TECHNICAL MEMORANDUM
FOR
SURFACTANT ENHANCED DNAPL REMOVAL TREATABILITY STUDY
AT
ALAMEDA POINT (SITE 5)

Subcontract No. S7609-98-057-808

Submitted to:

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June 23, 1999

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AT
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LIST OF ACRONYMS

BERC – Berkeley Environmental Restoration Center
BGS – below ground surface
COC – chain of custody
DCA – 1,1-Dichloroethane
DCE – 1,1-Dichloroethene
DNAPL – dense non-aqueous phase liquids
EBMUD – East Bay Municipal Utility District
FWI – fresh water injection well
IW – injection well
LFR – Levine Fricke Recon
LNAPL – light non-aqueous phase liquids
MLS – multi-level sampler
MW – monitor well
OVM – organic vapor monitor
PID – photo ionization detector
PPM - parts per million
PTT – partitioning tracer test
PVC-polyvinyl chloride
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

Naval Air Station (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 NAS 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.

The purposes of this report are to: 1) summarize site investigation activities and results, 2) present surfactant collection data and results, and 3) present the final demonstration system well locations and details.

The purpose of the site investigation was to find a suitable site at the Alameda Point Air Station for the demonstration of surfactant enhanced subsurface remediation (SESR). Two sites were investigated east of Building 5 including TtEMI sampling locations 2A-A and 4B-C (refer to Figure 1.1). A comprehensive laboratory screening was completed to select the most suitable surfactant system to be utilized, based on the Alameda Point geology and contaminant characteristics. Visual Modflow/Mt3D groundwater modeling analysis was completed using the site data and pump test results to determine the best well layout to achieve effective surfactant flushing and groundwater/surfactant capture in the demonstration cell.

This report has been divided into sections discussing the above mentioned tasks. Section 2.0 summarizes the site investigation procedures and results. Section 3.0 presents the SESR well installation locations, soil sampling results, groundwater sampling results, and installed demonstration well layout. Section 4.0 presents the final groundwater modeling and system well layout details. Section 5.0 details and summarizes the laboratory screening for selection of the surfactant system and tracer(s) to be used for SESR Implementation and Partitioning Tracer Test Implementation. Section 6.0 offers the recommendations for the demonstration.

The first step for this project was to select a suitable site for the test. In order to ensure a successful test, it was important to select a site that was conducive to SESR and to be representative of the subject aquifer. The following is a list of preferred conditions for site selection:

- Residual concentrations of DNAPL evidenced by either:
    1. Ground water concentrations of 1% or greater of the contaminant's water solubility (Huling and Weaver, 1991) (Keeley, 1989) or
    2. Enhanced solubilization during the surfactant push-pull test by 1.5-2.0 times the background concentration (Huling and Weaver, 1991) (Keeley, 1989).
- Hydraulic conductivity should range from 1 ft/day to 10 ft/day.
- Subsurface chemistry compatible with one of the candidate surfactant/co-solvent systems. Specific elements of concern include pH, hardness (divalent cations), and fraction of organic content.
- Lithologic and hydrogeologic conditions in which hydraulic control is possible through engineering design. It is preferable to have relatively homogeneous conditions within the flushed area.

To screen potential sites for application of this technology, Surbec reviewed the Alameda Point contaminants, the geological, and the hydrogeological information. Using the above criteria, Surbec rated two sites for additional investigation to determine applicability. Further geo-chemical, geological, and hydrogeological evaluation were conducted as part of the additional investigation of these two sites.

1.1 Objectives

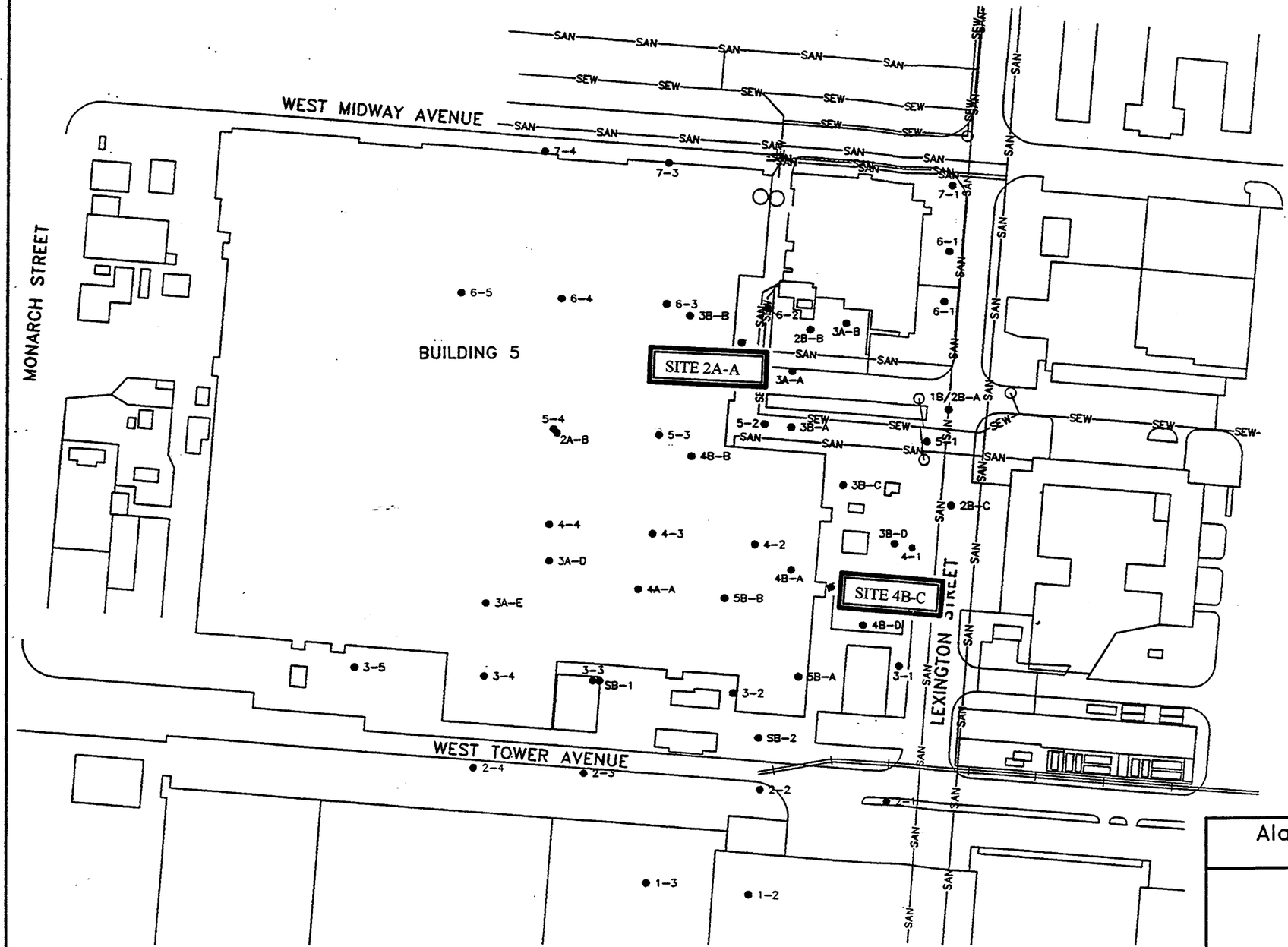
The Navy identified one primary objective and three secondary objectives for the treatability study. The primary objective of the study is to:

- 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 extent of horizontal and vertical DNAPL containment within the test area
- Determine the efficiency of surfactant recovery from the test area (overall goal of 93%).

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



LEGEND

SEW — SEW — STORM SEWER LINE

SAN — SAN — SANITARY SEWER LINE

2A-A ● SOIL BORING LOCATION

SCALE

0 200' 400'

Alameda Point Air Station Alameda, California	DATE: 1/99
	DESIGNED:
	CHECKED:
SITE MAP	APPROVED:
	DRAWN: COG
	PAGE:
SURBEC ENVIRONMENTAL, LLC Norman, Oklahoma	**FIGURE 1.1**

2.0 SITE INVESTIGATION

Two sites were investigated to locate the most suitable site for SESR Implementation. TtEMI sample locations 2A-A and 4B-C are located at the Alameda Station Site east of Building 5. TtEMI collected groundwater samples at these locations during a Site 5 Geoprobe investigation. The resulting groundwater analyses indicated the presence of high concentrations of DNAPL at both locations.

Surbec conducted a Preliminary Site Investigation (SI) which included the installation of groundwater walls and two Geoprobe Investigations (GI) (Phase I and Phase II) to further define the contaminant characteristics of the two locations.

This chapter is divided into the following five sections:

1. Site Setting and Geology/Hydrogeology.
2. Preliminary Site Investigation (conducted at 2A-A and 4B-C).
3. Phase I Geoprobe Investigation (conducted at 2A-A and 4B-C).
4. Phase II Geoprobe Investigation (conducted at 2A-A only).
5. Hypotheses and Conclusions.

2.1 Site Setting and Geology/Hydrogeology

The waters of San Francisco Bay once covered much of the land now occupied by the site. Tidal flats occupied most of the land not covered by the bay. 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 fill is approximately 17 feet thick on the east side of Building 5, the location of the Treatability Study. 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. In this area, these deposits are considered an aquitard.

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. 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 contain higher percentages of silt and sand in the western portion of the base, and is 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 lithology at Site 5 is characterized by a fill layer between 0 and 17 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. These deposits are primarily a lower permeability mixture of silty clay to sandy clay, with occasional sands, silts, and shell fragments. 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 Berkeley Environmental Restoration Center (BERC) Workplan. The depth to groundwater is approximately seven feet below ground surface (bgs). A pump test conducted by Surbec at Site 5 on May 23, 1999, indicated a hydraulic conductivity of 8.14 to 20.48 feet/day. The pump test was conducted in the Study well IW-1. IW-1 was screened from 13.5 to 17.5 feet bgs, which lies at the base of the aquifer. The variation of the hydraulic conductivity was observed during a three step draw down test, each lasting 80 minutes long (Section 3.4). It has been our experience that some variance in hydraulic conductivity is observed between the steps of a short draw down test. A variation by a factor of 1.5 is expected and is likely attributed to the release of water by capillary action during the dewatering process. The pump test data was also input into Visual Modflow to match the draw down curve and to calibrate the data. The results of this analysis indicated that a hydraulic conductivity of 10 ft/day matches the drawdown data.

2.2 Site Investigation (SI)

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

1. The completion of three soil borings:
   - 8 feet east of TtEMI sampling location 2A-A
   - 10 feet north of TtEMI sampling location 4B-C
   - 10 feet south of TtEMI sampling location 4B-C (Figures 2.1 & 2.2)
2. The collection of one soil sample per soil boring for laboratory analyses of volatile organics by EPA method 8260.
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 EPA method 8260.

The purpose of the SI was to determine which location, 2A-A or 4B-C, was more suitable for the Treatability Study. A comparison of the soil and groundwater data would be used to make this evaluation.

Soil Boring and Monitor Well Installation

Three soil borings were completed for the purposes of soil sample collection, lithologic description, and monitor well installation. The soil borings were completed with an Ingersol Rand A-400 hollow-stem auger (HSA) rig. Soil samples were collected using a five-foot split barrel continuous core barrel. Soil boring logs are enclosed in Appendix A.

Upon completion of the soil borings, monitor wells were installed through the HSA. The 4-inch diameter monitor wells consist of a 10 foot stainless steel (0.02 slot) screen with a PVC blank to the surface. The annulus surrounding the screen was filled with a #3 silica sand to a depth of one foot above the screen and the remaining portion of the annulus was filled with bentonite hole-plug to the surface.

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 which soil samples were to be submitted to the laboratory for analyses of volatile organics by EPA method 8260. The results are summarized in Table 2.1 (p. 2-9).

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 (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. The existence of methylene chloride was not expected based upon the review of previous data during preparation of the work plan. The other samples contained very low levels or were non-detect of volatile organics EPA method 8260.

The sample 2A-AE contained high concentrations of a possible fuel contaminant. A total petroleum hydrocarbons analysis 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 because the soil sample was preserved with methanol, which would blow out the flame during the detection run.

Groundwater Sample Results

Groundwater samples were collected from the three monitor wells installed in borings 4B-CN, 4B-CS, and 2A-AE. The wells were developed and purged, and allowed to equilibrate. They were then sampled for analyses of volatile organics EPA method 8260. The results are summarized in Table 2.2 (p. 2-10).

The groundwater results from the SI indicate that the groundwater in the vicinity of monitor well 4B-CN contains the highest level of volatile organics at 15.83 mg/l. The original proposed Study

site, 2A-A, indicated a volatile organics (EPA method 8260) groundwater concentration of 9.62 mg/l.

Upon assessment of the SI and TtEMI historical data, Surbec concluded that additional investigative work would be required to delineate the extent of NAPL contamination. The data gathered during the SI indicated that the groundwater in the vicinity of 4B-C had a higher concentration of volatile organics than in the vicinity of 2A-A. The concentrations measured by Surbec are significantly lower than the TtEMI reported concentrations. This could be due to dilution occurring in the Surbec well screens. The three 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 concluded that additional discrete sampling and analysis would remove much of the uncertainty and yield data necessary for selecting the final locations of the injection/recovery system wells.

Although the preliminary data indicated that 4B-C is potentially a more suitable site for the Study, Surbec proposed discrete sampling in the area of the three wells at both sites to verify this conclusion. In addition, the direction of greatest contaminant concentrations at each sampling location was not known based upon the limited data collected in the SI. Additional investigation of the source area will be conducted to delineate a study cell location.

2.3 Phase I Geoprobe Investigation

Upon assessment of the SI data, it was concluded that discrete sampling would be more appropriate to assess the two locations. Since DNAPL exists as residual droplets and ganglia in the soils, discrete sampling over a wider interval allows for better sampling resolution and definition of a highly contaminated discrete layer or zone. In addition, as the DNAPL is concentrated in small areas, sampling at discrete depths would allow a more accurate assessment of the groundwater quality since dilution would not effect a discrete groundwater sample concentration. To obtain discrete soil and groundwater samples, a geoprobe investigation (GI) was developed.

The geoprobe investigation consisted of the following activities.

1. Four additional geo-probe holes were drilled near 2A-A to collect discrete groundwater and soil samples. The holes were 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 added data to determine the vertical and horizontal direction of the source of contamination at 2A-A, and also added data to determine the influence of the LNAPL on DNAPL detection and movement (Figure 2.1).

2. Six additional geo-probe holes were drilled near 4B-C to collect discrete groundwater and soil samples. The holes were placed approximately 30 feet northwest of the northern well (4B-CN) previously installed at 4B-C by Surbec, 15 feet northeast of 4B-CN, 15 feet east of 4B-C, immediately adjacent to MW 4B-CN, immediately

adjacent to 4B-C, and approximately 40 feet southwest of 4B-C immediately outside the building (Figure 2.2).

The depth of the selected soil samples is documented in the following table. The soil sample interval distance decreased, or the sample frequency increased, toward the Bay Mud, the suspected confining layer. A duplicate soil sample was collected from one boring at each of the two sites.

Soil Boring Installation

Soil samples were collected using a Geoprobe rig with 2-inch diameter plastic liners, 4 feet in length. The four samples were used to record the lithology and to collect discrete samples from selected depths. Soil boring logs are enclosed in Appendix A.

Sample Intervals

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

Soil Sample Analytical Results

Fifty-two soil samples were collected from the ten geoprobe locations. Soil samples for VOC analysis were collected by pushing a syringe directly into sediment cores. The sediment (12 ml) was then injected into 40-ml glass containers containing 25-ml of methanol. The containers were immediately sealed with teflon-lined screw caps. The soil sample results are summarized in Table 2.3 (p. 2-11).

The highest total volatile organic carbon (VOC) concentration detected in the soil samples from location 2A-A was 9400 ug/kg at location 2A-G3/5 from the 15.0 foot depth with the dominant contaminant, 1,1-Dichlorethane, at 5700 ug/kg. Location 2A-G3 is located immediately adjacent to Surbec's monitor well 2A-AE. An LNAPL was detected at location 2A-G2/2 at the 10.0 foot depth with the dominant contaminant, 1,2-Dichlorobenzene, at a concentration of 4000 ug/kg. Location 2A-G2 is located approximately 20 feet northeast of 2A-A. The remaining samples collected at location 2A-A ranged from a total VOC concentration of non-detect to 3490 ug/kg.

The highest total VOC concentration detected in the soil samples from location 4B-C was 7220 ug/kg at location 4B-CG6/5 from the 13.0 foot depth with the dominant contaminant, 1,1-Dichlorethane, at 6200 ug/kg. Location 4B-CG6 is located immediately adjacent to TtEMI sampling location 4B-C. The remaining samples collected at location 4B-C ranged from a total VOC concentration of non-detect to 5100 ug/kg. None of the soil sample results are indicative of source area concentrations.

Groundwater Analytical Results

Thirty-eight groundwater samples were also collected from the ten geoprobe locations. A sample was not collected from locations 2A-G4 at the 15 foot depth and from location 4B-CG2 at the 12.0 foot depth due to lack of sufficient flow. The groundwater sample results are summarized in Table 2.4 (p. 2-14).

The highest total VOC concentration detected in the groundwater samples from location 2A-A was 378,000 ug/l at sample location 2A-G2 at the 15.0 foot depth. The dominant contaminant from this sample was 1,1,1-Trichloroethane (TCA) at a concentration of 200,000 ug/l with 1,1-Dichlorethane (DCA) at 57,000 ug/l, Trichloroethene (TCE) at 36,000 ug/l, and cis-1,2-Dichloroethene (cis-DCE) at 73,000 ug/l. The remaining groundwater samples collected from TtEMI location 2A-A ranged from a total VOC concentration of 46.1 ug/l to 231,100 ug/l.

The highest total VOC concentration detected in the groundwater samples from location 4B-C was 31,810 ug/l at sample location 4B-CG3 at the 11.0 foot depth. The primary contaminant from this sample was DCE at a concentration of 13,000 ug/l, with DCA at 8,100 ug/l, and TCA at 8,100 ug/l. The remaining groundwater samples collected from TtEMI location 4B-C ranged from a total VOC concentration of 28.4 ug/l to 25,720 ug/l.

Based upon the soil and groundwater results from Phase I, Surbec concluded that location 2A-A was more suitable for the completion of the Treatability Study. Further site investigation efforts were then focused on location 2A-A to more fully define the source area.

2.4 Phase II Geoprobe Investigation

Phase II consisted of the completion of four additional geo-probe holes drilled near 2A-G2 to collect discrete groundwater and soil samples. The purpose of the Phase II investigation was to define the location of the contamination detected at location 2A-G2 during Phase I GI. The Phase II holes were placed 5 feet northeast of 2A-G2 (2A-G5), 20 feet north of 2A-G5, 20 feet east of 2A-G5, and approximately 27 feet northeast of 2A-G5. The soil and groundwater sample results from these locations offered additional data to determine the vertical and horizontal direction of the source of contamination near 2A-A (Figure 2.1). Soil borings logs are enclosed in Appendix A.

Soil Sample Analytical Results

Fourteen soil samples were collected from the four geoprobe locations. Soil samples were collected from depths of 13.0, 15.0, and 17.0 feet from each boring, and 19.0 feet from 2A-G5 and 2A-G8. Phase II soil sample results are summarized in Table 2.5 (p. 2-17).

The highest total VOC concentration detected in the soil samples from these four locations was 357,200 ug/kg at location 2A-G5/3 from the 17.0 foot depth with the dominant contaminant TCA at 200,000 ug/kg. TCE was detected at 110,000 ug/kg from this location. Location 2A-G5 is located five feet northeast of location 2A-G2. The remaining samples collected from these four locations ranged from a total VOC concentration from 170 to 38,120 ug/kg.

Groundwater Analytical Results

Twelve groundwater samples were collected from the four geoprobe locations. Groundwater samples were collected from the 13.0, 15.0, and 17.0 foot depths. Phase II groundwater sample results are summarized in Table 2.6 (p. 2-18).

The highest total VOC concentration detected in the groundwater samples from these four locations was 493,000 ug/l at location 2A-G5/3 from the 15.0 foot depth with the dominant contaminant TCA at 270,000 ug/l. TCE was detected at a concentration of 71,000 ug/l at this location. Location 2A-G5 is located five feet northeast of location 2A-G2. The remaining samples collected from these four locations ranged from a total VOC concentration from 1309 to 237,700 ug/l.

2.5 Hypotheses and Conclusions

2.5.1 Preliminary Site Investigation Phase I Geoprobe Investigation

Based upon the groundwater sample results from the SI and Phase I GI, location 2A-A appeared to be a better candidate site for the Treatability Study Location 2A-A also appeared to be at or close to the source area. The dominant contaminants detected in the groundwater samples from 2A-A are parent products Trichloroethene (TCE) and 1,1,1-Trichloroethane (TCA), and degradation products 1,1-Dichloroethane (DCA), 1,1-Dichloroethene (DCE), cis-1,2-Dichloroethene (cis-DCE), chloroethane, and vinyl chloride (VC).

The high groundwater concentrations at location 2A-G2 (total VOC concentration of 378 mg/l) are indicative of NAPL within the area (over 30% of the solubility). However, the soil results from the same boring and interval were relatively low. It was hypothesized that the soil boring 2A-G2 is very near the DNAPL source, but not within the DNAPL area. An explanation for this discrepancy is discussed in Section 2.5.2 with the associated data.

Surbec assessed the chemical composition of the contaminants detected in the SI and Phase I. The following hypotheses are based upon literature currently used to understand TCE and TCA degradation and migration. Determination of proximity to the source area can be estimated by observing the spatial distribution of concentrations of the parent compounds and degradation products in the groundwater plume. The general degradation trend is from TCE to DCE to cis-DCE to VC, and from TCA to DCA to VC (Sims et al., 1990). TCE and TCA will appear at and immediately near the source area. DCE and DCA will be at its highest concentrations immediately downgradient of the source as the TCE and TCA degrade. Cis-DCE will be at its highest concentration immediately downgradient of DCE. Vinyl chloride is the final degradation product and will occur at its highest concentration furthest from the source area.

Based upon this understanding of the degradation process for TCA and TCE, location 2A-G2 appears to be at or closest to the source based on the high concentrations of TCA (200,000 ug/l) and TCE (36,000 ug/l). In addition, cis-DCE concentrations are much higher at 2A-G1 which is located further west. High chloroethane and vinyl chloride concentrations also appear further away at 2A-G1 and 2A-G3. TCA is not present at any of the other three geoprobe locations at 2A-A, and TCE appears at much lower concentrations at the other locations. This may suggest the degradation of the TCE and TCA downgradient, pointing again to a potential source further northeast from location 2A-G2.

Based on the spatial distribution of concentrations of the parent compounds and degradation products in the groundwater plume , Surbec recommended further investigation north, northeast, and east of location 2A-G2 to further delineate the source area for the high concentrations observed in the groundwater at location 2A-G2. Source location is ideal to monitor the success of the Study because success is based on mass removal quantified from the soils via samples and tracer tests. Hence, an area with high soil concentrations is ideal for the study cell.

2.5.2 Phase II Geoprobe Investigation

Based upon the soil and groundwater results from the four Phase II locations, and the discussion of parent and degradation products in Section 2.5.1, Surbec concludes that location 2A-G5 is closest to the source area. Relatively high concentrations of TCA and TCE were also detected in the soils and groundwater from location 2A-G8. High concentrations of DCE, DCA, vinyl chloride, and other degradation products were detected in 2A-G6 and 2A-G7, indicating that these locations were further from the source area.

In addition, based upon the results of the Phase I and Phase II sample results, high concentrations of DNAPL can be easily missed during sampling as the DNAPL is present in residual droplets and ganglia (observed in geoprobe cores from the well installation sampling). These droplets and ganglia were observed in the fill sand immediately above the Bay Mud.

Based upon these findings, Surbec recommended installation of the Demonstration Study wells around location 2A-G5, with the injection wells in a north-south direction near 2A-G5. Figure 3.1 and 3.5 show the SESR Design with the location of the Demonstration wells relative to 2A-G5 and Building 5.

2.5.3 Source Identification

Surbec searched available documents and identified two potential sources in the vicinity of 2A-G2. One source is a pair of sanitary and storm sewer lines that lie approximately twenty-five feet east of 2A-G2 and trend north/south. The location of these lines was confirmed by examining base utility maps belonging to the Naval Transition Office. Man-hole covers are visible east/southeast of 2A-G2. The second potential source is an excavated area at the southwest corner of the building, immediately northeast of 2A-G2.

Based upon the additional data presented in Section 3.0 and collected during installation of the system wells, the two mentioned sources do not appear to be source candidates. The soil and groundwater data collected during the system wells indicates a decrease in concentration toward these two potential candidates. Hence, the source of the contamination at 2A-A is currently unknown with no additional potential candidates.

Table 2.1: SI 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

Table 2.2: SI 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

Table 2.3: Phase I Geoprobe Soil Sample Results

Sample Number And Depth (ft)	Soil Concentrations (ug/kg)										
	2A-G1/1 (7.0 ft)	2A-G1/2 (10.0 ft)	2A-G1/3 (12.0 ft)	2A-G1/4 (14.0 ft)	2A-G1/5 (15.0 ft)	2A-G1/5a (15.0 ft)	2A-G2/1 (7.0 ft)	2A-G2/2 (10.0 ft)	2A-G2/3 (12.0 ft)	2A-G2/4 (14.0 ft)	2A-G2/5 (15.0 ft)
Contaminant											
Isopropylbenzene	ND	ND	ND	ND	ND	ND	ND	160	ND	ND	ND
Propylbenzene	ND	ND	ND	ND	ND	ND	ND	260	ND	ND	ND
1,2,4-Trimethylbenzene	ND	ND	ND	ND	ND	ND	ND	590	ND	ND	ND
sec-Butylbenzene	ND	ND	ND	ND	ND	ND	ND	370	ND	ND	ND
para-Isopropyl Toluene	ND	ND	ND	ND	ND	ND	ND	270	ND	ND	ND
1,4-Dichlorobenzene	ND	ND	ND	ND	ND	ND	ND	970	ND	ND	ND
n-Butylbenzene	ND	ND	ND	ND	ND	ND	ND	460	ND	ND	ND
1,2-Diclorobenzene	ND	ND	ND	ND	ND	ND	ND	4000	ND	ND	ND
1,1-Dichloroethane	ND	ND	750	ND	2300	2400	ND	ND	190	160	1400
1,1-Dichloroethene	ND	ND	ND	ND	180 J	180 J	ND	ND	ND	ND	150
Trichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloroethane	ND	ND	ND	ND	270 J	250 J	ND	ND	ND	ND	ND
cis-1,2-Dichloroethene	ND	ND	110 J	ND	510	340	ND	ND	ND	ND	ND
TOTAL	ND	ND	860	ND	3090	3170	ND	7080	190	160	1550

Sample Number And Depth (ft)	Soil Concentrations (ug/kg)										
	2A-G3/1 (7.0 ft)	2A-G3/2 (10.0 ft)	2A-G3/3 (12.0 ft)	2A-G3/4 (14.0 ft)	2A-G3/5 (15.0 ft)		2A-G4/1 (7.0 ft)	2A-G4/2 (10.0 ft)	2A-G4/3 (12.0 ft)	2A-G4/4 (14.0 ft)	2A-G4/5 (15.0 ft)
1,1-Dichloroethane	ND	ND	ND	1000	5700		ND	120 J	690	680	710
1,1-Dichloroethene	ND	ND	ND	ND	600		ND	ND	ND	ND	ND
Trichloroethene	97 J	ND	ND	ND	ND		ND	ND	1000	350	ND
Chloroethane	ND	ND	ND	ND	2900		ND	ND	350 J	2100	ND
cis-1,2-Dichloroethene	ND	ND	ND	ND	200		ND	ND	750	360	ND
TOTAL	97	ND	ND	1000	9400		ND	120	2790	3490	710
J = estimated value											

TABLE 2.3: Phase I Geoprobe Soil Sample Results, Cont'd

Sample Number And Depth (ft)	Soil Concentrations (ug/kg)										
	4B-CG1/1 (7.0 ft)	4B-CG1/2 (9.0 ft)	4B-CG1/3 (11.0 ft)	4B-CG1/4 (12.0 ft)	4B-CG1/5 (13.0 ft)		4B-CG2/1 (7.0 ft)	4B-CG2/2 (9.0 ft)	4B-CG2/3 (11.0 ft)	4B-CG2/4 (12.0 ft)	4B-CG2/5 (13.0 ft)
Contaminant											
1,1,1-Trichloroethane	ND	ND	1200	790	140 J		ND	1100	ND	ND	ND
Toluene	ND	ND	ND	ND	ND		ND	ND	ND	ND	ND
1,2-Dicloroethane	ND	ND	110 J	ND	ND		ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	1900	1600	750		350	290	ND	ND	ND
1,1-Dichloroethene	ND	ND	2200	1800	450		360	1100	ND	ND	ND
Trichloroethene	ND	ND	ND	ND	ND		ND	ND	ND	ND	ND
Chloroethane	ND	ND	ND	ND	ND		ND	ND	ND	ND	ND
cis-1,2-Dichloroethene	ND	ND	ND	ND	ND		ND	ND	ND	ND	130 J
trans-1,2-Dichloroethene	ND	ND	ND	ND	ND		ND	ND	ND	ND	ND
TOTAL	ND	ND	5410	4190	1340		710	2490	ND	ND	130

Sample Number And Depth (ft)	Soil Concentrations (ug/kg)										
	4B-CG3/1 (7.0 ft)	4B-CG3/2 (9.0 ft)	4B-CG3/3 (11.0 ft)	4B-CG3/4 (12.0 ft)	4B-CG3/5 (13.0 ft)		4B-CG4/1 (7.0 ft)	4B-CG4/2 (9.0 ft)	4B-CG4/3 (11.0 ft)	4B-CG4/4 (12.0 ft)	4B-CG4/5 (13.0 ft)
Contaminant											
1,1,1-Trichloroethane	180 J	1100	100 J	ND	ND		ND	ND	ND	ND	ND
Toluene	ND	ND	ND	ND	ND		ND	ND	ND	ND	ND
1,2-Dicloroethane	ND	ND	ND	ND	ND		ND	ND	ND	ND	ND
1,1-Dichloroethane	100 J	500	900	580	ND		ND	ND	ND	ND	240
1,1-Dichloroethene	350	1700	1400	ND	ND		ND	ND	ND	ND	ND
Trichloroethene	ND	ND	ND	ND	ND		ND	ND	ND	ND	ND
Chloroethane	ND	ND	ND	ND	ND		ND	ND	ND	ND	ND
cis-1,2-Dichloroethene	ND	ND	ND	ND	350		ND	ND	ND	ND	ND
trans-1,2-Dichloroethene	ND	ND	ND	ND	290		ND	ND	ND	ND	ND
TOTAL	630	3300	2400	580	640		ND	ND	ND	ND	240

J = estimated value

TABLE 2.3: Phase I Geoprobe Soil Sample Results, Cont'd

Sample Number And Depth (ft)	Soil Concentrations (ug/kg)										
	4B-CG5/1 (7.0 ft)	4B-CG5/2 (9.0 ft)	4B-CG5/3 (11.0 ft)	4B-CG5/4 (12.0 ft)	4B-CG5/5 (13.0 ft)	4B-CG6/1 (7.0 ft)	4B-CG6/2 (9.0 ft)	4B-CG6/3 (11.0 ft)	4B-CG6/4 (12.0 ft)	4B-CG6/5 (13.0 ft)	4B-CG6/6 (13.0 ft)
Contaminant											
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	200	270	ND	ND
Toluene	ND	ND	ND	130 J	ND	ND	ND	ND	ND	240	180J
1,2-Dicloroethane	ND	ND	ND	100 J	1900	ND	ND	ND	ND	160 J	ND
1,1-Dichloroethane	ND	ND	370	4600	ND	ND	ND	640	2400	6200	4000
1,1-Dichloroethene	ND	ND	ND	270	ND	ND	ND	390	820	ND	ND
Trichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	620	ND
cis-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
trans-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TOTAL	ND	ND	370	5100	1900	ND	ND	1230	3490	7220	4180

J = estimated value

TABLE 2.4: Phase I Geoprobe Groundwater Sample Results

Sample Number And Depth (ft)	Groundwater Concentrations (ug/l)								
	2A-G1/1 (10.0 ft)	2A-G1/2 (12.0 ft)	2A-G1/3 (14.0 ft)	2A-G1/4 (15.0 ft)		2A-G2/1 (10.0 ft)	2A-G2/2 (12.0 ft)	2A-G2/3 (14.0 ft)	2A-G2/4 (15.0 ft)
1,1,1-Trichloroethane	ND	ND	ND	ND		ND	ND	1400 J	200000
Vinyl chloride	57 J	1800 J	21000	46000		ND	ND	5000	ND
1,1-Dichloroethane	1500	42000	2200 J	4300		74	2500	52000	57000
1,1-Dichloroethene	63	2300	ND	2800 J		ND	ND	11000	12000
Trichloroethene	75	890 J	ND	ND		ND	ND	1200 J	36000
Chloroethane	51 J	3300	65000	48000		63	170	16000	ND
cis-1,2-Dichloroethene	260	1800	14000	130000		ND	ND	9300	73000
Benzene products	ND	ND	ND	ND		29.6	ND	ND	ND
TOTAL	2006	52090	102200	231100		166.6	2670	95900	378000

J = estimated value

Sample Number And Depth (ft)	Groundwater Concentrations (ug/l)								
	2A-G3/1 (10.0 ft)	2A-G3/2 (12.0 ft)	2A-G3/3 (14.0 ft)	2A-G3/4 (15.0 ft)		2A-G4/1 (10.0 ft)	2A-G4/2 (12.0 ft)	2A-G4/3 (14.0 ft)	2A-G4/4 (15.0 ft)
1,1,1-Trichloroethane	ND	ND	ND	ND		ND	ND	ND	
Vinyl chloride	ND	280 J	7200	1600 J		10	320	2600	
1,1-Dichloroethane	38	6500	49000	19000		70	2500	5400	
1,1-Dichloroethene	ND	ND	5000	1600		ND	250	ND	
Trichloroethene	ND	ND	ND	1100		27	1000	4500	
Chloroethane	5.1 J	410 J	15000	17000		8.5 J	1300	18000	
cis-1,2-Dichloroethene	3.0 J	210 J	2500	3100		29	1100	3900	
trans-1,2-Dichlorethene	ND	ND	ND	ND		ND	67	ND	
TOTAL	46.1	7400	78700	43400		144.5	6537	34400	NS

J = estimated value

TABLE 2.4: Phase I Geoprobe Groundwater Sample Results, Cont.'d

Sample Number And Depth (ft)	Groundwater Concentrations (ug/l)								
	4B-CG1/1 (9.0 ft)	4B-CG1/2 (11.0 ft)	4B-CG1/3 (12.0 ft)	4B-CG1/4 (13.0 ft)		4B-CG2/1 (9.0 ft)	4B-CG2/2 (11.0 ft)	4B-CG2/3 (12.0 ft)	4B-CG2/4 (13.0 ft)
1,1,1-Trichloroethane	730	3600	1200	1800		6500	ND		26
Vinyl chloride	ND	1200	350 J	390		ND	12 J		ND
1,1-Dichloroethane	410	13000	8200	4800		150 J	190		16
1,1-Dichloroethene	990	7400	2400	3000		6500	78		19
1,2-Dichloroethane	60	520	410	230		ND	4.9 J		3.0 J
Trichloroethene	31 J	ND	ND	ND		88 J	4.1 J		ND
Chloroethane	ND	ND	ND	ND		ND	ND		8.6 J
cis-1,2-Dichloroethene	ND	ND	ND	ND		2000	29		ND
trans-1,2-Dichlorethene	ND	ND	ND	ND		ND	4.5 J		ND
TOTAL	2221	25720	12560	10220		15238	322.5	NS	72.6

J = estimated value

Sample Number And Depth (ft)	Groundwater Concentrations (ug/l)								
	4B-CG3/1 (9.0 ft)	4B-CG3/2 (11.0 ft)	4B-CG3/3 (12.0 ft)	4B-CG3/4 (13.0 ft)		4B-CG4/1 (9.0 ft)	4B-CG4/2 (11.0 ft)	4B-CG4/3 (12.0 ft)	4B-CG4/4 (13.0 ft)
1,1,1-Trichloroethane	6200	8100	ND	ND		4.0 J	7.1	3.6 J	ND
Vinyl chloride	ND	ND	ND	ND		ND	ND	ND	ND
1,1-Dichloroethane	2400	8100	3800	770		7.5	67	89	190
1,1-Dichloroethene	6500	13000	210	ND		11	79	68	28
1,2-Dichloroethane	360	610	110 J	38		ND	ND	ND	ND
2-Butanone	400 J	2000	ND	ND		ND	ND	ND	ND
Trichloroethene	ND	ND	ND	ND		5.9	29	32	19
Chloroethane	ND	ND	1000	1100		ND	ND	ND	ND
cis-1,2-Dichloroethene	ND	ND	ND	ND		ND	19	37	66
trans-1,2-Dichlorethene	ND	ND	ND	ND		ND	4.9 J	13	30
Tetrachlorethene	ND	ND	ND	ND		ND	2.9 J	ND	ND
TOTAL	15860	31810	5120	1908		28.4	208.9	242.6	333

J = estimated value

TABLE 2.4: Phase I Geoprobe Groundwater Sample Results, Cont.'d

Sample Number And Depth (ft)	Groundwater Concentrations (ug/kl)								
	4B-CG5/1 (9.0 ft)	4B-CG5/2 (11.0 ft)	4B-CG5/3 (12.0 ft)	4B-CG5/4 (13.0 ft)		4B-CG6/1 (9.0 ft)	4B-CG6/2 (11.0 ft)	4B-CG6/3 (12.0 ft)	4B-CG6/4 (13.0 ft)
1,1,1-Trichloroethane	170	ND	66	ND		130	800	1700	630
Vinyl chloride	ND	990 J	590	ND		ND	690	1600	92 J
1,1-Dichloroethane	1100	12000	7800	9700		520	10000	17000	1300
1,1-Dichloroethene	640	1800	870	ND		180	2000	4400	1100
1,2-Dichloroethane	ND	280 J	200	170 J		50	370	530	53 J
2-Butanone	ND	ND	ND	ND		ND	ND	ND	ND
Trichloroethene	36 J	ND	ND	ND		ND	ND	ND	38 J
Chloroethane	ND	ND	63 J	940		ND	ND	ND	ND
cis-1,2-Dichloroethene	30 J	ND	59 J	ND		14 J	ND	ND	ND
trans-1,2-Dichlorethene	ND	ND	ND	ND		ND	ND	ND	ND
Toluene	ND	ND	47 J	ND		ND	ND	ND	ND
TOTAL	5540	15070	9695	10810		894	13860	25230	3213

J = estimated value

Table 2.5: Phase II Geoprobe Soil Sample Results

Sample Number And Depth (ft)	Soil Concentrations (ug/kg)							
	2A-G5/1 (13.0 ft)	2A-G5/2 (15.0 ft)	2A-G5/3 (17.0 ft)	2A-G5/4 (19.0 ft)		2A-G6/1 (13.0 ft)	2A-G6/2 (15.0 ft)	2A-G6/3 (17.0 ft)
1,1-Dichloroethane	540	5800	18000	7300		2700	4200	690
1,1-Dichloroethene	ND	910	7200 J	ND		220	1000	ND
Trichloroethene	ND	230	110000	240 J		120 J	190	ND
Chloroethane	ND	300 J	ND	ND		250 J	2800	ND
cis-1,2-Dichloroethene	ND	700	22000	160 J		83 J	4900	ND
trans-1,2-Dichloroethene	ND	ND	ND	ND		ND	110 J	ND
1,1,1-Trichloroethane	ND	340	200000	210 J		ND	ND	ND
Vinyl Chloride	ND	ND	ND	ND		ND	380	ND
TOTAL	540	8280	357200	7910		3373	13580	690

Sample Number And Depth (ft)	Soil Concentrations (ug/kg)							
	2A-G7/1 (13.0 ft)	2A-G7/2 (15.0 ft)	2A-G7/3 (17.0 ft)		2A-G8/1 (13.0 ft)	2A-G8/2 (15.0 ft)	2A-G8/3 (17.0 ft)	2A-G8/4 (19.0 ft)
1,1-Dichloroethane	180	ND	4200		170	10000	9500	1100
1,1-Dichloroethene	ND	ND	ND		ND	4800	ND	ND
Trichloroethene	ND	100 J	ND		ND	3400	ND	ND
Chloroethane	ND	2100	ND		ND	1300	ND	ND
cis-1,2-Dichloroethene	ND	990	3300		ND	2900	340	ND
trans-1,2-Dichlorethene	ND	90 J	380		ND	ND	ND	ND
1,1,1-Trichloroethane	ND	ND	ND		ND	15000	ND	ND
Vinyl Chloride	ND	540	1800		ND	720 J	1000	ND
TOTAL	180	3820	9680		170	38120	10840	1100

J = estimated value

Table 2.6: Phase II Geoprobe Groundwater Sample Results

Sample Number And Depth (ft)	Groundwater Concentrations (ug/l)							
	2A-G5/1 (13.0 ft)	2A-G5/2 (15.0 ft)	2A-G5/3 (17.0 ft)			2A-G6/1 (13.0 ft)	2A-G6/2 (15.0 ft)	2A-G6/3 (17.0 ft)
1,1-Dichloroethane	14000	65000	3700			23000	83000	380
1,1-Dichloroethene	780	24000	1500			1700	10000	12 J
Trichloroethene	340 J	71000	5500			ND	2200 J	49
Chloroethane	640 J	ND	ND			2100	18000	160
cis-1,2-Dichloroethene	680	63000	4400			630 J	99000	310
trans-1,2-Dichloroethene	ND	ND	240			ND	1500 J	ND
1,1,1-Trichloroethane	ND	270000	2000			ND	ND	100
Vinyl Chloride	ND	ND	910 J			2000	24000	20 J
Other 8260s			2440			ND	ND	278
TOTAL	16440	493000	20690			29430	237700	1309

Sample Number And Depth (ft)	Groundwater Concentrations (ug/l)							
	2A-G7/1 (13.0 ft)	2A-G7/2 (15.0 ft)	2A-G7/3 (17.0 ft)			2A-G8/1 (13.0 ft)	2A-G8/2 (15.0 ft)	2A-G8/3 (17.0 ft)
1,1-Dichloroethane	3200	ND	19000			3200	39000	8200
1,1-Dichloroethene	130	ND	ND			300	11000	ND
Trichloroethene	93 J	ND	ND			160	8900	ND
Chloroethane	380	33000	ND			2200	5100	ND
cis-1,2-Dichloroethene	75 J	24000	28000			67 J	9700	330
trans-1,2-Dichlorethene	ND	ND	ND			ND	ND	ND
1,1,1-Trichloroethane	ND	ND	ND			1300	49000	ND
Vinyl Chloride	400	60000	36000			570	4000	3300
TOTAL	4278	117000	83000			7797	126700	11830

J = estimated value

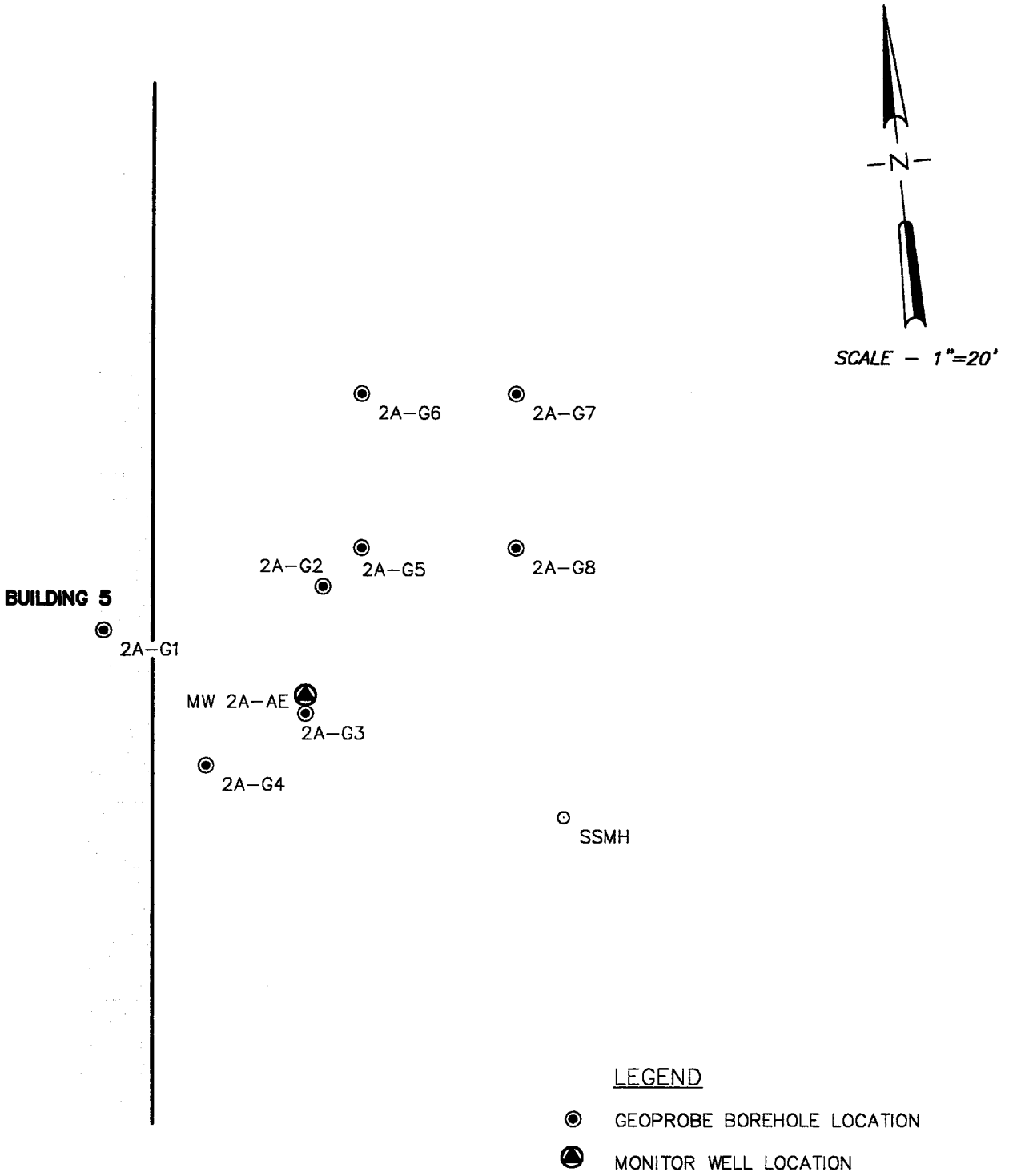
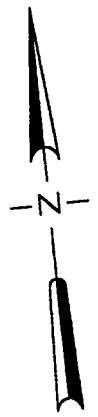


Figure Title: **LOCATION 2A-A BASE**	Project Title: **SITE INVESTIGATION**
SURBEC 3200 Marshall Ave., Ste. 200 Norman, OK 73072 405/364-9726 Fax 405/329-1602	Figure No.: **2.1** Project No.: **034-ALAM** Date: **6/9/99**



SCALE – 1"=20'

4B-CG2

4B-CG3

MW 4B-CN

4B-CG1

4B-CG6

4B-CG5

BUILDING 5

MW 4B-CS

4B-CG4

LEGEND

GEOPROBE BOREHOLE LOCATION

MONITOR WELL LOCATION

Figure Title: **LOCATION 4B-C BASE**	Project Title: **SITE INVESTIGATION**
SURBEC 3200 Marshall Ave., Ste. 200 Norman, OK 73072 405/364-9726 Fax 405/329-1602	Figure No.: **2.2** Project No.: **034-ALAM** Date: **6/9/99**

3.0 DEMONSTRATION WELL INSTALLATION

Upon completion of Phase II, Surbec selected the most suitable locations for the Treatability Study injection, recovery, and monitor wells (multi-level samplers). The locations of these wells is shown in Figure 3.1. During installation of the study wells, additional discrete soil and groundwater samples were collected to define the soil and groundwater quality in the study cell. The samples were also used to establish background soil and groundwater conditions prior to implementation of the surfactant flush. This section presents the results of the soil and groundwater sampling and presents isopleth maps to illustrate the soil and groundwater quality within the cell boundary.

3.1 Soil Sampling

Prior to installation of the Treatability Study wells, soil samples were collected from each of the ten well locations using a Geoprobe rig. Samples were collected from all of the boring locations at 15.0 and 17.0 foot depths, from several of the locations at the 16.0 foot depth, and from locations MLS-1 and MLS-2 at the 22.0 foot depth. Table 3.1 (p. 3-5) summarizes the soil sample results. Soil boring logs are in Appendix A.

The soil sample results indicate very high concentrations of VOCs in the samples IW-1 and 2 at 16.0 feet bgs, IW-2 and 3 at 17.0 feet bgs, FWI-1 and 2 at 17.0 feet bgs, MRW-1 and 2 at 17.0 feet bgs, MLS-1 and 2 at 16.0 feet bgs, and MLS-1 and 3 at 17.0 feet bgs. Total VOCs in these samples ranged from 1926.0 to 40,970.0 mg/kg. TCA concentrations ranged from 1700.0 to 32,000.0 mg/kg in these samples. TCE was also detected at high concentrations in these samples with a maximum concentration of 8300.0 mg/kg in MLS-1/3 at a depth of 17.0 feet bgs. Figures 3.2 and 3.3 show the concentration of TCA and TCE, and total VOCs concentrations in the soils in the cell.

During drilling of the soil borings, residual phase DNAPL was observed in soil samples obtained from an approximate depth of 17.0 feet bgs at locations IW-1, IW-2, MRW-1, FWI-1, and MLS-1. Strong organic vapor concentrations were measured in the soils at all locations. A map showing the location of the observed residual phase is shown in Figure 3.4.

Based upon these soil sample results and the results of the previous site investigation, it appears that the cell is overlying a source area. TCA and TCE concentrations decrease and completely diminish to the east, south, west, and north. The source of this contamination is unknown at this time.

3.2 Monitor Well Installation

The Treatability Study wells consist of 2 injection, 2 fresh water injection, 4 recovery, and 4 monitor/recovery wells, and 2 multi-level samplers (Figure 3.5). The injection and monitor/recovery wells were four inches in diameter. The screen was 4 feet long and 0.02 inch slot set from 13.5 to 17.5 feet bgs. The sand pack extended from 12.0 to 18.0 feet bgs. A bentonite hole plug was placed from 5.0 to 12.0 feet bgs and the remainder from 2.0 to 5.0 feet bgs was filled with a cement-bentonite (neat cement) grout. A twelve inch flush mount surface

protector was set in place with concrete. Four recovery wells will be installed on June 22, 1999 following the above specifications.

The multi-level samplers comprise a nest of four 1-inch piezometer/monitor wells. The four wells are screened at 21.75 to 22.0, 16.25 to 16.5, 14.75 to 15.0, and 12.75 to 13.0 feet bgs. The discrete sampling points allow assessment of the groundwater quality at discrete depths and zones in the cell. The lower sampling point is separated from the upper sand aquifer with a bentonite hole plug from 16.8 to 21.5 feet bgs. The main purpose of this hole plug was to prevent communication between the upper sand aquifer and the Bay Mud sand lenses. The uppermost three depths correspond to the bottom of the sand aquifer, where the focus of the study is on cleanup. The bottom depth is at the base of a clayey sand unit in the Bay Mud which will allow monitoring of contaminants in the Bay Mud. The well completion diagrams are in Appendix A.

3.3 Groundwater Samples

Groundwater samples were collected from the 4 injection, 4 recovery, and 2 multi-level sampler clusters. The samples were analyzed by EPA method 8260 for volatile organics. The results of the groundwater sampling are summarized in Table 3.2 (p. 3-7).

In all of the demonstration wells, the groundwater sample results indicate a very high concentrations of VOCs, in particular TCA. Total VOCs ranged from 220.2 to 449.3 mg/l in the wells. TCA ranged from 49.0 to 210.0 mg/l in the wells. All Demonstration wells are screened from 13.5 to 17.5 feet bgs. The total VOCs concentrations in the multi-level samplers ranged from 273.4 to 983.0 mg/l in the treatment zone (above the Bay Mud, 17.0 feet bgs). The TCA concentrations ranged from 150.0 to 580.0 mg/l in this zone. Total VOCs decreased significantly at a depth of 22.0 feet in the upper clayey sand unit of the Bay Mud. Figures 3.5, and 3.6 show the concentration of TCA and TCE, and total VOCs concentrations in the groundwater in the cell.

3.4 Aquifer Testing

Surbec conducted a step-drawdown pump test at IW-1 from May 24 to 25, 1999. During the pump test the drawdown in IW-2, MRW-2, MRW-3, FWI-2, and MW-2A-AE was also monitored. Transducers were placed in IW-2, MRW-2, MRW-3, FWI-2, and MW-2A-AE to measure the drawdown in each well during the pumping in well IW-1. The pumping rate was increased as the test proceeded to obtain step drawdown data.

A Pre-test was conducted on May 24 over a four hour period to determine the maximum sustained yield for IW-1. The step-drawdown rates were then determined to step up to the final sustained yield. Upon completion of the pumping, a final recovery stage was recorded. The three test steps and recovery stage were all evaluated.

The purpose of the pump test was to determine the hydraulic conductivity (K) and radius of influence (drawdown) at the site. This data was used in the modeling of the site groundwater

flow to determine the optimal locations of the system surfactant injection, fresh water injection, recovery, and monitor well pumping rates.

The pump test was analyzed using the Aquifer Parameters Estimator (APE) program designed by Dr. Michael Kasenow and Mr. Paul Pare. The assumed thickness of the aquifer for calculation purposes was 10 feet. The hydraulic conductivity was calculated for each of three steps of the test and recovery stage. The second step calculations were significantly higher than the first and third steps. The shape of the drawdown curve in the second step was anomalous with an increase in head during the run. As a result, this calculated hydraulic conductivity (5.08 ft/d) may also be anomalous. The hydraulic conductivity ranged from 8.14 feet/day to 20.48 feet/day. The steady state radius of influence for a flow rate of 1.82 to 2.93 gpm was calculated to be 18.51 to 58.45 feet. The transient limit of the cone of depression for flow rates of 1.82 to 2.93 gpm ranged from 35.59 to 88.21 feet. A summary of the program data output for the three steps follows.

STEP 1

Input Parameters
Q = pumping rate = 1.82 gpm
Aquifer Thickness = 10.0 feet
r = observation well distance = 1.0 feet
t = time duration of pump test = 80 minutes

Output Parameters
K = hydraulic conductivity = 8.14 feet/day, 60.77 gpd/sq. ft.
T = transmissivity = 81.44 sq. feet/day, 607.74 gpd/ft
S = storativity = 0.00004558
r(o) = limit of cone of depression at steady state = 42.85 feet
r(L) = transient limit of cone of depression = 88.21 feet

STEP 2

Input Parameters
Q = pumping rate = 2.36 gpm
Aquifer Thickness = 10.0 feet
r = observation well distance = 1.0 feet
t = time duration of pump test = 80 minutes

Output Parameters
K = hydraulic conductivity = 64.26 feet/day, 479.58 gpd/sq. ft.
T = transmissivity = 1028.22 sq. feet/day, 7673.29 gpd/ft
S = storativity = 0.03743953
r(o) = limit of cone of depression at steady state = 58.45 feet
r(L) = transient limit of cone of depression = 71.97 feet

STEP 3

Input Parameters
Q = pumping rate = 2.93 gpm
Aquifer Thickness = 10.0 feet

r = observation well distance = 1.0 feet
t = time duration of pump test = 100 minutes

Output Parameters
K = hydraulic conductivity = 20.03 feet/day, 149.47 gpd/sq. ft.
T = transmissivity = 200.29 sq. feet/day, 1494.72 gpd/ft
S = storativity = 0.09090034
r(o) = limit of cone of depression at steady state = 18.51 feet
r(L) = transient limit of cone of depression = 35.59 feet

Recovery Stage

Input Parameters
Q = pumping rate = gpm
Aquifer Thickness = 10.0 feet
r = observation well distance = 1.0 feet
t = time duration of pump test = 500 minutes

Output Parameters
K = hydraulic conductivity = 20.48 feet/day, 152.84 gpd/sq. ft.
T = transmissivity = 204.80 sq. feet/day, 1528.38 gpd/ft
S = storativity = 0.00391532
r(o) = limit of cone of depression at steady state = 220.90 feet
r(L) = transient limit of cone of depression =427.09 feet

Table 3.1: Monitor Well Installation Geoprobe Soil Sample Results

Sample Number And Depth (ft)	Soil Concentrations (ug/kg)										
	IW-1/1 (15.0 ft)	IW-1/2 (16.0 ft)	IW-1/3 (17.0 ft)		IW-2/1 (15.0 ft)	IW-2/2 (16.0 ft)	IW-2/3 (17.0 ft)		FWI-1/1 (15.0 ft)	FWI-1/2 (17.0 ft)	
Contaminant											
1,1-Dichloroethane (DCA)	14000	ND	15000		18000	17000	120000 J		12000	330000 J	
1,1-Dichloroethene (DCE)	3500	38000 J	5300		5700	5700	ND		2800	ND	
1,1,1-Trichloroethane (TCA)	20000	1700000	63000		31000	36000	5800000		15000	9300000	
Trichloroethene (TCE)	2600	190000	66000		7000	8000	3500000		3300	17000000	
Chloroethane	1200 J	ND	ND		ND	ND	ND		2100	ND	
Vinyl Chloride	ND	ND	4000 J		ND	ND	ND		ND	ND	
Tetrachloroethene (PCE)	ND	ND	ND		ND	ND	ND		ND	330000 J	
cis-1,2-Dichloroethene	4700	34000 J	28000		8500	9000	170000 J		2400	1600000	
TOTAL	46000	1962000	181300		70200	75700	9590000		37600	28560000	

J = estimated value

Sample Number And Depth (ft)	Soil Concentrations (ug/kg)										
	FWI-2/1 (15.0 ft)	FWI-2/2 (17.0 ft)		MRW-1/1 (15.0 ft)	MRW-1/2 (17.0 ft)		MRW-2/1 (15.0 ft)	MRW-2/2 (16.0 ft)	MRW-2/3 (17.0 ft)		
Contaminant											
1,1-Dichloroethane (DCA)	19000	10000		4600	ND		19000	19000	25000		
1,1-Dichloroethene (DCE)	5400	ND		1100	ND		3800	3400	7600		
1,1,1-Trichloroethane (TCA)	12000	41000		2100	32000000		5400	5100	42000		
Trichloroethene (TCE)	9100	160000		820	5400000		3000	3000	23000		
Chloroethane	1300 J	ND		4600	ND		1200 J	1200 J	ND		
Vinyl Chloride	1300 J	9400 J		580	ND		730 J	ND	5800		
Tetrachloroethene (PCE)	ND	ND		ND	ND		ND	ND	ND		
cis-1,2-Dichloroethene	14000	76000		3100	1100000 J		8400	8500	42000		
TOTAL	62100	296400		16900	38500000		41530	40200	145400		

J = estimated value

TABLE 3.1: Cont.'d

Sample Number And Depth (ft)	Soil Concentrations (ug/kg)										
	MRW-3/1 (15.0 ft)	MRW-3/2 (17.0 ft)		MRW-4/1 (15.0 ft)	MRW-4/2 (17.0 ft)		MLS-1/1 (15.0 ft)	MLS-1/2 (16.0 ft)	MLS-1/3 (17.0 ft)	MLS-1/4 (22.0 ft)	
Contaminant											
1,1-Dichloroethane (DCA)	10000	19000		9000	16000		7500	90000 J	ND	190	
1,1-Dichloroethene (DCE)	6800	5600		6100	1900		2100	ND	ND	ND	
1,1,1-Trichloroethane (TCA)	54000	36000		30000	4900		8200	3100000	32000000	560	
Trichloroethene (TCE)	5500	58000		19000	29000		2900	770000	8300000	ND	
Chloroethane	ND	ND		ND	ND		3600	ND	ND	ND	
Vinyl Chloride	ND	5800 J		ND	3400		430 J	ND	ND	ND	
Tetrachloroethene (PCE)	ND	ND		ND	ND		ND	ND	ND	ND	
cis-1,2-Dichloroethene	4400	44000		7200	15000		4700	ND	670000 J	ND	
TOTAL	80700	168400		71300	70200		29430	3960000	40970000	750	

J = estimated value

Sample Number And Depth (ft)	Soil Concentrations (ug/kg)										
	MLS-2/1 (15.0 ft)	MLS-2/2 (16.0 ft)	MLS-2/3 (17.0 ft)	MLS-2/4 (22.0 ft)							
Contaminant											
1,1-Dichloroethane (DCA)	11000	22000 J	21000	130 J							
1,1-Dichloroethene (DCE)	5500	25000 J	8800	ND							
1,1,1-Trichloroethane (TCA)	39000	270000	210000	630							
Trichloroethene (TCE)	6300	130000	180000	160							
Chloroethane	ND	ND	ND	ND							
Vinyl Chloride	ND	ND	ND	ND							
Tetrachloroethene (PCE)	ND	ND	ND	ND							
cis-1,2-Dichloroethene	4500	20000 J	27000	ND							
TOTAL	66300	467000	446800	920							

J = estimated value

Table 3.2: Monitor Well Installation Groundwater Sample Results

Sample Number And Depth (ft)	Groundwater Concentrations (ug/l)								
	IW-1 13.5 to 17.5 ft	IW-2 13.5 to 17.5 ft	FWI-1 13.5 to 17.5 ft	FWI-2 13.5 to 17.5 ft	MRW-1 13.5 to 17.5 ft	MRW-2 13.5 to 17.5 ft	MRW-3 13.5 to 17.5 ft	MRW-4 13.5 to 17.5 ft	MW 2A-AE 6.0 to 16.0 ft
Contaminant									
1,1-Dichloroethane (DCA)	67000	110000	49000	90000	46000	82000	38000	46000	25000
1,1-Dichloroethene (DCE)	24000	38000	13000	24000	13000	15000	20000	24000	2800
1,1,1-Trichloroethane (TCA)	210000	180000	91000	65000	120000	49000	190000	110000	5000
Trichloroethene (TCE)	37000	58000	54000	45000	37000	18000	35000	47000	2100
Chloroethane	8700 J	5300 J	15000	7400	35000	8200	ND	9000 J	12000
Vinyl Chloride	ND	11000	8400	18000	19000	11000	5400 J	7500 J	4200
trans-1,2-Dichloroethene	ND	ND	ND	1400 J	ND	ND	ND	ND	ND
cis-1,2-Dichloroethene	37000	47000	28000	66000	45000	37000	14000	18000	2600
TOTAL	383700	449300	258400	316800	315000	220200	302400	261500	53700

J = estimated value

Sample Number And Depth (ft)	Groundwater Concentrations (ug/l)							
	MLS-1A 12.75 to13.0 ft	MLS-1B 14.75 to 15.0 ft	MLS-1C 16.25 to 16.5 ft	MLS-1D 21.75 to 22.0 ft	MLS-2A 12.75 to 13.0 ft	MLS-2B 14.75 to 15.0 ft	MLS-2C 16.25 to 16.5 ft	MLS-2D 21.75 to 22.0 ft
Contaminant								
1,1-Dichloroethane (DCA)	48000	82000	86000	2200	38000	86000	79000	9600
1,1-Dichloroethene (DCE)	20000 J	33000	37000	480	14000	46000	45000	3900 J
1,1,1-Trichloroethane (TCA)	480000	370000	580000	12000	150000	400000	440000	190000
Trichloroethene (TCE)	120000	88000	150000	3500	54000	120000	120000	68000
Chloroethane	47000	40000	30000 J	1000	5400 J	ND	ND	ND
Vinyl Chloride	ND	18000 J	ND	ND	ND	ND	ND	ND
trans-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND
cis-1,2-Dichloroethene	43000	80000	100000	1200	12000	39000	39000	5500
TOTAL	758000	711000	983000	20380	273400	691000	723000	277000

J = estimated value

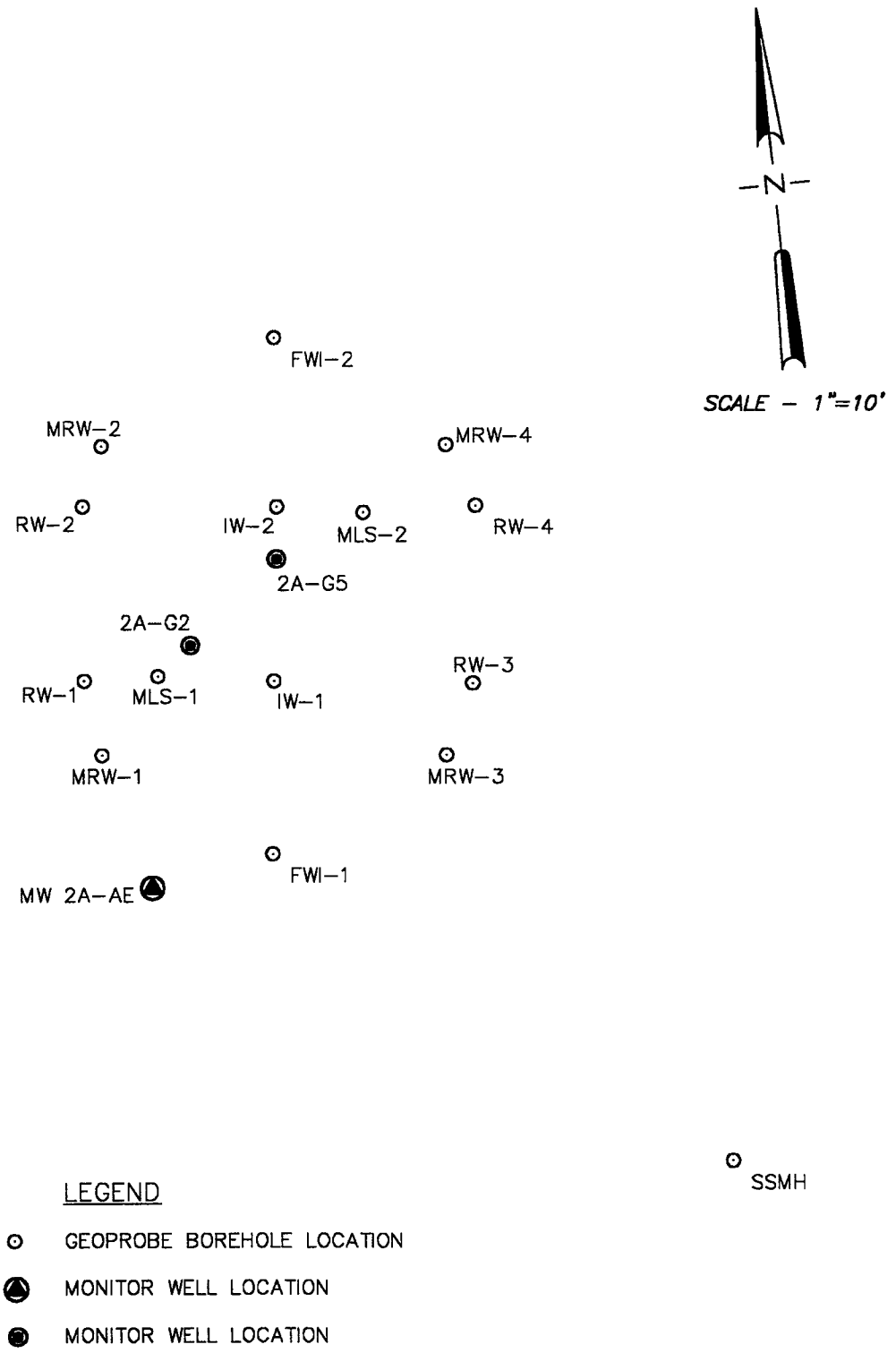


Figure Title: **TREATIBILITY STUDY WELLS**	*Project Title:* **DNAPL REMOVAL TREATIBILITY STUDY**

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Figure No.:	**3.1**
Project No.:	**034–ALAM**
Date:	**6/24/99**

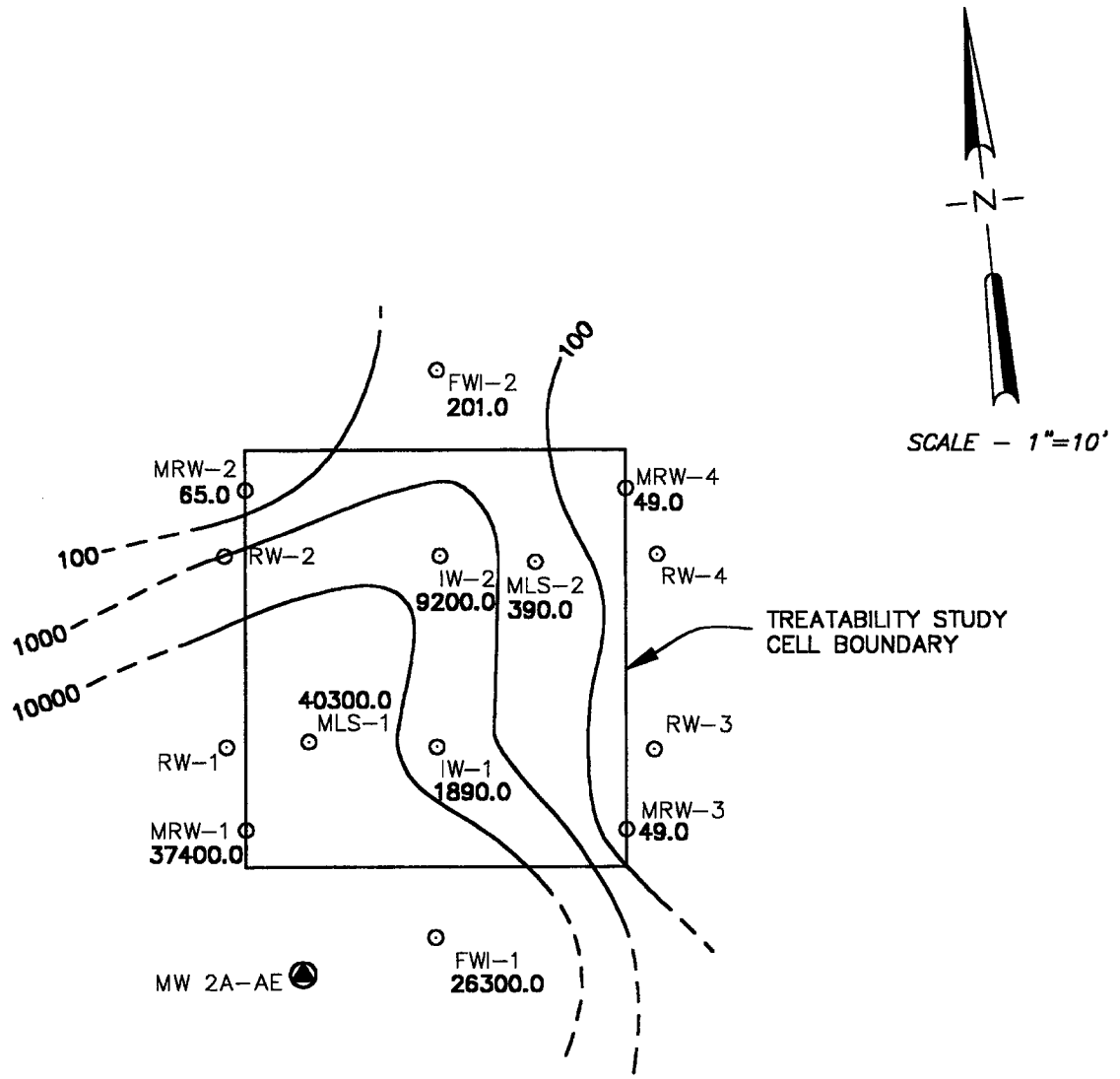

Figure Title: **TCA/TCE SOIL CONCENTRATION MAP**	*Project Title:* **DNAPL REMOVAL TREATIBILITY STUDY**

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Figure No.: **3.2**

Project No.: **034–ALAM**

Date: **6/9/99**

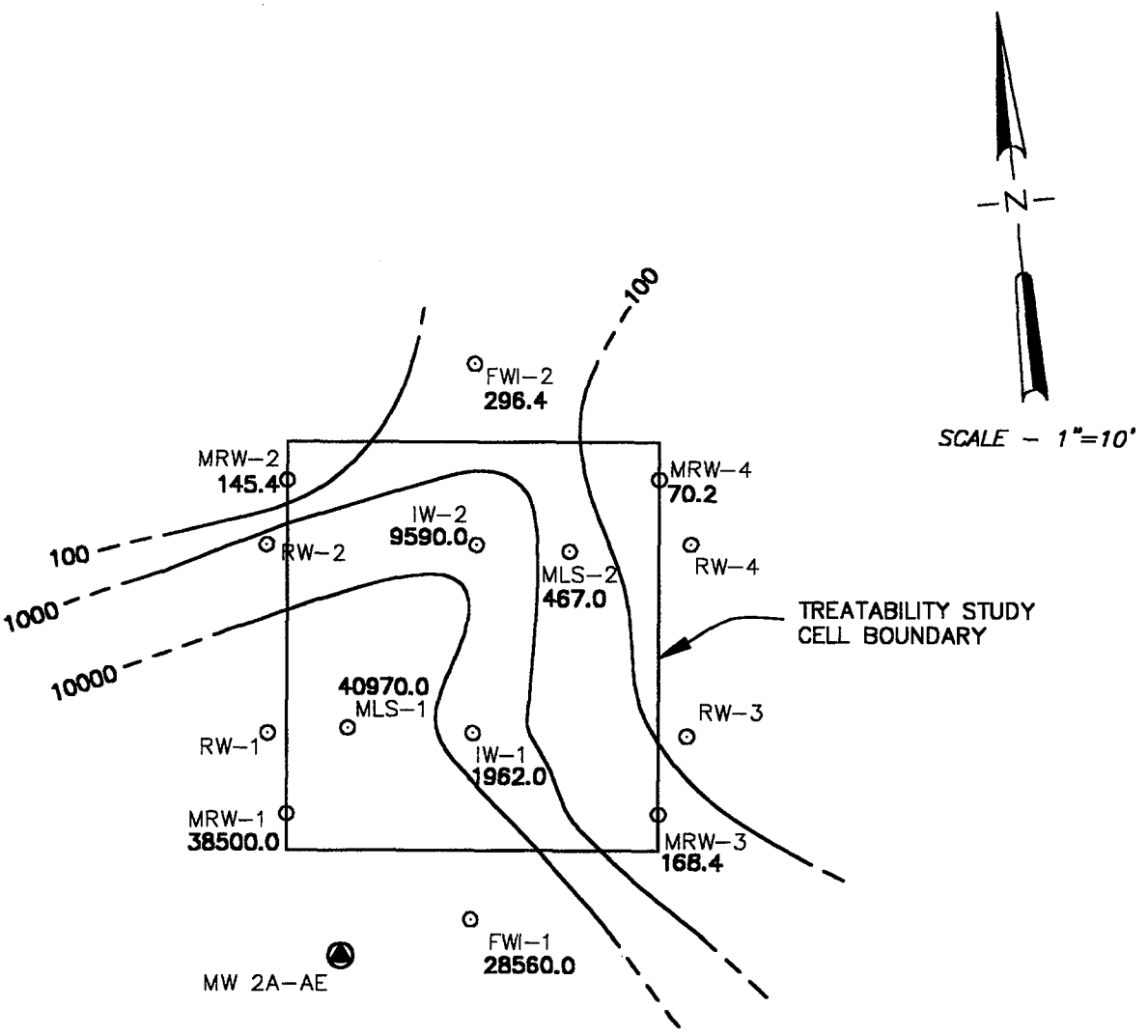

Figure Title: **VOC SOIL CONCENTRATION MAP**	*Project Title:* **DNAPL REMOVAL TREATIBILITY STUDY**

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Figure No.:	**3.3**
Project No.:	**034–ALAM**
Date:	**6/9/99**

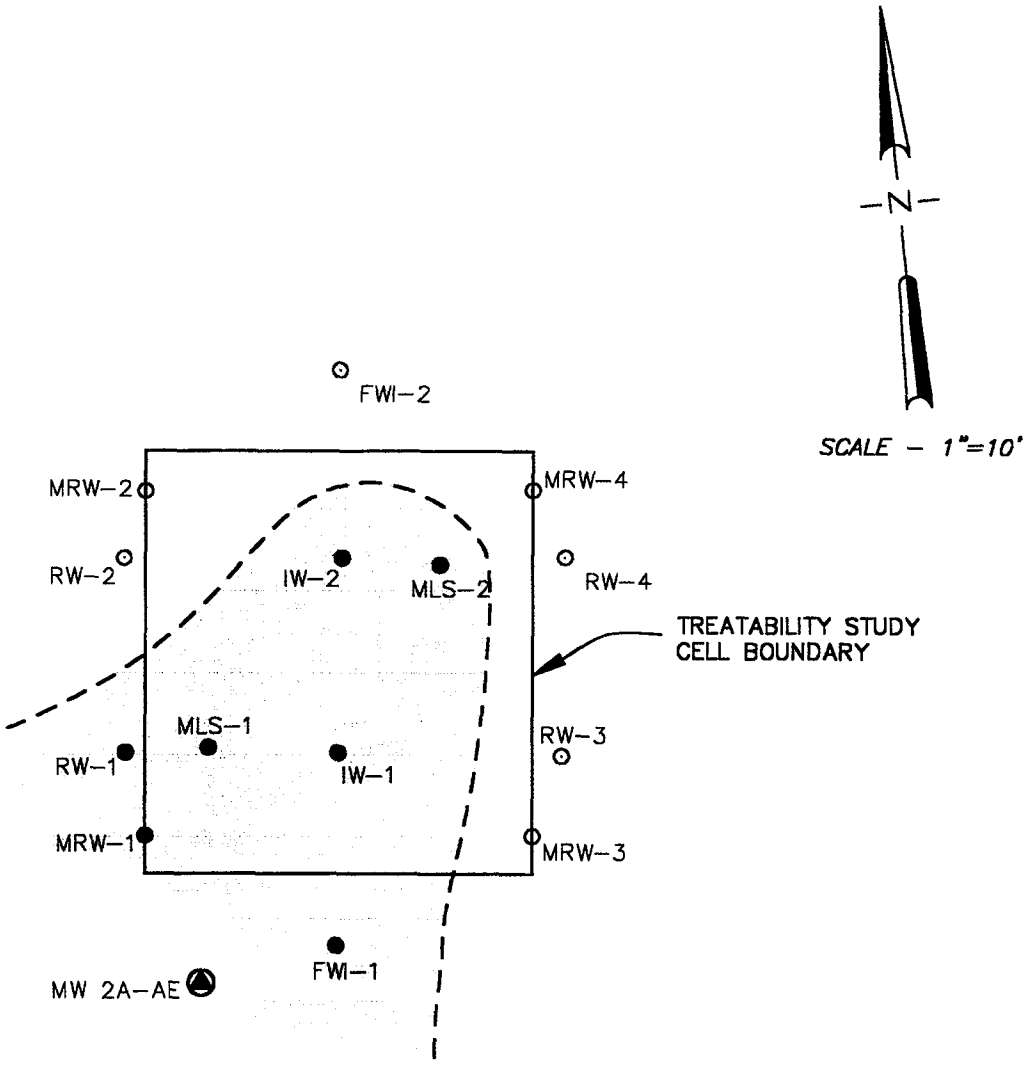

Figure Title: **STUDY WELLS DNAPL MAP**	Project Title: **DNAPL REMOVAL TREATIBILITY STUDY**

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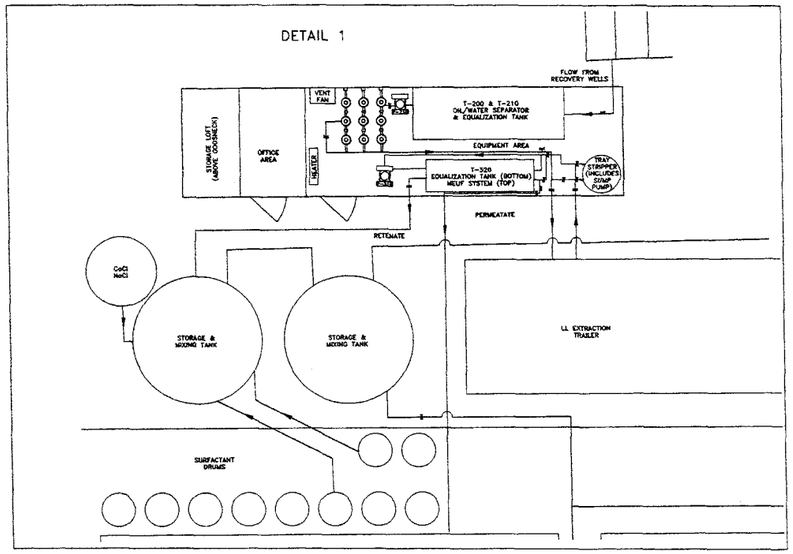
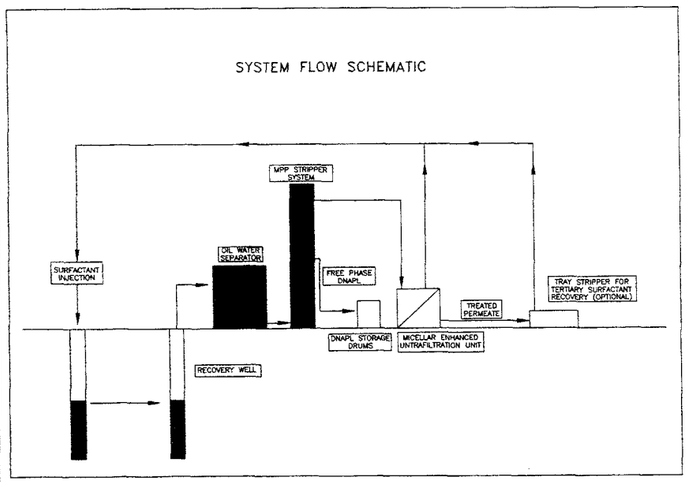
Figure No.:	3.4
Project No.:	034-ALAM
Date:	6/9/99

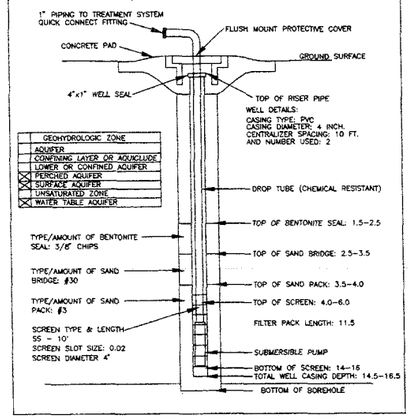
DETAIL 1



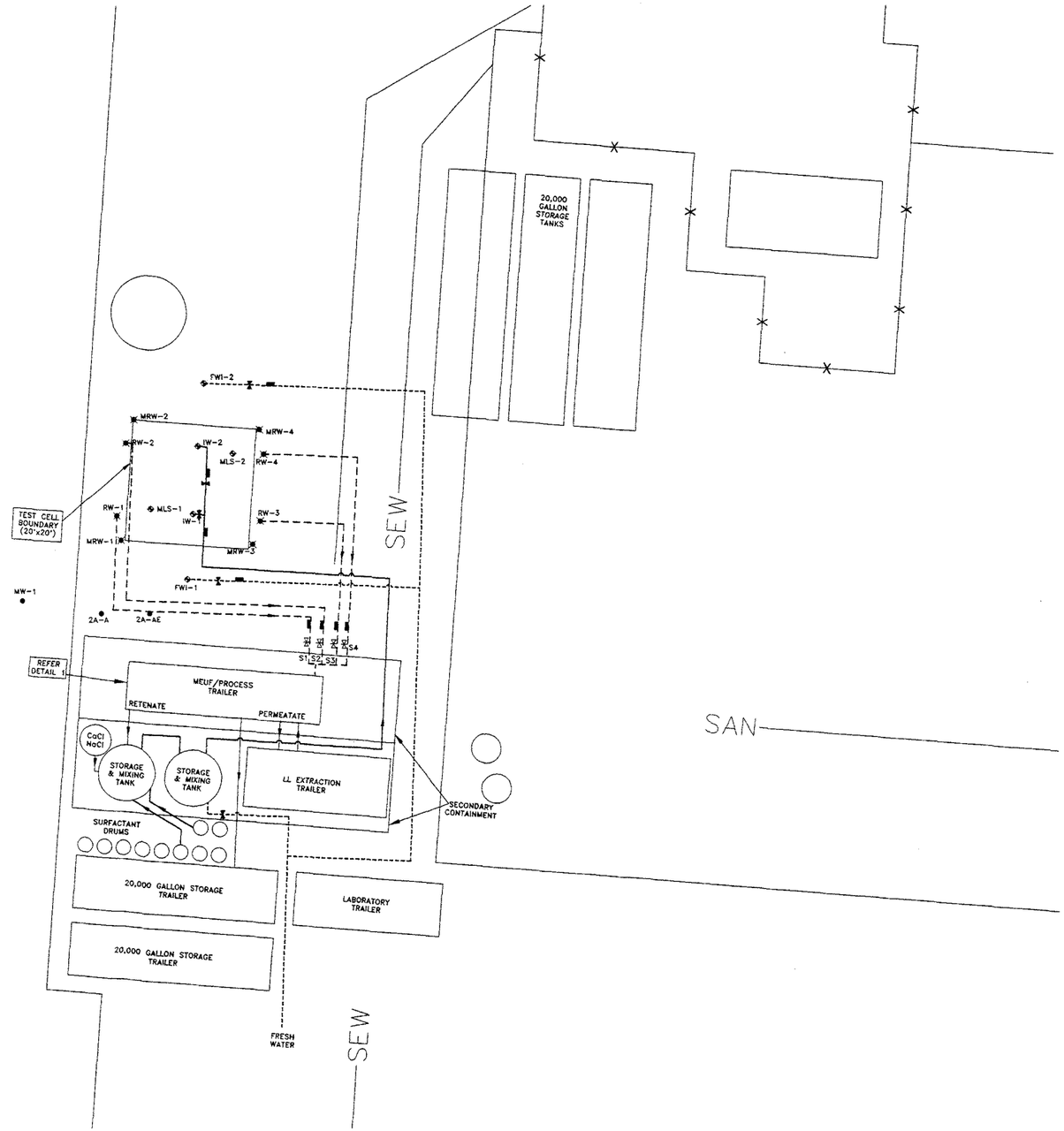
SYSTEM FLOW SCHEMATIC



DETAIL 2
INJECTION/RECOVERY WELL (RW-IW)



BUILDING 5



UTILITY REQUIREMENTS

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

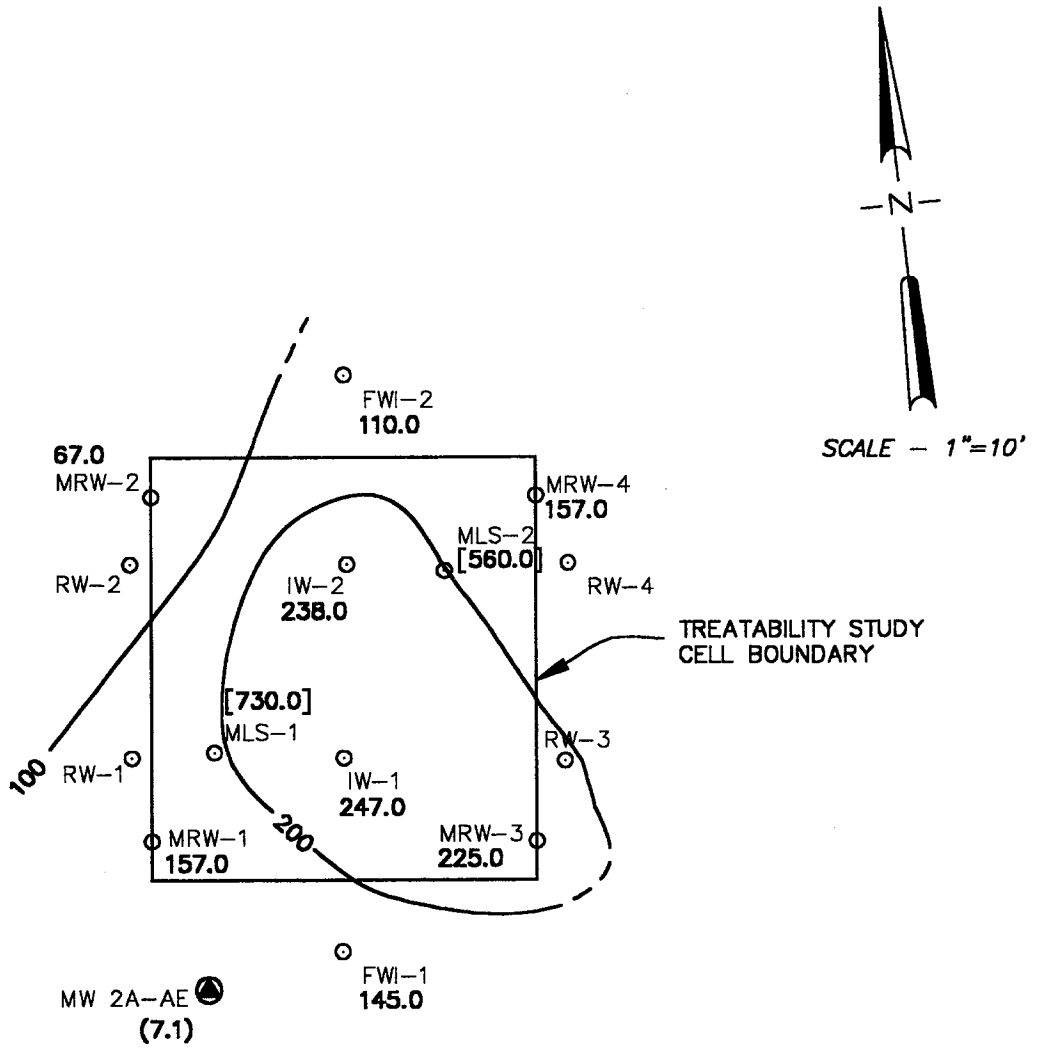
RECOVERY PUMPS 4 – 1/3 HP SINGLE PHASE SUBMERSIBLES OR VACUUM ENHANCED EXTRACTION (GROUDFOS SS OR EQUIVALENT)
PUMP 1-4 – 4-2 HP, 3 PHASE, 460 VOLT, CENTRIFUGAL PUMPS
PUMP 5A – 2 HP, 3 PHASE, 460 VOLT CENTRIFUGAL PUMPS
PUMP 5B – 3 HP, 3 PHASE, 460 VOLT CENTRIFUGAL PUMPS
PUMP 6, 7 – 2-1.5 HP, 3 PHASE, 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'

LEGEND
- SOIL BORING LOCATION
- PROPOSED INJECTION WELL
- PROPOSED RECOVERY WELL
- 1" BALL VALVE (AUTOMATED)
- SAMPLING PORT (MANUAL)
- FLOW METER
- PRESSURE GAUGE
- PROCESS LINES
- RECOVER WELL LINES
- FRESH WATER LINES

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: 6/99 DESIGNED: CHECKED: APPROVED: DRAWN: COG PAGE:
SESR DRAWING DIAGRAM	
SURBEC ENVIRONMENTAL, LLC Norman, Oklahoma	Figure 3.5



BUILDING 5

LEGEND

DASHED LINES INDICATE PLUME NOT FULLY DELINEATED

MRW–4 157.0 — TREATABILITY STUDY WELL AND GROUNDWATER TCA/TCE CONCENTRATION (mg/kg)

MONITOR WELL LOCATION

SSMH

—100— TCA/TCE GROUNDWATER CONCENTRATION CONTOUR (mg/l) – 13.5 TO 17.5 ft.

MW 2A–AE (7.1) — TCA/TCE GROUNDWATER CONCENTRATION (mg/l) – 6.0 TO 16.0 ft.

[730.0] MLS–1 — TCA/TCE GROUNDWATER CONCENTRATION (mg/l) – 16.25 TO 16.5 ft.

Figure Title: **TCA/TCE GROUNDWATER CONCENTRATION MAP**	Project Title: **DNAPL REMOVAL TREATIBILITY STUDY**

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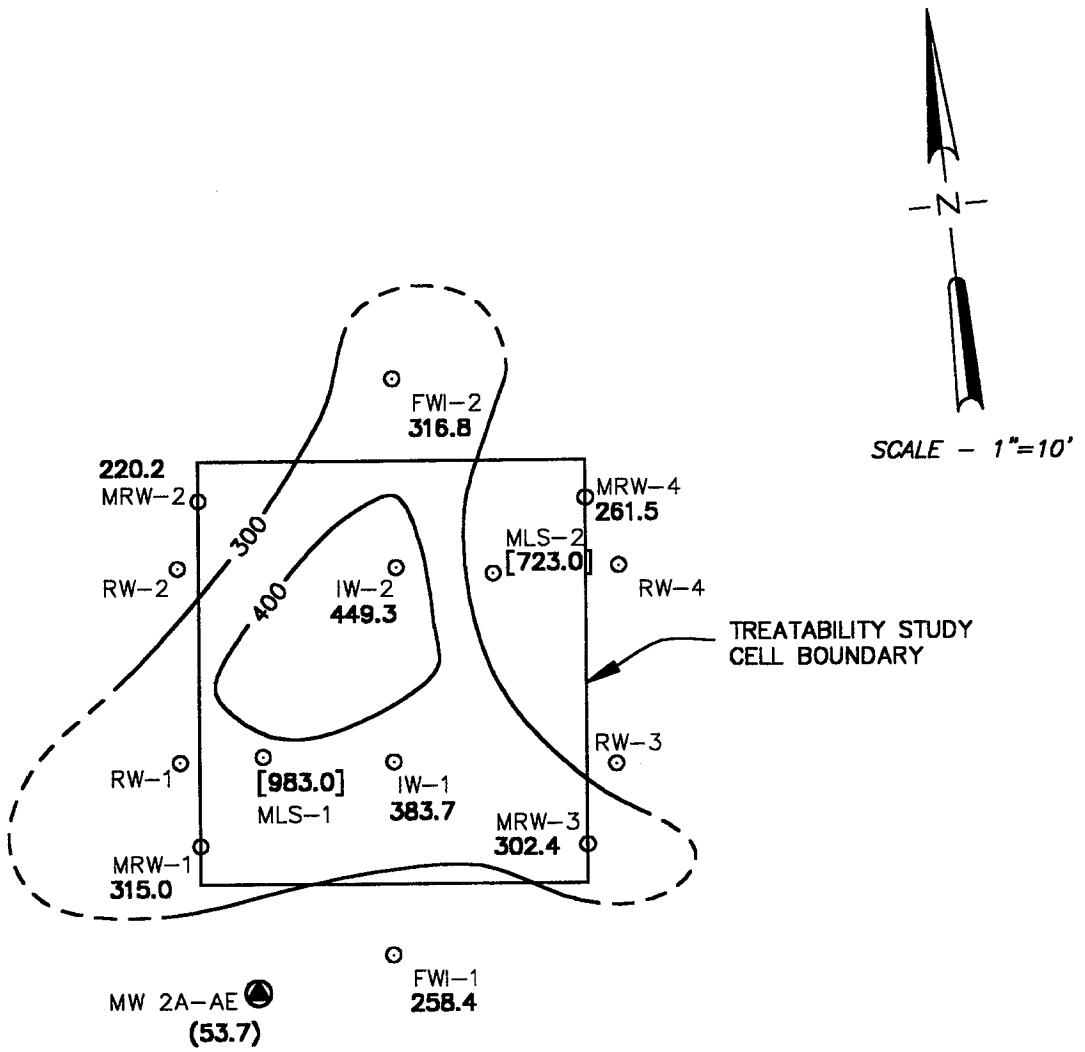
Figure No.:	3.6
Project No.:	034–ALAM
Date:	6/9/99



BUILDING 5

LEGEND

DASHED LINES INDICATE PLUME NOT FULLY DELINEATED

MRW-4 261.5 — TREATABILITY STUDY WELL AND GROUNDWATER VOC CONCENTRATION (mg/kg)

MONITOR WELL LOCATION

SSMH

—300— VOC GROUNDWATER CONCENTRATION CONTOUR (mg/l) – 13.5 TO 17.5 ft.

MW 2A-AE (53.7) — VOC GROUNDWATER CONCENTRATION (mg/l) – 6.0 TO 16.0 ft.

[983.0] MLS-1 — VOC GROUNDWATER CONCENTRATION (mg/l) – 16.25 TO 16.5 ft.

Figure Title: **VOC GROUNDWATER CONCENTRATION MAP**	*Project Title:* **DNAPL REMOVAL TREATIBILITY STUDY**

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Figure No.:	**3.7**
Project No.:	**034-ALAM**
Date:	**6/9/99**

4.0 GROUNDWATER MODELING AND WELL PLACEMENT DESIGN

4.1 Groundwater Modeling

Modflow and MT3D96 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.

In order to design an effective injection-extraction system, the site geology and hydrogeology must first be understood. As a result, Surbec has thoroughly reviewed site investigation reports as documented in Sections 2.0 and 3.0. Hydrogeological information, such as hydraulic conductivity, porosity, bulk density, and storage coefficient, were input into the numerical groundwater model to simulate aquifer conditions (refer to Appendix C for results). Various injection/extraction well scenarios were evaluated. Based on the MODFLOW results, a parallel flow injection/extraction configuration (line drive) with hydraulic control wells was selected for implementation at the site.

4.2 Model Setup and Calibration

To achieve the design goals, simplifying assumptions were made (e.g., homogeneity within a geological layer and uniform depths to each layer). The development of the model cross-section (Figure 4.1) is based on data from the site investigations. The key to the development of a realistic representation of the site is assigning appropriate conductivity distributions for the different hydrogeological layers. Data from boring logs, sieve analyses, and pump tests have led to the generation of a simple model that is separated into two distinct hydrogeological units. Hydraulic conductivity assigned to each hydrogeologic unit is included in Figure 4.1. The model was set-up using a 200' x 200' overall area with refined grid resolution in the area of interest (refer to Figure 4.2).

The calibration of the model was conducted to ensure that the simulated aquifer response to the pumping scenario simulates real world conditions. The lithology of the aquifer was developed using soil boring logging information, which resulted in the cross-section in Figure 4.1. A hydraulic conductivity was assigned to each layer as a result of core sample analysis and pump test results. The model was determined to be calibrated using the hydraulic conductivites illustrated in Figure 4.1 and Appendix C.

The overall Model input parameters are included in Table 4.1 (p. 4-4). Various well configurations were simulated to determine sweep efficiency and recovery of injected materials. The MT3D module was used to predict surfactant flow in the aquifer and to refine the Partitioning Interwell Tracer Test (PITTs). For additional details on model input parameters refer to Appendix C.

4.3 Well Location Scenario and Design

As mentioned, several well configurations, including vertical circulation wells and five spot well placements, have been evaluated. However, the line drive well is selected for this application due to its efficient flushing pattern. This configuration maximizes sweep efficiency, minimizes dilution of recovered fluids, and maximizes capture of injected fluids. A diagram of the labeled wells for Alameda Point is included in Figure 4.3. In this configuration, injection wells IW-1 and IW-2 are the surfactant injection wells, FWI-1 and FWI-2 are hydraulic control wells, and RW-1 through RW-4 are recovery wells. The wells were simulated to be screened from -14 feet to -18 feet bgs. Several pumping scenarios were evaluated to determine the maximum sweep efficiency and hydraulic control with minimal groundwater production. It appears that the model run presented in Appendix C best meets these criteria. In this scenario the pumping rate for all injection and recovery wells is 2 gpm. This results in a pumping scheme that ensures hydraulic control, maximizes the solubilization potential of the surfactant and sweeps the entire test cell. The total extraction rate of groundwater is 8 gpm. Based on this analysis, it will require approximately 1 day to flush 1 pore volume (PV) of surfactant.

4.4 Surfactant Fate and Transport

All of the chemicals proposed for use at the site are nontoxic and non-hazardous (Aerosol AMA and Dowfax). One has grade additive status (AMA) from the Food and Drug Administration and the other (Dowfax) has food contact grade status. 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 a food source for the microbial community. This might accelerate the biodegradation of contaminants at the site. Since an enhanced solubilization system is proposed, the calcium or sodium and chlorides in solution will increase the total dissolved solids at the site during flushing activities.

The surfactant transport has been simulated in the model by incorporating advection, dispersion, sorption and sometimes biodegradation mechanisms. Advection is the primary driving force for plume migration and has been incorporated based on pumping induced gradients and the natural gradient. Dispersion has been assumed based on the lithology encountered for the most permeable zone. This assumption results in the least dispersion and least potential dilution. Sorption has been simulated using linear sorption constants that represent surfactants evaluated in this study. Biodegradation has been incorporated into the model using a first order constant calculated from data provided by the surfactant manufacturers. The flushing model incorporates five PV surfactant flushing followed by five PV of fresh water flushing subsequent to the surfactant flush. This will ensure that steady state has been reached and simulates the proposed implementation plan. Based on our analysis, over 98% of the surfactant will be recovered during the first eight PV of surfactant and water flooding.

The MODFLOW/ MT3D simulation ran for 365 days after cessation of flooding activities to illustrate surfactant fate and transport. The center of mass of the remaining surfactant plume migrated approximately 20 feet in the upper layer (refer to Appendix C). The remaining surfactant plumes are very limited in size with surfactant concentrations less than a few hundred

parts per million. An additional two days of pumping fresh water from the recovery wells will aid in the recovery of the remaining surfactant.

4.5 Summary of Results

The injection/recovery wells scenario illustrated in Figure 4.3 has been evaluated for the implementation of this technology at Alameda Point. The modeling results indicated that this scenario showed effective sweep efficiency coupled with a high degree of surfactant captures. Any surfactant left behind due to sorption will be limited to two small plumes with low concentrations. It should also be noted that the selected surfactants are all biodegradable and can degrade rapidly under the proper conditions.

Table 4.1: Visual Modflow Input Parameters for Alameda Point

Layer		1	2
Conductivity (ft/day)	Kx	10	.001
	Ky	10	.001
	Kz	1	.0001
Storage Coefficient, Ss (1/ft)		0.0001	0.02
Specific Yield (Sy) (-)		0.15	0.15
Porosity %	Total	35	35
	Effective	30	5
Longitudinal Dispersion Coefficient		0.5	0.5
Horizontal Dispersivity Ratio		0.3	0.3
Vertical Transverse Dispersivity Ratio		0.1	0.1
Sorption, Kd (ft^3/Kg)		0.0015	0.0015
Bulk Density (lb/ft^3)		48.1	48.1

Figure 4.1: Groundwater Model Cross-section

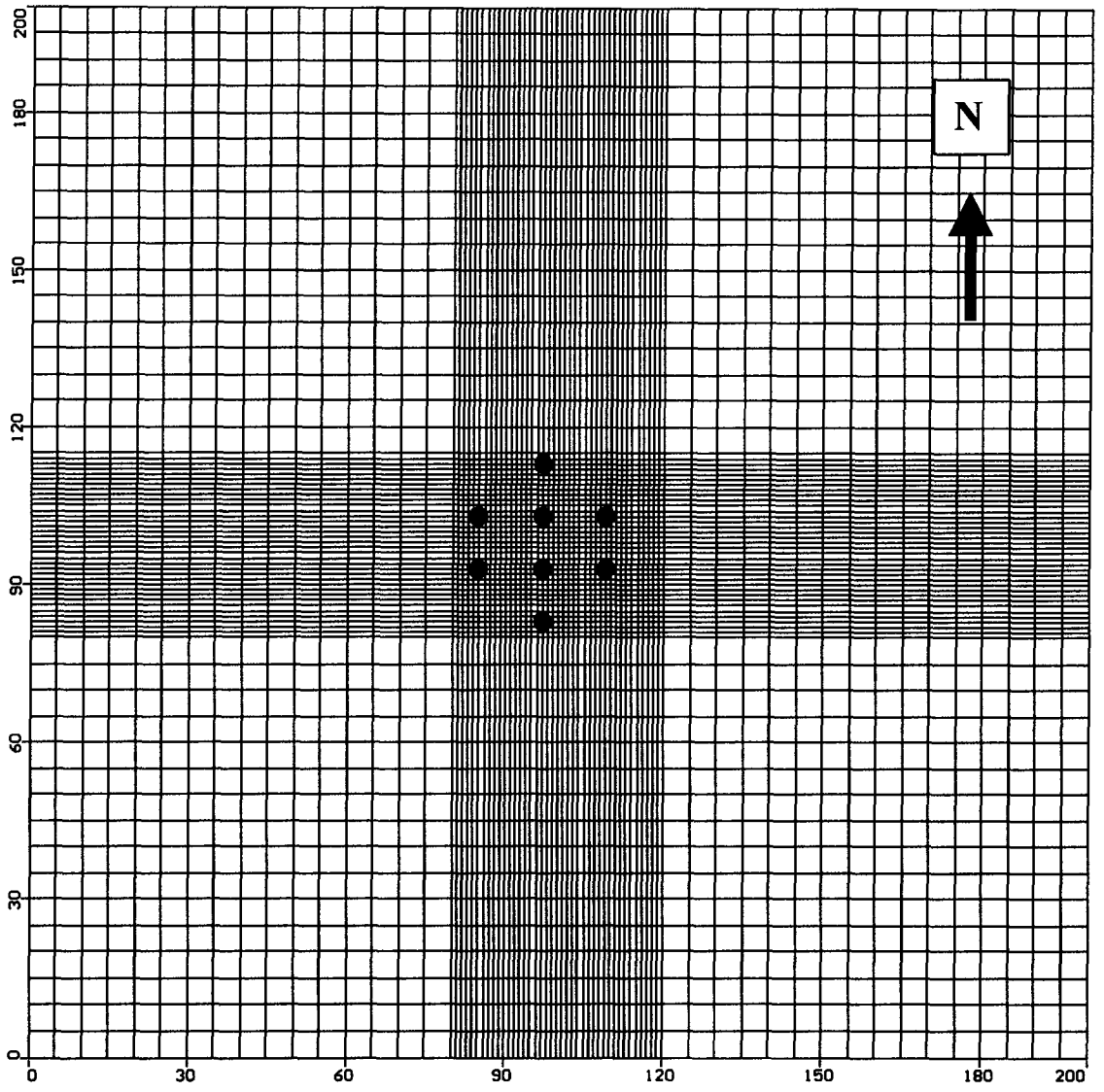

Figure 4.2: Groundwater Model Grid

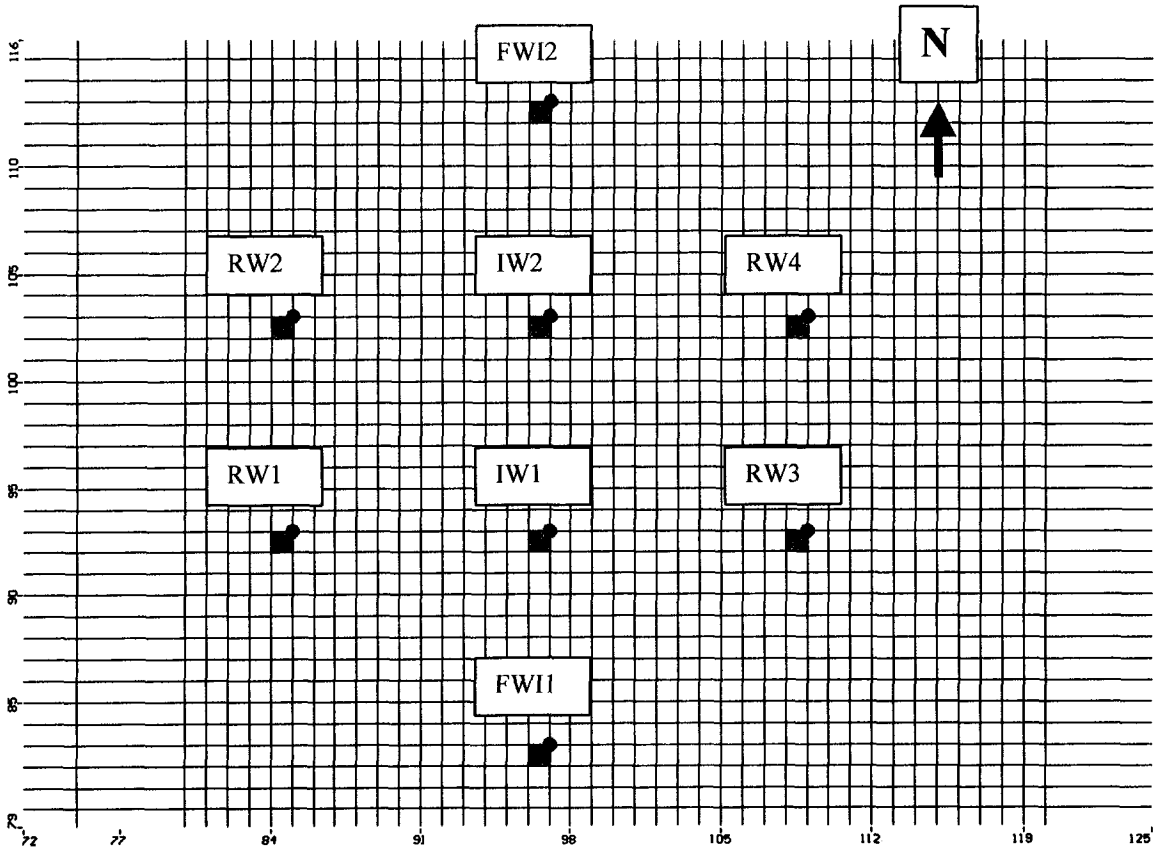

Figure 4.3: Groundwater Model Grid

5.0 LABORATORY TESTING AND RESULTS

The purpose of this section is to describe the results of the laboratory surfactant screening activities. The laboratory screening consisted of Critical Micelle Concentrations (CMC) measurements, Contaminant Solubilization, Surfactant Sorption and Precipitation, Surfactant-TCE Phase Properties, Contaminant Extraction-Column Studies, Partitioning Tracer Test, Surfactant Re-concentration/Micellar Enhanced Ultrafiltration testing. The purpose of these tests was to select the best surfactant system for application at the site.

5.1 Materials and Methods

This section summarizes the materials used to complete the laboratory experiments and analyses, and provides an overview of the methodologies used to complete each test. For a detailed break down of procedures refer to Section 5.2.

Materials

5.1.1 Selection of Surfactants

Eight anionic surfactants or mixtures were investigated for their potential use in remediation of TCA, DCE or their mixtures with the in situ surfactant flushing technology. The surfactants evaluated and their corresponding properties are summarized in Table 5.1 (p. 5-11). Selection of these surfactants was based on their previous use reported in literature, cost, toxicity, and availability.

Typically, anionic surfactants containing the negatively charged head group(s) will suffer less surfactant losses in soils due to the sorption process compared to nonionic surfactants. Yet nonionic surfactants tend to have higher solubilization capacity for organic pollutants than anionic surfactants. This is due to their low CMC and ability to yield more micelles on a same weight basis.

5.1.2 Contaminant and Additional Chemicals Used

The target contaminants used were TCA, DCE and mixture of TCA and DCE (50/50). Pinacyanol chloride was a dye used for the CMC measurements. Several electrolytes, including NaCl, $CaCl_2$, and $MgCl_2$, were used to change the surfactant-NAPL phase behavior. Isopropyl alcohol, pentanol, hexanol, heptanol, and 2,4-dimethyl-3-pentanol were selected for the partitioning tracer study. Isopropyl alcohol (IPA) was used as cosolvent for studying the surfactant-NAPL phase properties. Methanol was used as a mobile phase for high performance liquid chromatography (HPLC) analysis. Site ground water was used for preparing the sample solutions in most experiments. The laboratory procedures used for the surfactant screening test are described in Section 5.2.

Methods

5.1.3 CMC Measurements

The CMC is the concentration at which micelles begin to form. The CMC affects several properties of the surfactant solution that will have a significant impact on the effectiveness of the process including sorption, solubilization and foaming. To determine the CMC, two

methodologies were used, the pinacyanol chloride technique (or dye test) and the Wilhelmy Plate Tensiometer (or plate method).

5.1.4 Contaminant Solubilization of NAPL

The solubilization tests were used to determine the solubilization capacity of the surfactant/cosolvent solution. Typically, solubilization enhancements range from one to four orders of magnitude greater than water alone. The objective of the solubilization test was to select a surfactant system with ultra solubilization potential without mobilizing NAPL. The solubilization capacity of TCA (as predominant contaminant at the site) for the selected surfactants was determined by two methods, direct visual observation and gas Chromatography/Flame Ionization Detector (GC/FID) measurement. Direct visual observation was used as a preliminary screening tool for various surfactant and TCA systems. Over the course of these experiments, TCA was periodically added to the surfactant solution (30 ml) of various concentrations. This was prepared in a 40-mL EPA vial and was left for equilibration at room temperature (18 °C) following a 24 hour pre-mixing period.

5.1.5 Sorption, Precipitation, and Phase Behavior Analyses

These tests relate to the loss of surfactant under subsurface conditions. Surfactants/cosolvents can be lost due to sorption, precipitation, and adverse phase behavior reactions. Excess surfactant sorbed or precipitated onto soils inhibits system effectiveness and increases costs. Surfactant/cosolvent sorption will occur at varying degrees in all subsurface systems. Sorption testing helps to quantify the amount of surfactant lost to soil and facilitates surfactant comparison. Some surfactants may be subjected to precipitation or adverse phase behavior due to the presence of salts, divalent cations or temperature fluctuations. It is essential to ensure that the surfactant will not precipitate out under site specific aquifer conditions. Loss due to precipitation and/or phase separation could induce surfactant loss as well as a plug the aquifer pores. As a result, these tests will produce important information for designing a successful surfactant system for contaminant remediation.

Surfactant systems giving the highest molar solubilization ratio (MSRs) and the lowest CMC values were selected for additional analysis. All remaining surfactants were subjected to batch equilibrium sorption testing. Of those systems demonstrating the least propensity for sorption, two potential surfactants were selected for precipitation studies. After demonstrating resistance to precipitation, they were also subjected to phase behavior testing. All surfactant/cosolvent systems showing unfavorable phase behavior were eliminated from further consideration. Surfactant solutions showing acceptable phase behavior were also screened for viscosity and density. Test procedures are outlined in Section 5.2.

5.1.6 Contaminant Extraction-Column Studies

One-dimensional column tests were conducted to simulate flow through conditions in the aquifer. Although it is difficult to simulate actual site conditions, there is valuable information that can be obtained from the column studies. This information includes solubilization enhancement under continuous flow conditions and potential head loss increase in the media.

The results of the column studies aided in the design of pilot and potential full-scale application designs. Column tests results were used to quantify the number of PV required to mitigate the

NAPL for each surfactant system. Previous laboratory and field studies indicate that the solubilization mechanism requires 3-15 PV for complete DNAPL recovery.

From the site soil packed in the column, residual saturation was achieved in the column by adding TCA (4 to 6 mL) followed by water to remove excess TCA. A mass balance of TCA was determined to estimate the residual concentration. Our goal is to compare two systems for the following factors:

1. To determine the best solubilization system, and
2. To determine the best ultra solubilization system that does not produce ultra low interfacial tensions (< 0.1 dyne/cm).

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

A SEPA CF Membrane Cell Filtration Unit was used for membrane recovery of the surfactant solutions. The membrane unit simulated the performance of commercially available spiral-wound and tubular membrane elements. This was achieved by using the same materials of construction as the commercially available elements and also by creating similar fluid dynamics. A pneumatic pump was utilized to pressurize a piston clamping mechanism to seal the cell and to form a leak proof seal around the membrane. Back pressure and flow rates were controlled with a pneumatic pump. Gauges were used to detect back pressure.

5.2 Procedures

This section details the procedures to complete the laboratory screening tests.

5.2.1 CMC Measurements (18°C)

- 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.% was tested with a low concentration of the dye.
- If the dye became blue, then the 5 wt.% solution was above the CMC. The solution was then diluted by factors of 10 (1 mL of surfactant to 9 mL of ground water) until the solution became violet.
- The CMC of the surfactant was then approximately the average of the lowest concentration showing micelles and the highest concentration showing only monomers.
- The final CMC of the surfactant was determined by surface tension measurements using an automated Wilhelmy Plate Tensiometer.
- The surface tensions of 10 surfactant concentrations were spaced so that 5 evenly divided the decade below the estimated CMC and 5 evenly divided the decade above the CMC when plotted on a surface tension vs. log concentration plot.
- The break in the surface tension vs. log concentration plot identified the surfactant CMC.
- CMC measurements were performed using site ground water at the site ground water temperature.

5.2.2 Contaminant Solubilization (18°C)

- Contaminant solubilization was assessed in batch systems (40 mL EPA vials).
- Excess (2-ml) of pollutant, TCA, was added to 30-mL of the following surfactant concentrations (CMC/10, CMC/5, CMC, 5xCMC, 10xCMC, and 20xCMC) and prepared in site ground water at the site temperature (18°C).
- Sample vials were left on a shaker for a 24-hour pre-mixing period, followed by 24 hour equilibration time.
- Aqueous TCA concentrations were determined through GC/FID analysis.
- Results were graphed on a solubilization vs. surfactant concentration plot.
- Increasing TCA concentrations was evidenced in the aqueous phase as the surfactant concentration increased above the CMC value.
- Solubilization parameters (e.g., molar micellar solubilization, micellar-water partition coefficient) were determined from these plots.

5.2.3 Surfactant Sorption (18°C)

- Surfactant sorption has been assessed in batch systems by contacting varying surfactant concentrations with a constant mass (5g) of soil from the site aquifer.
- Ten concentrations per surfactant were used as follows: 1.5 x CMC, 3 x CMC, 4.5 x CMC, 6 x CMC, 7.5 x CMC, 9 x CMC, 10.5 x CMC, 12 x CMC, 13.5 x CMC, and 15 x CMC.
- The experiments used 5 g of soil with 25 mL of surfactant solution with equilibration times of at least 24 hours.
- Upon centrifugation (if necessary) for solids-liquid separation, aliquots of the supernatant were analyzed by HPLC for the equilibrium surfactant concentration.
- The mass of surfactant sorbed was 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) were analyzed for appropriate sorption parameters (e.g., Langmuirian or Linear sorption coefficients and capacity terms).

5.2.4 Surfactant Precipitation

- Precipitation (phase separation) assays were conducted using 40-mL glass vials with 30 mL of solution in each vial.
- Ionic strengths were varied from 1.0, 5.0, and 10.0 times the dominant monovalent and divalent cation concentrations present in the ground water.
- Temperatures were varied from 10°C below groundwater temperature, at groundwater temperature, and 10°C above the mean groundwater temperature for aquifer.
- For time constraints, three sets of samples were mixed to correspond with each temperature.
- Ionic strengths were added individually starting with the monovalent ion (added to same sample each time) then continuing with the divalent ion.
- Surfactant concentrations were varied from 0.1, 5, 25 and 50 x CMC for assessing phase separation.
- Surfactant phase diagrams were plotted by showing regions of phase separation for plots of surfactant concentration versus ionic strength at each temperature.

5.2.5 Surfactant-NAPL Phase Properties (18°C)

- TCA/surfactant or solution interfacial tensions were measured for the selected surfactant systems.
- Samples were prepared with 5 mL of NAPL (TCA, DCE, TCA/DCE mixture) and 5 mL of surfactant solution in 15 mL sample vials.
- The solutions were equilibrated at aquifer temperature for several days and checked periodically.
- The hydrophile-lipophile balance (HLB) of the surfactant/TCA system was controlled by such methods as holding one surfactant concentration constant (e.g., Isalchem 123-2PO) and varying the concentration of a second surfactant or a cosolvent (e.g., IPA), or salinity (Na^{+}) and hardness (Ca^{+2}).
- Visual inspection monitored the phase behaviors (surfactant in the oil versus water phase, appearance of a third phase-middle phase microemulsion).
- The phase diagram showed 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 3-parameter or phase optimization diagram.
- All systems exhibiting acceptable phase behavior were also examined for viscosity, density, and interfacial tensions (IFTs).
- Systems with unfavorable viscosity or density were either modified or abandoned.

5.2.6 Contaminant Extraction-Column Studies (18°C)

- Glass liquid chromatography columns (2.5 cm diameter by 15 cm length) were used for conducting column studies.
- Prior to packing the column, an initial weight (no soil) was recorded. Once the column was packed with core materials obtained from the subject site a second weight was recorded as dry weight.
- Following the saturation step with site groundwater injection (in a bottom to top mode), the saturated weight was recorded.
- The column was then flushed with a known volume of TCA (4 to 6 mL), followed by flushing with site groundwater to remove any excess TCE (CARE WAS TAKEN TO ENSURE COMPLETE MASS BALANCES WITH 5% MARGIN FOR ERROR).
- Hydraulic flow rates through the column were determined prior to flushing the surfactant solution.
- A time-controlled fraction collector was used to collect discrete samples for GC/FID analysis.
- The surfactant/cosolvent concentrations for each system were selected based on predicted performance from the batch study.
- The surfactant/cosolvent solutions were prepared using native groundwater and conducted at 18 °C.
- When surfactant flushing began, the following parameters were monitored continually: flow, injection rate, and pressure drop.
- The effluent samples were analyzed for concentrations of dissolved TCA.
- Each effluent sample was checked for the mobilized TCA free phase.
- Flushing continued until an asymptotic level of removal had achieved complete removal.

- At the conclusion of flushing, the columns were dismantled and the soil placed in methanol to extract any remaining TCA. The purpose for this was to determine the concentrations of NAPL constituents and surfactant in soil. This information was used to corroborate mass balances for the contaminant and surfactant.

5.2.7 Partitioning Tracer Tests

- The selected partitioning and conservative tracers were tested in column experiments. The sorption losses and the NAPL-water partitioning coefficients of the tracers used were pre-determined in the batch equilibrium partitioning experiments (i.e., soil-tracer solution, tracer-TCA-water).
- After TCA (4 to 6 mL) was added to the column as described, a 0.15 PV tracer solution containing 1,000 mg/L of individual tracer was injected into the column, followed by 7 to 10 PV of groundwater injection.
- The effluent samples were analyzed for concentrations of dissolved tracers. Bromide (conservative) was determined by HPLC method and the alcohols were determined by the GC/FID method. The detailed procedures used for the tracer analysis are listed in Appendix D.

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

- 1000-mL surfactant solution was pumped through the SEPA CF filtration unit used for membrane evaluation.
- Initial samples were taken to determine background surfactant concentrations.
- Back pressure values were set from 60 and 90 psi (metering pump) to force the solution through the membrane.
- At timed intervals, samples were taken from the retentate and permeate solutions.
- A membrane size of 5,000 molecular weight cut-off (MWCO) was used in these tests.
- Surfactant samples collected were analyzed by HPLC.
- An acceptable permeate concentration should be at or below the CMC of the surfactant.

5.2.9 Quality Assurance

The Quality Assurance Project Plan (QAPP) for this SESR has been closely followed during the course of laboratory screening tests, including sample preparation, sample collection and analysis, and generation of analytical results. Standard procedures and/or manufacture manuals were used for laboratory instrument calibration. All requirements for calibration procedures and frequency for specific parameters were previously documented in the Work Plan of this project (Appendix A).

5.3 Results and Discussion

The significant results of the laboratory screening tests are briefly summarized in this section. They were enlisted according to the specific measurement and test described above. Additional raw data and calculations performed during the screening test were compiled in Appendix D.

5.3.1 CMC Measurements

The CMC values were determined for all nine surfactants listed in Table 5.1 (p. 5-11). These results are also included in Table 5.1.

In this test, the CMC measurements with the plate method were significantly lower than those data from the dye test (two orders of magnitude differences--Table 5.1). Typically, the CMC values measured may deviate somewhat, but less than one order of magnitude between these two methods. Reason for this discrepancy was unclear. However, one can indirectly determine the CMC for the surfactants from other measurements such as solubilization and the MEUF experiments as described in the later section.

From the plate method, the CMC values for three Isalchem surfactants selected are in the following order: I45-4PO < 145-2PO < 123-2PO. Isalchem 145-4PO with the lowest CMC among these three is probably due to its long alkyl chain, i.e., C_{14} to C_{15}, compared to the C_{12} to C_{13} in Isalchem 123-series. Also, increasing the propylene oxide group (i.e., from 2PO to 4PO) in the surfactant should increase its hydrophobicity, thus lowering its CMC.

5.3.2 Contaminant Solubilization

When screening for a surfactant system, a pure surfactant is first selected and evaluated to determine baseline performance. If the surfactant demonstrates effective solubilization performance and no adverse phase behavior is observed, co-surfactant and salt are then added to optimize performance. Laboratory solubilization experiments for TCA were conducted at concentrations below and above the CMC (ranging from 1/10X, 1/5X, 1X, 5X, 10X, 20X CMC) for four pure surfactant systems listed in Table 5.1. The dissolution of TCA with the Isalchem and Dowfax 8390 (which has preferred sorption properties) were quantified by the GC/FID method.

The effects of various surfactant concentrations on total TCA dissolved for three Isalchem surfactants are shown in Figures 5.1 to 5.4. Surfactant capacity for contaminant solubilization can be described by the weight solubilization ratio (WSR) i.e., the linear slope of these curves. Beside WSR values, one can use additional parameters, such as the molar solubilization ratio (MSR) and micellar-water partition coefficient, K_m, to compare the effectiveness between different surfactants. Results of the parameters observed were calculated and summarized in Table 5.2 (p. 5-12). These values were calculated based on the average molecular weight of surfactant (MW) and the TCA aqueous solubility detected in this study (i.e., $S_{TCA, CMC}$).

Surfactants with large MSR and K_m values could potentially be a better flushing reagent to remove the contaminant effectively. Among the surfactants used, Isalchem 145-4PO showed the highest MSR and K_m values for TCA and Dowfax 8390 has the least number. On a weight basis, addition of Isalchem 145-4PO showed slightly better capacity for TCA solubilization (WSR = 1.26) compared to that of 145-2PO (WSR = 1.20).

Pure Dowfax surfactant solution yielded significant less TCA mass dissolved compared to Isalchem series surfactants (Table 5.2). However, our previous study showed that addition of different reagents (e.g., Aerosol MA-80) in Dowfax system significantly increased its NAPL solubilization capacity. Therefore, in the later experiments, the highly effective NAPL-dissolved

agents containing Dowfax mixtures, Dowfax/AMA/NaCl/$CaCl_2$, was selected for further evaluation. In the same way, use of mixtures of Isalchem surfactant and the HLB-adjusting additive may further improve the overall performance as well. This is described at the end of this section.

5.3.3 Surfactant Sorption and Precipitation

Previously, we had evaluated the sorption losses for Dowfax and Isalchem series surfactants for different media (Surbec, 1999). Among the surfactants tested, Dowfax 8390 has the most favorable sorption properties (least mass loss) compared to others. Between three Isalchem surfactants, sorption of 145-4PO and 145-2PO (q_e, g/g) was several fold less than 123-2PO for a silty sand media. Based on these previous tests, it is expected that Dowfax is the best system which exhibited the least sorption, followed by 145 series.

In surfactant precipitation study, two surfactants were selected (Isalchem 123-2PO and Aerosol MA-80) and studied for their precipitation tendency at three different temperatures. Previously, Dowfax 8390 has demonstrated no precipitation under normal aquifer or extreme environment (Rouse et al., 1994). Therefore, no precipitation study was conducted for Dowfax.

Precipitation data are summarized in Table 5.3 (p. 5-13). In this study, AMA showed no precipitation under all conditions. Under very low concentration and high Ca^{+2} concentration (388 mg/L), precipitates were detected in 123-2PO system (refer to Table 5.3). However, 123-PO may still have better precipitation tolerance (Ksp for $Ca^{+2} = 6.5 \times 10^{-9}$) than some surfactants, such as sodium dodecyl sulfate (SDS, Ksp, 2.14×10^{-10}) and sodium dodecyl benzene sulfonate (SDBS, Ksp, 3.9×10^{-10}) (Shiau et al., 1995). Previously, Dowfax 8390 showed extreme hardness tolerance due to its high Ksp value of $> 1 \times 10^{-3}$ (Rouse et al., 1994).

5.3.4 Surfactant-NAPL Phase Properties

Previously, proper selection of additives such as cosurfactant, cosolvent, or salt/hardness could alter the HLB of surfactant-DNAPL system to create phase transition between various types of microemulsions (Winsor Type I, Type II, and Type III). Selective scanning results for three major surfactants, Isalchem 123-2PO, Dowfax 8390, and Lubrizol 71, were documented in Appendix D. Although Isalchem 145-4PO has better sorption property compared to 123-2PO, the turbidity of 145-4PO solution interfered our visual inspection for phase behavior during the preliminary experiments and thus this system was removed from the list.

Three surfactant mixtures, which generated the Type I (oil-in-water or solubilization) microemulsion with TCA, DCE, or TCA/DCE, have significant amount of TCA dissolved in surfactant solution. They are:

1. Dowfax 8390 (5 wt%) + AMA-80-I (2 wt%) + NaCl (3 wt%) + $CaCl_2$ (1 wt%),
2. Lubrizol 71 (4 wt%) + IPA (2 wt%) + NaCl (2.5 wt%) + $CaCl_2$ (0.1 wt%)
3. Isalchem 123-2PO (2 wt%) + AMA-80-I (2 wt%) + IPA (1 wt%) + $MgCl_2$ (0.8 wt%).

Equilibrium TCA concentrations with these surfactant systems are listed in Table 5.4 (p. 5-14). In these batch experiments, the amounts of TCA dissolved in surfactant mixtures ranged from 99,000 mg/L to 259,000 mg/L. These values are much greater than those observed in pure (neat) surfactant systems (see Figures 5.1 to 5.4). It should be noted that the Dowfax and Lubrizol systems which both contain NaCl were compared with the Isalchem system that did not contain NaCl. The addition of salt to the Isalchem surfactant mixture led to poor phase behavior and therefore was not added to the system. Consequently, the Isalchem system had a limited solubilization capacity. These highly effective surfactant systems may provide similar NAPL removal capability within reasonable time frames without yielding unwanted vertical migration of DNAPL found in some Type III systems (mobilization). Selective measurements of the viscosity data for these systems are listed in Appendix D. Data from the viscosity measurement surfactants (ranging from 2 to 4 cp) also showed no major concern for unwanted vertical migration of DNAPL. Since Isalchem 123-2PO could not be provided in enough quantity by the manufacturer, Surbec decided to remove Isalchem 123-2PO from the list.

5.3.5 Contaminant Extraction-Column Studies

Several surfactant flushing tests were conducted to evaluate the performance of TCA removed by the selected surfactants. Surfactant systems and the conditions used in these column experiments were briefly summarized in Table 5.5 (p. 5-15). Selective column results are included in Appendix D.

Examples of TCA dissolution in column runs are shown in Figures 5.5 for Dowfax/AMA/NaCl/$CaCl_2$. Maximum TCA concentrations in the effluent were included in Table 5.4. The detailed information for these column tests is listed in Appendix D.

Total TCA removed by Dowfax/AMA/NaCl/$CaCl_2$ (Column B) were greater than 100% based on the GC/FID analysis for the column elute. Currently, the analyses of mass extraction of TCA from the soil remaining in the column are underway. Preliminary results of TCA elution by Lubrizol 71 indicated significant TCA removal (> 95%) observed after 5 to 7 PV surfactant injection.

In these column tests, negligible pressure drop increase were observed during the post groundwater flushing stage. Previously, Surbec had observed some pressure drop increases (> 10 psi) in column packed with a much finer medium. Negligible or no mobilization of TCA was observed in these column runs (B & C). Therefore, these systems are the best candidates for field application. Both of these systems are able to achieve the desired removal level within 5 PV of surfactants flushed.

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

Surfactant re-concentration for Dowfax/AMA mixture was carried out by a SEPA CF Membrane Cell, with results shown in Figure in 5.7. With a 5,000 molecular weight cut-off membrane (MWCO), the permeate and retentate portions of Dowfax/AMA are shown in this figure. The 5,000 MWCO membrane was able to re-concentrate Dowfax/AMA solution with back pressure at 55 psi or above. Surfactant concentrations in the retentate were between 3 to 3.8 wt.% and 0.4 wt.% in the permeate (Figure 5.7). This indicated that Dowfax/AMA present in the waste stream can be concentrated with this device.

5.3.7 Partitioning Tracer Study

Laboratory batch sorption and partitioning coefficient measurements were conducted to assess several potential partitioning tracers for field demonstration, including pentanol, hexanol, heptanol, and 2,4 dimethyl 3 pentaol. Data of the TCA-water partitioning coefficient and their sorption on the site soil (q_e, g/g soil) are listed in Appendix G. All alcohols showed no or negligible sorption on this soil (0 to 0.001 g/g). With low sorption and the proper partitioning coefficient data, pentanol, hexanol, and 2,4 dimethyl 3 pentanol will be used for pre-partitioning tracer test. For post-partitioning tracer test, bromide, hexanol 2,4 dimethyl 3 pentanol, and heptanol will be used in the field. Bromide will be used as conservative tracer in this study.

5.3.8 Biodegradability of the Selected Surfactants and Cosolvent

The biodegradability of the Dowfax surfactant mixtures, including Dowfax 8390, has been evaluated by studying the fate of a radiolabelled model compound (C16 MADS) used to represent the mixture of compounds that comprise Dowfax 8390 (Appendix D). After being added to activated sludge, surface soil, or subsurface soil, the alkyl side chain of this aromatic compound was partially oxidized forming an identified intermediate molecule. The further biodegradation of the intermediate compound was relatively slow, but observed in the surface sandy soil. The formation and relatively slow degradation rate of the intermediate molecule is a concern, but subsequent toxicology studies found the intermediate to be nontoxic to rainbow trout and daphnid.

We are not aware of specific biodegradation testing for the surfactant AMA. However, the linear nature (no branching) of the hydrophobe group of this surfactant should make this molecule extremely susceptible to aerobic biodegradation via beta-oxidation. Similarly, the cosolvent isopropyl alcohol (IPA) is known to be easily biodegraded. Low molecular weight alcohols including IPA are naturally occurring intermediates of microbial decay and are relatively rapidly biodegraded.

5.4 Summary of Laboratory Surfactant Screening Test

A series of laboratory batch and column experiments were conducted to evaluate the optimal surfactant systems for potential use in Alameda Point contaminated site. Based on these screening tests, it is recommended that the mixed surfactant systems, Dowfax/AMA/NaCl/$CaCl_2$ and probably Lubrizol/IPA/NaCl/$CaCl_2$, are best suitable for use at the Alameda site. This selection is based on their extremely high solubilization capacity for TCA while maintaining favorable phase behaviors during the flushing step. These surfactants are either with U.S.F.D.A. direct food grade status (AMA) or indirect food grade (Dowfax 8390). In addition, they are biodegradable under proper conditions. Detailed information about these surfactants, such as the material safety data sheet (MSDS), their biodegradation rates, and toxicity tests are included in Appendix D. Please note that the original MSDS sheets for the Dowfax did show that the solution contained some methylene chloride. That was an old data sheet and the methylene chloride has since been removed for the Dowfax formula. Overall, we believe that use of these highly effective surfactant systems should achieve the remediation goal at site.

Table 5.1: Surfactant Information and CMC Measurements Used In This Study

Trade Name	Type	MW	% Active	CMC (Pinacyanol) (wt%)	CMC Plate Tensiometer (wt%)
Aerosol MA-80I [A]	Sodium dihexyl sulfosuccinate	388	80	2.75	(2.1538)
Dowfax 8390 [A]	Diphenyl Sulfonate Derivative	642	36	0.04	-----
Lubrizol 68 [A]	Fatty amine	-----	30	0.25	-----
Lubrizol 71 [A]	Branched alkylsuccinic anhydride	-----	30	0.65	-----
Isalchem 123-2PO [A]	Alcohol Ether Sulfate	413	26.4	0.018	0.00505
Isalchem 145-2PO [A]	Alcohol Ether Sulfate	438	32.5	0.018	0.00174
Isalchem 145-4PO [A]	Alcohol Ether Sulfate	554	32.5	0.018	0.00174

[1]Type of surfactant, [A] = anionic, [N] = nonionic. Surfactant sources: Aerosol MA-80I, American Cyanamid; Dowfax 8390, Dow Chemical; Lubrizol series, Lubrizol Corp.; Isalchem series, ConDea Vista.
[2]Data in parentheses were CMC reported in literature (adapted from Rouse et al., 1994 & Shiau et al., 1995).

Table 5.2: Selected TCA Solubilization Results By Pure (neat) Surfactant Systems

Name	WSR[1]	MSR[2]	Log K_m[3]
Isalchem 123-2PO	0.65	2.01	3.83
Isalchem 145-2PO	1.20	3.94	3.91
Isalchem 145-4PO	1.26	5.23	3.93
Dowfax 8390	0.25	1.20	3.74

[1]WSR = weight solubilization ratio = slope of linear solubilization plot above CMC (in a wt% TCA solubilized vs. wt% surfactant used plot).
[2]MSR = molar solubilization ratio = WSRx (molecular weight of surfactant)/(molecular weight of TCA); average M.W. (g/mol) = 413, Isalchem 123-2PO; 438, 145-2PO; 554, 145-4PO; 642, Dowfax 8390.
[3]K_m = micellar-water partition coefficient = $[55.4/S_{TCA,\ CMC}]x[MSR/(1+MSR)]$; where $S_{TCA,\ CMC}$ = $5.47x10^{-3}$ M (730 mg/L).

Table 5.3: Results of Precipitation Study for Selective Surfactants Used

Surfactant	Concentration (WT%)	Temperature (°C)	1x Na^{+1}	5x Na^{+1}	10x Na^{+1}	1x Ca^{+2}	5x Ca^{+2}	10x Ca^{+2}
123-2PO	6.875	18	NONE	NONE	NONE	NONE	NONE	NONE
123-2PO	6.875	28	NONE	NONE	NONE	NONE	NONE	NONE
123-2PO	6.875	8	NONE	NONE	NONE	NONE	NONE	NONE
123-2PO	1.375	18	NONE	NONE	NONE	NONE	NONE	NONE
123-2PO	1.375	28	NONE	NONE	NONE	NONE	NONE	NONE
123-2PO	1.375	8	NONE	NONE	NONE	NONE	NONE	NONE
123-2PO	0.0275	18	NONE	NONE	NONE	NONE	NONE	**PPT**
123-2PO	0.0275	28	NONE	NONE	NONE	NONE	NONE	**PPT**
123-2PO	0.0275	8	NONE	NONE	NONE	NONE	NONE	**PPT**
MA-80	8.5	18	NONE	NONE	NONE	NONE	NONE	NONE
MA-80	8.5	28	NONE	NONE	NONE	NONE	NONE	NONE
MA-80	8.5	8	NONE	NONE	NONE	NONE	NONE	NONE
MA-80	4.25	18	NONE	NONE	NONE	NONE	NONE	NONE
MA-80	4.25	28	NONE	NONE	NONE	NONE	NONE	NONE
MA-80	4.25	8	NONE	NONE	NONE	NONE	NONE	NONE
MA-80	0.425	18	NONE	NONE	NONE	NONE	NONE	NONE
MA-80	0.425	28	NONE	NONE	NONE	NONE	NONE	NONE
MA-80	0.425	8	NONE	NONE	NONE	NONE	NONE	NONE

PPT = precipitation was observed
NONE = no precipitation was observed
Na^{+1} = 46.9 mg/L; Ca^{+2} = 38.8 mg/L

Table 5.4: Comparison of TCA Solubilization in Batch and Column Studies

Surfactant System	TCA Solubilized in batch test (mg/L)[1]	Maximum TCA Solubilized in column test (mg/L)
Dowfax/AMA/NaCl/$CaCl_2$	99,259	168,996
Lubrizol71/IPA/NaCl/ $CaCl_2$	259,355	NA[2]

[1]Volume determined by volumetric addition of TCE during the phase behavior study
[2]NA = not available

Table 5.5: Summary of 1-D Column Studies with Surfactant Flushing

Column	Flushing reagents	Pre-flushing step	Pre-PTT	Flushing step	Post-PTT	Comment
A	Dowafax 8390/AMA/NaCl/$CaCl_2$	4 mL TCA added	None	7 PV of 5% Dowfax/2% AMA/0.3% NaCl/1% $CaCl_2$ were injected	None	Pressure drop was less than 1 psi after 6 P.V. surfactant were injected; most dyed-TCA were eluted after 7 PV solution injected based on visual observation
B	Dowfax/AMA/NaCl/$CaCl_2$	4 mL TCA added	0.15 PV of Br, IPA, pentanol, hexanol, 2,4 dimethyl 3 pentanol @ 1,000 mg/L	7 PV of 5% Dowfax/2% AMA/3% NaCl/1% $CaCl_2$ were injected	0.15 PV of Br, IPA, hexanol, 2,4 dimethyl 3 pentanol, heptanol @ 1,000 mg/L	Pressure drop < 1 psi, trace TCA was mobilized after 1 PV surfactant injection; most dyed-TCA were eluted after 5 PV solution injected
C	Lubrizol 71/IPA /NaCl/$CaCl_2$	6.6 mL TCA added	0.15 PV of Br, IPA, pentanol, hexanol, 2,4 dimethyl 3 pentaol @ 1,000 mg/L	7 PV of 4% Lubrizol 71/2% IPA/2.5% NaCl/0.1 CaCl2 were injected	None	Pressure drop increase to 10 psi after 7 P.V. surfactant injection

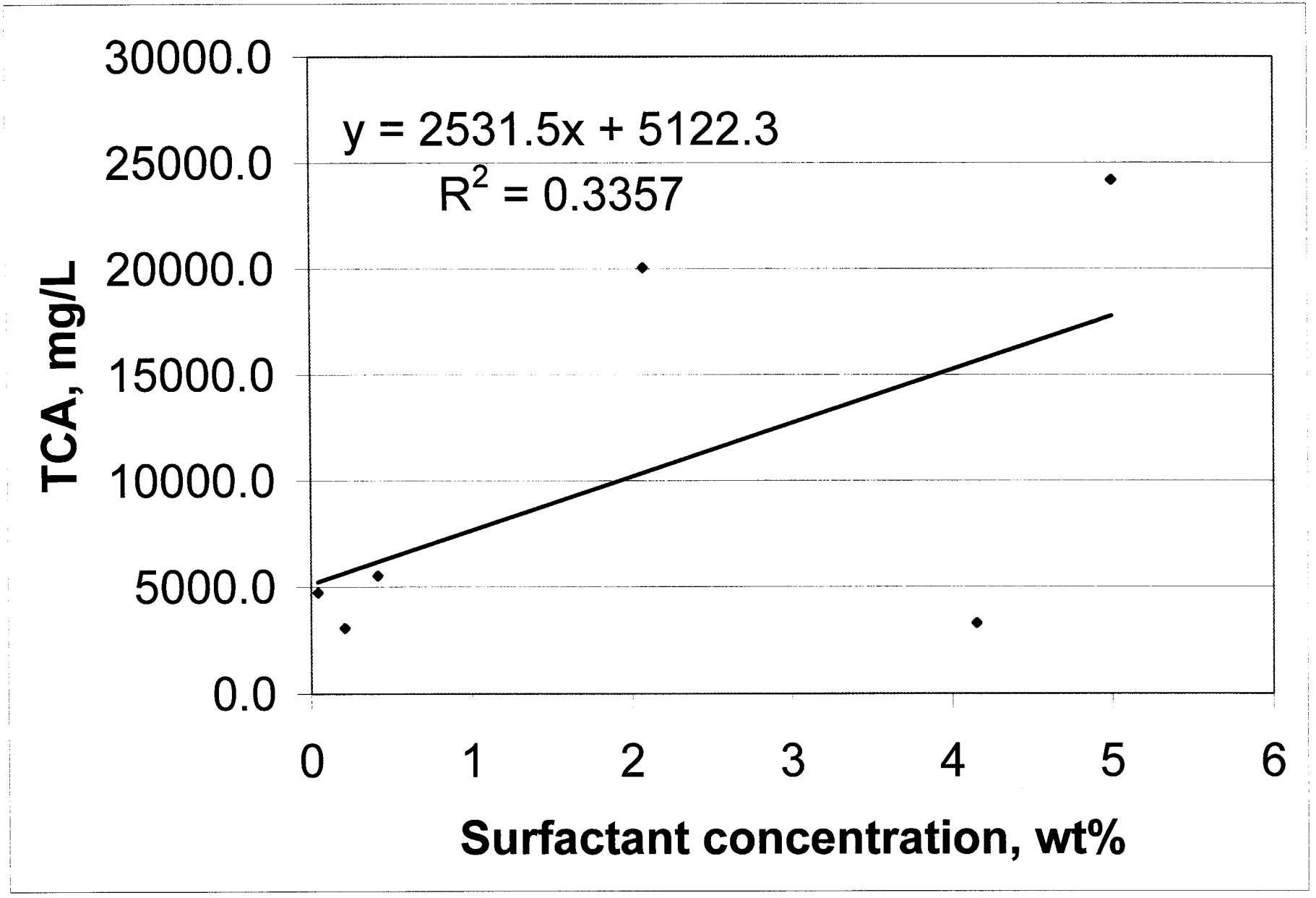

Figure 5.1 Solubilization of TCA by Dowfax 8390 @ 18°C; WSR = linear slope x 10^{-4}

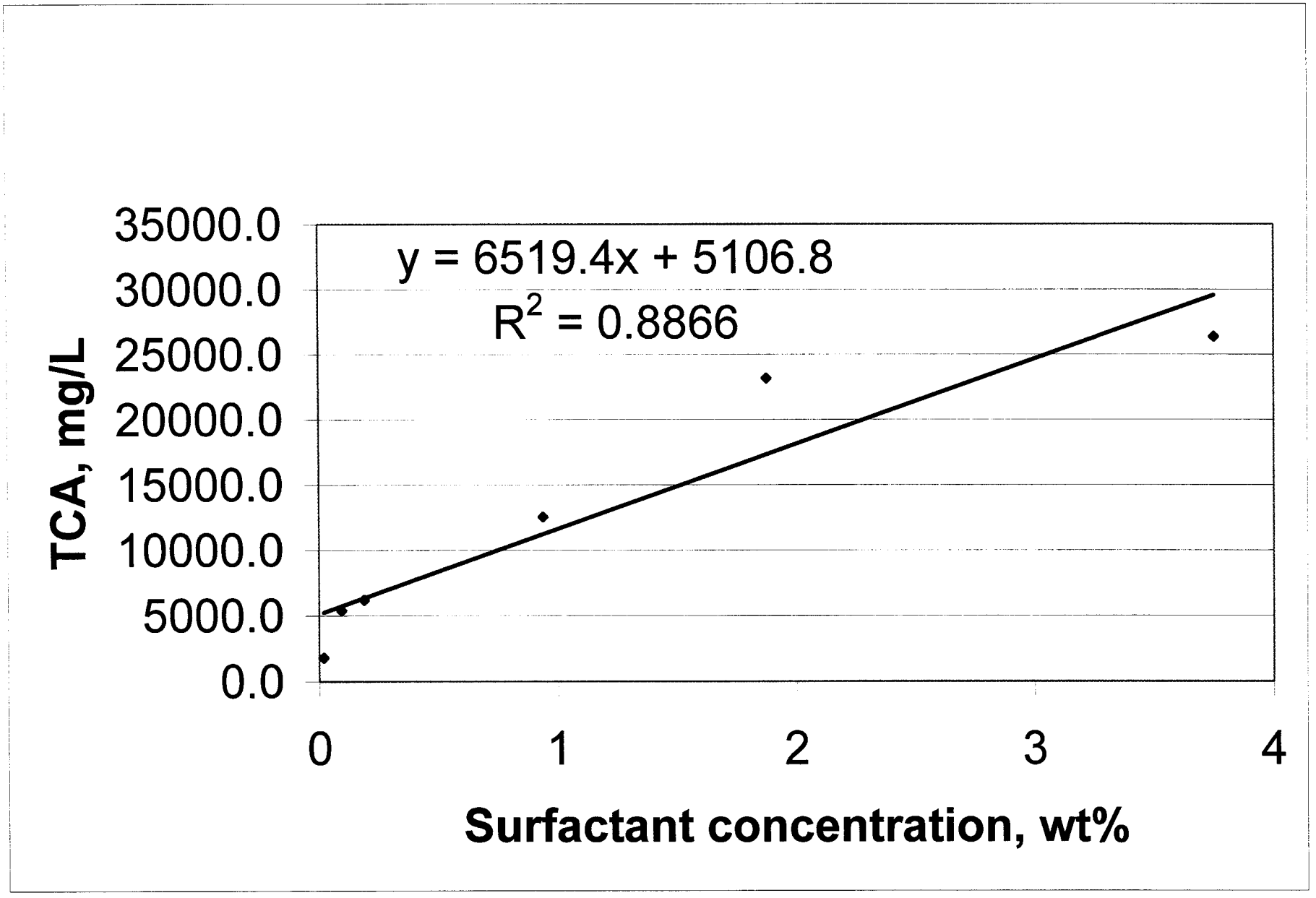

Figure 5.2 Solubilization of TCA by Isalchem 123-2PO surfactant @ 18°C; WSR = linear slope x 10^{-4}

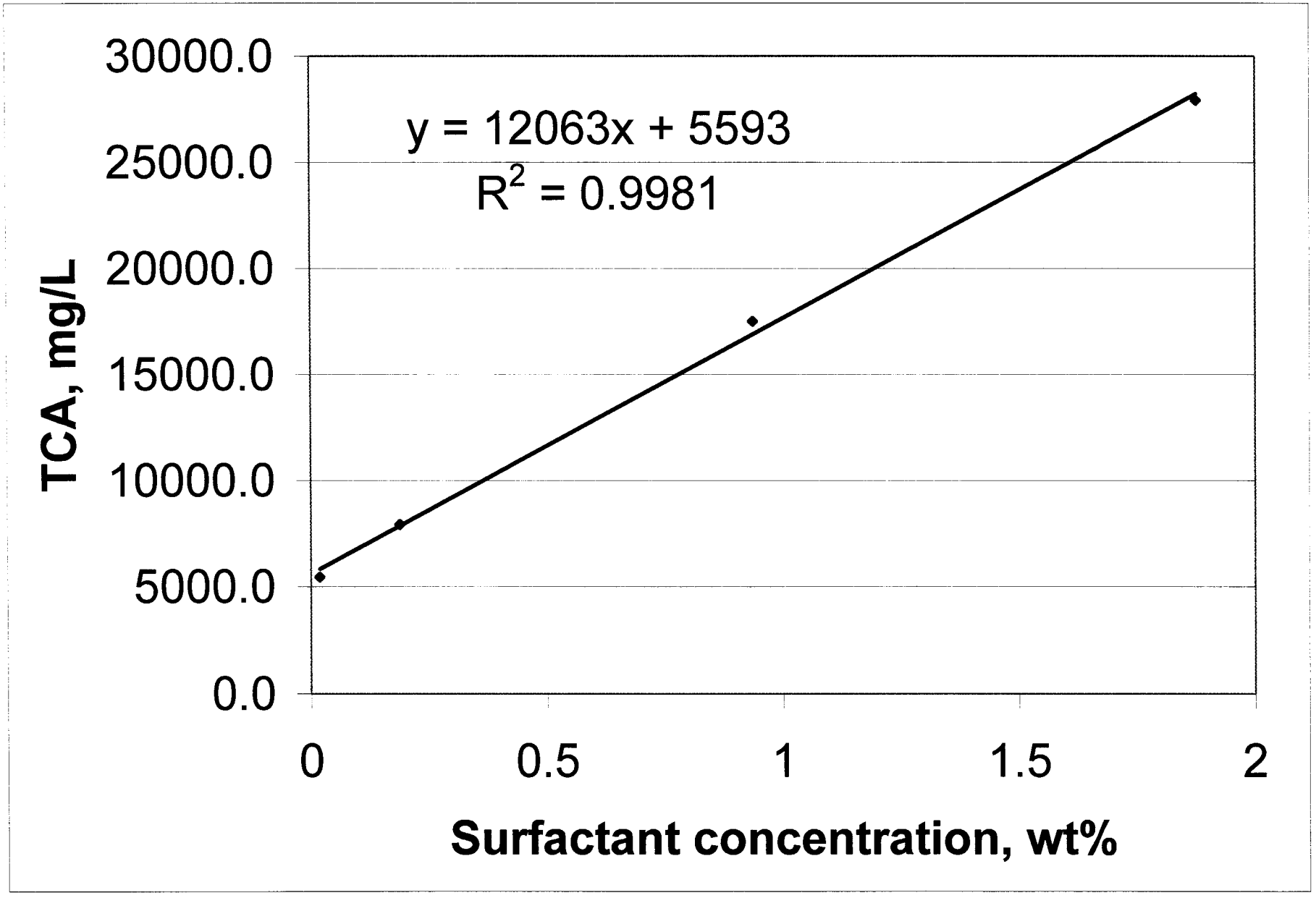

Figure 5.3 Solubilization of TCA by Isalchem 145-2PO surfactant @ 18°C; WSR = linear slope x 10^{-4}

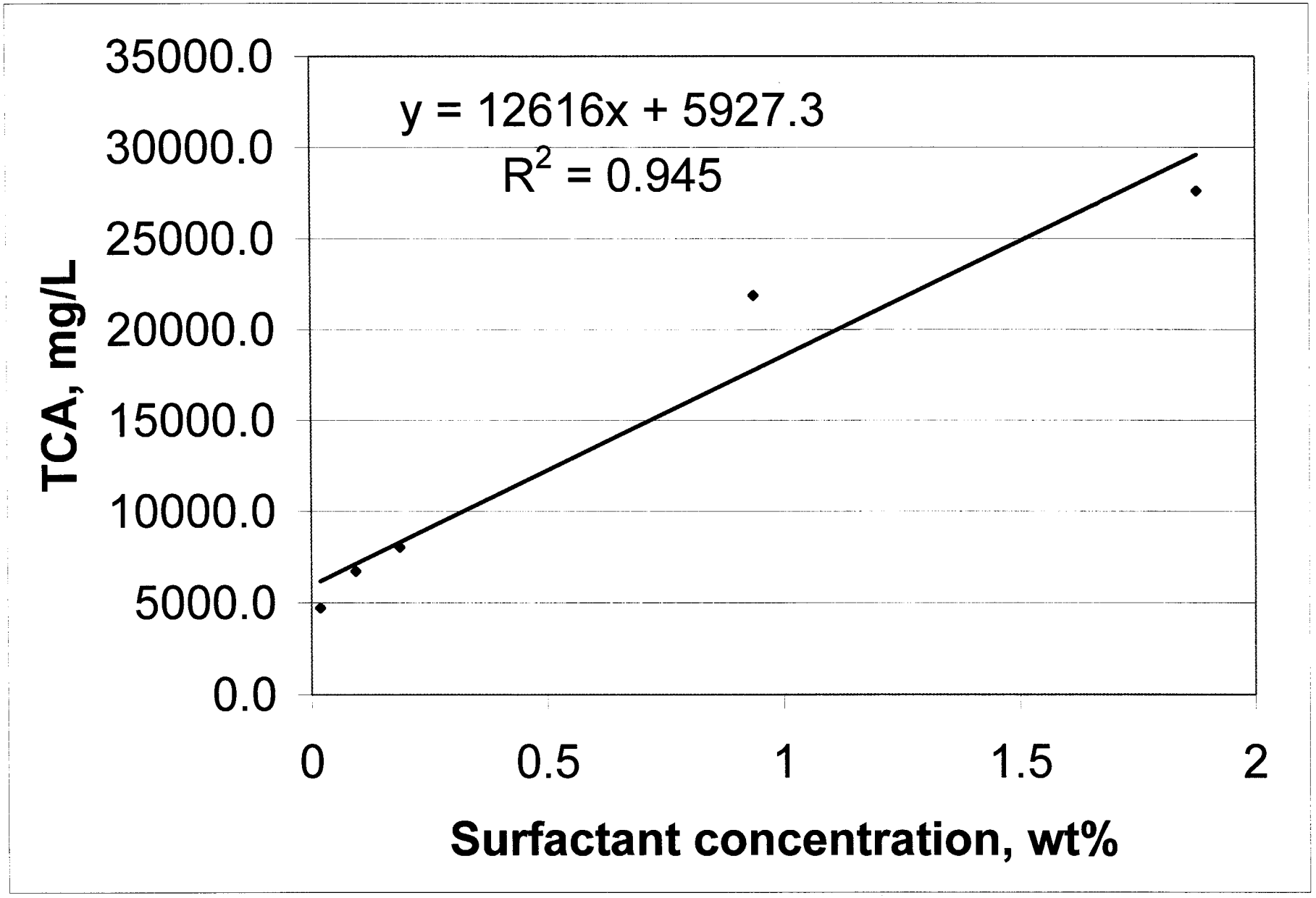

Figure 5.4 Solubilization of TCA by Isalchem 145-4PO surfactant @ 18°C; WSR = linear slope x 10^{-4}

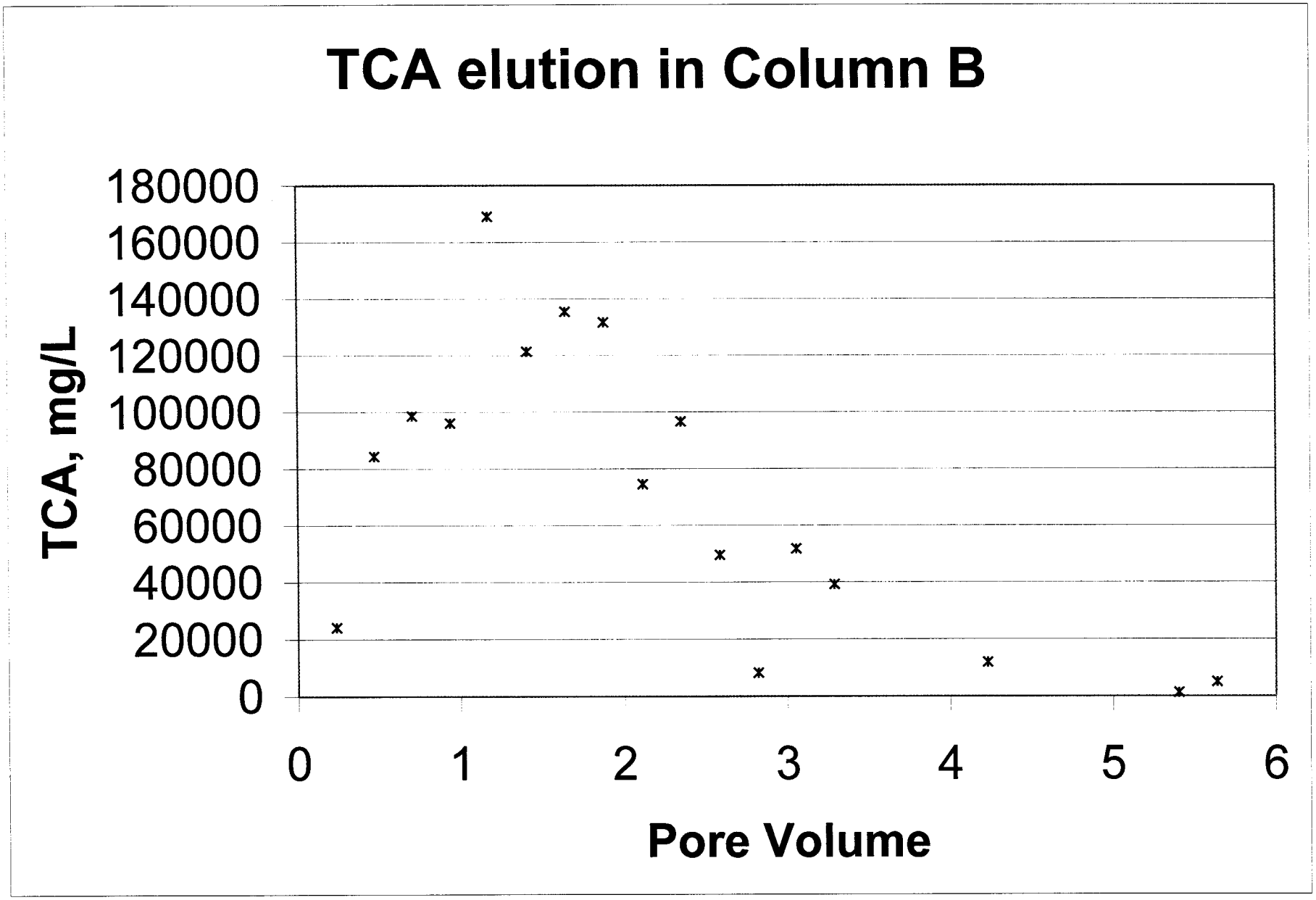

Figure 5.5 TCA elution by 5% Dowfax/2% AMA/3% NaCl/1% $CaCl_2$ @ 18°C

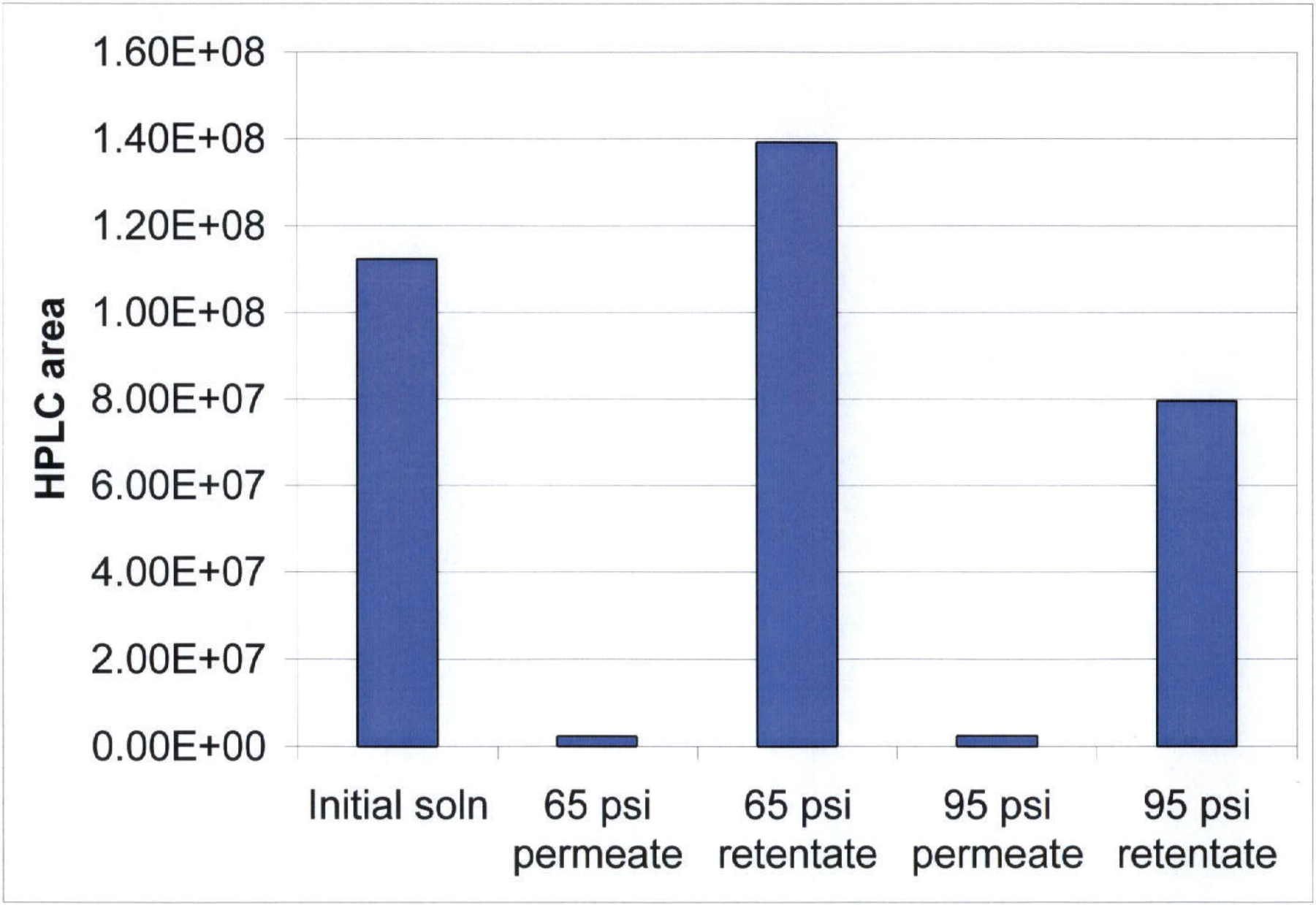

Figure 5.6 Surfactant re-concentration by MEUF for 5% Dowfax/2% AMA mixture

6.0 RECOMMENDATIONS

The purpose of this section is to summarize the results and make conclusions based upon the data summarized in Sections 2.0 through 5.0.

Site Investigation

1. Based upon the soil and groundwater sampling results, location 2A-A was the selected site to complete the SESR Treatability Study.
2. Residual phase DNAPL was observed in five of the Study wells; IW-1, IW-2, FWI-1, RW-1, and MLS-1, shown on Figure 3.4.
3. Soil contaminant concentrations were indicative of the presence of residual phase DNAPL in seven of the ten Study wells. High concentrations of volatile organics, in particular TCA, were detected in the other three well locations. Volatile organics concentrations, at the depth immediately above the Bay Mud, ranged from 71.3 to 40,970.0 mg/kg. The TCA concentrations ranged from 36.0 to 32,000.0 mg/kg.
4. Groundwater contaminant concentrations were indicative of the presence of residual phase DNAPL in the ten Study wells. High concentrations of volatile organics, in particular TCA, were detected in the other three well locations. Volatile organics concentrations, in the groundwater, ranged from 220.2 to 983.0 mg/l. The TCA concentrations ranged from 49.0 to 580.0 mg/l.
5. Based upon the Step Drawdown Test results, the groundwater hydraulic conductivity at location 2A-A ranged from 8.14 to 20.48 feet/day.
6. Surbec recommends the continuation of the demonstration at location 2A-A. The system wells were installed May 21st and 22nd, 1999.

Groundwater Modeling and Well Placement Design

1. Visual MODFLOW and MT3D96 analysis results indicate the proposed line drive well scenario (refer to Figure 4.3) produced an effective surfactant sweep efficiency and showed excellent hydraulic capture of the surfactant.
2. The fate and transport of the surfactant was modeled for one year subsequent to flushing activities to evaluate long term migratory potential. The results of this analysis indicated that the surfactant plume moved approximately 20 feet after a one year period and that the remaining surfactant concentrations in the groundwater within the sandy zone were at most 300 ppm.
3. Based on the modeling results, estimated time to flush 1 PV is one day. Assuming that 10 PV will be required to complete the surfactant flood and post test water flood, the total test duration may require up to two weeks.
4. Assuming a total of 8 gpm is recovered from all four wells combined, a total of 115,200 gallons of water will be produced during the surfactant flooding portion of the project.

Laboratory Testing and Results

1. The results of the laboratory analysis indicate that at least one of the surfactant systems tested is suitable for application at the site:
   - Dowfax (5 wt.%) + AMA (2 wt%) + NaCl (3 wt%) + $CaCl_2$ (1 wt%)

2. The Dowfax system outperformed other surfactant systems due to its lower sorption and absence of pressure increase during the column study. In addition, the Dowfax system is extremely resilient and will be more likely to resist precipitation or phase behavior as a result of changes in subsurface conditions due to spatial variability.
3. Preliminary batch results indicate that the Lubrizol surfactant system (i.e., Lubrizol 71 (4 wt%) + IPA (2 wt%) + NaCl (2.5 wt%) + $CaCl_2$ (0.5 wt%)) may also be a potential flushing reagent due to its higher solubilization potential. Further tests for the Lubrizol surfactant are underway.
4. All the listed surfactants and co-surfactants are nontoxic and biodegradable. Supportive toxicity and degradation information is included in Appendix D.

APPENDIX A
SOIL BORING LOGS
AND
MONITOR WELL COMPLETION DIAGRAMS

LOG OF DRILLING OPERATIONS

Boring No: 2A-G5 thru 8

Project: Alameda Point-SESR Investigation Phase Location: Alameda Point, Alameda, CA

Total Depth: 18.0 to 20.0 ft. Start Date: 5/10/99 Finish Date: 5/10/99

Geologist: Jeff Brammer Instrument/Units: OVM

Drilling Company: Fast Tek License # 589008 Driller: Ed

Drilling Method: geoprobe Rig Type: Geoprobe

Drill Bit Type and Size: 2.0"

Boring Locations (Street Address or Description): East side of Building 5, toward the north

Depth Below Surface (ft)	Sample Interval	Core Run / Recovery	Field Sample ID	BH/BZ	Soil Core PID (ppm)	Time (military)	Drilling Notes	Lithology	Depth Below Surface (ft)
0	1.0	NR					Concrete		0
1							Sand, 2.5 Y 4/4, olive brown, very loose, slightly moist, poorly sorted, fine to very fine grained, silty		1
2		3.0					Clay lens at 1.4 to 1.8 feet	SM	2
3	4.0								3
4									4
5		4.0					Sand, 2.5 Y 4/4, olive brown, very loose, moist, massive, trace silt, poorly sorted		5
6								SP	6
7	8.0						Wet at 7.0 feet		7
8							Sand, 5 Y 3/2, dark olive gray, very loose, wet, trace silt, massive, color due to contaminant		8
9		4.0						SP	9
10									10

LOG OF DRILLING OPERATIONS

Boring No: 2A-G5 thru 8

Start Date: 5/10/99

Geologist: Jeff Brammer

Depth Below Surface (ft)	Sample Interval	Core Run / Recovery	Field Sample ID	BH/BZ	Soil Core PID (ppm)	Time (military)	Drilling Notes	Lithology	Depth Below Surface (ft)
10							Sand, 5 Y 3/2, dark olive gray, very loose, wet, massive, trace silt	SP	10
11									11
	12.0								
12					300				12
13					to				13
		4.0							
14					500				14
15									15
	16.0								
16							Clayey sand, 2.5/5B, bluish black, poorly sorted, trace silt	SP	16
17					>2000		Silty clay, 2.5/5B, bluish black, very soft, low to med. plasticity	CL	17
		4.0			to				
18					12				18
19							Clayey sand, 2.5/5B, bluish black, poorly sorted, Silty, abundant shells	SP	19
	20.0						*Reviewed By:* _____ *RG No.:* _____ *Date:*		
20									20

LOG OF DRILLING OPERATIONS

Boring No: **2A-G9 thru 18**

Project: Alameda Point-SESR Investigation Phase Location: Alameda Point, Alameda, CA

Total Depth: 18.0 to 25.0 ft. Start Date: 5/19/99 Finish Date: 5/20/99

Geologist: Jeff Brammer Instrument/Units: OVM

Drilling Company: Fast Tek License # 589008 Driller: Ed

Drilling Method: geoprobe Rig Type: Geoprobe

Drill Bit Type and Size: 2.0"

Boring Locations (Street Address or Description): East side of Building 5, toward the north

Depth Below Surface (ft)	Sample Interval	Core Run / Recovery	Field Sample ID	BH/BZ	Soil Core PID (ppm)	Time (military)	Drilling Notes	Lithology	Depth Below Surface (ft)
0							Concrete		0
1							Sand, 2.5 Y 4/4, olive brown, very loose, slightly moist, poorly sorted, fine to very fine grained, silty		1
2							Clay lens at 1.4 to 1.8 feet	SM	2
3									3
4		NS							4
5							Sand, 2.5 Y 4/4, olive brown, very loose, moist, massive, trace silt, poorly sorted		5
6								SP	6
7							Wet at 7.0 feet		7
8							Sand, 5 Y 3/2, dark olive gray, very loose, wet, trace silt, massive, color due to contaminant		8
9								SP	9
10									10

LOG OF DRILLING OPERATIONS

Boring No: 2A-G9 thru 18

Start Date: 5/19/99

Geologist: Jeff Brammer

Depth Below Surface (ft)	Sample Interval	Core Run / Recovery	Field Sample ID	BH/BZ	Soil Core PID (ppm)	Time (military)	Drilling Notes	Lithology	Depth Below Surface (ft)
10							Sand, 5 Y 3/2, dark olive gray, very loose, wet, massive, trace silt	SP	10
11									11
12									12
13									13
14	14.0								14
15		4.0			300				15
16					to		Clayey sand, 2.5/5B, bluish black, poorly sorted, trace silt	SP	16
17					<2000		Silty clay, 2.5/5B, bluish black, very soft, low to med. plasticity	CL	17
18	18.0								18
19		4.0			89 to 300		Clayey sand, 2.5/5B, bluish black, poorly sorted, Silty, abundant shells	SP	19
20									20

LOG OF DRILLING OPERATIONS

Boring No: 2A-G9 thru 18

Start Date: 5/19/99 Geologist: Jeff Brammer

Depth Below Surface (ft)	Sample Interval	Core Run / Recovery	Field Sample ID	BH/BZ	Soil Core PID (ppm)	Time (military)	Drilling Notes	Lithology	Depth Below Surface (ft)
20							Clayey sand, 2.5/5B, bluish black, poorly sorted, Silty, abundant shells	SP	20
21									21
	22.0								
22					89.0		Silty clay, 2.5/5B, bluish black, very soft, low to med. plasticity	CL	22
23		4.0			to				23
24					12.0				24
	25.0								
25							T.D. = 18.0 to 25.0 feet bgs.		25
26									26
27									27
28									28
29									29
							Reviewed By: _____ *RG No.:* *Date:*		
30									30

WELL CONSTRUCTION DETAILS

Well Name: MLS-1
Supervised by: Jeff Brammer
Well Type: GWMW

Boring No: 2A-G9 Location Description: East side of Building 5, toward the north

Installation Date: 05/21/99 Project: Alameda Point - SESR for DNAPL

Location Proximity : Building 5, toward north, SW quadrant of Treatability Study Cell
(Inside or Outside Facility)

Drilling Company: Beylik Drilling

Construction Method: HSA

Drilling Method: Hollow Stem Auger

wner: Alameda Point

wner's Address: Alameda, CA

wner's Telephone: 650/244-2526

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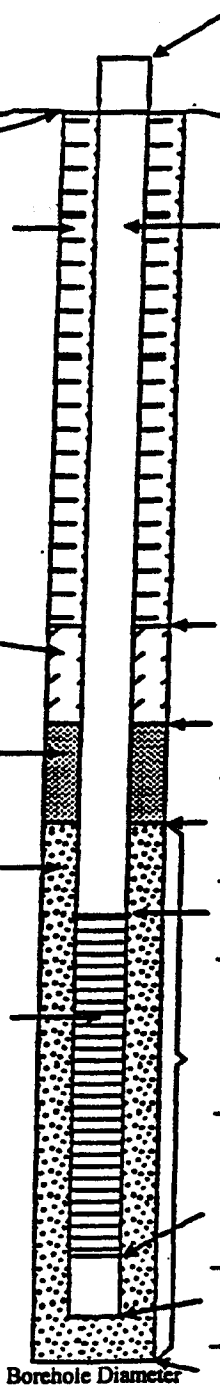

Measuring Point Location (i.e., TOC)

Ground Surface Elevation:

Surface Completion Type
12" Christie Box

Type/Amount of Grout
Neat Cement/20 gallons

Gallons of Water
8 gallons

Sacks of Cement
2 (100) lb. Sks.

Pounds of Bentonite
6 lbs.

Well Details:

Casing Type
PVC

And Amount
12.5 to 21.75 ft

Casing Diameter
1 inch

Centralizer Spacing
NA

And Number Used
NA

	Geohydrologic zone
	Aquifer
	Confining Layer or Aquiclude
	Lower or Confined Aquifer
	Perched Aquifer
X	Surface Aquifer
	Unsaturated Zone
	Water Table Aquifer

Type/Amount of Bentonite Seal
3/8" bentonite chips
(3) 50 lb. sacks

Bentonite Seal:
4.0' to 9.0', 16.8 to 21.5'

Natural Sand Bridge
9.0 to 12.5', 13.0 to 14.5', 15.0 to 16.25'

Type/Amount of Sand Bridge
NA

Type/Amount of Sand Pack
#3/ (0.5) 100 lb. sacks

Top of Sand Pack
12.5', 14.5', 16.0', 21.5'

Top of Screen
12.75', 14.75', 16.25', 21.75'

Screen Type and Length
Stainless Steel: PVC/0.25 ft

Filter Pack Length:
0.5 to 0.8'

Screen Slot Size: 0.01 inch

Screen Diameter: 1 inch

Screen % Open

Screen Material
Factory slotted

Bottom of Screen:
13.0', 15.0', 16.5', 22.0'

Total Well Casing Depth:
22.0'

Borehole Diameter
10.25"

Borehole Depth
25.0'

Reviewed By: _____ *Date:* _____

RG No.: _____

WELL CONSTRUCTION DETAILS

Well Name: MLS-2
Supervised by: Jeff Brammer
Well Type: GWMW

Boring No: 2A-G10 Location Description: East side of Building 5, toward the north

Installation Date: 05/21/99 Project: Alameda Point - SESR for DNAPL

Location Proximity: Building 5, toward north, NE quadrant of Treatability Study Cell
(Inside or Outside Facility)

Drilling Company: Beylik Drilling

Construction Method: HSA

Drilling Method: Hollow Stem Auger

Owner: Alameda Point

Owner's Address: Alameda, CA

Owner's Telephone: 650/244-2526

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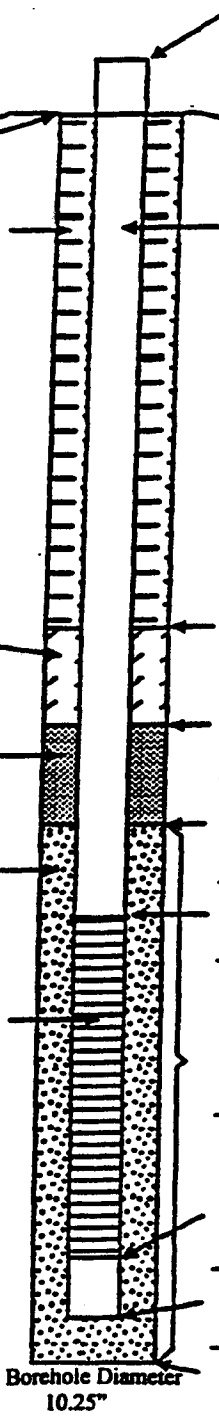

Measuring Point Location (i.e., TOC)

Ground Surface Elevation:

Surface Completion Type
12" Christie Box

Type/Amount of Grout
Neat Cement/20 gallons

Gallons of Water
8 gallons

Sacks of Cement
2 (100) lb. Sks.

Pounds of Bentonite
6 lbs.

Well Details:
Casing Type
PVC
And Amount
12.5 to 21.75 ft
Casing Diameter
1 inch
Centralizer Spacing
NA
And Number Used
NA

	Geohydrologic zone
	Aquifer
	Confining Layer or Aquiclude
	Lower or Confined Aquifer
	Perched Aquifer
X	Surface Aquifer
	Unsaturated Zone
	Water Table Aquifer

Type/Amount of Bentonite Seal
3/8" bentonite chips
(3) 50 lb. sacks

Bentonite Seal:
4.0' to 9.0', 16.8 to 21.5'

Natural Sand Bridge
9.0 to 12.5', 13.0 to 14.5', 15.0 to 16.25'

Type/Amount of Sand Bridge
NA

Type/Amount of Sand Pack
#3/ (0.5) 100 lb. sacks

Top of Sand Pack
12.5', 14.5', 16.0', 21.5'

Top of Screen
12.75', 14.75', 16.25', 21.75'

Screen Type and Length
Stainless Steel: PVC/0.25 ft

Screen Slot Size: 0.01 inch

Screen Diameter: 1 inch

Screen % Open

Screen Material
Factory slotted

Filter Pack Length:
0.5 to 0.8'

Bottom of Screen:
13.0', 15.0', 16.5', 22.0'

Total Well Casing Depth:
22.0'

Borehole Diameter
10.25"

Borehole Depth
25.0'

Reviewed By: _____ *Date:* _____
RG No.: _____

WELL CONSTRUCTION DETAILS

Well Name: RW-1
Supervised by: Jeff Brammer
Well Type: GWMW

Boring No: 2A-G11 Location Description: East side of Building 5, toward the north

Installation Date: 05/21/99 Project: Alameda Point - SESR for DNAPL

Location Proximity : Building 5, toward north, SW corner of Treatability Study Cell
(Inside or Outside Facility)

Drilling Company: Beylik Drilling

Construction Method: HSA

Drilling Method: Hollow Stem Auger

Owner: Alameda Point

Owner's Address: Alameda, CA

Owner's Telephone: 650/244-2526

Surface Completion Type
12" Christie Box

Type/Amount of Grout
Neat Cement/20 gallons

Gallons of Water
8 gallons

Sacks of Cement
2 (100) lb. Sks.

Pounds of Bentonite
6 lbs.

Type/Amount of Bentonite Seal
3/8" bentonite chips
(3) 50 lb. sacks

Type/Amount of Sand Bridge
NA

Type/Amount of Sand Pack
#3/ (2) 100 lb. sacks

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Measuring Point Elevation

Surveyor Company

Survey Date

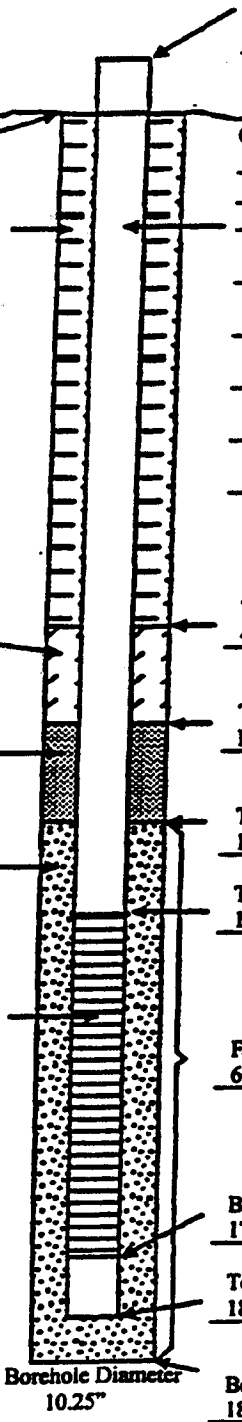
Screen Type and Length
Stainless Steel: PVC/4 ft

Screen Slot Size: 0.02 inch

Screen Diameter: 4 inch

Screen % Open

Screen Material
Factory slotted



Measuring Point Location (i.e., TOC)

Ground Surface Elevation:

Well Details:
Casing Type
PVC
And Amount
13.5 ft
Casing Diameter
4 inch
Centralizer Spacing
NA
And Number Used
NA

Top of Bentonite Seal:
4.0'

Top of Sand Bridge
NA

Top of Sand Pack
12.0'

Top of Screen
13.5'

Filter Pack Length:
6.0'

Bottom of Screen:
17.5'

Total Well Casing Depth:
18.0'

Borehole Diameter
10.25"

Borehole Depth
18.0'

Geohydrologic zone	
	Aquifer
	Confining Layer or Aquiclude
	Lower or Confined Aquifer
	Perched Aquifer
X	Surface Aquifer
	Unsaturated Zone
	Water Table Aquifer

Reviewed By: _____ Date: _____
RG No.: _____

WELL CONSTRUCTION DETAILS

Well Name: FWI-1
Supervised by: Jeff Brammer
Well Type: GWMW

Boring No: 2A-G12 Location Description: East side of Building 5, toward the north

Installation Date: 05/22/99 Project: Alameda Point - SESR for DNAPL

Location Proximity : Building 5, toward north, South central outside of Treatability Study Cell
(Inside or Outside Facility)

Drilling Company: Beylik Drilling

Construction Method: HSA

Drilling Method: Hollow Stem Auger

Owner: Alameda Point

Owner's Address: Alameda, CA

Owner's Telephone: 650/244-2526

Surface Completion Type
12" Christie Box

Type/Amount of Grout
Neat Cement/20 gallons

Gallons of Water
8 gallons

Sacks of Cement
2 (100) lb. Sks.

Pounds of Bentonite
6 lbs.

Type/Amount of Bentonite Seal
3/8" bentonite chips
(3) 50 lb. sacks

Type/Amount of Sand Bridge
NA

Type/Amount of Sand Pack
#3/ (2) 100 lb. sacks

Survey Data
Northing

Easting

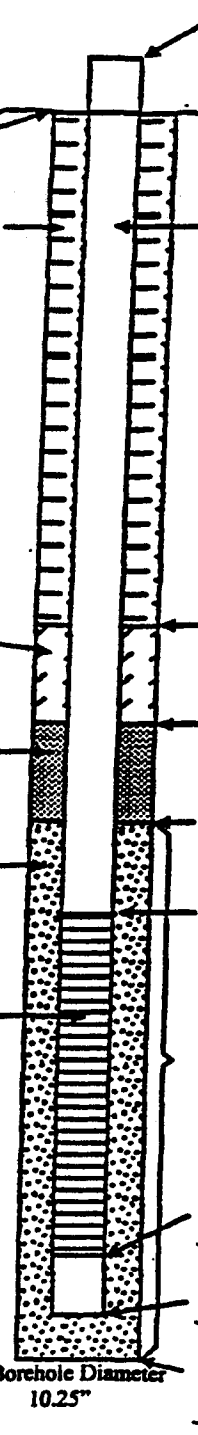
Units for Coordinates

Coord. System

Measuring Point Elevation

Company

Survey Date



	Geohydrologic zone
	Aquifer
	Confining Layer or Aquiclude
	Lower or Confined Aquifer
	Perched Aquifer
X	Surface Aquifer
	Unsaturated Zone
	Water Table Aquifer

Screen Type and Length
Stainless Steel: PVC/4 ft

Screen Slot Size: 0.02 inch

Screen Diameter: 4 inch

Screen % Open

Screen Material
Factory slotted

Reviewed By: _____ Date: _____
RG No.: _____

WELL CONSTRUCTION DETAILS

Well Name: IW-1
Supervised by: Jeff Brammer
Well Type: GWMW

Boring No: 2A-G13 Location Description: East side of Building 5, toward the north

Installation Date: 05/22/99 Project: Alameda Point - SESR for DNAPL

Location Proximity : Building 5, toward north, South central area inside of Treatability Study Cell
(Inside or Outside Facility)

Drilling Company: Beylik Drilling

Construction Method: HSA

Drilling Method: Hollow Stem Auger

Owner: Alameda Point

Owner's Address: Alameda, CA

Owner's Telephone: 650/244-2526

Surface Completion Type
12" Christie Box

Type/Amount of Grout
Neat Cement/20 gallons

Gallons of Water
8 gallons

Sacks of Cement
2 (100) lb. Sks.

Pounds of Bentonite
6 lbs.

Type/Amount of Bentonite Seal
3/8" bentonite chips
(3) 50 lb. sacks

Type/Amount of Sand Bridge
NA

Type/Amount of Sand Pack
#3/ (2) 100 lb. sacks

Survey Data
Northing

Easting

Units for Coordinates

Coord. System

Measuring Point Elevation

Survey Company

Survey Date

Screen Type and Length
Stainless Steel: PVC/4 ft

Screen Slot Size: 0.02 inch

Screen Diameter: 4 inch

Screen % Open

Screen Material
Factory slotted

Measuring Point Location (i.e., TOC)

Ground Surface Elevation:

Well Details:
Casing Type
PVC
And Amount
13.5 ft
Casing Diameter
4 inch
Centralizer Spacing
NA
And Number Used
NA

	Geohydrologic zone
	Aquifer
	Confining Layer or Aquiclude
	Lower or Confined Aquifer
	Perched Aquifer
X	Surface Aquifer
	Unsaturated Zone
	Water Table Aquifer

Top of Bentonite Seal:
4.0'

Top of Sand Bridge
NA

Top of Sand Pack
12.0'

Top of Screen
13.5'

Filter Pack Length:
6.0'

Bottom of Screen:
17.5'

Total Well Casing Depth:
18.0'

Borehole Diameter
10.25"

Borehole Depth
18.0'

Reviewed By: _____ Date: _____
RG No.: _____

WELL CONSTRUCTION DETAILS

Well Name: RW-3
Supervised by: Jeff Brammer
Well Type: GWMW

Boring No: 2A-G14 Location Description: East side of Building 5, toward the north

Installation Date: 05/22/99 Project: Alameda Point - SESR for DNAPL

Location Proximity : Building 5, toward north, SE corner of Treatability Study Cell
(Inside or Outside Facility)

Drilling Company: Beylik Drilling

Construction Method: HSA

Drilling Method: Hollow Stem Auger

Owner: Alameda Point

Owner's Address: Alameda, CA

Owner's Telephone: 650/244-2526

Surface Completion Type
12" Christie Box

Type/Amount of Grout
Neat Cement/20 gallons

Gallons of Water
8 gallons

Sacks of Cement
2 (100) lb. Sks.

Pounds of Bentonite
6 lbs.

Type/Amount of Bentonite Seal
3/8" bentonite chips
(3) 50 lb. sacks

Type/Amount of Sand Bridge
NA

Type/Amount of Sand Pack
#3/ (2) 100 lb. sacks

Survey Data
Northing

Easting

Units for Coordinates

Coord. System

Measuring Point Elevation

Survey Company

Survey Date

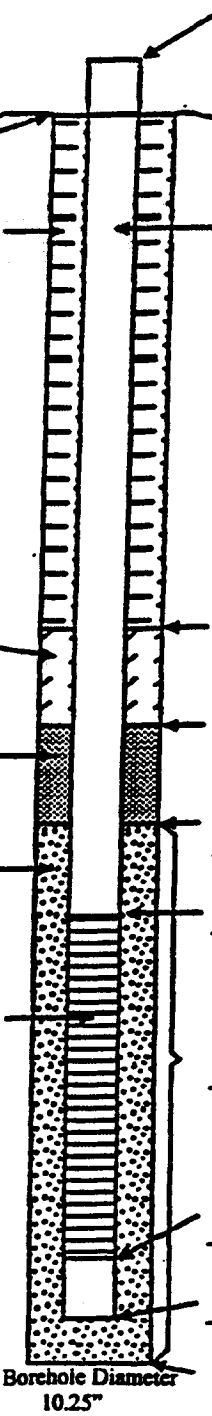
Screen Type and Length
Stainless Steel: PVC/4 ft

Screen Slot Size: 0.02 inch

Screen Diameter: 4 inch

Screen % Open

Screen Material
Factory slotted



Borehole Diameter
10.25"

Measuring Point Location (i.e., TOC)

Ground Surface Elevation:

Well Details:

Casing Type
PVC

And Amount
13.5 ft

Casing Diameter
4 inch

Centralizer Spacing
NA

And Number Used
NA

Top of Bentonite Seal:
4.0'

Top of Sand Bridge
NA

Top of Sand Pack
12.0'

Top of Screen
13.5'

Filter Pack Length:
6.0'

Bottom of Screen:
17.5'

Total Well Casing Depth:
18.0'

Borehole Depth
18.0'

	Geohydrologic zone
	Aquifer
	Confining Layer or Aquiclude
	Lower or Confined Aquifer
	Perched Aquifer
X	Surface Aquifer
	Unsaturated Zone
	Water Table Aquifer

Reviewed By: _____ *Date:* _____

RG No.: _____

WELL CONSTRUCTION DETAILS

Well Name: **RW-2**
Supervised by: Jeff Brammer
Well Type: GWMW

Boring No: 2A-G15 Location Description: East side of Building 5, toward the north

Installation Date: 05/22/99 Project: Alameda Point - SESR for DNAPL

Location Proximity: Building 5, toward north, NW corner of Treatability Study Cell
(Inside or Outside Facility)

Drilling Company: Beylik Drilling

Construction Method: HSA

Drilling Method: Hollow Stem Auger

Owner: Alameda Point

Owner's Address: Alameda, CA

Owner's Telephone: 650/244-2526

Surface Completion Type
12" Christie Box

Type/Amount of Grout
Neat Cement/20 gallons

Gallons of Water
8 gallons

Sacks of Cement
2 (100) lb. Sks.

Pounds of Bentonite
6 lbs.

Type/Amount of Bentonite Seal
3/8" bentonite chips
(3) 50 lb. sacks

Type/Amount of Sand Bridge
NA

Type/Amount of Sand Pack
#3/ (2) 100 lb. sacks

Survey Data
Northing

Easting

Units for Coordinates

Coord. System

Measuring Point Elevation

Company

Survey Date

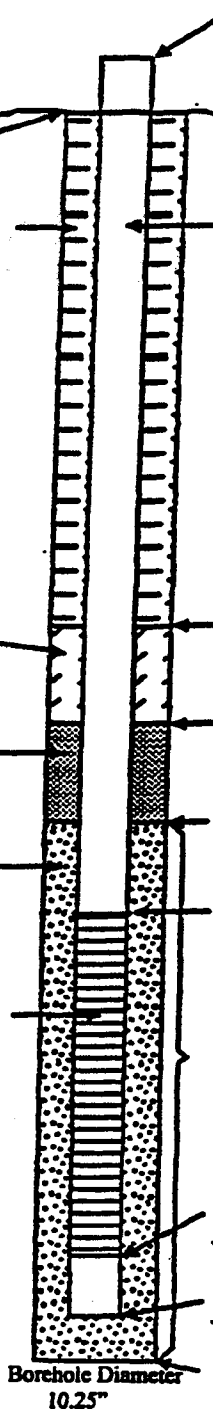
Screen Type and Length
Stainless Steel: PVC/4 ft

Screen Slot Size: 0.02 inch

Screen Diameter: 4 inch

Screen % Open

Screen Material
Factory slotted



Measuring Point Location (i.e., TOC)

Ground Surface Elevation:

Well Details:
Casing Type
PVC
And Amount
13.5 ft
Casing Diameter
4 inch
Centralizer Spacing
NA
And Number Used
NA

Top of Bentonite Seal:
4.0'

Top of Sand Bridge
NA

Top of Sand Pack
12.0'

Top of Screen
13.5'

Filter Pack Length:
6.0'

Bottom of Screen:
17.5'

Total Well Casing Depth:
18.0'

Borehole Diameter
10.25"

Borehole Depth
18.0'

	Geohydrologic zone
	Aquifer
	Confining Layer or Aquiclude
	Lower or Confined Aquifer
	Perched Aquifer
X	Surface Aquifer
	Unsaturated Zone
	Water Table Aquifer

Reviewed By: _____ *Date:* _____

RG No.: _____

WELL CONSTRUCTION DETAILS

Well Name: RW-4
Supervised by: Jeff Brammer
Well Type: GWMW

Boring No: 2A-G16 Location Description: East side of Building 5, toward the north

Installation Date: 05/22/99 *Project: Alameda Point - SESR for DNAPL*

Location Proximity : Building 5, toward north, NE corner of Treatability Study Cell
(Inside or Outside Facility)

Drilling Company: Beylik Drilling

Construction Method: HSA

Drilling Method: Hollow Stem Auger

Owner: Alameda Point

Owner's Address: Alameda, CA

Owner's Telephone: 650/244-2526

Measuring Point Location (i.e., TOC)

Ground Surface Elevation:

Surface Completion Type
12" Christie Box

Type/Amount of Grout
Neat Cement/20 gallons

Gallons of Water
8 gallons

Sacks of Cement
2 (100) lb. Sks.

Pounds of Bentonite
6 lbs.

Well Details:

Casing Type
PVC

And Amount
13.5 ft

Casing Diameter
4 inch

Centralizer Spacing
NA

And Number Used
NA

	Geohydrologic zone
	Aquifer
	Confining Layer or Aquiclude
	Lower or Confined Aquifer
	Perched Aquifer
X	Surface Aquifer
	Unsaturated Zone
	Water Table Aquifer

Type/Amount of Bentonite Seal
3/8" bentonite chips
(3) 50 lb. sacks

Top of Bentonite Seal:
4.0'

Type/Amount of Sand Bridge
NA

Top of Sand Bridge
NA

Type/Amount of Sand Pack
#3/ (2) 100 lb. sacks

Top of Sand Pack
12.0'

Top of Screen
13.5'

Survey Data
Northing

Easting

Units for Coordinates

Coord. System

Measuring Point Elevation

Company

Survey Date

Screen Type and Length
Stainless Steel: PVC/4 ft

Screen Slot Size: 0.02 inch

Screen Diameter: 4 inch

Screen % Open

Screen Material
Factory slotted

Filter Pack Length:
6.0'

Bottom of Screen:
17.5'

Total Well Casing Depth:
18.0'

Borehole Diameter
10.25"

Borehole Depth
18.0'

Reviewed By: _____ *Date:* _____

RG No.: _____

WELL CONSTRUCTION DETAILS

Well Name: FWI-2
Supervised by: Jeff Brammer
Well Type: GWMW

Boring No: 2A-G18 Location Description: East side of Building 5, toward the north

Installation Date: 05/22/99 Project: Alameda Point - SESR for DNAPL

Location Proximity : Building 5, toward north, North central outside of Treatability Study Cell
(Inside or Outside Facility)

Drilling Company: Beylik Drilling

Construction Method: HSA

Drilling Method: Hollow Stem Auger

Owner: Alameda Point

Owner's Address: Alameda, CA

Owner's Telephone: 650/244-2526

Surface Completion Type
12" Christie Box

Type/Amount of Grout
Neat Cement/20 gallons

Gallons of Water
8 gallons

Sacks of Cement
2 (100) lb. Sks.

Pounds of Bentonite
6 lbs.

Type/Amount of Bentonite Seal
3/8" bentonite chips
(3) 50 lb. sacks

Type/Amount of Sand Bridge
NA

Type/Amount of Sand Pack
#3/ (2) 100 lb. sacks

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Company

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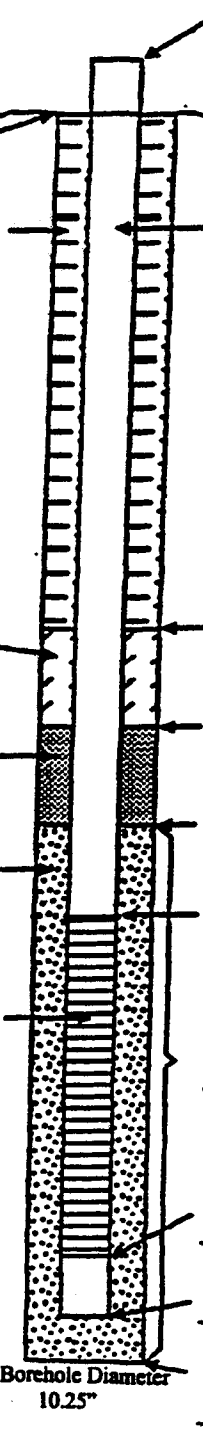
Screen Type and Length
Stainless Steel: PVC/4 ft

Screen Slot Size: 0.02 inch

Screen Diameter: 4 inch

Screen % Open

Screen Material
Factory slotted



Measuring Point Location (i.e., TOC)

Ground Surface Elevation:

Well Details:
Casing Type
PVC
And Amount
13.5 ft
Casing Diameter
4 inch
Centralizer Spacing
NA
And Number Used
NA

	Geohydrologic zone
	Aquifer
	Confining Layer or Aquiclude
	Lower or Confined Aquifer
	Perched Aquifer
X	Surface Aquifer
	Unsaturated Zone
	Water Table Aquifer

Top of Bentonite Seal:
4.0'

Top of Sand Bridge
NA

Top of Sand Pack
12.0'

Top of Screen
13.5'

Filter Pack Length:
6.0'

Bottom of Screen:
17.5'

Total Well Casing Depth:
18.0'

Borehole Diameter
10.25"

Borehole Depth
18.0'

Reviewed By: _____ *Date:* _____
RG No.: _____

APPENDIX B
AQUIFER CHARACTERIZATION
PUMP TEST DATA

PUMP TEST DATA
STEP 1 – 1.82 GPM

SE2000
Environmental Logger
05/24 10:21

Unit# 604 Test 0

Setups:	INPUT 1	INPUT 2	INPUT 3	INPUT 4	INPUT 5	INPUT 6
Type	Level (F)	Level (F)	Level (F)	Level (F)	Level (F)	Level (F)
Mode	TOC	TOC	TOC	TOC	TOC	TOC
I.D.	IW1	MW2A	RW2	RW3	IW2	FWI2
Reference	0.000	0.000	0.000	0.000	0.000	0.000
PSI at Ref.	3.063	3.194	3.967	4.039	3.403	3.318
SG	1.000	1.000	1.000	1.000	1.000	1.000
Linearity	0.005	0.042	0.012	0.045	0.005	0.019
Scale factor	10.032	10.038	10.061	9.963	9.991	9.996
Offset	-0.059	-0.194	-0.040	-0.048	-0.053	0.009
Delay mSEC	50.000	50.000	50.000	50.000	50.000	50.000

Step 0 05/23 13:13:45

Elapsed Time	INPUT 1	INPUT 2	INPUT 3	INPUT 4	INPUT 5	INPUT 6
0.0000	0.006	8.943	-0.019	-0.069	-0.103	-0.028
0.0083	0.009	8.940	-0.019	-0.072	-0.097	-0.028
0.0166	0.022	8.918	-0.019	-0.069	-0.084	-0.028
0.0250	0.031	8.937	-0.019	-0.069	-0.078	-0.028
0.0333	0.047	8.931	-0.019	-0.069	-0.072	-0.028
0.0416	0.069	8.937	-0.019	-0.069	-0.069	-0.028
0.0500	0.094	8.934	-0.019	-0.069	-0.069	-0.031
0.0583	0.116	8.940	-0.019	-0.069	-0.069	-0.028
0.0666	0.138	8.931	-0.019	-0.069	-0.065	-0.028
0.0750	0.161	8.940	-0.019	-0.069	-0.065	-0.028
0.0833	0.186	8.934	-0.019	-0.069	-0.065	-0.028
0.0916	0.208	8.931	-0.019	-0.069	-0.065	-0.028
0.1000	0.230	8.940	-0.019	-0.069	-0.059	-0.031
0.1083	0.255	8.931	-0.019	-0.069	-0.056	-0.028
0.1166	0.277	8.940	-0.015	-0.069	-0.053	-0.028
0.1250	0.300	8.931	-0.019	-0.069	-0.050	-0.031
0.1333	0.322	8.931	-0.019	-0.069	-0.050	-0.031
0.1416	0.344	8.937	-0.019	-0.069	-0.050	-0.031
0.1500	0.366	8.934	-0.019	-0.069	-0.053	-0.031
0.1583	0.391	8.943	-0.015	-0.069	-0.056	-0.028
0.1666	0.413	8.934	-0.015	-0.069	-0.056	-0.028
0.1750	0.435	8.934	-0.019	-0.069	-0.059	-0.031
0.1833	0.458	8.940	-0.015	-0.069	-0.059	-0.031
0.1916	0.480	8.931	-0.015	-0.069	-0.062	-0.031
0.2000	0.502	8.931	-0.015	-0.069	-0.062	-0.028
0.2083	0.524	8.937	-0.015	-0.069	-0.065	-0.028
0.2166	0.546	8.934	-0.015	-0.069	-0.059	-0.028

0.2250	0.568	8.940	-0.015	-0.069	-0.059	-0.028
0.2333	0.590	8.934	-0.015	-0.069	-0.062	-0.028
0.2416	0.609	8.931	-0.015	-0.069	-0.065	-0.028
0.2500	0.631	8.940	-0.015	-0.069	-0.069	-0.028
0.2583	0.650	8.931	-0.015	-0.069	-0.069	-0.028
0.2666	0.672	8.931	-0.015	-0.069	-0.069	-0.028
0.2750	0.691	8.940	-0.015	-0.069	-0.069	-0.028
0.2833	0.710	8.931	-0.015	-0.069	-0.065	-0.031
0.2916	0.729	8.931	-0.015	-0.069	-0.065	-0.028
0.3000	0.748	8.940	-0.015	-0.066	-0.065	-0.028
0.3083	0.767	8.931	-0.015	-0.066	-0.069	-0.031
0.3166	0.786	8.934	-0.015	-0.066	-0.069	-0.031
0.3250	0.805	8.934	-0.015	-0.066	-0.069	-0.028
0.3333	0.824	8.934	-0.015	-0.066	-0.072	-0.028
0.3500	0.862	8.934	-0.015	-0.066	-0.069	-0.028
0.3666	0.897	8.940	-0.015	-0.066	-0.069	-0.028
0.3833	0.931	8.931	-0.015	-0.066	-0.069	-0.028
0.4000	0.972	8.931	-0.015	-0.066	-0.069	-0.028
0.4166	1.004	8.937	-0.015	-0.066	-0.069	-0.028
0.4333	1.039	8.940	-0.015	-0.066	-0.069	-0.028
0.4500	1.070	8.931	-0.015	-0.066	-0.069	-0.028
0.4666	1.105	8.934	-0.015	-0.062	-0.065	-0.028
0.4833	1.137	8.934	-0.015	-0.062	-0.065	-0.028
0.5000	1.168	8.937	-0.015	-0.062	-0.062	-0.028
0.5166	1.200	8.940	-0.015	-0.062	-0.062	-0.028
0.5333	1.231	8.931	-0.012	-0.062	-0.059	-0.028
0.5500	1.263	8.934	-0.015	-0.059	-0.056	-0.028
0.5666	1.291	8.931	-0.012	-0.059	-0.059	-0.028
0.5833	1.320	8.937	-0.012	-0.059	-0.059	-0.028
0.6000	1.351	8.940	-0.012	-0.059	-0.059	-0.028
0.6166	1.380	8.943	-0.012	-0.056	-0.059	-0.028
0.6333	1.408	8.931	-0.012	-0.056	-0.059	-0.028
0.6500	1.437	8.934	-0.012	-0.056	-0.059	-0.028
0.6666	1.462	8.934	-0.012	-0.056	-0.059	-0.028
0.6833	1.490	8.937	-0.012	-0.056	-0.059	-0.028
0.7000	1.519	8.940	-0.012	-0.053	-0.059	-0.025
0.7166	1.544	8.943	-0.012	-0.053	-0.059	-0.025
0.7333	1.569	8.940	-0.012	-0.053	-0.059	-0.025
0.7500	1.595	8.931	-0.012	-0.053	-0.059	-0.025
0.7666	1.620	8.934	-0.012	-0.050	-0.059	-0.025
0.7833	1.645	8.934	-0.012	-0.050	-0.059	-0.025
0.8000	1.667	8.934	-0.012	-0.050	-0.059	-0.025
0.8166	1.689	8.937	-0.009	-0.047	-0.059	-0.025
0.8333	1.715	8.940	-0.009	-0.047	-0.062	-0.025
0.8500	1.737	8.943	-0.009	-0.047	-0.059	-0.025
0.8666	1.759	8.940	-0.009	-0.047	-0.059	-0.025
0.8833	1.784	8.931	-0.009	-0.044	-0.059	-0.025
0.9000	1.806	8.934	-0.009	-0.044	-0.059	-0.025
0.9166	1.828	8.931	-0.009	-0.044	-0.059	-0.025
0.9333	1.847	8.931	-0.009	-0.040	-0.059	-0.025
0.9500	1.869	8.934	-0.009	-0.040	-0.059	-0.025
0.9666	1.888	8.937	-0.009	-0.040	-0.059	-0.025

0.9833	1.911	8.940	-0.009	-0.037	-0.059	-0.025
1.0000	1.929	8.940	-0.009	-0.037	-0.059	-0.025
1.2000	2.154	8.937	-0.003	-0.028	-0.037	-0.022
1.4000	2.334	8.934	0.000	-0.018	-0.028	-0.018
1.6000	2.482	8.946	0.003	-0.009	-0.021	-0.018
1.8000	2.609	8.940	0.003	-0.003	-0.015	-0.018
2.0000	2.719	8.934	0.006	0.009	-0.009	-0.015
2.2000	2.814	8.943	0.012	0.018	-0.003	-0.012
2.4000	2.890	8.943	0.012	0.028	0.000	-0.012
2.6000	2.959	8.937	0.015	0.037	0.003	-0.009
2.8000	3.016	8.937	0.022	0.040	0.009	-0.006
3.0000	3.067	8.943	0.022	0.047	0.009	-0.003
3.2000	3.108	8.937	0.025	0.053	0.012	0.000
3.4000	3.145	8.934	0.028	0.062	0.012	0.003
3.6000	3.177	8.940	0.028	0.066	0.009	0.003
3.8000	3.205	8.946	0.031	0.069	0.006	0.003
4.0000	3.228	8.937	0.031	0.072	0.003	0.000
4.2000	3.250	8.940	0.034	0.075	0.000	0.003
4.4000	3.272	8.946	0.038	0.081	-0.003	0.006
4.6000	3.294	8.946	0.041	0.088	-0.006	0.009
4.8000	3.310	8.946	0.041	0.094	-0.006	0.012
5.0000	3.322	8.946	0.044	0.094	-0.009	0.015
5.2000	3.332	8.943	0.044	0.100	-0.012	0.015
5.4000	3.344	8.937	0.047	0.100	-0.015	0.018
5.6000	3.351	8.934	0.047	0.103	-0.018	0.018
5.8000	3.329	8.943	0.047	0.103	-0.021	0.018
6.0000	3.297	8.934	0.050	0.107	-0.025	0.025
6.2000	3.269	8.946	0.053	0.107	-0.031	0.022
6.4000	3.250	8.937	0.053	0.103	-0.037	0.022
6.6000	3.237	8.943	0.053	0.103	-0.040	0.025
6.8000	3.221	8.937	0.053	0.103	-0.047	0.025
7.0000	3.209	8.940	0.053	0.103	-0.053	0.025
7.2000	3.202	8.946	0.053	0.103	-0.062	0.025
7.4000	3.199	8.940	0.057	0.107	-0.065	0.025
7.6000	3.205	8.937	0.057	0.107	-0.072	0.028
7.8000	3.237	8.946	0.057	0.103	-0.081	0.028
8.0000	3.265	8.943	0.057	0.103	-0.087	0.028
8.2000	3.291	8.937	0.060	0.110	-0.091	0.028
8.4000	3.316	8.937	0.060	0.113	-0.094	0.031
8.6000	3.335	8.946	0.060	0.116	-0.097	0.031
8.8000	3.354	8.946	0.060	0.116	-0.103	0.034
9.0000	3.373	8.940	0.063	0.119	-0.109	0.034
9.2000	3.385	8.937	0.063	0.119	-0.113	0.034
9.4000	3.398	8.946	0.066	0.122	-0.116	0.034
9.6000	3.404	8.940	0.066	0.125	-0.119	0.034
9.8000	3.408	8.937	0.066	0.125	-0.122	0.034
10.0000	3.417	6.115	0.069	0.129	-0.097	0.144
11.0000	3.439	5.957	0.069	0.129	-0.122	0.125
12.0000	3.461	5.043	0.076	0.138	-0.153	0.119
13.0000	3.477	6.877	0.076	0.141	-0.182	0.116
14.0000	3.493	2.913	0.079	0.147	-0.210	0.110
15.0000	3.509	7.003	0.085	0.154	-0.232	0.107

16.0000	3.499	5.991	0.088	0.151	-0.251	0.100
17.0000	3.528	6.801	0.091	0.160	-0.276	0.100
18.0000	3.543	3.765	0.088	0.163	-0.295	0.097
19.0000	3.559	3.242	0.095	0.166	-0.314	0.103
20.0000	3.566	7.101	0.095	0.166	-0.342	0.103
21.0000	3.575	3.879	0.095	0.166	-0.370	0.107
22.0000	3.591	6.222	0.101	0.179	-0.389	0.113
23.0000	3.600	4.420	0.104	0.179	-0.411	0.116
24.0000	3.610	5.979	0.107	0.182	-0.430	0.119
25.0000	3.616	3.970	0.107	0.176	-0.449	0.119
26.0000	3.629	5.824	0.107	0.185	-0.468	0.122
27.0000	3.635	6.200	0.110	0.192	-0.480	0.122
28.0000	3.644	6.153	0.114	0.195	-0.496	0.125
29.0000	3.651	2.945	0.114	0.192	-0.518	0.122
30.0000	3.654	6.586	0.114	0.195	-0.537	0.122
31.0000	3.660	6.048	0.117	0.201	-0.553	0.129
32.0000	3.667	3.075	0.117	0.204	-0.571	0.129
33.0000	3.673	3.170	0.120	0.207	-0.600	0.132
34.0000	3.673	5.830	0.120	0.207	-0.628	0.129
35.0000	3.679	6.617	0.123	0.210	-0.650	0.132
36.0000	3.682	2.859	0.120	0.207	-0.685	0.132
37.0000	3.689	5.669	0.123	0.207	-0.713	0.132
38.0000	3.692	5.640	0.123	0.204	-0.782	0.132
39.0000	3.698	6.039	0.126	0.204	-0.813	0.138
40.0000	3.701	3.689	0.126	0.198	-0.832	0.135
41.0000	3.708	6.649	0.129	0.198	-0.845	0.138
42.0000	3.714	5.299	0.129	0.204	-0.857	0.138
43.0000	3.717	3.410	0.129	0.204	-0.870	0.141
44.0000	3.723	4.018	0.133	0.201	-0.886	0.141
45.0000	3.727	6.513	0.133	0.210	-0.898	0.144
46.0000	3.730	3.293	0.133	0.207	-0.917	0.144
47.0000	3.733	4.806	0.133	0.210	-0.930	0.144
48.0000	3.733	2.622	0.136	0.210	-0.945	0.144
49.0000	3.739	2.707	0.136	0.210	-0.958	0.147
50.0000	3.739	3.223	0.133	0.217	-0.967	0.144
51.0000	3.749	3.015	0.136	0.214	-0.980	0.147
52.0000	3.752	2.505	0.136	0.214	-0.986	0.151
53.0000	3.755	3.106	0.139	0.220	-0.996	0.151
54.0000	3.752	3.404	0.136	0.217	-1.011	0.151
55.0000	3.752	3.464	0.139	0.223	-1.021	0.154
56.0000	3.755	6.538	0.139	0.220	-1.033	0.157
57.0000	3.752	5.707	0.139	0.223	-1.049	0.157
58.0000	3.755	6.810	0.142	0.229	-1.055	0.160
59.0000	3.749	3.195	0.142	0.226	-1.068	0.160
60.0000	3.746	3.030	0.142	0.226	-1.081	0.160
61.0000	3.742	5.508	0.142	0.229	-1.093	0.163
62.0000	3.736	4.053	0.142	0.226	-1.103	0.160
63.0000	3.733	5.239	0.142	0.229	-1.115	0.163
64.0000	3.733	3.629	0.142	0.229	-1.125	0.163
65.0000	3.727	3.220	0.142	0.229	-1.137	0.160
66.0000	3.708	2.926	0.142	0.232	-1.147	0.160
67.0000	3.660	3.907	0.142	0.232	-1.153	0.160

68.0000	3.588	5.508	0.139	0.226	-1.169	0.160
69.0000	3.581	5.603	0.142	0.229	-1.184	0.160
70.0000	3.670	5.707	0.142	0.229	-1.191	0.160
71.0000	3.695	4.824	0.142	0.229	-1.200	0.160
72.0000	3.701	5.334	0.142	0.236	-1.209	0.163
73.0000	3.711	3.249	0.142	0.236	-1.216	0.160
74.0000	3.714	5.242	0.139	0.232	-1.225	0.160
75.0000	3.720	4.739	0.139	0.236	-1.231	0.160
76.0000	3.714	3.799	0.139	0.236	-1.241	0.160
77.0000	3.733	5.489	0.139	0.239	-1.247	0.163
78.0000	3.749	4.606	0.139	0.242	-1.253	0.163
79.0000	3.761	3.220	0.139	0.236	-1.263	0.163
80.0000	3.768	4.859	0.139	0.242	-1.272	0.163
81.0000	3.771	3.223	0.139	0.242	-1.279	0.163
82.0000	3.768	6.210	0.139	0.245	-1.285	0.166
83.0000	3.739	6.017	0.139	0.242	-1.294	0.166
84.0000	3.723	3.280	0.139	0.242	-1.310	0.163
85.0000	3.739	4.122	0.136	0.245	-1.319	0.166
86.0000	3.739	4.875	0.139	0.245	-1.329	0.166
87.0000	3.739	3.882	0.139	0.245	-1.332	0.166
88.0000	3.749	5.134	0.139	0.245	-1.338	0.166
89.0000	3.746	5.701	0.139	0.245	-1.345	0.166
90.0000	3.733	5.365	0.136	0.245	-1.348	0.166
91.0000	3.733	3.825	0.136	0.242	-1.357	0.166
92.0000	3.749	3.369	0.139	0.248	-1.360	0.166
93.0000	3.752	4.872	0.136	0.242	-1.367	0.166
94.0000	3.752	5.438	0.133	0.245	-1.373	0.163
95.0000	3.752	5.400	0.133	0.248	-1.379	0.163
96.0000	3.752	3.638	0.133	0.245	-1.385	0.163
97.0000	3.723	6.169	0.133	0.245	-1.395	0.163
98.0000	3.749	4.492	0.133	0.248	-1.398	0.166
99.0000	3.733	5.131	0.133	0.248	-1.404	0.163
100.000	3.720	3.372	0.133	0.248	-1.411	0.163
101.000	3.714	6.548	0.133	0.248	-1.411	0.166
102.000	3.714	6.194	0.133	0.248	-1.417	0.166
103.000	3.708	6.279	0.129	0.248	-1.420	0.166
104.000	3.708	6.105	0.129	0.245	-1.423	0.166
105.000	3.711	2.996	0.129	0.248	-1.429	0.163
106.000	3.711	3.034	0.126	0.245	-1.436	0.163
107.000	3.708	6.564	0.126	0.245	-1.442	0.163
108.000	3.720	6.570	0.126	0.248	-1.445	0.166
109.000	3.720	5.647	0.126	0.248	-1.448	0.163
110.000	3.723	3.543	0.126	0.251	-1.451	0.166
111.000	3.723	4.331	0.126	0.251	-1.458	0.163
112.000	3.727	3.296	0.126	0.248	-1.464	0.163
113.000	3.730	3.059	0.126	0.251	-1.464	0.166
114.000	3.733	6.365	0.123	0.251	-1.467	0.166
115.000	3.739	6.146	0.123	0.251	-1.470	0.166
116.000	3.736	5.916	0.123	0.254	-1.473	0.166
117.000	3.739	3.730	0.123	0.251	-1.477	0.163
118.000	3.736	6.140	0.123	0.251	-1.483	0.163
119.000	3.739	3.489	0.120	0.254	-1.486	0.166

120.000	3.739	3.261	0.120	0.254	-1.486	0.166
121.000	3.739	3.822	0.120	0.254	-1.489	0.166
122.000	3.742	3.556	0.120	0.254	-1.492	0.163
123.000	3.749	3.318	0.120	0.254	-1.499	0.163
124.000	3.749	4.144	0.117	0.254	-1.502	0.163
125.000	3.749	3.977	0.117	0.254	-1.505	0.163
126.000	3.749	4.100	0.117	0.258	-1.508	0.163
127.000	3.755	5.277	0.117	0.258	-1.508	0.166
128.000	3.755	6.532	0.117	0.258	-1.508	0.163
129.000	3.755	3.958	0.117	0.258	-1.511	0.166
130.000	3.752	6.042	0.117	0.258	-1.511	0.166
131.000	3.752	3.204	0.114	0.258	-1.514	0.166
132.000	3.752	4.375	0.114	0.258	-1.517	0.166
133.000	3.755	3.166	0.114	0.258	-1.517	0.166
134.000	3.578	3.208	0.110	0.258	-1.521	0.166
135.000	3.534	3.622	0.110	0.251	-1.527	0.163
136.000	3.635	3.489	0.110	0.251	-1.530	0.163
137.000	3.689	3.065	0.110	0.251	-1.530	0.160
138.000	3.717	3.698	0.110	0.251	-1.536	0.160
139.000	3.739	3.173	0.110	0.254	-1.536	0.160
140.000	3.746	5.656	0.107	0.258	-1.536	0.163
141.000	3.746	3.502	0.107	0.258	-1.539	0.163
142.000	3.749	3.192	0.110	0.258	-1.539	0.163
143.000	3.749	5.688	0.107	0.261	-1.543	0.163
144.000	3.755	5.893	0.107	0.261	-1.543	0.163
145.000	3.758	5.536	0.107	0.261	-1.546	0.163
146.000	3.761	4.011	0.107	0.261	-1.549	0.163
147.000	3.752	5.305	0.107	0.261	-1.552	0.163
148.000	3.752	3.809	0.107	0.261	-1.555	0.163
149.000	3.752	4.711	0.107	0.261	-1.558	0.163
150.000	3.758	5.811	0.107	0.261	-1.561	0.163
151.000	3.761	6.090	0.104	0.264	-1.561	0.163
152.000	3.761	4.698	0.104	0.261	-1.561	0.163
153.000	3.758	3.695	0.104	0.261	-1.561	0.163
154.000	3.761	3.337	0.101	0.261	-1.565	0.163
155.000	3.768	3.663	0.101	0.261	-1.565	0.163
156.000	3.764	3.742	0.098	0.261	-1.568	0.163
157.000	3.764	5.065	0.098	0.261	-1.568	0.163
158.000	3.771	4.881	0.098	0.261	-1.571	0.163

PUMP TEST DATA
STEP 2 – 2.36 GPM

SE2000
Environmental Logger
05/24 10:32

Unit# 604 Test 0

Setups:	INPUT 1	INPUT 2	INPUT 3	INPUT 4	INPUT 5	INPUT 6
Type	Level (F)	Level (F)	Level (F)	Level (F)	Level (F)	Level (F)
Mode	TOC	TOC	TOC	TOC	TOC	TOC
I.D.	IW1	MW2A	RW2	RW3	IW2	FWI2
Reference	0.000	0.000	0.000	0.000	0.000	0.000
PSI at Ref.	3.063	3.194	3.967	4.039	3.403	3.318
SG	1.000	1.000	1.000	1.000	1.000	1.000
Linearity	0.005	0.042	0.012	0.045	0.005	0.019
Scale factor	10.032	10.038	10.061	9.963	9.991	9.996
Offset	-0.059	-0.194	-0.040	-0.048	-0.053	0.009
Delay mSEC	50.000	50.000	50.000	50.000	50.000	50.000

Step 1 05/23 15:52:41

Elapsed Time	INPUT 1	INPUT 2	INPUT 3	INPUT 4	INPUT 5	INPUT 6
0.0000	3.771	8.934	0.095	0.261	-1.590	0.141
0.0083	3.771	8.931	0.095	0.264	-1.599	0.141
0.0166	3.774	8.940	0.095	0.264	-1.599	0.141
0.0250	3.777	8.946	0.095	0.264	-1.599	0.141
0.0333	3.783	8.937	0.095	0.264	-1.596	0.141
0.0416	3.787	8.943	0.095	0.264	-1.596	0.141
0.0500	3.790	8.937	0.095	0.264	-1.596	0.141
0.0583	3.793	8.937	0.095	0.264	-1.596	0.141
0.0666	3.799	8.937	0.095	0.264	-1.596	0.141
0.0750	3.802	8.940	0.095	0.264	-1.596	0.141
0.0833	3.809	8.937	0.095	0.264	-1.596	0.141
0.0916	3.812	8.937	0.095	0.264	-1.593	0.141
0.1000	3.815	8.940	0.095	0.264	-1.596	0.141
0.1083	3.818	8.946	0.095	0.264	-1.593	0.141
0.1166	3.825	8.946	0.095	0.264	-1.593	0.141
0.1250	3.828	8.946	0.095	0.264	-1.593	0.141
0.1333	3.831	8.943	0.095	0.264	-1.593	0.141
0.1416	3.837	8.943	0.098	0.264	-1.593	0.141
0.1500	3.840	8.940	0.095	0.264	-1.593	0.141
0.1583	3.847	8.940	0.098	0.264	-1.593	0.141
0.1666	3.850	8.940	0.095	0.264	-1.593	0.141
0.1750	3.853	8.937	0.098	0.264	-1.593	0.141
0.1833	3.859	8.937	0.095	0.264	-1.593	0.141
0.1916	3.862	8.940	0.095	0.264	-1.593	0.141
0.2000	3.866	8.940	0.098	0.264	-1.593	0.141
0.2083	3.869	8.937	0.095	0.264	-1.593	0.141
0.2166	3.875	8.937	0.098	0.264	-1.593	0.141

0.2250	3.878	8.943	0.098	0.264	-1.593	0.141
0.2333	3.881	8.946	0.095	0.264	-1.593	0.141
0.2416	3.885	8.946	0.098	0.264	-1.593	0.141
0.2500	3.891	8.946	0.098	0.264	-1.593	0.141
0.2583	3.894	8.946	0.098	0.264	-1.593	0.141
0.2666	3.897	8.943	0.098	0.264	-1.593	0.141
0.2750	3.900	8.943	0.095	0.264	-1.593	0.141
0.2833	3.903	8.943	0.098	0.264	-1.593	0.141
0.2916	3.907	8.940	0.098	0.264	-1.593	0.141
0.3000	3.910	8.940	0.098	0.264	-1.593	0.141
0.3083	3.916	8.940	0.098	0.264	-1.593	0.141
0.3166	3.919	8.937	0.098	0.264	-1.590	0.141
0.3250	3.922	8.937	0.098	0.264	-1.590	0.141
0.3333	3.922	8.937	0.098	0.264	-1.590	0.141
0.3500	3.932	8.940	0.095	0.264	-1.587	0.141
0.3666	3.938	8.937	0.095	0.264	-1.587	0.141
0.3833	3.945	8.946	0.095	0.264	-1.587	0.141
0.4000	3.951	8.946	0.095	0.264	-1.587	0.141
0.4166	3.957	8.946	0.095	0.264	-1.587	0.141
0.4333	3.963	8.943	0.095	0.264	-1.590	0.141
0.4500	3.970	8.943	0.095	0.264	-1.590	0.141
0.4666	3.976	8.940	0.095	0.264	-1.590	0.141
0.4833	3.982	8.937	0.095	0.264	-1.590	0.141
0.5000	3.989	8.940	0.095	0.264	-1.590	0.141
0.5166	3.995	8.940	0.095	0.264	-1.590	0.141
0.5333	4.001	8.946	0.095	0.264	-1.590	0.141
0.5500	4.008	8.946	0.095	0.264	-1.590	0.141
0.5666	4.014	8.946	0.095	0.264	-1.590	0.141
0.5833	4.017	8.943	0.095	0.264	-1.590	0.141
0.6000	4.023	8.940	0.095	0.264	-1.590	0.141
0.6166	4.030	8.937	0.095	0.264	-1.590	0.141
0.6333	4.036	8.940	0.095	0.264	-1.590	0.141
0.6500	4.039	8.940	0.095	0.264	-1.590	0.141
0.6666	4.046	8.946	0.095	0.264	-1.590	0.141
0.6833	4.052	8.949	0.095	0.264	-1.590	0.141
0.7000	4.058	8.946	0.095	0.267	-1.590	0.141
0.7166	4.061	8.943	0.095	0.264	-1.590	0.141
0.7333	4.065	8.940	0.095	0.264	-1.593	0.141
0.7500	4.071	8.937	0.095	0.264	-1.593	0.141
0.7666	4.077	8.940	0.095	0.264	-1.593	0.141
0.7833	4.080	8.943	0.095	0.264	-1.593	0.141
0.8000	4.087	8.949	0.095	0.264	-1.593	0.141
0.8166	4.090	8.946	0.095	0.264	-1.593	0.141
0.8333	4.096	8.943	0.095	0.267	-1.593	0.141
0.8500	4.099	8.940	0.095	0.264	-1.593	0.141
0.8666	4.106	8.937	0.095	0.264	-1.593	0.141
0.8833	4.109	8.940	0.095	0.267	-1.593	0.141
0.9000	4.112	8.940	0.095	0.267	-1.593	0.141
0.9166	4.118	8.946	0.095	0.267	-1.593	0.141
0.9333	4.121	8.946	0.095	0.267	-1.593	0.141
0.9500	4.128	8.943	0.095	0.267	-1.593	0.141
0.9666	4.131	8.943	0.095	0.267	-1.593	0.141

0.9833	4.137	8.940	0.095	0.267	-1.593	0.141
1.0000	4.140	8.937	0.095	0.267	-1.593	0.141
1.2000	4.191	8.940	0.095	0.270	-1.580	0.144
1.4000	4.229	8.946	0.098	0.270	-1.580	0.144
1.6000	4.264	8.940	0.095	0.273	-1.577	0.144
1.8000	4.289	8.940	0.095	0.276	-1.577	0.144
2.0000	4.314	8.940	0.095	0.276	-1.577	0.144
2.2000	4.333	8.949	0.095	0.280	-1.574	0.144
2.4000	4.352	8.937	0.095	0.280	-1.574	0.144
2.6000	4.368	8.949	0.095	0.283	-1.574	0.144
2.8000	4.380	8.946	0.095	0.283	-1.571	0.147
3.0000	4.393	8.937	0.095	0.286	-1.571	0.147
3.2000	4.402	8.946	0.095	0.286	-1.568	0.147
3.4000	4.412	8.940	0.095	0.286	-1.571	0.147
3.6000	4.415	8.943	0.095	0.289	-1.568	0.151
3.8000	4.425	8.937	0.095	0.289	-1.568	0.151
4.0000	4.428	8.943	0.095	0.289	-1.568	0.151
4.2000	4.428	8.937	0.095	0.292	-1.565	0.151
4.4000	4.393	8.937	0.095	0.292	-1.565	0.151
4.6000	4.368	8.946	0.095	0.292	-1.565	0.151
4.8000	4.346	8.943	0.095	0.292	-1.565	0.151
5.0000	4.324	8.946	0.095	0.292	-1.565	0.151
5.2000	4.308	8.937	0.095	0.292	-1.565	0.151
5.4000	4.292	8.946	0.095	0.292	-1.565	0.154
5.6000	4.279	8.946	0.095	0.292	-1.568	0.154
5.8000	4.289	8.940	0.095	0.292	-1.565	0.154
6.0000	4.308	8.937	0.091	0.292	-1.565	0.151
6.2000	4.324	8.943	0.091	0.292	-1.568	0.154
6.4000	4.339	8.946	0.091	0.292	-1.568	0.154
6.6000	4.352	8.940	0.091	0.292	-1.568	0.154
6.8000	4.365	8.940	0.091	0.292	-1.568	0.154
7.0000	4.371	8.943	0.091	0.292	-1.568	0.154
7.2000	4.384	8.946	0.091	0.292	-1.568	0.154
7.4000	4.393	8.937	0.091	0.292	-1.568	0.154
7.6000	4.399	8.943	0.091	0.295	-1.568	0.154
7.8000	4.406	8.940	0.091	0.295	-1.568	0.154
8.0000	4.412	8.937	0.091	0.295	-1.568	0.154
8.2000	4.418	8.943	0.091	0.295	-1.568	0.154
8.4000	4.418	8.940	0.091	0.295	-1.568	0.154
8.6000	4.425	8.940	0.091	0.299	-1.568	0.154
8.8000	4.428	8.943	0.091	0.299	-1.568	0.154
9.0000	4.431	8.940	0.091	0.299	-1.568	0.154
9.2000	4.434	8.940	0.088	0.299	-1.568	0.154
9.4000	4.434	8.946	0.088	0.299	-1.568	0.154
9.6000	4.434	8.940	0.088	0.299	-1.568	0.154
9.8000	4.440	8.940	0.088	0.299	-1.568	0.154
10.0000	4.440	5.384	0.088	0.299	-1.558	0.176
11.0000	4.450	3.473	0.088	0.302	-1.552	0.179
12.0000	4.450	4.147	0.088	0.302	-1.552	0.179
13.0000	4.453	4.783	0.088	0.302	-1.552	0.179
14.0000	4.456	3.416	0.088	0.302	-1.552	0.179
15.0000	4.469	3.499	0.088	0.305	-1.549	0.179

16.0000	4.472	3.407	0.088	0.308	-1.549	0.182
17.0000	4.469	4.692	0.088	0.308	-1.552	0.182
18.0000	4.466	5.308	0.085	0.308	-1.552	0.179
19.0000	4.466	3.337	0.085	0.308	-1.555	0.182
20.0000	4.472	5.606	0.085	0.308	-1.555	0.182
21.0000	4.475	3.407	0.085	0.308	-1.555	0.182
22.0000	4.478	4.401	0.082	0.308	-1.558	0.182
23.0000	4.475	5.549	0.082	0.308	-1.558	0.182
24.0000	4.478	3.410	0.079	0.308	-1.561	0.182
25.0000	4.478	5.451	0.079	0.311	-1.561	0.182
26.0000	4.485	3.375	0.079	0.311	-1.565	0.182
27.0000	4.497	3.360	0.082	0.314	-1.565	0.185
28.0000	4.507	4.182	0.079	0.314	-1.565	0.185
29.0000	4.497	3.372	0.079	0.314	-1.565	0.185
30.0000	4.491	4.904	0.079	0.314	-1.568	0.185
31.0000	4.500	3.166	0.079	0.314	-1.568	0.185
32.0000	4.510	3.299	0.076	0.317	-1.568	0.185
33.0000	4.504	5.691	0.076	0.314	-1.568	0.188
34.0000	4.491	4.979	0.076	0.317	-1.568	0.185
35.0000	4.497	5.172	0.072	0.317	-1.568	0.185
36.0000	4.500	3.306	0.072	0.314	-1.568	0.185
37.0000	4.497	4.707	0.072	0.314	-1.574	0.185
38.0000	4.500	4.410	0.072	0.317	-1.574	0.188
39.0000	4.494	3.068	0.072	0.317	-1.574	0.188
40.0000	4.507	3.404	0.072	0.321	-1.577	0.188
41.0000	4.485	5.612	0.076	0.317	-1.577	0.188
42.0000	4.500	3.439	0.076	0.321	-1.580	0.191
43.0000	4.522	5.388	0.076	0.321	-1.580	0.191
44.0000	4.532	4.078	0.079	0.321	-1.580	0.191
45.0000	4.532	3.103	0.079	0.324	-1.580	0.191
46.0000	4.535	4.663	0.079	0.324	-1.580	0.191
47.0000	4.526	3.271	0.076	0.324	-1.583	0.191
48.0000	4.513	4.644	0.076	0.324	-1.583	0.191
49.0000	4.529	3.508	0.076	0.324	-1.580	0.195
50.0000	4.535	4.261	0.072	0.324	-1.583	0.191
51.0000	4.538	4.853	0.072	0.324	-1.583	0.191
52.0000	4.529	3.040	0.069	0.324	-1.587	0.191
53.0000	4.526	5.590	0.069	0.324	-1.587	0.191
54.0000	4.538	4.220	0.069	0.324	-1.587	0.195
55.0000	4.548	3.075	0.069	0.327	-1.587	0.195
56.0000	4.522	5.520	0.069	0.327	-1.587	0.195
57.0000	4.513	3.920	0.069	0.327	-1.587	0.195
58.0000	4.526	3.432	0.066	0.327	-1.587	0.195
59.0000	4.541	5.369	0.066	0.327	-1.590	0.195
60.0000	4.551	5.267	0.066	0.327	-1.590	0.195
61.0000	4.541	4.923	0.066	0.327	-1.593	0.195
62.0000	4.551	2.834	0.063	0.327	-1.593	0.198
63.0000	4.551	3.249	0.063	0.327	-1.596	0.198
64.0000	4.545	4.195	0.063	0.330	-1.596	0.198
65.0000	4.541	3.128	0.063	0.327	-1.599	0.198
66.0000	4.541	3.736	0.063	0.327	-1.599	0.198
67.0000	4.538	5.210	0.063	0.330	-1.599	0.198

68.0000	4.535	3.239	0.063	0.330	-1.599	0.198
69.0000	4.541	2.913	0.063	0.330	-1.602	0.198
70.0000	4.545	5.444	0.060	0.330	-1.602	0.198
71.0000	4.545	2.954	0.063	0.330	-1.605	0.201
72.0000	4.548	3.353	0.063	0.333	-1.605	0.201
73.0000	4.551	2.983	0.060	0.333	-1.605	0.201
74.0000	4.551	4.359	0.060	0.330	-1.605	0.201
75.0000	4.554	3.005	0.057	0.333	-1.605	0.201
76.0000	4.557	3.211	0.057	0.333	-1.605	0.198
77.0000	4.557	3.420	0.053	0.333	-1.605	0.201
78.0000	4.554	3.024	0.053	0.333	-1.609	0.198
79.0000	4.554	5.103	0.053	0.333	-1.609	0.201
80.0000	4.551	3.185	0.050	0.333	-1.609	0.201
81.0000	4.551	5.422	0.050	0.333	-1.609	0.198
82.0000	4.557	3.372	0.047	0.333	-1.609	0.201
83.0000	4.560	4.502	0.047	0.333	-1.609	0.198
84.0000	4.567	3.667	0.047	0.333	-1.612	0.198
85.0000	4.570	4.208	0.047	0.336	-1.612	0.201
86.0000	4.573	2.878	0.047	0.336	-1.612	0.201
87.0000	4.576	4.397	0.044	0.336	-1.615	0.201
88.0000	4.576	3.138	0.044	0.336	-1.615	0.201
89.0000	4.570	5.198	0.044	0.336	-1.615	0.201
90.0000	4.564	3.948	0.044	0.336	-1.615	0.204
91.0000	4.557	5.394	0.044	0.336	-1.618	0.204
92.0000	4.567	3.201	0.044	0.336	-1.618	0.204
93.0000	4.570	2.809	0.041	0.336	-1.618	0.204
94.0000	4.573	5.147	0.041	0.339	-1.618	0.204
95.0000	4.579	3.198	0.041	0.339	-1.621	0.204
96.0000	4.592	5.356	0.041	0.339	-1.624	0.204
97.0000	4.595	5.312	0.038	0.339	-1.621	0.204
98.0000	4.595	2.999	0.038	0.339	-1.621	0.204
99.0000	4.592	5.476	0.038	0.343	-1.618	0.207
100.000	4.592	3.375	0.038	0.339	-1.618	0.207
101.000	4.592	4.249	0.038	0.343	-1.618	0.204
102.000	4.589	3.290	0.034	0.343	-1.621	0.204
103.000	4.589	3.382	0.034	0.343	-1.621	0.207
104.000	4.589	3.337	0.034	0.343	-1.624	0.207
105.000	4.592	4.091	0.034	0.343	-1.621	0.207
106.000	4.601	2.758	0.031	0.343	-1.624	0.207
107.000	4.601	5.097	0.031	0.343	-1.624	0.207
108.000	4.592	3.024	0.031	0.343	-1.624	0.204
109.000	4.589	3.059	0.031	0.343	-1.627	0.207
110.000	4.586	3.116	0.028	0.343	-1.627	0.207
111.000	4.586	4.363	0.031	0.346	-1.627	0.207
112.000	4.589	4.192	0.031	0.346	-1.631	0.207
113.000	4.595	5.172	0.031	0.346	-1.634	0.210
114.000	4.595	3.556	0.028	0.346	-1.631	0.210
115.000	4.595	5.059	0.028	0.346	-1.631	0.210
116.000	4.592	3.344	0.028	0.346	-1.631	0.210
117.000	4.595	3.733	0.025	0.346	-1.634	0.210
118.000	4.592	5.552	0.025	0.346	-1.634	0.210
119.000	4.595	4.847	0.022	0.346	-1.631	0.210

120.000	4.595	3.170	0.022	0.346	-1.631	0.210
121.000	4.598	3.954	0.022	0.346	-1.634	0.210
122.000	4.605	5.318	0.022	0.346	-1.637	0.210
123.000	4.598	3.116	0.019	0.346	-1.640	0.210
124.000	4.601	2.980	0.019	0.346	-1.640	0.210
125.000	4.605	5.116	0.022	0.349	-1.640	0.210
126.000	4.614	3.761	0.022	0.349	-1.640	0.214
127.000	4.614	5.125	0.022	0.349	-1.640	0.214
128.000	4.624	5.489	0.019	0.349	-1.640	0.214
129.000	4.624	3.410	0.019	0.352	-1.640	0.214
130.000	4.627	3.106	0.019	0.352	-1.640	0.214
131.000	4.630	2.939	0.015	0.349	-1.643	0.214

PUMP TEST DATA
STEP 3 – 2.93 GPM

SE2000
Environmental Logger
05/24 10:40

Unit# 604 Test 0

Setups:	INPUT 1	INPUT 2	INPUT 3	INPUT 4	INPUT 5	INPUT 6
Type	Level (F)	Level (F)	Level (F)	Level (F)	Level (F)	Level (F)
Mode	TOC	TOC	TOC	TOC	TOC	TOC
I.D.	IW1	MW2A	RW2	RW3	IW2	FWI2
Reference	0.000	0.000	0.000	0.000	0.000	0.000
PSI at Ref.	3.063	3.194	3.967	4.039	3.403	3.318
SG	1.000	1.000	1.000	1.000	1.000	1.000
Linearity	0.005	0.042	0.012	0.045	0.005	0.019
Scale factor	10.032	10.038	10.061	9.963	9.991	9.996
Offset	-0.059	-0.194	-0.040	-0.048	-0.053	0.009
Delay mSEC	50.000	50.000	50.000	50.000	50.000	50.000

Step 2 05/23 18:04:40

Elapsed Time	INPUT 1	INPUT 2	INPUT 3	INPUT 4	INPUT 5	INPUT 6
0.0000	4.630	8.940	0.012	0.349	-1.659	0.201
0.0083	4.630	8.946	0.012	0.349	-1.665	0.198
0.0166	4.633	8.943	0.012	0.352	-1.665	0.201
0.0250	4.636	8.940	0.012	0.352	-1.665	0.201
0.0333	4.639	8.940	0.012	0.352	-1.668	0.201
0.0416	4.646	8.940	0.012	0.352	-1.668	0.198
0.0500	4.652	8.940	0.012	0.352	-1.665	0.201
0.0583	4.658	8.934	0.012	0.352	-1.668	0.198
0.0666	4.661	8.943	0.012	0.352	-1.668	0.198
0.0750	4.668	8.937	0.012	0.352	-1.668	0.201
0.0833	4.674	8.927	0.012	0.352	-1.668	0.198
0.0916	4.677	8.943	0.012	0.352	-1.668	0.198
0.1000	4.684	8.934	0.012	0.352	-1.668	0.201
0.1083	4.690	8.937	0.012	0.352	-1.668	0.198
0.1166	4.696	8.940	0.012	0.352	-1.668	0.198
0.1250	4.702	8.943	0.012	0.352	-1.668	0.201
0.1333	4.709	8.927	0.012	0.352	-1.668	0.201
0.1416	4.718	8.937	0.012	0.352	-1.668	0.198
0.1500	4.721	8.940	0.012	0.352	-1.668	0.198
0.1583	4.728	8.943	0.012	0.352	-1.668	0.201
0.1666	4.734	8.931	0.012	0.352	-1.668	0.198
0.1750	4.740	8.931	0.012	0.352	-1.668	0.198
0.1833	4.744	8.937	0.012	0.352	-1.668	0.198
0.1916	4.750	8.940	0.012	0.352	-1.668	0.198
0.2000	4.756	8.943	0.012	0.352	-1.668	0.198
0.2083	4.759	8.943	0.012	0.352	-1.668	0.198
0.2166	4.766	8.927	0.012	0.352	-1.668	0.198

0.2250	4.772	8.931	0.012	0.352	-1.668	0.198
0.2333	4.778	8.934	0.012	0.352	-1.668	0.201
0.2416	4.781	8.937	0.012	0.352	-1.668	0.198
0.2500	4.788	8.931	0.012	0.352	-1.668	0.198
0.2583	4.794	8.943	0.012	0.352	-1.668	0.198
0.2666	4.800	8.927	0.012	0.352	-1.668	0.198
0.2750	4.804	8.940	0.012	0.352	-1.668	0.201
0.2833	4.810	8.937	0.012	0.352	-1.668	0.198
0.2916	4.813	8.937	0.012	0.352	-1.668	0.198
0.3000	4.819	8.937	0.012	0.352	-1.668	0.201
0.3083	4.823	8.940	0.012	0.352	-1.668	0.198
0.3166	4.829	8.937	0.012	0.352	-1.668	0.201
0.3250	4.835	8.931	0.012	0.352	-1.668	0.198
0.3333	4.838	8.924	0.012	0.352	-1.668	0.198
0.3500	4.848	8.940	0.012	0.352	-1.665	0.198
0.3666	4.860	8.943	0.012	0.352	-1.665	0.198
0.3833	4.873	8.927	0.012	0.352	-1.665	0.201
0.4000	4.879	8.943	0.012	0.352	-1.665	0.198
0.4166	4.892	8.934	0.012	0.352	-1.665	0.198
0.4333	4.898	8.943	0.012	0.352	-1.665	0.198
0.4500	4.908	8.937	0.012	0.352	-1.665	0.198
0.4666	4.917	8.940	0.012	0.352	-1.665	0.198
0.4833	4.924	8.940	0.012	0.352	-1.668	0.201
0.5000	4.933	8.937	0.012	0.352	-1.665	0.201
0.5166	4.939	8.934	0.012	0.352	-1.665	0.201
0.5333	4.949	8.934	0.012	0.352	-1.665	0.201
0.5500	4.955	8.937	0.012	0.352	-1.665	0.198
0.5666	4.965	8.934	0.012	0.352	-1.665	0.201
0.5833	4.971	8.943	0.012	0.352	-1.665	0.201
0.6000	4.980	8.943	0.012	0.352	-1.665	0.198
0.6166	4.987	8.934	0.012	0.352	-1.665	0.201
0.6333	4.996	8.934	0.012	0.352	-1.665	0.201
0.6500	5.003	8.940	0.012	0.352	-1.665	0.201
0.6666	5.009	8.943	0.012	0.352	-1.665	0.201
0.6833	5.015	8.931	0.012	0.352	-1.665	0.201
0.7000	5.025	8.937	0.012	0.352	-1.665	0.198
0.7166	5.031	8.943	0.012	0.352	-1.665	0.198
0.7333	5.037	8.931	0.012	0.355	-1.665	0.198
0.7500	5.044	8.934	0.012	0.355	-1.665	0.198
0.7666	5.050	8.940	0.012	0.355	-1.665	0.201
0.7833	5.056	8.943	0.012	0.355	-1.665	0.201
0.8000	5.063	8.927	0.012	0.355	-1.665	0.198
0.8166	5.069	8.937	0.012	0.355	-1.665	0.201
0.8333	5.078	8.943	0.012	0.355	-1.665	0.198
0.8500	5.081	8.940	0.012	0.355	-1.665	0.198
0.8666	5.091	8.931	0.012	0.355	-1.665	0.198
0.8833	5.097	8.937	0.012	0.355	-1.665	0.198
0.9000	5.104	8.943	0.012	0.355	-1.665	0.201
0.9166	5.110	8.934	0.012	0.355	-1.665	0.201
0.9333	5.116	8.934	0.012	0.355	-1.665	0.201
0.9500	5.119	8.940	0.012	0.355	-1.665	0.201
0.9666	5.126	8.943	0.012	0.355	-1.665	0.201

0.9833	5.132	8.934	0.012	0.355	-1.665	0.201
1.0000	5.138	8.934	0.012	0.355	-1.665	0.201
1.2000	5.198	8.940	0.012	0.358	-1.656	0.201
1.4000	5.249	8.943	0.012	0.361	-1.653	0.201
1.6000	5.296	8.943	0.012	0.365	-1.649	0.201
1.8000	5.331	8.940	0.012	0.365	-1.646	0.201
2.0000	5.359	8.943	0.012	0.368	-1.646	0.204
2.2000	5.385	8.943	0.012	0.371	-1.646	0.204
2.4000	5.407	8.943	0.012	0.371	-1.643	0.204
2.6000	5.426	8.943	0.009	0.374	-1.643	0.204
2.8000	5.445	8.940	0.009	0.377	-1.640	0.204
3.0000	5.460	8.934	0.012	0.377	-1.640	0.204
3.2000	5.479	8.940	0.012	0.380	-1.640	0.207
3.4000	5.489	8.943	0.012	0.380	-1.637	0.207
3.6000	5.505	8.943	0.012	0.384	-1.637	0.207
3.8000	5.517	8.943	0.012	0.384	-1.637	0.207
4.0000	5.530	8.943	0.012	0.384	-1.634	0.207
4.2000	5.539	8.931	0.012	0.387	-1.634	0.210
4.4000	5.549	8.934	0.012	0.387	-1.634	0.210
4.6000	5.561	8.943	0.012	0.387	-1.634	0.210
4.8000	5.546	8.943	0.012	0.390	-1.634	0.210
5.0000	5.524	8.937	0.012	0.390	-1.631	0.210
5.2000	5.505	8.943	0.012	0.390	-1.631	0.210
5.4000	5.495	8.937	0.012	0.390	-1.631	0.210
5.6000	5.486	8.940	0.012	0.390	-1.631	0.210
5.8000	5.479	8.934	0.009	0.390	-1.634	0.210
6.0000	5.483	8.943	0.009	0.390	-1.634	0.210
6.2000	5.505	8.943	0.009	0.390	-1.634	0.210
6.4000	5.524	8.934	0.009	0.390	-1.634	0.210
6.6000	5.543	8.940	0.009	0.390	-1.634	0.214
6.8000	5.552	8.946	0.009	0.390	-1.634	0.214
7.0000	5.558	8.937	0.009	0.390	-1.634	0.214
7.2000	5.577	8.931	0.009	0.390	-1.634	0.214
7.4000	5.599	8.931	0.009	0.390	-1.634	0.214
7.6000	5.618	8.931	0.009	0.390	-1.634	0.214
7.8000	5.637	8.934	0.009	0.390	-1.634	0.214
8.0000	5.656	8.934	0.009	0.390	-1.634	0.214
8.2000	5.672	8.937	0.009	0.390	-1.634	0.214
8.4000	5.688	8.940	0.006	0.390	-1.634	0.214
8.6000	5.704	8.943	0.006	0.390	-1.634	0.214
8.8000	5.719	8.943	0.006	0.390	-1.634	0.217
9.0000	5.735	8.931	0.009	0.390	-1.634	0.214
9.2000	5.754	8.927	0.006	0.390	-1.634	0.217
9.4000	5.767	8.934	0.006	0.390	-1.634	0.217
9.6000	5.779	8.940	0.006	0.393	-1.631	0.217
9.8000	5.795	8.943	0.006	0.393	-1.634	0.217
10.0000	5.808	2.625	0.006	0.393	-1.627	0.229
11.0000	5.874	3.695	0.006	0.396	-1.621	0.232
12.0000	5.928	1.796	0.003	0.396	-1.621	0.232
13.0000	5.969	2.524	0.003	0.399	-1.621	0.232
14.0000	6.007	3.834	0.003	0.399	-1.621	0.232
15.0000	6.035	5.435	0.000	0.402	-1.618	0.236

16.0000	6.064	2.277	0.000	0.402	-1.618	0.236
17.0000	6.092	3.733	-0.003	0.406	-1.615	0.236
18.0000	6.111	3.511	-0.003	0.402	-1.615	0.232
19.0000	6.146	2.413	0.000	0.406	-1.615	0.236
20.0000	6.162	3.458	0.000	0.409	-1.615	0.239
21.0000	6.180	5.508	0.000	0.409	-1.618	0.239
22.0000	6.206	4.919	0.000	0.412	-1.618	0.239
23.0000	6.228	4.992	0.000	0.412	-1.621	0.239
24.0000	6.237	2.726	0.003	0.412	-1.618	0.239
25.0000	6.244	1.834	0.003	0.412	-1.621	0.242
26.0000	6.244	4.745	0.003	0.412	-1.621	0.242
27.0000	6.253	4.802	0.003	0.412	-1.624	0.242
28.0000	6.272	1.146	0.000	0.415	-1.624	0.242
29.0000	6.278	5.767	0.006	0.415	-1.624	0.242
30.0000	6.291	5.460	0.003	0.418	-1.627	0.242
31.0000	6.300	4.543	0.006	0.415	-1.627	0.242
32.0000	6.307	1.805	0.006	0.418	-1.631	0.242
33.0000	6.326	5.852	0.006	0.418	-1.631	0.242
34.0000	6.351	2.467	0.006	0.418	-1.631	0.245
35.0000	6.379	2.046	0.006	0.421	-1.631	0.245
36.0000	6.408	1.954	0.009	0.421	-1.631	0.245
37.0000	6.430	1.523	0.009	0.421	-1.631	0.245
38.0000	6.443	4.432	0.009	0.424	-1.631	0.248
39.0000	6.471	0.902	0.009	0.424	-1.634	0.248
40.0000	6.490	5.116	0.009	0.424	-1.634	0.248
41.0000	6.503	3.812	0.009	0.424	-1.637	0.245
42.0000	6.531	3.128	0.009	0.424	-1.640	0.248
43.0000	6.540	5.391	0.012	0.424	-1.640	0.248
44.0000	6.553	2.942	0.012	0.424	-1.643	0.248
45.0000	6.575	3.296	0.009	0.428	-1.646	0.251
46.0000	6.594	3.692	0.012	0.428	-1.646	0.251
47.0000	6.616	5.868	0.012	0.428	-1.653	0.248
48.0000	6.635	3.673	0.012	0.428	-1.653	0.251
49.0000	6.660	2.277	0.012	0.431	-1.656	0.251
50.0000	6.679	3.163	0.012	0.431	-1.656	0.251
51.0000	6.689	4.337	0.019	0.431	-1.659	0.251
52.0000	6.695	5.669	0.015	0.434	-1.662	0.254
53.0000	6.711	2.641	0.015	0.434	-1.665	0.254
54.0000	6.724	5.084	0.019	0.434	-1.665	0.254
55.0000	6.724	3.856	0.019	0.434	-1.668	0.254
56.0000	6.727	5.612	0.019	0.434	-1.668	0.254
57.0000	6.727	0.595	0.019	0.437	-1.671	0.254
58.0000	6.736	0.332	0.022	0.437	-1.675	0.258
59.0000	6.749	4.084	0.022	0.437	-1.675	0.258
60.0000	6.777	2.359	0.019	0.437	-1.678	0.258
61.0000	6.793	4.979	0.022	0.437	-1.684	0.258
62.0000	6.809	3.432	0.022	0.440	-1.684	0.258
63.0000	6.818	1.517	0.022	0.440	-1.687	0.258
64.0000	6.818	1.226	0.022	0.440	-1.690	0.258
65.0000	6.815	0.956	0.025	0.440	-1.693	0.261
66.0000	6.818	5.040	0.025	0.440	-1.697	0.258
67.0000	6.822	1.821	0.025	0.440	-1.697	0.261

68.0000	6.822	5.119	0.025	0.440	-1.700	0.261
69.0000	6.834	1.723	0.025	0.440	-1.703	0.261
70.0000	6.847	2.394	0.025	0.443	-1.706	0.261
71.0000	6.847	1.919	0.025	0.443	-1.709	0.261
72.0000	6.840	4.559	0.028	0.443	-1.712	0.261
73.0000	6.840	2.242	0.025	0.443	-1.712	0.264
74.0000	6.844	4.926	0.025	0.443	-1.715	0.261
75.0000	6.850	2.799	0.025	0.443	-1.715	0.261
76.0000	6.856	5.577	0.025	0.446	-1.715	0.264
77.0000	6.863	0.678	0.028	0.446	-1.719	0.264
78.0000	6.872	5.900	0.025	0.443	-1.722	0.261
79.0000	6.882	5.391	0.028	0.446	-1.725	0.264
80.0000	6.882	5.476	0.028	0.446	-1.725	0.264
81.0000	6.872	3.265	0.028	0.446	-1.728	0.264
82.0000	6.894	4.401	0.028	0.446	-1.731	0.264
83.0000	6.916	5.100	0.031	0.450	-1.734	0.264
84.0000	6.942	4.787	0.028	0.450	-1.734	0.264
85.0000	6.964	1.748	0.028	0.446	-1.737	0.264
86.0000	6.989	0.950	0.031	0.450	-1.741	0.264
87.0000	7.005	2.600	0.028	0.450	-1.741	0.264
88.0000	7.020	3.337	0.031	0.450	-1.744	0.264
89.0000	7.033	5.245	0.031	0.450	-1.747	0.267
90.0000	7.055	3.015	0.031	0.453	-1.747	0.267
91.0000	7.062	3.363	0.031	0.450	-1.753	0.267
92.0000	7.080	5.141	0.034	0.453	-1.759	0.267
93.0000	7.096	2.546	0.034	0.453	-1.763	0.270
94.0000	7.099	2.508	0.034	0.453	-1.766	0.270
95.0000	7.099	5.043	0.034	0.456	-1.772	0.270
96.0000	7.106	2.840	0.038	0.456	-1.772	0.270
97.0000	7.103	4.429	0.034	0.453	-1.775	0.270
98.0000	7.106	1.422	0.034	0.456	-1.778	0.270
99.0000	7.109	5.378	0.034	0.456	-1.781	0.270
100.000	7.106	1.020	0.034	0.456	-1.781	0.270
101.000	7.109	3.043	0.034	0.456	-1.785	0.270
102.000	7.109	5.163	0.034	0.453	-1.791	0.270
103.000	7.109	5.944	0.034	0.456	-1.794	0.270
104.000	7.109	4.182	0.034	0.456	-1.797	0.270
105.000	7.109	2.264	0.034	0.456	-1.797	0.270
106.000	7.106	5.255	0.041	0.459	-1.803	0.273
107.000	7.106	3.135	0.041	0.459	-1.807	0.273
108.000	7.106	2.324	0.041	0.459	-1.813	0.273
109.000	7.109	0.712	0.041	0.459	-1.813	0.273
110.000	7.109	4.420	0.041	0.459	-1.816	0.273
111.000	7.109	2.476	0.041	0.462	-1.819	0.276
112.000	7.109	1.834	0.041	0.462	-1.822	0.276
113.000	7.109	3.926	0.041	0.462	-1.825	0.276
114.000	7.109	2.286	0.041	0.462	-1.825	0.276
115.000	7.109	1.948	0.041	0.459	-1.832	0.276
116.000	7.109	1.188	0.041	0.462	-1.835	0.276
117.000	7.106	3.891	0.041	0.462	-1.838	0.276
118.000	7.109	1.400	0.044	0.462	-1.841	0.276
119.000	7.109	2.980	0.047	0.465	-1.844	0.280

120.000	7.112	0.088	0.044	0.465	-1.847	0.280
121.000	7.112	2.381	0.044	0.465	-1.851	0.280
122.000	7.109	-0.129	0.044	0.465	-1.854	0.280
123.000	7.112	5.723	0.047	0.465	-1.854	0.280
124.000	7.109	2.486	0.044	0.465	-1.860	0.280
125.000	7.109	2.907	0.044	0.465	-1.863	0.280
126.000	7.112	5.599	0.047	0.465	-1.866	0.280
127.000	7.112	4.821	0.044	0.468	-1.866	0.280
128.000	7.109	5.125	0.044	0.465	-1.869	0.280
129.000	7.112	2.372	0.047	0.468	-1.869	0.280
130.000	7.109	2.603	0.044	0.465	-1.876	0.280
131.000	7.109	0.655	0.044	0.468	-1.879	0.280
132.000	7.112	3.898	0.047	0.468	-1.882	0.280
133.000	7.112	4.284	0.044	0.468	-1.882	0.280
134.000	7.112	4.888	0.047	0.468	-1.885	0.283
135.000	7.112	4.091	0.047	0.468	-1.885	0.283
136.000	7.112	5.830	0.050	0.468	-1.888	0.283
137.000	7.112	2.347	0.047	0.468	-1.891	0.283
138.000	7.112	1.330	0.047	0.468	-1.895	0.280
139.000	7.112	0.991	0.050	0.472	-1.895	0.283
140.000	7.112	5.432	0.047	0.472	-1.898	0.283
141.000	7.112	4.688	0.047	0.472	-1.901	0.283
142.000	7.109	4.325	0.050	0.472	-1.901	0.283
143.000	7.112	5.043	0.050	0.472	-1.904	0.283
144.000	7.112	2.790	0.053	0.475	-1.904	0.286
145.000	7.112	1.621	0.050	0.472	-1.907	0.283
146.000	7.109	4.211	0.050	0.475	-1.907	0.283
147.000	7.112	2.802	0.050	0.475	-1.913	0.283
148.000	7.115	1.045	0.050	0.475	-1.913	0.286
149.000	7.115	5.337	0.053	0.475	-1.917	0.286
150.000	7.112	3.530	0.050	0.475	-1.917	0.286
151.000	7.115	2.166	0.050	0.475	-1.920	0.283
152.000	7.112	0.864	0.053	0.475	-1.923	0.286
153.000	7.112	3.315	0.053	0.478	-1.926	0.286
154.000	7.112	4.859	0.053	0.478	-1.926	0.286
155.000	7.112	1.327	0.053	0.478	-1.929	0.286
156.000	7.112	3.062	0.053	0.478	-1.926	0.289
157.000	7.112	2.302	0.057	0.478	-1.929	0.289
158.000	7.115	4.492	0.057	0.478	-1.929	0.286
159.000	7.115	4.957	0.053	0.478	-1.932	0.289
160.000	7.115	4.967	0.057	0.478	-1.935	0.289
161.000	7.112	3.923	0.057	0.481	-1.939	0.289
162.000	7.112	3.812	0.053	0.478	-1.942	0.289
163.000	7.112	4.046	0.057	0.478	-1.942	0.289
164.000	7.112	3.632	0.057	0.481	-1.945	0.289
165.000	7.112	5.337	0.057	0.478	-1.951	0.289
166.000	7.112	2.426	0.057	0.481	-1.951	0.292
167.000	7.112	5.378	0.060	0.481	-1.951	0.292
168.000	7.115	0.747	0.060	0.481	-1.954	0.292
169.000	7.112	5.463	0.060	0.481	-1.957	0.292
170.000	7.112	2.929	0.060	0.481	-1.957	0.292
171.000	7.112	-0.256	0.063	0.484	-1.961	0.292

172.000	7.115	4.113	0.060	0.484	-1.957	0.295
173.000	7.115	2.657	0.060	0.484	-1.961	0.295
174.000	7.112	3.796	0.060	0.484	-1.961	0.292
175.000	7.115	2.074	0.063	0.484	-1.964	0.295
176.000	7.112	3.973	0.060	0.484	-1.964	0.295
177.000	7.112	1.387	0.060	0.484	-1.967	0.295
178.000	7.112	4.321	0.063	0.484	-1.967	0.295
179.000	7.112	2.863	0.063	0.484	-1.970	0.295
180.000	7.112	3.632	0.063	0.487	-1.970	0.295
181.000	7.109	-0.237	0.060	0.487	-1.973	0.295
182.000	7.112	4.480	0.063	0.487	-1.976	0.295
183.000	7.112	4.467	0.066	0.487	-1.976	0.295
184.000	7.115	1.561	0.063	0.487	-1.976	0.298
185.000	7.112	0.852	0.063	0.487	-1.976	0.295
186.000	7.115	4.410	0.066	0.487	-1.976	0.298
187.000	7.109	1.140	0.063	0.487	-1.976	0.295
188.000	7.109	5.609	0.063	0.487	-1.979	0.298
189.000	7.112	4.404	0.063	0.491	-1.979	0.298
190.000	7.109	3.458	0.066	0.491	-1.983	0.298
191.000	7.109	1.412	0.066	0.491	-1.983	0.298
192.000	7.112	4.584	0.063	0.491	-1.983	0.298
193.000	7.112	3.173	0.066	0.491	-1.983	0.298
194.000	7.112	2.856	0.066	0.491	-1.986	0.298
195.000	7.112	1.488	0.066	0.491	-1.989	0.298
196.000	7.112	5.653	0.069	0.491	-1.992	0.298
197.000	7.112	5.270	0.069	0.491	-1.989	0.298
198.000	7.112	2.840	0.066	0.494	-1.992	0.302
199.000	7.112	4.742	0.066	0.491	-1.995	0.302
200.000	7.112	-0.082	0.069	0.494	-1.995	0.302
201.000	7.115	3.125	0.069	0.494	-1.995	0.302
202.000	7.112	4.954	0.069	0.494	-1.995	0.302
203.000	7.115	1.666	0.069	0.494	-1.995	0.302
204.000	7.112	2.258	0.069	0.494	-1.995	0.302
205.000	7.115	5.255	0.069	0.494	-1.998	0.302
206.000	7.112	1.745	0.069	0.494	-1.998	0.302
207.000	7.112	4.859	0.072	0.494	-1.998	0.302
208.000	7.112	4.166	0.069	0.497	-1.998	0.305
209.000	7.112	1.647	0.069	0.497	-1.998	0.305
210.000	7.112	0.272	0.072	0.497	-1.998	0.305
211.000	7.112	2.638	0.072	0.497	-2.001	0.305
212.000	7.112	1.226	0.072	0.497	-2.001	0.305
213.000	7.112	5.406	0.072	0.497	-2.005	0.305
214.000	7.115	2.090	0.072	0.497	-2.001	0.305
215.000	7.112	4.802	0.072	0.497	-2.001	0.305
216.000	7.112	0.377	0.072	0.497	-2.005	0.305
217.000	7.112	4.125	0.072	0.500	-2.001	0.305
218.000	7.115	-0.142	0.072	0.497	-2.008	0.305
219.000	7.115	2.062	0.076	0.497	-2.005	0.305
220.000	7.112	3.761	0.072	0.497	-2.008	0.305
221.000	7.112	5.473	0.072	0.497	-2.008	0.305
222.000	7.115	4.021	0.072	0.497	-2.008	0.305
223.000	7.109	-0.180	0.072	0.497	-2.011	0.305

224.000	7.109	2.587	0.072	0.500	-2.011	0.308
225.000	7.112	1.305	0.076	0.500	-2.011	0.308
226.000	7.112	2.932	0.076	0.500	-2.011	0.308
227.000	7.112	2.537	0.076	0.500	-2.011	0.308
228.000	7.112	3.948	0.079	0.503	-2.011	0.308
229.000	7.109	3.227	0.076	0.500	-2.011	0.308
230.000	7.112	1.672	0.076	0.500	-2.011	0.308
231.000	7.112	1.035	0.076	0.500	-2.011	0.308
232.000	7.112	2.201	0.076	0.500	-2.011	0.308
233.000	7.112	5.492	0.076	0.500	-2.011	0.308
234.000	7.112	1.447	0.079	0.503	-2.011	0.311
235.000	7.115	0.402	0.076	0.500	-2.014	0.308
236.000	7.112	5.255	0.076	0.503	-2.014	0.311
237.000	7.115	4.688	0.079	0.503	-2.011	0.311
238.000	7.112	0.177	0.076	0.503	-2.014	0.311
239.000	7.115	1.207	0.079	0.503	-2.014	0.311
240.000	7.112	0.693	0.076	0.503	-2.014	0.311
241.000	7.112	4.682	0.076	0.503	-2.011	0.308
242.000	7.112	2.606	0.076	0.503	-2.011	0.308

PUMP TEST DATA
STEP 4 – RECOVERY STAGE

SE2000
Environmental Logger
05/24 10:53

Unit# 604 Test 0

Setups:	INPUT 1	INPUT 2	INPUT 3	INPUT 4	INPUT 5	INPUT 6
Type	Level (F)	Level (F)	Level (F)	Level (F)	Level (F)	Level (F)
Mode	TOC	TOC	TOC	TOC	TOC	TOC
I.D.	IW1	MW2A	RW2	RW3	IW2	FWI2
Reference	0.000	0.000	0.000	0.000	0.000	0.000
PSI at Ref.	3.063	3.194	3.967	4.039	3.403	3.318
SG	1.000	1.000	1.000	1.000	1.000	1.000
Linearity	0.005	0.042	0.012	0.045	0.005	0.019
Scale factor	10.032	10.038	10.061	9.963	9.991	9.996
Offset	-0.059	-0.194	-0.040	-0.048	-0.053	0.009
Delay mSEC	50.000	50.000	50.000	50.000	50.000	50.000

Step 3 05/23 22:07:21

Elapsed Time	INPUT 1	INPUT 2	INPUT 3	INPUT 4	INPUT 5	INPUT 6
0.0000	7.109	8.937	0.079	0.503	-2.014	0.302
0.0083	7.109	8.937	0.079	0.503	-2.020	0.302
0.0166	7.112	8.937	0.079	0.503	-2.020	0.302
0.0250	7.112	8.937	0.079	0.503	-2.020	0.302
0.0333	7.109	8.934	0.079	0.503	-2.020	0.302
0.0416	7.112	8.937	0.079	0.503	-2.020	0.302
0.0500	7.112	8.934	0.079	0.503	-2.020	0.302
0.0583	7.109	8.937	0.079	0.503	-2.020	0.302
0.0666	7.109	8.937	0.079	0.503	-2.020	0.302
0.0750	7.109	8.934	0.079	0.503	-2.020	0.298
0.0833	7.109	8.937	0.079	0.503	-2.020	0.302
0.0916	7.109	8.934	0.079	0.503	-2.023	0.302
0.1000	7.109	8.934	0.079	0.503	-2.023	0.302
0.1083	7.109	8.934	0.079	0.503	-2.020	0.302
0.1166	7.109	8.934	0.079	0.503	-2.023	0.302
0.1250	7.109	8.934	0.079	0.503	-2.023	0.302
0.1333	7.109	8.934	0.079	0.503	-2.020	0.298
0.1416	7.109	8.934	0.079	0.503	-2.023	0.302
0.1500	7.109	8.934	0.079	0.503	-2.020	0.302
0.1583	7.109	8.934	0.079	0.503	-2.020	0.302
0.1666	7.109	8.934	0.079	0.503	-2.020	0.302
0.1750	7.109	8.934	0.079	0.503	-2.020	0.302
0.1833	7.109	8.934	0.079	0.503	-2.020	0.302
0.1916	7.109	8.934	0.079	0.503	-2.020	0.298
0.2000	7.109	8.934	0.079	0.503	-2.020	0.302
0.2083	7.109	8.934	0.079	0.503	-2.020	0.302
0.2166	7.109	8.934	0.079	0.503	-2.020	0.302

0.2250	7.109	8.934	0.079	0.503	-2.020	0.302
0.2333	7.109	8.934	0.079	0.503	-2.020	0.302
0.2416	7.109	8.934	0.079	0.503	-2.020	0.302
0.2500	7.106	8.934	0.079	0.503	-2.020	0.302
0.2583	7.099	8.934	0.079	0.506	-2.020	0.302
0.2666	7.077	8.934	0.079	0.503	-2.020	0.302
0.2750	7.046	8.934	0.079	0.503	-2.020	0.302
0.2833	7.017	8.934	0.079	0.503	-2.020	0.302
0.2916	6.989	8.934	0.079	0.503	-2.020	0.302
0.3000	6.964	8.934	0.079	0.503	-2.020	0.302
0.3083	6.929	8.934	0.079	0.503	-2.020	0.302
0.3166	6.900	8.934	0.079	0.503	-2.020	0.302
0.3250	6.869	8.934	0.076	0.503	-2.020	0.302
0.3333	6.840	8.934	0.076	0.503	-2.020	0.302
0.3500	6.777	8.934	0.079	0.503	-2.020	0.302
0.3666	6.714	8.937	0.076	0.503	-2.020	0.302
0.3833	6.654	8.934	0.079	0.503	-2.020	0.302
0.4000	6.588	8.934	0.076	0.503	-2.020	0.302
0.4166	6.528	8.934	0.076	0.503	-2.020	0.302
0.4333	6.468	8.934	0.079	0.503	-2.020	0.302
0.4500	6.408	8.934	0.076	0.503	-2.020	0.302
0.4666	6.351	8.937	0.079	0.503	-2.020	0.302
0.4833	6.297	8.934	0.076	0.503	-2.020	0.302
0.5000	6.244	8.934	0.076	0.503	-2.020	0.302
0.5166	6.193	8.934	0.076	0.503	-2.020	0.302
0.5333	6.146	8.937	0.076	0.503	-2.020	0.302
0.5500	6.095	8.934	0.076	0.503	-2.020	0.302
0.5666	6.051	8.934	0.076	0.503	-2.020	0.302
0.5833	6.010	8.934	0.076	0.503	-2.020	0.302
0.6000	5.966	8.934	0.076	0.503	-2.020	0.302
0.6166	5.928	8.937	0.076	0.503	-2.020	0.298
0.6333	5.890	8.934	0.076	0.503	-2.020	0.302
0.6500	5.849	8.934	0.076	0.503	-2.020	0.302
0.6666	5.811	8.937	0.076	0.503	-2.020	0.302
0.6833	5.773	8.934	0.076	0.503	-2.020	0.302
0.7000	5.738	8.934	0.076	0.503	-2.020	0.302
0.7166	5.700	8.934	0.076	0.503	-2.020	0.302
0.7333	5.663	8.937	0.076	0.503	-2.020	0.302
0.7500	5.628	8.934	0.076	0.503	-2.020	0.302
0.7666	5.590	8.934	0.076	0.503	-2.020	0.302
0.7833	5.555	8.937	0.076	0.500	-2.020	0.302
0.8000	5.520	8.937	0.076	0.500	-2.020	0.302
0.8166	5.473	8.934	0.076	0.503	-2.020	0.302
0.8333	5.423	8.934	0.076	0.503	-2.020	0.302
0.8500	5.372	8.934	0.079	0.503	-2.020	0.302
0.8666	5.321	8.934	0.076	0.503	-2.020	0.302
0.8833	5.271	8.934	0.076	0.503	-2.020	0.302
0.9000	5.224	8.934	0.076	0.500	-2.020	0.302
0.9166	5.176	8.934	0.076	0.500	-2.020	0.302
0.9333	5.126	8.934	0.076	0.500	-2.020	0.302
0.9500	5.078	8.934	0.076	0.500	-2.023	0.302
0.9666	5.031	8.934	0.076	0.500	-2.023	0.302

0.9833	4.984	8.934	0.076	0.500	-2.023	0.302
1.0000	4.936	8.934	0.076	0.500	-2.020	0.302
1.2000	4.399	8.934	0.076	0.494	-2.020	0.302
1.4000	3.922	8.937	0.076	0.484	-2.023	0.302
1.6000	3.509	8.934	0.076	0.475	-2.030	0.298
1.8000	3.142	8.934	0.076	0.465	-2.039	0.298
2.0000	2.820	8.934	0.072	0.453	-2.049	0.295
2.2000	2.552	8.934	0.072	0.440	-2.058	0.295
2.4000	2.312	8.934	0.072	0.428	-2.067	0.292
2.6000	2.103	8.934	0.072	0.415	-2.077	0.289
2.8000	1.917	8.934	0.069	0.402	-2.089	0.286
3.0000	1.759	8.934	0.069	0.390	-2.099	0.286
3.2000	1.626	8.934	0.069	0.377	-2.108	0.280
3.4000	1.506	8.934	0.069	0.365	-2.118	0.280
3.6000	1.396	8.934	0.069	0.355	-2.127	0.276
3.8000	1.304	8.934	0.069	0.346	-2.133	0.273
4.0000	1.219	8.934	0.066	0.336	-2.143	0.270
4.2000	1.146	8.934	0.066	0.327	-2.149	0.267
4.4000	1.083	8.934	0.066	0.317	-2.159	0.264
4.6000	1.026	8.934	0.066	0.308	-2.165	0.261
4.8000	0.976	8.931	0.066	0.302	-2.174	0.258
5.0000	0.931	8.934	0.063	0.295	-2.177	0.254
5.2000	0.887	8.934	0.063	0.286	-2.187	0.251
5.4000	0.852	8.934	0.063	0.283	-2.193	0.248
5.6000	0.824	8.934	0.063	0.276	-2.199	0.245
5.8000	0.799	8.934	0.063	0.270	-2.203	0.245
6.0000	0.773	8.934	0.063	0.267	-2.209	0.242
6.2000	0.748	8.934	0.063	0.261	-2.212	0.239
6.4000	0.729	8.934	0.063	0.258	-2.218	0.236
6.6000	0.707	8.934	0.063	0.251	-2.221	0.232
6.8000	0.691	8.934	0.063	0.248	-2.228	0.229
7.0000	0.672	8.934	0.063	0.245	-2.231	0.229
7.2000	0.660	8.934	0.063	0.242	-2.234	0.226
7.4000	0.647	8.934	0.060	0.239	-2.237	0.226
7.6000	0.634	8.934	0.063	0.236	-2.243	0.223
7.8000	0.625	8.934	0.060	0.232	-2.247	0.220
8.0000	0.612	8.934	0.060	0.232	-2.250	0.220
8.2000	0.606	8.934	0.060	0.229	-2.253	0.217
8.4000	0.597	8.934	0.060	0.226	-2.253	0.217
8.6000	0.590	8.934	0.060	0.223	-2.256	0.214
8.8000	0.584	8.934	0.060	0.220	-2.259	0.214
9.0000	0.578	8.934	0.060	0.220	-2.262	0.214
9.2000	0.571	8.934	0.060	0.217	-2.262	0.210
9.4000	0.568	8.934	0.060	0.214	-2.265	0.210
9.6000	0.562	8.934	0.060	0.214	-2.269	0.207
9.8000	0.555	8.934	0.060	0.210	-2.272	0.207
10.0000	0.552	2.451	0.060	0.210	-2.269	0.214
11.0000	0.543	2.600	0.057	0.201	-2.275	0.207
12.0000	0.533	2.660	0.057	0.195	-2.284	0.201
13.0000	0.527	2.644	0.057	0.188	-2.291	0.195
14.0000	0.518	2.685	0.053	0.182	-2.297	0.191
15.0000	0.511	2.565	0.053	0.176	-2.303	0.188

16.0000	0.505	2.606	0.053	0.169	-2.306	0.182
17.0000	0.499	2.445	0.053	0.166	-2.313	0.182
18.0000	0.492	2.362	0.050	0.163	-2.316	0.179
19.0000	0.489	2.321	0.050	0.160	-2.319	0.176
20.0000	0.483	2.274	0.047	0.154	-2.325	0.169
21.0000	0.476	2.318	0.047	0.151	-2.328	0.169
22.0000	0.473	2.229	0.047	0.147	-2.331	0.166
23.0000	0.467	2.312	0.044	0.144	-2.335	0.163
24.0000	0.464	2.286	0.044	0.141	-2.338	0.163
25.0000	0.461	2.280	0.044	0.138	-2.341	0.160
26.0000	0.454	2.185	0.041	0.135	-2.344	0.157
27.0000	0.454	2.264	0.041	0.132	-2.347	0.157
28.0000	0.451	2.233	0.041	0.129	-2.350	0.154
29.0000	0.448	2.191	0.038	0.125	-2.350	0.151
30.0000	0.448	2.201	0.034	0.122	-2.353	0.151
31.0000	0.445	2.324	0.034	0.122	-2.353	0.147
32.0000	0.439	2.359	0.034	0.119	-2.357	0.144
33.0000	0.435	2.296	0.031	0.116	-2.357	0.141
34.0000	0.432	2.296	0.028	0.113	-2.360	0.141
35.0000	0.429	2.331	0.028	0.113	-2.360	0.141
36.0000	0.420	2.375	0.025	0.110	-2.363	0.138
37.0000	0.407	2.397	0.025	0.107	-2.366	0.135
38.0000	0.401	2.359	0.022	0.103	-2.366	0.135
39.0000	0.394	2.356	0.019	0.100	-2.366	0.132
40.0000	0.391	2.429	0.019	0.100	-2.369	0.132
41.0000	0.388	2.429	0.015	0.097	-2.372	0.129
42.0000	0.385	2.397	0.015	0.094	-2.372	0.125
43.0000	0.382	2.400	0.015	0.094	-2.375	0.125
44.0000	0.382	2.480	0.012	0.091	-2.375	0.125
45.0000	0.379	2.495	0.012	0.091	-2.379	0.125
46.0000	0.375	2.483	0.009	0.088	-2.379	0.122
47.0000	0.372	2.568	0.006	0.084	-2.379	0.122
48.0000	0.369	2.524	0.006	0.084	-2.382	0.119
49.0000	0.369	2.565	0.003	0.081	-2.382	0.116
50.0000	0.366	2.486	0.003	0.081	-2.382	0.116
51.0000	0.363	2.511	0.000	0.078	-2.385	0.116
52.0000	0.363	2.581	0.000	0.078	-2.385	0.113
53.0000	0.360	2.549	0.000	0.078	-2.385	0.113
54.0000	0.360	2.619	-0.003	0.075	-2.385	0.113
55.0000	0.356	2.575	-0.003	0.072	-2.388	0.110
56.0000	0.356	2.565	-0.003	0.072	-2.388	0.110
57.0000	0.353	2.603	-0.003	0.072	-2.391	0.110
58.0000	0.353	2.631	-0.006	0.069	-2.391	0.110
59.0000	0.350	2.657	-0.006	0.069	-2.391	0.107
60.0000	0.350	2.666	-0.006	0.066	-2.394	0.107
61.0000	0.347	2.669	-0.009	0.066	-2.394	0.107
62.0000	0.344	2.638	-0.009	0.066	-2.394	0.103
63.0000	0.344	2.707	-0.012	0.062	-2.394	0.103
64.0000	0.341	2.707	-0.012	0.062	-2.397	0.100
65.0000	0.341	2.714	-0.015	0.059	-2.397	0.100
66.0000	0.337	2.669	-0.015	0.059	-2.401	0.100
67.0000	0.337	2.682	-0.019	0.056	-2.401	0.100

68.0000	0.334	2.673	-0.019	0.056	-2.401	0.097
69.0000	0.331	2.783	-0.022	0.053	-2.401	0.097
70.0000	0.331	2.749	-0.022	0.053	-2.401	0.094
71.0000	0.331	2.771	-0.022	0.053	-2.401	0.094
72.0000	0.328	2.749	-0.025	0.053	-2.401	0.094
73.0000	0.328	2.777	-0.025	0.050	-2.404	0.094
74.0000	0.325	2.752	-0.025	0.050	-2.404	0.094
75.0000	0.325	2.844	-0.025	0.050	-2.404	0.091
76.0000	0.325	2.771	-0.028	0.047	-2.407	0.091
77.0000	0.322	2.796	-0.028	0.047	-2.407	0.091
78.0000	0.322	2.790	-0.028	0.047	-2.407	0.091
79.0000	0.319	2.866	-0.028	0.047	-2.410	0.088
80.0000	0.319	2.790	-0.031	0.044	-2.410	0.088
81.0000	0.319	2.809	-0.031	0.044	-2.410	0.088
82.0000	0.315	2.847	-0.031	0.044	-2.410	0.088
83.0000	0.315	2.831	-0.034	0.040	-2.410	0.084
84.0000	0.315	2.809	-0.034	0.040	-2.410	0.084
85.0000	0.312	2.821	-0.034	0.037	-2.413	0.084
86.0000	0.312	2.844	-0.038	0.037	-2.410	0.081
87.0000	0.309	2.837	-0.038	0.037	-2.413	0.081
88.0000	0.309	2.844	-0.041	0.037	-2.413	0.081
89.0000	0.306	2.863	-0.041	0.034	-2.416	0.081
90.0000	0.306	2.894	-0.041	0.034	-2.416	0.081
91.0000	0.306	2.913	-0.044	0.034	-2.416	0.081
92.0000	0.303	2.897	-0.044	0.031	-2.419	0.078
93.0000	0.303	2.869	-0.044	0.031	-2.419	0.078
94.0000	0.303	2.951	-0.047	0.031	-2.419	0.075
95.0000	0.303	2.999	-0.047	0.031	-2.419	0.075
96.0000	0.300	2.926	-0.050	0.028	-2.419	0.075
97.0000	0.300	2.977	-0.053	0.028	-2.423	0.075
98.0000	0.296	2.983	-0.053	0.028	-2.423	0.075
99.0000	0.293	3.005	-0.057	0.025	-2.423	0.072
100.000	0.293	2.996	-0.060	0.025	-2.423	0.072
101.000	0.290	3.034	-0.060	0.022	-2.423	0.072
102.000	0.293	3.015	-0.063	0.025	-2.423	0.069
103.000	0.290	3.062	-0.066	0.022	-2.423	0.069
104.000	0.287	3.072	-0.066	0.022	-2.423	0.069
105.000	0.287	2.970	-0.069	0.022	-2.423	0.069
106.000	0.287	3.046	-0.072	0.018	-2.419	0.066
107.000	0.287	3.097	-0.072	0.018	-2.419	0.066
108.000	0.284	3.049	-0.072	0.018	-2.423	0.066
109.000	0.284	3.046	-0.076	0.015	-2.426	0.066
110.000	0.284	3.046	-0.076	0.015	-2.426	0.066
111.000	0.284	3.037	-0.076	0.015	-2.426	0.066
112.000	0.281	3.106	-0.079	0.015	-2.426	0.066
113.000	0.281	3.078	-0.079	0.015	-2.426	0.062
114.000	0.281	3.049	-0.079	0.015	-2.426	0.066
115.000	0.277	3.116	-0.079	0.012	-2.429	0.062
116.000	0.277	3.128	-0.082	0.012	-2.429	0.062
117.000	0.277	3.144	-0.082	0.012	-2.429	0.062
118.000	0.274	3.100	-0.082	0.012	-2.429	0.062
119.000	0.274	3.106	-0.082	0.012	-2.429	0.062

120.000	0.274	3.062	-0.082	0.009	-2.432	0.059
121.000	0.274	3.182	-0.082	0.009	-2.435	0.059
122.000	0.274	3.065	-0.085	0.009	-2.435	0.059
123.000	0.274	3.138	-0.085	0.009	-2.435	0.059
124.000	0.271	3.100	-0.085	0.009	-2.435	0.059
125.000	0.271	3.204	-0.088	0.006	-2.438	0.059
126.000	0.271	3.163	-0.088	0.006	-2.435	0.056
127.000	0.268	3.100	-0.091	0.006	-2.435	0.056
128.000	0.268	3.144	-0.091	0.006	-2.435	0.056
129.000	0.268	3.192	-0.095	0.006	-2.438	0.056
130.000	0.268	3.128	-0.095	0.006	-2.435	0.056
131.000	0.265	3.144	-0.095	0.003	-2.438	0.053
132.000	0.265	3.151	-0.098	0.003	-2.435	0.056
133.000	0.265	3.132	-0.098	0.003	-2.438	0.053
134.000	0.262	3.230	-0.098	0.003	-2.438	0.053
135.000	0.262	3.185	-0.098	0.000	-2.438	0.053
136.000	0.262	3.249	-0.098	0.000	-2.438	0.053
137.000	0.262	3.182	-0.098	0.000	-2.441	0.053
138.000	0.262	3.258	-0.098	0.000	-2.441	0.053
139.000	0.262	3.255	-0.101	0.000	-2.441	0.053
140.000	0.259	3.163	-0.101	0.000	-2.441	0.053
141.000	0.259	3.230	-0.104	0.000	-2.441	0.050
142.000	0.259	3.192	-0.104	-0.003	-2.441	0.050
143.000	0.255	3.176	-0.107	-0.003	-2.441	0.050
144.000	0.255	3.261	-0.110	-0.003	-2.441	0.047
145.000	0.255	3.303	-0.110	-0.006	-2.441	0.047
146.000	0.255	3.287	-0.114	-0.006	-2.441	0.047
147.000	0.252	3.211	-0.117	-0.006	-2.441	0.047
148.000	0.252	3.315	-0.117	-0.006	-2.441	0.044
149.000	0.252	3.312	-0.120	-0.006	-2.441	0.044
150.000	0.252	3.265	-0.120	-0.006	-2.441	0.044
151.000	0.249	3.252	-0.123	-0.009	-2.441	0.044
152.000	0.249	3.347	-0.123	-0.009	-2.438	0.044
153.000	0.249	3.309	-0.123	-0.009	-2.438	0.044
154.000	0.249	3.296	-0.126	-0.009	-2.438	0.044
155.000	0.249	3.280	-0.126	-0.009	-2.438	0.044
156.000	0.249	3.350	-0.126	-0.009	-2.441	0.044
157.000	0.246	3.344	-0.126	-0.009	-2.438	0.044
158.000	0.246	3.296	-0.126	-0.009	-2.438	0.044
159.000	0.246	3.347	-0.126	-0.012	-2.438	0.044
160.000	0.246	3.261	-0.129	-0.012	-2.438	0.044
161.000	0.246	3.360	-0.129	-0.012	-2.438	0.040
162.000	0.246	3.344	-0.133	-0.012	-2.435	0.040
163.000	0.243	3.328	-0.136	-0.012	-2.435	0.040
164.000	0.243	3.293	-0.136	-0.015	-2.435	0.040
165.000	0.243	3.284	-0.139	-0.015	-2.435	0.037
166.000	0.240	3.268	-0.139	-0.015	-2.435	0.037
167.000	0.240	3.331	-0.142	-0.015	-2.435	0.037
168.000	0.240	3.341	-0.145	-0.018	-2.432	0.037
169.000	0.240	3.372	-0.148	-0.018	-2.432	0.037
170.000	0.236	3.385	-0.148	-0.018	-2.432	0.034
171.000	0.236	3.341	-0.152	-0.018	-2.429	0.034

172.000	0.236	3.363	-0.152	-0.022	-2.429	0.034
173.000	0.236	3.385	-0.155	-0.022	-2.429	0.034
174.000	0.236	3.375	-0.155	-0.022	-2.429	0.034
175.000	0.236	3.451	-0.158	-0.022	-2.426	0.034
176.000	0.233	3.442	-0.161	-0.022	-2.426	0.031
177.000	0.233	3.401	-0.164	-0.022	-2.426	0.031
178.000	0.233	3.467	-0.164	-0.025	-2.426	0.031
179.000	0.230	3.477	-0.168	-0.025	-2.423	0.031
180.000	0.230	3.454	-0.168	-0.025	-2.423	0.031
181.000	0.230	3.483	-0.171	-0.025	-2.423	0.031
182.000	0.230	3.492	-0.171	-0.025	-2.423	0.028
183.000	0.230	3.464	-0.174	-0.025	-2.419	0.028
184.000	0.230	3.489	-0.174	-0.025	-2.419	0.028
185.000	0.230	3.492	-0.177	-0.025	-2.419	0.028
186.000	0.227	3.508	-0.177	-0.025	-2.419	0.028
187.000	0.227	3.423	-0.180	-0.028	-2.419	0.028
188.000	0.227	3.429	-0.183	-0.028	-2.419	0.028
189.000	0.227	3.439	-0.183	-0.028	-2.416	0.028
190.000	0.227	3.454	-0.187	-0.028	-2.416	0.025
191.000	0.227	3.464	-0.187	-0.028	-2.416	0.025
192.000	0.224	3.521	-0.190	-0.031	-2.416	0.025
193.000	0.224	3.524	-0.190	-0.031	-2.416	0.025
194.000	0.224	3.521	-0.190	-0.031	-2.416	0.025
195.000	0.224	3.445	-0.193	-0.031	-2.416	0.025
196.000	0.224	3.470	-0.196	-0.031	-2.416	0.025
197.000	0.224	3.410	-0.196	-0.031	-2.416	0.025
198.000	0.221	3.464	-0.196	-0.031	-2.413	0.025
199.000	0.221	3.489	-0.199	-0.031	-2.416	0.025
200.000	0.221	3.562	-0.199	-0.034	-2.413	0.022
201.000	0.221	3.518	-0.199	-0.031	-2.416	0.025
202.000	0.221	3.483	-0.199	-0.034	-2.416	0.025
203.000	0.221	3.515	-0.199	-0.031	-2.416	0.025
204.000	0.221	3.524	-0.199	-0.034	-2.416	0.025
205.000	0.221	3.499	-0.199	-0.034	-2.416	0.025
206.000	0.221	3.518	-0.202	-0.034	-2.416	0.022
207.000	0.217	3.461	-0.202	-0.034	-2.416	0.022
208.000	0.217	3.556	-0.202	-0.034	-2.419	0.022
209.000	0.217	3.492	-0.202	-0.034	-2.419	0.022
210.000	0.217	3.530	-0.202	-0.034	-2.419	0.022
211.000	0.217	3.534	-0.202	-0.034	-2.419	0.022
212.000	0.217	3.575	-0.206	-0.034	-2.419	0.022
213.000	0.217	3.515	-0.206	-0.034	-2.419	0.022
214.000	0.214	3.572	-0.209	-0.037	-2.419	0.022
215.000	0.214	3.499	-0.209	-0.037	-2.419	0.022
216.000	0.214	3.530	-0.212	-0.037	-2.416	0.018
217.000	0.214	3.616	-0.212	-0.037	-2.416	0.018
218.000	0.214	3.511	-0.215	-0.037	-2.416	0.018
219.000	0.214	3.534	-0.215	-0.037	-2.416	0.018
220.000	0.211	3.644	-0.215	-0.040	-2.419	0.018
221.000	0.211	3.594	-0.215	-0.040	-2.419	0.018
222.000	0.214	3.597	-0.215	-0.040	-2.419	0.018
223.000	0.211	3.562	-0.218	-0.040	-2.419	0.018

224.000	0.211	3.530	-0.218	-0.040	-2.416	0.018
225.000	0.211	3.594	-0.218	-0.040	-2.416	0.018
226.000	0.211	3.578	-0.221	-0.040	-2.416	0.018
227.000	0.211	3.568	-0.221	-0.040	-2.416	0.018
228.000	0.208	3.616	-0.225	-0.040	-2.416	0.015
229.000	0.208	3.632	-0.225	-0.040	-2.416	0.015
230.000	0.208	3.597	-0.228	-0.044	-2.416	0.015
231.000	0.208	3.594	-0.228	-0.044	-2.416	0.015
232.000	0.208	3.584	-0.228	-0.044	-2.416	0.015
233.000	0.208	3.559	-0.231	-0.044	-2.416	0.015
234.000	0.205	3.597	-0.231	-0.044	-2.416	0.012
235.000	0.208	3.689	-0.231	-0.044	-2.413	0.015
236.000	0.205	3.603	-0.234	-0.044	-2.413	0.015
237.000	0.205	3.676	-0.234	-0.044	-2.410	0.012
238.000	0.205	3.723	-0.237	-0.047	-2.410	0.012
239.000	0.205	3.632	-0.240	-0.047	-2.410	0.012
240.000	0.205	3.685	-0.240	-0.047	-2.410	0.012
241.000	0.205	3.682	-0.244	-0.047	-2.407	0.012
242.000	0.202	3.644	-0.244	-0.047	-2.407	0.012
243.000	0.202	3.667	-0.244	-0.047	-2.407	0.012
244.000	0.202	3.667	-0.247	-0.047	-2.404	0.012
245.000	0.202	3.670	-0.250	-0.050	-2.404	0.012
246.000	0.202	3.682	-0.250	-0.050	-2.404	0.009
247.000	0.202	3.755	-0.253	-0.050	-2.404	0.009
248.000	0.199	3.689	-0.253	-0.050	-2.404	0.009
249.000	0.199	3.758	-0.256	-0.050	-2.404	0.009
250.000	0.199	3.708	-0.256	-0.050	-2.404	0.009
251.000	0.199	3.717	-0.259	-0.050	-2.404	0.009
252.000	0.199	3.755	-0.259	-0.050	-2.404	0.009
253.000	0.199	3.739	-0.256	-0.050	-2.404	0.009
254.000	0.199	3.755	-0.259	-0.053	-2.404	0.009
255.000	0.199	3.793	-0.259	-0.050	-2.404	0.009
256.000	0.199	3.727	-0.259	-0.053	-2.401	0.006
257.000	0.195	3.632	-0.259	-0.053	-2.407	0.006
258.000	0.199	3.648	-0.259	-0.053	-2.407	0.006
259.000	0.195	3.689	-0.263	-0.053	-2.404	0.006
260.000	0.195	3.768	-0.259	-0.053	-2.404	0.006
261.000	0.195	3.752	-0.259	-0.053	-2.404	0.006
262.000	0.195	3.714	-0.259	-0.053	-2.404	0.006
263.000	0.195	3.790	-0.263	-0.053	-2.404	0.006
264.000	0.195	3.723	-0.263	-0.053	-2.404	0.006
265.000	0.195	3.790	-0.259	-0.053	-2.404	0.006
266.000	0.195	3.708	-0.259	-0.053	-2.407	0.006
267.000	0.195	3.663	-0.263	-0.053	-2.407	0.006
268.000	0.192	3.685	-0.263	-0.056	-2.407	0.006
269.000	0.192	3.673	-0.263	-0.056	-2.407	0.003
270.000	0.192	3.701	-0.263	-0.056	-2.407	0.006
271.000	0.192	3.733	-0.263	-0.056	-2.404	0.003
272.000	0.192	3.727	-0.263	-0.056	-2.404	0.003
273.000	0.192	3.701	-0.263	-0.056	-2.404	0.003
274.000	0.192	3.739	-0.266	-0.056	-2.404	0.003
275.000	0.189	3.733	-0.263	-0.056	-2.404	0.003

276.000	0.189	3.768	-0.266	-0.059	-2.407	0.003
277.000	0.189	3.736	-0.266	-0.059	-2.407	0.000
278.000	0.189	3.780	-0.266	-0.059	-2.407	0.003
279.000	0.189	3.730	-0.266	-0.059	-2.404	0.003
280.000	0.189	3.787	-0.266	-0.059	-2.404	0.003
281.000	0.189	3.723	-0.266	-0.059	-2.404	0.000
282.000	0.189	3.733	-0.269	-0.059	-2.404	0.000
283.000	0.189	3.787	-0.266	-0.059	-2.407	0.000
284.000	0.189	3.790	-0.266	-0.059	-2.407	0.000
285.000	0.189	3.708	-0.266	-0.059	-2.407	0.000
286.000	0.186	3.758	-0.269	-0.059	-2.407	0.000
287.000	0.189	3.774	-0.269	-0.059	-2.407	0.000
288.000	0.186	3.796	-0.266	-0.059	-2.407	0.000
289.000	0.186	3.717	-0.266	-0.059	-2.407	0.000
290.000	0.186	3.736	-0.266	-0.059	-2.407	0.000
291.000	0.186	3.771	-0.269	-0.059	-2.407	0.000
292.000	0.186	3.780	-0.269	-0.059	-2.407	0.000
293.000	0.186	3.752	-0.269	-0.062	-2.407	0.000
294.000	0.186	3.834	-0.269	-0.062	-2.407	0.000
295.000	0.186	3.758	-0.269	-0.062	-2.407	0.000
296.000	0.183	3.746	-0.269	-0.062	-2.407	-0.003
297.000	0.183	3.847	-0.272	-0.062	-2.404	0.000
298.000	0.183	3.815	-0.269	-0.062	-2.413	-0.003
299.000	0.183	3.758	-0.269	-0.062	-2.416	-0.003
300.000	0.183	3.784	-0.272	-0.062	-2.416	-0.003
301.000	0.183	3.774	-0.272	-0.062	-2.416	-0.003
302.000	0.183	3.834	-0.272	-0.062	-2.416	-0.003
303.000	0.183	3.774	-0.272	-0.062	-2.416	-0.003
304.000	0.183	3.787	-0.272	-0.062	-2.419	-0.003
305.000	0.183	3.771	-0.272	-0.066	-2.423	-0.003
306.000	0.180	3.831	-0.275	-0.066	-2.423	-0.003
307.000	0.180	3.777	-0.272	-0.066	-2.423	-0.006
308.000	0.180	3.853	-0.272	-0.066	-2.419	-0.003
309.000	0.180	3.799	-0.275	-0.066	-2.419	-0.006
310.000	0.180	3.856	-0.272	-0.069	-2.419	-0.006
311.000	0.180	3.809	-0.275	-0.066	-2.419	-0.006
312.000	0.180	3.863	-0.275	-0.066	-2.419	-0.006
313.000	0.176	3.910	-0.272	-0.069	-2.419	-0.006
314.000	0.176	3.834	-0.275	-0.069	-2.419	-0.006
315.000	0.180	3.910	-0.275	-0.069	-2.416	-0.006
316.000	0.176	3.837	-0.275	-0.066	-2.416	-0.006
317.000	0.176	3.847	-0.272	-0.069	-2.416	-0.006
318.000	0.176	3.891	-0.272	-0.066	-2.416	-0.006
319.000	0.176	3.904	-0.275	-0.069	-2.413	-0.006
320.000	0.176	3.879	-0.275	-0.069	-2.413	-0.006
321.000	0.176	3.863	-0.278	-0.069	-2.410	-0.006
322.000	0.176	3.901	-0.275	-0.069	-2.410	-0.006
323.000	0.176	3.856	-0.275	-0.069	-2.410	-0.006
324.000	0.176	3.885	-0.275	-0.069	-2.407	-0.006
325.000	0.176	3.882	-0.275	-0.069	-2.407	-0.006
326.000	0.176	3.910	-0.275	-0.069	-2.407	-0.006
327.000	0.176	3.847	-0.275	-0.069	-2.407	-0.006

328.000	0.176	3.793	-0.275	-0.069	-2.404	-0.006
329.000	0.176	3.777	-0.275	-0.069	-2.404	-0.006
330.000	0.173	3.856	-0.278	-0.072	-2.401	-0.009
331.000	0.173	3.803	-0.275	-0.072	-2.397	-0.006
332.000	0.173	3.828	-0.278	-0.072	-2.397	-0.009
333.000	0.173	3.818	-0.278	-0.072	-2.394	-0.009
334.000	0.170	3.850	-0.282	-0.072	-2.394	-0.009
335.000	0.173	3.841	-0.278	-0.072	-2.391	-0.009
336.000	0.173	3.853	-0.278	-0.072	-2.391	-0.009
337.000	0.173	3.904	-0.278	-0.072	-2.388	-0.009
338.000	0.170	3.856	-0.282	-0.072	-2.388	-0.009
339.000	0.170	3.904	-0.278	-0.072	-2.385	-0.009
340.000	0.170	3.913	-0.278	-0.072	-2.385	-0.009
341.000	0.170	3.869	-0.282	-0.075	-2.382	-0.012
342.000	0.170	3.904	-0.278	-0.075	-2.382	-0.009
343.000	0.170	3.904	-0.278	-0.072	-2.382	-0.009
344.000	0.170	3.929	-0.282	-0.075	-2.379	-0.012
345.000	0.170	3.863	-0.282	-0.075	-2.379	-0.009
346.000	0.170	3.951	-0.278	-0.072	-2.375	-0.009
347.000	0.167	3.904	-0.282	-0.075	-2.375	-0.012
348.000	0.170	3.964	-0.282	-0.075	-2.375	-0.012
349.000	0.167	3.977	-0.282	-0.075	-2.375	-0.012
350.000	0.167	3.986	-0.282	-0.075	-2.375	-0.012
351.000	0.167	3.964	-0.285	-0.075	-2.375	-0.012
352.000	0.167	3.920	-0.282	-0.075	-2.372	-0.012
353.000	0.167	3.923	-0.285	-0.075	-2.372	-0.012
354.000	0.164	3.954	-0.285	-0.078	-2.372	-0.012
355.000	0.167	3.939	-0.285	-0.078	-2.372	-0.012
356.000	0.167	3.926	-0.282	-0.078	-2.369	-0.012
357.000	0.167	3.945	-0.285	-0.078	-2.369	-0.012
358.000	0.167	3.954	-0.285	-0.078	-2.369	-0.012
359.000	0.164	3.907	-0.285	-0.078	-2.369	-0.015
360.000	0.164	3.932	-0.285	-0.078	-2.369	-0.012
361.000	0.164	3.926	-0.288	-0.078	-2.369	-0.015
362.000	0.164	3.989	-0.285	-0.078	-2.369	-0.015
363.000	0.164	3.942	-0.288	-0.078	-2.369	-0.015
364.000	0.164	3.932	-0.288	-0.078	-2.366	-0.015
365.000	0.164	3.970	-0.285	-0.078	-2.363	-0.015
366.000	0.164	4.021	-0.285	-0.078	-2.363	-0.015
367.000	0.161	3.983	-0.288	-0.081	-2.360	-0.015
368.000	0.164	3.945	-0.285	-0.081	-2.363	-0.015
369.000	0.161	3.970	-0.288	-0.081	-2.360	-0.015
370.000	0.161	3.964	-0.288	-0.081	-2.360	-0.015
371.000	0.161	4.027	-0.288	-0.081	-2.360	-0.015
372.000	0.161	4.021	-0.288	-0.081	-2.360	-0.018
373.000	0.161	3.980	-0.288	-0.081	-2.363	-0.018
374.000	0.161	4.043	-0.288	-0.081	-2.363	-0.018
375.000	0.161	3.967	-0.291	-0.081	-2.363	-0.018
376.000	0.161	3.970	-0.291	-0.081	-2.363	-0.018
377.000	0.157	4.040	-0.288	-0.081	-2.363	-0.018
378.000	0.161	4.002	-0.288	-0.081	-2.363	-0.018
379.000	0.157	4.075	-0.291	-0.084	-2.363	-0.018

380.000	0.157	4.005	-0.291	-0.084	-2.366	-0.018
381.000	0.157	4.034	-0.288	-0.081	-2.366	-0.018
382.000	0.157	3.992	-0.288	-0.084	-2.366	-0.018
383.000	0.157	4.049	-0.291	-0.084	-2.369	-0.018
384.000	0.157	4.056	-0.291	-0.084	-2.372	-0.018
385.000	0.157	4.084	-0.291	-0.084	-2.372	-0.018
386.000	0.157	3.992	-0.288	-0.081	-2.372	-0.018
387.000	0.157	4.056	-0.288	-0.084	-2.375	-0.018
388.000	0.157	3.989	-0.288	-0.084	-2.372	-0.018
389.000	0.157	3.977	-0.288	-0.084	-2.372	-0.018
390.000	0.157	4.049	-0.288	-0.084	-2.375	-0.018
391.000	0.157	3.983	-0.288	-0.084	-2.375	-0.018
392.000	0.157	3.964	-0.291	-0.081	-2.375	-0.018
393.000	0.157	4.018	-0.291	-0.081	-2.375	-0.018
394.000	0.157	3.958	-0.288	-0.081	-2.372	-0.018
395.000	0.157	3.989	-0.288	-0.084	-2.372	-0.018
396.000	0.154	3.980	-0.291	-0.084	-2.372	-0.018
397.000	0.154	3.973	-0.294	-0.084	-2.372	-0.018
398.000	0.154	4.008	-0.291	-0.084	-2.369	-0.022
399.000	0.154	4.043	-0.294	-0.084	-2.369	-0.022
400.000	0.154	4.056	-0.291	-0.088	-2.369	-0.022
401.000	0.154	4.034	-0.291	-0.088	-2.369	-0.022
402.000	0.154	4.043	-0.294	-0.088	-2.366	-0.022
403.000	0.154	4.078	-0.291	-0.088	-2.366	-0.022
404.000	0.154	4.103	-0.294	-0.088	-2.366	-0.022
405.000	0.154	4.037	-0.294	-0.088	-2.363	-0.022
406.000	0.151	4.087	-0.294	-0.088	-2.366	-0.022
407.000	0.151	4.024	-0.294	-0.088	-2.363	-0.022
408.000	0.151	4.084	-0.294	-0.088	-2.360	-0.022
409.000	0.151	4.008	-0.291	-0.088	-2.360	-0.025
410.000	0.151	3.989	-0.294	-0.088	-2.360	-0.025
411.000	0.151	4.110	-0.294	-0.088	-2.360	-0.022
412.000	0.151	4.034	-0.294	-0.088	-2.360	-0.022
413.000	0.151	4.049	-0.294	-0.088	-2.357	-0.022
414.000	0.151	4.005	-0.294	-0.088	-2.357	-0.022
415.000	0.151	4.078	-0.294	-0.088	-2.357	-0.022
416.000	0.151	4.053	-0.297	-0.088	-2.353	-0.022
417.000	0.151	4.021	-0.294	-0.088	-2.353	-0.025
418.000	0.151	4.065	-0.297	-0.091	-2.350	-0.025
419.000	0.151	4.049	-0.297	-0.091	-2.350	-0.025
420.000	0.148	4.030	-0.294	-0.091	-2.347	-0.025
421.000	0.148	4.059	-0.297	-0.091	-2.347	-0.025
422.000	0.148	4.084	-0.297	-0.091	-2.347	-0.025
423.000	0.148	4.094	-0.294	-0.091	-2.344	-0.025
424.000	0.148	4.094	-0.297	-0.091	-2.344	-0.025
425.000	0.148	4.040	-0.297	-0.091	-2.344	-0.025
426.000	0.148	4.065	-0.297	-0.091	-2.344	-0.025
427.000	0.148	4.097	-0.294	-0.091	-2.344	-0.025
428.000	0.148	4.056	-0.294	-0.091	-2.341	-0.025
429.000	0.148	4.034	-0.297	-0.091	-2.341	-0.025
430.000	0.148	4.110	-0.297	-0.091	-2.341	-0.025
431.000	0.148	4.100	-0.294	-0.091	-2.341	-0.025

432.000	0.148	4.065	-0.294	-0.091	-2.341	-0.025
433.000	0.148	4.024	-0.297	-0.091	-2.341	-0.025
434.000	0.148	4.043	-0.297	-0.091	-2.341	-0.025
435.000	0.148	4.021	-0.297	-0.091	-2.338	-0.025
436.000	0.148	4.113	-0.297	-0.091	-2.338	-0.025
437.000	0.148	4.087	-0.297	-0.091	-2.335	-0.025
438.000	0.145	4.040	-0.297	-0.091	-2.338	-0.025
439.000	0.145	4.024	-0.297	-0.091	-2.335	-0.028
440.000	0.145	4.062	-0.301	-0.091	-2.335	-0.028
441.000	0.145	4.030	-0.297	-0.094	-2.335	-0.025
442.000	0.145	4.043	-0.297	-0.091	-2.335	-0.025
443.000	0.145	4.116	-0.297	-0.091	-2.335	-0.025
444.000	0.145	4.068	-0.301	-0.094	-2.331	-0.025
445.000	0.145	4.097	-0.301	-0.094	-2.331	-0.028
446.000	0.145	4.030	-0.297	-0.094	-2.331	-0.028
447.000	0.145	4.097	-0.297	-0.094	-2.331	-0.028
448.000	0.145	4.030	-0.297	-0.094	-2.331	-0.025
449.000	0.145	4.046	-0.301	-0.094	-2.331	-0.025
450.000	0.145	4.097	-0.301	-0.094	-2.328	-0.028
451.000	0.145	4.072	-0.301	-0.094	-2.328	-0.028
452.000	0.142	4.059	-0.301	-0.094	-2.325	-0.028
453.000	0.142	4.043	-0.304	-0.094	-2.325	-0.028
454.000	0.142	4.113	-0.301	-0.094	-2.325	-0.028
455.000	0.142	4.097	-0.301	-0.094	-2.325	-0.028
456.000	0.142	4.062	-0.301	-0.094	-2.325	-0.028
457.000	0.142	4.087	-0.304	-0.094	-2.322	-0.028
458.000	0.142	4.043	-0.301	-0.094	-2.322	-0.028
459.000	0.142	4.078	-0.301	-0.094	-2.319	-0.028
460.000	0.142	4.059	-0.304	-0.094	-2.319	-0.028
461.000	0.142	4.084	-0.301	-0.097	-2.319	-0.028
462.000	0.142	4.049	-0.301	-0.097	-2.316	-0.031
463.000	0.142	4.125	-0.304	-0.097	-2.316	-0.031
464.000	0.142	4.040	-0.304	-0.097	-2.313	-0.031
465.000	0.142	4.053	-0.304	-0.097	-2.313	-0.031
466.000	0.142	4.132	-0.304	-0.097	-2.309	-0.031
467.000	0.138	4.119	-0.301	-0.097	-2.309	-0.031
468.000	0.138	4.138	-0.304	-0.097	-2.306	-0.031
469.000	0.138	4.151	-0.307	-0.097	-2.306	-0.031
470.000	0.138	4.100	-0.304	-0.097	-2.303	-0.031
471.000	0.138	4.135	-0.304	-0.097	-2.303	-0.031
472.000	0.138	4.151	-0.307	-0.097	-2.300	-0.034
473.000	0.138	4.084	-0.307	-0.097	-2.300	-0.034
474.000	0.138	4.103	-0.307	-0.097	-2.300	-0.034
475.000	0.138	4.160	-0.307	-0.100	-2.297	-0.034
476.000	0.135	4.097	-0.307	-0.100	-2.294	-0.034
477.000	0.135	4.144	-0.307	-0.100	-2.294	-0.034
478.000	0.135	4.189	-0.307	-0.100	-2.291	-0.031
479.000	0.135	4.154	-0.310	-0.100	-2.291	-0.034
480.000	0.135	4.106	-0.307	-0.100	-2.291	-0.034
481.000	0.135	4.151	-0.307	-0.100	-2.291	-0.034
482.000	0.135	4.147	-0.307	-0.100	-2.291	-0.034
483.000	0.135	4.151	-0.307	-0.100	-2.291	-0.034

484.000	0.138	4.094	-0.304	-0.100	-2.291	-0.034
485.000	0.135	4.110	-0.304	-0.100	-2.287	-0.031
486.000	0.138	4.110	-0.304	-0.100	-2.287	-0.034
487.000	0.135	4.087	-0.307	-0.100	-2.287	-0.031
488.000	0.135	4.128	-0.307	-0.100	-2.287	-0.031
489.000	0.135	4.119	-0.307	-0.100	-2.287	-0.031
490.000	0.135	4.081	-0.307	-0.100	-2.284	-0.034
491.000	0.135	4.049	-0.304	-0.100	-2.284	-0.031
492.000	0.135	4.125	-0.304	-0.100	-2.284	-0.034
493.000	0.135	4.078	-0.307	-0.100	-2.284	-0.031
494.000	0.135	4.065	-0.307	-0.100	-2.281	-0.034
495.000	0.135	4.091	-0.307	-0.100	-2.281	-0.034
496.000	0.135	4.138	-0.307	-0.100	-2.281	-0.034
497.000	0.135	4.084	-0.310	-0.100	-2.281	-0.034
498.000	0.135	4.132	-0.310	-0.100	-2.278	-0.034
499.000	0.135	4.081	-0.307	-0.100	-2.278	-0.034
500.000	0.132	4.100	-0.307	-0.100	-2.278	-0.034
501.000	0.135	4.097	-0.310	-0.100	-2.278	-0.034
502.000	0.132	4.128	-0.310	-0.100	-2.275	-0.034
503.000	0.132	4.056	-0.307	-0.100	-2.275	-0.034
504.000	0.132	4.091	-0.307	-0.100	-2.272	-0.034
505.000	0.132	4.091	-0.307	-0.100	-2.272	-0.034
506.000	0.132	4.110	-0.310	-0.100	-2.269	-0.034
507.000	0.132	4.094	-0.307	-0.100	-2.272	-0.034
508.000	0.132	4.084	-0.307	-0.103	-2.269	-0.034
509.000	0.132	4.154	-0.310	-0.103	-2.265	-0.034
510.000	0.132	4.072	-0.310	-0.103	-2.265	-0.034
511.000	0.132	4.100	-0.307	-0.100	-2.265	-0.034
512.000	0.132	4.154	-0.307	-0.103	-2.262	-0.034
513.000	0.132	4.081	-0.310	-0.103	-2.262	-0.037
514.000	0.132	4.154	-0.307	-0.103	-2.259	-0.037
515.000	0.132	4.138	-0.310	-0.103	-2.259	-0.037
516.000	0.132	4.097	-0.310	-0.103	-2.259	-0.037
517.000	0.132	4.100	-0.310	-0.103	-2.259	-0.037
518.000	0.129	4.094	-0.310	-0.103	-2.259	-0.037
519.000	0.132	4.113	-0.307	-0.103	-2.259	-0.037
520.000	0.129	4.094	-0.310	-0.103	-2.259	-0.037
521.000	0.132	4.122	-0.310	-0.103	-2.259	-0.037
522.000	0.129	4.128	-0.310	-0.103	-2.259	-0.037
523.000	0.129	4.081	-0.310	-0.103	-2.256	-0.034
524.000	0.129	4.081	-0.310	-0.103	-2.253	-0.037
525.000	0.129	4.119	-0.313	-0.103	-2.253	-0.037
526.000	0.129	4.113	-0.310	-0.103	-2.253	-0.037
527.000	0.129	4.056	-0.310	-0.103	-2.250	-0.037
528.000	0.129	4.119	-0.313	-0.103	-2.250	-0.037
529.000	0.129	4.087	-0.310	-0.107	-2.247	-0.037
530.000	0.129	4.103	-0.310	-0.107	-2.247	-0.037
531.000	0.129	4.119	-0.313	-0.107	-2.243	-0.037
532.000	0.129	4.185	-0.310	-0.107	-2.240	-0.037
533.000	0.129	4.147	-0.313	-0.107	-2.240	-0.040
534.000	0.126	4.182	-0.313	-0.107	-2.237	-0.037
535.000	0.129	4.106	-0.310	-0.107	-2.237	-0.040

536.000	0.129	4.122	-0.313	-0.107	-2.234	-0.040
537.000	0.126	4.192	-0.317	-0.107	-2.234	-0.040
538.000	0.126	4.097	-0.313	-0.107	-2.231	-0.040
539.000	0.126	4.138	-0.313	-0.107	-2.228	-0.040
540.000	0.126	4.170	-0.313	-0.107	-2.228	-0.040
541.000	0.126	4.173	-0.313	-0.107	-2.225	-0.040
542.000	0.126	4.122	-0.317	-0.107	-2.221	-0.040
543.000	0.126	4.154	-0.313	-0.107	-2.218	-0.040
544.000	0.126	4.214	-0.317	-0.107	-2.218	-0.040
545.000	0.126	4.211	-0.313	-0.110	-2.215	-0.040
546.000	0.126	4.239	-0.317	-0.110	-2.212	-0.040
547.000	0.126	4.151	-0.317	-0.110	-2.212	-0.040
548.000	0.126	4.198	-0.317	-0.110	-2.209	-0.044
549.000	0.126	4.192	-0.317	-0.110	-2.206	-0.040
550.000	0.123	4.208	-0.313	-0.110	-2.203	-0.040
551.000	0.123	4.211	-0.317	-0.110	-2.199	-0.040
552.000	0.123	4.154	-0.317	-0.110	-2.196	-0.040
553.000	0.123	4.192	-0.313	-0.110	-2.196	-0.040
554.000	0.123	4.223	-0.317	-0.110	-2.193	-0.044
555.000	0.123	4.211	-0.313	-0.110	-2.190	-0.044
556.000	0.123	4.204	-0.317	-0.110	-2.187	-0.044
557.000	0.123	4.135	-0.317	-0.110	-2.184	-0.044
558.000	0.123	4.154	-0.313	-0.110	-2.184	-0.044
559.000	0.123	4.179	-0.317	-0.110	-2.181	-0.044
560.000	0.123	4.223	-0.317	-0.110	-2.177	-0.044
561.000	0.123	4.135	-0.320	-0.110	-2.174	-0.044
562.000	0.123	4.154	-0.317	-0.110	-2.171	-0.044
563.000	0.123	4.163	-0.317	-0.110	-2.171	-0.044
564.000	0.123	4.141	-0.317	-0.110	-2.171	-0.044
565.000	0.123	4.208	-0.317	-0.110	-2.168	-0.040

APPENDIX C
GROUNDWATER MODELING

Modflow and MT3D Model Summary

1.0 Model Input

1.1 Model area: 200 ft x 200 ft

1.2 Model grid:

Number of Columns:	78	Grid refined from 16 to 51
Number of Rows:	78	Grid refined from 16 to 51
Number of Layers:	2	

The horizontal and vertical scales show the extension of the model area in [ft].

It has to be pointed out that this model is intentionally simple. It assumes horizontal layering and does not account for horizontal anisotropy concerning conductivity or variations in thickness. Its main purpose is to provide help in the initial screening phase.

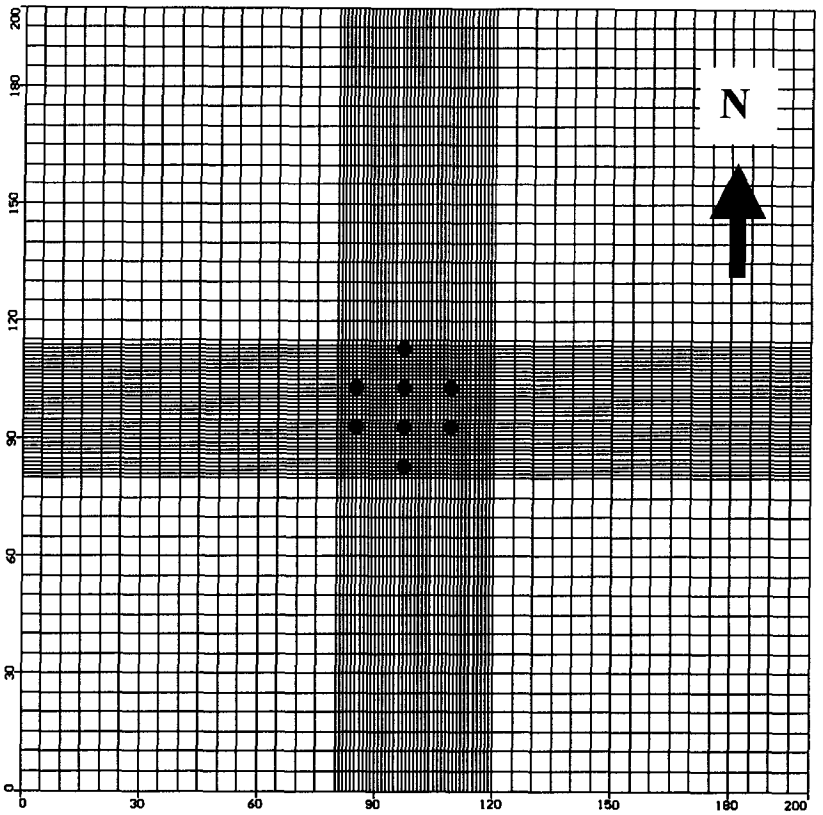
1.3 Constant Heads:
To resemble the general groundwater flow in this area, constant head boundaries have been assigned to the model ground water aquifer. According to data collected at monitoring wells from previous site investigations, groundwater flow direction is highly variable and can change direction by 180°. As a result, for modeling purposes it was assumed to be in a southern direction with a gradient of 0.002 ft/ft.

1.4 Conductivity:
Assigning conductivity distributions for the different model layers has been the most sensitive part of the generation of the model. Data from boring logs and pump tests have been used to calculate hydraulic conductivities for the different layers represented in the model. Conductivities calculated for the layers from the pump tests were initially imputed into the model and were altered slightly to match model draw-down to pump test draw-down.

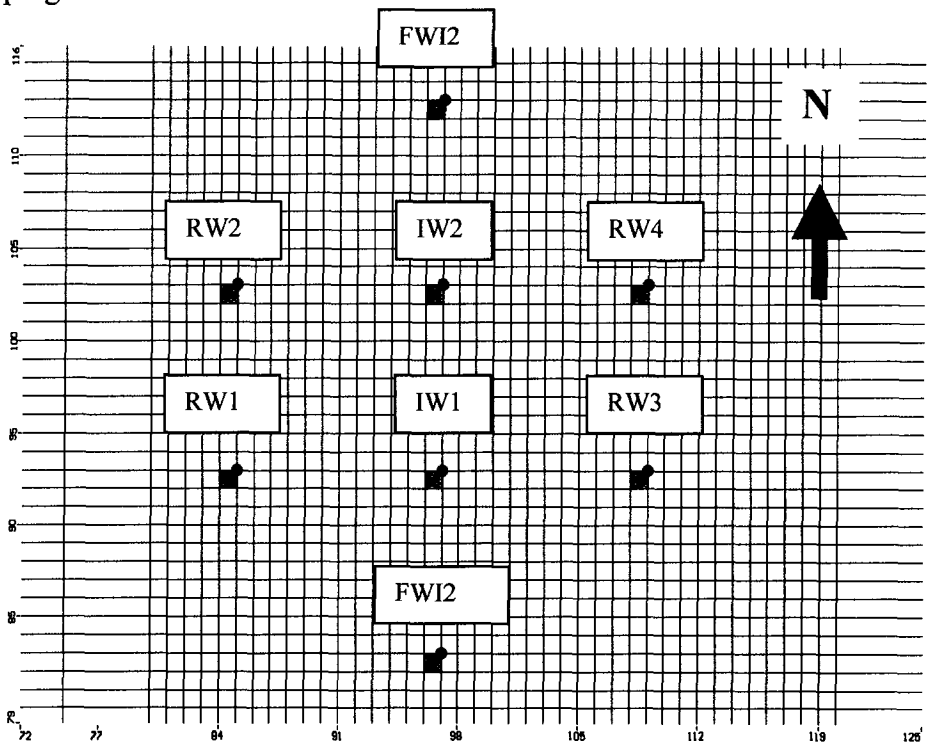
Assigned Conductivities:

Layers	Conductivities		
	Kx (ft/day)	Ky(ft/day)	Kz(ft/day)
1	10	10	1.0
2	0.001	0.001	0.0001

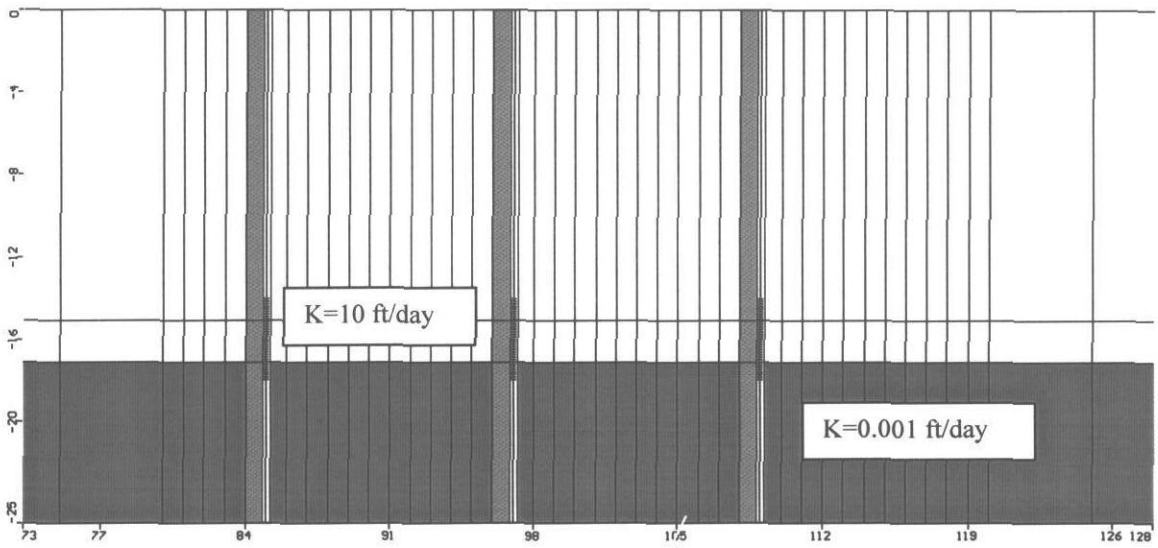
The diagram below shows a plan view of the MODFLOW grid and pumping wells.



The following diagram shows an enlarged plan view of the area of interest with the pumping wells labeled.



The following diagram shows a cross-section of the model at row 30 with the 2 different conductivity layers. The diagram also shows (from left to right) RW2, IW2 and RW4.

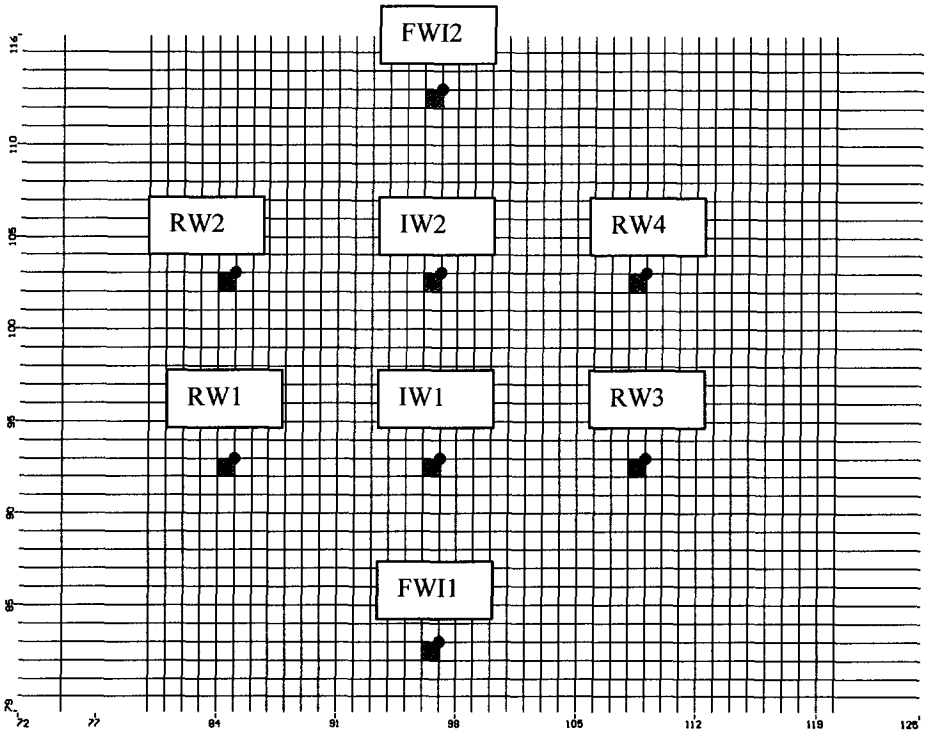


1.5 Input Parameters

Parameter	Value	Reference
Hydraulic Conductivity	10 ft/day (fill) 0.001 ft/day (Bay mud)	Soil cores, Pump tests
Hydraulic Gradient	0.002 ft/ft	Groundwater sampling Events
Storage Coefficient (Sc)	0.0001	Freeze and Cherry, 1979
Specific Yield	0.1	Freeze and Cherry, 1979
Bulk Density	48 kg/ft^3	Site 5 Geotechnical analysis
Porosity	0.35	Freeze and Cherry, 1979
Decay Constant	0.000028 1/day	Surfactant Manufacturers data
Linear Sorption Coefficient	0.0015 ft^3/kg	Previous lab analysis
Dispersivity	0.5 ft	L/Pe# = 10ft/20
Model Surface Elevation	0	Model simplification
Depth to Groundwater	-7	Groundwater Sampling Events
Grid Resolution	1ft-5ft	Previous experience
Grid Size	200ft x 200ft	Previous experience

2.0 Simulation of Divergent Flow Scenario

It was decided that a line drive flow system should be evaluated. Two central injection wells (IW1 and IW2) surrounded by 4 recovery wells. Two hydraulic control wells (FWI1 and FWI2) minimize horizontal migration of surfactant and solublized contaminant.



2.1 Dispersion:

A longitudinal dispersion coefficient of 0.5 ft has been used in the model. This value is based on the assumption of a Peclet number of 20 and a travel distance of 10 ft between injection and recovery wells.

2.2 Chemical Reactions:

Since the actual goal is to simulate surfactant flushing through contaminated areas the transport model has to account for sorption of the surfactant on porous media. Sorption of the surfactant on the soil has been determined from laboratory batch tests and previous field tests. Sorption used in the final analysis was 0.0015 ft^3/Kg. However, a sensitivity analysis using 0.001 and 0.005 ft^3/Kg did not significantly alter the results.

2.3 Bulk density (soil samples from this site): B 48 [lb/ft^3]

To ensure the sorption was not underestimated a linear isotherm has been assumed. However, a Freundlich or Langmuirian isotherm should result in less overall sorption.

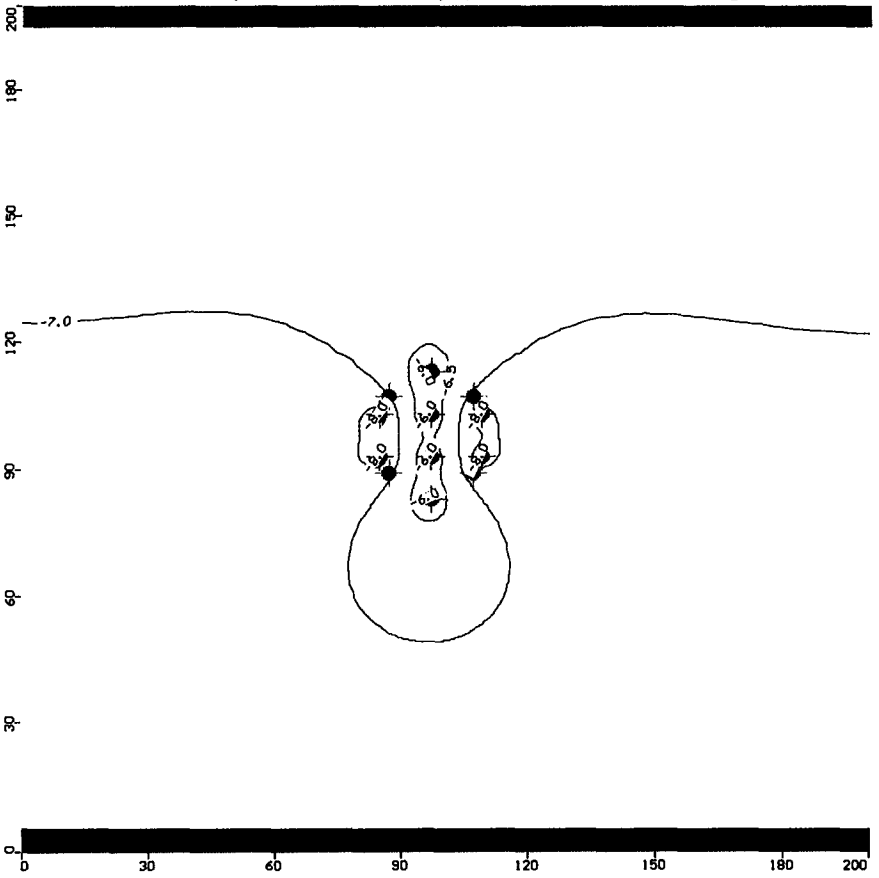
The injected surfactant concentration is 40,000 mg/l (4wt%).

2.4 Pumping Schedule

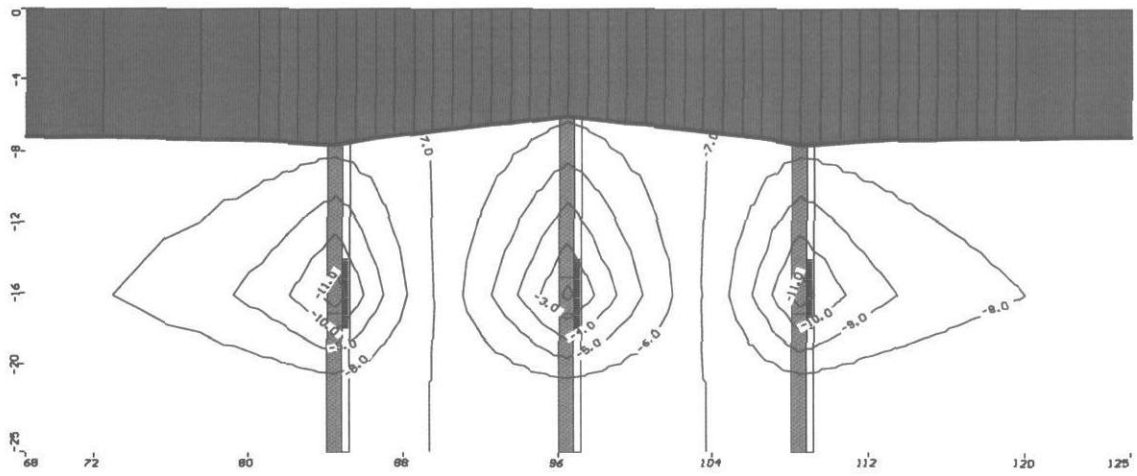
The pumping schedule for the injection, fresh water injection and recovery wells are presented in the following Table. The first 1000 days is for the water table to reach equilibrium given the constant head boundaries. Once the water table has become stable the wells are pumped for five days to ensure steady state has been reached. This will be equal to roughly 5 pore volumes. The next five days are for the surfactant flush followed by five days of freshwater. The next 365 days is to evaluate plume migration and the effects of biodegradation.

TIME (day)	IW1	IW2	RW1	RW2	RW3	RW4	FWI1	FWI2
0-1000	0 gpm freshwater	0 gpm freshwater	0 gpm	0 gpm	0 gpm	0 gpm	0 gpm freshwater	0 gpm freshwater
1000-1005	2 gpm freshwater	2 gpm freshwater	-2 gpm	-2 gpm	-2 gpm	-2 gpm	2 gpm freshwater	2 gpm freshwater
1005-1010	2 gpm surfactant	2 gpm surfactant	-2 gpm	-2 gpm	-2 gpm	-2 gpm	2 gpm freshwater	2 gpm freshwater
1010-1015	2 gpm freshater	2 gpm freshwater	-2 gpm	-2 gpm	-2 gpm	-2 gpm	2 gpm freshwater	2 gpm freshwater
1015-1380	0	0	0	0	0	0	0	0

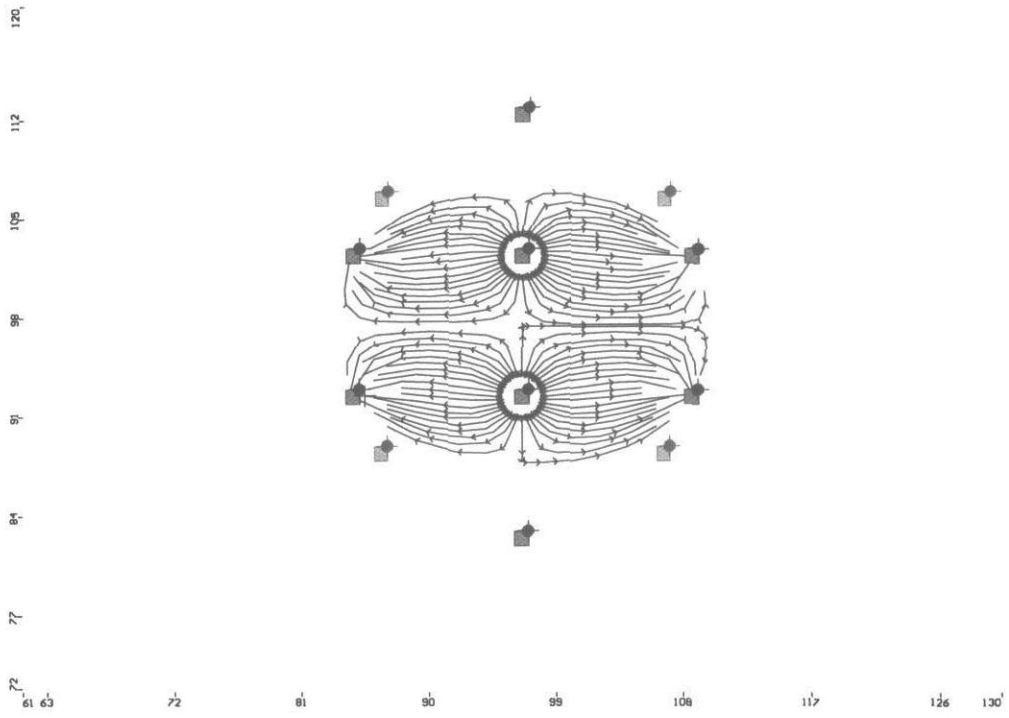
The water table contours at steady state (1005 days) is shown in the diagram below.



The diagram below shows a cross section at row 30 after steady has been reached (1005 days). The wells from left to right are RW2, IW2 and RW4.

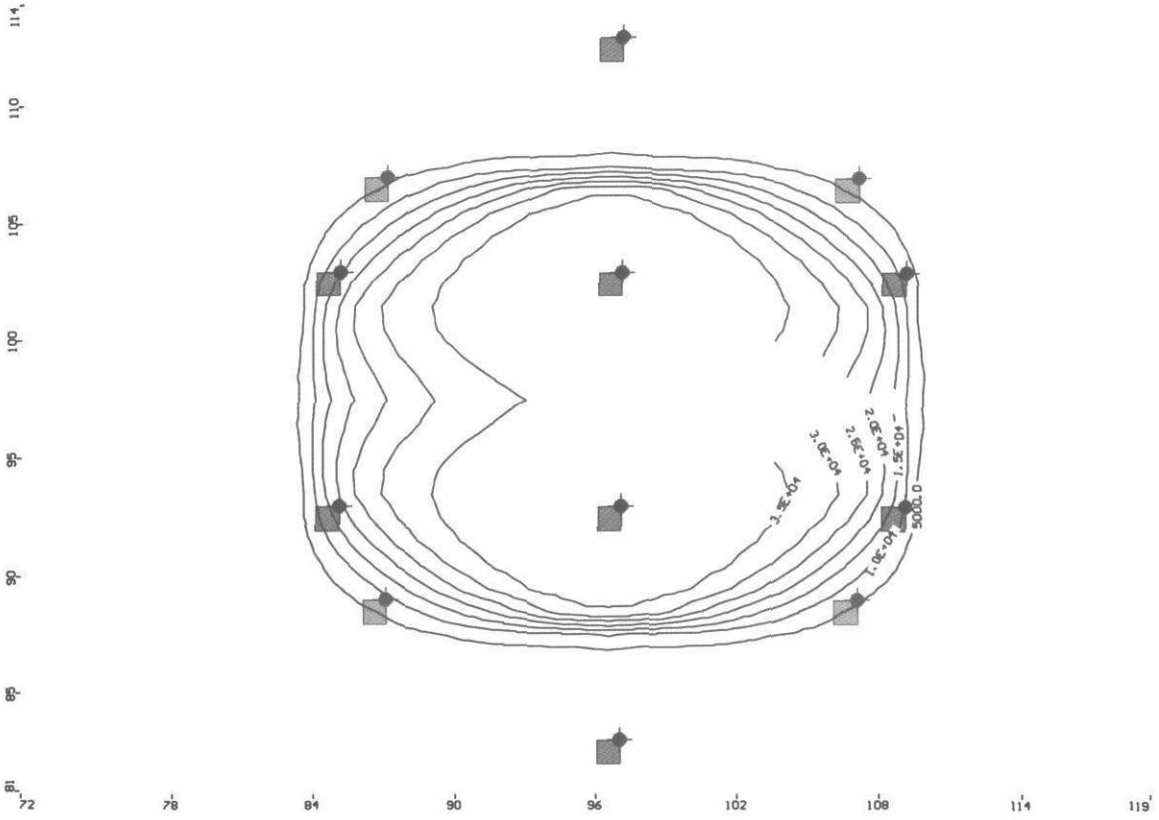


This diagram shows the flow paths and capture of particles (injected surfactant) using this pumping scenario.

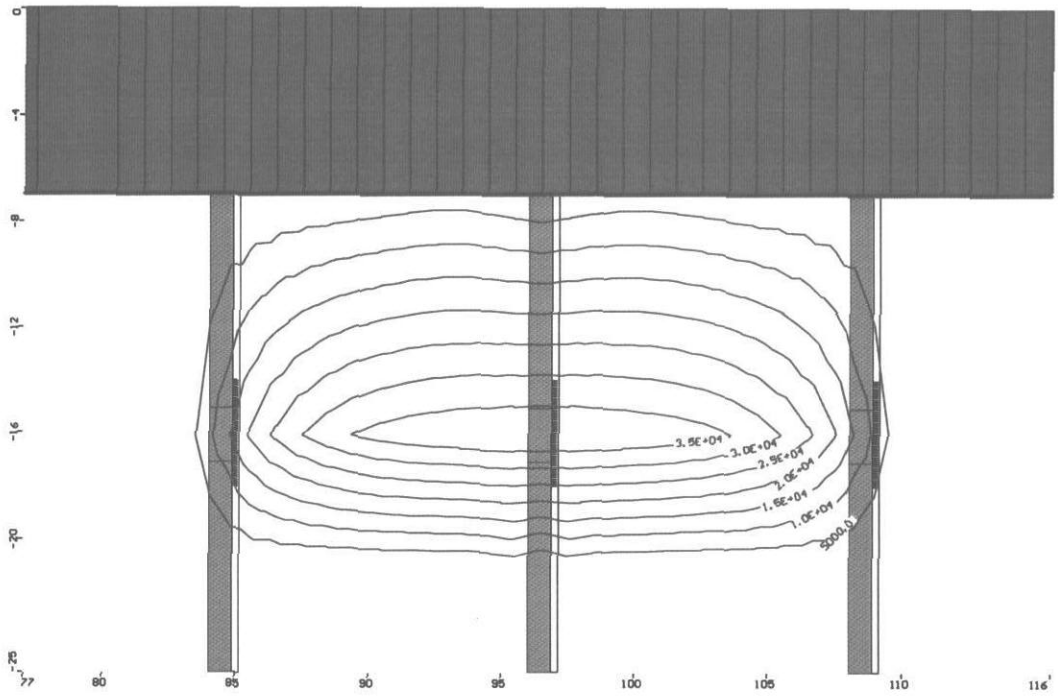


2.5 Results:

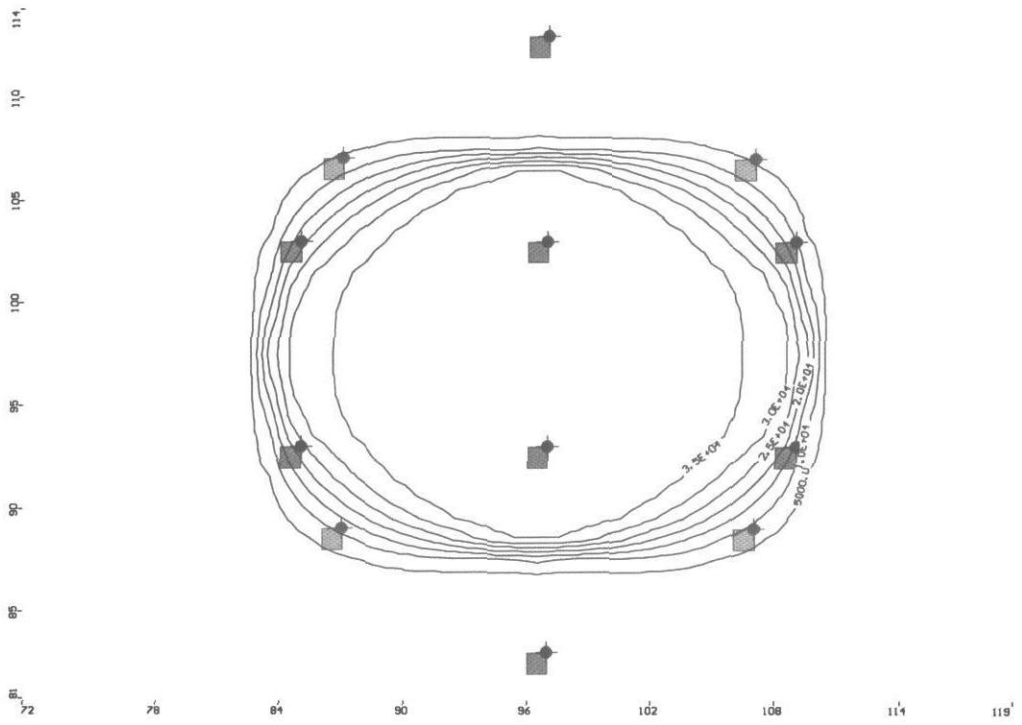
This diagrams shows that this pumping scenario in this media is capable of exchanging about one pore volume in 1.0 day in the sandy fill layer. The diagram below is a plan view of the fill layer after 1.0 day of flushing with surfactants. This pumping scenario targets the lower portion of the first layer where the highest amount of contaminant is located. The model shows the surfactant front reaching the recovery wells and good coverage of the targeted zone. The red contour lines and labels represent surfactant concentrations in mg/L. The blue labels represent water table elevations.



This diagram shows a cross section at row 29 (through RW2, IW2 and RW4) after 1.0 day of surfactant injection. The well in the diagram is an observation point at RW2 and shows the surfactant front reaching the well.

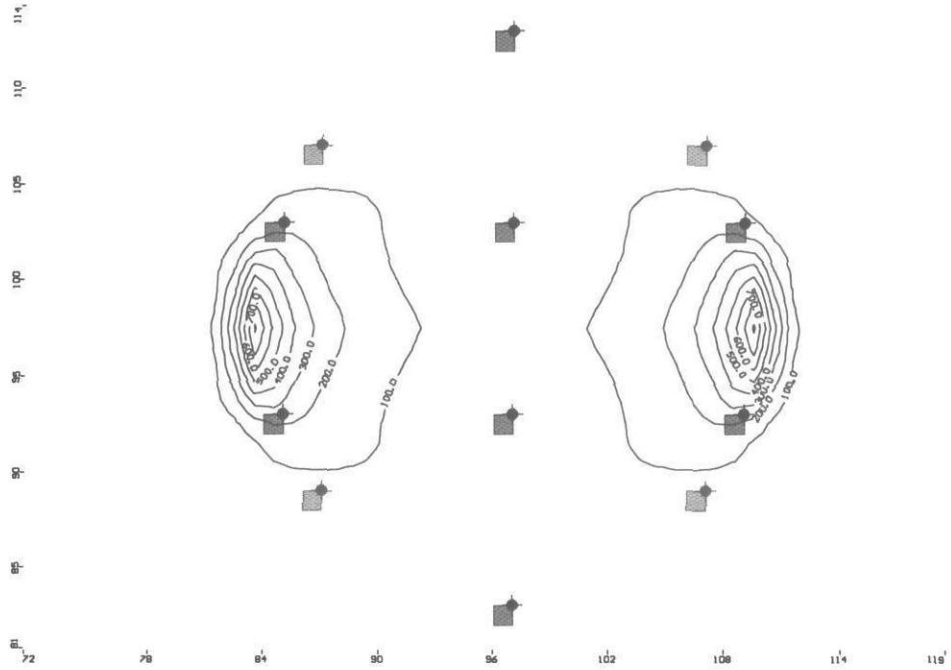


This diagram shows the surfactant plume after 5 days of injection. Note the effectiveness of the hydraulic control wells.

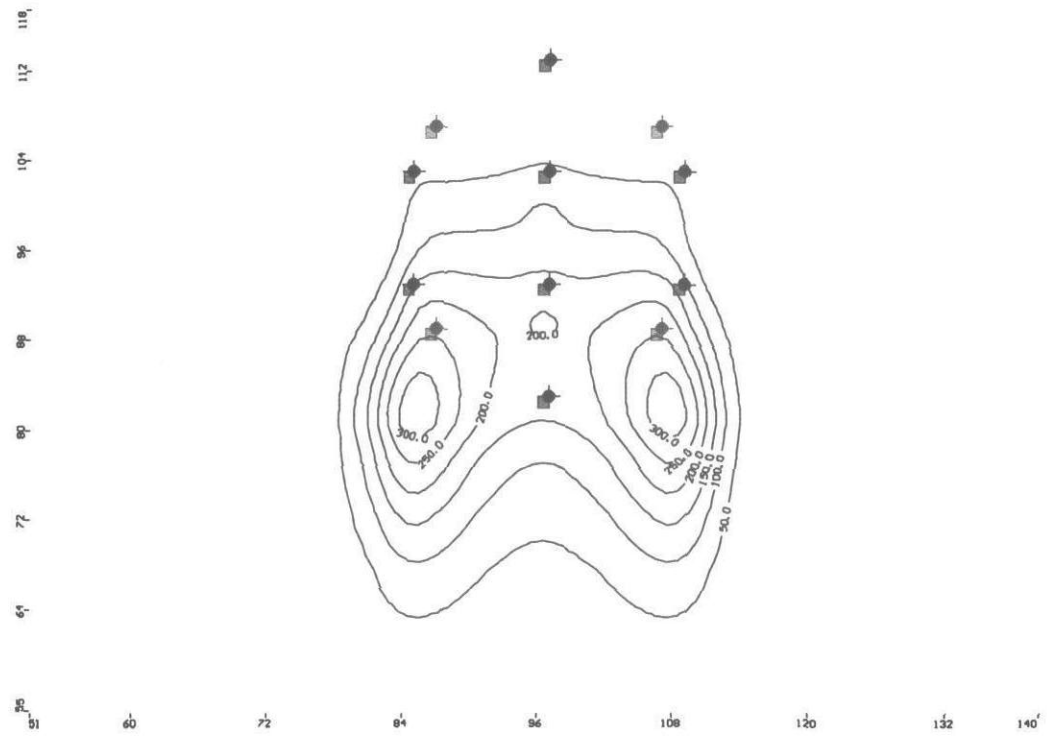


APPENDIX D
LABORATORY SCREENING DATA AND TOXICITY DATA AND MSDS SHEETS

Below is the test area after 5 days of injecting fresh water. The 5 days of post-surfactant water flooding represents the termination of flooding operations on site. These plumes would be further reduced by 1 or 2 days of pumping the recovery wells.



This picture shows the remaining surfactant plume 1 year after flush.



Surfactant-NAPLs Phase Properties

Surfactant System: 5 wt% Dowfax 8390 + 2 wt% AMA

Scanning Parameter: NaCl
W = aqueous phase, **O = 1,1,1 TCA**, M = middle phase
Temp = 18 °C

NaCl wt%	Winsor Type	Volume of W mL	Volume of O mL	Volume of M mL	Comment
0.5	I	5.1	4.9	0	W: clear, O: clear+trace milky
1	I	5.2	4.8	0	W: clear, O: clear+trace milky
1.5	I	5.3	4.7	0	W: clear, O: clear+trace milky
2	I	5.4	4.6	0	W: clear, O: clear+trace milky
2.5	I	5.3	4.7	0	W: clear, O: clear+trace milky

Oil = 1,1 DCE

NaCl wt%	Winsor Type	Volume of W mL	Volume of O mL	Volume of M mL	Comment
0.5	I	5.1	4.9	0	milky phases presence
1	I	5.2	4.8	0	milky phases presence
1.5	I	5.4	4.6	0	milky phases presence
2	I	5.2	4.8	0	milky phases presence
2.5	I	5.3	4.7	0	milky phases presence

Oil = TCA/DCE mixture (50/50)

NaCl wt%	Winsor Type	Volume of W mL	Volume of O mL	Volume of M mL	Comment
0.5	I	5	5	0	W: clear, O: cloudy phase presence
1	I	5.5	4.5	0	W: clear, O: cloudy phase presence
1.5	I	5.3	4.7	0	W: clear, O: cloudy phase presence
2	I	5.4	4.6	0	W: clear, O: cloudy phase presence
2.5	I	5.4	4.6	0	W: clear, O: cloudy phase presence

Scanning Parameter: NaCl+$CaCl_2$
Oil = TCA, or TCA/DCE mixture (50/50)

NaCl wt%	$CaCl_2$ wt%	Oil	Winsor Type	Volume of W mL	Volume of O mL	Volume of mL	Comment
0.3	1	TCA	I	5	5	0	W: clear, O: clear
3	1	TCA	I	5.4	4.6	0	W: clear, O: clear
2	1	TCA/DCE	I	5.3	4.7	0	W: clear, O: clear
2.5	1	TCA/DCE	I	5.4	4.6	0	W: clear, O: clear
3	1	TCA/DCE	I	5.4	4.6	0	W: clear, O: clear

Surfactant-NAPLs Phase Properties
(Continued)

Surfactant System: 4 wt% Lubrizol 71 + 2 wt% IPA

Scanning Parameter: $NaCl+CaCl_2$
Oil = TCA

$CaCl_2$ wt%	NaCl wt%	Winsor Type	Volume of W mL	Volume of O mL	Volume of M mL	Comment
0.05	2.5	I	5	5	0	W: cloudy, O: clear
0.075	2.5	I	5.3	4.7	0	W: cloudy, O: clear
0.1	2.5	I	6.2	3.8	0	W: hazy, O: clear
0.15	2.5	III	4	4.6	1.4	W: clear, O: hazy, M: hazy
0.25	2.5	III	3.2	5.1	1.7	W: clear, O: hazy, M: hazy
0.5	2.5	II	4.7	5.3	0	W:clear, O: cloudy

Surfactant System: 2 wt% Isalchem 123-2PO + 2 wt% AMA + 1 wt% Isopropyl alcohol (IPA)

Scanning Parameter: Isopropyl alcohol, IPA and $MgCl_2$
Oil = TCA

$MgCl_2$ wt%	Winsor Type	Volume of W mL	Volume of O mL	Volume of M mL	Comment
0.2	I	5.2	4.8	0	W: milky, O: clear
0.4	I	5.4	4.6	0	W: cloudy, O: clear
0.6	I	5.5	4.5	0	W: translucent, O: clear
0.8	I	5.8	4.2	0	W: translucent, O: clear
1	III	1.3	4.8	3.9	W: translucent, O: clear, M: hazy

Oil = DCE

$MgCl_2$ wt%	Winsor Type	Volume of W mL	Volume of O mL	Volume of M mL	Comment
0.2	I	5.1	4.9	0	W: milky, O: clear
0.25	I	6.3	3.7	0	W: milky, O: clear
0.3	I	7.4	2.6	0	W: cloudy, O: clear
0.35	I	8.1	1.9	0	W: cloudy, O: clear
0.4	II	3	7	0	W: clear, O: hazy
0.6	II	4	6	0	W: clear, O: hazy

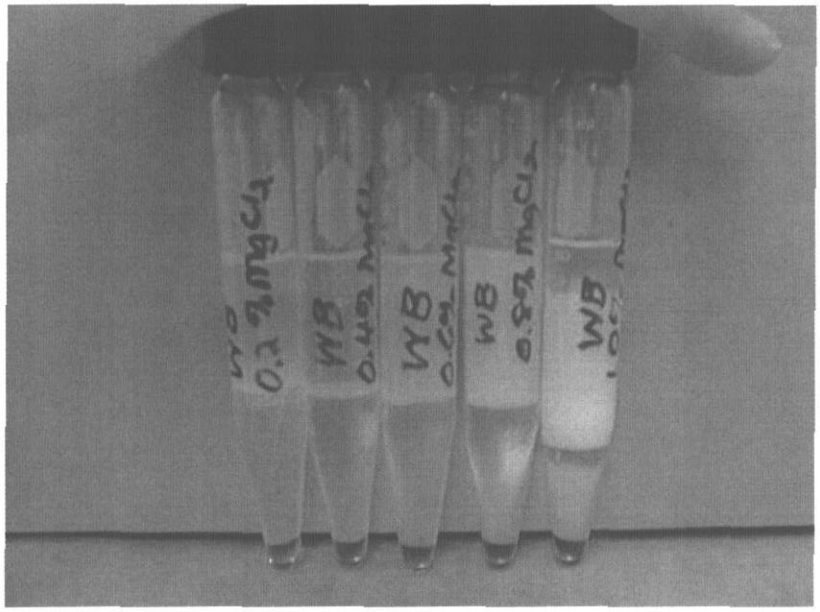
Oil = TCA/DCE mixture

$MgCl_2$ wt%	Winsor Type	Volume of W mL	Volume of O mL	Volume of M mL	Comment
0.2	I	5	5	0	W: milky phase+clear, O: milky phase+clear
0.4	I	5.5	4.5	0	W: milky phase+clear, O: milky phase+clear
0.5	I	6.7	3.5	0	W: hazy, O: clear
0.6	III	2.6	4.4	3	W: hazy, O: clear, M: cloudy
0.7	III	2.9	5.1	2	W: clear, O: hazy, M: cloudy

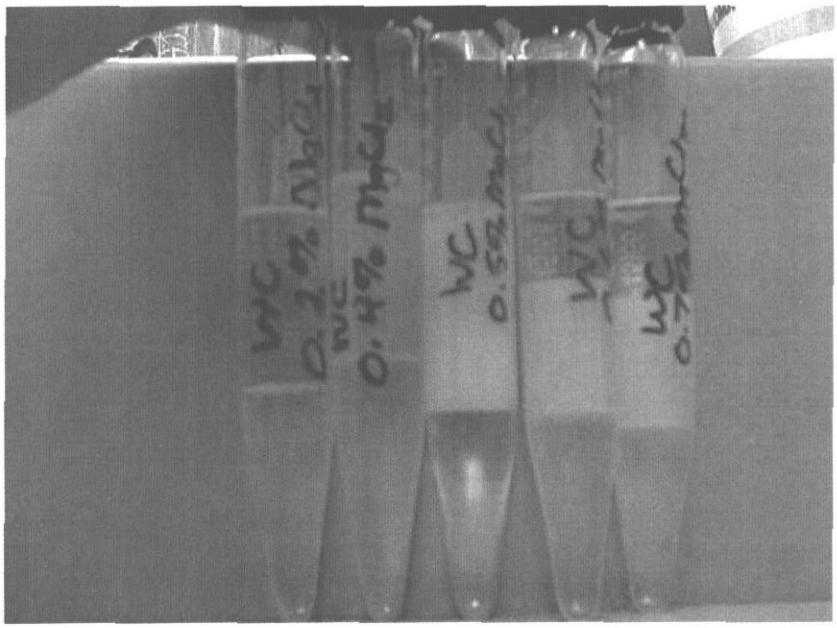
Surfactant System: 2 wt% Isalchem 145-4PO + 2 wt% AMA + 1 wt% IPA

Scanning Parameter: $MgCl_2$
Oil = TCA/DCE mixture

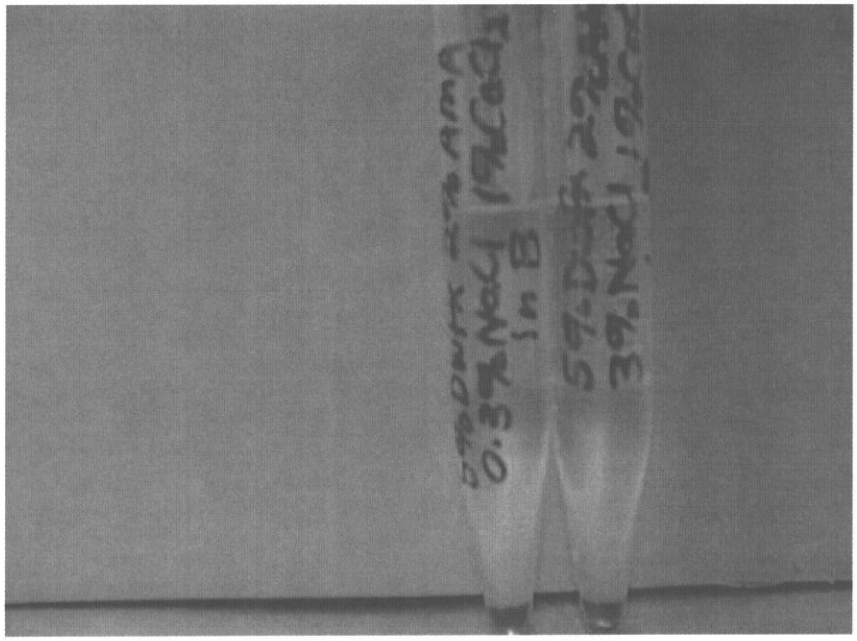
$MgCl_2$ wt%	Winsor Type	Volume of W mL	Volume of O mL	Volume of M mL	Comment
0.2	I	7.3	2.7	0	W: milky+hazy, O: cloudy
0.4	II	4.6	5.4	0	W: clear, O: cloudy
0.6	II	4.7	5.3	0	W: clear, O: cloudy



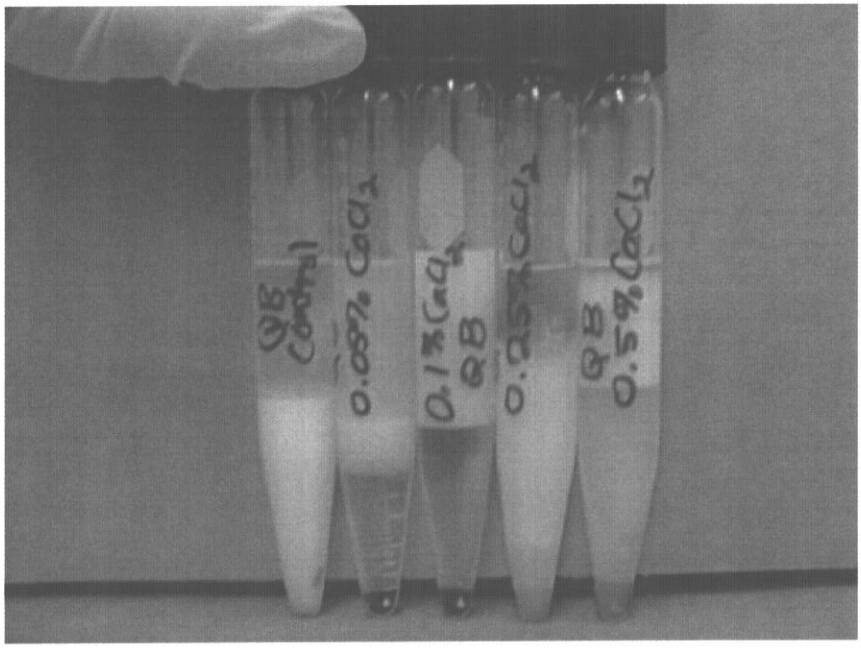
2% Isalchem 123-2PO + 2% AMA + 1% IPA scanned with MgCl2 from 0.2 to 1.0 wt % to enhance TCA ultrasolubilization



2% Isalchem 123-2PO + 2% AMA + 1% IPA scanned with MgCl2 from 0.2 to 0.7 wt % to enhance TCA/DCE ultrasolubilization



5% Dowfax + 2% AMA + 1% CaCl2 scanned with 0.3 and 3 wt% NaCl to determine ultrasolubilization of TCA



4% Lubrizol 71 + 2% IPA + 2.5% NaCl scanned with CaCl2 from 0.05 to 0.5 wt% to determine ultrasolubilization of TCA

Density and Viscosity Measurements

Temp = 18 °C

Viscosity Formula: $\mu = Kx(PT-P)xT$

μ = viscosity in Centipoises (cp)
K = viscometer constant
PT = density of ball (g/mL) = 8.02
P = density of liquid (g/mL)
T = time of descent (min)

Surfactant	Conc., WT%	Contaminant	Net Weight, g	Density, g/mL	T, min	μ, cp
ISA 123-2PO/AMA-80/IPA/MgCl2	2/ 2/ 1/ 0.3	1,1 DCE	1.057	0.9902	1.717	3.603
ISA 123-2PO/AMA-80/IPA/MgCl2	2/ 2/ 1/ 0.25	1,1 DCE	1.056	0.9846	1.27	2.672
ISA 123-2PO/AMA-80/IPA/MgCl2	2/ 2/ 1/ 0.4	1,1,1 TCA	1.03	0.9764	1.08	2.288
ISA 123-2PO/AMA-80/IPA/MgCl2	2/ 2/ 1/ 0.4	1,1 DCE+1,1,1, TCA (50/50)	1.04	1.0229	1.08	2.273

Size 1 viscometer @18degrees C 5/21/99

Sample ID	**Run 1 (min:sec)**	**Run 2 (min:sec)**	**Run 3 (min:sec)**	**Average**	**Viscosity (cp)**
WA 0.3%MgCl2	1:39	1:45	1:45	1:43	3.603
WA 0.25% MgCl2	1:15	1:18	1:14	1:16	2.672
WB 0.4% MgCl2	1:03	1:07	1:04	1:05	2.288
WC 0.4% MgCl2	1:01	1:05	1:08	1:05	2.273

WA= 2% 123-2PO 2%AMA 1%IPA IN 1,1 DCE
WB= 2% 123-2PO 2% AMA 1% IPA IN 1,1,1 TCA
WC= 2% 123-2PO 2%AMA 1% IPA IN 1,1 DCE/1,1,1 TCA 50/50 MIX

5 wt% Dowfax 8390 + 2 wt% Aerosol MA-80-I + 3 wt% NaCl + 1 wt% $CaCl_2$

Column B

Flow rate = 0.51 mL/min

Pore Volume = 38 mL

Cumulative samples collected by fraction collector = 17.5 minutes

Solution injected = 0.805 pore volumes per hour

Initial TCA added = 4 mL

Series #	Sample ID	TCA conc. mg/L	Time hr	Cumulative volume mL	Cumulative P.V.	Mass collected g	TCA recovered mg
tca 6001	34-B 25	24091.4	0.291667	8.925	0.234868421	8.925	215.015745
tca 6002	34-B 26	84336.1	0.583333	17.85	0.469736842	8.925	752.6996925
tca 6003	34-B 27	98597.4	0.875	26.775	0.704605263	8.925	879.981795
tca 6004	34-B 28	96057	1.166667	35.7	0.939473684	8.925	857.308725
tca 6005	34-B 29	168996	1.458333	44.625	1.174342105	8.925	1508.2893
tca 6006	34-B 30	121305.7	1.75	53.55	1.409210526	8.925	1082.653373
tca 6007	34-B 31	135431.3	2.041667	62.475	1.644078947	8.925	1208.724353
tca 6008	34-B 32	131684.5	2.333333	71.4	1.878947368	8.925	1175.284163
tca 6009	34-B 33	74512.3	2.625	80.325	2.113815789	8.925	665.0222775
tca 4017	34-B 34	96620.44	2.916667	89.25	2.348684211	8.925	862.3374582
tca 4018	34-B 35	49480.83	3.208333	98.175	2.583552632	8.925	441.6164238
tca 4019	34-B 36	8228.936	3.5	107.1	2.818421053	8.925	73.44325094
tca 4020	34-B 37	51657.36	3.791667	116.025	3.053289474	8.925	461.0419179
tca 4021	34-B 38	39159.24	4.083333	124.95	3.288157895	8.925	349.4962161
tca 4022	34-B 42	11877.76	5.25	160.65	4.227631579	35.7	424.0362062
tca 5003	34-B 47	1202.757	6.708333	205.275	5.401973684	44.625	53.67304898
tca 4026	34-B 54	5035.461	7	214.2	5.636842105	8.925	44.94148684
						mg TCA recovered	11010.62394
						mg TCA added	5360
						TCA left, %	**0**

HPLC analysis of bromide

HPLC system:
Hitachi L-7200 autosampler
Hitachi D-7000 interface
Hitachi L-7400 UV detector
Hitachi L-7100 pump

Mobile phase: 100% 0.9 mM Na_2CO_3 + 0.85 mM $NaHCO_3$
Flow rate: 1.5 ml/min
UV wavelength: 205 nm
Sample size: 20 uL
Run time: 12 minutes
HPLC column used: Alltech Allsep Anion 7u, Part #51209, Serial # 98120224, length of 150 mm x 4.6 mm, length x ID

GC analysis of VOCs (1,1,1, TCA, 1,1, DCE)

GC system:
Shimadzu GC-17A Gas Chromatograph
Autosampler: Tekmar 7000 Headspace Autosampler

- Method 3
- Platen 40 °C
- Platen equilibrium: 0
- Sample equilibrium: 20 minutes
- Vial size: 22 mL
- Mixer: on
- Mix: 5 minutes
- Mix power: 5
- Stabilize: 0.3 minutes
- Cryo cooldown: no
- Pressurize: 0.5 minutes
- Pressurize equilibrium: 0.05 minutes
- Injects: 2 minutes
- Cryo Inject: no
- Sample loop: 140 °C
- Line: 140 °C
- Cryo Union Htr: 175 °C
- Inject per vial: 1
- GC cycletime: 30 minutes

Data system: Varian Star 4.5 Workstation

Column: DB5
Flame Ionization Detector (FID): Temperature 250 °C

Injector temperature: 175 °C
GC conditions:
Oven Initial temperature: 50 °C
Initial time: 2 min
Program rate: 8 °C/min
Final temperature: 150 °C

GC analysis of alcohols (PTT)

GC system: Varian 3300
Autosampler: Varian 8100
Sample volume: 1 μL

Data system: Varian Star 4.5 Workstation

Column: Supelco Cowax 10 (length 60 m, ID 0.32 mm, Film 0.5 μm

Flame Ionization Detector (FID): Temperature 250 °C
Injector temperature: 200 °C
GC conditions:
Oven Initial temperature: 70 °C
Initial time: 2 min
Program rate: 10 °C/min
Final temperature: 150 °C

Partitioning Tracers Batch Resutls

K_{tw} = TCA-water partitioning coefficient

	Pentanol	Hexanol	Heptanol	2,4 dimethyl 3 pentanol
K_{tw}	3.1	15.2	160.1	35.2

q_e = PTT sorbed on soil

Initial Conc.	Pentanol	Hexanol	Heptanol	2,4 dimethyl 3 pentanol
mg/L	q_e	q_e	q_e	q_e
1000	0.001135115	0.000776644	0.000559141	0.001412543
750	0.000586188	0.000429434	0.000412261	0.000756069
500	-0.000801752	-0.000430341	-0.000219884	-0.000741738
250	-1.46339E-05	-7.28724E-06	-1.23688E-05	3.77352E-05

Prediction of retardation factor for PTT at different residual saturations

Rf = retardation factor
S = TCA residual saturation
Rf = [1+S*(K-1)]/(1-S)

S = 0.15
Rf

Pentanol	Hexanol	Heptanol	2,4 dimethyl 3 pentanol
1.547059	3.682353	29.25294	7.211765

S = 0.1
Rf

Pentanol	Hexanol	Heptanol	2,4 dimethyl 3 pentanol
1.344444	2.688889	18.78889	4.911111

S = 0.05
Rf

Pentanol	Hexanol	Heptanol	2,4 dimethyl 3 pentanol
1.163158	1.8	9.426316	2.852632

S = 0.01
Rf

Pentanol	Hexanol	Heptanol	2,4 dimethyl 3 pentanol
1.031313	1.153535	2.617172	1.355556

S = 0.001
Rf

Pentanol	Hexanol	Heptanol	2,4 dimethyl 3 pentanol
1.003103	1.015215	1.16026	1.035235

REFERENCE

Rouse, J. D., Sabatini, D. A., Harwell, J. H., Environmental Science & Technology, 1993, 27, 2072.

Surbec Enviornmental, "First Progress Report for Surfactant/cosolvent Enhanced Subsurface Remediation of Dense Nonaqueous Phase Liquids, McClellan Air Force Base, CA", 1999, May.

Shiau, B. J., Sabatini, D. A., Harwell, J. H., Ground Water, 1994, 32, 561.

Shiau, B. J., Sabatini, D. A., Harwell, J. H. Environmental Science & Technology, 1995, 29, 2929.

Young, C. M., Jackson, R. E., Jin, M., Longdergan, J. T., Mariner, P. E., Pope, G. A., Anderson, F. J., Houk, T., Ground Water Monitoring & Remediation, Winter, 1999, 84.

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

Product Information

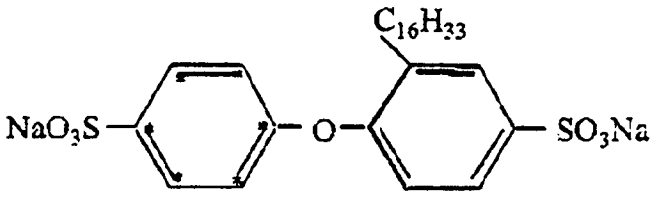
DOWFAX* Surfactants

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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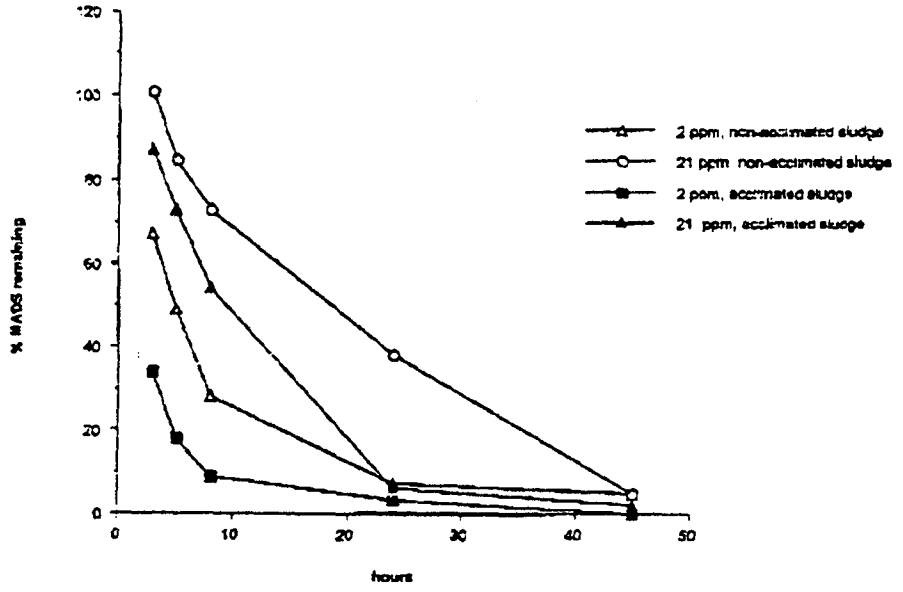
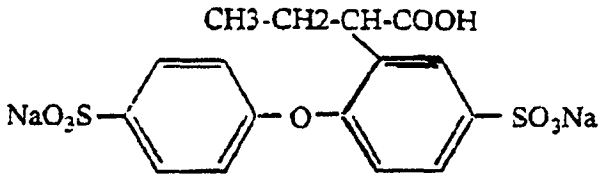
Degradation in Activated Sludge

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.

APPENDIX D – LABORATORY SCREENING DATA AND TOXICITY DATA AND MSDS SHEETS

DOWFAX SURFACTANTS

DEGRADATION OF DOWFAX SURFACTANTS
PAGE 3 OF 5

TECHNICAL MEMORANDUM FOR SURFACTANT ENHANCED DNAPL REMOVAL TREATABILITY STUDY AT SITE 5

THE ABOVE IDENTIFIED PAGE IS NOT AVAILABLE.

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

QUESTIONS MAY BE DIRECTED TO:

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

TELEPHONE: (619) 532-3676

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.

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.

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

* Trademark of The Dow Chemical Company

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.

* Trademark of The Dow Chemical Company

Material Safety Data Sheet

The Dow Chemical Company
Midland, Michigan 48674
Emergency 517-636-4400

1. CHEMICAL PRODUCT & COMPANY IDENTIFICATION

24-Hour Emergency Phone Number: 517-636-4400

Product: DOWFAX* 8390 SOLUTION SURFACTANT

Product Code: 05802

Effective Date: 01/08/99 Date Printed: 04/20/99 MSD: 001177

The Dow Chemical Company, Midland, MI 48674

Customer Information Center: 800-258-2436

2. COMPOSITION/INFORMATION ON INGREDIENTS

Disodium hexadecyldiphenyloxide disulfonate,	CAS# 065143-89-7	15-35%
Disodium dihexadecyldiphenyloxide disulfonate	CAS# 070191-76-3	5-10%
Water	CAS# 007732-18-5	Balance
Sodium sulfate	CAS# 007757-82-6	1.5% Max
Sodium chloride	CAS# 007647-14-5	< 1%

3. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

****
* Amber to light brown. Liquid. Disinfectant odor. Toxic fumes *
* are released in fire situations. *
****

POTENTIAL HEALTH EFFECTS (See Section 11 for toxicological data.)

EYE: May cause moderate eye irritation. May cause slight corneal injury.

SKIN: Prolonged or repeated exposure may cause slight skin irritation. May cause more severe response if skin is abraded (scratched or cut). Animal test indicate some potential for allergic skin reaction to undiluted or higher

(Continued on page 2)

concentrations of the surfactant 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 use conditions. A single prolonged skin exposure is not likely to result in the material being absorbed through skin in harmful amounts.

INGESTION: Single dose oral toxicity is extremely low. No hazards anticipated from swallowing small amounts incidental to normal handling operations.

INHALATION: Excessive exposure may cause irritation to upper respiratory tract.

SYSTEMIC (OTHER TARGET ORGAN) EFFECT: Excessive exposure may cause liver and kidney effects.

CANCER INFORMATION: Did not cause cancer in long-term animal studies. (product similar to active ingredients)

4. FIRST AID

EYE: IRRIGATE WITH FLOWING WATER IMMEDIATELY AND CONTINUOUSLY for 15 minutes. Consult medical personnel.

SKIN: Wash off in flowing water or shower.

INGESTION: If swallowed, seek medical attention. Do not induce vomiting unless directed to do so by medical 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.

5. FIRE FIGHTING MEASURES

FLAMMABLE PROPERTIES
FLASH POINT: Flame extinguished; none to boiling.

(Continued on page 3)

APPENDIX D – LABORATORY SCREENING DATA AND TOXICITY DATA AND MSDS SHEETS

MATERIAL SAFETY DATA SHEET

PRODUCT: DOWFAX
8390 SOLUTION SURFACTANT
PAGE 3 OF 8

TECHNICAL MEMORANDUM FOR
SURFACTANT ENHANCED DNAPL
REMOVAL TREATABILITY STUDY AT SITE 5

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NAVAL FACILITIES ENGINEERING COMMAND SOUTHWEST
1220 PACIFIC HIGHWAY
SAN DIEGO, CA 92132

TELEPHONE: (619) 532-3676

ENGINEERING CONTROLS: Provide general and/or local exhaust ventilation to control airborne levels below the exposure guidelines.

PERSONAL PROTECTIVE EQUIPMENT
EYE/FACE PROTECTION: Use chemical goggles.

SKIN PROTECTION: Use gloves impervious to this material when prolonged or frequently repeated contact could occur. If hands are cut or scratched, use gloves impervious to this materials even for brief exposures.

RESPIRATORY PROTECTION: Atmospheric levels should be maintained below the exposure guideline. When respiratory protection is required for certain operations, use an approved air-purifying respirator.

EXPOSURE GUIDELINE(S): Sodium sulfate: Dow IHG is 10 mg/m3.

9. PHYSICAL AND CHEMICAL PROPERTIES

APPEARANCE: Amber to light brown liquid (aqueous solution).
ODOR: Disinfectant-type.
VAPOR PRESSURE: 17.8 mmHg @ 20C, 68F
VAPOR DENSITY: No data available.
BOILING POINT: 100C, 212F
SOLUBILITY IN WATER: Completely miscible.
SPECIFIC GRAVITY: 1.03-1.13

10. STABILITY AND REACTIVITY

CHEMICAL STABILITY: Stable.

CONDITIONS TO AVOID: None known.

INCOMPATIBILITY WITH OTHER MATERIALS: Avoid unintended contact with acids.

HAZARDOUS DECOMPOSITION PRODUCTS: Hazardous decomposition products may include and are not limited to sulfur dioxide.

(Continued on page 5)

APPENDIX D – LABORATORY SCREENING DATA AND TOXICITY DATA AND MSDS SHEETS

MATERIAL SAFETY DATA SHEET

PRODUCT: DOWFAX
8390 SOLUTION SURFACTANT
PAGE 5 OF 8

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SAN DIEGO, CA 92132

TELEPHONE: (619) 532-3676

DEPARTMENT OF TRANSPORTATION (D.O.T.):

This product is not regulated by D.O.T. when shipped domestically by land.

CANADIAN TDG INFORMATION:
For TDG regulatory information, if required, consult transportation regulations, product shipping papers, or your Dow representative.

15. 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 other sections for health and safety information.

U.S. REGULATIONS

SARA 313 INFORMATION: To the best of our knowledge, this product contains no chemical subject to SARA Title III Section 313 supplier notification requirements.

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

(Continued on page 7)

APPENDIX D – LABORATORY SCREENING DATA AND TOXICITY DATA AND MSDS SHEETS

MATERIAL SAFETY DATA SHEET

PRODUCT: DOWFAX
8390 SOLUTION SURFACTANT
PAGE 7 OF 8

TECHNICAL MEMORANDUM FOR
SURFACTANT ENHANCED DNAPL
REMOVAL TREATABILITY STUDY AT SITE 5

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1220 PACIFIC HIGHWAY
SAN DIEGO, CA 92132

TELEPHONE: (619) 532-3676

REGULATORY INFORMATION (CONTINUED)

Refer elsewhere in the MSDS for specific warnings and safe handling information. Refer to the employer's workplace education program.

\- - - - -

CPR STATEMENT: This product has been classified in accordance with the hazard criteria of the Canadian Controlled Products Regulations (CPR) and the MSDS contains all the information required by the CPR.

\- - - - -

HAZARDOUS PRODUCTS ACT INFORMATION: This product contains the following ingredients which are Controlled Products and/or on the Ingredient Disclosure List (Canadian HPA section 13 and 14):

COMPONENTS:	CAS #	AMOUNT (%w/w)
Disodium hexadecyldiphenyloxide disulfonate	CAS# 065143-89-7	15-35%
Disodium dihexadecyldiphenyloxide disulfonate	CAS# 070191-76-3	5-10%

16. OTHER INFORMATION

MSDS STATUS: Revised Section 13.

CYTEC

MATERIAL SAFETY DATA

MSDS No: 8269
Date: 07/01/97
Supersedes: 01/27/97

1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

PRODUCT NAME: **AEROSOL® MA 80-I Surfactant**

SYNONYMS: Sodium dihexyl sulfosuccinate in mixture of isopropanol and water

CHEMICAL FAMILY: Ester

MOLECULAR FORMULA: C16H29O7NaS

MOLECULAR WGT: 388

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	
Isopropanol	000067-63-0	~5.0	400 ppm 500 ppm STEL	OSHA/ACGIH

3. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

APPEARANCE AND ODOR: Clear, viscous liquid; pleasant fruity odor

STATEMENTS OF HAZARD:
WARNING! CAUSES EYE AND SKIN IRRITATION
COMBUSTIBLE LIQUID AND VAPOR

POTENTIAL HEALTH EFFECTS

EFFECTS OF OVEREXPOSURE:
Acute oral (rat) and acute (rabbit) LD 50 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 LC 50 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: 101 F; 38 C
METHOD: Pensky-Martens Closed Cup

FLAMMABLE LIMITS
(% BY VOL): 2.5 Lower; 12 Upper; (values for isopropanol)

AUTOIGNITION TEMP: Not available

DECOMPOSITION TEMP: Not available

EXTINGUISHING MEDIA AND FIRE FIGHTING INSTRUCTIONS

Use water spray, carbon dioxide or dry chemical to extinguish fires. Use water to keep containers cool. Wear self-contained, positive pressure breathing apparatus and full fire-fighting 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

Avoid contact with eyes, skin and clothing. Keep away from heat and flame. 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 II Combustible 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).

9. PHYSICAL AND CHEMICAL PROPERTIES

APPEARANCE AND ODOR: Clear, viscous liquid; pleasant fruity odor

BOILING POINT: 176.5 F; 80 C; (value for isopropanol/water)

MELTING POINT: Not available

VAPOR PRESSURE: Not available

SPECIFIC GRAVITY: ~1.12 @ 25 C

VAPOR DENSITY: Not available

% VOLATILE (BY WT): ~20

pH: 5-7; (10% aqueous solution)

SATURATION IN AIR (% BY VOL): Not available

EVAPORATION RATE: Not available

SOLUBILITY IN WATER: ~32 @ 25 C

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.

Isopropanol has acute oral (rat) and dermal (rabbit) LD50 values of 5.0 g/kg and 12.8 g/kg, respectively. The 4-hour inhalation LC50 (rat) for isopropanol is >16,000 ppm (40.86 mg/L). Acute overexposure to isopropanol vapor may cause mild irritation of the eyes and respiratory tract. Chronic overexposure to isopropanol vapors may cause central nervous system depression, headaches, dizziness, nausea, and staggered gait. Liquid isopropanol is a severe eye irritant.

12. ECOLOGICAL INFORMATION

No aquatic LC50, BOD, or COD data available.

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 220	Not Applicable

ADDITIONAL TRANSPORT INFORMATION

TECHNICAL NAME (N.O.S.):	(Contains isopropanol)

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.
This product contains a chemical substance that is subject to export notification under Section 12 (b) 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
Isopropanol	000067-63-0	~5.0	NONE	NONE	NO	YES

PRODUCT CLASSIFICATION UNDER SECTION 311 OF SARA				
ACUTE (Y)	CHRONIC (N)	FIRE (Y)	REACTIVE (N)	PRESSURE (N)

16. OTHER INFORMATION

NFPA HAZARD RATING (National Fire Protection Association)

Fire 2
Health 2 0 Reactivity
—
Special

FIRE: Materials that must be moderately heated or exposed to relatively high ambient temperatures before ignition can occur.

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

04/14/99

SECTION 1 - CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

THE LUBRIZOL CORPORATION
29400 LAKELAND BOULEVARD
WICKLIFFE, OHIO 44092
440/943-4200

This material is to be used for research purposes only under the supervision of a technically qualified individual. The toxicological properties may have not been completely characterized. To determine your responsibilities under the Toxic Substances Control Act (TSCA), please see the Regulatory Information Section.

PRODUCT TRADE NAME: OS#132071, 1X8 OZ

CAS NO:	Not applicable for mixtures.
SYNONYMS:	None.
GENERIC/CHEMICAL NAME:	Mixture.
PRODUCT TYPE:	Experimental.
PREPARATION/REVISION DATE:	14 Apr 1999
TRANSPORTATION EMERGENCY PH NO:	(CHEMTREC) 1-800-424-9300.
MSDS NO:	5231626-4729086-1361024

SECTION 2 - COMPOSITION/INFORMATION ON INGREDIENTS

- This material has no known hazards under applicable laws.

SECTION 3 - HAZARDS IDENTIFICATION

PRINCIPAL HAZARDS: - This material has no known hazards.

See Section 11 for complete health hazard information.

SECTION 4 - FIRST AID MEASURES

ORAL: DO NOT INDUCE VOMITING. If conscious, give 2 glasses of water. Get immediate medical attention.

EYE: Flush with water at least 15 minutes. Get medical attention if eye irritation develops or persists.

SKIN: Wash with soap and water. Get medical attention if irritation develops. Launder contaminated clothing before reuse.

INHALATION: Remove exposed person to fresh air if adverse effects are observed.

ADDITIONAL: Note to physician: Treat symptomatically.

SECTION 5 - FIRE FIGHTING MEASURES

FLASH POINT :	Not applicable.
UPPER FLAMMABLE LIMIT:	Not determined.
LOWER FLAMMABLE LIMIT:	Not determined.
EXTINGUISHING MEDIA:	Not applicable.
SPECIAL FIREFIGHTING PROCEDURES:	Not applicable.
UNUSUAL FIRE & EXPLOSION HAZARDS:	Material will not burn.
AUTOIGNITION TEMPERATURE:	Not determined.
EXPLOSION DATA:	Material does not have explosive properties.

SECTION 6 - ACCIDENTAL RELEASE MEASURES

SPILL PROCEDURES: Personal Protective Equipment must be worn, see Personal Protection Section for PPE recommendations. Prevent entry into sewers and waterways. Pick up free liquid for recycle and/or disposal if can be accomplished safely with explosion proof equipment. Residual liquid can be absorbed on inert material. Check under Transportation and Labeling (DOT/CERCLA) and Other Regulatory Information Section (SARA) for hazardous substances to determine regulatory reporting requirements for spills.

SECTION 7 - HANDLING AND STORAGE

HANDLING PROCEDURES: Keep containers closed when not in use. Wash thoroughly after handling. Empty container contains product residue which may exhibit hazards of product.

STORAGE PROCEDURES: No special storage precautions required.

SECTION 8 - EXPOSURE CONTROLS/PERSONAL PROTECTION

VENTILATION PROCEDURE:	Use with adequate ventilation.
GLOVES PROTECTION:	Use nitrile or neoprene gloves.
EYE PROTECTION:	Safety Glasses.
RESPIRATORY PROTECTION:	Under normal use conditions, respirator is not usually required.
CLOTHING RECOMMENDATION:	Long sleeve shirt is recommended.

SECTION 9 - PHYSICAL AND CHEMICAL PROPERTIES

VAPOR PRESSURE:	Not determined.
PH:	Not determined.
SPECIFIC GRAVITY:	0.97 at 15.6 Deg C
WATER SOLUBILITY:	Insoluble.
PERCENT VOLATILE:	Unknown.
VAPOR DENSITY:	Not determined.
EVAPORATION RATE:	Not determined.
ODOR:	Mild
APPEARANCE:	Milky white liquid.
VISCOSITY:	Unknown.
ODOR THRESHOLD:	Unknown.
BOILING POINT :	Not determined.
FREEZING POINT:	Not determined.
MOLECULAR WEIGHT:	Not determined.

SECTION 10 - STABILITY AND REACTIVITY

STABILITY: Material is normally stable at moderately elevated temperatures and pressures.
COMPATIBILITY: None known, avoid contact with reactive chemicals.
POLYMERIZATION: Will not occur.
THERMAL DECOMPOSITION: Thermal decomposition and combustion are not expected to occur except under extreme conditions.

SECTION 11 - TOXICOLOGICAL INFORMATION

-- ACUTE EXPOSURE --

ORAL TOXICITY: The LD50 in rats is > 5000 mg/kg. Based on data from components or similar materials.
EYE IRRITATION: Not expected to cause eye irritation. Based on data from components or similar materials.
SKIN IRRITATION: Not expected to be a primary skin irritant. Based on data from components or similar materials.
DERMAL TOXICITY: The LD50 in rabbits is > 2000 mg/Kg. Based on data from components or similar materials.
INHALATION TOXICITY: No data available to indicate product or components may be a toxic inhalation hazard.
RESPIRATORY IRRITATION: No data available to indicate product or components may cause respiratory irritation under normal workplace conditions and good industrial hygiene practices.
DERMAL SENSITIZATION: No data available to indicate product or components may be a skin sensitizer.
INHALATION SENSITIZATION: No data available to indicate product or components may be respiratory sensitizers.

SECTION 11 - TOXICOLOGICAL INFORMATION --- CONTINUED

-- CHRONIC EXPOSURE --

CHRONIC TOXICITY: No data available to indicate product or components present at greater than 1% are chronic health hazards.
CARCINOGENICITY: No data available to indicate any components present at greater than 0.1% may present a carcinogenic hazard.
MUTAGENICITY: No data available to indicate product or any components present at greater than 0.1% are mutagenic or genotoxic.
REPRODUCTIVE TOXICITY: No data available to indicate either product or components present at greater than 0.1% that may cause reproductive toxicity.
TERATOGENICITY: No data available to indicate product or any components contained at greater than 0.1% may cause birth defects.

-- ADDITIONAL INFORMATION --

OTHER: No other health hazards known.
EXPOSURE LIMITS: See Hazardous Ingredients Section for any applicable exposure limits for components.

SECTION 12 - ECOLOGICAL INFORMATION

FRESHWATER FISH TOXICITY:	Not determined.
FRESHWATER INVERTEBRATES TOXICITY:	Not determined.
ALGAE TOXICITY:	Not determined.
SALTWATER FISH TOXICITY:	Not determined.
SALTWATER INVERTEBRATES:	Not determined.
BACTERIA TOXICITY:	Not determined.
MISCELLANEOUS TOXICITY:	Not determined.
BIODEGRADATION:	Not determined.
BIOCONCENTRATION:	Not determined.
SOIL MOBILITY:	Not determined.

SECTION 13 - DISPOSAL CONSIDERATIONS

WASTE DISPOSAL: This material, if discarded, is a hazardous waste under RCRA Regulation 40 CFR 261. Waste management should be in compliance with federal, state and local laws. 0.02% XYLENES, CAS no. 1330-20-7; 0.007% Ethyl benzene, CAS no. 100-41-4; 0.0002% Toluene, CAS no. 108-88-3.

SECTION 14 - TRANSPORT INFORMATION

U.S.DOT BULK SHIPPING DESCRIPTION:	Not applicable.
U.S.DOT NON-BULK SHIPPING DESCRIPTION:	Not applicable.
IMDG SHIPPING DESCRIPTION:	Not applicable.
ICAO SHIPPING DESCRIPTION:	Not applicable.
ADR/RID HAZARD CLASS:	Not regulated.

SECTION 15 - REGULATORY INFORMATION

U.S. TSCA INVENTORY:	May require notification in the U.S. Commercial shipments from Lubrizol's U.S. location must be exported to non U.S. customers only. Research and development quantities must bear special labels and shipping papers. Sample recipients must comply with the requirements for an R&D exemption under TSCA.
OTHER TSCA REG.:	None known.
SARA EXT. HAZ. SUBST.:	This product does not contain greater than 1.0% of any chemical substance on the SARA Extremely Hazardous Substances list.
SARA SECTION 313:	This product does not contain greater than 1.0% (greater than 0.1% for carcinogenic substance) of any chemical substances listed under SARA Section 313.
CERCLA HAZARDOUS SUBSTANCES:	FOR STATIONARY SOURCES: 49857 gal. due to Xylene
CAL. PROP. 65:	This product contains the following chemical(s) known to the state of California to cause cancer and/or birth defects based on maximum impurity levels of components: < 1 ppm Benzene, CAS no. 71-43-2 2 ppm Toluene, CAS no. 108-88-3
U.S. FUEL REGISTRATION:	Not applicable.
U.S. DEPT. OF AGRICULTURE:	This product has not been filed with the USDA to support H2 approvals.
FDA APPROVAL:	Not applicable.
EEC EINECS:	May require notification under EC Seventh Amendment Directive 92/32/EEC.
JAPAN MITI:	May require notification in Japan.
AUSTRALIA:	May require notification before sale under Australian regulations.
CANADA:	May require notification before sale under Canadian regulations.
CANADIAN FUEL REGISTRATION:	Not applicable.
SWITZERLAND:	May require notification before sale in Switzerland.
KOREA:	May require notification before sale in Korea.
KOREA FUEL REGISTRATION:	Not applicable.
PHILIPPINES:	May require notification before sale under Philippines Republic Act 6969.

SECTION 16 - OTHER INFORMATION

NFPA CODE: Health: 1 Fire: 0 Reactivity: 0
HMIS CODE: Health: 0 Fire: 0 Reactivity: 0

PRECAUTIONARY LABELS: - This material has no known hazards.

REVISION INDICATORS:

- Section 01,DISCLAIMER	Changed: 14 Apr 1999
- Section 04,EYE FIRST AID	Changed: 14 Apr 1999
- Section 05,FLASH POINT	Changed: 14 Apr 1999
- Section 07,STORAGE PROCEDURES	Changed: 14 Apr 1999
- Section 08,VENTILATION PROCEDURES	Changed: 14 Apr 1999
- Section 09,PH	Changed: 14 Apr 1999
- Section 10,STABILITY	Changed: 14 Apr 1999
- Section 11,EYE IRRITATION	Changed: 14 Apr 1999
- Section 12,FRESHWATER FISH TOXICITY	Changed: 14 Apr 1999
- Section 14,ICAO SHIPPING DESCRIPTION	Changed: 14 Apr 1999
- Section 15,U.S. TSCA INVENTORY	Changed: 14 Apr 1999
- Section 16,HMIS CODES	Changed: 14 Apr 1999

04/06/99

SECTION 1 - CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

THE LUBRIZOL CORPORATION
29400 LAKELAND BOULEVARD
WICKLIFFE, OHIO 44092
440/943-4200

This material is to be used for research purposes only under the supervision of a technically qualified individual. The toxicological properties may have not been completely characterized. To determine your responsibilities under the Toxic Substances Control Act (TSCA), please see the Regulatory Information Section.

PRODUCT TRADE NAME: OS#132072A, 1X8 OZ

CAS NO: Not applicable for mixtures.
SYNONYMS: None.
GENERIC/CHEMICAL NAME: Mixture.
PRODUCT TYPE: Experimental.
PREPARATION/REVISION DATE: 06 Apr 1999
TRANSPORTATION EMERGENCY PH NO: (CHEMTREC) 1-800-424-9300.
MSDS NO: 8557255-1922356-2302015

SECTION 2 - COMPOSITION/INFORMATION ON INGREDIENTS

- This material has no known hazards under applicable laws.

SECTION 3 - HAZARDS IDENTIFICATION

PRINCIPAL HAZARDS: - This material has no known hazards.

See Section 11 for complete health hazard information.

SECTION 4 - FIRST AID MEASURES

ORAL: DO NOT INDUCE VOMITING. If conscious, give 2 glasses of water. Get immediate medical attention.
EYE: Flush with water at least 15 minutes. Get medical attention if eye irritation develops or persists.
SKIN: Wash with soap and water. Get medical attention if irritation develops. Launder contaminated clothing before reuse.
INHALATION: Remove exposed person to fresh air if adverse effects are observed.
ADDITIONAL: Note to physician: Treat symptomatically.

SECTION 5 - FIRE FIGHTING MEASURES

FLASH POINT :	Not applicable.
UPPER FLAMMABLE LIMIT:	Not Determined.
LOWER FLAMMABLE LIMIT:	Not Determined.
EXTINGUISHING MEDIA:	Not applicable.
SPECIAL FIREFIGHTING PROCEDURES:	Not applicable.
UNUSUAL FIRE & EXPLOSION HAZARDS:	Material will not burn.
AUTOIGNITION TEMPERATURE:	Not Determined.
EXPLOSION DATA:	Material does not have explosive properties.

SECTION 6 - ACCIDENTAL RELEASE MEASURES

SPILL PROCEDURES: Personal Protective Equipment must be worn, see Personal Protection Section for PPE recommendations. Prevent entry into sewers and waterways. Pick up free liquid for recycle and/or disposal if can be accomplished safely with explosion proof equipment. Residual liquid can be absorbed on inert material. Check under Transportation and Labeling (DOT/CERCLA) and Other Regulatory Information Section (SARA) for hazardous substances to determine regulatory reporting requirements for spills.

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STORAGE PROCEDURES: No special storage precautions required.

SECTION 8 - EXPOSURE CONTROLS/PERSONAL PROTECTION

VENTILATION PROCEDURE:	Use with adequate ventilation.
GLOVES PROTECTION:	Use nitrile or neoprene gloves.
EYE PROTECTION:	Safety Glasses.
RESPIRATORY PROTECTION:	Under normal use conditions, respirator is not usually required.
CLOTHING RECOMMENDATION:	Long sleeve shirt is recommended.

SECTION 9 - PHYSICAL AND CHEMICAL PROPERTIES

VAPOR PRESSURE:	Not Determined.
PH:	Not Determined.
SPECIFIC GRAVITY:	0.97 at 15.6 Deg C
WATER SOLUBILITY:	Partially soluble.
PERCENT VOLATILE:	Unknown.
VAPOR DENSITY:	Not Determined.
EVAPORATION RATE:	Not Determined.
ODOR:	Mild
APPEARANCE:	Off-white liquid.
VISCOSITY:	Unknown.
ODOR THRESHOLD:	Unknown.
BOILING POINT :	Not Determined.
FREEZING POINT:	Not Determined.
MOLECULAR WEIGHT:	Not Determined.

SECTION 10 - STABILITY AND REACTIVITY

STABILITY: Material is normally stable at moderately elevated temperatures and pressures.
INCOMPATIBILITY: None known, avoid contact with reactive chemicals.
POLYMERIZATION: Will not occur.
THERMAL DECOMPOSITION: Thermal decomposition and combustion are not expected to occur except under extreme conditions.

SECTION 11 - TOXICOLOGICAL INFORMATION

-- ACUTE EXPOSURE --

ORAL TOXICITY: The LD50 in rats is > 5000 mg/kg. Based on data from components or similar materials.
EYE IRRITATION: Not expected to cause eye irritation. Based on data from components or similar materials.
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DERMAL TOXICITY: The LD50 in rabbits is > 2000 mg/Kg. Based on data from components or similar materials.
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DERMAL SENSITIZATION: No data available to indicate product or components may be a skin sensitizer.
INHALATION SENSITIZATION: No data available to indicate product or components may be respiratory sensitizers.

SECTION 11 - TOXICOLOGICAL INFORMATION --- CONTINUED

-- CHRONIC EXPOSURE --

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TERATOGENICITY: No data available to indicate product or any components contained at greater than 0.1% may cause birth defects.

-- ADDITIONAL INFORMATION --

OTHER: No other health hazards known.
EXPOSURE LIMITS: See Hazardous Ingredients Section for any applicable exposure limits for components.

SECTION 12 - ECOLOGICAL INFORMATION

FRESHWATER FISH TOXICITY:	Not Determined.
FRESHWATER INVERTEBRATES TOXICITY:	Not Determined.
ALGAE TOXICITY:	Not Determined.
SALTWATER FISH TOXICITY:	Not Determined.
SALTWATER INVERTEBRATES:	Not Determined.
BACTERIA TOXICITY:	Not Determined.
MISCELLANEOUS TOXICITY:	Not Determined.
BIODEGRADATION:	Not Determined.
BIOCONCENTRATION:	Not Determined.
SOIL MOBILITY:	Not Determined.

SECTION 13 - DISPOSAL CONSIDERATIONS

WASTE DISPOSAL: This material, if discarded, is a hazardous waste under RCRA Regulation 40 CFR 261. Waste management should be in compliance with federal, state and local laws. 0.02% XYLENES, CAS no. 1330-20-7; 0.007% Ethyl benzene, CAS no. 100-41-4; 0.0002% Toluene, CAS no. 108-88-3.

SECTION 14 - TRANSPORT INFORMATION

U.S.DOT BULK SHIPPING DESCRIPTION:	Not applicable.
U.S.DOT NON-BULK SHIPPING DESCRIPTION:	Not applicable.
IMDG SHIPPING DESCRIPTION:	Not applicable.
ICAO SHIPPING DESCRIPTION:	Not applicable.
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SECTION 15 - REGULATORY INFORMATION

U.S. TSCA INVENTORY:	May require notification in the U.S. Commercial shipments from Lubrizol's U.S. location must be exported to non U.S. customers only. Research and development quantities must bear special labels and shipping papers. Sample recipients must comply with the requirements for an R&D exemption under TSCA.
OTHER TSCA REG.:	None known.
SARA EXT. HAZ. SUBST.:	This product does not contain greater than 1.0% of any chemical substance on the SARA Extremely Hazardous Substances list.
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CERCLA HAZARDOUS SUBSTANCES:	FOR STATIONARY SOURCES: 49857 gal. due to Xylene
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U.S. FUEL REGISTRATION:	Not applicable.
U.S. DEPT. OF AGRICULTURE:	This product has not been filed with the USDA to support H2 approvals.
FDA APPROVAL:	Not applicable.
EEC EINECS:	May require notification under EC Seventh Amendment Directive 92/32/EEC.
JAPAN MITI:	May require notification in Japan.
AUSTRALIA:	May require notification before sale under Australian regulations.
CANADA:	May require notification before sale under Canadian regulations.
CANADIAN FUEL REGISTRATION:	Not applicable.
SWITZERLAND:	May require notification before sale in Switzerland.
KOREA:	May require notification before sale in Korea.
KOREA FUEL REGISTRATION:	Not applicable.
PHILIPPINES:	May require notification before sale under Philippines Republic Act 6969.

SECTION 16 - OTHER INFORMATION

NFPA CODE: Health: 1 Fire: 0 Reactivity: 0
HMIS CODE: Health: 0 Fire: 0 Reactivity: 0

PRECAUTIONARY LABELS: - This material has no known hazards.

REVISION INDICATORS:

- Section 01,DISCLAIMER	Changed: 06 Apr 1999
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- Section 10,STABILITY	Changed: 06 Apr 1999
- Section 11,EYE IRRITATION	Changed: 06 Apr 1999
- Section 12,FRESHWATER FISH TOXICITY	Changed: 06 Apr 1999
- Section 14,ICAO SHIPPING DESCRIPTION	Changed: 06 Apr 1999
- Section 15,U.S. TSCA INVENTORY	Changed: 06 Apr 1999
- Section 16,HMIS CODES	Changed: 06 Apr 1999

APPENDIX E
REFERENCES

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