; Industrial Hygiene Review: PA Roy, MPH, CIH; Medical Review: AC Darlington, MPH, MD

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Material Safety Data Sheet

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GENIUM PUBLISHING CORP.

No. 359
ETHYLENE DICHLORIDE
(Formerly 1,2-Dichloroethane)
(Revision C)
Issued: November 1978
Revised: August 1987

SECTION 1. MATERIAL IDENTIFICATION

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CHEMICAL NAME: ETHYLENE DICHLORIDE (Changed to reflect common industrial practice)
DESCRIPTION (Origin/Uses): Made from acetylene and HCl. Used as a degreaser, a scavenger in leaded gasoline, as an intermediate in the manufacture of vinyl chloride, in paint removers, in wetting and penetration agents, in ore flotation processes, as a fumigant, and as a solvent for fats, oils, waxes, and gums.
OTHER DESIGNATIONS: 1,2-Dichloroethane; *sym*-Dichloroethane; Dutch Liquid; Dutch Oil; EDC; Ethane Dichloride; Ethylene Chloride; 1,2-Ethylene Dichloride; Glycol Dichloride; $C_2H_4Cl_2$; NIOSH *RTECS* KI0525000; CAS #0107-06-2
MANUFACTURERS/SUPPLIERS: Available from several suppliers, including: Dow Chemical USA, 2020 Dow Center, Midland, MI 48640; Telephone: (517) 636-1000

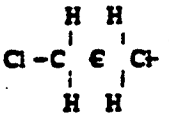
COMMENTS: Ethylene dichloride is a flammable, toxic liquid.

HMIS			
H	1	R	1
F	3	I	4
R	0	S	2
PPE*		K	4

* See Sect. 8

SECTION 2. INGREDIENTS AND HAZARDS

Ingredients	%	HAZARD DATA
Ethylene Dichloride, CAS #0107-06-2; NIOSH *RTECS* #KI0525000	100	ACGIH Values 1987-88 TLV-TWA: 10 ppm, 40 mg/m^3 OSHA PEL* 1986-87 8-Hr TWA: 50 ppm; Ceiling: 100 ppm (15 Min.) NIOSH REL 1986-87 10-Hr TWA: 1 ppm Ceiling: 2 ppm (15 Min.) Toxicity Data Man, Inhalation, TC_{Lo}: 4000 ppm/1 Hr Human, Oral, TD_{Lo}: 428 mg/kg Man, Oral, TD_{Lo}: 892 mg/kg Man, Oral, LD_{Lo}: 714 mg/kg Rat, Oral, LD_{50}: 670 mg/kg



*The maximum allowable peak concentration (above the ceiling level value) of ethylene dichloride is 200 ppm for 5 minutes in any 3-hour period.
COMMENTS: Additional data concerning toxic doses and tumorigenic, reproductive, and mutagenic effects is listed (with references) in the NIOSH *RTECS* 1983-84 supplement, pages 865-66.

SECTION 3. PHYSICAL DATA

Boiling Point ... 182.3°F (83.5°C)
Vapor Pressure ... 87 Torr at 77°F (25°C)
Water Solubility ... Soluble in about 120 Parts Water
Vapor Density (Air = 1) ... 3.4
Evaporation Rate (n-BuAc = 1) ... Not Listed
Specific Gravity ... 1.2569 at 69°F (20°C)
Freezing Point ... -31.9°F (-35.5°C)
Molecular Weight ... 98.96 Grams/Mole

Appearance and odor: Colorless, clear liquid. Sweet, chloroformlike odor is typical of chlorinated hydrocarbons. The recognition threshold (100% of test panel) for ethylene dichloride is 40 ppm. Odor detection probably indicates an excessive exposure to vapor. High volatility and flammability, coupled with its toxicity and carcinogenic potential, make this material a major health hazard.
COMMENTS: Ethylene dichloride is miscible with alcohol, chloroform, and ether.

SECTION 4. FIRE AND EXPLOSION DATA

Flash Point and Method	Autoignition Temperature	Flammability Limits in Air % by Volume	LOWER	UPPER
See Below	775°F (413°C)		6.2	15.9

EXTINGUISHING MEDIA: Use chemical, carbon dioxide, alcohol foam, water spray/fog, or dry sand to fight fires involving ethylene dichloride. Direct water sprays may be ineffective extinguishing agents, but they may be successfully used to cool fire-exposed containers. Use a smothering effect to extinguish fires involving this material. UNUSUAL FIRE/EXPLOSION HAZARDS: Ethylene dichloride is a dangerous fire and explosion hazard when exposed to sources of ignition such as heat, open flames, sparks, etc. Its vapors are heavier than air and can flow along surfaces to distant, low-lying sources of ignition and flash back. If it is safe to do so, remove this material from the fire area. Ethylene dichloride burns with a smoky flame.
SPECIAL FIRE-FIGHTING PROCEDURES: Wear a self-contained breathing apparatus with a full facepiece operated in a pressure-demand or another positive-pressure mode.
COMMENTS: Flash Point and Method: 56°F (13°C) CC; 65°F (18°C) OC.
OSHA Flammability Class (29 CFR 1910.106): IB. DOT Flammability Class (49 CFR 173.115): Flammable Liquid

SECTION 5. REACTIVITY DATA

Ethylene dichloride is stable. Hazardous polymerization cannot occur.

CHEMICAL INCOMPATIBILITIES include strong oxidizing agents. Explosions have occurred with mixtures of this material and liquid ammonia or dimethylaminopropylamine. Finely divided aluminum or magnesium metal may be hazardous in contact with ethylene dichloride.
CONDITIONS TO AVOID: Eliminate sources of ignition such as excessive heat, open flames, or electrical sparks, particularly in low-lying areas, because the explosive, heavier-than-air vapors will concentrate there.
PRODUCTS OF HAZARDOUS DECOMPOSITION can include vinyl chloride, chloride fumes, and phosgene. Phosgene is an extremely poisonous gas. Products of thermal-oxidative degradation (i.e., fire conditions) must be treated with appropriate caution.

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SECTION 6. HEALTH HAZARD INFORMATION

Ethylene dichloride is listed as an anticipated human carcinogen by the NTP and as a probable human carcinogen (Group 2B), by the IARC. It was found to be an animal-positive carcinogen by the IARC. NCI reported positive results (mouse, rat) from its carcinogenesis bioassay. SUMMARY OF RISKS: Ethylene dichloride is considered to be one of the more toxic of the common chlorinated hydrocarbons. Deaths from accidental ingestion of this material have been reported. Inhalation of vapors reportedly caused three fatalities. Excessive inhalation of ethylene dichloride vapors can cause respiratory irritation, intoxication, narcotic and anesthetic effects, vomiting, dizziness, depression, and diarrhea. The hepatoxic (injurious to liver) effects of this material are significant. The systemic effects from overexposure can appear in the liver, kidneys, digestive tract, blood, lungs, adrenal glands, and the central nervous system. Tests on animals have revealed reproductive failure and fetal resorption. There may be increased risk to nursing infants of exposed mothers. TARGET ORGANS: Central nervous system, eyes, kidneys, liver, heart, adrenal glands, and skin. PRIMARY ENTRY: Inhalation, absorption through skin, oral, or eye contact. ACUTE EFFECTS: Skin contact causes irritation, defatting, and, if repeated or prolonged, burning. Eye contact causes irritation and serious injury (clouding of the cornea) if it is not removed promptly. CHRONIC EFFECTS: Injuries to the liver (hepatoxicity) and kidneys, weight loss, low blood pressure, jaundice, oliguria (reduced excretion of urine), or anemia. MEDICAL CONDITIONS AGGRAVATED BY LONG-TERM EXPOSURE: Persons taking anticoagulants could experience an increase in tendency to bleed. Persons taking insulin face an increased risk of lowered blood sugar. FIRST AID: Be prepared to restrain a hyperactive victim. EYE CONTACT: Flush eyes, including under the eyelids, gently but thoroughly with plenty of running water for at least 15 minutes. Get medical help.* SKIN CONTACT: Immediately flush the affected area with water. Wash thoroughly with soap and water. Remove and launder contaminated clothing before wearing it again; clean material from shoes and equipment. Get medical help.* INHALATION: Remove victim to fresh air; restore and/or support his breathing as needed. Get medical help.* INGESTION: Never give anything by mouth to someone who is unconscious or convulsing. Rinse victim's mouth with water. Oxygen and artificial respiration may be needed. Get medical help.* *GET MEDICAL ASSISTANCE = IN PLANT, PARAMEDIC, COMMUNITY. Get prompt medical assistance for further treatment, observation, and support after first aid.

SECTION 7. SPILL, LEAK, AND DISPOSAL PROCEDURES

SPILL/LEAK: Before using ethylene dichloride, it is essential that proper emergency procedures be established and made known to all personnel involved in handling it. Notify safety personnel of ethylene dichloride spills or leaks and implement containment procedures. Remove and eliminate all possible sources of ignition such as heat, sparks, and open flames from the area. Cleanup personnel should use protection against inhalation of vapors and contact with liquid. Contain spills by using an absorbent material such as dry sand or vermiculite. Use nonsparking tools to mix waste material thoroughly with absorbent and place it in an appropriate container for disposal. Flush trace residues with large amounts of water. Do not flush waste to sewers or open waterways. WASTE DISPOSAL: Consider reclamation, recycling, or destruction rather than disposal in a landfill. Waste may be burned in an approved incinerator equipped with an afterburner and a scrubber. Follow Federal, state, and local regulations.

Ethylene dichloride is designated as a hazardous substance by the EPA (40 CFR 116.4). Ethylene dichloride is reported in the 1983 EPA TSCA Inventory.

EPA Hazardous Waste Number (40 CFR 261.33): U077

EPA Reportable Quantity (40 CFR 117.3): 5000 lbs (2270 kgs)

Aquatic Toxicity Rating, TLm 96: 1000 - 100 ppm

SECTION 8. SPECIAL PROTECTION INFORMATION

GOGGLES: Always wear protective eyeglasses or chemical safety goggles. Ethylene dichloride is particularly harmful to the eyes, and direct contact results in corneal opacity (permanent clouding of the eye). GLOVES: Wear impervious rubber gloves to prevent skin contact. RESPIRATOR: Use a NIOSH-approved respirator per the NIOSH *Pocket Guide to Chemical Hazards* (Genium ref. 88) for the maximum-use concentrations and/or the exposure limits cited in section 2. Follow the respirator guidelines in 29 CFR 1910.134. Any detectable concentration of ethylene dichloride requires an SCBA, full facepiece, and pressure-demand/positive-pressure modes. Warning: Air-purifying respirators will not protect workers from oxygen-deficient atmospheres. OTHER: Wear rubber boots, aprons, and other protective clothing suitable for use conditions to prevent skin contact. Remove contaminated clothing and launder it before wearing it again. Discard contaminated shoes. VENTILATION: Provide maximum explosion-proof local fume exhaust ventilation systems to maintain the airborne concentrations of ethylene dichloride vapors below the exposure limits cited in section 2. Install properly designed hoods that maintain a minimum face velocity of 100 lfm (linear feet per minute). SAFETY STATIONS: Make eyewash stations, washing facilities, and safety showers available in areas of use and handling. SPECIAL CONSIDERATIONS: Vapors are heavier than air and will collect in low-lying areas. Eliminate sources of ignition in these areas and again provide good ventilation there. COMMENTS: Practice good personal hygiene. Keep materials off of your clothes and equipment. Avoid transferring this material from hands to mouth while eating, drinking, or smoking. Immediately remove ethylene dichloride-saturated clothing to avoid flammability and health hazards. Contact lenses pose a special hazard; soft lenses may absorb irritants, and all lenses concentrate them.

SECTION 9. SPECIAL PRECAUTIONS AND COMMENTS

STORAGE SEGREGATION: Store ethylene dichloride in tightly closed containers in a cool, dry, well-ventilated area away from sources of ignition. Protect containers from physical damage and from exposure to excessive heat. Avoid direct physical contact with strong acids, bases, oxidizing agents, and reducing agents. SPECIAL HANDLING/STORAGE: Use nonsparking tools. Outside or detached storage is preferred. Store and handle ethylene dichloride in accordance with the regulations concerning OSHA class IB flammable liquids. ENGINEERING CONTROLS: During transfer operations involving ethylene dichloride, the liquid and its vapors must not be exposed to nearby sources of ignition from engineering systems that are not explosion proof. Preplan emergency response procedures.

TRANSPORTATION DATA (per 49 CFR 172.101-2):

DOT Hazard Class: Flammable Liquid

DOT Label: Flammable Liquid

IMO Class: 3.2

DOT Shipping Name: Ethylene Dichloride

DOT ID No. UN 1184

IMO Label: Flammable Liquid, Poison

References: 1-9, 12, 19, 21, 26, 43, 47, 73, 87-102. CK

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Approvals

Indust. Hygiene/Safety

Medical Review

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Material Safety Data Sheets Collection:

Sheet No. 703
1,2-Dichloroethylene

Issued: 4/90

Section 1. Material Identification

1,2-Dichloroethylene Description: An industrial solvent composed of 60% cis- and 40% trans-isomers. Both isomers, cis and trans, are made by partial chlorination of acetylene. Used as a general solvent for organic materials, lacquers, dye extraction, thermoplastics, organic synthesis, and perfumes. The trans-isomer is more widely used in industry than either the cis-isomer or the mixture. Toxicity also varies between the two isomers.
Other Designations: CAS No. 0540-59-0; $C_2H_2Cl_2$; acetylene dichloride; *cis*-1,2-dichloroethylene; *sym*-dichloroethylene; *trans*-1,2-dichloroethylene, dioform.
Manufacturer: Contact your supplier or distributor. Consult the latest *Chemicalweek Buyers' Guide*(73) for a suppliers list.

R	1
I	2
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NFPA

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F 3
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PPG*
* Sec. 8

Section 2. Ingredients and Occupational Exposure Limits

1,2-Dichloroethylene, ca 100%

OSHA PEL
8-hr TWA: 790 mg/m³, 200 ppm

ACGIH TLV, 1989-90
TLV-TWA: 790 mg/m³, 200 ppm

NIOSH REL, 1987
790 mg/m³, 200 ppm

Toxicity Data*
Rat, oral, LD_{50}: 770 mg/kg; toxic effects not yet reviewed
Frog, inhalation, TC_{Lo}: 117 mg/m³ inhaled for 1 hr affects the peripheral nerve and sensation (flaccid paralysis without anesthesia); behavior (excitement); lungs, thorax, or respiration (respiratory depression)

* See NIOSH, *RTECS* (KV9360000), for additional toxicity data.

Section 3. Physical Data

Boiling Point: 119 °F/48 °C
Melting Point: -56 to -115 °F/-49 to -82 °C/
Vapor Pressure: 180 to 264 torr at 68 °F/20 °C
Vapor Density (Air = 1): 3.4
Molecular Weight: 96.95 g/mol
Specific Gravity (H_2O = 1 at 39 °F/4 °C): 1.27 at 77 °F/25 °C
Water Solubility: Insoluble

Appearance and Odor: A colorless, low-boiling liquid with a pleasant odor.

Section 4. Fire and Explosion Data

Flash Point: 37 °F/2.8 °C, CC	Autoignition Temperature: 860 °F/460 °C	LEL: 5.6% v/v	UEL: 12.8% v/v

Extinguishing Media: Use dry chemical, CO_2, halon, water spray, or standard foam. Water may be ineffective unless used to blanket the fire.
Unusual Fire or Explosion Hazards: This material's vapors are a dangerous fire hazard and moderate explosion hazard when exposed to any heat or ignition source or oxidizer.
Special Fire-fighting Procedures: Since fire may produce toxic fumes, wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in the pressure-demand or positive-pressure mode and a fully encapsulating suit. Vapors may travel to heat or ignition sources and flash back. Stay upwind and out of low areas. Be aware of runoff from fire control methods. Do not release to sewers or waterways.

Section 5. Reactivity Data

Stability/Polymerization: This material is stable at room temperature in closed containers under normal storage and handling conditions. Hazardous polymerization cannot occur.
Chemical Incompatibilities: This material is incompatible with alkalies, nitrogen tetraoxide, difluoromethylene, strong oxidizers, and dihypofluorite. When in contact with copper or copper alloys or by reaction with potassium hydroxide, explosive chloroacetylene may be released.
Conditions to Avoid: Addition of hot liquid to cold 1,2-dichloroethylene may cause sudden emission of vapor that could flash back to an ignition source.
Hazardous Products of Decomposition: Thermal oxidative decomposition of 1,2-dichloroethylene can produce highly toxic fumes of chlorine (Cl).

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Section 6. Health Hazard Data

Carcinogenicity: Neither the NTP, IARC, nor OSHA lists 1,2-dichloroethylene as a carcinogen.
Summary of Risks: 1,2-Dichloroethylene's most important effect is its irritation of the central nervous system (CNS) and narcosis. This material is toxic by inhalation, ingestion, and skin contact. It is also irritating to the eyes. The trans-isomer at 2200 ppm causes nausea, vertigo, and burning of the eyes. The trans-isomer is twice as potent as the cis-isomer. If renal effects occur, they are transient.
Medical Conditions Aggravated by Long-Term Exposure: None reported.
Target Organs: Central nervous system, eyes, respiratory system.
Primary Entry Routes: Inhalation, ingestion, skin and eye contact.
Acute Effects: Inhalation of 1,2-dichloroethylene causes narcosis, respiratory tract irritation, nausea, vomiting, tremor, weakness, central nervous depression, and epigastric (the abdomen's upper midregion) cramps. Contact with the liquid causes eye and skin (on prolonged contact) irritation. Ingestion causes slight depression to deep narcosis.
Chronic Effects: None reported.
FIRST AID
Eyes: Flush immediately, including under the eyelids, gently but thoroughly with flooding amounts of running water for at least 15 min.
Skin: *Quickly* remove contaminated clothing. After rinsing affected skin with flooding amounts of water, wash it with soap and water.
Inhalation: Remove exposed person to fresh air and support breathing as needed. Have trained personnel administer 100% oxygen, preferably with humidification.
Ingestion: Never give anything by mouth to an unconscious or convulsing person. If ingested, have a *conscious* person drink 1 to 2 glasses of water, then induce repeated vomiting until vomit is clear.
After first aid, get appropriate in-plant, paramedic, or community medical support.
Physician's Note: Intravenous injections of calcium gluconate may relieve cramps and vomiting. Treat central nervous system effects symptomatically.

Section 7. Spill, Leak, and Disposal Procedures

Spill/Leak: *Design and practice a 1,2-dichloroethylene spill control and countermeasure plan (SCCP).* Notify safety personnel, remove all heat and ignition sources, evacuate hazard area, and provide adequate ventilation. Cleanup personnel should protect against vapor inhalation and skin or eye contact. Absorb small spills on paper towels. After evaporating the 1,2-dichloroethylene from these paper towels in a fume hood, burn the paper in a suitable location away from combustible material. Collect and atomize large quantities in a suitable combustion chamber equipped with an appropriate effluent gas cleaning device. Follow applicable OSHA regulations (29 CFR 1910.120).
Disposal: Contact your supplier or a licensed contractor for detailed recommendations. Follow applicable Federal, state, and local regulations.
EPA Designations
Listed as a RCRA Hazardous Waste (40 CFR 261.33)
Listed as a CERCLA Hazardous Substance* (40 CFR 302.4), Reportable Quantity (RQ): 100 lb (45.4 kg) [* per RCRA, Sec. 3001, per Clean Water Act, Sec. 307(a)]†
SARA Extremely Hazardous Substance (40 CFR 355): Not listed
Listed as a SARA Toxic Chemical (40 CFR 372.65)
OSHA Designations
Listed as an Air Contaminant (29 CFR 1910.1000, Table Z-1)
† Listed as 1,2-*trans*-dichloroethylene.

Section 8. Special Protection Data

Goggles: Wear protective eyeglasses or chemical safety goggles, per OSHA eye- and face-protection regulations (29 CFR 1910.133).
Respirator: Follow OSHA respirator regulations (29 CFR 1910.134) and, if necessary, wear a NIOSH-approved respirator. For emergency or nonroutine operations (cleaning spills, reactor vessels, or storage tanks), wear an SCBA.
Warning: Air-purifying respirators do *not* protect workers in oxygen-deficient atmospheres.
Other: Wear impervious gloves, boots, aprons, and gauntlets to prevent prolonged or repeated skin contact. 1,2-dichloroethylene attacks some forms of plastics, rubber, and coatings.
Ventilation: Provide general and local explosion-proof ventilation systems to maintain airborne concentrations below the OSHA PEL and ACGIH TLV (Sec. 2). Local exhaust ventilation is preferred since it prevents contaminant dispersion into the work area by controlling it at its source.[103]
Safety Stations: Make available in the work area emergency eyewash stations, safety/quick-drench showers, and washing facilities.
Contaminated Equipment: Never wear contact lenses in the work area: soft lenses may absorb, and all lenses concentrate, irritants. Remove this material from your shoes and equipment. Launder contaminated clothing before wearing.
Comments: Never eat, drink, or smoke in work areas. Practice good personal hygiene after using this material, especially before eating, drinking, smoking, using the toilet, or applying cosmetics.

Section 9. Special Precautions and Comments

Storage Requirements: Store in tightly closed containers in a cool, well-ventilated area away from all incompatible materials (Sec. 5) and oxidizing materials. Outside or detached storage is preferred. If stored inside, place containers in a standard flammable liquids storage cabinet or room. Protect containers from physical damage.
Engineering Controls: Avoid vapor inhalation and skin and eye contact. Use only with adequate ventilation and appropriate personal protective gear. Institute a respiratory protection program that includes regular training, maintenance, inspection, and evaluation. 1,2-dichloroethylene is a dangerous fire hazard. All engineering systems should be of maximum explosion-proof design and electrically grounded and bonded. Provide preplacement questionnaires which emphasize detecting a history of chronic respiratory disease.
Transportation Data (49 CFR 172.101, .102): Not listed

MSDS Collection References: 7, 26, 38, 73, 84, 85, 87, 88, 100, 101, 103, 109, 126, 127, 136, 137
Prepared by: MJ Allison, BS; Industrial Hygiene Review: DJ Wilson, CIH; Medical Review: MJ Hardies, MD

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Material Safety Data Sheets Collection:

Sheet No. 708
Vinylidene Chloride

Issued: 4/90

Section 1. Material Identification

Vinylidene Chloride Description: Prepared from ethylene chloride. Also prepared from vinyl chloride by successive chlorination and dehydrochlorination steps. Used primarily as a co-monomer in producing vinylidene copolymers (Saran®, Velon®) for films and coatings. Also used in producing methyl chloroform, vinyl chloride resins, plastics, chloracetyl chloride; in adhesives; as a component of synthetic fibers; a chemical intermediate in vinylidene fluoride synthesis; and for 1,1,1-trichloroethane. A common constituent in our environment, measurable quantities of vinylidene chloride are found in poorly ventilated areas with a high concentration of plastics. It is a notable contaminant in recycled air environments such as nuclear submarines and spacecraft.
Other Designations: CAS No. 0075-35-4; $C_2H_2Cl_2$; 1,1-DCE; 1,1-dichloroethene; *asym*-dichloroethylene; VDC; vinylidene dichloride.
Manufacturer: Contact your supplier or distributor. Consult the latest *Chemicalweek Buyers' Guide*(TM) for a suppliers list.
Comment: At temperatures above 32 °F/0 °C and especially in the presence of oxygen or other suitable catalysts, vinylidene chloride polymerizes to a plastic. Therefore, commercial products may contain small proportions of inhibitors to preserve the monomer.

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* Sec. 8

Section 2. Ingredients and Occupational Exposure Limits

Vinylidene chloride, ca 100%

OSHA PEL
8-hr TWA: 1 ppm, 4 mg/m³

ACGIH TLVs, 1989-90
TLV-TWA: 5 ppm, 20 mg/m³
TLV-STEL: 20 ppm, 79 mg/m³

NIOSH REL, 1987
None established

Toxicity Data*
Mouse, skin, TD_{Lo}: 4840 mg/kg has tumorigenic effects on skin, appendages, lungs, thorax, and respiration
Rat, inhalation, LC_{50}: 6350 ppm/4 hr
Human, inhalation, TC_{Lo}: 25 ppm produces changes in behavior (general anesthetic), the liver, kidney, ureter, and bladder

* See NIOSH, *RTECS* (YZ8061000), for additional mutative, reproductive, tumorigenic, and toxicity data.

Section 3. Physical Data

Boiling Point: 89.1 °F/31.7 °C at 760 mm Hg
Melting Point: -188.5 °F/-122.5 °C
Vapor Pressure: 591 mm Hg at 77 °F/25 °C
Vapor Density (Air = 1): 3.4
Molecular Weight: 96.94 g/mol
Specific Gravity (H_2O = 1 at 39 °F/4 °C): 1.2129 at 68 °F/20 °C
Water Solubility: Sparingly soluble (0.04 % wt/vol in water at 68 °F/20 °C)

Appearance and Odor: Colorless, volatile liquid with a mild, sweet odor that resembles chloroform. Most persons can detect vinylidene chloride at 1000 ppm, but others can detect it at less than 500 ppm. Neither odor is adequate to warn of excessive exposure.

Section 4. Fire and Explosion Data

Flash Point: -19 °F/-28 °C	Autoignition Temperature: 1058 °F/570 °C	LEL: 5.6% v/v	UEL: 11.4% v/v

Extinguishing Media: Use dry chemical, alcohol foam, or carbon dioxide. Use water to cool fire-exposed containers.
Unusual Fire or Explosion Hazards: Vinylidene chloride is a very flammable and volatile liquid with a burning rate of 2.7 mm/min. This material is a very dangerous fire hazard and moderately explosive when exposed to heat or flame. It may explode spontaneously since the vapor forms explosive mixtures with air. At elevated temperatures, polymerization may take place and containers may rupture.
Special Fire-fighting Procedures: Since vinylidene chloride may be poisonous if inhaled or absorbed through the skin, wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in the pressure-demand or positive-pressure mode with a fully encapsulating suit. Keep unnecessary people away from the hazard area. Vapors may travel to an ignition source and flash back. Be aware of runoff from fire control methods. Do not release to sewers or waterways.

Section 5. Reactivity Data

Stability/Polymerization: Vinylidene chloride is self-reactive. If stored between -40 °F/-40 °C and 77 °F/25 °C in air without an inhibitor, this material rapidly absorbs oxygen and forms a violently explosive peroxide. The heat of polymerization is -185 cal/g (inhibited). When unstable, vinylidene chloride decomposes into chlorine, hydrogen chloride, phosgene, and formaldehyde. Hazardous polymerization can occur if exposed to sunlight, air, copper, aluminum, or heat.
Chemical Incompatibilities: This material reacts violently with chlorosulfonic acid, nitric acid, and oleum; and vigorously with oxidizing materials.
Hazardous Products of Decomposition: Thermal oxidative decomposition of vinylidene chloride can produce highly toxic fumes of chlorine (Cl_2) and hydrogen chloride (HCl).

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Section 6. Health Hazard Data

Carcinogenicity: Neither the NTP, IARC, nor OSHA lists vinylidene chloride as a carcinogen, although the ACGIH suggests it is a suspected carcinogen. Various animal studies suggest a high rate of cancer in species-specific testing; application to humans does not appear valid.
Summary of Risks: Vinylidene chloride is an irritant to the skin, eyes, and mucous membranes, although any inhibitor in vinylidene chloride may partly cause the irritation. VDC is narcotic at concentrations greater than 4000 ppm, and has caused liver and kidney injury in experimental animals. Solutions containing the inhibitor MEHQ (monomethyl ether of hydroquinone) may cause leucoderma (white skin) and serious eye injury.
Medical Conditions Aggravated by Long-Term Exposure: None reported.
Target Organs: Skin, eyes, central nervous system, liver, and kidneys.
Primary Entry Routes: Inhalation.
Acute Effects: Inhalation of VDC causes narcosis and respiratory irritation. Concentrations of 4000 ppm lead to symptoms of drunkenness and eventually unconsciousness if the exposure continues. In monkey studies, exposure to 200 ppm caused acute liver injury with a mechanism similar to carbon tetrachloride. Animal studies indicate acute kidney changes in high-level exposures. Eye contact may cause conjunctivitis, transient corneal injury, and iritis. VDC also causes skin and mucous membrane irritation.
Chronic Effects: With chronic inhalation, vinylidene chloride may cause hepatic and renal dysfunction. In monkey studies, long-term inhalation at a 48-ppm level caused liver and kidney damage and death.
FIRST AID
Eyes: Flush immediately, including under the eyelids, gently but thoroughly with flooding amounts of running water for at least 15 min.
Skin: *Quickly* remove contaminated clothing. After rinsing affected skin with flooding amounts of water, wash it with soap and water.
Inhalation: Remove exposed person to fresh air and support breathing as needed.
Ingestion: Never give anything by mouth to an unconscious or convulsing person. If ingested, have a *conscious* person drink 1 to 2 glasses of water, then induce repeated vomiting until vomit is clear.
After first aid, get appropriate in-plant, paramedic, or community medical support.
Physician's Note: Solutions containing increased MEHQ concentrations are caustic and should not be removed by emesis. There is no specific treatment for VDC intoxication, but if significant amounts have been ingested, monitor the patient for liver and kidney failure.

Section 7. Spill, Leak, and Disposal Procedures

Spill/Leak: *Design and practice a vinylidene chloride spill control and countermeasure plan (SCCP).* Notify safety personnel, evacuate all unnecessary personnel from hazard area, remove all heat and ignition sources, and ventilate area. Cleanup personnel should protect against inhalation and skin and eye contact. For lab spills, absorb the spill with paper towels and place in a hood to allow liquid to evaporate. For large spills, absorb bulk spill with cement powder, fly ash, sawdust, or commercial sorbents. Place waste in appropriate disposal containers. Follow applicable OSHA regulations (29 CFR 1910.120).
Disposal: Contact your supplier or a licensed contractor for detailed recommendations. Follow applicable Federal, state, and local regulations.
EPA Designations
RCRA Hazardous Waste (40 CFR 261.33): Not listed
Listed as a CERCLA Hazardous Substance* (40 CFR 302.4), Reportable Quantity (RQ): 5000 lb (2270 kg) [* per Clean Water Act, Sec. 31 (b)(4), Sec. 307(a); per RCRA, Sec. 3001]
SARA Extremely Hazardous Substance (40 CFR 355): Not listed
Listed as a SARA Toxic Chemical (40 CFR 372.65)
OSHA Designations
Air Contaminant (29 CFR 1910.1000, Subpart Z): Not listed

Section 8. Special Protection Data

Goggles: Wear protective eyeglasses or chemical safety goggles, per OSHA eye- and face-protection regulations (29 CFR 1910.133).
Respirator: Follow OSHA respirator regulations (29 CFR 1910.134) and, if necessary, wear a NIOSH-approved respirator. Respiratory canisters containing alkaline materials should not be used because dichloro acetylene can be formed. For emergency or nonroutine operations (cleaning spills, reactor vessels, or storage tanks), wear an SCBA.
Warning: Air-purifying respirators do *not* protect workers in oxygen-deficient atmospheres.
Other: Wear impervious gloves, boots, aprons, and gauntlets to prevent skin contact. Rubber gloves are recommended.
Ventilation: Provide general and local explosion-proof ventilation systems to maintain airborne concentrations below the OSHA PEL and ACGIH TLVs (Sec. 2). Local explosion-proof exhaust ventilation is preferred since it prevents contaminant dispersion into the work area by controlling it at its source.[140]
Safety Stations: Make available in the work area emergency eyewash stations, safety/quick-drench showers, and washing facilities.
Contaminated Equipment: Never wear contact lenses in the work area: soft lenses may absorb, and all lenses concentrate, irritants. Remove this material from your shoes and equipment. Launder contaminated clothing before wearing.
Comments: Never eat, drink, or smoke in work areas. Practice good personal hygiene after using this material, especially before eating, drinking, smoking, using the toilet, or applying cosmetics.

Section 9. Special Precautions and Comments

Storage Requirements: Store vinylidene chloride in tanks with nickel, glass, or baked phenolic linings at 14 °F/-10 °C in the absence of light, air, water, and other polymerization initiators under a nitrogen blanket (at 10-psi pressure and an oxygen content less than 100 ppm). Outside or detached storage is preferable. If stored inside, store in a standard flammable liquids storage cabinet separate from oxidizing materials and incompatible materials (Sec. 5).
Engineering Controls: VDC requires special handling, precautions, and employee training. Do not handle VDC without adequate ventilation and personal protective gear. Limit exposures to vinylidene chloride by improving housekeeping procedures. Keep VDC away from all heat and ignition sources. All engineering systems should be of maximum explosion-proof design, electrically grounded, and bonded.

Transportation Data (49 CFR 172.101, .102)

DOT Shipping Name: Vinylidene chloride, inhibited
DOT Hazard Class: Flammable liquid
ID No.: UN1303
DOT Label: Flammable liquid
DOT Packaging Requirements: 173.119
DOT Packaging Exceptions: 173.118

IMO Shipping Name: Vinylidene chloride, inhibited
IMO Hazard Class: 3.1
IMO Label: Flammable liquid
IMDG Packaging Group: I
ID No.: UN1303

MSDS Collection References: 7, 26, 38, 53, 73, 84, 85, 87, 89, 100, 103, 124, 126, 127, 129, 134, 136
Prepared by: MJ Allison, BS; Industrial Hygiene Review: DJ Wilson, CIH; Medical Review: W Silverman, MD

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Material Safety Data Sheets Collection:

Sheet No. 83
Chromium Metal/Powder

Issued: 3/81 Revision: A, 11/89

Section 1. Material Identification

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Chromium Metal/Powder Description: Obtained from chrome ore, chromite ($FeCr_2O_4$), by electrolysis of chromium solutions, by direct reduction (ferrochrome), and by reducing the oxide with finely divided carbon or aluminum. Used for chromeplating other metals; for greatly increasing metal resistance and durability; in manufacturing chrome-steel or chrome-nickel-steel alloys (stainless steel); as a constituent of inorganic pigments; as protective coating for automotive and equipment accessories; and in nuclear and high-temperature research.
Other Designations: Chrome; Cr; CAS No. 7440-47-3.
Manufacturer: Contact your supplier or distributor. Consult the latest *Chemicalweek Buyers' Guide* (Genium ref. 73) for a suppliers list.

R	1
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S	1
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* Sec. 8

Section 2. Ingredients and Occupational Exposure Limits

Chromium metal/powder, ca 100%

OSHA PEL	ACGIH TLV, 1988-89*	NIOSH REL, 1987†	Toxicity Data‡
8-hr TWA: 1 mg/m³	TLV-TWA: 0.5 mg/m³	8-hr TWA (for chromium metal and insoluble salts): 1 mg Cr/m³	Rat, implant, TD_{Lo}: 1200 µg/kg body weight administered intermittently over six weeks

* This TLV is applicable to Cr^{+3} and Cr^{+6} compounds. For water soluble and water-insoluble Cr^{+6}, the 8-hr TWA is 0.05 mg Cr^{+6}/m³. Certain water-insoluble Cr^{+6} compounds (zinc chromate, calcium chromate, lead chromate, barium chromate, strontium chromate, and sintered chromium trioxide) are designated as A1a (human carcinogen).
† The NIOSH REL (10-hr TWA) for carcinogen Cr^{+6} compounds is 1 µg/m³; for noncarcinogenic Cr^{+6} compounds (including chromic acid), the RELs (10-hr TWAs) are 25 µg/m³ and 50 µg/m³ (15-min ceiling). The noncarcinogenic compounds include mono- and dichromates of hydrogen, cesium, sodium, lithium, potassium, rubidium, ammonia, and Cr^{+6} (chromic acid anhydride). Any and all Cr^{+6} materials excluded from the noncarcinogenic group above are carcinogenic Cr^{+6} compounds.
‡ See NIOSH, *RTECS* (GB4200000), for additional data with references to tumorigenic effects.

Section 3. Physical Data

Boiling Point: 4788 °F (2642 °C)
Melting Point: 3452 °F (1900 °C)
Vapor Pressure: 1 mm Hg at 2941 °F (1616 °C)
Vapor Density (Air = 1): 1.79
Atomic Weight: 51.996 g/mol
Specific Gravity (H_2O = 1 at 39 °F (4 °C)): 7.2 at 68 °F (20 °C)
Water Solubility: Insoluble

Appearance and Odor: Steel-gray, lustrous metal; no odor.

Section 4. Fire and Explosion Data

Flash Point: None reported	Autoignition Temperature: Cloud, 1076 °F (580 °C); dust layer, 752 °F (400 °C)	LEL: Dust cloud explosion, 0.230 oz/ft³	UEL: None reported

Extinguishing Media: Use dry chemical or sand.
Unusual Fire or Explosion Hazards: Particle size and dispersion in air determine reactivity. Chromium powder explodes spontaneously in air, while chromium dust suspended in CO_2 is ignitable and explosive when heated.
Special Fire-fighting Procedures: Wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in the pressure-demand or positive-pressure mode.

*One hundred percent of dust goes through a 74-µm sieve. A 140-mJ spark can ignite a dust cloud.

Section 5. Reactivity Data

Stability/Polymerization: Chromium is stable when properly handled and stored. Hazardous polymerization cannot occur.
Chemical Incompatibilities: Chromium reacts readily with dilute, not nitric, acids to form chromous salts. It is soluble in acids (not nitric) and strong alkalis. Its powder is incompatible with strong oxidizing agents, including high O_2 concentration. Evaporation of mercury (Hg) from Cr amalgam leaves pyrophoric chromium. Finely divided Cr attains incandescence with nitrogen oxide, potassium chlorate, and sulfur dioxide. Molten lithium at 18 °C severely attacks Cr. Fused ammonium nitrate below 200 °C reacts explosively and may ignite or react violently with bromine pentafluoride.
Hazardous Products of Decomposition: Thermal oxidative decomposition of Cr can produce toxic chromium oxide fumes.

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Section 6. Health Hazard Data

Carcinogenicity: The NTP and OSHA list chromium as a human carcinogen.

mmary of Risks: When ingested chromium is a human poison, with gastrointestinal (GI) effects. Chromium 3 (Cr^{+3}) compounds show little or xicity. Less soluble chromium 6 (Cr^{+6}) compounds are suspected carcinogens and severe irritants of the larynx, nasopharynx, lungs, and skin 2). Chromic acid or chromate salts cause irritation of the skin and respiratory passage. Ingestion leads to severe irritation of the gastrointestinal tract, renal damage, and circulatory shock. Chromium metal (when heated to high temperatures) and insoluble salts are said to be involved in histological fibrosis of the lungs, which may progress to clinically evident pneumoconiosis. Exposure to chromate dust and powder can cause skin (dermatitis) and eye irritation (conjunctivitis).

Medical Conditions Aggravated by Long-Term Exposure: An increased incidence of bronchogenic carcinoma occurs in workers exposed to chromate dust.

Target Organs: Respiratory system.

Primary Entry: Inhalation, percutaneous absorption, and ingestion.

Acute Effects: Acute exposures to dust may cause headache, coughing, shortness of breath, pneumoconiosis, fever, weight loss, nasal irritation, inflammation of the conjunctiva, and dermatitis.

Chronic Effects: Asthmatic bronchitis.

FIRST AID

Eyes: Flush immediately, including under the eyelids, gently but thoroughly with flooding amounts of running water for at least 15 min.

Skin: Brush off chromium dust. After rinsing affected area with flooding amounts of water, wash it with soap and water.

Inhalation: Remove exposed person to fresh air and support breathing as needed.

Ingestion: Never give anything by mouth to an unconscious or convulsing person. If ingested, have that conscious person slowly drink 1 to 2 glasses of water to dilute. Do not induce vomiting. A physician should evaluate all ingestion cases.

After first aid, get appropriate in-plant, paramedic, or community medical attention and support.

Physician's Note: Acute toxicity causes a two-phase insult: 1) multisystem shock due to gastrointestinal corrosivity and 2) hepatic, renal, hematopoetic insult. Treatment should use ascorbic acid as a neutralizer with gastric lavage. If the ingestion is substantial, exchange transfusions and/or consider hemodialysis. Treat allergic dermatitis with local cortisone or 10% ascorbic acid to reduce Cr^{+6} to Cr^{+3}. Ten percent EDTA in a lanolin base applied every 24 hr helps heal skin ulcers.

Section 7. Spill, Leak, and Disposal Procedures

Spill/Leak: Notify safety personnel of large spills. Cleanup personnel should wear protective clothing and approved respirators. Remove heat and ignition sources. Provide adequate ventilation. Keep airborne dust at a minimum. Remove spills quickly and place in appropriate containers for disposal or reuse.

Disposal: Reclaim salvageable metal. Contact your supplier or a licensed contractor for detailed recommendations. Follow applicable Federal, and local regulations.

s Designations

Listed as an Air Contaminant (29 CFR 1910.1000, Table Z-1)

EPA Designations

RCRA Hazardous Waste (40 CFR 261.33): Not listed

Listed as a CERCLA Hazardous Substance* (40 CFR 302.4), Reportable Quantity (RQ): 1 lb (0.454 kg) [* per Clean Water Act, Sec. 307(a)]

SARA Extremely Hazardous Substance (40 CFR 355): Not listed

Listed as a SARA Toxic Chemical (40 CFR 372.65)

Section 8. Special Protection Data

Goggles: Wear protective eyeglasses or chemical safety goggles, per OSHA eye- and face-protection regulations (29 CFR 1910.133).

Respirator: Wear a NIOSH-approved respirator if necessary. Wear an SCBA with a full facepiece when the particle concentration's upper limit is 50 mg/m³.

Warning: Air-purifying respirators do *not* protect workers in oxygen-deficient atmospheres.

Other: Wear impervious rubber gloves, boots, aprons, and gauntlets to prevent prolonged or repeated skin contact.

Ventilation: Provide general and local explosion-proof ventilation systems to maintain airborne concentrations below the OSHA standard (Sec. 2). Local exhaust ventilation is preferred since it prevents contaminant dispersion into the work area by eliminating it at its source (Genium ref. 103).

Safety Stations: Make available in the work area emergency eyewash stations, safety/quick-drench showers, and washing facilities.

Contaminated Equipment: Never wear contact lenses in the work area: soft lenses may absorb, and all lenses concentrate, irritants. Launder contaminated clothing before wearing. Remove this material from your shoes and equipment.

Comments: Never eat, drink, or smoke in work areas. Practice good personal hygiene after using this material, especially before eating, drinking, smoking, using the toilet, or applying cosmetics.

Section 9. Special Precautions and Comments

Storage Requirements: Store material in cool, dry, well-ventilated area separate from acids and oxidizing agents. Seal and protect containers from physical damage. Keep away from heat or ignition sources.

Engineering Controls: Avoid dust inhalation. Practice good housekeeping (vacuuming and wet sweeping) to minimize airborne particulates and to prevent dust accumulation. Use nonsparking tools and ground electrical equipment and machinery.

ortation Data (49 CFR 172.101, .102): Not listed

MSDS Collection References: 1, 2, 26, 38, 80, 87, 88, 89, 100, 109, 124, 126

Prepared by: MJ Allison, BS; Industrial Hygiene Review: DJ Wilson, CIH; Medical Review: MJ Hardies, MD

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Material Safety Data Sheets Collection:

Sheet No. 713
Lead (Inorganic)

Issued: 8/90

Section 1. Material Identification

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Lead (Inorganic) (Pb) Description: Exists widely throughout the world in a number of ores. Its main commercial source is galena (lead sulphide). Lead mineral is separated from crude ores by blast-furnace smelting, drossing, or electrolytic refining. Lead is used mostly in manufacturing storage batteries. Other uses are in manufacturing tetraethyllead and both organic and inorganic lead compounds in ceramics, plastics, and electronic devices; in producing ammunition, solder, cable covering, sheet lead, and other metal products (brass, pipes, caulking); in metallurgy; in weights and as ballast; as a chemical intermediate for lead alkyls and pigments; as a construction material for the tank linings, piping, and equipment used to handle the corrosive gases and liquids used in sulfuric acid manufacturing, petroleum refining, halogenation, sulfonation, extraction, and condensation; and for x-ray and atomic radiation protection.
Other Designations: CAS No. 7439-92-1, lead oxide; lead salts, inorganic; metallic lead; plumbum.
Manufacturer: Contact your supplier or distributor. Consult the latest *Chemicalweek Buyers' Guide*™ for a suppliers list.

R	0
I	4
S	-
K	0

Genium

HMIS
H 3
F 1
R 0
PPG*
* Sec. 8

Cautions: *Inorganic lead is a potent systemic poison.* Organic lead (for example, tetraethyl lead) has severe, but different, health effects. Occupational lead poisoning is due to inhalation of dust and fumes. Major affected organ systems are the nervous, blood, and reproductive systems, and kidneys. Health impairment or disease may result from a severe acute short- or long-term exposure.

Section 2. Ingredients and Occupational Exposure Limits

Lead (inorganic) fumes and dusts, as Pb, ca 100%

1989 OSHA PELs (Lead, inorganic compounds)
8-hr TWA: 50 μg/m³
Action Level TWA*: 30 μg/m³

29 CFR 1910.1025 Lead Standard
Blood Lead Level: 40 μg/100 g

1989-90 ACGIH TLV (Lead, inorganic, fumes and dusts)
TLV-TWA: 150 μg/m³

1988 NIOSH REL
10-hr TWA: <100 μg/m³

1985-86 Toxicity Data†
Human, inhalation, TC_{Lo}: 10 μg/m³ affects gastrointestinal tract and liver
Human, oral, TD_{Lo}: 450 mg/kg ingested over 6 yr affects peripheral and central nervous systems
Rat, oral, TD_{Lo}: 790 mg/kg affects multigeneration reproduction

* Action level applies to employee exposure without regard to respirator use.
† See NIOSH, *RTECS* (OF7525000), for additional mutative, reproductive, and toxicity data.

Section 3. Physical Data

Boiling Point: 3164 °F (1740 °C)
Melting Point: 621.3 °F (327.4 °C)
Vapor Pressure: 1.77 mm Hg at 1832 °F (1000 °C)
Viscosity: 3.2 cp at 621.3 °F (327.4 °C)
Molecular Weight: 207.20
Specific Gravity (20 °C/4 °C): 11.34
Water Solubility: Relatively insoluble in hot or cold water*
Appearance and Odor: Bluish-white, silvery, gray, very soft metal.

* Lead dissolves more easily at a low pH.

Section 4. Fire and Explosion Data

Flash Point: None reported	Autoignition Temperature: None reported	LEL: None reported	UEL: None reported

Extinguishing Media: Use dry chemical, carbon dioxide, water spray, or foam to extinguish fire.
Unusual Fire or Explosion Hazards: Flammable and moderately explosive in the form of dust when exposed to heat or flame.
Special Fire-fighting Procedures: Isolate hazard area and deny entry. Since fire may produce toxic fumes, wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in the pressure-demand or positive-pressure mode and full protective equipment. Be aware of runoff from fire control methods. Do not release to sewers or waterways.

Section 5. Reactivity Data

Stability/Polymerization: Lead is stable at room temperature in closed containers under normal storage and handling conditions. It tarnishes on exposure to air. Hazardous polymerization cannot occur.
Chemical Incompatibilities: Mixtures of hydrogen peroxide + trioxane explode on contact with lead. Lead is incompatible with sodium azide, zirconium, disodium acetylide, and oxidants. A violent reaction on ignition may occur with concentrated hydrogen peroxide, chlorine trifluoride, sodium acetylide (with powdered lead), ammonium nitrate (below 200 °C with powdered lead). Lead is attacked by pure water and weak organic acids in the presence of oxygen. Lead is resistant to tap water, hydrofluoric acid, brine, and solvents.
Conditions to Avoid: Rubber gloves containing lead may ignite in nitric acid.
Hazardous Products of Decomposition: Thermal oxidative decomposition of lead can produce highly toxic fumes of lead.

Section 6. Health Hazard Data

Carcinogenicity: Although the NTP and OSHA do not list lead as a carcinogen, the IARC lists it as probably carcinogenic to humans, but having (usually) no human evidence. However, the literature reports instances of lead-induced neoplasms, both benign and malignant, of the kidney and other organs in laboratory rodents. Excessive exposure to lead has resulted in neurologic disorders in infants. Experimental studies show lead has reproductive and teratogenic effects in laboratory animals. Human male and female reproductive effects are also documented.
Summary of Risks: Lead is a potent, systemic poison that affect a variety of organ systems, including the nervous system, kidneys, reproductive system, blood formation, and gastrointestinal (GI) system. The most important way lead enters the body is through inhalation, but it can also be ingested when lead dust or unwashed hands contaminate food, drink, or cigarettes. Much of ingested lead passes through feces without absorption into the body. Adults may absorb only 5 to 15% of ingested lead; children may absorb a much larger fraction. Once in the body, lead enters the bloodstream and circulates to various organs. Lead concentrates and remains in bone for many years. The amount of lead the body stores increases as exposure continues, with possibly cumulative effects. Depending on the dose entering the body, lead can be deadly within several days or affect health after many years. Very high doses can cause brain damage (encephalopathy).
Medical Conditions Aggravated by Exposure: Lead may aggravate nervous system disorders (e.g., epilepsy, neuropathies), kidney diseases, high blood pressure (hypertension), infertility, and anemia. Lead-induced anemia and its effect on blood pressure can aggravate cardiovascular disease.

Continue on next page

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Section 6. Health Hazard Data, *continued*

Target Organs: Blood, central and peripheral nervous systems, kidneys, and gastrointestinal (GI) tract.
Primary Entry Routes: Inhalation, ingestion.
Acute Effects: An acute, short-term dose of lead could cause acute encephalopathy with seizures, coma, and death. However, short-term exposures of this magnitude are rare. Reversible kidney damage can occur from acute exposure, as well as anemia.
Chronic Effects: Symptoms of chronic long-term overexposure include appetite loss, nausea, metallic taste in the mouth, lead line on gingival (gum) tissue, constipation, anxiety, anemia, pallor of the face and the eye grounds, excessive tiredness, weakness, insomnia, headache, nervous irritability, fine tremors, numbness, muscle and joint pain, and colic accompanied by severe abdominal pain. Paralysis of wrist and, less often, ankle extensor muscles may occur after years of increased lead absorption. Kidney disease may also result from chronic overexposure, but few, if any, symptoms appear until severe kidney damage has occurred. Reproductive damage is characterized by decreased sex drive, impotence, and sterility in men; and decreased fertility, abnormal menstrual cycles, and miscarriages in women. Unborn children may suffer neurologic damage or developmental problems due to excessive lead exposure in pregnant women. Lead poisoning's severest result is encephalopathy manifested by severe headache, convulsions, coma, delirium, and possibly death.
FIRST AID
Eyes: Gently lift the eyelids and flush immediately and continuously with flooding amounts of water until transported to an emergency medical facility. Consult a physician immediately.
Skin: *Quickly* remove contaminated clothing. Rinse with flooding amounts of water for at least 15 min. Consult a physician if any health complaints develop.
Inhalation: Remove exposed person to fresh air and support breathing as needed. Consult a physician.
Ingestion: Never give anything by mouth to an unconscious or convulsing person. If large amounts of lead were ingested, induce vomiting with Ipecac syrup. Consult a physician immediately.
After first aid, get appropriate in-plant, paramedic, or community medical support.
Physician's Note: For diagnosis, obtain blood pressure, blood lead level (PbB), zinc protoporphyrin (ZPP), complete blood count for microcytic anemia and basophilic stippling, urinalysis, and blood urea nitrogen (BUN) of creatinine. Examine peripheral motor neuropathy, pallor, and gingival lead line. Use Ca-EDTA to treat poison, but *never* chelate prophylactically. Consult an occupational physician or toxicologist.

Section 7. Spill, Leak, and Disposal Procedures

Spill/Leak: Notify safety personnel and evacuate all unnecessary personnel immediately. Cleanup personnel should protect against inhalation of dusts or fume and contact with skin or eyes. Avoid creating dusty conditions. Water sprays may be used in large quantities to prevent the formation of dust. Cleanup methods such as vacuuming (with an appropriate filter) or wet mopping minimizes dust dispersion. Scoop the spilled material into closed containers for disposal or reclamation. Follow applicable OSHA regulations (29 CFR 1910.120).
Disposal: Contact your supplier or a licensed contractor for detailed recommendations. Follow applicable Federal, state, and local regulations.
EPA Designations
Listed as a RCRA Hazardous Waste (40 CFR 261.33, Appendix II—EP Toxicity Test Procedures)
Listed as a CERCLA Hazardous Substance* (40 CFR 302.4), Reportable Quantity (RQ): 1 lb (0.454 kg) [* per Clean Water Act, Sec. 307(a)]
SARA Extremely Hazardous Substance (40 CFR 355): Not listed
Listed as a SARA Toxic Chemical (40 CFR 372.65)
OSHA Designations
Listed as an Air Contaminant (29 CFR 1910.1000, Table Z-1-A)

Section 8. Special Protection Data

Goggles: Wear protective eyeglasses or chemical safety goggles, per OSHA eye- and face-protection regulations (29 CFR 1910.133).
Respirator: Seek professional advice prior to respirator selection and use. Follow OSHA respirator regulations (29 CFR 1910.134) and, if necessary, wear a NIOSH-approved respirator. For emergency or nonroutine operations (cleaning spills, reactor vessels, or storage tanks), wear an SCBA. *Warning! Air-purifying respirators do not protect workers in oxygen-deficient atmospheres.*
Other: Wear impervious gloves, boots, aprons, and gauntlets to prevent skin contact. Protective clothing made of man-made fibers and lacking turn-ups, pleats, or pockets retain less dust from lead.
Ventilation: Provide general and local ventilation systems to maintain airborne concentrations below the OSHA PELs (Sec. 2). Local exhaust ventilation is preferred since it prevents contaminant dispersion into the work area by controlling it at its source.[165]
Safety Stations: Make available in the work area emergency eyewash stations, safety/quick-drench showers, and washing facilities.
Contaminated Equipment: Never wear contact lenses in the work area: soft lenses may absorb, and all lenses concentrate, irritants. Remove this material from your shoes and equipment. Launder contaminated clothing before wearing.
Comments: Never eat, drink, or smoke in work areas. Practice good personal hygiene after using this material, especially washing hands before eating, drinking, smoking, using the toilet, or applying cosmetics.

Section 9. Special Precautions and Comments

Storage Requirements: Store in tightly closed containers in a cool, dry, well-ventilated area away from all incompatible materials, direct sunlight, and heat and ignition sources.
Engineering Controls: Educate worker about lead's hazards. Follow and inform employees of the lead standard (29 CFR 1910.1025). Avoid inhalation of lead dust and fumes and ingestion of lead. Use only with appropriate personal protective gear and adequate ventilation. Institute a respiratory protection program that includes regular training, maintenance, inspection, and evaluation. Avoid creating dusty conditions. Segregate and launder contaminated clothing. Take precautions to protect laundry personnel. Practice good personal hygiene and housekeeping procedures. For a variety of reasons, the lead concentration in workroom air may not correlate with the blood lead levels in individuals.
Other Precautions: Provide preplacement and periodic medical examinations which emphasize blood, nervous system, gastrointestinal tract, and kidneys, including a complete blood count and urinalysis. Receive a complete history including previous surgeries and hospitalization, allergies, smoking history, alcohol consumption, proprietary drug intake, and occupational and nonoccupational lead exposure. Maintain records for medical surveillance, airborne exposure monitoring, employee complaints, and physician's written opinions for at least 40 years or duration of employment plus 20 years. Measurement of blood lead level (PbB) and zinc protoporphyrin (ZPP) are useful indicators of your body's lead absorption level. Maintain worker PbBs at or below 40 µg/100 g of whole blood. To minimize adverse reproductive health effects to parents and developing fetus, maintain the PbBs of workers intending to have children below 30 µg/100 g. Elevated PbBs increase your risk of disease, and the longer you have elevated PbBs, the greater your chance of substantial permanent damage.

Transportation Data (49 CFR 172.102)
IMO Shipping Name: Lead compounds, soluble, n.o.s.
IMO Hazard Class: 6.1
ID No.: UN2291
IMO Label: St. Andrews Cross (X, Stow away from foodstuffs)
IMDG Packaging Group: III

MSDS Collection References: 26, 38, 73, 84, 85, 88, 89, 90, 100, 101, 103, 109, 124, 126, 132, 133, 134, 136, 138, 139, 142, 143
Prepared by: MJ Allison, BS; **Industrial Hygiene Review:** DJ Wilson, CIH; **Medical Review:** MJ Upfal, MD, MPH; **Edited by:** JR Stuart, MS

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APPENDIX G

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APPENDIX H

RESPONSES TO COMMENTS

Response to Comments
SESR Demonstration at Alameda Point

034-ALAM -cor

Comment	Response
DTSC John Wesnousky, P.E *Per your request I have reviewed the Draft Work Implementation Plan for Surfactant Enhanced DNAPL Removal Treatability Study at Alameda Point (Site 5), dated January 26, 1999 which was prepared by Surbec Environmental for the U.S. Navy. Following are my comments concerning the proposed in-situ field demonstration project/treatability study.*	
General In-situ soil flushing with surfactants or cosolvents for hazardous waste site remediation has been around a number of years but remains more of an "emerging technology" and has yet to be fully demonstrated. Although there have been a number of demonstrations and research field studies involving in situ surfactant/cosolvent flushing, these projects have met with varied success with mass removals reported ranging from 15 to 80 percent. Currently, a treatability study by the same company, Surbec Environmental, is planned to soon be implemented at McClellan AFB, a much deeper and more complicated site for this technology than Alameda. Implementation of this technology is very complex, requiring multiple disciplines to address the subsurface chemistry, hydrogeology and engineering aspects. I am not aware of any commercial application to successfully clean up a site in the U.S. The technology is generally applied to address only the source areas (NAPLs present) or hot spots (region of highest concentration in the plume), not to restore low concentration plumes to background conditions. Also this technology is not effectively applied in low permeable zones. A difficult key to successful implementation is the selection of the right surfactant for the specific site conditions. The surfactant must be able to both solubilize or mobilize the NAPL in the aqueous phase without partitioning into the NAPL phase or sorption onto the aquifer materials. In the latter case the surfactant is ineffective, cannot readily be recovered and may pose an environmental problem. A good reference on this technology is The Technology Practices Manual for Surfactants and cosolvents, February 1997 which was a project funded through the AATDF (Advanced Applied Technology Development Facility led by Rice University). A primary concern with any in situ application of fluids or additives is containment to ensure that contaminants or additives do not migrate outside the volume being treated (i.e. spread the contamination and make the problem worse). From this perspective in-situ soil flushing poses a higher risk than other approaches. Mobilizing or solubilizing DNAPLs with surfactants/cosolvents could result in a denser phase which would migrate downward. Design of both the surfactant/cosolvents system and the recovery well system is critical to effectively capturing the contaminants versus being confronted with a contaminant spreading problem.	Surfactant Enhanced Subsurface Remediation (SESR) has been effectively implemented in a formation with a hydraulic conductivity of less than 1 ft/day (Tinker AFB, 1997). However, the successful implementation of this technology in such a formation requires careful surfactant selection. For example any potential phase behavioral phenomena (i.e. partitioning into the NAPL) must be evaluated and sorption t the soil matrix quantified. It also is much more difficult to mobilize in such a formation than to solubilize. The proposed screening process will evaluate all of these factors to select the best surfactant for implementation. The surfactant recovery from the sub-surface is an important issue. The first step to ensuring good surfactant recovery is to obtain site specific aquifer properties using pump or similar aquifer tests. This information is then input into models to develop a well configuration scenario for injection/recovery of surfactant. Prior to the injection of surfactant, conservative tracer tests are conducted to ensure that the recovery wells indeed provide sufficient hydraulic capture. When surfactants are injected, surfactant will be sorbed to the soil matrix. However, several pore volumes of water will be flushed through the test zone to help recover sorbed surfactant. Bio degradable surfactants will be selected so that the remaining surfactant can degrade naturally. The fate of this remaining surfactant will also be modeled to determine migratory potential. As with any technology there is risk but that risk can be minimized through conducting thorough bench screening and good engineering design

Comment	Response
Application to Alameda Point, Site 5 The small area in Site 5 selected for demonstrating the technology appears to have favorable hydrogeological conditions for an in-situ flushing study. The contaminated zone for the study is relatively shallow (<20 feet), composed of a relatively uniform hydraulic fill and underlain by a lesser permeable bay sediment. Also, the underlying bay sediment which may act as an aquitard is apparently relatively thick (~50 feet). Having a relatively shallow (thin), homogeneous and permeable zone underlain by a thick lesser permeable zone (K=8 ft/day vs. .001 ft/day) is an optimal situation for designing a controlled injection/recovery well system. Based on the plates included in the draft work plan, there is a localized "hot spot" of groundwater contamination in the immediate vicinity of the test area. In well 4b-c concentrations of total chlorinated compounds and 1,1-DCA are 20 mg/l and 2.4 mg/l, respectively. These levels do not necessarily confirm that a large amount of free phase DNAPLs are present at this location The draft plan does not indicate how these groundwater isoconcentration plots (areal and cross-section) were developed. Are these results derived from the one contaminated well at this location (well 4b-c show on plates) and was this well a multiple depth completion well? Data presented for soil borings closest to demo area (3-1,4-1,4-2) do not show significant contamination, indicating the localized nature of the contamination in this area. To be successful, the treatability study area must be located in a high contaminated area.	The amount of data available at each site (2A-A and 4B-C) is limited to the groundwater results from a geoprobe investigation conducted by TtEMI. These results show that the maximum concentrations of DNAPL constituents in the groundwater (4B-C at 12' deep) was 195.4 mg/l . The primary constituents in that sample include: 1-1-1 –TCA, 1-2 DCE, and 1-2 DCA. The average solubility of these three compounds is approximately 3000 mg/l. Based on this information the observed groundwater concentrations are about 6.5 % of the average solubility of these three compounds. From our experience, this is indicative of DNAPL trapped within the soil matrix. However, these results are limited to one geoprobe boring per location. As a result additional investigation is provided to confirm the presence of DNAPL at the site. The additional investigation includes a geoprobe investigation for soil and groundwater sampling.
Surfactants/cosolvents selected from the laboratory tests to be used during the field demonstration) should be reviewed by a toxicologist prior to implementation. Even though some compounds may have food grade additive status they may pose aquatic toxicity or other problems in the environment. Additionally, biodegradable compounds are preferred in the event that the surfactant/cosolvents cannot be recovered from the subsurface for some reason. This effort should probably be restricted only to those selected and proposed for the field tests since there are numerous surfactant/cosolvents combinations that may be considered.	All of the surfactants that we select will be biodegradable. Research on the biodegradation of surfactants over the past decade has provided general rules relating surfactant structure and degradation potential. For example, increased branching of the hydrocarbon tail group decreases the susceptibility of that molecule to degradation. We have tested the biodegradation of two common surfactants (SDS and STEOL) of which both were found to be easily degraded under aerobic conditions (Rouse 1996, Water Environment Research Vol 68 No. 2). While this information and studies are useful it should be recognized that the natural degradation process is dependant on site specific conditions. Surbec can also test for the biodegradation potential of the surfactant selected for the project. Most of the surfactant manufacturers have information detailing the toxicological implications

	of the molecules they provide. This information will be provided in the work plan. If this information is not available, a toxicologist will review surfactant formulations.
PITT test. This multiple tracer test is a good approach to evaluating the injection/recovery well system and the mass NAPL present for the demonstration. The conservative tracer selected (bromide) will indicate whether the recovery well system can recover all of the injected fluids. I recommend that the regional office should establish a criteria for percent capture of the conservative tracer in this recovery well system test. If not met, the reason should be explained and a decision made on whether or to allow the injection of surfactants to proceed.	The observed capture of the conservative tracer will be used to quantify hydraulic capture within the test cell. Capture of the conservative tracer in past tests has ranged from 85% to 95%.
Push-Pull Test. The work plan gives what appears to be an acceptance criterion, "An increase in VOC concentration in the groundwater over background by a factor of 1.5 or more indicates enhanced solubilization and existence of NAPL in the radius of influence." This value seems low in terms of the technology's ability to remove only 50% more than what could be removed with conventional groundwater extraction.	Since the test is conducted in a well that is screened across the entire aquifer, the results are highly subjective to Well dilution factors. However, the acceptance criteria can be raised to 2 – 2.5 times the baseline concentrations observed in that well.
Baseline groundwater sampling of installed wells is specified for a two week period prior to conducting the push pull test. As a baseline or control for the push pull test, sampling of this well could be performed after pumping at the same rate and removing the same volume of groundwater as in the push-pull test. This only would have to be performed at the one well where the push-pull test is to be performed.	The control sampling would be used to determine pre-test groundwater concentrations for the entire cell.
DNAPL Mobility and Migration. The work plan discussed how creation of density gradients and prevention of downward migration of denser DNAPLs are mitigated with appropriate surfactant/cosolvents selection and design of their recovery well system. The assumed vertical to horizontal conductivity used in their analysis is 1:5; In figure 4.1 showing the modeled cross-section the ratio is given as 1:8. Hydraulic fill in the demonstration area may be more homogenous than this and perhaps a more conservative estimate should be used in their model. Also, it should be noted that modeling results presented in Appendix D show surfactant concentrations at 90 feet elevation, 6 feet below the Bay Sediment/fill contact, indicating possible influence of the injection well system in the uncontaminated Bay Sediment.	Additional modeling will be conducted to evaluate the affect of varying vertical conductivity on the potential for surfactant migration.
The work plan specifies soil sampling borings in the in the demonstration area. These will identify the depth of soil contamination in this area with respect to the Bay Sediments. To confirm that vertical migration has not occurred consideration should be given to strategic soil sampling between the injection and extraction wells in the uncontaminated Bay Sediment underlying the treatment zone. Alternatively, one or two microwells could be installed, screened in the uncontaminated Bay Sediment underlying the treatment zone to monitor whether vertical migration is a problem or not. Sampling this well should be completed before PITT test (background), during the PITT test for the conservative tracer, and post demonstration.	The Navy concurs that it would be useful to add a sampling point in the bay sediments beneath the test cell. The work plan will reflect this change

COMMENT	RESPONSE
Demonstration area. The area selected is appropriately small for an in-situ treatability study of this nature. There is minor confusion on the actual area involved: Figure 4.2 shows 24X22 are based on well layout; Figure 4.3 well layout and scale show 30X25 ft , text on page 4-12 states 20X20 ft.	The size of the test area is 20' x 20'. The scaled test cell delineation line in Figure 4.3 is not correct and will be corrected.
System Operation. Treatment goal is stated to be 95% DNAPL recovery and is expected to be achieved in 3 to 5 pore-volume exchanges. This goal appears ambitious considering mass recoveries reported for other studies. The amount of surfactant solution required for 5 pore volume exchanges for a 20X20x10 volume is quite large, 50,000 gallons. It is stated that there will be 5 days of surfactant flooding and 5 days of water flooding. However, an injection rate is not provided for this flooding operation. It is unclear whether the 3 to 5 volume exchanges applies to only the surfactant flood or if an additional 50,000 gallons is required for the water flood.	The test has been proposed to include 5 pore volumes of surfactant solution and 5 pore volumes of water flood. A summary of potential fluid production is included in Table 4.4 of the Work Plan. Based on the surfactant systems that have been developed in recent years, it is our opinion that these goals are not unreasonable.
Implementation of an in-situ flushing technology is only warranted or cost-effective in an area that has a high mass of DNAPL contamination. This would be the case where free phase DNAPL has been pumped out and what remains entrapped in the aquifer materials can best be removed with surfactant/cosolvent flushing. Based on groundwater contamination levels indicated in the report it is not clear whether this level of contamination is present in the proposed study area. Lastly, it should also be noted that the presence of vinyl chloride indicates that biological degradation of some degree is occurring at the site. Addition of surfactant could enhance or drastically reduce biological activity depending on the surfactant and specific site conditions.	This technology is focused on enhanced DNAPL removal. However, it has been our experience that "free phase DNAPL" is not a common occurrence and that small amounts of trapped DNAPL (in the soil matrix) can be a continuing source of groundwater contamination. Very high NAPL residual concentrations were observed at Cape Canaveral (up to 5%) without any observed DNAPL recovered from the sampling well. Using the 1% solubility rule in groundwater as an indicator of DNAPL, we see a strong potential for DNAPL existence near sample locations 2A-A and 4B-C. Surfactants/ cosolvents can act as an electron donor (dehalogenation) which may or may not stimulate contaminant degradation. However, this process is highly subjective to site specific conditions. Site groundwater contaminant profile data suggest that anaerobic conditions prevail and that surfactant addition may stimulate the biological reductive dechlorination of the contaminants (Isalou, et al., 1998 ES&T vol. 32, pp. 3579-3585; Cobb, G. D. 1991, Environ. Sci. Technol. Vol 25, pp 1068-1074).

COMMENT	RESPONSE
Given the above concerns, I would propose proceeding with the treatability study. The small scale and hydrologic conditions of the project site are favorable for conducting the treatability study with a minimum of risk. However, if the soil sampling at the site in conjunction with the PITT test do not indicate a significant mass of free phase DNAPL present, then it is probably not advisable to proceed further. [Please call me at (916) 322-2543 if you have questions or concerns regarding the above comments.]	Based on the information obtained to date, there does appear to be a "NAPL" source at the site. To confirm this, additional investigation has been added to further quantify the existence or absence of DNAPL. If the results of this investigation indicate that there is no DNAPL at the proposed sites, the pursuance of this technology at those sites will be terminated.

Comment	Response
USEPA - Anna-Marie Cook *I have reviewed the above referenced document, and am in the process of compiling my comments which I will get to you next Monday. I apologize for missing this last Monday's deadline, and appreciate the call reminding me to send the comments to you.*	
I have a significant concern regarding the site characterization used for The project. The Site 5 groundwater information used in the workplan is taken from Tetra Tech documents. Tetra Tech utilized monitoring wells with screen lengths on the order of feet, which leads to a significant dilution of concentrations in groundwater. This dilution may not matter so much for certain types of characterization, but when it comes to targeting DNAPL it is a major concern. The data in the BERC Steam Enhanced Extraction workplan shows data taken over much more discrete sampling intervals and shows that the concentrations of solvents are orders of magnitude higher than data collected by Tetra Tech. This difference will matter particularly when it comes to calculating percent recovery of solvent, as well as knowing in which areas in the subsurface to concentrate surfactant injection. Using the Tetra Tech concentrations to calculate contaminant mass in the subsurface will underestimate the amount of contamination. In subsequent recovery operations, much more mass will be extracted than expected, because there is really more contaminant mass subsurface than calculated, and the treatability study will appear an outstanding, maybe even unbelievable, success. In reality, if the site were characterized carefully as BERC has done, calculated subsurface contaminant mass would be higher, % recovery would be lower, and the treatability study could be evaluated realistically for effectiveness.	In this and other studies the primary methodologies used for evaluation of technology performance (i.e. mass of DNAPL removed) are: 1) Pre and Post partitioning tracer tests 2) Pre and post soil coring analysis 3) Mass of NAPL recovered in the recovered groundwater stream 4) Pre and post groundwater analysis Of the above listed methodologies, items 1 and 2 are considered to be the most accurate. The overall performance of this test will be evaluated using those methodologies. As you indicated in your comment, the evaluation of a technology using groundwater information is highly subjective to the screened interval of the test well. It is very difficult to correlate groundwater analysis with DNAPL concentrations.
I have looked at the proposed schedule for well installation provided in The workplan, and notice that SURBEC plans to be in the field next week. I am not sure how my concerns over site characterization can be addressed in the short time frame allotted to response to comments and realize that I am a few days over the comment due date which does not help the problem. However, I strongly urge the contractor for this study to try and get better groundwater data in the process of well installation, because it will be a matter that is taken into account in evaluating the effectiveness of this technology in the Feasibility Study. *Thank you for your attention to this concern.*	The purpose of the preliminary site investigation is to obtain additional information about each potential site for selection purposes only. Baseline groundwater sampling will not occur until the site has been selected and the injection/recovery wells and sampling wells have been installed. The current work plan proposes groundwater sampling to be conducted in wells screened over a 6'-7' interval.

United States Environmental Protection Agency/Anna-Marie Cook	
1. Page 2-1, Section 2.0: EPA strongly recommends that the data included in the Berkeley Environmental Restoration Center's (BERC) "Draft Treatability Study Work Plan Steam Enhanced Extraction" be reviewed in addition to the listed documents in this section to obtain an understanding of Site 5 soil and groundwater conditions. The BERC workplan shows data with much higher concentrations of solvents than that give in the Tetra Tech documents. The differences are primarily a result of the method by which groundwater data was obtained, in particular the depth interval over which each sample was taken and the type of instrument used to obtain groundwater concentrations. The reason this issue is of particular concern is twofold. Firstly, in order to target the areas with highest concentrations of solvent for surfactant flushing, good characterization is needed. Secondly, the success of the study is determined largely by percent recovery of solvent. If concentrations used to calculate subsurface contaminant mass are lower than really exist, then much more solvent will be recovered than anticipated, giving the appearance of an extremely successful study. When it comes time to evaluate the feasibility of this study as a remedy, it will be difficult to answer how successful the study really was if the initial assumptions and calculations underestimated the solvent concentrations.	A thorough review of the BERC workplan has been completed. A summary of the BERC findings will been included in the workplan, Section 2.2.3. The pre- and post partitioning tracer tests will be the primary methodology for evaluation of DNAPL remediation.
2. Page 2-3, Section 2.2 and 2.2.1: The 1998 BERC study has not been included in this section.	BERC results will be summarized in the work plan
3. Page 2-4, Summary of Findings Section: While the contaminants reported in this section are present at high concentrations, according to the BERC report trichlorethene is found at the highest concentrations of 1,786,000 ug/l. The highest concentrations were generally found at 4.5 feet and between 8 and 9 feet.	This information has been considered in generating the Geoprobe investigation work completed at locations 2A-A and 4B-C on April 5 through 7, 1999.
4. Page 2-4, Section 2.3: EPA urges a more thorough site characterization and delineation of the plume than that proposed in this section. The effectiveness of the treatability study is highly dependent on adequate plume characterization and contaminant mass calculations prior to the start of the study. Three soil borings do not appear adequate to delineate the extent and concentrations of the solvent contamination at the proposed site.	A Geoprobe site investigation was conducted on April 5 through 7, 1999. The investigation included the collection of 50 soil samples and 40 groundwater samples from 10 locations, 6 at 4B-C and 4 at 2A-A.
5. Page 2-6, Section 2.3.4: What is the purpose of the groundwater sampling described in this section? Is it to be used as a means of determining appropriate disposal? If it is to be used as a mean of characterizing the groundwater conditions, EPA would like to point out that the screened interval is too long to provide useful characterization data and the method of purging will result in falsely low concentrations of volatiles.	The purpose of these groundwater samples was to obtain a qualitative assessment of the groundwater quality at 2A-A and 4B-C. The Geoprobe investigation will quantitatively characterize the groundwater.
6. Page 4-1, Section 4.1: A permit waiver is not necessary for reinjection activities because this pilot project is being done as a part of the ongoing CERCLA activities on the base. In other words, it is being reviewed as part of a CERCLA action and therefore does not need a separate permit or permit waiver.	This information will be added to Section 4.1.

7. Page 4-2, first paragraph, last sentence: Revise wording from "...is allowable as long as any of the solution constituents exceed..." to "...s allowable as long as none of the solution constituents exceed...." Also, note that the prohibition on exceedance is restricted to primary as opposed to secondary MCLs.	This change will be incorporated.
8. Page 4-3, Section 4.2: The model may give a different result and affect the design of the injection/extraction system if BERC data is used in addition to that provided by Tetra Tech.	This will be assessed in addition to inclusion of the Geoprobe data during the final modeling. Soil and groundwater data obtained during well installation will also be used to develop baseline conditions.
9. Table 4-1: What is the purpose of this table? Soil boring data is given in ppb which would translate to ug/kg for concentrations in soil. Perhaps this data is really groundwater data in which case the title on the columns is very misleading. In addition, the use of the Toxicity Characteristics leaching Procedure as a cleanup criteria makes no sense. TCLP is used to determine whether a waste is a characteristic hazardous waste for disposal purposes and generally would never be used as a cleanup criteria.	The table headings will be changed to reflect that the data is groundwater data. The 40 CFR 261.24 Table 1 MCLs are commonly used during RCRA