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GROUNDWATER INVESTIGATION REPORT AND FOCUSED FEASIBILITY STUDY

REVISION 1

CRAB ORCHARD NATIONAL WILDLIFE REFUGE
PCB OPERABLE UNIT
SITES 32/33
MARION, ILLINOIS

PREPARED BY
RMT, INC.
MADISON, WISCONSIN

January 2000

PART II – FOCUSED FEASIBILITY STUDY

VOLUME 1 OF 1

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Part II - Focused Feasibility Study
Table of Contents

1. Introduction 1-1
   1.1 Background 1-1
   1.2 Purpose and Scope of Feasibility Study 1-1

2. Cleanup Standards 2-1

3. Remedial Action Objective 3-1

4. Remediation Pilot Tests 4-1
   4.1 Aquifer Pumping Tests 4-2
   4.2 Dual-Phase Extraction Tests 4-2
      4.2.1 Building I-1-23 Source Area 4-2
      4.2.2 Building I-1-2 Source Area 4-3
      4.2.3 Area 9 Repository Source Area 4-5
   4.3 Air Sparging/Soil Vapor Extraction Tests 4-6
      4.3.1 Building I-1-23 Source Area 4-6
      4.3.2 Building I-1-2 Source Area 4-7
      4.3.3 Area 9 Repository Source Area 4-8
   4.4 Pilot Tests Conclusions 4-9

5. Identification and Screening of Remedial Technologies 5-1
   5.1 Containment Technologies 5-2
      5.1.1 Slurry Walls 5-2
      5.1.2 Sheet Piles 5-3
      5.1.3 Injected Screens 5-3
      5.1.4 Grout Curtains 5-3
   5.2 Removal Technologies 5-3
      5.2.1 Soil Excavation and Consolidation 5-3
      5.2.2 Groundwater Extraction 5-5
   5.3 Treatment Technologies 5-5
      5.3.1 In Situ Treatment 5-6
      5.3.2 Ex Situ Treatment 5-7

5.4 Disposal Technologies 5-8
5.4.1 Soil Disposal 5-8
5.4.2 Groundwater Disposal 5-9
5.5 Technologies Suitable for Further Development 5-10

6. Development and Modeling Simulations of Remedial Alternatives 6-1
6.1 Alternative A - No Action 6-2
6.2 Alternative B - Monitored Natural Attenuation 6-3
6.2.1 Design Concepts 6-3
6.2.2 Simulation 6-3
6.3 Alternative C - Phytoremediation 6-4
6.3.1 Design Concepts 6-4
6.3.2 Simulation 6-5
6.4 Alternative D - Enhanced Bioremediation 6-6
6.4.1 Design Concepts 6-6
6.4.2 Simulation 6-7
6.5 Alternative E - Multiple-Phase Extraction 6-9
6.5.1 Design Concepts 6-9
6.5.2 Simulation 6-10
6.6 Alternative F – Mobile Injection Treatment Unit (MITU) 6-11
6.6.1 Design Concepts 6-11
6.6.2 Simulation 6-13
6.7 Sensitivity Testing 6-14
6.8 Implications of Predictive Simulations of Remedial Alternatives 6-15

7. Screening of Remedial Alternatives 7-1
7.1 Alternative A - No Action 7-2
7.2 Alternative B - Monitored Natural Attenuation 7-2
7.2.1 Effectiveness 7-2
7.2.2 Implementation 7-2
7.2.3 Cost 7-3
7.3 Alternative C - Phytoremediation and MNA 7-3
7.3.1 Effectiveness 7-3
7.3.2 Implementability 7-5
7.3.3 Cost 7-5
7.4 Alternative D - Enhanced *In Situ* Bioremediation with Limited Phytoremediation and MNA 7-6
7.4.1 Effectiveness 7-6
7.4.2 Implementability 7-6

7.4.3 Cost 7-7
7.5 Alternative E – Multiple-Phase Extraction (MPE) with Limited Phytoremediation and MNA 7-8
7.5.1 Effectiveness 7-8
7.5.2 Implementability 7-8
7.5.3 Cost 7-9
7.6 Alternative F – *In Situ* Soil Thermal Treatment with MITU®, Limited Phytoremediation, MNA, and MPE at Repository 7-10
7.6.1 Effectiveness 7-10
7.6.2 Implementability 7-10
7.6.3 Cost 7-11
7.7 Summary of Remedial Alternatives Screening 7-11

8. Comparative Analysis of Alternatives 8-1
8.1 Introduction 8-1
8.2 Overall Protection of Human Health and the Environment 8-2
8.3 Compliance with ARARs 8-3
8.4 Long-term Effectiveness and Permanence 8-7
8.5 Reduction of Toxicity, Mobility, and Volume Through Treatment 8-9
8.6 Short-term Effectiveness 8-10
8.7 Implementability 8-11
8.8 Cost 8-12
8.9 State Acceptance 8-13
8.10 Community Acceptance 8-13

9. References 9-1

List of Tables

Table 4-1 Pilot Test Laboratory Data – Air – Sites 32/33 – FDGTI
Table 4-2 Pilot Test Laboratory Data – Groundwater – Sites 32/33 - FDGTI
Table 4-3 Pilot Test Summary - Crab Orchard National Wildlife Refuge - PCBOU Sites 32/33 - Marion, Illinois
Table 5-1 Identification and Screening of Groundwater Response Technologies
Table 5-2 Definition of Matrix Treatment Technologies
Table 6-1 Primary Components of Remedial Alternatives
Table 6-2 Summary of Assumed TCE Source Reductions Used for Transport Model Runs – Alternatives B through F
Table 6-3 Sensitivity Testing, Predictive Simulations
Table 8-1 Summary of Remedial Alternative Costs

List of Figures

Figure 4-1	Pilot Test Well Locations - Building I-1-23
Figure 4-2	Pilot Test Well Locations - Building I-1-2
Figure 4-3	Pilot Test Well Locations - Area 9 Repository
Figure 4-4	Generalized Stratigraphy and Pilot Test Well Screen Locations – Building I-1-23
Figure 4-5	Generalized Stratigraphy and Pilot Test Well Screen Locations – Building I-1-2
Figure 4-6	Generalized Stratigraphy and Pilot Test Well Screen Locations – Area 9 Repository
Figure 6-1	Conceptual Design – Remedial Alternatives C-F
Figure 6-2	Monitored Natural Attenuation – Alternative B – Predicted TCE Concentrations at 20 Years
Figure 6-3	Predicted TCE Concentration in Groundwater Near Crab Orchard Lake (I-1-23 Plume) versus Time
Figure 6-4	Predicted TCE Mass in Sites 32/33 Aquifer versus Time
Figure 6-5	Phytoremediation – Alternative C – Predicted TCE Concentrations at 20 Years
Figure 6-6	Enhanced Bioremediation – Alternative D – Predicted TCE Concentrations at 20 Years
Figure 6-7	Multi-Phase Extraction – Alternative E – Predicted TCE Concentrations at 20 Years – After 2 Years of MPE
Figure 6-8	Mobile Injection Treatment Unit – Alternative F – Predicted TCE Concentrations at 20 Years
Figure 6-9	Multi-Phase Extraction – Alternative E – Sensitivity Test, High Initial Concentration in Source Areas, Predicted TCE Concentrations at 20 Years
Figure 6-10	Phytoremediation - Alternative C - Sensitivity Test, High Initial Concentrations in Source Areas, Predicted Concentrations at 20 Years

List of Appendices

Appendix A	FDGTI Pilot Test Well Construction Field Notes and Pilot Test Well Construction Data Table
Appendix B	Laboratory Reports – Pilot Test Air and Extraction Well Pump Discharge Samples
Appendix C	FDGTI Pilot Test Schematic Diagrams
Appendix D	FDGTI Field Data Collection Sheets
Appendix E	FDGTI Field Notes
Appendix F	Pilot Test Calculations

Appendix G	Model Output from Remedial Alternatives Simulations
Appendix H	Contractor/Vendor's Information – MITU 30
Appendix I	Opinion of Probable Cost for Remedial Alternatives – Cost Breakdown Tables

Section 1
Introduction

1.1 Background

Part I of this document, the Groundwater Investigation Report (bound separately), includes a description of the fieldwork tasks and the results from the groundwater investigation at Sites 32/33 performed during the summer of 1998, and from the additional groundwater and surface water sampling performed in December 1998.

Part II of the document, the Focused Feasibility Study, includes an evaluation of a number of alternatives for remediation of contaminated groundwater. Part II also includes a description of the facilities and results associated with pilot tests (air sparging/soil vapor extraction, dual-phase extraction) performed at the site during summer 1998.

The document is being issued in this two-part format, rather than as two sequentially issued separate reports, to assist in expediting the selection and implementation of a remedial alternative for groundwater at Sites 32/33.

1.2 Purpose and Scope of Feasibility Study

The purpose of this Feasibility Study (FS) is to develop and evaluate alternatives for remediation of groundwater at Sites 32/33 of the PCB Operable Unit. The significant body of information defining groundwater occurrence and the nature and extent of groundwater contamination provided from various investigations and reports issued since 1988, and in Part I of this document, formed the basis for the FS. The requirements of the existing Record of Decision and Consent Decree for the PCB Operable Unit, and in the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as implemented through various USEPA guidance documents, have also been addressed in developing and evaluating the alternatives.

The scope of the FS includes the following:

- Statement of the Cleanup Standards and definition of the Remedial Action Objective for groundwater at Sites 32/33.
- A description of, and summary of results from, pilot tests performed at the sites during summer 1998.
- A review and screening of available remedial technologies.

- Development and screening of site-specific remedial alternatives, including computer modeling simulations to estimate the effectiveness of the alternatives in meeting the remedial objective for the sites.
- Presentation of opinions of probable cost to construct, operate, and maintain facilities, and to monitor performance, for each alternative.

The response action objectives for groundwater are well defined in the existing decision documents for the PCB Operable Unit. For this reason and to expedite the decision-making process for groundwater, as agreed by the USEPA, this FS proceeds directly from an initial screening of a limited number of alternatives to a more "focused" comparative analysis of the alternatives using "the nine criteria" specified in USEPA guidance documents.

Section 2
Cleanup Standards

The Consent Decree executed by the USEPA and Schlumberger Industries, Inc. (SII) (effective date August 27, 1992) for environmental remediation at the Crab Orchard National Wildlife Refuge (CONWR) near Marion, Illinois, includes a Scope of Work for Remedial Design/Remedial Action of the PCB Areas Operable Unit (PCBOU). The Scope of Work specifies Cleanup Standards for soil and sediment, groundwater, and surface water at the study sites comprising the PCBOU. The standards are based on the risk assessment as documented in the RI Report (O'Brien & Gere, 1988), which evaluated potential risk to human health and the environment.

The Cleanup Standards for groundwater, excerpted directly from the Consent Decree Scope of Work, are as follows:

> "Before soil remediation begins, the groundwater at the study sites comprising the PCB Areas Operable Unit will be monitored to establish current concentrations of site-related contaminants. Groundwater at the remediated study sites, and groundwater and leachate at the containment unit will then be monitored during and after remediation of the sites. The monitoring results will be evaluated to see if any of the following levels of contaminants above naturally occurring background levels has [have] been exceeded in groundwater:
>
> 1. any MCL or non-zero MCLG for carcinogens
> 2. a cumulative, excess life-time cancer risk greater than 1.0×10^{-6}; or
> 3. any MCL, non-zero MCLG, or a hazard index of 1.0, for noncarcinogens.
>
> If, at any time following completion of the remedy, groundwater at a remediated study site exceeds any of the stated cleanup standards, the need for additional remedial work, as contemplated by Section VII of the Decree shall be evaluated. The risk assessment shall follow procedures established in the "Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual" (RAGS) (EPA/540/1-89/02) or any amendments thereof. All of the assumptions used in the risk assessment calculations shall be subject to the review and approval by U.S. EPA prior to their use."

The remedial alternatives that are developed and evaluated in this feasibility study, and the alternative ultimately selected for implementation, focus on attainment of the concentration-based Cleanup Standards (federal Primary Drinking Water Standards Maximum Contaminant

Levels [MCLs] and non-zero Maximum Contaminant Level Goals) rather than risk-based cleanup goals. The MCLs for volatile organic compounds detected in groundwater at Sites 32/33 are listed in Tables 6-5 through 6-8 of the Groundwater Investigation Report (Part I of this document).

Section 3
Remedial Action Objective

As defined in the USEPA's RI/FS guidance (USEPA, 1988), remedial action objectives developed for a site are to consist of medium-specific or operable unit-specific goals for protecting human health and the environment. The objectives should be as specific as possible, but not so specific that the range of remedial alternatives that can be developed is unduly limited.

As stated in the Record of Decision issued for remediation of the PCB Operable Unit, the PCB remedial action, which has already been completed, was intended to accomplish the objective of restoring Sites 32/33 to an acceptable level of protectiveness for human health and the environment for all media at the sites, including groundwater. Therefore, the objective for further remediation of groundwater at Sites 32/33 will address the remaining groundwater quality requirements defined for the sites, specifically, the attainment of the chemical-specific Cleanup Standards for groundwater contained in the Consent Decree Scope of Work.

The objective for further remedial action at Sites 32/33 is to mitigate the potential for further transfer of VOC residuals remaining within the unsaturated and saturated soil at the identified source areas into groundwater by reducing the mass of residual VOCs to the degree necessary to allow naturally occurring processes to approach the groundwater Cleanup Standards specified in the Consent Decree Scope of Work within a reasonable time period.

Section 4
Remediation Pilot Tests

Pilot testing of selected remediation technologies was conducted at Sites 32/33 by Fluor Daniel GTI (FDGTI) during the summer of 1998, in accordance with a workplan (FDGTI, 1998) approved by the USEPA. Because of differences in subsurface conditions, such as site stratigraphy and soil properties, depth to groundwater, and variations in concentrations of contaminants, separate pilot tests were conducted at each of the following source area locations:

- Building I-1-2
- Building I-1-23
- Area 9 Repository

Two remediation technologies were evaluated at each of the three locations:

- Air sparging (AS) with soil vapor extraction (SVE)
- Dual-phase extraction (DPE)

As stated in the approved workplan (FDGTI, 1998), the purpose of the pilot tests was "to obtain hydraulic characteristics within [the] sand lens and to prove that vacuum extraction will be effective within the vadose zone at the areas of highest CVOC concentrations." As further stated in the workplan, "Pilot testing will be performed to identify hydraulic characteristics within the sand lens at each installed monitoring well and to determine if air sparging/vacuum extraction and dual phase vacuum extraction can be performed in the areas of highest CVOC concentrations." The objectives of the pilot testing were also to estimate the optimal areal extent of influence and the air and groundwater flowrates or CVOC recovery rates associated with the respective technologies at each of the locations.

AS/SVE and DPE pilot tests were conducted from July 13 to July 20, 1998. The pilot test wells were installed during a previous mobilization. At each site, one 4-inch-diameter DPE well, one 4-inch-diameter AS well, three to four 2-inch-diameter monitoring points (MPs), and three 2-inch-diameter SVE monitoring wells were installed in a similar fashion near existing groundwater monitoring wells (MWs). The pilot test well locations at each site are shown on Figures 4-1 to 4-3, and cross-sections showing the soil stratigraphy and well screen elevations at each site are shown on Figures 4-4 to 4-6. FDGTI's pilot test well completion reports, construction field notes, and a pilot test well construction data table are included in Appendix A.

In general, a similar testing sequence was followed at each of the three locations, whereby the DPE test was conducted the first day and the AS/SVE test was conducted on the second day. First, an aquifer pumping test was conducted for 3 to 6 hours as the beginning of the dual-phase extraction test, then a vacuum source was connected to the pumping well (the "DPE" well), and the DPE test continued for an additional 5 hours. On the following day, the AS/SVE test was conducted, by inducing a vacuum on the extraction well (the "DPE" well) for approximately 2 hours, then injecting air into the AS well for the next 4 to 6 hours while continuing the SVE test. The only exception to this routine was at the Building I-1-23 site, where a separate, day-long aquifer pumping test was conducted before the DPE and AS/SVE tests were conducted.

Water and air grab samples were collected during each test. These samples were informational in purpose and were not included in the pilot testing workplan. One grab sample of the well pump discharge collected during the DPE or pumping test in each area was analyzed for VOCs. One air sample during each DPE test and two air samples per SVE test were collected and analyzed for VOCs. The results of these samples, as reported by FDGTI, are shown in Tables 4-1 and 4-2. The laboratory reports are included in Appendix B.

The test results are described in the subsections below and are summarized in Table 4-3. FDGTI's pilot test flow schematics, field data collection sheets, and field notes are included in Appendices C, D, and E, respectively. Calculations related to the pilot tests are included in Appendix F.

4.1 Aquifer Pumping Tests

An aquifer pumping test was performed in the Upper Sand by FDGTI at each of the three source areas. RMT analyzed the pumping test data for each of the tests. The results of these analyses are included in Section 4 of Part I of this report.

4.2 Dual-Phase Extraction Tests

4.2.1 Building I-1-23 Source Area

A DPE pilot test near Building I-1-23 was performed on July 15, 1998, 2 days after a day-long aquifer pumping test was completed at this location. The test began by pumping from the DPE well for an initial 4 hours, and monitoring water levels at each of four MPs screened in the Upper Sand unit and located at distances ranging from approximately 8 to 34 feet from the DPE well (Figure 4-1). The well was pumped at 6 gallons per minute (gpm). The drawdown of hydraulic head during this time was limited and ranged from 1.1 to 2.1 feet at the monitoring points.

The venturi vacuum system was connected to the DPE well after the initial 4 hours, while groundwater pumping continued at the same rate (6 gpm) for the next 5 hours. Vacuum readings at the DPE well ranged from 126 to 218 inches water column (in. H_2O), and the air flowrate averaged 12 cubic feet per minute (cfm). No vacuum response was detected in any MPs or SVE wells, regardless of distance from the DPE well. This is due to the low permeability of the Upper Clay soil, the short vacuum test duration, and because the groundwater pumping duration was not sufficient to draw the water table down into the more permeable sand layer below. Potential blinding of the well screens caused by smearing of the clay across the borehole or screen surfaces during construction may also have contributed to the absence of any measurable vacuum response.

Analysis of the grab sample of the well pump discharge collected during the test (Table 4-2) indicated PCE at 130 μg/L, TCE at 2,000 μg/L, and cis-1,2-DCE at 200 μg/L. Vinyl chloride was not detected.

Analysis of the air samples collected during the tests (Table 4-1) indicated total CVOCs at 524 parts per billion by volume (ppbv), while other VOCs were detected at 862 ppbv. Also, 1,1,2-TC-1,2,2-TFA (also known as Freon 113) was detected at 28 ppbv. It was also detected at 120,000 ppbv in the air sample collected during the DPE pilot test at the Building I-1-2 area. The values for Freon 113 listed for samples 146-DPVE-1-2, 147-SPRC-1-2, and 148-SPRC-2-2 in the table provided by FDGTI (Table 4-1) each have an "R" flag, denoting that it was a "rejected value" (e.g., lab contamination), according to the footnote.

Based on a groundwater pumping rate of 6 gpm, the total VOC recovery rate from the groundwater is estimated at 0.007 lb VOCs per hour via pumping. The calculated VOC mass removal rate in the airflow, including Freon 113, is 0.0004 lb VOCs per hour. No radius of influence (ROI) can be estimated, since no vacuum response was recorded in any of the wells during the DPE and SVE tests.

4.2.2 Building I-1-2 Source Area

A DPE pilot test near Building I-1-2 was performed on July 17, 1998. The test began by pumping from the DPE well for an initial 6 hours, and monitoring water levels at each of four MPs screened in the Upper Clay and located at distances ranging from approximately 11 to 43 feet from the DPE well (Figure 4-2). The well was pumped at 6 gpm. The groundwater surface drawdown in the MPs during this time was substantial; head levels in these wells dropped at a rate that was nearly equivalent to the drawdown in the DPE well. Drawdown in the MPs at the end of the pumping portion of the test

ranged from below the bottom of the well screen at MP-3 to 6.3 feet at MP-1. The DPE well had a drawdown of 20.7 feet before the vacuum source was connected to the well.

The venturi vacuum system was connected to the DPE well after the initial 6 hours, while groundwater pumping continued at 5 gpm over the next 5 hours. Vacuum readings at the DPE well ranged from 142 to 188 in. H_2O and the air flowrate averaged 11 cfm. Vacuum response was recorded in all MPs except in MP-1 (approximately 43 feet from the DPE well), where the water level was not drawn down to the sand layer. No vacuum response was noted in any of the SVE wells, which are screened above the water table in the Upper Clay layer, regardless of their distance from the DPE well. This is due to the low permeability of the Upper Clay soil. Potential blinding of the well screens caused by smearing of the clay across the borehole or screen surfaces during construction may also have contributed to the absence of any measurable vacuum response. This indicates that, over the short duration of the tests, vacuum was propagated only in the sand layer when the water table was lowered sufficiently into that layer. This results in an "artificial" ROI of approximately 30 feet, that is conditional on sustained groundwater pumping.

Analysis of the grab sample of the well pump discharge collected during the test (Table 4-2) indicated PCE at 31 μg/L, TCE at 230 μg/L, cis-1,2-DCE at 69 μg/L, and di-N-butylphthalate at 14 μg/L. Vinyl chloride was not detected.

Analysis of the air samples collected during the tests (Table 4-1) indicated total CVOCs at 100 ppbv, while other VOCs were detected at 122 ppbv. Also, 1,1,2-TC-1,2,2-TFA (Freon 113) was detected at 120,000 ppbv.

Based on a groundwater pumping rate of 6 gpm, the total VOC recovery rate from the groundwater is estimated at 0.001 lb VOCs per hour via pumping. The calculated VOC mass removal rate in the air flow, not including Freon 113, was approximately 0.0001 lb VOCs/hr. The calculated VOC mass removal rate in the air flow, including Freon 113, was 0.033 lb VOCs per hour.

As mentioned above, the ROI, which only exists in the sand layer during sustained pumping, is estimated at 30 feet. This distance corresponds to 1 percent of the normalized vacuum (normalized with respect to applied vacuum at the DPE well), extrapolated graphically using the best-fit line on a semilog plot of normalized vacuum versus distance from the DPE well. No ROI in the clay layer was estimated since there was no measurable vacuum in the SVE wells.

4.2.3 Area 9 Repository Source Area

A DPE pilot test at the Area 9 Repository was performed on July 19, 1998. The test began by pumping from the DPE well for an initial 2.75 hours, and monitoring water levels at each of four MPs, located at distances ranging from approximately 9 to 35 feet from the DPE well (Figure 4-3). The well, which was screened in silt and clay of moderately low permeability, was pumped initially at approximately 0.3 gpm. The drawdown of hydraulic head in the MPs during this time was limited and ranged from 0.03 to 0.6 feet. The DPE well had a drawdown of 13.69 feet before the vacuum source was connected to the well.

Pumping stopped after 2.75 hours, and a pneumatic-activated groundwater pump was installed for the vacuum portion of the test. The venturi vacuum system was connected to the DPE well at about the 3.3-hour mark, and groundwater pumping resumed with the pneumatic pump, apparently at the same flowrate of approximately 0.3 gpm, for the next 4.5 hours. Vacuum readings at the DPE wellhead ranged from 227 to 240 in. H_2O, and the air flowrate averaged 16 cfm. No vacuum response was detected in any MPs except in MP-1 (approximately 35 feet from the DPE well), where a vacuum of only 0.1 to 0.5 in. H_2O was measured after the vacuum source was connected for 1.5 hours. Based on the relatively low permeability of the soil and the lack of response in wells close to the vacuum source, the vacuum observed at MP-1 may be due to a preferential air flow pathway in the clay. This is supported by the air sparging test data, which show higher pressure readings in MP-1 than in other MPs closer to the AS well. No vacuum response was detected in the SVE wells.

Analysis of the grab sample of the well pump discharge collected during the test (Table 4-2) indicated PCE at 120 μg/L, TCE at 2,400 μg/L, cis-1,2-DCE at 3,300 μg/L, and vinyl chloride at 17 μg/L. Other chlorinated and nonchlorinated VOCs totaling 145 μg/L were also detected.

Analysis of the air samples collected during the tests (Table 4-1) indicated total CVOCs at 248 ppbv, while other VOCs were detected at 45 ppbv.

Based on a groundwater pumping rate of 0.3 gpm, the total VOC recovery rate from the groundwater is estimated at 0.0009 lb VOCs per hour via pumping. The calculated VOC mass removal rate in the air flow was negligible due to the low concentrations and low air flowrate recorded.

Based on the lack of vacuum response observed in the MPs (except for the slight response noted at MP-1), the ROI can be assumed to be much less than 9.5 feet, which is the distance between the DPE well and MP-3, the closest MP.

4.3 Air Sparging/Soil Vapor Extraction Tests

4.3.1 Building I-1-23 Source Area

An AS/SVE test at the Building I-1-23 source area was performed on July 16, 1998. A venturi vacuum source connected to the DPE well, and an air compressor connected to the AS well, were operated for 4 hours. Measurements of pressure (positive and negative), water levels, and dissolved oxygen were recorded in four MPs located between 5 and 24 feet from the AS well (Figure 4-1). The vacuum at the DPE well ranged from 271 to 278 in. H_2O at an air flowrate between 7.5 and 10.8 cfm. No vacuum (negative pressure) response at any of the MPs was noted in the data.

Compressed air was injected into the air sparging well at 21 to 30 pounds per square inch (psi) and at a flowrate between 1.8 and 4.7 cfm. During this time, bubbling was noted at the ground surface around the outer casing of monitoring well 33MWC-21 (Figure 4-1), apparently the result of air flow short-circuiting through the outer well seal material, which prevented air flow/influence at MP-1. Moderately high positive pressure responses were noted 5 and 14 feet away at MP-4 and MP-2, respectively. In particular, the response at MP-4 appears to be significant (2,387 "units"), but the units used to record pressure on the data sheet are different from other wells, and the units are not identified. However, the response does not appear to be uniform across the site, because at MP-3 (12 feet from the AS well), the response was only 21 "units." A rise in groundwater head in each of the MPs during sparging appeared to be relatively uniform at the site. Water levels increased approximately 1.1 feet in the MPs located 12 to 24 feet from the AS well, while at 5 feet from the well the water level increased by over 3 feet under the same air injection pressure and air flowrate. Increases in the dissolved oxygen (DO) concentrations were recorded at MP-4 and MP-2 only, where DO increased by about 5 ppm and 1 ppm, respectively, as compared with background values.

Based on this information, the subsurface influence due to air sparging does not appear to be uniform across the site, likely due to well construction or possibly due to aquifer heterogeneities. Considering the data recorded and the possible well construction problems, the radius of influence for air sparging is estimated to be in the range of 10 to 14 feet.

Analysis of the air samples collected from the SVE exhaust during the tests (Table 4-1) indicated total CVOCs at 9,310 ppbv (TCE: 7,400 ppbv), while other VOCs (acetone, 2-butanone, toluene, and chlorobenzene) were detected at 1,312 ppbv. 1,1,2-TC-1,2,2-TFA (Freon 113) was detected at 28 ppbv. Some significant changes in air quality data

from the SVE system exhaust were observed during air sparging. One compound, cis-1,2-DCE showed a significant increase in concentration (75 μg/L to 700 μg/L) after sparging for 4 hours. Three other compounds showed a significant decrease in concentration after air sparging. TCE decreased from 260 μg/L to below quantification limits (BQL); acetone decreased from 69 μg/L to BQL; and 2-butanone decreased from 1,200 μg/L to BQL. Due to consistently low air flowrate and vacuum level recorded at the extraction well, it is unlikely that these changes are directly related to air sparging, and instead are likely due to desorption of the VOCs from unsaturated zone soil.

The calculated VOC mass removal rate in the SVE air flow (approximately 10.8 cfm) was calculated to be 0.0022 lbs/hr.

4.3.2 Building I-1-2 Source Area

An AS/SVE test at the Building I-1-2 source area was performed on July 18, 1998. The venturi vacuum system was connected to the DPE well and was operated for 2 hours. An air compressor was connected to the AS well and was then operated in conjunction with the vacuum source for an additional 6 hours. Measurements of pressure (positive and negative), water levels, and dissolved oxygen were recorded in four MPs located between 5 and 27 feet from the AS well (Figure 4-2).

The vacuum at the DPE well ranged from 165 to 188 in. H_2O. However, air flow from the extraction well was not recordable during any portion of the test except at the end of the test when approximately 6 cfm was detected. Also, no vacuum (negative pressure) response at the MPs was noted in the data.

The air sparging well injected air at 10 psi and at a flowrate of less than 2 cfm. Positive pressure responses in the range of 4.8 to 5.3 psi were noted 5 to 8 feet from the DPE well (MP-3 and MP-4). At MP-2 (19 feet from the AS well), the response was only 0.2 psi, and no pressure response was noted 27 feet from the DPE well at MP-1. A rise in groundwater head in each of the MPs during sparging appeared to be relatively uniform at the site. Water levels increased 0.5 to 0.7 feet in the MPs located 5 to 27 feet from the AS well. Dissolved oxygen increased from 1.2 mg/L or less to saturation concentrations (>11 mg/L) at MP-4 and MP-3 (5 to 8 feet from the DPE well), but remained unaffected at MP-2 and MP-1.

Analysis of the air samples collected during the tests (Table 4-1) indicated that the concentration of total CVOCs was below detection limits, while other VOCs (2-butanone) were detected at 160 ppbv. 1,1,2-TC-1,2,2-TFA (Freon 113) was detected in the air sample at 8,900 ppbv. Except for a modest increase in the 2-butanone

concentration in air samples collected during the test, no changes in air quality data from the SVE system exhaust during the air sparging test were noted. The increase in 2-butanone concentration can likely be attributed to desorption from unsaturated zone soil.

The VOC mass removal rate in the air flow was calculated, based on the flowrate and total VOC concentrations (not including Freon 113) recorded, to be approximately 0.00002 lbs. VOCs/hr. The VOC mass removal rate in the air flow, including Freon 113 is approximately 0.001 lb VOCs/hr.

Based on the lack of vacuum response observed in any MPs during the SVE test, the ROI can be assumed to be less than 5.5 feet, which is the distance between the DPE well and MP-4, the closest MP. Based on the increase in DO concentration and in positive pressure, the air sparge ROI is estimated to be between 8 and 19 feet.

4.3.3 Area 9 Repository Source Area

An AS/SVE test at the Area 9 Repository source area was performed on July 20, 1998. The venturi vacuum system was connected to the DPE well and was operated for 2 hours. An air compressor was connected to the AS well and was then operated in conjunction with the vacuum source for an additional 6 hours. Measurements of pressure (positive and negative), water levels, and dissolved oxygen were recorded in four MPs located between 5 and 24 feet from the AS well (Figure 4-3).

The vacuum at the DPE well ranged from 110 to 201 in. H_2O. Air flowrates ranging from 7.5 to 10.8 cfm were calculated from data recorded during the test. No vacuum (negative pressure) response at the MPs was noted in the data.

The air sparging well injected air at 15 to 30 psi and at air flowrates ranging from 1.0 to 4.9 cfm. Positive-pressure responses were noted at all MPs, but the magnitude of the responses is unclear because the units of measurement were not noted. It is worthwhile to observe, however, that the positive pressure response at MP-1, which is located the greatest distance away from the AS well, showed the greatest positive pressure, while the three closer MPs showed relatively uniform pressures, all of which were less than half the pressure recorded at MP-1. This suggests that short-circuiting between the AS well and MP-1 is occurring. The changes in groundwater head levels in each of the MPs during sparging were minimal. The two closest wells, MP-4 and MP-3, showed an increase of 0.21 and 0.23 feet, respectively. The level in MP-2 (17 feet from the DPE well) decreased throughout the test from 0.44 to 0.13 feet. The greatest increase,

0.56 feet, was at MP-1, the farthest MP from the AS well. There was a negligible increase in dissolved oxygen in each of the MPs, ranging from 0.22 mg/L to 0.39 mg/L.

Analysis of the air samples collected during the tests (Table 4-1) indicated total CVOCs at 1,393 ppbv, while other VOCs (acetone, chlorobenzene, and 1,2,4-trimethylbenzene) were detected at 24 ppbv. Some significant changes in air quality data from the SVE system exhaust during air sparging were noted. In particular, TCE increased from 230 μg/L to 1,300 μg/L after 6 hours of sparging. Vinyl chloride, trans-1,2-DCE, and acetone also showed moderate increases during this time, while cis-1,2-DCE showed a decrease from 44 μg/L to BQL. The air flowrate and vacuum level at the extraction well seemed to change when air sparging was started. It is unknown whether these changes are the result of adjustments made to the SVE system by FDGTI or if they were a direct effect of air sparging.

The calculated total VOCs mass removal rate in the air flow during the test is 0.0005 lb VOCs/hour, based on the maximum recorded air flowrate (18.3 cfm) and VOC concentrations (1,417 ppbv).

Based on the lack of observed vacuum response, the SVE ROI can be assumed to be less than 5.8 feet, which is the distance between the DPE well and MP-4, the closest MP. Based on the lack of significant changes in DO concentrations and the absence of positive pressure at the MPs, particularly at relatively high air injection pressures (up to 30 psi), the air sparge ROI cannot be estimated with certainty, but it is likely to be less than 5.8 feet, which is the distance between the AS well and MP-4, the closest MP.

4.4 Pilot Tests Conclusions

Overall, the DPE and AS/SVE pilot tests showed that none of these technologies by themselves are feasible or would be effective at subsurface remediation at any of the three source areas. Therefore, the objective of the pilot tests "to prove that vacuum extraction will be effective within the vadose zone," was not met. However, due to uncertainties regarding actual effectiveness of these technologies because of limitations of the design and operating methods used for the pilot tests, the application of portions of these technologies as a component of a remedial action for one or more of the CVOC source areas may still be appropriate.

SVE alone is severely limited, given the low air-filled porosity of the Upper Clay unit and the relatively shallow groundwater table at the source areas. These limitations might be overcome, or at least improved, with a vacuum pump capable of higher vacuums, such as a liquid ring vacuum pump that is typically used with multiple-phase extraction (MPE) systems. DPE, as it was implemented in the pilot tests, was largely ineffective at Building I-1-23 and the Area 9

Repository, but was somewhat effective at Building I-1-2. This is because the water table at that location was drawn down into the relatively thin Upper Sand layer, where vacuum and air flow was propagated through the permeable sand.

The attempts to transfer CVOCs from the dissolved phase in groundwater within the Upper Sand unit into the gas phase via air sparging into the sand, and then to transfer the volatilized contaminants in the gas phase up through several feet of saturated Upper Clay, and to extract the contaminated soil vapor in a single SVE well, were unsuccessful. A cursory review of existing soil boring logs from drilling in the source areas would indicate the futility of this approach; compressed air blown into the Upper Sand unit will not flow upward through several feet of water-saturated clay to a well screened only a few feet above the water table, regardless of the vacuum pressure applied to the well. The potential effects of the air sparging tests at each source area may have been the lateral spreading of the CVOC plumes into a larger area of the Upper Sand, and also possible inhibitory effects of the addition of oxygen into the groundwater on the anaerobic biodegradation of the CVOCs that was occurring in the source areas. For these reasons, air sparging into the Upper Sand at any of the Sites 32/33 source areas is not an advisable remedial approach.

Multiple-phase extraction, also referred to as bioslurping, as defined by the USEPA, is "a technology that uses a high-vacuum system to remove various combinations of contaminated groundwater, separate-phase... product, and... vapor from the subsurface" (USEPA, 1997). This is typically done using one pump, e.g., liquid ring-type vacuum pump, to achieve extraction of multiple phases of contamination. It is expected that implementation of MPE instead of DPE would be more effective at all three sites. This is because the groundwater is pumped and vapors are extracted simultaneously with one high-vacuum pump from the soil zone that is targeted for cleanup. Also, a combination of extraction wells screened only in the Upper Sand (primarily to assist in dewatering the Upper Clay) and other wells screened only in the Upper Clay (to optimize vapor-phase CVOC removal from the clay as it is gradually dewatered), could enhance the effectiveness of MPE at all source areas.

Section 5
Identification and Screening of Remedial Technologies

The objective of this section is to identify specific technologies that may be appropriate to accomplish the remedial action objective. After a general discussion, these technologies are screened to eliminate those that are inappropriate for inclusion in specific integrated alternatives. The universe of remedial technologies includes those that have been widely applied using standard construction and operating techniques, as well as those that have been recently developed for very specific remedial situations. Remediation of CVOC contamination of groundwater at Sites 32/33 is the focus of this feasibility study. Some additional remediation of soil at specific areas may be an additional component of the remedial action for the site, since CVOC residuals remaining within the soil provide a continuing source of dissolved CVOCs in the groundwater. Therefore, technologies for remediation of CVOC contamination of both soil and groundwater have been identified and screened.

Technologies are grouped into four categories: containment, removal, treatment, and disposal. These categories correspond to individual potential response actions, and can be linked together to provide comprehensive remedial alternatives. In addition, institutional controls, such as fencing, deed restrictions, and monitoring, can be incorporated with any of the potential response actions.

Identification of remedial technologies is provided in Subsections 5.1 through 5.4. This identification is based on the following:

- A review of recent technical literature
- A review of recent USEPA guidance documents
- A review of USEPA S.I.T.E. program results
- On-line remediation information database services
- Discussions with commercial vendors of specific technologies
- Field observations of specific technology applications, both through the S.I.T.E. program and private cleanups
- Experience on similar projects involving remediation of CVOC contamination of soil and groundwater

A screening of those technologies that are appropriate for inclusion in specific remedial alternatives is summarized in Table 5-1. This screening is based on the criteria of "effectiveness" and "implementability." These criteria are used since they directly address the primary concerns about the appropriateness of a specific technology to site conditions, and site-specific questions related to implementation.

5.1 Containment Technologies

Containment can be used in conjunction with other remedial response actions or as a sole means of site stabilization. The containment alternative may address soil as well as groundwater at or downgradient of a CVOC source. In either case, it is essential to incorporate a well-designed post-closure monitoring program with the containment alternative.

Subsurface barriers are used to isolate and contain soil with residual CVOC source material, and redirect or contain groundwater flow to minimize groundwater contact with this soil or with water that has leached through the contaminated soil from surface water infiltration. To control the groundwater head within or upgradient of such a barrier, pumping wells or subsurface drains are frequently used. To effectively control migration of constituents of concern within the groundwater, a perimeter barrier wall must be keyed into a confining layer of low permeability at its base, extend upward to an elevation above the groundwater level, and completely encompass the area of concern. Hydraulic containment does not address the actual removal of waste constituents.

The Lower Clay is continuous over Sites 32/33, with a relatively uniform average thickness of 40 feet. The top of the Lower Clay is present at depths of approximately 30 to 50 feet below ground surface over the site. The groundwater within the Lower Clay has not been significantly impacted by CVOCs. This clay unit would function adequately as a low-permeability confining layer to be used with vertical subsurface barriers to encompass and contain a zone of impacted groundwater within the Upper Sand and Upper Clay units. To be effective, an alternative that relied on groundwater containment would need to include a perimeter barrier wall, some portions of which would have to reach depths of 50 feet or more at some locations.

A discussion of common groundwater containment options is presented below.

5.1.1 Slurry Walls

This technology involves excavating a trench to the depth of a confining base layer while adding a slurry into the excavation. The slurry generally consists of a bentonite/water mixture. The slurry holds the excavation open while creating a low-permeability cake on the sidewalls of the trench. The wall is usually completed by

backfilling with a soil/bentonite mixture. The effectiveness of slurry walls depends on the control of proper excavation procedures and proper proportioning and placement of the select backfill material. In addition to soil/bentonite mixtures, cement-bentonite mixtures have been used, or a synthetic membrane may be placed in the trench in a "U" configuration by filling it with a highly permeable sand material. With the synthetic membrane installation, observation wells may then be placed within the permeable sand material to detect infiltration and to determine the integrity of the synthetic membrane.

5.1.2 Sheet Piles

This technology involves driving steel sheet piles around the perimeter of the area to be contained. The piles are driven until the tips reach and penetrate an underlying low-permeability layer. The sheet piling sections are usually not water-tight at the section joints. Recent advancements in the application of plastics for subsurface containment include construction methods to install sheets of high-density polyethylene (HDPE) with interlocking, water-tight sheet sections as vertical barrier walls around contaminated soil areas.

5.1.3 Injected Screens

This technology also includes driving steel sheet piles into the soil around an area of concern. The sheet piles are then subsequently extracted one at a time, and the resulting void is filled with a grout injected under pressure.

5.1.4 Grout Curtains

This technology involves drilling holes along the perimeter of the area to be contained until an underlying low-permeability layer is reached. The drill is then extracted, and a grout is injected under pressure through the drill holes. The drill holes are spaced along a line at distances such that the cemented zone of each grout hole overlaps the preceding zone.

5.2 Removal Technologies

5.2.1 Soil Excavation and Consolidation

This technology involves the excavation of soil from an identified area followed by disposal or treatment of the soil. Excavation is technically considered a remedial technology for soil. It is included in this section for groundwater as a means of

removing contaminant mass from the source areas at the site, thereby minimizing the potential for continued leaching of CVOCs to the groundwater.

Excavation of VOC-contaminated soil is a readily implementable technology at this site, except for the source area(s) located beneath the Area 9 Repository. However, several factors that may affect the feasibility of this approach include the method of excavation, especially with respect to the required excavation depth; disposal options due to uncertainties regarding CVOC concentrations in the excavated material; the need to excavate beneath the groundwater table elevation; and uncertainties regarding the lateral and vertical locations of the CVOC residuals at each source area. Each of these issues has a direct bearing on the overall cost of the technology.

It is possible to excavate to the range of depths that may be required at this site (up to 35 to 40 feet bgs), but equipment with greater reach capability than that offered by a conventional tracked excavator (e.g., clamshells or draglines) would be required. Alternatively, sheeting or shoring could be installed to allow excavations at these depths with tracked excavators. However, at any of the CVOC source areas, excavation of soil that contains CVOC residual source material beneath the groundwater table would be necessary. If excavation to depths near the Upper Sand unit is needed, installation and operation of equipment for dewatering the soil and for treatment of the contaminated groundwater would be required.

For dry materials, dust suppression may be necessary to reduce the release of airborne particulates. Water and/or synthetic covers can be used as suppressants. Although little CVOC data are available for the soil, it is assumed that much of the excavated material would be classified as a toxicity-characteristic hazardous waste (40 CFR 261.24) based on the available data. This presents cost and administrative issues regarding transportation and disposal of the excavated soil.

Finally, CERCLA includes a statutory preference for treatment of contaminants (as opposed to simply transferring contaminants from one location to another), making excavation and direct land disposal less acceptable than other technologies that provide treatment.

In general, the technology would be viable and effective in minimizing the future transfer of concentrated CVOC residuals from soil into groundwater, assuming that all significant CVOC sources are located, and that the potential construction difficulties can be overcome.

5.2.2 Groundwater Extraction

Extraction wells can be used to remove groundwater for treatment and/or disposal. This technology can also be used to control hydraulic gradients in the vicinity of a source area, limiting the migration of constituents, or reducing flow through subsurface areas. Extraction wells are frequently used in conjunction with subsurface barriers to physically and hydraulically isolate contaminated soil areas. The spacing and sizing are determined by the extent of groundwater to be controlled and by aquifer properties. Extraction wells can be installed in a standard vertical configuration, or can be installed horizontally in preferential geologic units using relatively recent improvements in horizontal drilling technology.

As an alternative, groundwater collection trenches can sometimes be employed. This technology serves the same general purpose as that of pumping wells—to remove impacted groundwater. Subsurface drains are generally limited to shallow depths, and thus may serve as a substitute for pumping wells in shallow aquifer conditions. Subsurface drains normally include a drain pipe or gravel bed, protective filter media to prevent clogging by fine particulate matter, manholes or wet wells for the collection of groundwater, and pumping equipment to remove the accumulated water. Drains are typically situated transverse to the direction of groundwater flow, and may be placed downgradient of contaminant source areas to collect groundwater, or upgradient to keep groundwater from coming in contact with contaminated soil areas.

Use of vertical or horizontal extraction wells would be feasible for capture and removal of contaminated groundwater at Sites 32/33. Collection trenches would not be practical for extraction of groundwater from the low-permeability Upper Clay. However, trenches could potentially be feasible for interception and extraction of groundwater from the Upper Sand at the shallower elevations.

5.3 Treatment Technologies

For soil and groundwater treatment, many new technologies are being introduced at various stages of development, and existing technologies are being applied in alternative ways. Unlike the more conventional technologies for containment and removal, treatment technologies (or process options) are frequently patented and proprietary, and available only through a limited number of vendors. In some cases, technologies exist at a "full-scale" stage of development, but have yet to be permitted by regulatory agencies for specific applications. In all cases, a treatment technology is specific to particular chemical compounds or classes of compounds.

5.3.1 *In Situ* Treatment

Significant research, development, and commercialization efforts have occurred in the 1990s in the field of *in situ* treatment technologies for soil and groundwater. Many of these recently developed technologies, as well as other more proven *in situ* processes and equipment, are applicable to remediation of chlorinated solvent contamination. *In situ* technologies available today apply a wide range of biological, physical, and chemical processes and principles, often as part of an integrated remediation approach tailored to site-specific physical conditions that are encountered. Many companies offer specialty equipment, chemicals, and services for field application of various technologies, often using proprietary and patented equipment and materials. A list of the types of *in situ* treatment technologies for soil and/or groundwater considered for application at Sites 32/33 is presented below, using commonly accepted terminology in the environmental remediation field. Some examples of proprietary trade names or companies that utilize certain technologies are also listed:

- Soil vapor extraction
- Air sparging
- Steam sparging (Steam Injection & Vacuum Extraction - SIVE)
- Enhanced biological treatment, aerobic and anaerobic (M-1000®, Bio Luxing®, Biopim, BioInjection, Anaerobic Biotransformation With Steam Injection, Mobile Injection Treatment Unit – MITU®)
- Chemical oxidation (Clean OX®, TR-DETOX, Oxy VAC™, Geo-Cleanse Process®, ISOTEC®, Mobile Injection Treatment Unit – MITU®)
- Permeable reactive barrier walls (EnviroMetal®)
- Fracturing, pneumatic and hydraulic (Bio Luxing®, Pneumatic Fracturing Extraction - PFE®, Injection Vac™, FE ACTIVE™)
- Phytoremediation
- Electro-osmosis/electromigration (Lasagna™, Electro-Petroleum, Inc.)
- In-well aeration (UVB™ wells)
- In-well adsorption (RECLAIM®)
- Soil flushing (Injecsol®; Bio Solver, Mobility Controlled Surfactant Flushing)
- Thermal desorption, low and high temperature (Hrubout™, Six-Phase Soil Heating - SPSH®, Radio Frequency Heating Systems, EM/RF Heating, Electro Heated Dual Phase Extraction - EH/DPE®, PCS Low Temperature Thermal Desorption, Mobile Injection Treatment Unit – MITU®, Shallow Soil Mixing/Thermally Enhanced Vapor Extraction/Soil Vapor Extraction - WWM/TEVE/SVE)
- Stabilization/immobilization

- Vitrification (Vitriflux™)

A brief description of several of these and other technologies for soil and groundwater treatment is included in Table 5-2, which was excerpted from a USEPA document (USEPA, 1997).

5.3.2 *Ex Situ* Treatment

Soil

After excavation of saturated or unsaturated soil contaminated with CVOCs or other organic compounds, several technologies are available for treatment, using many of the same biological, physical, and chemical processes discussed above that are often applied for *in situ* soil treatment. The technologies can be defined under the following general classifications:

- Biological treatment
- Chemical extraction
- Thermal destruction
- Thermal desorption
- Solidification/chemical fixation
- Physical separation (preprocessing)

Several of these technologies are described further in Table 5-2.

Groundwater

Extracted groundwater often requires some form of treatment prior to discharge to surface water or to groundwater via subsurface injection, or for other forms of water reuse. Many types of groundwater treatment processes exist, and are based on proven wastewater treatment technology. Several common processes include the following:

- Biological treatment
- Carbon adsorption
- Air or steam stripping
- Precipitation/flocculation/sedimentation
- Reverse osmosis
- Ion exchange

– Chemical oxidation

Of these technologies, only biological treatment, carbon adsorption, stripping, and chemical oxidation are generally appropriate for treatment of CVOCs in groundwater. Some of these technologies are briefly discussed in Table 5-2.

5.4 Disposal Technologies

5.4.1 Soil Disposal

Land disposal of both hazardous and nonhazardous soil or solids is a proven technology that has been used for many years. Excavated solids could be disposed in engineered off-site or on-site landfill facilities, although such options are only appropriate when waste volumes are limited. In either case, disposal must comply with the USEPA's regulations applicable to RCRA-regulated hazardous wastes if such wastes will be placed in disposal units. Off-site disposal may be discouraged because USEPA policy states that off-site transport and disposal without treatment is the least favored alternative where practicable treatment technologies are available. Both off-site and on-site disposal are discussed further below.

Off-Site Facility

Excavation of material would be performed by a backhoe or other mechanical means. Excavated material would then be transported by licensed waste haulers to an off-site permitted disposal facility. Imported fill material would be required to backfill the excavated areas. This technology permits full future use of the site, if all areas of CVOC soil contamination that may present an unacceptable level of potential future risk of human exposure are identified with a high degree of certainty and are effectively excavated. Long-term management of the removed material would become the responsibility of a third party; however, the liability associated with the material remains that of the generator.

On-Site Facility

In contrast to excavation and consolidation, this technology could involve the construction of a completely new disposal facility on-site. A newly constructed landfill would have to meet applicable and relevant and appropriate land disposal design requirements. Sufficient land area must be available, and future land use would be restricted.

5.4.2 Groundwater Disposal

Groundwater that is extracted via pumping wells or collection trenches can be disposed by one of the following options:

Discharge to On-site Surface Water Drainage Swales

This option is applicable to both treated and untreated groundwater, provided that both the quality and quantity meet the relevant and appropriate discharge requirements for surface water as regulated under federal and state standards. Sampling of the groundwater to be discharged would be required to determine its quality and to identify whether or not it meets the allowable discharge requirements.

Discharge to POTW

Discharge to a Publicly Owned Treatment Works (POTW) is applicable to both treated and untreated water, provided that the quality and quantity of the water meet the pretreatment requirements of the local regulatory agency or authority. The quantity allowed would likely depend on the capacity of the discharge system and the POTW. Sampling and analysis of the groundwater to be discharged would be required to determine its quality.

Reinjection

This option may be appropriate for disposal of treated groundwater. The reinjection of treated groundwater may serve as a means of hydraulic control in limiting the further migration of a plume, as well as in providing flushing of residual constituents from local soil. Extraction and injection wells can be sized and spaced based on aquifer properties for effective containment. This option would also depend upon regulatory approval of the reinjection system.

Re-use

In some site-specific situations, re-use of treated groundwater may be appropriate. Potential uses include process supply water for nonpotable industrial uses, irrigation, and potable use after polishing treatment and disinfection.

5.5 Technologies Suitable for Further Development

A screening of technologies for soil and groundwater treatment is summarized in Table 5-1. Each technology was screened on the basis of effectiveness and implementability, and a determination was made of whether it is appropriate for application as part of a broader remedial alternative. These alternatives are presented in Section 6.

Section 6
Development and Modeling Simulations of Remedial Alternatives

The purpose of this portion of the FS is to develop a range of remedial alternatives assembled from the appropriate individual treatment technologies identified in Section 5. The primary design concepts for each alternative are described, including the major system components and the intended performance objectives or effects of the alternative. Specific design details of the selected alternative will be determined during the design phase.

Six alternatives were developed to address the CVOC source areas (Building I-1-2, Building I-1-23, and the Repository Area) and associated plumes. The alternatives are identified and generally described as follows:

- Alternative A - No Action
- Alternative B - Monitored Natural Attenuation
- Alternative C - Phytoremediation
- Alternative D - *In Situ* Enhanced Bioremediation
- Alternative E – Multiple-Phase Extraction
- Alternative F *In Situ* Physical/Thermal Removal (Mobile Injection Treatment Unit - MITU®)

The primary components of these alternatives are summarized in Table 6-1. The design concepts for Alternatives C, D, E, and F as described in the following sections are shown on Figure 6-1.

Each of the developed remedial alternatives was simulated using the calibrated contaminant transport model to compare the effectiveness of the various designs in limiting and reducing the extent of TCE and related compounds in the groundwater. The calibrated model can be a potent tool for comparison, because it quantitatively estimates the extent of contaminants in the groundwater over time for each of the remedial alternatives. However, because of the substantial uncertainties inherent in modeling remedial alternatives that have not been field-tested at the site, caution should be exercised in using these results. The results should be considered as a semiquantitative evaluation, and predicted concentrations should be considered more in a relative, rather than an absolute, sense. Nonetheless, within the limits of the model's assumptions, the contaminant transport model provides a useful means of

projecting the relative effectiveness of various remedial options in lowering contaminant concentrations in the groundwater.

A 20-year time period following the start of remediation was selected for simulation. This period was chosen because it was long enough to reveal significant differences between the remedial alternatives as they become fully implemented, but was short enough to minimize the substantial computer run-time for each simulation. Also, it is commonly expected that a successful remedial measure will likely show significant effects within a 20-year time span.

The model simulations attempted to realistically estimate the effectiveness of the remedial alternatives by estimating the percent reduction in source concentration. The estimated amount of this reduction was based on a review of case histories of the alternatives. Recognizing the uncertainty in the percent reduction estimates, a conservative approach was taken in assuming that the source concentration achieved by the remediation activity would remain constant for the 20 years of simulation, even though it is possible that some additional reduction could occur during the 20 years.

The remedial alternatives that were selected for quantitative evaluation include no action, monitored natural attenuation, phytoremediation, *in situ* enhanced biodegradation, multiple-phase extraction, and *in situ* soil treatment using the Mobile Injection Treatment Unit®. As discussed below, some decrease in TCE concentrations in the source areas of I-1-23 and I-1-2, caused by removal of CVOC-impacted soil during the PCB remedial action, was assumed to have occurred in all of the simulations that follow (see Table 6-2). The conceptual framework, model setup, and results for each simulation are presented below. Additional model output documentation for the remedial alternative simulations is presented in Appendix G.

6.1 Alternative A - No Action

Evaluation of a No-Action alternative is required by CERCLA guidance to provide a baseline against which other alternatives can be compared. The No-Action alternative consists of leaving the site in its present condition; that is, there is no work and no cost other than the costs for additional long-term monitoring of groundwater and surface water, as required under the ROD and Consent Decree.

With respect to the modeling simulations, the No-Action alternative would be consistent with the results of the model simulation performed for the alternative that uses monitored natural attenuation to achieve the remedial action objective (Alternative B).

6.2 Alternative B - Monitored Natural Attenuation

6.2.1 Design Concepts

This alternative consists of regular, periodic monitoring of groundwater and surface water to assess the attenuation of contaminant plumes via natural chemical, physical, and biological processes. The monitoring data are evaluated to determine whether the groundwater contaminant plumes are stable or receding, and the rate of change of the CVOC concentrations. Selected wells in each plume will be monitored for VOCs, as required for compliance monitoring, and also for other parameters that support lines-of-evidence for biodegradation of chlorinated solvents, such as nitrate, sulfate, iron, methane, ethane, ethene, dissolved oxygen, E_H, pH, chloride, DOC, and temperature. At each source area, several existing wells will be selected for periodic monitoring. These wells will best represent conditions at the following locations in the plumes:

- One or two upgradient (or sidegradient) wells with no recorded impacts from historical sampling data
- One well in or near the source area of the plume
- Two wells in the plume, downgradient of the source area
- One well in the general area where the groundwater discharges to surface water

An estimated total of 15 to 18 monitoring wells would be sampled for the parameters listed above, semiannually for the initial 2 years of the remedial action, and annually thereafter.

6.2.2 Simulation

For this option, it was assumed that the future aquifer conditions and processes continue essentially unchanged from current conditions. Aquifer flow and transport parameter values remained identical to those in the calibrated model, with one exception: the values assigned to the constant concentration nodes at the I-1-23 and I-1-2 source areas were decreased by 50 percent and 25 percent, respectively, in order to simulate an assumed depletion of TCE source material due primarily to soil excavation during the PCB remedial action. This assumption is based on the fact that an extensive amount of PCB-impacted soil was excavated from the source areas near Buildings I-1-23 and I-1-2, and it is likely that this soil contained significant amounts of TCE and other CVOCs, based on analyses of soil and groundwater samples collected in the soil excavation areas. During sensitivity testing, an extremely conservative (and probably unrealistic) assumption that no CVOCs were removed during the PCB soil removal action was made; the results of model runs using this assumption indicate that the

relative effectiveness of one remedial option versus another would not change. These results are discussed further in Subsection 6.7.

The assumption that only 50 percent and 25 percent of the source material was removed from the I-1-23 and I-1-2 source areas, respectively, is based on a conservative assessment of the extent of the source material (based on soil and groundwater data) relative to the amount of soil that was removed at each location, with an additional conservative "contingency factor." The PCB-impacted soil was treated in a temporary on-site Thermal Treatment Unit, or placed directly into the Repository, depending on the PCB concentration of the excavated soil with respect to specified action levels. It is assumed that the soil removal depleted a substantial percentage of the mass of CVOCs in the source areas, although insufficient data were collected during the PCB remedial action to quantify the mass of CVOCs removed or remaining in the outlying source areas soil. No change in CVOC concentrations was assumed in the Repository source area nodes, as a conservative assumption to account for the possibility that some leachable CVOC residuals remained in the Category 1 soil and sediment placed in the Repository.

The results of the simulation are shown on Figure 6-2. For clarity, only the area containing the I-1-23 plume and the Repository plume is shown on Figure 6-2. The results indicate that due to soil removal in the source areas during the PCB remedial action, and continued natural attenuation, concentrations in the groundwater would decrease slowly. At the end of 20 years, the model indicates that the 2,000 μg/L TCE contour for the I-1-23 plume would lie south of the Northern Access Road at the site (see Figure 6-2) (see Figure 6-1 for location of the Northern Access Road). Concentrations at a point just south of Crab Orchard Lake would decrease from more than 600 μg/L to less than 500 μg/L (see Figure 6-3). The total mass of TCE in the aquifer, over all of Sites 32/33, both in the dissolved and the sorbed phase, would decrease from approximately 1,500 kg to below 1,000 kg (see Figure 6-4).

6.3 Alternative C - Phytoremediation

6.3.1 Design Concepts

Fast-growing and deep-rooted hybrid poplar trees take-up relatively large quantities of groundwater and transpire many CVOCs at a relatively high rate, thereby oxidizing significant amounts of CVOCs to carbon dioxide and water. Field demonstration sites have confirmed the ability of these trees to nearly eliminate the movement of TCE in shallow groundwater passing beneath a barrier of densely planted poplars.

For this alternative, hybrid poplar groves would be planted in each of the areas shown as Alternative C on Figure 6-1. Areas 1, 2, and 3 as identified on this figure show poplar groves planted in the source areas, while Areas 4 and 5 show poplar groves at the downgradient areas of the I-1-23 and Repository Area plumes near the surface water discharge locations. The objectives of the groves in Areas 1 and 2 are to take-up and transpire CVOCs within approximately the top 10 feet of the subsurface, and also to minimize water infiltration through these source areas. The grove shown at Area 3 (on top of the Repository) is designed to cut off water infiltration into the Repository waste material and subsequently into the native soil and groundwater below. The groves at Areas 4 and 5 are intended to provide some hydraulic control of the plume at its downgradient extent, thereby reducing concentrations of CVOCs in the groundwater before it discharges to the lake or swale. The design also includes using existing trees and plants in the area on the eastern side of Highway 148 (downgradient of the source area near Building I-1-2) to reduce the mass of dissolved CVOCs remaining in the saturated soil prior to groundwater discharge to the intermittent stream. Due to its relatively low cost and effectiveness, as well as its environmental and aesthetic benefits at the Refuge, the groves at Areas 4 and 5 are also included as a component of each of the remedial alternatives that follow (D, E, and F), and are referred to as "limited phytoremediation."

6.3.2 Simulation

Simulation of this phytoremediation alternative was intended to test the effectiveness of utilizing hybrid poplar trees to attenuate TCE in the source areas and discharge areas at the downgradient ends of the plumes. The poplar trees withdraw a substantial amount of water from the soil, and can remove it from both the unsaturated zone and from the water table. After reviewing the existing literature on the water uptake rates by hybrid poplar trees, a conservative value of 500,000 gallons of water per acre per year from the saturated zone was simulated. The estimated acreage of the areas to be planted with hybrid poplar trees was calculated, and a water removal rate was then simulated in the model using an equivalent number and configuration of "pumping wells" distributed across the affected areas.

Depending on the node spacing in each area, the rates of pumping for each "well" were calculated so the correct amount of water removal was simulated. Because the model is a saturated zone (groundwater) flow and transport model, the water was removed from the saturated zone, along with the corresponding TCE concentration in the groundwater at the time of removal. For simplicity, it was assumed that water uptake by the poplar trees was continuous and at a constant rate after an initial growth period of 3 years. Although actual uptake by the trees would vary seasonally, the assumption of a

constant rate is not considered to have a significant effect over the 20-year period of evaluation.

The results from this simulation are shown on Figures 6-3, 6-4, and 6-5. The results indicate the TCE concentrations in the plumes would decrease substantially over 20 years, with the 2,000 μg/L contour of the I-1-23 plume retreating back to approximately 400 feet south of the Northern Access Road at the site. The concentration of TCE in groundwater in an area just south of Crab Orchard Lake would decrease from over 600 μg/L to approximately 200 μg/L (Figure 6-3). The model results indicate that the total mass of dissolved and sorbed TCE in the aquifer over all of Sites 32/33 would decrease from approximately 1,500 kg to 600 kg over the 20-year simulation period (Figure 6-4).

6.4 Alternative D - Enhanced Bioremediation

6.4.1 Design Concepts

The anaerobic biodegradation of PCE and TCE can occur by a process known as reductive dehalogenation. This process consists of reduction of an electron acceptor (PCE or TCE in this case) by the replacement of a chlorine atom with a hydrogen atom, and the concurrent oxidation of an electron donor (organic substrate). Lactate, as an electron donor, has been shown to stimulate and support reductive dehalogenation of PCE and TCE. Lactate is relatively innocuous and is often selected over other electron donor materials, such as methanol, acetate, and propionate.

The approach is to mix a dilute solution of lactate (and trace nutrients via yeast extract) and introduce it into the aquifer by gravity or pressure injection wells and infiltration galleries. Because this process requires reducing conditions to be effective, a commonly used chemical reducing compound, such as sodium sulfite, may be added to the solution to remove dissolved oxygen and create strongly reducing conditions in the zone of treatment.

The enhancement process would be monitored in existing and new monitoring wells by the analysis of field and laboratory parameters.

Introduction of the lactate solution would occur by direct injection into wells screened in the Upper Sand layer at the Building I-1-2, Building I-1-23, and Repository Areas (including below the Repository and in the area south of the Repository) and into the Upper Clay layer via infiltration galleries constructed above the source areas at

Building I-1-2, Building I-1-23, and south of the Repository. No infiltration gallery above the Repository is proposed.

Six injection wells are proposed at the Repository, while three injection wells are proposed for each of the other areas (Building I-1-2, Building I-1-23, and south of the Repository). Injection of the lactate solution would occur on a quarterly basis in each of the 15 injection wells for a period of 2 years (eight total rounds of injection). The volume of solution injected per well varies based on the thickness of the Upper Sand layer, and would likely range from approximately 8,000 gallons at Building I-1-2 and the Repository to approximately 25,000 gallons at the south Repository area, to 50,000 gallons at Building I-1-23.

Infiltration would occur using infiltration galleries with approximate dimensions of 150 feet by 200 feet by 4 feet deep. Each gallery would be backfilled with 3 feet of washed stone, and a 1- to 2-foot-thick soil grading layer, graded to provide positive drainage away from the footprint of the gallery. A high-density polyethylene liner would be placed over the grading layer to prevent oxygenated rainwater from entering the infiltration gallery, and to help reduce oxygen transfer from the atmosphere into the soil due to natural barometric pressure variations.

Each gallery would be charged initially with approximately 225,000 gallons of the lactate solution. The solution would be maintained at a constant head in the gallery (approximately 2 feet below ground surface) by a system consisting of a groundwater recovery pump, level controls in the gallery and recovery well, storage tanks for substrate and deoxygenating chemical, and a solution metering pump. When the head in the gallery decreases to below 2 feet bgs, the groundwater pump would automatically turn on, supplying water with low dissolved oxygen that would be mixed with the appropriate dosage of lactate, trace minerals, and sodium sulfite, if needed. The mixing would take place in-line by injecting the chemical with a metering pump designed to operate only when the groundwater pump operates. According to infiltration estimates based on the data currently available, the infiltration rate for each gallery would be approximately 2,000 gallons per day at each of the three galleries.

This alternative also includes "limited phytoremediation" as described in Subsection 6.3, as well as monitored natural attenuation and compliance monitoring.

6.4.2 Simulation

Enhanced bioremediation in the source areas was simulated, in conjunction with phytoremediation in the downgradient discharge zones. In this alternative, enhanced

biodegradation was focused in the source areas of the I-1-23, I-1-2, and the Repository Area CVOC plumes. Review of the literature indicates that the rate and degree of contaminant removal with enhanced bioremediation varies widely. It was assumed that bioremediation would remove 75 percent of the contaminant concentration in the source nodes in model Layer 1, but that some of the TCE would remain there as small concentrated pockets of solvent blebs or ganglia, representing a continuing, but depleted source. This effect was simulated by progressively decreasing the concentration of the constant concentration nodes to an overall 75 percent over 4 years, and then holding the concentration constant (at the 75 percent reduced concentration value). For the Repository, no enhanced bioremediation treatment of model Layer 1 (the Upper Clay unit) was assumed because difficulties in treating the thick layer of low-permeability soil contained within the Repository would make it impractical; instead, the enhanced bioremediation was simulated in model Layer 2 (the Upper Sand unit), based on the conceptual design described in Subsection 6.4.1.

Injection of nutrients into the Upper Sand unit at the source areas to enhance the bioremediation of that unit was also simulated with the model for the I-1-23 and I-1-2 plumes, as well as the Repository. For model Layer 2 (the Upper Sand), the approach used was to adjust the TCE biodegradation half-life value for the source areas, to range from 1 month to 8 months, in four successive zones downgradient of the source areas. The areas of enhanced biodegradation in the Upper Sand were assumed to extend for approximately 300 feet downgradient of the injection points. This distance corresponds to the approximate distance groundwater travels in a year in the Upper Sand unit.

The design for this remedy entails nutrient additions for 2 years; however, the enhanced biodegradation effects were simulated for 3 years in the Upper Clay unit, where the low permeability would tend to keep the nutrients present for a longer period of time after nutrient additions ended. For the Upper Sand unit, the effects of enhanced bioremediation were assumed to last only 2 years, because the higher permeability of this unit would cause the nutrients to be flushed out relatively quickly after additions ended.

The results of the simulation are shown on Figures 6-3, 6-4, and 6-6. After 20 years, the model predicts that the 2,000 μg/L TCE contour on the plume map for the I-1-23 plume would have receded to approximately 600 feet south of the northern access road at the site (Figure 6-6). The total dissolved and adsorbed mass of TCE in the aquifer over all of Sites 32/33 would have been reduced from 1,500 kg to less than 400 kg (Figure 6-4). The concentration of TCE in groundwater at the area of groundwater discharge to the

lake and to the East Swale is predicted to decrease to below 150 μg/L over the 20-year simulation period (Figure 6-3).

6.5 Alternative E - Multiple-Phase Extraction

6.5.1 Design Concepts

Multiple-phase extraction (MPE) is an *in situ* technology that uses a single, high-vacuum pump to extract liquid and vapor simultaneously from the subsurface. Extracted liquid and vapor are treated and disposed, or discharged. The vacuum applied to the subsurface with MPE systems creates vapor-phase pressure gradients toward the vacuum well. These vapor-phase pressure gradients are also transmitted directly to the subsurface liquids, which will flow toward the vacuum well in response to the imposed gradients. The higher the applied vacuum, the larger the hydraulic gradients that can be achieved in both vapor and liquid phases, and thus, the greater the vapor and liquid recovery rates.

Several extraction wells can be connected to a single high-vacuum pump, usually a liquid-ring vacuum pump capable of over 400 inches water column (in. H_2O), or 29 inches mercury (in. Hg) vacuum. In each well, an extraction tube (also known as a "spear" or "stinger pipe") is installed with its tip at the elevation to which drawdown of the groundwater is to occur. The extraction tubes are connected to the vacuum pump via manifold piping. This configuration differs from that of dual-phase extraction (DPE) in that DPE uses a submersible pump in each well to create drawdown of the water table, while vacuum is induced at the well by separate vapor-only piping that is manifolded to a vacuum blower. The vacuum blowers used in DPE applications are typically not expected to extract groundwater by vacuum lift pumping. For this reason, a different type of vacuum blower is used (usually either a regenerative or a positive-displacement type) that is capable of higher flow, but has only about half of the vacuum capability of a liquid-ring pump. MPE is therefore preferred over DPE in lower permeability formations, such as the Upper Clay at this site.

At each of the source areas, a combination of vertical and horizontal wells will be installed. Two horizontal wells will be installed using directional drilling techniques at the bottom of the Upper Sand layer at each source area. Conventional vertical extraction wells will also be installed in the Upper Clay layer only. Based on trial runs using the calibrated groundwater flow model to estimate optimum pumping configurations, 25 vertical and 2 horizontal extraction wells would be installed at the Building I-1-2 area; 20 vertical and 2 horizontal extraction wells would be installed at the Building I-1-23 area and also at the South Repository area; and 44 vertical and

2 horizontal extraction wells would be installed at the Repository. All vertical wells would be constructed of nominal 2-inch-diameter PVC pipe, while the horizontal wells would be constructed of nominal 4-inch-diameter HDPE pipe.

The extracted groundwater would be treated using tray-type air stripping units and granular activated carbon, and subsequently discharged to the drainage swale nearest the particular source. Vapors recovered via the liquid-ring pump and those generated in the air stripping process would be treated using granular activated carbon, as needed, exhausted to the atmosphere.

At the Building I-1-2 area, a complete multiple-phase extraction and groundwater treatment system would be installed in a new, separate treatment building.

At the Repository area, a larger extraction system, likely consisting of multiple liquid-ring pumps, would be connected to the wells at the Repository and those in the South Repository area. Extracted groundwater would be treated in an air stripping unit of similar design, but of larger capacity than the unit at Building I-1-2. The treatment system would discharge to the East Swale.

At the Building I-1-23 area, only an extraction system (liquid-ring pumps) would be installed in a smaller, separate building. The groundwater extracted from that area would be pumped to the treatment system in the Repository/South Repository area.

6.5.2 Simulation

The effects of multiple-phase extraction of groundwater and soil vapor in the source areas was simulated, in conjunction with phytoremediation in the groundwater discharge zones. With this scenario, multiple-phase wells would be placed in the Upper Clay unit in the CVOC source areas of Buildings I-1-23, I-1-2, and the Repository. In addition, horizontal wells installed into the Upper Sand unit beneath the source areas of I-1-23, I-1-2, and the Repository were simulated.

The multiple-phase wells would be screened over both the saturated and unsaturated portions of the Upper Clay. A relatively dense network of multiple-phase wells is envisioned that would effectively capture groundwater and soil vapor over the source areas. The sizes of the source areas that were covered with multiple-phase wells in this simulation were 70 x 100 feet for I-1-23, 80 x 80 feet for I-1-2, and 60 x 150 feet for the Repository. This effect was simulated with constant concentration nodes in model Layer 1 set to 0 μg/L TCE in the source areas during the 2 years of operation of the wells. After 2 years, it was assumed that the constant concentration nodes would retain 20 percent of the original concentration (before multiple-phase extraction was begun)

due to residual TCE that could not be removed, and that served as a continuing source of CVOCs entering the groundwater.

The horizontal wells set in the Upper Sand unit (model Layer 2) were also simulated for 2 years of operation. These wells were simulated as DRAIN nodes in Modflow. This avoids constraining the pumping rates to an arbitrary value, and allows withdrawal of only as much water as the formation will yield, while maintaining reasonable head levels in the wells. Pumping of groundwater from the multiple-phase wells was simulated for 2 years, at a conservative (low) rate that drew down the water table but did not allow the nodes to go dry. This approach is conservative, in that higher rates of pumping could likely be achieved, but cannot be readily simulated due to difficulties in simulating "dry" nodes.

If the actual hydraulic conductivity value of the Upper Sand unit at each source area is found to be significantly lower than the value used in the model, the cost of the required horizontal groundwater extraction well design and construction would increase slightly. However, these increased costs would not significantly affect the cost comparison of this remedial alternative with respect to the other alternatives.

The results of this simulation are presented on Figures 6-3, 6-4, and 6-7. As seen on Figure 6-7, the plume after 20 years is predicted to have decreased substantially in size and concentration, such that the 2,000 μg/L TCE contour has receded back almost to the source areas. The model predicts that the TCE concentration in the groundwater near the lake would be reduced from over 600 μg/L to approximately 60 μg/L, over the 20-year time period simulated. The total dissolved and adsorbed mass of TCE in the aquifer over all of Sites 32/33 is predicted to decrease from 1,500 kg to 200 kg over the same time period.

6.6 Alternative F – Mobile Injection Treatment Unit (MITU)

6.6.1 Design Concepts

This alternative involves a modified *in situ* process for soil excavation and mixing with hot air injection to thermally desorb solvents from the source areas soil. The solvents are transferred from the soil matrix to a gaseous matrix. The vapors generated are captured and treated by carbon adsorption for subsequent off-site management, or treated on-site using portable thermal oxidizer equipment. This process would be accomplished using a modified rock trenching machine called the Mobile Injection Treatment Unit or MITU®, patented by a remediation contractor, CBA Environmental

Services, Inc., of Hegins, Pennsylvania. Manufacturer's information describing this equipment is included in Appendix H.

The MITU® is capable of deep subsurface treatment operations to a maximum of 30 feet below ground surface, while simultaneously performing soil treatment and backfill operations using the same machine. The soil is excavated and transported through up to three on-board treatment chambers, where hot air (1,100°-1,700°F) is injected to desorb and destroy solvents. A vacuum blower that recovers the generated vapors is connected to the treatment chambers. The solvents that are not destroyed are recovered in on-board granular activated carbon canisters for off-site disposal, or treated in a separate oxidizer, as noted above.

The MITU® operates most efficiently on unsaturated soil, so the source areas receiving treatment would require a dewatering operation. The groundwater recovered during dewatering would likely require treatment prior to discharge, and this would be addressed with a mobile air stripping unit and liquid-phase granular activated carbon, if needed. Dewatering also provides beneficial removal of a limited mass of dissolved CVOCs in the groundwater pumped from each source area.

Predesign soil characterization would be necessary to more accurately define the locations and volume of source area material to be treated by the MITU®, as well as to provide more data regarding the elevation of the bottom of the Upper Sand layer at each site. (The thickness of the Upper Sand unit is needed for design of the dewatering wells.) In areas where the CVOC-impacted soil depth is greater than 30 feet bgs, benching would be necessary to allow the MITU® machine to reach the required treatment depth. For initial estimates of the effectiveness of this alternative and for cost estimation, the following dimensions were used in the groundwater model simulation, and therefore define the proposed treatment zone for the MITU® in each area:

▪ Building I-1-2	80 ft x 83 ft x 35 ft deep
▪ Building I-1-23	68 ft x 100 ft x 35 ft deep
▪ South of Repository	68 ft x 100 ft x 35 ft deep
▪ Repository	MITU® not used
Total volume	Approximately 26,200 cubic yards

The MITU® would be used in each of the source areas except at the Repository, where treatment of the fill by the MITU® would be avoided. Instead, an MPE system as described in Subsection 6.5 would be implemented at the Repository.

6.6.2 Simulation

Simulation of the MITU® alternative assumed *in situ* heating and stripping of volatile organic contaminants from the full estimated thickness of the Upper Clay portion of the source areas. For the MITU® to operate most effectively, some groundwater extraction is necessary to decrease the water content of the soil that must be treated. Therefore, 4 months of groundwater extraction using horizontal wells installed in the Upper Sand unit at each source area that receives MITU® treatment were simulated, representing a 3-month period prior to the onset of MITU® operation, and a 1-month period during operation of the MITU® on-site. Actual dewatering and treatment with the MITU® may extend over a 6-month period or possibly longer, if retreatment of any soil is found to be necessary, or if unforeseen operational problems are encountered. However, for this simulation, it was assumed that operation of the MITU® and associated dewatering would occur simultaneously at all source areas over a 4-month period. As with the preceding alternatives, phytoremediation of the downgradient discharge zones of the plumes is included.

If the actual hydraulic conductivity value of the Upper Sand unit at each source area is found to be significantly lower than the value used in the model, the cost of the required horizontal dewatering well design and construction would increase slightly. However, these increased costs would not significantly affect the cost comparison of this remedial alternative with respect to the other alternatives.

The effect of the MITU® soil treatment was simulated by setting the constant concentration nodes in model Layer 1 to values that were 0 percent of the initial TCE groundwater concentration during the 4-month period of groundwater extraction and MITU® treatment; after that point, the values were set at only 5 percent of the concentration prior to soil treatment. Although 97-percent removal efficiencies for VOCs have been documented using the MITU® at some sites, a 95-percent removal efficiency was simulated. However, this may be an optimistic assumption of the achievable percent VOC removal. Potential factors that could decrease the achievable percent removal include possible small zones of remnant VOCs that may not be located and/or treated, insufficient dewatering of the clay (which negatively affects VOC removal efficiency in the unit), and other potential unforeseen operational difficulties with this new technology.

For the Repository, the constant groundwater TCE concentration nodes were set to 20 percent of the original values (prior to MITU® treatment at the other source areas) to account for depletion of the source due to the MPE system that would be installed there.

Two years of groundwater extraction utilizing horizontal wells within the Upper Sand unit and vertical multiple-phase wells within the Upper Clay unit were simulated.

The results of the MITU® simulation are presented on Figures 6-3, 6-4, and 6-8. On Figure 6-8, it is evident that the TCE concentrations after 20 years have been greatly reduced in the I-1-23 plume, such that the 500 μg/L zone is limited to a small area around the source. As expected, the Repository plume closely resembles that of the Multiple-Phase Extraction simulation (Figure 6-7) discussed above, since MPE is the approach used for treatment of the Repository source area under this alternative. The concentration of TCE in groundwater near the lake is predicted to decrease from over 600 μg/L to approximately 80 μg/L over the 20-year time period. Similarly, the total mass of TCE in the aquifer over all of Sites 32/33 is predicted to decline from 1,500 kg to less than 80 kg during the 20-year time period.

6.7 Sensitivity Testing

Sensitivity testing was conducted on two of the predictive runs (the multiple-phase extraction simulation and the phytoremediation simulation), to test whether the conclusions regarding the relative effectiveness of one remedial measure over another might change, if the constant-concentration boundary conditions changed. The tests were designed to answer the question, if the PCB soil removal action did **not** remove a substantial mass of CVOCs, would this change the conclusions regarding the relative effectiveness of one remedial option over another?

The effect of changing boundary conditions for predictive simulations was tested in model runs Crab224 and Crab226. The results of the simulations are summarized in Table 6-3. In Crab224 (multiple-phase extraction predictive run), the values of the constant-concentration source nodes were held at the original value of 100 μg/L, instead of decreased to 60 μg/L for the predictive simulation. This simulation tested the effect of no assumed decrease in source concentrations as a result of the PCB soil removal activities that have occurred on-site. With the constant-concentration source nodes held at 100 μg/L, the concentrations at the Northern Access Road would increase to from 300 to over 600 μg/L; concentrations near the source zones would also increase significantly.

Similar results were observed for a different predictive simulation that tested the effect of changing the constant-concentration node values. In Crab 226 (phytoremediation simulation), the effect of holding the constant-concentration nodes at a higher value resulted in an increase in concentrations at the Northern Access Road and in the source area, as in Crab 224. The relative effect of the change on the phytoremediation simulation was nearly identical to that observed with the multiple-phase extraction simulation, in both cases causing a doubling of the concentration at the Northern Access Road, and a 50 percent increase in the total mass in the

aquifer. Because both simulations reacted in essentially the same way, the results indicate that the conclusions regarding the relative effectiveness of one remedial option over the other would likely remain the same, if the constant-concentration nodes were held at a higher value. This result is important in that it indicates that the relative effectiveness of one remedial measure over another would likely remain the same, regardless of whether substantial removal of concentrated TCE occurred during the PCB soil removal activities or not. Thus, these results indicate that the conclusions regarding which remedial alternative would be most effective at the site would not change if the PCB soil removal action removed no CVOCs from the source areas.

6.8 Implications of Predictive Simulations of Remedial Alternatives

Comparison of the results of the simulations of the five alternatives, as shown on Figures 6-3 and 6-4, leads to the following conclusions:

- The relative effectiveness of the five alternatives, with respect to the lowest TCE concentrations remaining in the groundwater and the least remaining mass of TCE in the aquifer in the future, are as follows (from most effective to least effective):

  1.a. Multiple-phase extraction

  1.b. MITU® (1.a. and 1.b. have comparable effectiveness)

  2. Enhanced bioremediation

  3. Phytoremediation

  4. Monitored natural attenuation

- The MITU®, multiple-phase extraction, and enhanced bioremediation alternatives all included phytoremediation at the downgradient end of the plumes, which helped lower the concentrations prior to discharge to surface water.
- The MITU® alternative may result in lower TCE concentrations remaining in the source areas where use of this equipment is feasible. However, the MITU® is less effective than multiple-phase extraction at lowering the concentrations at the downgradient end of the plume near Crab Orchard Lake. In terms of the remaining mass of CVOCs in the aquifer, the model results indicate that the MITU® may be most effective at lowering the overall mass of TCE over a 20-year time period, although multiple-phase extraction appears to more effective over the initial 5 to 10 years. Use of the MITU® to remediate the CVOC source beneath the Repository is not feasible.
- The results of the model predictions (e.g., predicted concentrations and mass of TCE in the aquifer) must be considered more in a relative sense, than an absolute sense, because of the significant uncertainties associated with simulating remedial alternatives for which there have been no field tests at the site to determine probable effectiveness.

- It is not possible to reliably estimate the amount of time until groundwater target cleanup levels will be attained for the entire site. At this time, there are limited physical and contaminant distribution data for the Upper Clay unit to make this estimate. However, these data may be obtained during a pre-design phase, depending on the remedy selected. Also, as discussed above, the continued presence of some CVOC residuals in the source zones represents a source of CVOCs to the groundwater that will persist for as long as the residuals remain. Typically, solvent residuals exist beneath the water table as dispersed small blebs and ganglia that remain along the path of the solvent spill as it migrated through the aquifer. While the remediation alternatives examined here address the source areas to varying degrees, it is likely with all of the alternatives that some of the CVOC residuals will remain in a portion of the aquifer and represent a continuing source. This situation is typical of sites that have solvent residuals present; in fact, the National Research Council (1994) has concluded that, of the thousands of sites that are contaminated with these materials in North America, none of them has been completely restored to drinking water standards. Over time, as the sources are depleted, the plumes will shrink in size and groundwater cleanup targets will be achieved over increasingly larger portions of the site. However, groundwater target cleanup standards will not be achieved over the entire site until the CVOC residual sources are essentially gone.

Section 7
Screening of Remedial Alternatives

As outlined in the USEPA's RI/FS guidance document (USEPA, 1988), defined alternatives are initially evaluated against the short- and long-term aspects of the following three broad criteria:

- *Effectiveness* - Addresses the question: "How effective is this alternative at achieving the remedial objective, from both a short-term and a long-term perspective?"
- *Implementability* - Evaluates the technical and administrative feasibility of the alternative.
- *Cost* - Evaluates the capital and operation, maintenance, and monitoring costs of the alternative, based on the design concepts.

As defined in the RI/FS guidance, the intent of this initial screening step for multiple alternatives developed during a "standard" feasibility study is to retain only those alternatives with the most favorable composite evaluation of all factors for further consideration during a detailed analysis of a "short list" of alternatives. In keeping with the "focused" format of this feasibility study, all of the remedial alternatives identified and developed in Section 6 are evaluated in this section against the three screening criteria, and all alternatives are then carried forward to a comparative analysis in Section 8.

An opinion of probable cost to implement each alternative is presented. Tables presenting a breakdown of the costs are included in Appendix I. The opinions of probable cost are individually itemized for direct and indirect capital costs, annual operation, maintenance, and monitoring (OM&M) costs, and a present worth cost for an assumed implementation duration for each alternative, assuming a discount rate of 7 percent (USEPA, 1993). The opinions of probable cost are intended to be in the range of +50 to -30 percent of the actual cost, per the RI/FS guidance document (USEPA, 1988), and are intended to allow for relative comparison between and among alternatives. After final design criteria have been developed for the selected alternative, refinement of the opinion of probable cost will be required.

As discussed in the Groundwater Investigation Report (Part I of this document), the nature and extent of a potential additional CVOC source in the vicinity of Building I-1-36A will be investigated during the pre-design fieldwork program for the groundwater remedial action that is selected for the other identified CVOC source areas. After completion of this investigation, estimated costs to implement an appropriate remedial alternative to address a CVOC source at the Building I-1-36A area will be prepared and submitted to the USEPA, if remediation of this area is determined to be necessary.

7.1 Alternative A - No Action

Evaluation of a No-Action alternative is established as a baseline with which other alternatives can be compared. This alternative consists of no additional actions beyond those already implemented or required in the future at the site. It includes continuation of compliance monitoring of groundwater and surface water as required under the ROD and Consent Decree.

No Action is considered to be ineffective at achieving the remedial objective in a reasonable period of time. It is readily implementable, as it requires no additional systems or actions beyond what is already in place. Costs are associated only with compliance monitoring for groundwater and surface water. No significant capital expenditures are required. This alternative does not vary for any of the CVOC source areas.

A summary of the opinion of probable cost for this alternative is as follows:

- Capital costs: $6,000
- Annual OM&M costs: $107,000
- Present worth (monitoring for 30 years; range represents –30 percent to +50 percent of present worth cost) $935,000 to $2,003,000

7.2 Alternative B - Monitored Natural Attenuation

7.2.1 Effectiveness

Based on the presence and distribution of the breakdown products of PCE and TCE in the groundwater contaminant plumes, some level of natural attenuation is presently occurring at the site. With the data currently available, it is difficult to determine the degree of effectiveness of this alternative. The effectiveness of natural attenuation processes in each of the source areas and in the groundwater plumes is expected to be limited unless most of the total CVOC mass originally present in the source areas was removed with the soil excavated during the PCB remedial action in 1996/1997. The results of the transport modeling simulation of this alternative presented in Section 6 confirm that, using conservative estimates of the CVOC mass removed with the PCB-soil, a slow rate of groundwater quality improvement will be seen, with a time period much longer than 20 years required to approach the target cleanup standards for groundwater.

7.2.2 Implementation

This alternative would be readily implementable. The data needed to evaluate monitored natural attenuation (MNA) would be collected during regularly scheduled compliance monitoring sampling events.

7.2.3 Cost

Capital costs associated with MNA are limited to the initial sampling program design and workplan preparation and approvals. Annual costs include labor and expenses for sampling, data evaluation and reporting, laboratory analytical costs, and any groundwater (well purge water) disposal fees.

A summary of the opinion of probable cost for this alternative is as follows:

- Capital costs: $27,000
- Annual OM&M costs:
  - Short term (first 2 years) $143,000
  - Long term (years 3 through 30) $124,000
- Present worth (monitoring for 30 years; range represents -30 percent to +50 percent of present worth cost) $1,122,000 to $2,403,000

7.3 Alternative C - Phytoremediation and MNA

7.3.1 Effectiveness

Phytoremediation is a current developing technology that uses vegetation for *in situ* treatment of contaminated soil, sediment, and groundwater. Phytotransformation refers to the uptake of organic and nutrient contaminants from soil and groundwater and the subsequent transformation by plants. This transformation depends on the direct uptake of contaminants from soil water and the accumulation of metabolites in plant tissue. Direct uptake by plants of organic compounds present in relatively shallow groundwater is an efficient removal mechanism for sites with contaminants consisting of moderately hydrophobic organic chemicals, including most BTEX compounds, chlorinated solvents, and short-chain aliphatic compounds (Schnoor, 1997).

The direct uptake of a chemical into the plant through roots depends on the uptake efficiency, transpiration rate, and the concentration of the chemical in soil water (Burken and Schnoor, 1996). Uptake efficiency, in turn, depends on physical-chemical properties, chemical speciation, and the plant itself. Transpiration is a key variable that determines the rate of chemical uptake for a given phytoremediation design; it depends on the plant type, leaf area, nutrients, soil moisture, temperature, wind conditions, and relative humidity (Schnoor, 1997).

When an organic compound has been translocated, the plant may incorporate the compound and its fragments into new plant structures via lignification, or it can volatilize, metabolize, or mineralize the compound completely to carbon dioxide and

water. Chlorinated aliphatic compounds such as TCE have been reported to be mineralized to carbon dioxide and less toxic aerobic metabolites (Schnoor, 1997). The form of phytotransformation whereby volatile compounds or their metabolic products are released to the atmosphere through plant transpiration is known as phytovolatilization.

Poplar trees have been found to be capable of taking-up TCE and degrading it to several known metabolic products, including trichloroethanol, trichloroacetic acid, and dichloroacetic acid. Poplars have also been shown to transpire TCE in measurable amounts (Newman et al., 1997). In addition to poplars, other types of phreatophytic trees, such as cottonwoods and willows, are also capable of CVOC uptake or phytovolatilization.

There are no reports in the technical literature of sites where remediation of groundwater contaminated with CVOCs using poplar trees has been completed. However, there are currently at least 5 sites in the USEPA's Superfund Innovative Technology Evaluation (SITE) Program that involve field demonstrations of phytoremediation (Schnoor, 1997). One of these sites involves the use of cottonwood trees to take-up TCE from shallow groundwater (Betts, 1997).

Phytoremediation, and the use of hybrid poplar trees in particular, has been shown to be effective at removing CVOCs in shallow soil and groundwater (10 feet or less) and also at minimizing water infiltration through a soil cap or cover over landfills. At a U.S. Army testing facility in Maryland, poplar trees are being used as hydraulic "pumps" to prevent the migration of contaminants to a nearby marsh, in a manner similar to the proposed use of poplars in Areas 4 and 5 (previously referred to as "limited phytoremediation"). Phytoremediation has proved to be effective at removing TCE in the subsurface in climates similar to, and more harsh than, the southern Illinois climate.

Phytoremediation is a relatively new technology and has been in field applications less than 10 years, so its long-term effectiveness is unknown at this time. Also, the poplars reach maturity, and thereby reach optimum remediation effectiveness, about 3 years after planting. Therefore, a time lag would occur after completing the tree planting before the full treatment effectiveness would be observed. Due to limitations of the trees' root system, the technology's effectiveness in terms of CVOC removal may be limited at this site to approximately the top 10 feet of soil and the upper few feet of saturated clay. The reported life of a hybrid poplar is in the range of 30 years.

7.3.2 Implementability

This technology is readily implementable at this site. The groves of poplar trees may require considerable area (approximately 25 acres, as shown on Figure 6-1) to be effective at all of the source areas and at the discharge areas of the I-1-23 and Repository Area plumes. Based on limited available information regarding current use of the site facilities by the present tenant (Primex Technologies, Inc.), it is anticipated that establishing these tree groves in the locations shown would not have an adverse effect on the current operations at the site. The areas selected appear to be suitable for planting the trees and capable of supporting their continued growth. The design proposed for this alternative will require an initial planting of approximately 37,000 trees (as small single "whips") at a density of 1,500 trees per acre. Tree "whips" for planting are commercially available from various sources; it is expected that the quantity required will be readily available. In the final design layouts for the planting areas, the amount of existing trees and other vegetation that would have to be cleared for planting the poplar trees will be minimized.

7.3.3 Cost

Overall, costs for this alternative are low relative to other active technologies. Capital costs associated with phytoremediation include design, site preparation, and procurement and planting of the trees, as well as off-site disposal of contaminated soil that may be generated during planting. Design costs range from $50,000 to $75,000, while costs for installation of the trees range from approximately $12,000 to $15,000 per acre. Annual operation and maintenance costs are approximately $1,000 to $1,500 per acre for fertilizing, mowing, and watering. The hybrid poplars have a lifespan of about 30 years. However, if desired, the trees can be harvested every 6 to 10 years and the wood can be sold for lumber, chips, or paper-making. It is assumed that if phytoremediation is implemented at the Crab Orchard site, the trees will not be harvested, but will be left in place and replanted as needed.

Costs for implementation and maintenance of limited phytoremediation are included in each of Alternatives C, D, E, and F. "Limited phytoremediation" consists of establishing a grove of hybrid poplars at the downgradient edge of the plumes from the source areas near Building I-1-23 (approximately 8 acres) and the Repository Area (approximately 6 acres).

A summary of the opinion of probable cost for this alternative is as follows:

- Capital costs: $889,000
- Annual OM&M costs:
  - Short term (first 2 years) $201,000
  - Long term (years 3 through 30) $184,000
- Present worth (monitoring and O&M for 30 years; range represents -30 percent to +50 percent of present worth cost) $2,240,000 to $4,799,000

7.4 Alternative D - Enhanced *In Situ* Bioremediation with Limited Phytoremediation and MNA

7.4.1 Effectiveness

Enhanced *in situ* bioremediation of chlorinated solvents is a developing technology that has proved to be effective in field applications. Trends in groundwater quality data suggest that the unavailability of an electron donor (organic carbon source) may be a limiting factor at this site. Therefore, the introduction of lactate would likely stimulate biodegradation of PCE and TCE at an accelerated rate compared to the present rate.

Overall, the effectiveness of the technology is dependent upon the redox conditions in the zone of treatment and the availability of specific electron donors and acceptors (Cookson, 1995). In addition, and more specific to this site, delivery of the electron donor (lactate solution) plays a key role in the effectiveness. The design concept described in Section 6 assumes simultaneous treatment of the Upper Sand (via injection) and the Upper Clay (via infiltration). Treatment in the Upper Sand will be more effective and efficient than in the Upper Clay due to significant differences in hydraulic conductivity for the two layers.

In general, this alternative would be effective in the long term in degrading dissolved CVOCs in the Upper Sand layer at the source areas, as well as in the Upper Clay at a slower rate. Depending on the overall completeness of the sequential degradation of the more chlorinated VOCs, some accumulation and increased concentrations of vinyl chloride, a degradation end product, may occur in some portions of the impacted aquifer.

7.4.2 Implementability

This technology is readily implementable at this site. It can be constructed with conventional equipment and materials that are readily available either local to, or

within a reasonable distance from, the site. Operation of the system presents some uncertainty with regard to the actual rates of injection and infiltration that are achievable at each of the areas. This uncertainty may be further complicated if bacterial growth in the zone of treatment negatively affects the injection or infiltration flow. After these uncertainties are resolved, the system would be allowed to operate in an automated fashion with only periodic (quarterly) site visits to conduct the injections and monitor the groundwater.

Approval to inject and/or infiltrate the lactate solution would be required prior to implementation. Also, groundwater from the area of treatment would be extracted as a source of nearly deoxygenated water in which to dissolve and carry the lactate and nutrients. Sodium sulfite would be added at a dosage sufficient to scavenge the remaining dissolved oxygen. The water would not be treated for removal of VOCs (e.g., air stripping) prior to reinjection to avoid reoxygenation. Injection of untreated water that may contain CVOCs may require special considerations for approval.

7.4.3 Cost

Capital costs for this alternative are relatively high due to the construction of infiltration galleries and injection wells, and the procurement and installation of pumps, tanks, piping, and controls. In addition, a 25 percent contingency was applied to the estimate of capital costs due to uncertainty regarding the frequency of lactate injections and the volume of lactate solution required.

Annual costs include labor and expenses for injection events and monitoring visits. Chemical costs are estimated to be approximately $35,000 per year for the 2-year injection/infiltration period.

Costs for this alternative include capital and annual costs for limited phytoremediation, monitored natural attenuation, and compliance monitoring for a 30-year period.

A summary of the opinion of probable cost for this alternative is as follows:

- Capital costs: $1,205,000
- Annual OM&M costs:
  - Short term (first 2 years) $247,000
  - Long term (years 3 through 30) $165,000
- Present worth (includes 2 years of bioenhancement injection, 30 years of monitoring; range represents -30 percent to +50 percent of present worth cost) $2,378,000 to $5,096,000

7.5 Alternative E - Multiple-Phase Extraction (MPE) with Limited Phytoremediation and MNA

7.5.1 Effectiveness

MPE combines the benefits of groundwater recovery and vapor extraction in one technology. Conventional groundwater recovery systems are limited by low hydraulic conductivity or thin saturated zones. The vacuum induced at the extraction well with MPE increases the effective pressure differential between the extraction well casing and the adjacent aquifer formation, resulting in an increased capture zone for both air and water, especially in formations with low permeabilities, such as the Upper Clay layer.

Results of the DPE pilot tests conducted in June 1998 suggest that DPE would not be effective at this site. However, several factors may have contributed to this outcome. First, the pilot test used a submersible pump in the extraction wells and a venturi vacuum system that developed only limited vacuum pressures while inducing nearly negligible rates of airflow from the formation. Second, the complete lack of vacuum influence at wells only 5 feet away from the extraction well suggests that a complication may have occurred in monitoring well and/or extraction well construction, such as clogged or smeared well screens and/or boreholes. Finally, a consistent drawdown was not maintained in the extraction well during each test, and this had a negative effect on the vacuum influence in the Upper Sand zone.

MPE, using a high-vacuum liquid ring-type pump, will recover groundwater and propagate airflow in the clay and sand using its much higher vacuum capacity. Also, the two sets of wells (vertical, screened only in the Upper Clay; and horizontal, screened only in the Upper Sand) will maximize vacuum influence and airflow rates in the Upper Clay and groundwater extraction rates from the Upper Sand, to maximize the dewatering rate of the clay. Liquid-ring pumps are capable of lifting a column of water up to 30 feet high if pipe losses are minimal. Air entrainment can be used to lift water beyond 30 feet. This may be necessary at area I-1-2 and at the Repository.

7.5.2 Implementability

MPE is readily implementable at this site. Conventional construction equipment would be used for installing the vertical wells, underground piping, and other equipment. Directional drilling equipment would be used to install the horizontal extraction wells. The stratigraphy at the location of the horizontal wells would need to be characterized to a greater extent prior to the installation of these wells to place them accurately at the bottom of the Upper Sand layer. This would likely be done using a direct-push

sampling method (e.g., Geoprobe® rig) which would be less costly than a conventional drilling rig. The mechanical extraction and treatment equipment is also readily available from a number of manufacturers. The liquid ring vacuum pump requires a liquid to provide a seal and develop vacuum. This liquid is typically provided in one of three ways—by recirculating a portion of the extracted groundwater through the pump; by a separate pressurized water source (water utility or reservoir tank); or with oil, which requires an oil-sealed type of pump. At this site, either a pressurized water source or oil-sealed pumps would be used, because of potential operation and maintenance concerns with using recirculated groundwater.

7.5.3 Cost

Capital costs for this technology are higher than costs for Alternatives A through D, mostly due to the large number of wells, the feet of trenching required, and the mechanical equipment required for extraction and treatment.

Annual costs for the first 2 years (the period during which the MPE is anticipated to operate) are greater than the annual costs for the remainder of the 30-year estimating period, due to the frequency of site visits, and the influent and effluent water sampling and air sampling that would be required.

Costs for this alternative also include capital and annual costs for limited phytoremediation, monitored natural attenuation, and compliance monitoring for a 30-year period.

A summary of the opinion of probable cost for this alternative is as follows:

- Capital costs: $2,150,000
- Annual OM&M costs:
  - Short term (first 2 years) $261,000
  - Long term (years 3 through 30) $165,000
- Present worth (includes 2 years of MPE, 30 years of monitoring; range represents -30 percent to +50 percent of present worth cost) $3,057,000 to $6,549,000

7.6 Alternative F - *In Situ* Soil Thermal Treatment with MITU®, Limited Phytoremediation, MNA, and MPE at Repository

7.6.1 Effectiveness

As reported by the company that owns the equipment, the MITU® has been shown to effectively remove up to 97 percent of the mass of CVOCs at other sites with chlorinated solvents contamination. The effectiveness of the MITU® at Sites 32/33, however, may depend largely on the success of the dewatering operation at each source area. The MITU® can treat saturated soil effectively, but it essentially has to evaporate the soil moisture before effective desorption of CVOCs will occur. If the soil is saturated as it enters the treatment chamber of the machine, this process will require much more time and energy, and the cost would increase substantially. Therefore, *in situ* dewatering of the soil to be treated would greatly improve the CVOC removal efficiency and effectiveness, and the cost-effectiveness, of this alternative.

7.6.2 Implementability

The use of the MITU® is implementable at all but one of the CVOC source areas (the Repository) at this site. The MITU® is restricted to larger sites because of its size, but space is not a concern at any of the three areas where it would be employed. The MITU® is a very large, specialized machine, and repair parts may not be available locally, so the contractor stocks replacement parts in his support trailer.

Compaction of the treated soil that is returned to the source area excavations to avoid subsequent settlement may pose some difficulty. However, since construction over the source areas that are to be treated is not expected, the soil can initially be mechanically compacted using a tamper attachment on the tracked excavator as the excavation is backfilled by the MITU® with treated soil. Then, the area can be allowed to settle and compact by gravity for 2 to 3 years following soil treatment, when final grading would occur.

Use of the MITU® for treatment of the Repository area is not practical, due to the depth of soil requiring treatment and the preference to avoid disturbing the materials in the Repository as much as possible. However, as described in Subsection 7.5.2, there are no implementability concerns with Multiple-Phase Extraction that would be employed at the Repository (similar approach as in Alternative E).

7.6.3 Cost

Capital costs for this alternative are the highest of all the alternatives considered. This is due to unit treatment cost, dewatering costs, mobilization/demobilization of the MITU®-30, movement and setup of the MITU® at the separate source areas, as well as the capital costs associated with the MPE system at the Repository. In addition, a 25 percent contingency was applied to the estimate of capital costs due to uncertainties regarding the effectiveness of dewatering in each of the areas, and its effect on the efficiency of treatment by the MITU®.

Annual costs include OM&M costs for the first 2 years of operation of the MPE system. No annual costs are directly associated with soil treatment by the MITU®.

Costs for this alternative also include capital and annual costs for limited phytoremediation, monitored natural attenuation, and compliance monitoring for a 30-year period.

A summary of the opinion of probable cost for this alternative is as follows:

- Capital costs: $5,327,000
- Annual costs:
  - Short term (first 2 years) $235,000
  - Long term (years 3 through 30) $165,000
- Present worth (includes 2 years of MPE at the Repository, 30 years of monitoring; range represents -30 percent to +50 percent of present worth cost) $5,249,000 to $11,247,000

7.7 Summary of Remedial Alternatives Screening

In summary, the six remedial alternatives were assembled and developed to address the CVOC source areas at the site. Alternatives A and B are passive, while Alternatives C, D, E, and F have active remediation components.

Of the active alternatives, the phytoremediation alternative (Alternative C) would require 3 years before the full treatment effectiveness would occur, while treatment would begin as soon as the remedy is implemented for Alternatives D, E, and F. The duration of active treatment for Alternative F will be approximately 6 months, while the duration of active treatment for Alternatives D and E will be 2 years. Under Alternative C, treatment would continue over the full 30-year evaluation period.

Each alternative, except the No-Action alternative, contains a monitored natural attenuation component, and all of the active alternatives contain a component of limited phytoremediation, each of which lasts for the life of the alternatives, which is assumed to be 30 years.

Section 8
Comparative Analysis of Alternatives

8.1 Introduction

This section presents an evaluation of the relative performance of each alternative. The purpose of this comparative analysis is to identify the key advantages and disadvantages of each alternative relative to the other alternatives, so that the key tradeoffs can be identified and balanced by the decision makers. The alternatives are discussed relative to one another, and with respect to each of nine specific criteria.

Overall protection of human health and the environment (Criterion 1) and compliance with Applicable or Relevant and Appropriate Requirements (ARARs) (Criterion 2) will generally serve as threshold determinations in that they must be met by any alternative in order for it to be eligible for selection. The next five criteria, long-term effectiveness and permanence (Criterion 3); reduction of toxicity, mobility, and volume through treatment (Criterion 4); short-term effectiveness (Criterion 5); implementability (Criterion 6); and cost (Criterion 7) represent "balancing" criteria that will be discussed with regard to tradeoffs among the alternatives. State acceptance (Criterion 8) and community acceptance (Criterion 9) are typically evaluated following comment on an RI/FS report and Proposed Plan, and are addressed when a final decision is being made regarding the selected remedial action and a Record of Decision (ROD) is being prepared. For this feasibility study and selection-of-remedy process for Sites 32/33, the state and community acceptance criteria will be addressed after the USEPA (lead agency) has made a preliminary selection of a preferred remedial alternative.

Each of the alternatives includes identical programs for compliance monitoring (per the Consent Decree) of groundwater and surface water. Alternatives B through F also include identical programs for monitored natural attenuation. Alternatives C through F include identical programs for limited phytoremediation (Alternative C includes phytoremediation at other areas in addition to those in Alternatives D through F). Because of the similarities of each alternative with respect to these supplemental long-term remediation technologies, this comparative analysis focuses on the primary technologies of each alternative (i.e., phytoremediation, *in situ* enhanced bioremediation, MPE, and MITU®).

Generally, alternatives are discussed from highest to lowest rankings with respect to each criterion.

8.2 Overall Protection of Human Health and the Environment

The findings of the risk evaluation performed as part of the remedial investigation for the PCBOU (O'Brien & Gere, 1988) were that "...the groundwater exposure pathway is incomplete at the Area 9 Landfill...," and that "...the groundwater exposure pathway is incomplete because there are no exposed users of groundwater at the Area 9 Building Complex."

The Record of Decision (ROD) for the PCB Areas Operable Unit (effective date August 1, 1990) states (Section IX): "The Selected Remedy also addresses the threat from surface water and groundwater by removing the material that could contaminate the water." The ROD further states (Section X): "The Selected Remedy...is protective of human health and the environment for the four study sites comprising the PCB Areas Operable Unit."

During the PCB remedial action, Sites 32/33 were further characterized to identify three source areas (Area 9 Repository, Building I-1-23, Building I-1-2) that were suspected of potentially contributing to contamination of groundwater and surface water. During this additional sampling, groundwater contamination by volatile organic compounds was detected.

Based on the findings of the remedial investigation and on the ROD, as noted above, all of the alternatives presented in this feasibility study, including the No-Action alternative, provide an acceptable level of overall protection of human health and the environment. Any further reduction of CVOC contamination of soil or groundwater at Sites 32/33 that would result from implementation of any of the remedial alternatives provides an incremental improvement of an already acceptable level of risk.

Alternatives C, D, E, and F would provide some degree of destruction or removal of CVOCs from the source areas and at the downgradient edges of the plumes. Alternative F would provide the most immediate increase in the level of protectiveness, by destruction of significant contaminant mass within approximately 6 months time following the start of on-site remediation.

Alternatives D and E would provide an enhanced degree of protection in about 2 years time, while Alternative C would require about 3 years before some level of increased protectiveness would be provided.

Alternative B is currently providing attenuation of the high concentrations of CVOCs in the groundwater to concentrations that are orders of magnitude lower by the time the plumes reach the lake or other surface water. Alternative B does not provide additional protection over any other alternative by itself, however.

Alternative A, the No-Action alternative, does not provide increased protection of human health or the environment above the existing acceptable conditions.

8.3 Compliance with ARARs

The applicable or relevant and appropriate requirements (ARARs) for implementation of the remedial alternatives must be consistent with the ARARs specified in the Record of Decision (ROD) for the PCBOU. The ARARs that would be pertinent to one or more of the remedial alternatives for groundwater at Sites 32/33 are identified in the following direct excerpt from the ROD (pages 40 to 45):

1. *Surface Water Discharge*

   Clean Water Act

   - *If pond or stream water from Site 17 or stream or ditch water from Area 9 (Sites 32 and 33) must be discharged to a surface water body during site preparation, the discharge shall meet the effluent standards and prohibitions and water quality standards established under Sections 301, 302, 303, 307, 318, and 405 of the Clean Water Act (40 CFR 122.41 and 122.44).*

2. *Excavation of Soil and Sediment*

   Resource Conservation and Recovery Act, Subtitle C

   - *Excavated material which is RCRA hazardous will be handled and stored in accordance with the substantive technical standards applicable to generators of hazardous waste and for owners and operators of hazardous waste storage facilities (40 CFR 262.34; and 264, Subparts B, C, I, J, and L).*
   - *Excavated material which is RCRA hazardous will be handled and stored in accordance with the land disposal restrictions (40 CFR 268).*
   - *The excavation activities, when completed, shall meet the closure performance standards for clean closure (40 CFR 264, Subpart G) for the specific hazardous waste constituents.*
   - *The excavation and storage activities must also meet any more stringent State of Illinois equivalent provisions (35 IAC Part 724 design requirements).*

   Toxic Substances Control Act

   - *Excavated material which contains PCBs at concentrations greater than 50 parts per million will be handled and stored in accordance with the requirements of 40 CFR 761.65.*

   Clean Air Act

   - *During excavation the national ambient air quality standards (NAAQS) for particulate matter and lead shall not be exceeded (40 CFR 50.6 and 50.12).*

3. *Incineration of Soil and Sediment*

[not pertinent to groundwater remedial action]

4. *Vitrification*

[not pertinent to groundwater remedial action]

5. *Stabilization/Fixation*

[not pertinent to groundwater remedial action]

6. *Disposal or Decontamination of Equipment*

Resource Conservation and Recovery Act, Subtitle C

- *During remediation and closure all equipment, structures, and soils that are used on/with RCRA hazardous materials must be properly decontaminated or disposed of (40 CFR 264.114).*
- *Decontamination of equipment, structures, and soils that are used on/with RCRA hazardous materials must meet any more stringent regulatory decontamination or disposal standards of the State of Illinois (35 IAC Part 724).*

Toxic Substances Control Act

- *During remediation and closure all equipment, structures, and soils that are used on/with TSCA regulated PCB-contaminated soil and sediment must be properly decontaminated (40 CFR 761.79).*

7. *Industrial Landfill or Caps*

[not pertinent to groundwater remedial action]

8. *Backfill Excavation*

- *During backfilling activities the NAAQS for particulate matter shall not be exceeded (40 CFR 50.6).*

9. *Monitoring and Maintenance*

Resource Conservation and Recovery Act, Subtitle C

- *Groundwater monitoring for the remediated study sites shall be in accordance with the groundwater monitoring requirements of RCRA (40 CFR 264, Subpart F).*

Solid Waste Disposal Act as amended by RCRA Subtitle D

- *Groundwater and leachate monitoring for the on-site landfill shall be in accordance with the RCRA Subtitle D, solid waste landfill requirements (40 CFR 241.204).*
- *Groundwater and leachate monitoring for the on-site landfill will meet any more stringent technical regulations of the State of Illinois (35 IAC Part 807).*

10. *Personnel Protection*

Occupational Safety and Health Act (OSHA)

- *During all remedial activities the requirements of the Occupational Safety and Health Act for the training and safety of workers will be observed (29 CFR 1910.120 and 1926, Subparts C, D, E, and P).*

11. *Remediation Goals*

Crab Orchard Enabling Legislation (16 U.S.C. 666f and g)

National Wildlife Refuge Administration Act (16 U.S.C. 668dd)

Eagle Protection Act of 1940 (16 U.S.C. 668a)

Migratory Bird Treaty Act of 1918 (16 U.S.C. 703-711), as amended

- *The chemical specific remediation goals which have been established for the study sites comprising the PCB Areas, and any other that will be established for this operable unit, will be consistent with the statutory requirements cited above.*

For implementation of the Selected Remedy, U.S. EPA, DOI, and IEPA have agreed to consider a number of procedures as guidance. These include, but are not limited to: U.S. EPA's Risk Assessment Guidance for Superfund; U.S. EPA's Superfund Remedial Design and Remedial Action Guidance; U.S. EPA's RCRA Technical Enforcement Guidance Document; U.S. EPA's proposed MCL for PCBs; any proposed revisions to U.S. EPA's design standards for RCRA Subtitle D landfills, which are available before remedial design; the State of Illinois Waste Management Facilities Design Criteria; and State of Illinois Monitoring Well Construction and Installation Criteria.

In addition to the ARARs specified in the ROD as cited above, the IEPA has identified the chemical-specific and action-specific standards and regulations listed below that may be pertinent for consideration during evaluation of the remedial alternatives and selection of a preferred alternative for groundwater:

Chemical-specific State Standards and Regulations

- *35 IAC Part 620 - Groundwater Quality, Subpart D, Section 620.410, Class I* - Groundwater Standards (refer to Tables 6-5 through 6-8 in the Groundwater Investigation Report for a listing of these numerical standards)
- *35 IAC Part 302, Subpart B - General Use Water Quality Standards, specifically Part 302.208* - Numeric Standards for Chemical Constituents, and Part 302.1210 - Other Toxic Substances (refer to Table 6-12 in the Groundwater Investigation Report for a listing of these numerical standards, as excerpted from the referenced regulations and as calculated for Crab Orchard Lake by the IEPA Bureau of Water)

Potential Action-specific State Regulations

- *35 IAC Subtitle B - Air Pollution, Part 201* - Substantive permitting requirements under Parts 201.141, .143, .152-.165, .207-.210, .261-.265, .282-.283, .310-.312 for construction or modification of an emission source.
- *35 IAC Part 304, Subpart A - General Effluent Standards, specifically Parts 304.102 and 304.105-.141* - For discharges to waters of the state.
- *35 IAC Part 305 - Monitoring and Reporting, specifically Parts 305.102 -.103* - For discharges to waters of the state.
- *35 IAC Part 306, Subpart A* - Systems Reliability, specifically Part 306.102
- *35 IAC Part 309, Subpart A - NPDES Permits* - Substantive requirements pertinent to construction and operation of contaminated groundwater treatment or pretreatment works and to point source discharges to waters of the state on all CERCLA sites.
- *35 IAC Part 704 - UIC Permit Program; 35 IAC Part 730 - Underground Injection Control Operating Requirements* - Substantive permitting requirements for underground injection of hazardous liquids (Class IV UIC well) or non-hazardous fluid (Class V UIC well). Injection of contaminated fluid into underground sources of drinking water in excess of any primary drinking water regulations is prohibited. 35 IAC Part 704.124(c) exempts Class IV wells (hazardous) from this prohibition on RCRA and CERCLA sites; however, no exemption exists for Class V wells.
- *35 IAC Part 722 - Standards Applicable to Generators of Hazardous Waste* - If solid waste (defined per 35 IAC Part 721.102) is generated, the generator must determine if that waste is a hazardous waste.
- *35 IAC Subtitle G - Waste Disposal, specifically Parts 724 and 728* - If hazardous waste is present on a site, pertinent requirements of hazardous waste treatment, storage, and disposal under 35 IAC Subtitle G (Waste Disposal) must be followed.
- *35 IAC Part 808 - Special Waste Classifications* - Generators of a waste must classify the waste. A special waste (defined per Section 3.45 of Illinois Environmental Protection Act) determination is required under 35 IAC Part 808.12. Management of special waste must be in accordance with 35 IAC Subtitle G (Waste Disposal),

including 35 IAC Part 809 (Special Waste Hauling) and 35 IAC Part 810 (Solid Waste Disposal).

It is expected that compliance with ARARs specified in the ROD, and with the additional standards and regulations identified by the IEPA as listed above, can be most readily achieved in the design and implementation of Alternatives C through F. Alternative B alone is not expected to be capable of achieving the ARARs and other state standards and regulations listed above in a reasonable time period.

Since the naturally occurring discharge of groundwater to surface water (drainage swales, marshes, and the lake) is the source of VOCs that have been observed in surface water at the site, it is expected that the destruction or removal of VOC source material remaining in soil at the identified source areas, as provided by Alternatives C through F, will result in a reduction in VOC concentrations observed in surface water over time. The amount and rate of reduction in surface water VOC concentrations at the groundwater/surface water interface for the remedial alternatives are expected to be proportionately comparable to the reductions in groundwater VOC concentrations over time as projected by the computer model simulations discussed in Section 6. The relatively rapid volatilization of VOCs from the shallow drainage swales and lake embayment, and the mixing of the groundwater with the lake water, are expected to provide additional attenuation of VOC concentrations in the lake as the concentrations at the groundwater/surface water interface decline over time.

As determined from the modeling simulations discussed in Section 6, the time required to attain the target Cleanup Standards for groundwater over all of Sites 32/33 will be lengthy (greater than 20 years) for any of the remedial alternatives. However, significant improvements in groundwater quality would be expected to occur over much shorter time periods.

This criterion is not considered to be a significant impediment or discriminating factor in the comparative analysis of the alternatives.

8.4 Long-term Effectiveness and Permanence

The assessment of alternatives against this criterion evaluates the comparative long-term effectiveness of the alternatives in maintaining the current acceptable level of protection of human health and the environment.

All alternatives offer a similar degree of permanence of groundwater quality improvement, which would generally be consistent with the short-term effectiveness of CVOC removal or destruction. The extraction of contaminated groundwater at the source areas provided in Alternatives E and F would result in a marked improvement in groundwater quality within the

zone of influence of the pumping wells, during and for a short time following groundwater extraction. However, because it is reasonable to assume that less than complete removal or destruction of the CVOC source material will be accomplished, a partial rebound in the groundwater contaminant concentrations would be expected to occur following completion of the short-term active remediation in the source areas, thus affecting the long-term effectiveness of these alternatives.

Alternative D could have the greatest potential for maintaining effectiveness in the long-term, compared with the other alternatives. Any excess electron donor and nutrient solution that is injected or infiltrated, but is not consumed in the short term, would be available to microorganisms in the future, either in the Upper Clay or the Upper Sand, to continue promoting enhanced rates of biodegradation of the remaining CVOCs. Conversely, Alternative D could present the greatest risk of diminished effectiveness, if the stimulated degradation of the more chlorinated compounds (PCE and TCE) in the source areas leads to production of a more toxic end product, vinyl chloride, in the Upper Sand plumes due to incomplete degradation to carbon dioxide and water.

Alternative C would provide some level of continuing effectiveness over the lifespan of the poplar trees, which is expected to be 20 to 30 years. However, the effectiveness would vary greatly on an annual cycle, since contaminant treatment provided by the trees is only effective during the growing season. In addition, the degree of effectiveness provided in the short term with Alternative C is less than D, E, and F due to limitations of the trees in removing contaminant mass in the source areas (due primarily to rooting depth). Thus, Alternative C has limitations of both short-term and long-term effectiveness in the source areas. At the downgradient edges of the plumes, however, Alternative C would provide the greatest degree of long-term effectiveness of any of the six alternatives.

The long-term effectiveness of Alternatives E and F is greatly dependent on the short-term effectiveness of the CVOC source material removal from implementation of MPE or the MITU®.

As indicated from the results of the modeling simulations, all of the alternatives will require a relatively long time (more than 20 years) to provide a degree of effectiveness approaching the target groundwater cleanup standards. A ranking of the alternatives with respect to the rate at which they will improve groundwater quality at the overall site, as a measure of comparative long-term effectiveness, is as follows (listed from fastest to slowest):

- Alternative E - Multiple-Phase Extraction
- Alternative F – MITU® (approximately equivalent to Alternative E)
- Alternative D – *In Situ* Enhanced Bioremediation

- Alternative C - Phytoremediation
- Alternative B - Monitored Natural Attenuation
- Alternative A - No-Action

8.5 Reduction of Toxicity, Mobility, and Volume Through Treatment

Alternative F (MITU®) provides the greatest reduction of toxicity and volume of all the alternatives. The MITU® is expected to remove a maximum of 95 percent of the CVOC contaminant mass from the soil treated. This removal rate is 15 percent greater than that estimated for the next highest alternative, MPE (Alternative E). The technology will require a dewatering effort in each of the source areas while MPE or MITU® treatment is taking place. This groundwater extraction done in conjunction with the MITU® provides an added benefit with respect to this particular criterion and would temporarily reduce the mobility of CVOCs in the source area for approximately 6 months. The model results estimate that the MITU® alternative would result in the removal of 95 percent of the total mass of TCE in the entire aquifer, over a 20-year time period. MPE would be implemented at the Repository as part of Alternative F, since operation of the MITU® would not be feasible there. Alternative F also provides the greatest amount of actual contaminant destruction. Most of the CVOCs will be thermally destroyed, and only a small percentage of CVOC mass is expected to be transferred to a different media (activated carbon adsorption of CVOCs from the hot air).

Alternative E (MPE) also provides significant removal of contaminant volume (mass) by extraction of groundwater and soil vapor at each of the source areas. It was estimated as an input parameter for the modeling simulations that 80 percent of existing contaminant mass in the source areas would be removed in 2 years of operation of a MPE system. This mass is eventually transferred to the air through the discharges of the vacuum pump and the groundwater treatment system (air stripping unit). Model results indicate that 87 percent of the total mass of TCE would be removed from the aquifer over a 20-year time period. MPE would be the most effective of all the alternatives at decreasing the concentration at the downgradient end of the plumes, over the 20-year period evaluated by the model simulations. The toxicity of contaminants is not reduced by this alternative.

Alternative D (*in situ* enhanced bioremediation) ranks first in the reduction of toxicity in the short term, as it reduces PCE to TCE and then to the less toxic compound 1,2-DCE. However, there is a potential to actually increase groundwater toxicity as the breakdown products degrade to vinyl chloride. This effect, if it occurs, is expected to be for a relatively short time, since vinyl chloride has been shown (including evidence from Sites 32/33) to degrade to low toxicity products relatively quickly in slightly aerobic conditions and is very volatile when discharged to surface water. Through this degradation process, the volume (mass) of

contaminants is also reduced, but to a lesser degree than in Alternative E and F. It was estimated as an input parameter of the modeling simulations that 75 percent of the existing contaminant mass in the source areas would be reduced by enhanced bioremediation (Alternative D). After 20 years, it is estimated by the model that 76 percent of the total mass of TCE would be removed from the aquifer over the entire site. This alternative provides very little reduction in the mobility of CVOCs, except that which is provided indirectly by pumping groundwater from the Upper Sand layer as a source of deoxygenated water for preparation of the substrate (lactate) solution.

Alternative C (phytoremediation) ranks behind Alternatives D, E, and F in most aspects of this criterion, mostly due to the passive nature of the technology. It will, however, provide an increased level of mobility reduction over Alternative D, since it would act as a cap by minimizing infiltration through the source areas, thus reducing the extent of leaching and, in turn, the mobility of the CVOCs.

Alternatives A and B provide much less reduction of toxicity, mobility, or volume than the other alternatives.

8.6 Short-term Effectiveness

The site is located in a moderately secured, largely unpopulated area. Comments regarding protection of the community under this criterion will be limited to workers at the Primex plant and temporary visitors to the site, such as Fish and Wildlife Service personnel.

Both Alternatives A and B provide the greatest amount of protection of the community and of workers during implementation, as well as the least adverse impacts to the environment, because potential exposure routes are limited to activities associated with groundwater sampling. Each, however, represents the alternative with the longest time until the remedial objective is achieved.

Of the remaining alternatives, Alternative C ranks highest with respect to least impact to the environment. It actually enhances the environment at the wildlife refuge by providing greenery and habitat for wildlife. This alternative also presents a very low risk to the community and to workers during implementation. The greatest hazards would involve inhalation or ingestion of VOCs or dermal contact with VOC-contaminated soil during planting activities, and hazards associated with operating medium-sized earth-moving equipment and perhaps in handling horticultural chemicals (fertilizers, pesticides, etc.). This alternative requires a longer time to begin treatment (3 years until trees reach maturity) and to reach the remedial objective than Alternatives D, E, and F.

Alternatives D, E, and F all involve the use of heavy equipment (drill rigs, dozers, excavators, MITU®), which will be a source of noise, combustion exhaust, and physical hazards from operation of heavy equipment. Alternative F will likely have the largest equipment operating for the longest time, while Alternatives D and E will use equipment of similar, smaller size and for similar durations. All will involve some degree of hazard related to inhalation or ingestion of VOCs while excavating or drilling, but the MITU® will have the lowest hazard due to its enclosed treatment chambers. The MITU® is more likely to create a dust concern than most other alternatives, except possibly Alternative D. Alternative F will have areas with varied compaction, leaving them to settle over time after treatment is completed. This is not viewed as a significant problem, since construction in the source areas following treatment is not expected. Alternative F requires the shortest time until the remedial objective is met of any alternative. Alternatives D and E rank behind F in this category, while the other alternatives are well behind D and E.

Alternatives D and E have similar low impacts regarding risk to the community during implementation. Each requires well installation, trenching, and earth moving. Alternative D will have a greater concern with dust control than other alternatives, except Alternative F, because of the earthwork involved with constructing the infiltration galleries. This is not expected to be a serious problem. Alternative E will have similar concerns, although to a lesser extent, due to trenching activity. Alternatives D and E will also involve construction of buildings and/or tankage at each source area.

Alternatives E and F will produce a water and air discharge during implementation. Neither is expected to be detrimental to the community, workers, or the environment.

8.7 Implementability

Each of the alternatives is readily implementable at the site. Alternatives A and B present the least concern with respect to implementability. In fact, both have already been successfully implemented at the site to some degree.

Alternative E would rank highest of the remaining alternatives under this criterion. Its installation is straightforward, using conventional construction equipment and system components. MPE has been implemented at full scale on several sites, and has a proven track record. It is as reliable as any of the other alternatives in terms of performance, and may be more robust than the MITU® in that regard. Other than weather, few technical problems would delay the implementation schedule for MPE.

Alternative F ranks next under implementability. The power unit that drives the MITU® allows it to pulverize subsurface obstacles, such as cobbles, concrete, etc., so difficulties with the

excavation component of the process are expected to be minimal. Also, if a particular zone in the treatment area does not meet the cleanup standard, it can be retreated in-place with relative ease by the MITU®. The MITU® is a patented technology and is only available through one contractor, so competitive bidding would be limited. The largest uncertainty with this alternative is the achievable treatment effectiveness of the Upper Clay soil, because the clay will likely contain a relatively high moisture content at the time of treatment, despite the dewatering step prior to use of the MITU®. If the moisture content is too high, the rate of treatment will be significantly reduced because the moisture will have to be heated and evaporated before desorption and destruction of the VOCs takes place. In addition to possibly decreasing the achievable VOC removal efficiency, the reduction in the treatment rate caused by excessive soil moisture would significantly lengthen the overall treatment duration, and increase costs.

Existing underground utilities, if present, could be a relatively significant problem for implementing Alternatives E and F at the I-1-2 and I-1-23 source areas. However, the successful completion of the PCB-soil excavations and installation of monitoring wells in these areas provides some indication that existing buried utilities may not be extensive.

Alternative C is likely to be no more difficult to implement than the other alternatives, except for the uncertainty at this time of the required planting technique in the source areas. The trees can be planted rapidly using a trenching machine in most areas where it is assumed no subsurface obstructions (cobble, concrete, utilities, etc.) exist that would slow or stop the trencher. However, wherever the rooting depth approaches or exceeds 10 feet below grade, such as at each of the source areas, the supply of oxygen to the roots becomes a concern that must be addressed. This problem has been addressed at other sites by using air tubes that are installed near the root zone and extend to the surface, where they can be vented passively or actively with a blower and pipe manifold. Questions regarding the feasibility of and need for this oxygen supply approach present uncertainty with respect to schedule and overall cost of implementation for Alternative C.

Alternative D is as straightforward to install as the MPE systems. It also would require no special equipment or system components, and bulk chemicals (nutrient solution and sodium sulfite) are available from a number of vendors who will deliver to the site. Implementation of the infiltration galleries, as well as the injection rates at the site, pose the greatest uncertainty. These are also difficult to predict without a pilot-scale test at the site.

8.8 Cost

A comparison of estimated costs for each alternative is presented in Table 8-1.

Alternative A is the least costly alternative, since it requires no action other than the compliance monitoring required by the Consent Decree. Alternative B has additional monitoring costs and ranks second.

Alternative C has the lowest cost of all of the "active" alternatives, but this could increase significantly depending on planting depth requirements and techniques in the source areas. Also, the level of increased protection provided is much lower than Alternatives D through F. Alternative F provides the highest level of increased protectiveness based on groundwater quality improvement (along with Alternative E), but at a significantly higher cost than either Alternative D or E.

Alternative E provides increased protectiveness over Alternative D at a moderately high cost. Both of these alternatives allow flexibility in the future for additional treatment, if required, simply by extending the duration of operation. This would occur at a predictable cost in both cases. Also, both alternatives would allow flexibility of adding enhancements to the treatment technology in the future. For example, Alternative D could be enhanced by injection/infiltration of an alternative substrate or other material. Alternative E could be enhanced by adding *in situ* soil heating by electric, steam, or radio frequency heating techniques. Costs for these enhancements are less predictable at this time and would likely be significantly higher than simply extending the period of operation.

8.9 State Acceptance

The state (support agency) acceptance criterion evaluates the technical and administrative issues and concerns the state may have regarding each of the alternatives. As discussed earlier in this section, this criterion will be addressed by the USEPA in the Decision Document prepared for the groundwater remedy.

8.10 Community Acceptance

The community acceptance criterion evaluates issues and concerns the public may have regarding each of the alternatives. This criterion will be addressed by the USEPA following public notice and participation procedures to be determined by the USEPA.

Section 9
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Part II
Tables

Table 4-1

Table prepared by FDGTI

Laboratory Data
Site 32/33 Air (T12-3233-xxxx-xx)
Pilot Test
Informational: Not in QAPP

Analyte	Method	Sample #	141-DPVE-1-2-3	142-SPRC-1-23	143-SPRC-1-23	146-DPVE-1-2	147-SPRC-1-2	148-SPRC-2-2	150-DPVE-A9	152-SPRC-1-A9	153-SPRC-2-A9
		Location #	I-1-23	I-1-23	I-1-23	I-1-2	I-1-2	I-1-2	Repository	Repository	Repository
		Time	1500	1230	1630	1700	0900	1540	1410	1000	1600
		CAS#	07/15/98	07/16/98	07/16/98	'07/17/98	07/18/98	07/18/98	07/19/98	07/20/98	07/20/98
Dichlorodifluoromethane	CLP (in ug/kg)	75-71-8	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
Chloromethane	CLP	74-87-3	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
1,2-DC-1,1,2,2-TFA	CLP	76-14-2	28 B	BQL	BQL	120000 R	8900 R	6000 R	BQL	BQL	BQL
Bromomethane	CLP	-18	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
Vinyl Chloride	CLP	75-01-4	BQL	BQL	BQL	58	BQL	BQL	7	5	48
Chloroethane	CLP	75-00-3	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
Trichlorofluoromethane	CLP	75-69-4	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
Methylene Chloride	CLP	75-09-2	590	BQL	BQL	22	BQL	BQL	2 J	BQL	BQL
Acetone	CLP	67-64-1	200	69	BQL	BQL	BQL	BQL	14	BQL	15
Carbon Disulfide	CLP	75-15-0	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
1,1-Dichloroethene	CLP	36	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
1,1-Dichloroethane	CLP	38	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
1,1,2-TC-1,2,2-TFA	CLP	76-13-1	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
cis-1,2-Dichloroethene	CLP	540-59-0	58	75	700	22	BQL	BQL	51	44	BQL
trans-1,2-Dichloroethene	CLP	156-60-5	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	34
Chloroform	CLP	67-66-3	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
1,2-Dichloroethane	CLP	99	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
2-Butanone	CLP	-18	16	1200	BQL	85	160 J	240	6	BQL	BQL
1,1,1-Trichloroethane	CLP	10	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
Carbon Tetrachloride	CLP	28	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
1,2-Dichloropropane	CLP	-14	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
cis-1,3-Dichloropropane	CLP	105	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL

See RMT attachment for footnotes

Table 4-1

Table prepared by FDGTI

Trichloroethene	CLP	79-01-6	440	260	BQL	20 J	BQL	BQL	190	230	1300
1,1,2-Trichloroethane	CLP	74	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
Benzene	CLP	26	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
trans-1,3-Dichloropropene	CLP	461	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
4-Methyl-2-Pentanone	CLP	108-10-1	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
2-Hexanone	CLP	591-78-6	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
1,2-Dibromoethane	CLP	106-93-4	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
Tetrachloroethene	CLP	105	10 J	16 J	BQL	BQL	BQL	BQL	BQL	2 J	11
1,1,2,2-Tetrachloroethane	CLP	40	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
Toluene	CLP	108-88-3	56	43	BQL	37	BQL	BQL	25	7	5
Chlorobenzene	CLP	11	16	46	BQL	BQL	BQL	BQL	BQL	BQL	BQL
Ethylbenzene	CLP	100-41-4	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
Styrene	CLP	53	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
m,p-Xylene	CLP	13-302-07	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
o-Xylene	CLP	95-47-6	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
4-Ethyltoluene	CLP	622-96-8	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
1,3,5-Trimethylbenzene	CLP	108-67-8	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
1,2,4-Trimethylbenzene	CLP	95-63-6	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	4
1,3-Dichlorobenzene	CLP	541-73-1	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
Benzyl Chloride	CLP	100-44-7	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
1,4-Dichlorobenzene	CLP	106-46-7	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
1,2-Dichlorobenzene	CLP	95-50-1	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
1,2,4-Trichlorobenzene	CLP	120-82-1	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
Hexachlorobutadiene	CLP	87-68-3	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
GP Work Order #			9808074	9808074	9808074	9808074	9808074	9808074	9808074	9808074	9808074

Legend:

J - Value less than the reporting limits but greater than zero.

R - Rejected value (e.g., lab contamination)

B - Indicates that the compound was found in the associated blank and exceeds the Quantitation Limit (CRDL)

BQL - Below Quantitation Limit

See RMT attachment for footnotes

Footnotes For Laboratory Data
Site 32/33 Air (T12-3233-xxxx-xx)
Pilot Test

Notes for FDGTI Pilot Test Air Data Table:

1. Data are from submittal from FDGTI to USEPA dated 10/23/98.
2. Reported units of μg/kg are not believed to be accurate for these air sample data. Possible units may be parts per billion by volume (ppbv), not by weight.
3. Sample I.D. of "SPRC" is believed to be incorrect. Correct I.D. believed to be "SPRG," based on consistency with laboratory data reports.
4. Lab report shows 1,2-DC-1,1,2,2-TFA concentration for sample 146-DPVE-1-2 as 22,000 ppbv.

Table 4-2

Table prepared by FDGTI

Laboratory Data
Blank Corrected
Site 32/33 Groundwater (T16-3233-xxxx-xx)
Pilot Test

Analyte	Method	Sample #	0135-DPH	0144-DPVE	0149-DPVE-A9
		Well #	I-1-23	I-1-2	Repository
		CAS#	07/13/98	07/17/98	07/19/98
bis(2-Ethylhexl)phthalate	CLP (in ug/kg)	29	BQL	BQL	BQL
di-n-Octylphthalate	CLP	33	BQL	BQL	BQL
Benzo[b]fluoranthene	CLP	104	BQL	BQL	BQL
Benzo[k]fluoranthene	CLP	190	BQL	BQL	BQL
Benzo[a]pyrene	CLP	10	BQL	BQL	BQL
Indeno[1,2,3-cd]pyrene	CLP	149	BQL	BQL	BQL
Dibenz[a,h]anthracene	CLP	-20	BQL	BQL	BQL
Benzo[g,h,i]perylene	CLP	-	BQL	BQL	BQL
Phenol	CLP	11	4 J	BQL	BQL
Bis(2-Chloroethyl) ether	CLP	63	BQL	BQL	BQL
2-Chlorophenol	CLP	30	BQL	BQL	BQL
1,3-Dichlorobenzene	CLP	467	BQL	BQL	BQL
1,4-Dichlorobenzene	CLP	53	BQL	BQL	BQL
1,2-Dichlorobenzene	CLP	44	BQL	BQL	BQL
2-Methylphenol	CLP	40	BQL	BQL	BQL
2,2-oxybis-(1-chloropropane)	CLP	-	BQL	BQL	BQL
4-Methylphenol	CLP	57	BQL	BQL	BQL
N-Nitroso-di-n-propylamine	CLP	550	BQL	BQL	BQL
Hexachloroethane	CLP	-6	BQL	BQL	BQL
Nitrobenzene	CLP	0	BQL	BQL	BQL
Isophorone	CLP	18	BQL	BQL	BQL
2-Nitrophenol	CLP	No CASRN	BQL	BQL	BQL
2,4-Dimethylphenol	CLP	29	BQL	BQL	BQL
bis(2-Chloroethoxy) methane	CLP	-	BQL	BQL	BQL
2,4-Dichlorophenol	CLP	35	BQL	BQL	BQL
1,2,4-trichlorobenzene	CLP	37	2 J	BQL	BQL
Naphthalene	CLP	68	BQL	BQL	BQL
4-Chloroaniline	CLP	51	BQL	BQL	BQL
Hexachlorobutadiene	CLP	16	BQL	BQL	BQL
4-Chlor-3-methylphenol	CLP	-	BQL	BQL	BQL
2-Methylnaphthalene	CLP	-	BQL	BQL	BQL
Hexachlorocyclopentadiene	CLP	26	BQL	BQL	BQL
2,4,6-Trichlorophenol	CLP	80	BQL	BQL	BQL
2,4,5-Trichlorophenol	CLP	-4	BQL	BQL	BQL
2-Chloronaphthalene	CLP	-	BQL	BQL	BQL
2-Nitroaniline	CLP	10	BQL	BQL	BQL
Dimethyl phthalate	CLP	117	BQL	BQL	BQL
Acenaphthylene	CLP	104	BQL	BQL	BQL
2,6-Dintrotoluene	CLP	584	BQL	BQL	BQL
3-Nitroaniline	CLP	-	BQL	BQL	BQL
GP Work Order #			9807107	9807142	9807153

See RMT attachment for footnotes

Table 4-2 Table prepared by FDGTI

Laboratory Data
Blank Corrected
Site 32/33 Groundwater (T16-3233-xxxx-xx)
Pilot Test

Analyte	Method	Sample #	0135-DPH	0144-DPVE	0149-DPVE-A9
		Well #	I-1-23	I-1-2	Repository
		CAS#	07/13/98	07/17/98	07/19/98
Chloromethane	CLP (in ug/kg)	74-87-3	BQL	BQL	BQL
Bromomethane	CLP	-18	BQL	BQL	BQL
Vinyl Chloride	CLP	75-01-4	BQL	BQL	17
Chloroethane	CLP	75-00-3	BQL	BQL	BQL
Methylene Chloride	CLP	75-09-2	BQL	BQL	BQL
Acetone	CLP	67-64-1	BQL	BQL	BQL
Carbon Disulfide	CLP	75-15-0	BQL	BQL	BQL
1,1-Dichloroethene	CLP	36	1 J	BQL	13
1,1-Dichloroethane	CLP	38	BQL	BQL	1 J
1,2-Dichloroethene (total)	CLP	540-59-0	200	69	3300
trans-1,2-Dichloroethene	CLP	156-60-5	3 J	BQL	32
Chloroform	CLP	67-66-3	BQL	BQL	BQL
1,2-Dichloroethane	CLP	99	BQL	BQL	13
2-Butanone	CLP	-18	BQL	BQL	BQL
1,1,1-Trichloroethane	CLP	10	BQL	BQL	BQL
Carbon Tetrachloride	CLP	28	BQL	BQL	BQL
Bromodichloromethane	CLP	75-27-4	BQL	BQL	BQL
1,2-Dichloropropane	CLP	-24	BQL	BQL	BQL
cis-1,3-Dichloropropane	CLP	105	BQL	BQL	BQL
Trichloroethene	CLP	79-01-6	2000	230	2400
Dibromochloromethane	CLP	124-48-1	BQL	BQL	BQL
1,1,2-Trichloroethane	CLP	74	BQL	BQL	44
Benzene	CLP	26	3 J	BQL	5 J
trans-1,3-Dichloropropene	CLP	461	BQL	BQL	BQL
Bromoform	CLP	75-25-2	BQL	BQL	BQL
4-Methyl-2-Pentanone	CLP	108-10-1	BQL	BQL	BQL
2-Hexanone	CLP	591-78-6	BQL	BQL	BQL
Tetrachloroethene	CLP	105	130	31	120
1,1,2,2-Tetrachloroethane	CLP	40	BQL	BQL	2 J
Toluene	CLP	108-88-3	BQL	BQL	6 J
Chlorobenzene	CLP	11	180	BQL	BQL
Ethylbenzene	CLP	100-41-4	BQL	BQL	2 J
Styrene	CLP	53	BQL	BQL	BQL
Xylenes (total)	CLP	1330-20-7	BQL	BQL	10
Acenaphthene	CLP	42	BQL	BQL	BQL

See RMT attachment for footnotes.

2,4-Dinitrophenol	CLP	18	BQL	BQL	BQL
4-Nitrophenol	CLP	No CASRN	BQL	BQL	BQL
Dibenzofuran	CLP	59	BQL	BQL	BQL
2,4-Dinitrotoluene	CLP	105	BQL	BQL	BQL
Diethylphthalate	CLP	16	BQL	BQL	BQL
4-Chlorophenyl phenyl ether	CLP	49	BQL	BQL	BQL
Fluorene	CLP	6	BQL	BQL	BQL
4-Nitroaniline	CLP	100-01-6	BQL	BQL	BQL
4,6-Dinitro-2-methylphenol	CLP	-	BQL	BQL	BQL
N-nitrosodiphenylamine	CLP	50	BQL	BQL	BQL
4-Bromophenyl-phenylether	CLP	43	BQL	BQL	BQL
Hexachlorobenzene	CLP	43	BQL	BQL	BQL
Pentachlorophenol	CLP	-4	BQL	BQL	BQL
Phenanthrene	CLP	85-01-8	BQL	BQL	BQL
Anthracene	CLP	101	BQL	BQL	BQL
Carbazole	CLP	4	BQL	BQL	BQL
di-n-Butylphthalate	CLP	8	BQL	BQL	BQL
Flouranthene	CLP	162	BQL	BQL	BQL
Pyrene	CLP	129	BQL	BQL	BQL
Butyl benzyl phthalate	CLP	10	2 J	BQL	BQL
3,3-Dichlorobenzidene	CLP	-4	BQL	BQL	BQL
Benzo[a]anthracene	CLP	-2	BQL	BQL	BQL
Chrysene	CLP	208	BQL	BQL	BQL
GP Work Order #			9807107	9807142	9807153

Legend:
J - Value less than the repporting limits but greater than zero.
B - Indicates that the compound was found in the associated blank and exceeds the Quantitiation Limit
R - Rejected value (e.g., lab contamination)
BQL - Below Quantitation Limit

See RMT attachment for footnotes.

Footnotes For Laboratory Data
Site 32/33 Air (T12-3233-xxxx-xx)
Pilot Test

Notes for FDGTI Pilot Test Air Data Table:

1. Data are from submittal from FDGTI to USEPA dated 10/23/98.
2. Reported units of μg/kg are not believed to be accurate for these air sample data. Possible units may be parts per billion by volume (ppbv), not by weight.
3. Sample I.D. of "SPRC" is believed to be incorrect. Correct I.D. believed to be "SPRG," based on consistency with laboratory data reports.
4. Lab report shows 1,2-DC-1,1,2,2-TFA concentration for sample 146-DPVE-1-2 as 22,000 ppbv.

Table 4-3
Pilot Test Summary -
Crab Orchard National Wildlife Refuge - PCBOU Sites 32/33 -
Marion, Illinois

PARAMETER	BUILDING I-1-23	BUILDING I-1-2	AREA 9 REPOSITORY
Dual-Phase Extraction (DPE) Test	***July 13, 1998 and July 15, 1998*** ***11.5 hr pump test; 4.0 hr pump test, DPE + 5 hrs***	***July 17, 1998*** ***6 hr pump test, DPE + 5 hrs***	***July 19, 1998*** ***2.75 hr pump test, DPE + 4.5 hr***
Pumping rate - DPE	6 gpm for DPE test	5 - 6 gpm	0.3 gpm
Maximum drawdown at DPE well	Unclear, probably 2 - 3 feet, but not down to sand unit.	> 20.9 feet	13.7 feet
Drawdown notes	Draw down less than 3 feet in MPs, which affects vacuum influence.	Heads in MPs 2, 3 & 4 dropped almost as quickly as the DPE extraction well. Not able to dewater at MP-1 to the sand layer, which affects vacuum influence. See note under "vacuum response" below.	Very little response in monitoring points, even at 9.5 feet away.
Vacuum response notes	No vacuum response in any MPs.	Good vacuum response noted in MPs 2, 3 & 4 while drawdown occurred. None noted in MP-1 (43' away) or in SVE wells. Artificial ROI of 30' in sand unit.	Slight vacuum response only in MP-1, which is furthest MP from DPE well.
Vacuum & airflow	218 in H2O, 12 cfm(1)	188 in H2O, 11 cfm(1)	240 in H2O, 16 cfm(1)
Water sample analysis	PCE: 130 µg/L TCE: 2000 µg/L cis-1,2-DCE: 200 µg/L VC: BQL	PCE: 31 µg/L TCE: 230 µg/L cis-1,2-DCE: 69 µg/L VC: BQL	PCE: 120 µg/L TCE: 2,400 µg/L cis-1,2-DCE: 3,300 µg/L VC: 17 µg/L
Air sample analysis	Total CVOCs: 524 ppbv TCE: 440 ppbv Freon 113: 28 ppbv Other VOCs: 862 ppbv	Total CVOCs: 78 ppbv TCE: 20 ppbv Freon 113: 120,000 ppbv Other VOCs: 122 ppbv	Total CVOCs: 248 ppbv TCE: 190 ppbv Other VOCs: 45 ppbv
Air Sparge/Soil Vapor Extraction Test	***July 16, 1998*** ***AS/SVE test 4 hrs***	***July 18, 1998*** ***2 hr SVE only, sparge/vent + 6 hrs***	***July 20, 1998*** ***2 hr SVE only, 6 hr air sparge/vent***
Sparge well pressure & airflow	21 - 30 psi, 1.8 to 4.7 cfm(1)	10 psi, 0.8 to 1.3 cfm(1)	15 - 30 psi, 1.0 to 4.9 cfm(1)
SVE extraction well vacuum & airflow	Reported vacuum questionable, 7.5 - 10.8 cfm,(1) some flow noted	188 in. H2O, no airflow (0.0 cfm) (1)	200 in H2O, 6.8 - 18.3 cfm
Radius of influence - air sparge	Unclear, approximately 10 to 15 feet, 33MWC-21 noted as "bubbling".	8 to 19 feet	Unclear, <5.8
Radius of influence - SVE	<8.5 feet, no response noted	<5.5 feet, no response noted	<5.8 feet, no response noted, except for slight response at MP-1
Air sample analysis	Total CVOCs: 9,310 ppbv TCE: 7,400 ppbv Other VOCs: 900 ppbv	Total CVOCs: BQL TCE: BQL Freon 113: 8,900 ppbv Other VOCs: 160 ppbv	Total CVOCs: 1393 ppbv TCE: 1,300 ppbv Other VOCs: 24 ppbv
Notes for AS/SVE test	Unable to recover vapors generated by air sparging due to low permeability soil above area of treatment.	Unable to recover vapors generated by air sparging due to low permeability soil above area of treatment.	Unable to recover vapors generated by air sparging due to low permeability soil above area of treatment.

Notes:
(1) Annubar readings were recorded by FDGTI; readings were converted to flowrates using annubar manufacturer's data.

Legend:
- Inappropriate as potential response component
- Appropriate to consider as component of response action

TABLE 5-1
Identification and Screening of Groundwater Response Technologies

General Response Action	Technology	Process Option	Description	Effectiveness	Implementability	Comparative Capital Cost
No Action	None	None	No Action is carried through as a "baseline" for comparative evaluation of potential responses.	Does not measure effectiveness of naturally occurring contaminant attenuation because monitoring not included.	Can be implemented.	Low
Limited Action	On-Site Access Restrictions	Fencing	Permanent fencing at East & West Swales to minimize potential human and wildlife contact with contaminated surface water.	Generally provides no additional long-term effectiveness compared to existing conditions. Temporary fencing may be appropriate as component of remedial construction in some areas.	Can be implemented in several areas at site.	Low
		Security	Manned security service or camera surveillance.	Not necessary based on potential hazards or risk to environment. No additional effectiveness compared to existing conditions.	Can be implemented.	Medium
	Institutional Controls	Property Agreements	Place Groundwater Use Restriction in property deed.	Not effective since groundwater use already controlled on property owned by federal government.	Feasibility based on legal issues uncertain. May not be acceptable to regulatory agencies.	Medium
		Property Acquisition	Purchase property.	Not effective since no groundwater impacts off of existing site property owned by federal government.	Feasibility based on legal issues uncertain. May not be acceptable to regulatory agencies.	Medium

To Table Page 2

5

TABLE 5-1
(continued)
Identification and Screening of Groundwater Response Technologies

General Response Action	Technology	Process Option	Description	Effectiveness	Implementability	Comparative Capital Cost
	From Table Page 1					
	Monitoring	Monitored Natural Attenuation	Long-term monitoring of groundwater quality improvements by natural attenuation processes, under USEPA-approved workplans.	Effective approach for confirming expected groundwater quality improvement following contaminant source area remediation.	Can be implemented.	Low
Containment	Vertical Barriers	Slurry Walls	Soil-bentonite or cement-bentonite slurry placed in trench around perimeter of contaminant source areas, keyed into confining base layer.	Potentially effective in preventing further leaching of CVOC source material into groundwater at some site source areas, if wall can be keyed into Lower Clay unit. Not effective for source beneath Repository. Not effective in destroying CVOC source material.	Construction believed to be possible with specialized equipment, due to depth requirement for wall.	High
		Sheet Piling	Steel sheet piling or HDPE interlocking barrier sheets installed around perimeter of contaminant source areas, keyed into confining base layer.	Potentially effective in preventing further leaching of CVOC source material into groundwater at some site source areas, if piling can be keyed into Lower Clay unit. Not effective for source beneath Repository. Not effective in destroying CVOC source material.	Construction may be impractical due to physical difficulties.	High
		Injected Screens	Similar to sheet piling, except piles are removed and grout injected into void space.	Potentially effective in preventing further leaching of CVOC source material into groundwater at some site source areas, if grout screen can be keyed into Lower Clay unit. Not effective for source beneath Repository. Not effective in destroying CVOC source material.	Construction may be impractical due to physical difficulties.	High
		Grout Curtains	Closely-spaced holes drilled around perimeter of contaminant source areas, to confining base layer. Grout injected into boreholes to provide overlapping grout zones.	Potentially effective in preventing further leaching of CVOC source material into groundwater at some site source areas, if grout curtain can be keyed into Lower Clay unit. Not effective for source beneath Repository. Not effective in destroying CVOC source material.	Construction may be impractical due to physical difficulties.	High

TABLE 5-1
(continued)
Identification and Screening of Groundwater Response Technologies

General Response Action	Technology	Process Option	Description	Effectiveness	Implementability	Comparative Capital Cost
Removal	Extraction	Interceptor Trenches	Perforated pipe laid in trench installed across groundwater flow path, with pump in sump.	Effective in intercepting plumes in Upper Sand, to remove dissolved CVOC mass via groundwater extraction.	Construction may be impractical due to physical difficulties of trenching depths.	High
		Vertical Extraction Wells	Vertical extraction well(s) to remove contaminated groundwater using various types of equipment and methods.	Effective in removing dissolved CVOC mass via groundwater extraction at source areas and in preventing further source mass from entering plumes.	Can be constructed. Difficult to route electrical conduit and pump discharge pipe to well(s) constructed through Repository waste since trenching into waste material not desirable.	Medium/High
		Horizontal Extraction Wells	Well(s) drilled and installed horizontally into Upper Sand at source areas	Effective in removing dissolved CVOC mass via groundwater extraction at source areas and in preventing further source mass from entering plumes. Additional benefit of dewatering Upper Clay for application of other technologies.	Can be constructed. Better approach for source beneath Repository since wellheads can be at ground elevation at base of Repository waste.	Medium/High
		Multiple Phase Extraction	High-vacuum pump removes combination of contaminated groundwater, and soil vapors from vertical well(s).	Capable of removing liquid and gas (soil vapors) from low-permeability or heterogeneous formations.	Can be constructed. Difficult to route pump discharge pipe(s) to well(s) constructed through Repository waste since trenching into waste material not desirable.	Medium/High
		Dual Phase Extraction	Submersible pump used in vertical well(s) at source areas to create cone of depression. CVOCs then removed from enlarged vadose zone via a vacuum pump connected to the same well(s).	Capable of removing liquid and gas (soil vapors) from heterogeneous formations. Effectiveness is limited based on results of 1998 pilot testing at the site.	Can be constructed. Difficult to route pump discharge pipe(s) to well(s) constructed through Repository waste since trenching into waste material not desirable.	Medium/High
	Excavation	Excavation and Disposal	Conventional heavy excavation equipment is used to excavate contaminated soil. Soil is disposed at an off-site Subtitle D or C landfill. Objective is to minimize further leaching of CVOCs to groundwater.	Pending detailed characterization, capable of complete removal of CVOC mass, thereby minimizing further leaching of CVOCs to the groundwater in a relatively short period of time.	Can be constructed. May need to use sheeting/shoring for deep excavations. Not feasible for Repository due to presence of PCB impacted soil. Disposal costs are uncertain.	High

TABLE 5-1
(continued)
Identification and Screening of Groundwater Response Technologies

General Response Action	Technology	Process Option	Description	Effectiveness	Implementability	Comparative Capital Cost
Treatment	In-Situ Treatment	Air Sparging	Injection of compressed air below water table within plume through series of wells to volatilize VOCs and stimulate biodegradation. Recovery of VOCs in soil pore gas via soil vapor extraction (SVE) system.	Pilot-scale field tests at Sites 32/33 showed air sparging to be ineffective and possibly detrimental to groundwater cleanup due to stratification. Potential to cause increased groundwater contaminant concentrations if rate of VOC volatilization and vertical movement to atmosphere or soil vapor collection point is insufficient.	Can be constructed. May precipitate dissolved ferrous iron over time, causing plugging of saturated soil pores and restricted effectiveness of VOC volatilization and removal due to reduced soil permeability for vertical air movement.	Medium
		Steam Sparging	Similar to air sparging except steam injected instead of air to enhance VOC volatilization and possibly stimulate biodegredation.	Uncertain effectiveness due to same limitations as Air Sparging.	Can be constructed, but potential operating problems similar to Air Sparging. Significant amount of operation and maintenance attention required.	High
		Permeable Treatment Walls	Trench or pit installed across groundwater plumes flow path in Upper Sand, filled with permeable material mixture (e.g., zero-valent iron) to "actively" or "passively" treat water flowing through the wall.	Potentially effective for destruction of CVOCs in Upper Sand plumes via chemical redox reactions. Technology still in early stages of full-scale application. Typically installed downgradient of source area(s); does not directly destroy CVOC mass at source.	Probably constructable, but potential difficulties due to trenching depths required. Potentially significant operational problems or limitations.	High
		Electro-Thermal Recovery	Uses electro-thermal process to volatilize CVOCs from unsaturated soil, which are then removed by vapor extraction.	May not be effective due to soil characteristics. Does not require dewatering of Upper Clay prior to use, but may be more effective if clay is dewatered.	Can be constructed. Must be used with vapor extraction option.	High
		Electro-osmotic Recovery	Uses electro-osmosis in treatment zones located directly in contaminated soil areas.	Effective in low-permeability soils, and for removing CVOCs.	Difficult or impractical construction. Must be used with vapor extraction.	High

To Table Page 5 *To Table Page 5*

TABLE 5-1
(continued)
Identification and Screening of Groundwater Response Technologies

General Response Action	Technology	Process Option	Description	Effectiveness	Implementability	Comparative Capital Cost
From Table Page 4	*From Table Page 4*					
Treatment		Chemical Oxidation	Series of injection wells or infiltration trenches to introduce oxidizing chemical solutions into groundwater to react with and degrade organic contaminants.	Requires full-scale field test to determine effectiveness and design criteria. Probably minimal effectiveness, due to low permeability of Upper Clay at CVOC source areas.	Significant engineering and process control problems. May precipitate dissolved ferrous iron and other metal ions, causing plugging of saturated soil pores and restricted effectiveness of organics degradation.	High
		Co-Metabolic Treatment	A primary substrate solution is injected into a contaminated groundwater area. In the process of oxidizing the substrate, the microbial population degrades the contaminants.	Bench-scale and/or field pilot-scale tests, and characterization of existing microorganism populations, required to determine ability to influence degradation. Co-metabolic degredation is an aerobic process; would require significant alteration of existing anaerobic conditions in source areas.	Potentially difficult to maintain aerobic conditions throughout impacted Upper Clay that are sufficient for active co-metabolic biodegredation.	Medium
		Enhanced Bioremediation	Providing nutients, electron acceptors and/or electron donor (food source) materials to impacted groundwater/soil to accelerate the natural biodegradation process. Nutrient solutions can be delivered to soil via injection or gravity infiltration.	Bench-scale and/or field pilot-scale tests and characterization of existing microorganism populations required to determine ability to influence biodegradation, and site-specific effectiveness.	Generally implementable. Potential limitation due to low rate of delivery of substrate/nutrient solution into low-permeability clay in source areas.	Medium
		In-Situ Recirc. Wells	Various designs provide below-grade air stripping, vacuum vapor extraction, and/ or biological treatment, some within patented well design.	New technology with little documented results. Would require full-scale field test to determine effectiveness and design criteria. May not be effective for site conditions (low-permeability soil).	Can probably be constructed. Uncertain operation and maintenance requirements and potential problems due to new technology.	Medium/High
To Table Page 6	*To Table Page 6*					

TABLE 5-1
(continued)
Identification and Screening of Groundwater Response Technologies

General Response Action	Technology	Process Option	Description	Effectiveness	Implementability	Comparative Capital Cost
From Table Page 5	*From Table Page 5*	Mobile Injection Treatment Unit [R]	Equipment excavates, treats soil via hot air stripping of VOCs, and backfills deep trenches in source areas in one pass.	Effective in removing residual CVOCs from Upper Clay and reducing need for off-site disposal of excavated material. Proprietary equipment provided by only 1 company.	Expected to be implementable at I-1-2 and I-1-23 source areas. Not feasible for source beneath Repository. Requires dewatering of Upper Clay prior to use of equipment.	High
		Phytoremediation	Use of various plant species to remediate soil and groundwater.	New technology - little long-term performance data exists. Some documented effectiveness for CVOCs in groundwater.	Implementable, particularly in areas of shallow contamination.	Low
		Monitored Natural Attenuation	Use of existing naturally occurring contaminant attenuation and degradation mechanisms.	Source control measures with natural attenuation processes expected to reduce contaminant concentrations over time.	Current conditions indicate natural degradation of CVOCs in groundwater is already occurring at the site.	Low
	At-Grade (Ex-Situ) Treatment	Air Stripping	Packed-column or shallow-tray type air stripping unit or cascade aeration at point of discharge.	Effective for VOC constituents of concern in groundwater.	Can be constructed. Proven technology with predictable results and known design criteria. Must be used in combination with groundwater extraction option.	Medium
		Activated Carbon	Activated carbon in removable canisters or fixed-mounted vessels for gas-phase or liquid-phase treatment of VOCs.	Effective for detected VOCs except vinyl chloride.	Can be constructed. Proven technology. Must be used in combination with groundwater extraction option.	High
		Thermal Destruction	Thermal or catalytic oxidizer for destruction of VOCs in gas-phase.	Effective for all VOCs in site groundwater. Not practical for low VOC concentrations in groundwater.	Can be constructed. Supplemental fuel source required. Must be used in combination with groundwater extraction or soil vapor extraction option.	Medium/High

To Table Page 7

TABLE 5-1
(continued)
Identification and Screening of Groundwater Response Technologies

General Response Action	Technology	Process Option	Description	Effectiveness	Implementability	Comparative Capital Cost
	From Table Page 6					
		Aerobic Biological	Various process options for aerobic biological treatment.	May not produce treated water quality required for discharge without supplemental polishing treatment. Requires bench-scale and/or pilot-scale testing to determine effectiveness and design criteria.	Can be designed and constructed. Treatment process is more susceptible to upsets and requires more operation and maintenance attention and operator skill than physical-chemical process equipment. Must be used in combination with groundwater extraction option.	Medium
		Anaerobic Biological	Various process options for anaerobic biological treatment.	Comments similar to those shown for Aerobic Biological.	Comments similar to those shown for Aerobic Biological. Anaerobic conditions may be impractical to maintain.	Medium/High
		Chemical Oxidation	Addition of oxidizing chemicals to groundwater, sometimes with ultraviolet light, to oxidize organics.	Some concurrent oxidation and precipitation of metals likely to occur. Bench-scale and/or pilot-scale testing required to confirm effectiveness and design criteria.	Can be designed and constructed. Must be used in combination with groundwater extraction option.	Medium/High
	Untreated Groundwater	To POTW	Install pump station and force main to nearest POTW, or truck from site to POTW.	POTW expected to be effective in treating groundwater contaminants, but confirmation required.	Impractical due to distance. Dependent on willingness of POTW to accept groundwater over a several-year period, and special requirements or limitations that may be imposed.	Low/Medium
		To Surface Water	Pump extracted groundwater directly to point-source discharge into lake at new outfall.	Not effective for removal of VOCs from groundwater. Relies on dilution and volatilization in surface water to reduce VOC concentrations.	Requires discharge permit. Would not likely be implementable (regulatorily acceptable) without treatment. Could result in unacceptable VOC concentrations in lake.	Low
Off-Site Disposal	Treated Groundwater	To Surface Water	Pump extracted groundwater after treatment to point-source discharge into lake at new outfall or into surface water impoundments for wildlife on west side of Highway 148.	Effective and beneficial use of groundwater, especially during drought conditions.	Expected to be constructible, although significant length of buried force main required. Requires discharge permit.	Medium

TABLE 5-1
(continued)
Identification and Screening of Groundwater Response Technologies

General Response Action	Technology	Process Option	Description	Effectiveness	Implementability	Comparative Capital Cost
On-Site Disposal	Treated Groundwater	Injection Wells	Series of wells for injecting treated water into sandstone aquifer for recharge.	Provides conservation of groundwater resource.	Can be constructed. Injection flowrate expected to be adequate for extracted groundwater flowrate from shallow system. May be subject to state statutory prohibition. If not, may still require variance and will require state permit. Requires polishing step to meet MCLs and to provide stable water chemistry with low nonfilterable solids level. High level of maintenance required compared with other disposal options.	Medium/High
		Infiltration Basin or Trenches/ Drainfield	Gravity discharge of water to perforated pipe laid in trench system or drainfield with permeable backfill, or to earth basin for gravity infiltration into groundwater.	Not as effective as injection wells, but potentially viable in combination with other disposal technologies. No additional effectiveness compared to discharge to on-site surface drainage channels. Provides conservation of groundwater resource.	Uncertain ability to achieve required infiltration rate due to local site hydrogeologic and hydrologic conditions. May have seasonal limitations. Impractical due to high water table. Discharge limits would likely equal MCLs.	Low/Medium
		Drainage Channels	Discharge to existing drainage channels on-site (with ultimate discharge into lake).	Effective disposal option that takes advantage of existing site drainage patterns. Would meet limits required in surface water discharge permit.	Implementable design, construction, operation, and maintenance. Requires discharge permit. Discharge limits equal to MCLs likely.	Low/Medium
		Non-Potable Service Water	Provide pumps and piping to distribute treated groundwater to existing use points at site production facilities.	Provides effective use of groundwater resource. Potential service water supply for on-site production operations and general maintenance.	Impractical as sole disposal method due to variable water flowrate demand. Current production operations not believed to require continuous service water supply.	Low
		Irrigation	Provide pumps and piping to distribute treated groundwater to selected site areas for irrigation.	Provides effective use of groundwater resource. Could provide irrigation for trees or plants used as part of phytoremediation approach for groundwater treatment. Does not provide means for disposal of treated groundwater during non-growing season.	Expected to be constructible, although significant length of bured force main required.	Medium

To Table Page 9

TABLE 5-1
(continued)
Identification and Screening of Groundwater Response Technologies

General Response Action	Technology	Process Option	Description	Effectiveness	Implementability	Comparative Capital Cost
From Table Page 8						
	Untreated Groundwater	Non-Potable Service Water	Provide pumps and piping to distribute untreated groundwater to existing use points at site production facilities.	Provides effective use of groundwater resource. Potential service water supply for on-site production operations and general maintenance. However, potential for exposure of on-site workers to groundwater contaminants.	Impractical as sole disposal method due to variable water flowrate demand. Current production operations not believed to require continuous service water supply.	Low
		Drainage Channels	Discharge to existing on-site drainage channels (with ultimate discharge into lake).	Effective disposal option that takes advantage of existing site drainage patterns. Not expected to meet limits required in surface water discharge permit.	Implementable design, construction, operation, and maintenance. Requires compliance with discharge permit limitations, but would not likely be implementable (regulatorily acceptable) without treatment to reach MCLs.	Low
		Irrigation	Provide pumps and piping to distribute untreated groundwater to selected site areas for irrigation.	Provides effective use of groundwater resource. However, potential for exposure of on-site workers and wildlife to groundwater contaminants.	Expected to be constructible, although significant length of buried force main required. Not likely to be implementable (regulatorily acceptable) without some amount of groundwater treatment.	Medium

Table 5-2

Definition of Matrix Treatment Technologies

Technology	Description
Soil, Sediment, and Sludge Technologies	
3.1 In Situ Biological Treatment	
4.1 Bioventing	Oxygen is delivered to contaminated unsaturated soils by forced air movement (either extraction or injection of air) to increase oxygen concentrations and stimulate biodegradation.
4.2 Enhanced Biodegradation	The activity of naturally occurring microbes is stimulated by circulating water-based solutions through contaminated soils to enhance in situ biological degradation of organic contaminants. Nutrients, oxygen, or other amendments may be used to enhance biodegradation and contaminant desorption from subsurface materials.
4.3 Landfarming	Contaminated soils are periodically turned over or tilled into the soil to aerate the waste.
4.4 Natural Attenuation	Natural subsurface processes - such as dilution, volatilization, biodegradation, adsorption, and chemical reactions with subsurface materials - are allowed to reduce contaminant concentrations to acceptable levels.
4.5 Phytoremediation	Phytoremediation is a set of processes that use plants to clean contamination in soil, ground water, surface water, sediment, and air.
3.2 In Situ Physical/Chemical Treatment	
4.6 Electrokinetic Separation	The Electrokinetic Remediation (ER) process removes metals and organic contaminants from low permeability soil, mud, sludge, and marine dredging. ER uses electrochemical and electrokinetic processes to desorb, and then remove, metals and polar organics. This in situ soil processing technology is primarily a separation and removal technique for extracting contaminants from soils.
4.7 Fracturing	Pressurized air is injected beneath the surface to develop cracks in low permeability and over-consolidated sediments, opening new passageways that increase the effectiveness of many in situ processes and enhance extraction efficiencies.
4.8 Soil Flushing	Water, or water containing an additive to enhance contaminant solubility, is applied to the soil or injected into the ground water to raise the water table into the contaminated soil zone. Contaminants are leached into the ground water, which is then extracted and treated.
4.9 Soil Vapor Extraction	Vacuum is applied through extraction wells to create a

4.9 Soil Vapor Extraction	pressure/concentration gradient that induces gas-phase volatiles to diffuse through soil to extraction wells. The process includes a system for handling off-gases. This technology also is known as in situ soil venting, in situ volatilization, enhanced volatilization, or soil vacuum extraction.
4.10 Solidification/Stabilization	Contaminants are physically bound or enclosed within a stabilized mass (solidification), or chemical reactions are induced between the stabilizing agent and contaminants to reduce their mobility (stabilization).
3.3 In Situ Thermal Treatment	
4.11 Soil Vapor Extraction, Thermally Enhanced	Steam/hot air injection or electromagnetic/fiber optic/radio frequency/electrical conduction heating is used to increase the mobility of volatiles and facilitate extraction. The process includes a system for handling off-gases.
Technology	**Description**
Soil, Sediment, and Sludge Technologies	
3.4 Ex Situ Biological Treatment	
4.12 Biopiles	Excavated soils are mixed with soil amendments and placed in aboveground enclosures. Processes include prepared treatment beds, biotreatment cells, soil piles, and composting.
4.13 Composting	Contaminated soils are excavated and mixed with bulking agents and organic amendments such as wood chips, animal and vegetative wastes, which are added to enhance the porosity and organic content of the mixture to be decomposed.
4.14 Genetically Engineered Organisms	Genetically engineered organisms refer to microorganisms that have undergone external processes by which its basic set of genes has been altered.
4.15 Landfarming	Contaminated soils are applied onto the soil surface and periodically turned over or tilled into the soil to aerate the waste.
4.16 Slurry Phase Biological Treatment	An aqueous slurry is created by combining soil or sludge with water and other additives. The slurry is mixed to keep solids suspended and microorganisms in contact with the soil contaminants. Upon completion of the process, the slurry is dewatered and the treated soil is disposed of.
3.5 Ex Situ Physical/Chemical Treatment	
4.17 Chemical Extraction	Waste contaminated soil and extractant are mixed in an extractor, dissolving the contaminants. The extracted solution is then placed in a separator, where the contaminants and extractant are separated for treatment and further use.
4.18 Chemical Reduction/Oxidation	Reduction/oxidation chemically converts hazardous contaminants to non-hazardous or less toxic compounds that are more stable, less mobile, and/or inert. The oxidizing agents most commonly used are ozone, hydrogen peroxide, hypochlorites, chlorine, and chlorine dioxide.
4.19 Dehalogenation	Reagents are added to soils contaminated with halogenated organics.

4.19 Dehalogenation	The dehalogenation process is achieved by either the replacement of the halogen molecules or the decomposition and partial volatilization of the contaminants.
4.20 Separation	Separation techniques concentrate contaminated solids through physical and chemical means. These processes seek to detach contaminants from their medium (i.e., the soil, sand, and/or binding material that contains them).
4.21 Soil Washing	Contaminants sorbed onto fine soil particles are separated from bulk soil in an aqueous-based system on the basis of particle size. The wash water may be augmented with a basic leaching agent, surfactant, pH adjustment, or chelating agent to help remove organics and heavy metals.
4.22 Soil Vapor Extraction	A vacuum is applied to a network of aboveground piping to encourage volatilization of organics from the excavated media. The process includes a system for handling off-gases.
4.23 Solar Detoxification	Solar detoxification is a process that destroys contaminants by using the ultraviolet energy in sunlight.
4.24 Solidification/Stabilization	Contaminants are physically bound or enclosed within a stabilized mass (solidification), or chemical reactions are induced between the stabilizing agent and contaminants to reduce their mobility (stabilization).
Technology	**Description**
Soil, Sediment, and Sludge Technologies	
3.6 Ex Situ Thermal Treatment	
4.25 Hot Gas Decontamination	The process involves raising the temperature of the contaminated equipment or material for a specified period of time. The gas effluent from the material is treated in an afterburner system to destroy all volatilized contaminants.
4.26 Incineration	High temperatures, 871-1,204 °C (1,600- 2,200 °F), are used to combust (in the presence of oxygen) organic constituents in hazardous wastes.
4.27 Open Burn/Open Detonation	In open burn operations, explosives or munitions are destroyed by self-sustained combustion, which is ignited by an external source, such as flame, heat, or a detonatable wave (that does not result in a detonation). In open detonation operations, detonatable explosives and munitions are destroyed by a detonation, which is initiated by the detonation of a disposal charge.
4.28 Pyrolysis	Chemical decomposition is induced in organic materials by heat in the absence of oxygen. Organic materials are transformed into gaseous components and a solid residue (coke) containing fixed carbon and ash.
4.29 Thermal Desorption	Wastes are heated to volatilize water and organic contaminants. A carrier gas or vacuum system transports volatilized water and organics to the gas treatment system.
3.7 Containment	
4.30 Landfill Cap	Landfill caps are used for contaminant source control.
4.31 Water Harvesting	Water harvesting vegetative cover is a land cover that, through

Vegetative Cover	engineered vegetative design, enhances evaporation, plant transpiration, and moisture removal from the soil.
3.8 Other Treatment Technologies	
4.32 Excavation, Retrieval, and Off-Site Disposal	Contaminated material is removed and transported to permitted off-site treatment and disposal facilities. Pretreatment may be required.
Technology	**Description**
Ground Water, Surface Water, and Leachate Technologies	
3.9 In Situ Biological Treatment	
4.33 Co-metabolic Treatment	Injection of a dilute solution of liquids and/or gases (e.g., toluene, methane or oxygen) into the contaminated ground water zone to enhance the rate of methanotrophic biological degradation of organic contaminants.
4.34 Enhanced Biodegradation	The rate of biodegradation of organic contaminants by microbes is enhanced by increasing the concentration of electron acceptors in ground water. Oxygen is the main electron acceptor for aerobic biodegradation. Nitrate can serve as an alternative electron acceptor under anaerobic conditions.
4.35 Natural Attenuation	Natural subsurface processes—such as dilution, volatilization, biodegradation, adsorption, and chemical reactions with subsurface materials—are allowed to reduce contaminant concentrations to acceptable levels.
4.36 Phytoremediation of Organics	Phytoremediation is a set of processes that uses plants to clean contamination, particularly organic substances, in ground water and surface water.
3.10 In Situ Physical/Chemical Treatment	
4.37 Aeration	Aeration is the process by which the area of contact between water and air is increased, either by natural methods or by mechanical devices.
4.38 Air Sparging	Air is injected into saturated matrices to remove contaminants through volatilization.
4.39 Bioslurping	Bioslurping combines the two remedial approaches of bioventing and vacuum-enhanced free-product recovery. Bioventing stimulates the aerobic bioremediation of hydrocarbon-contaminated soils. Vacuum-enhanced free-product recovery extracts LNAPLs from the capillary fringe and the water table.
4.40 Directional Wells	Drilling techniques are used to position wells horizontally, or at an angle, to reach contaminants not accessible by direct vertical drilling.
4.41 Dual Phase Extraction	A high vacuum system is applied to simultaneously remove various combinations of contaminated ground water, separate-phase petroleum product, and hydrocarbon vapor from the subsurface.
4.42 Fluid/Vapor Extraction	A high vacuum system is applied to simultaneously remove liquid and gas from low permeability or heterogeneous formations.
4.43 Hot Water or Steam Flushing/Stripping	Steam is forced into an aquifer through injection wells to vaporize volatile and semivolatile contaminants. Vaporized components rise to

28

Flushing/Stripping	
	the unsaturated zone where they are removed by vacuum extraction and then treated.
4.44 Hydrofracturing	Injection of pressurized water through wells cracks low permeability and over-consolidated sediments. Cracks are filled with porous media that serve as avenues for bioremediation or to improve pumping efficiency.
4.45 In-Well Air Stripping	Air is injected into a double screened well, lifting the water in the well and forcing it out the upper screen. Simultaneously, additional water is drawn in the lower screen. Once in the well, some of the VOCs in the contaminated ground water are transferred from the dissolved phase to the vapor phase by air bubbles. The contaminated air rises in the well to the water surface where vapors are drawn off and treated by a soil vapor extraction system.
4.46 Passive/Reactive Treatment Walls	These barriers allow the passage of water while prohibiting the movement of contaminants by employing such agents as chelators (ligands selected for their specificity for a given metal), sorbents, microbes, and others.
Technology	**Description**
Ground Water, Surface Water, and Leachate Technologies	
3.11 Ex Situ Biological Treatment	
4.47 Bioreactors	Contaminants in extracted ground water are put into contact with microorganisms in attached or suspended growth biological reactors. In suspended systems, such as activated sludge, contaminated ground water is circulated in an aeration basin. In attached systems, such as rotating biological contractors and trickling filters, microorganisms are established on an inert support matrix.
4.48 Constructed Wetlands	The constructed wetlands-based treatment technology uses natural geochemical and biological processes inherent in an artificial wetland ecosystem to accumulate and remove metals and other contaminants from influent waters.
3.12 Ex Situ Physical/Chemical Treatment	
4.49 Adsorption/ Absorption	In liquid adsorption, solutes concentrate at the surface of a sorbent, thereby reducing their concentration in the bulk liquid phase.
4.50 Air Stripping	Volatile organics are partitioned from ground water by increasing the surface area of the contaminated water exposed to air. Aeration methods include packed towers, diffused aeration, tray aeration, and spray aeration.
4.51 Granulated Activated Carbon (GAC)/Liquid Phase Carbon Adsorption	Ground water is pumped through a series of canisters or columns containing activated carbon to which dissolved organic contaminants adsorb. Periodic replacement or regeneration of saturated carbon is required.
4.52 Ion Exchange	Ion exchange removes ions from the aqueous phase by exchange with innocuous ions on the exchange medium.
4.53 Precipitation/ Coagulation/Flocculation	This process transforms dissolved contaminants into an insoluble solid, facilitating the contaminant's subsequent removal from the liquid phase

Coagulation/Flocculation	
	by sedimentation or filtration. The process usually uses pH adjustment, addition of a chemical precipitant, and flocculation.
4.54 Separation	Separation techniques concentrate contaminated waste water through physical and chemical means.
4.55 Sprinkler Irrigation	Wastewater is distributed over the top of the filter bed through which wastewater is trickled. The organic contaminants in wastewater are degraded by the microorganisms attached to the filter medium.
4.56 Ultraviolet Oxidation	Ultraviolet (UV) radiation, ozone, and/or hydrogen peroxide are used to destroy organic contaminants as water flows into a treatment tank. An ozone destruction unit is used to treat off-gases from the treatment tank.
3.13 Containment	
4.57 Deep Wall Injection	Deep well injection is a liquid waste disposal technology. This alternative uses injection wells to place treated or untreated liquid waste into underground reservoirs where it will not cause environmental harm.
4.58 Ground Water Pumping	Ground water pumping is a component of many pump-and-Treat processes, which are some of the most commonly used ground water remediation technologies at contaminated sites.
4.59 Slurry Walls	These subsurface barriers consist of vertically excavated trenches filled with slurry. The slurry, usually a mixture of bentonite and water, hydraulically shores the trench to prevent collapse and retards ground water flow.
Technology	**Description**
Air Emissions/Off-Gas Treatment Technologies	
3.14 Air Emissions/Off-Gas Treatment	
4.60 Biofiltration	Vapor-phase organic contaminants are pumped through a soil bed and sorb to the soil surface where they are degraded by microorganisms in the soil.
4.61 High Energy Corona	The HEC process uses high-voltage electricity to destroy VOCs at room temperature.
4.62 Membrane Separation	This organic vapor/air separation technology involves the preferential transport of organic vapors through a nonporous gas separation membrane (a diffusion process analogous to putting hot oil on a piece of waxed paper).
4.63 Oxidation	Organic contaminants are destroyed in a high temperature 1,000°C (1,832 °F) combustor. Trace organics in contaminated air streams are destroyed at lower temperatures, 450 °C (842 °F), than conventional combustion by passing the mixture through a catalyst.
4.64 Vapor Phase Carbon Adsorption	Off-gases are pumped through a series of canisters or columns containing activated carbon to which organic contaminants adsorb. Periodic replacement or regeneration of saturated carbon is required.

This table is a direct excerpt from the USEPA document titled "Remediation Technologies Screening Matrix and Reference Guide," prepared by the Federal Remediation Technologies Roundtable, NTIS PB98-108590, 3rd Edition, Nov. 1997.

Table 6-1
Primary Components of Remedial Alternatives

ALTERNATIVE	SOURCE AREA AND ASSOCIATED PLUME			GENERAL TYPE OF TECHNOLOGY APPLIED
	BUILDING I-1-2	BUILDING I-1-23	REPOSITORY AREA	
A	■ Compliance monitoring of groundwater and surface water under ROD and Consent Decree.	■ Compliance monitoring of groundwater and surface water under ROD and Consent Decree.	■ Compliance monitoring of groundwater and surface water under ROD and Consent Decree.	None; limited action (baseline) alternative
B	■ Groundwater monitoring to evaluate effectiveness of existing natural attenuation processes. ■ Compliance monitoring of groundwater and surface water under ROD and Consent Decree.	■ Groundwater monitoring to evaluate effectiveness of existing natural attenuation processes. ■ Compliance monitoring of groundwater and surface water under ROD and Consent Decree.	■ Groundwater monitoring to evaluate effectiveness of existing natural attenuation processes. ■ Compliance monitoring of groundwater and surface water under ROD and Consent Decree.	Monitored natural attenuation
C	*Source Area:* ■ Planting of selected trees and plants to reduce source mass and leaching of VOC residuals into saturated sand layer. *Plume:* ■ Use of existing trees and plants in marsh/wetland area on east side of Hwy. 148 to reduce mass of dissolved VOCs remaining in saturated sand layer prior to groundwater discharge to intermittent stream. *Source Area and Plume:* ■ Groundwater monitoring to evaluate effectiveness of phytoremediation and existing natural attenuation processes. ■ Compliance monitoring of groundwater and surface water under ROD and Consent Decree.	*Source Area:* ■ Planting of selected trees and plants to reduce source mass and leaching of VOC residuals into saturated sand layer. *Plume:* ■ Planting of selected trees and plants along lake shoreline and at west swale to reduce mass of dissolved VOCs remaining in saturated clay and sand layers prior to groundwater discharge to the swale and the lake. *Source Area and Plume:* ■ Groundwater monitoring to evaluate effectiveness of phytoremediation and existing natural attenuation processes. ■ Compliance monitoring of groundwater and surface water under ROD and Consent Decree.	*Source Area:* ■ **Source South of Repository:** Planting of selected trees and plants at source location to reduce source mass and leaching of VOC residuals into saturated sand layer. ■ **Source Beneath Repository:** Planting of selected trees and plants over top area of Repository to cut off surface water infiltration into waste materials and minimize potential leaching of VOCs into groundwater. *Plume:* ■ Planting of selected trees and plants across plume width along East Swale, to reduce mass of dissolved VOCs remaining prior to groundwater discharge to east swale. *Source Area and Plume:* ■ Groundwater monitoring to evaluate effectiveness of phytoremediation and existing natural attenuation processes. ■ Compliance monitoring of groundwater and surface water under ROD and Consent Decree.	Phytoremediation and monitored natural attenuation

Table 6-1 (continued)
Primary Components of Remedial Alternatives

ALTERNATIVE	SOURCE AREA AND ASSOCIATED PLUME			GENERAL TYPE OF TECHNOLOGY APPLIED
	BUILDING I-1-2	BUILDING I-1-23	REPOSITORY AREA	
D	*Source Area:* ■ Saturate (via gravity percolation) source area with soluble substrate and reducing chemical solution to promote biological breakdown of more highly chlorinated VOCs (PCE, TCE) by anaerobic reductive dechlorination. *Plume:* ■ Injection wells to introduce soluble substrate and reducing chemical solution into saturated sand layer at source area to accelerate biological breakdown of more highly chlorinated VOCs (PCE, TCE) that have already leached into the sand, by anaerobic reductive dechlorination. ■ Use of existing trees and plants in marsh/wetland area on east side of Hwy. 148 to reduce mass of dissolved VOCs remaining in saturated sand layer prior to groundwater discharge to intermittent stream. *Source Area and Plume:* ■ Groundwater monitoring to evaluate effectiveness of source area and plume remediation and existing natural attenuation processes. ■ Compliance monitoring of groundwater and surface water under ROD and Consent Decree.	*Source Area:* ■ Saturate (via gravity percolation) source area with soluble substrate and reducing chemical solution to promote biological breakdown of more highly chlorinated VOCs (PCE, TCE) by anaerobic reductive dechlorination. *Plume:* ■ Injection wells to introduce soluble substrate and reducing chemical solution into saturated sand layer at source area to accelerate biological breakdown of more highly chlorinated VOCs (PCE, TCE) that have already leached into the sand, by anaerobic reductive dechlorination. ■ Planting of selected trees and plants along lake shoreline and at West Swale to reduce mass of dissolved VOCs remaining in saturated clay and sand layers prior to groundwater discharge to the swale and lake. *Source Area and Plume:* ■ Groundwater monitoring to evaluate effectiveness of source area and plume remediation and existing natural attenuation processes. ■ Compliance monitoring of groundwater and surface water under ROD and Consent Decree.	*Source Area:* ■ **Source South of Repository:** Saturate (via gravity percolation) source area with soluble substrate and reducing chemical solution to promote biological breakdown of more highly chlorinated VOCs (PCE, TCE) by anaerobic reductive dechlorination. ■ **Source Beneath Repository:** Injection wells to introduce soluble substrate and reducing chemical solution into saturated sand layer beneath Repository to accelerate biological breakdown of more highly chlorinated VOCs (PCE, TCE) that have already leached into the sand, by anaerobic reductive dechlorination. *Plume:* ■ Planting of selected trees and plants across plume width to reduce mass of dissolved VOCs remaining prior to groundwater discharge to East Swale. *Source Area and Plume:* ■ Groundwater monitoring to evaluate effectiveness of source area and plume remediation and existing natural attenuation processes. ■ Compliance monitoring of groundwater and surface water under ROD and Consent Decree.	*In situ* enhanced bioremediation, phytoremediation, and monitored natural attenuation

32

Table 6-1 (continued)
Primary Components of Remedial Alternatives

ALTERNATIVE	SOURCE AREA AND ASSOCIATED PLUME			GENERAL TYPE OF TECHNOLOGY APPLIED
	BUILDING I-1-2	BUILDING I-1-23	REPOSITORY AREA	
E	*Source Area:* ■ Vertical multiple-phase extraction (MPE) wells screened in Upper Clay layer and separate horizontal pumping wells screened in Upper Sand layer. ■ Groundwater treatment using tray-type air stripping unit, liquid-phase carbon for effluent polishing, gas-phase carbon for air stripping unit exhaust and soil vapor from vacuum pump, housed in new treatment building adjacent to source area. ■ Treated groundwater discharge to existing drainage ditch tributary to lake. *Plume:* ■ Use of existing trees and plants in marsh/wetland area on east side of Hwy. 148 to reduce mass of dissolved VOCs remaining in saturated sand layer prior to groundwater discharge to intermittent stream. *Source Area and Plume:* ■ Groundwater monitoring to evaluate effectiveness of source area remediation and existing natural attenuation processes. ■ Compliance monitoring of groundwater and surface water under ROD and Consent Decree.	*Source Area:* ■ Vertical multiple-phase extraction (MPE) wells screened in upper clay layer and separate horizontal pumping wells screened in upper sand layer. ■ Groundwater treatment using tray-type air stripping unit, liquid-phase carbon for effluent polishing, gas-phase carbon for air stripping unit exhaust and soil vapor from vacuum pump, housed in new treatment building located near Repository. ■ Treated groundwater discharge to existing drainage ditch tributary to lake. *Plume:* ■ Planting of selected trees and plants along lake shoreline and at West Swale to reduce mass of dissolved VOCs remaining in saturated clay and sand layers prior to groundwater discharge to the swale and the lake. *Source Area and Plume:* ■ Groundwater monitoring to evaluate effectiveness of source area remediation and existing natural attenuation processes. ■ Compliance monitoring of groundwater and surface water under ROD and Consent Decree.	*Source Area:* ■ **Source South of Repository:** Vertical multiple-phase extraction (MPE) wells screened in upper clay layer and separate horizontal pumping wells screened in upper sand layer. ■ **Source Beneath Repository:** Vertical MPE wells screened in Repository fill material and upper clay layer, and separate horizontal pumping wells screened in upper sand layer. ■ Groundwater treatment using same system installed to treat I-1-23 groundwater. ■ Treated groundwater discharge to existing drainage ditch tributary to lake. *Plume:* ■ Planting of selected trees and plants across plume width along East Swale, to reduce mass of dissolved VOCs remaining prior to groundwater discharge to East Swale. *Source Area and Plume:* ■ Groundwater monitoring to evaluate effectiveness of source area remediation and existing natural attenuation processes. ■ Compliance monitoring of groundwater and surface water under ROD and Consent Decree.	*In situ* source physical removal with multiple-phase extraction (vapor and groundwater extraction) and monitored natural attenuation

Table 6-1 (continued)
Primary Components of Remedial Alternatives

ALTERNATIVE	SOURCE AREA AND ASSOCIATED PLUME			GENERAL TYPE OF TECHNOLOGY APPLIED
	BUILDING I-1-2	BUILDING I-1-23	REPOSITORY AREA	
F	*Source Area:* ■ Thermal (hot air) stripping of residual VOCs from saturated and unsaturated soil using MITU®. ■ Treatment of captured stripping vapors using gas-phase carbon. ■ Placement of VOC-stripped soil back into source area. ■ Horizontal dewatering wells screened in Upper Sand layer. ■ Groundwater treatment using mobile air stripping unit, liquid-phase carbon for effluent polishing, and gas-phase carbon for air stripping unit exhaust. ■ Treated groundwater discharge to existing drainage ditch tributary to lake. *Plume:* ■ Use of existing trees and plants in marsh/wetland area on east side of Hwy. 148 to reduce mass of dissolved VOCs remaining in saturated sand layer prior to groundwater discharge to intermittent stream. *Source Area and Plume:* ■ Groundwater monitoring to evaluate effectiveness of source area remediation and existing natural attenuation processes. ■ Compliance monitoring of groundwater and surface water under ROD and Consent Decree.	*Source Area:* ■ Thermal (hot air) stripping of residual VOCs from saturated and unsaturated soil using MITU®. ■ Treatment of captured stripping vapors using gas-phase carbon. ■ Placement of VOC-stripped soil back into source area. ■ Horizontal dewatering wells screened in Upper Sand layer. ■ Groundwater treatment using mobile air stripping unit, liquid-phase carbon for effluent polishing, and gas-phase carbon for air stripping unit exhaust. ■ Treated groundwater discharge to existing drainage ditch tributary to lake. *Plume:* ■ Planting of selected trees and plants along lake shoreline and at West Swale to reduce mass of dissolved VOCs remaining in saturated clay and sand layers prior to groundwater discharge to the swale and the lake. *Source Area and Plume:* ■ Groundwater monitoring to evaluate effectiveness of source area remediation and existing natural attenuation processes. ■ Compliance monitoring of groundwater and surface water under ROD and Consent Decree.	*Source Area:* **Source South of Repository:** ■ Thermal (hot air) stripping of residual VOCs from saturated and unsaturated soil using MITU®. ■ Treatment of captured stripping vapors using gas-phase carbon. ■ Placement of VOC-stripped soil back into source area. **Source Beneath Repository:** ■ Vertical multiple-phase extraction (MPE) wells screened in Repository fill material and upper clay layer, and separate horizontal pumping wells screened in upper sand layer. ■ Groundwater treatment using tray-type air stripping unit, liquid-phase carbon for effluent polishing, gas-phase carbon for air stripping unit exhaust and soil vapor from vacuum pump, housed in new treatment building located near Repository. ■ Treated groundwater discharge to existing drainage ditch tributary to lake *Plume:* ■ Planting of selected trees and plants across plume width along East Swale, to reduce mass of dissolved VOCs remaining prior to groundwater discharge to East Swale. *Source Area and Plume:* ■ Groundwater monitoring to evaluate effectiveness of source area remediation and existing natural attenuation processes. ■ Compliance monitoring of groundwater and surface water under ROD and Consent Decree.	Source physical removal with Mobile Injection Treatment Unit (MITU®) and monitored natural attenuation (for identified source areas except for beneath Repository) *In situ* source physical removal with multiple-phase extraction (vapor and groundwater extraction) and monitored natural attenuation (for source area beneath Repository)

Table 6-2
Summary of Assumed TCE Source Reductions Used for Transport Model Runs - Alternatives B through F

Alternative	Model Run[1]	Description	Source Area	Percent TCE Reduction[2]	TCE Concentration[3] (ug/L)	Time (years)	Comments
--	crab151	Calibration	--	--	--	--	Model calibration to existing conditions.
B	crab210	Monitored Natural Attenuation	I-1-23	50%	50,000	0-20	Lowered source-concentration due to PCB remedial action. No phytoremediation.
			I-1-2	25%	75,000	0-20	
			Repository	0%	20,000	0-20	

Alternative	Model Run	Description	Source Area	Percent Reduction from Alt. B	Concentration (ug/L)	Time (years)	Comments
C	crab 211	Phytoremediation	I-1-23	0%	50,000	0-3	Allows a 3-year time lag for source-concentrations in I-1-23 and I-1-2 source areas to be reduced. Includes phytoremediation in discharge areas.
				30%	35,000	3-20	
			I-1-2	0%	75,000	0-3	
				30%	52,500	3-20	
			Repository	0%	20,000	0-20	
D	crab212bd	Enhanced Bioremediation	I-1-23	19%	40,625	0-1	Zoned TCE half-lives in source areas for the first 3 years. Half-lives range from 1 month to 24 years. Set TCE half-life to 24 years for years 3-20 Includes phytoremediation in discharge areas.
				38%	31,250	1-2	
				56%	21,875	2-3	
				75%	12,500	3-20	
			I-1-2	19%	60,938	0-1	
				38%	46,875	1-2	
				56%	32,812	2-3	
				75%	18,750	3-20	
			Repository	0%	20,000	0-20	
E	crab213a	Multiple-Phase Extraction	I-1-23	100%	0	0-2	Assumes 100% recovery in source areas during the 2-year operation of the system. Includes phytoremediation in discharge areas.
				80%	10,000	2-20	
			I-1-2	100%	0	0-2	
				80%	15,000	2-20	
			Repository	100%	0	0-2	
				80%	4,000	2-20	
F	crab216	MITU	I-1-23	100%	0	0-0.33 (4 months)	Assumes 100% recovery in source areas in the first four months as a result of horizontal wells. Includes phytoremediation in discharge areas.
				95%	2,500	0.33-20	
			I-1-2	100%	0	0-0.33 (4 months)	
				95%	3,750	0.33-20	
			Repository	0%	0	0-2	
				80%	4,000	2-20	

Notes.
(1) Refer to Appendix G for model run documentation.
(2) Percent reduction in dissolved and sorbed TCE concentration in defined source area soil due to effects of the remedial alternative.
(3) TCE source area concentration in groundwater held constant during indicated time period.

Table 6-3
Sensitivity Testing, Predictive Simulations

RUN #	PARAMETER/ BOUNDARY CONDITION	CHANGE	RESULTS	
			MAX. CONC. AT N. ACCESS RD. (μg/L)	TOTAL MASS OF TCE IN AQUIFER (kg)
Crab 213a (multi-phase extraction) (Base Case #1)	--	--	300	200
Crab 224	Constant concentration node values - for multi-phase extraction	Assume no decrease following soil excavation; keep at 100 mg/L	682	304
Crab 211 (phytoremediation base case)	--	--	1,028	598
Crab 226	Constant concentration node values - for phytoremediation	Assume no decrease following soil excavation; keep at 100 mg/L	2,102	900

TABLE 8-1
SUMMARY OF REMEDIAL ALTERNATIVE COSTS

ALTERNATIVE	ESTIMATED PROBABLE COSTS FOR SOURCE AREA AND ASSOCIATED PLU			PROBABLE COST RANGE
	BUILDING I-1-2	BUILDING I-1-23	REPOSITORY AREA	(-30% to +50%)
A No Action / Compliance Monitoring (CM)				
Capital Costs	1,900	1,900	1,900	$5,000 to $9,000
Annual OM&M Costs				
•Short Term (not applicable)	-	-	-	-
•Long Term*	35,400	35,400	35,400	$75,000 to $161,000
Present Worth	-	-	-	$935,000 to $2,003,000
B Monitored Natural Attenuation (MNA)				
Capital Costs	9,100	9,100	9,100	$20,000 to $41,000
Annual OM&M Costs				
•Short Term (First 2 years)	47,300	47,300	47,300	$101,000 to $215,000
•Long Term*	41,000	41,000	41,000	$87,000 to $187,000
Present Worth	-	-	-	$1,122,000 to $2,403,000
C Phytoremediation				
Capital Costs	160,000	391,100	337,800	$623,000 to $1,334,000
Annual OM&M Costs				
•Short Term (First 2 years)	36,200	88,400	76,300	$141,000 to $302,000
•Long Term*	33,100	80,900	69,800	$129,000 to $276,000
Present Worth	-	-	-	$2,240,000 to $4,799,000

* Long-term annual operation, maintenance, and monitoring beginning after completion of short-term source area remedial action.
"Present Worth" represents total capital cost plus present worth of all annual costs for 30 years at 7% discount rate.

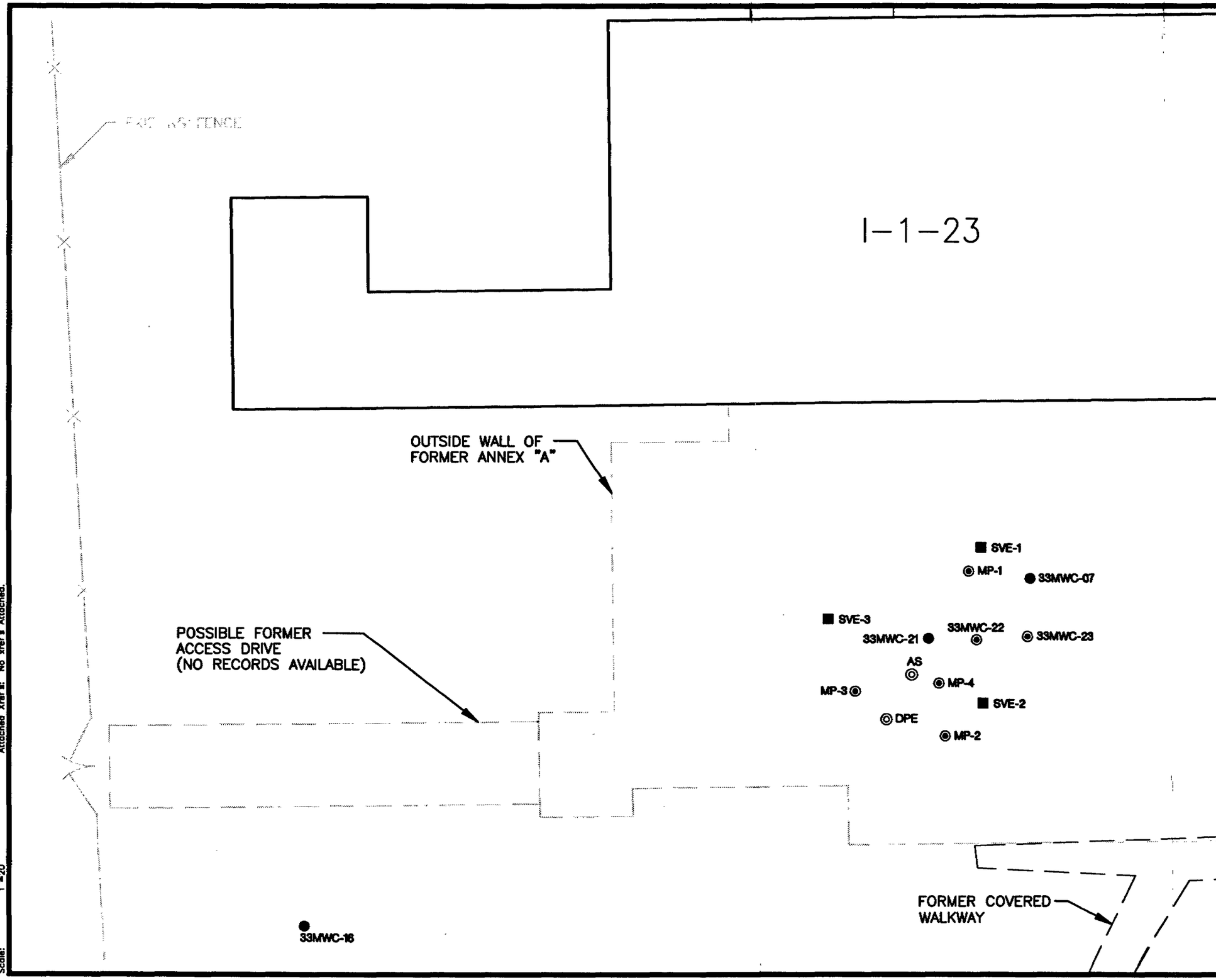
39

TABLE 8-1 (cont'd)
SUMMARY OF REMEDIAL ALTERNATIVE COSTS

ALTERNATIVE	ESTIMATED PROBABLE COSTS FOR SOURCE AREA AND ASSOCIATED PLU			PROBABLE COST RANGE
	BUILDING I-1-2	BUILDING I-1-23	REPOSITORY AREA	(-30% to +50%)
D Enhanced In Situ Bioremediation				
Capital Costs	325,300	457,900	421,700	$844,000 to $1,808,000
Annual OM&M Costs				
•Short Term (First 2 years)	66,800	94,000	86,600	$174,000 to $372,000
•Long Term*	44,500	62,600	57,600	$116,000 to $247,000
Present Worth	-	-	-	$2,378,000 to $5,096,000
E Multiple Phase Extraction (MPE)				
Capital Costs	430,100	645,100	1,075,200	$1,506,000 to $3,226,000
Annual OM&M Costs				
•Short Term (First 2 years)	52,200	78,200	130,300	$183,000 to $391,000
•Long Term*	32,900	49,400	82,300	$116,000 to $247,000
Present Worth	-	-	-	$3,057,000 to $6,549,000
F Physical/Thermal Removal (MITU®)				
Capital Costs	1,758,100	1,758,100	2,241,500	$3,730,000 to $7,991,000
Annual OM&M Costs				
•Short Term (First 2 years)	59,300	59,300	115,200	$165,000 to $354,000
•Long Term*	54,300	54,300	54,300	$116,000 to $247,000
Present Worth	-	-	-	$5,249,000 to $11,247,000

* Long-term annual operation, maintenance, and monitoring beginning after completion of short-term source area remedial action.
"Present Worth" represents total capital cost plus present worth of all annual costs for 30 years at 7% discount rate.

46



LEGEND

● 33MWC-21	GROUNDWATER MONITORING WELL (2")
◉ MP-1	MONITORING POINT (2")
■ SVE-2	SOIL VAPOR EXTRACTION WELL (2")
◎ DPE	DUAL PHASE EXTRACTION WELL (4")
◎ AS	AIR SPARGING WELL (4")

0 20' 40'

SCALE: 1" = 20'

PILOT TEST WELL LOCATIONS
BUILDING I-1-23

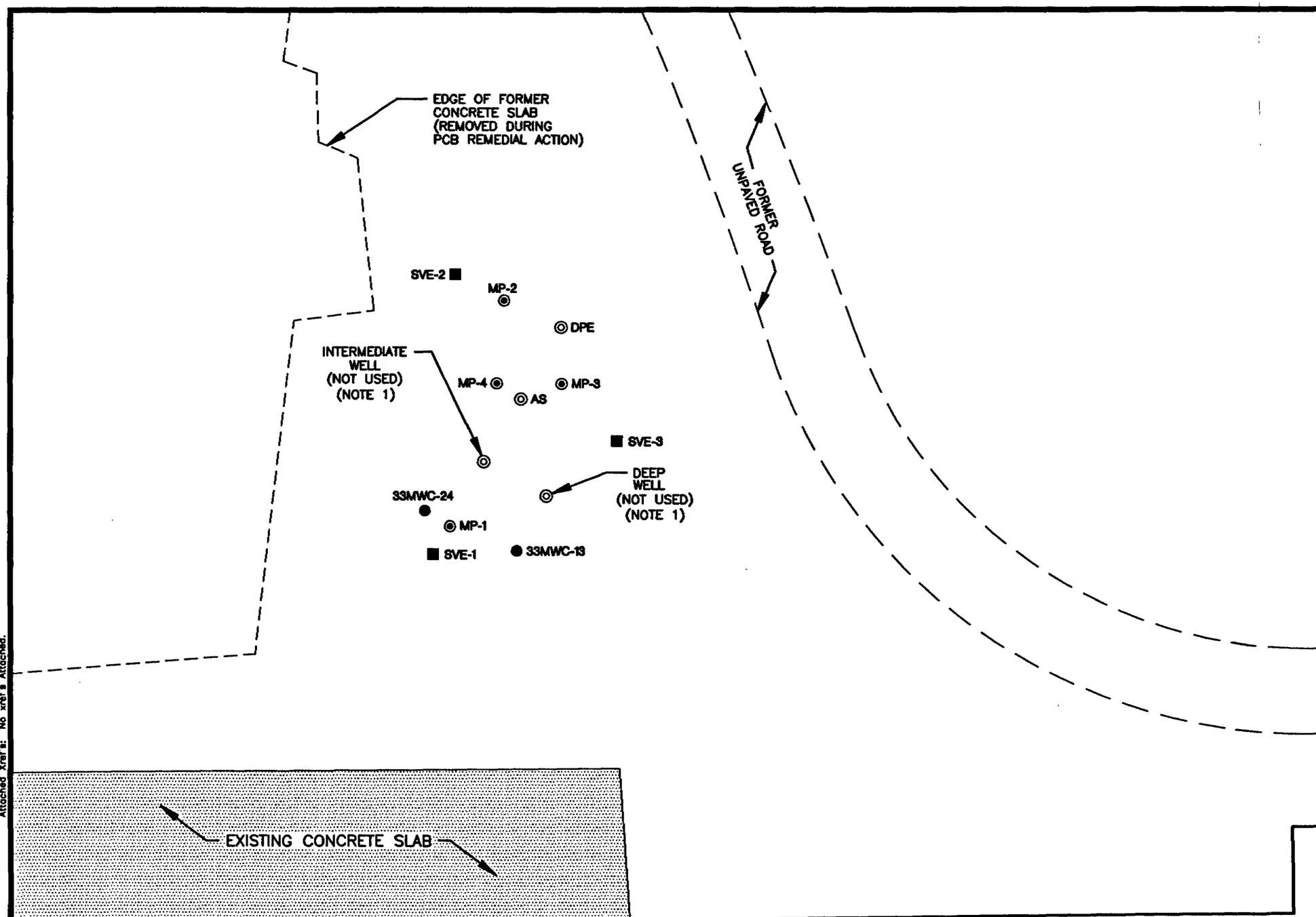
CRAB ORCHARD NWR - PCB O.U.
MARION, ILLINOIS

RMT.

DWN. BY:	BREWSTEK
APPROVED BY:	TEG
DATE:	JANUARY 2000
PROJ. #	4781.03
FILE #	47810329.DWG

FIGURE 4-1

PLOT DATA
Drawing Name: J:\04781\03\47810329.dwg
Operator Name: BREWSTEK
Scale: 1"=20'
Dwg Size: 540697 Bytes
Plot Date: Tuesday, January 11, 2000
Plot Time: 4:04:29 PM
Attached Xref's: No xref's Attached.



I-1-2

LEGEND

● 33MWC-24	GROUNDWATER MONITORING WELL (2")
◉ MP-2	MONITORING POINT (2")
■ SVE-1	SOIL VAPOR EXTRACTION WELL (2")
◎ DPE	DUAL PHASE EXTRACTION WELL (4")
◎ AS	AIR SPARGING WELL (4")

NOTES

1. WELL CASING CUT-OFF APPROXIMATELY 1 FOOT ABOVE GROUND AND COVER PLATE WELDED TO OPENING.

0 20' 40'

SCALE: 1"=20'

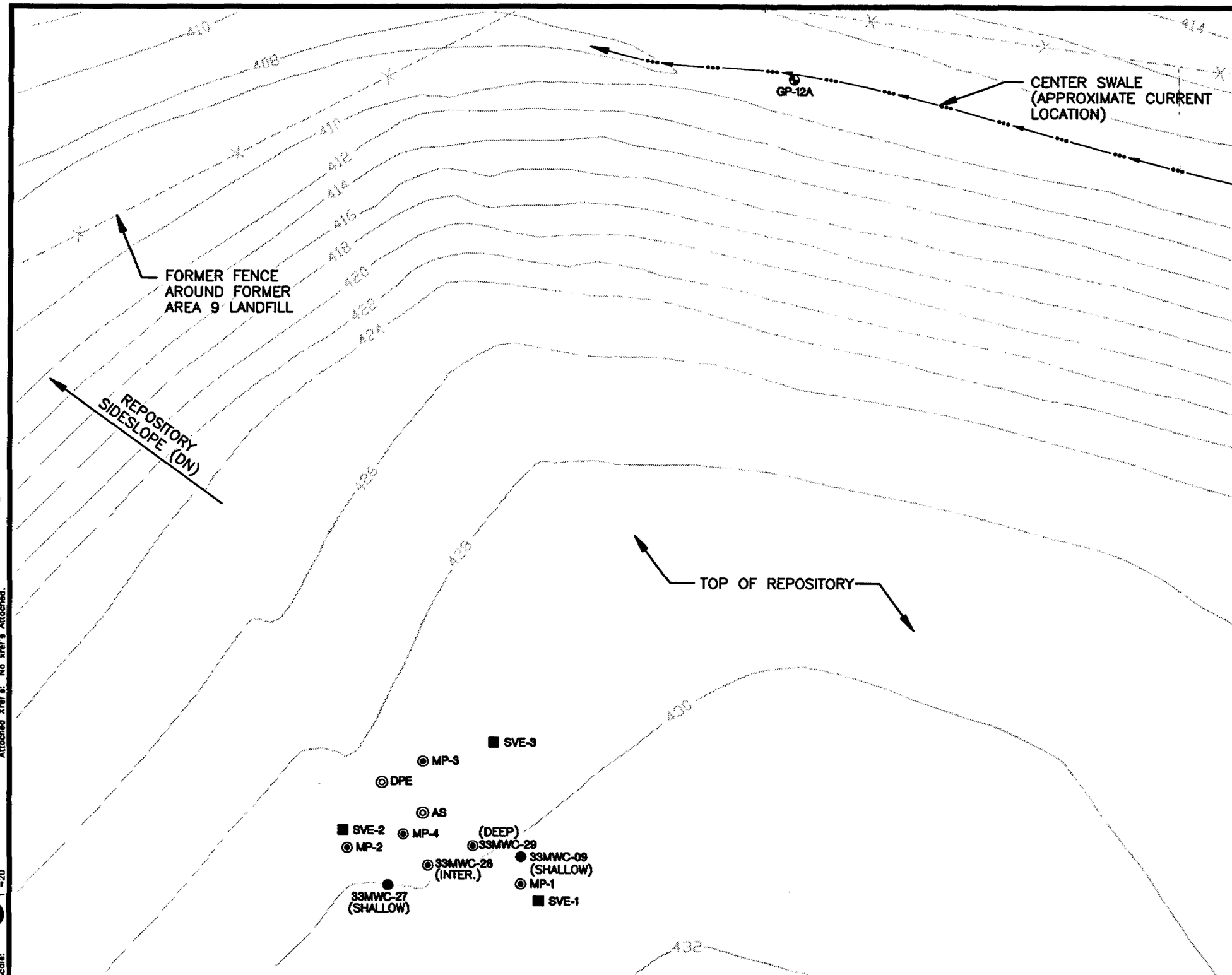
PILOT TEST WELL LOCATIONS
BUILDING I-1-2
CRAB ORCHARD NWR - PCB O.U.
MARION, ILLINOIS

RMT.

DWN. BY:	BREWSTEK
APPROVED BY:	TEG
DATE:	JANUARY 2000
PROJ. #	4781.03
FILE #	47810330.DWG

FIGURE 4-2

PLOT DATA
Drawing: J:\04781\03\47810330.dwg
Operator: BREWSTEK
Scale: 1"=20'
Dwg Size: 254429 Bytes
Plot Date: Tuesday, January 11, 2000
Plot Time: 4:01:00:40 PM
Attached Xref's: No xref's Attached.



LEGEND

● 33MWC-27	GROUNDWATER MONITORING WELL (2")
◉ MP-2	MONITORING POINT (2")
■ SVE-1	SOIL VAPOR EXTRACTION WELL (2")
◎ DPE	DUAL PHASE EXTRACTION WELL (4")
◎ AS	AIR SPARGING WELL (4")
⊕ GP-12A	GEOPROBE BORING LOCATION (1998)

0 20' 40'

SCALE: 1" = 20'

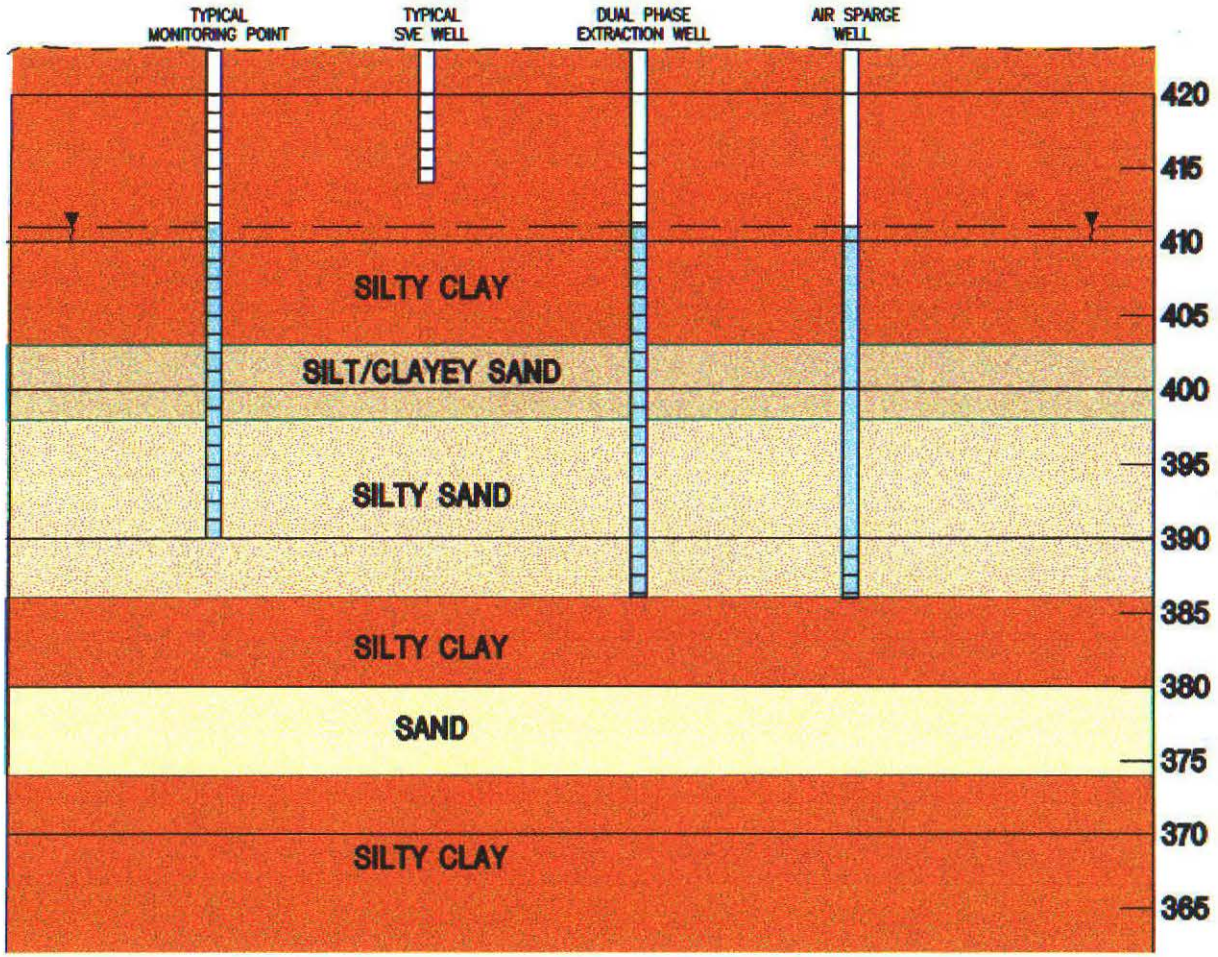
PILOT TEST WELL LOCATIONS
AREA 9 REPOSITORY
CRAB ORCHARD NWR - PCB O.U.
MARION, ILLINOIS

RMT.

DWN. BY:	SIEWERTD
APPROVED BY:	TEG
DATE:	JANUARY 2000
PROJ. #	4781.03
FILE #	47810331.DWG

FIGURE 4-3

PLOT DATA
Drawing Name: J:\04781\03\47810331.dwg
Operator Name: SIEWERTD
Scale: 1"=20'
Dwg Size: 1960237 Bytes
Plot Date: Thursday, December 30, 1999
Plot Time: 11:03:54a2 AM
Attached Xref's: No xref's Attached.



LEGEND

WATER TABLE SURFACE

EXISTING GROUND SURFACE

WELL SCREEN LOCATION

NOTES

1. PILOT TEST WELLS ARE SCREENED MOSTLY IN SOIL THAT WAS NOT DISTURBED DURING THE PCB REMEDIAL ACTION.

VERTICAL SCALE 0 5 10

NO HORIZONTAL SCALE

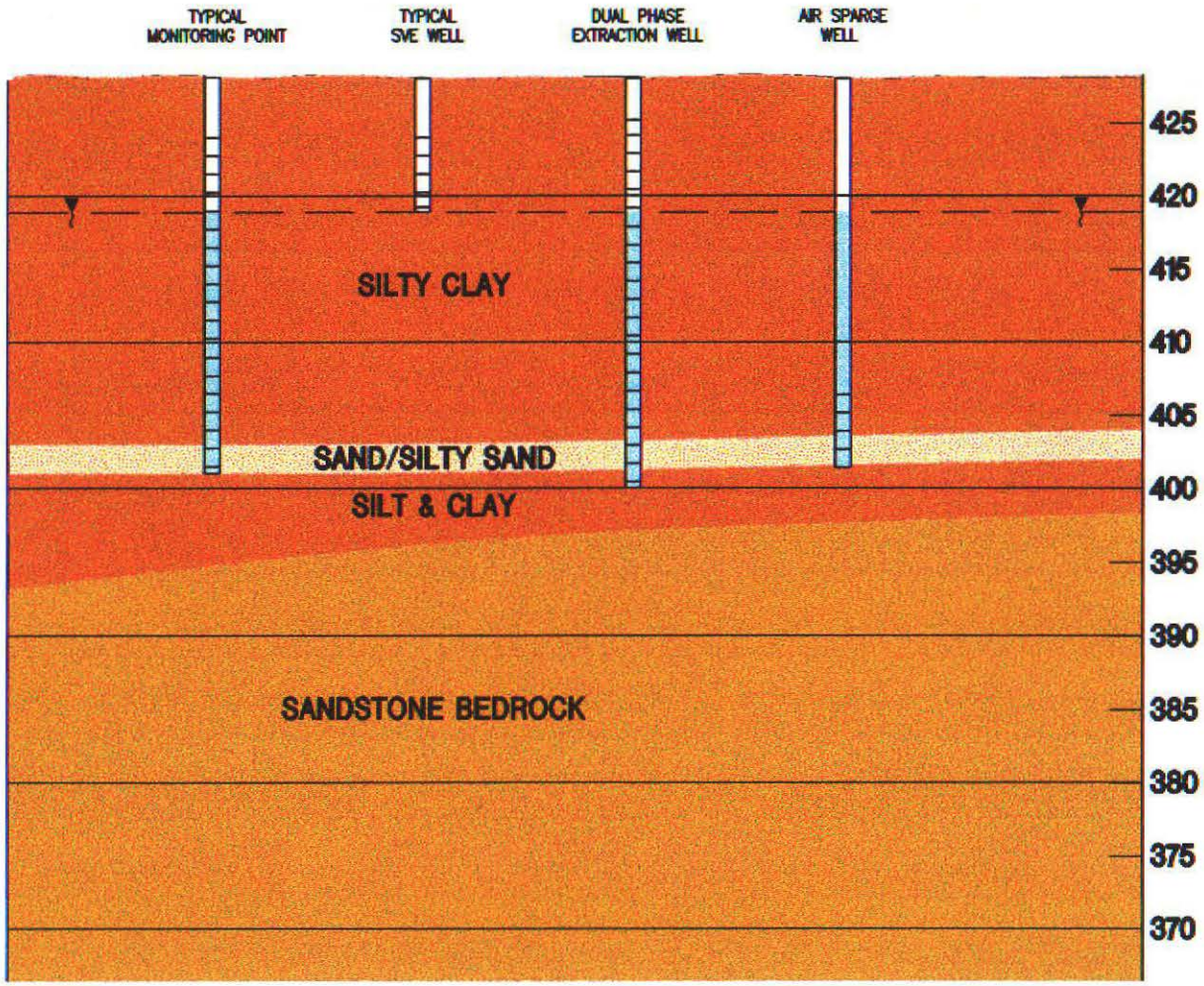
GENERALIZED STRATIGRAPHY AND PILOT TEST WELL SCREEN LOCATIONS
BUILDING I-1-23
CRAB ORCHARD NWR PCB O.U.
MARION, ILLINOIS

RMT INC.

DWN. BY: BREWSTEK
APPROVED BY: TEG
DATE: JANUARY 2000
PROJ. # 4781.03
FILE # 8X111123.DWG

FIGURE 4-4

PLOT_INFO
Drawing Name: J:\04781\03\8X111123.dwg
Operator Name: BREWSTEK
Scale: 1"=10'
Dwg Size: 240030 Bytes
Plot Date: Tuesday, January 11, 2000
Plot Time: 3:38:38p PM
Attached Xref's: No Xref's Attached.



LEGEND

WATER TABLE SURFACE

EXISTING GROUND SURFACE

WELL SCREEN LOCATION

NOTES

1. PILOT TEST WELLS WERE INSTALLED IN AREA WHERE PCB EXCAVATION OCCURRED TO APPROX. 7'-8' BGS. (420')

VERTICAL SCALE 0 5 10

NO HORIZONTAL SCALE

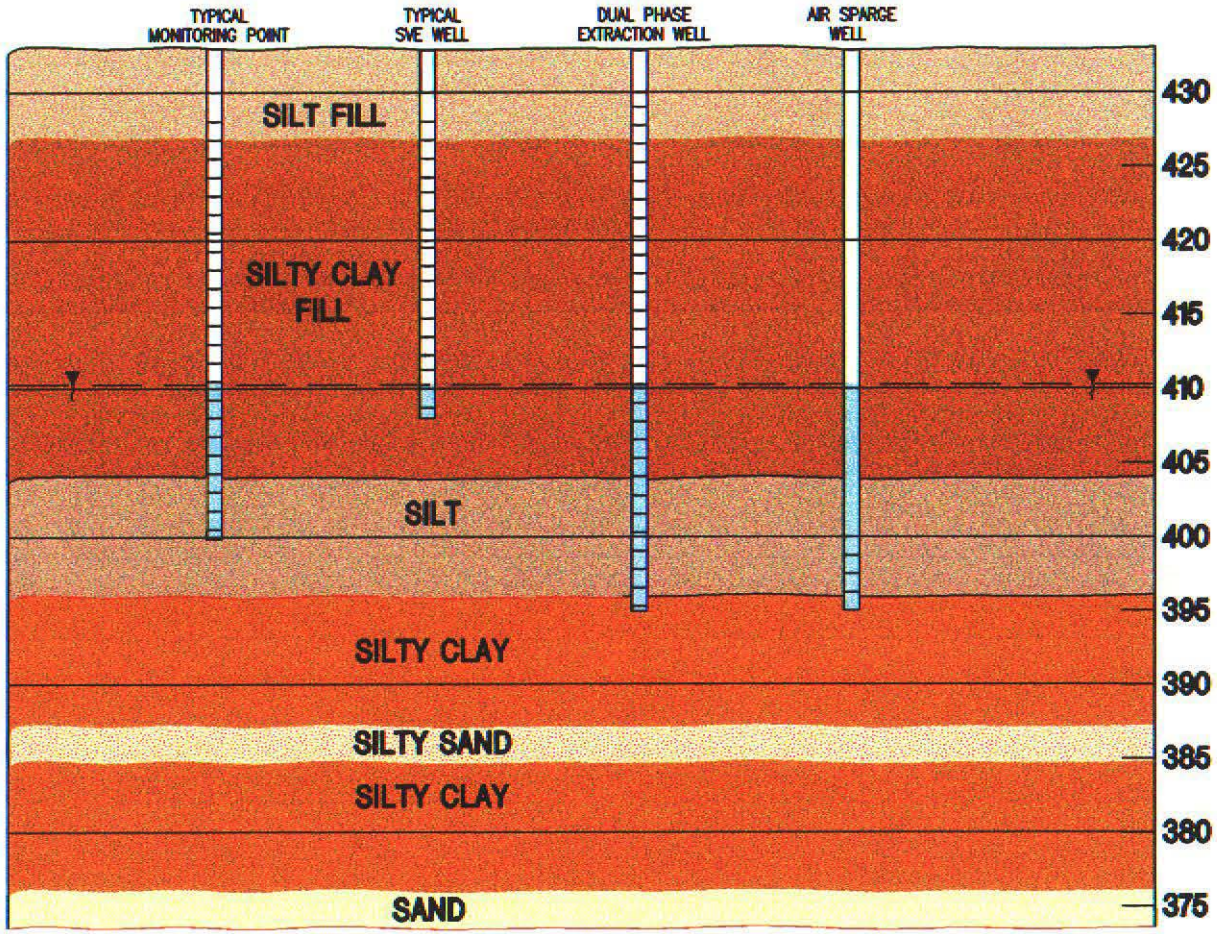
GENERALIZED STRATIGRAPHY AND PILOT TEST WELL SCREEN LOCATIONS
BUILDING I-1-2
CRAB ORCHARD NWR PCB O.U.
MARION, ILLINOIS

RMT INC.

DWN. BY:	SIEWERTD
APPROVED BY:	TEG
DATE:	JANUARY 2000
PROJ. #	4781.03
FILE #	I12.DWG

FIGURE 4-5

PLOT DATA
Drawing Name: J:\04781\03\I12.dwg
Operator Name: SIEWERTD
Scale: 1"=10'
Dwg Size: 138317 Bytes
Plot Date: Tuesday, July 13, 1999
Plot Time: 08:02:20:20 AM
Attached Xref's: No xref's Attached.



LEGEND

WATER TABLE SURFACE

EXISTING GROUND SURFACE AT TOP OF REPOSITORY.

WELL SCREEN LOCATION

NOTES

1. PILOT TEST WELLS WERE INSTALLED THROUGH LOW-LEVEL PCB SOIL FILL INTO AN AREA THAT WAS EXCAVATED TO 4 FT. BELOW ORIGINAL GROUND SURFACE (TO ELEV. 406' +/-).

VERTICAL SCALE 0 5 10

NO HORIZONTAL SCALE

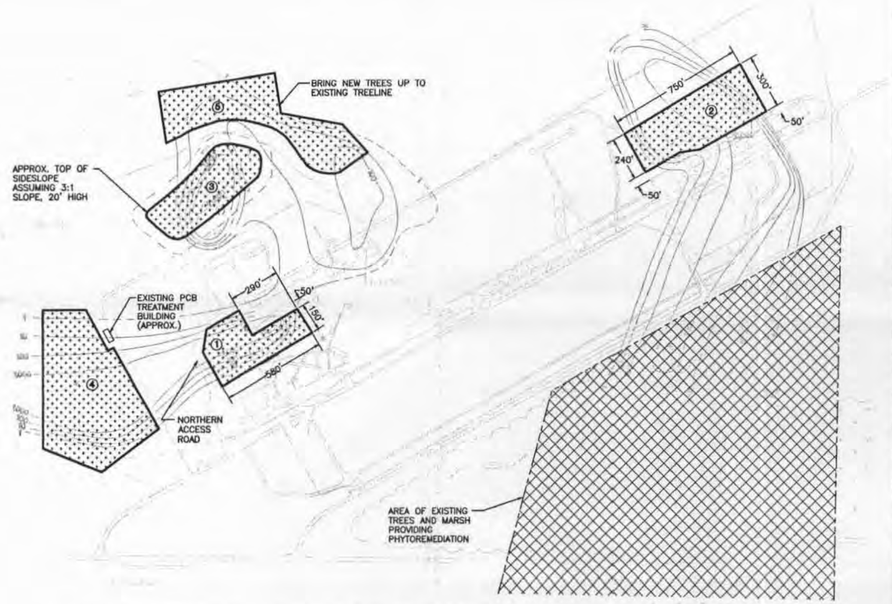
GENERALIZED STRATIGRAPHY AND PILOT TEST WELL SCREEN LOCATIONS
AREA 9 REPOSITORY
CRAB ORCHARD NWR PCB O.U.
MARION, ILLINOIS

RMT INC.

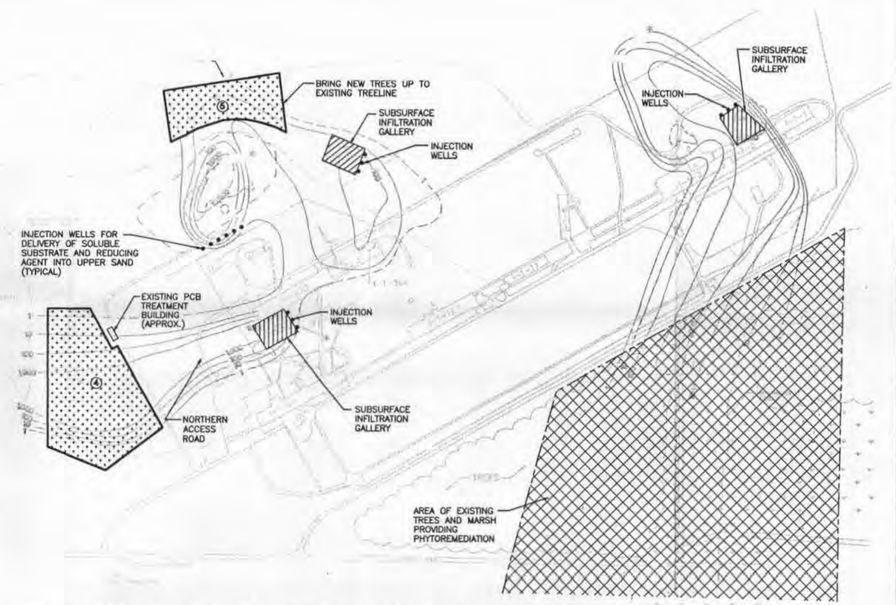
DWN. BY:	BREWSTEK
APPROVED BY:	TEG
DATE:	JANUARY 2000
PROJ. #	4781.03
FILE #	AREA9.DWG

FIGURE 4-6

PLOT DATA
Drawing Name: J:\04781\03\AREA9.dwg
Operator Name: BREWSTEK
Scale: 1"=10'
Dwg Size: 311199 Bytes
Plot Date: Tuesday, January 11, 2000
Plot Time: 3:46:30:03 PM
Attached Xref's: No xref's Attached.



ALTERNATIVE C - PHYTOREMEDIATION WITH MNA



ALTERNATIVE D - IN SITU ENHANCED BIOREMEDIATION WITH PHYTOREMEDIATION AND MNA

LEGEND

- APPROXIMATE CENTERLINE OF SURFACE DRAINAGE CHANNEL/SWALE
- FENCE
- APPROXIMATE LIMITS OF SOIL EXCAVATION
- APPROXIMATE FOOTPRINT OF AREA 9 REPOSITORY
- 10 — TCE ISOCONCENTRATION CONTOUR (ppb) (DASHED WHERE INFERRED)
- AREAS TO BE PLANTED WITH HYBRID POPLAR TREES (~ 1,500 TREES/ACRE)

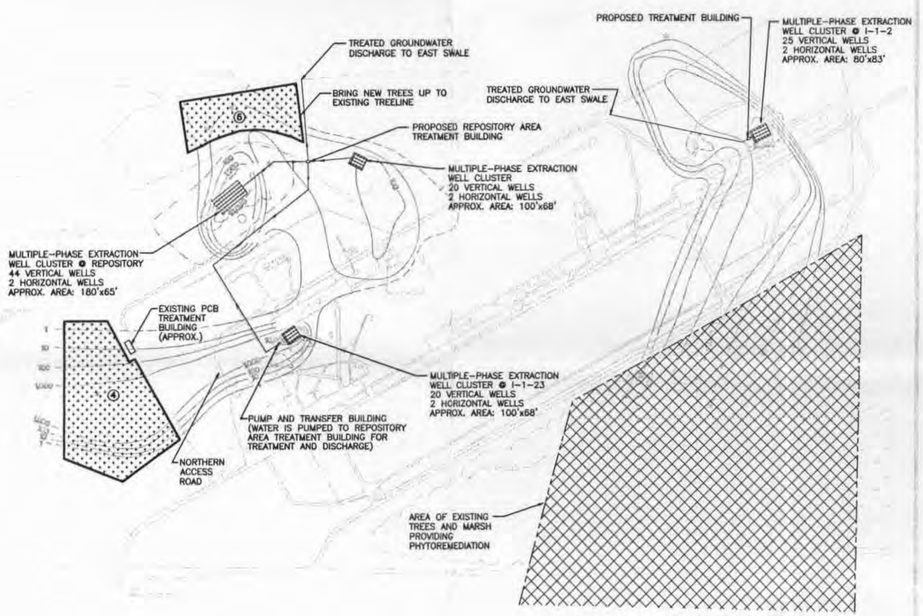
NOTES

1. SOURCE: BASE MAP FROM "1998 TCE INVESTIGATION, WORKPLAN AND PILOT STUDY FOR THE PCB OPERABLE UNIT AT THE CRAB ORCHARD NATIONAL WILDLIFE REFUGE SUPERFUND SITE, MARION, ILLINOIS" REV. 1, MAY 1998, PREPARED BY FLUOR DANIEL GTI.
2. ✳ INDICATES WELL IS SCREENED ACROSS THE UPPER SAND UNIT. OTHER BORINGS AND MONITORING WELLS ARE COMPLETED IN THE UPPER CLAY AND OR THE UPPERMOST PORTION OF THE UPPER SAND UNITS.
3. CVOC DATA FOR THE MONITORING WELLS ARE FROM THE DECEMBER 1998 SAMPLING EVENT. CVOC DATA FOR THE GEOPROBE LOCATIONS ARE FROM MAY THROUGH JULY 1998.
4. MNA = MONITORED NATURAL ATTENUATION

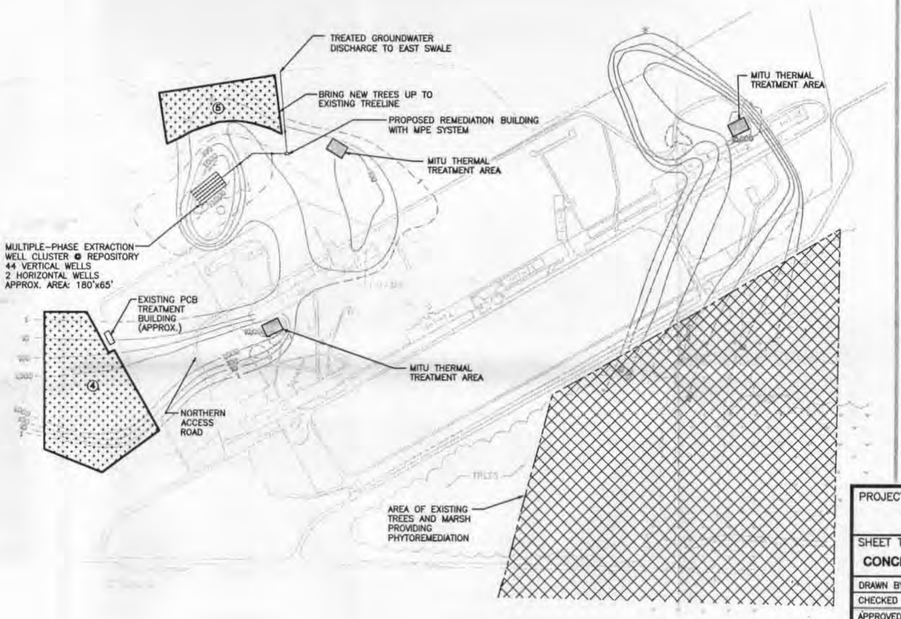
   MPE = MULTIPLE-PHASE EXTRACTION

   MITU = MOBILE INJECTION TREATMENT UNIT®

0 400' 800'
SCALE: 1"= 400'



ALTERNATIVE E - MULTIPLE-PHASE EXTRACTION (MPE) WITH PHYTOREMEDIATION AND MNA

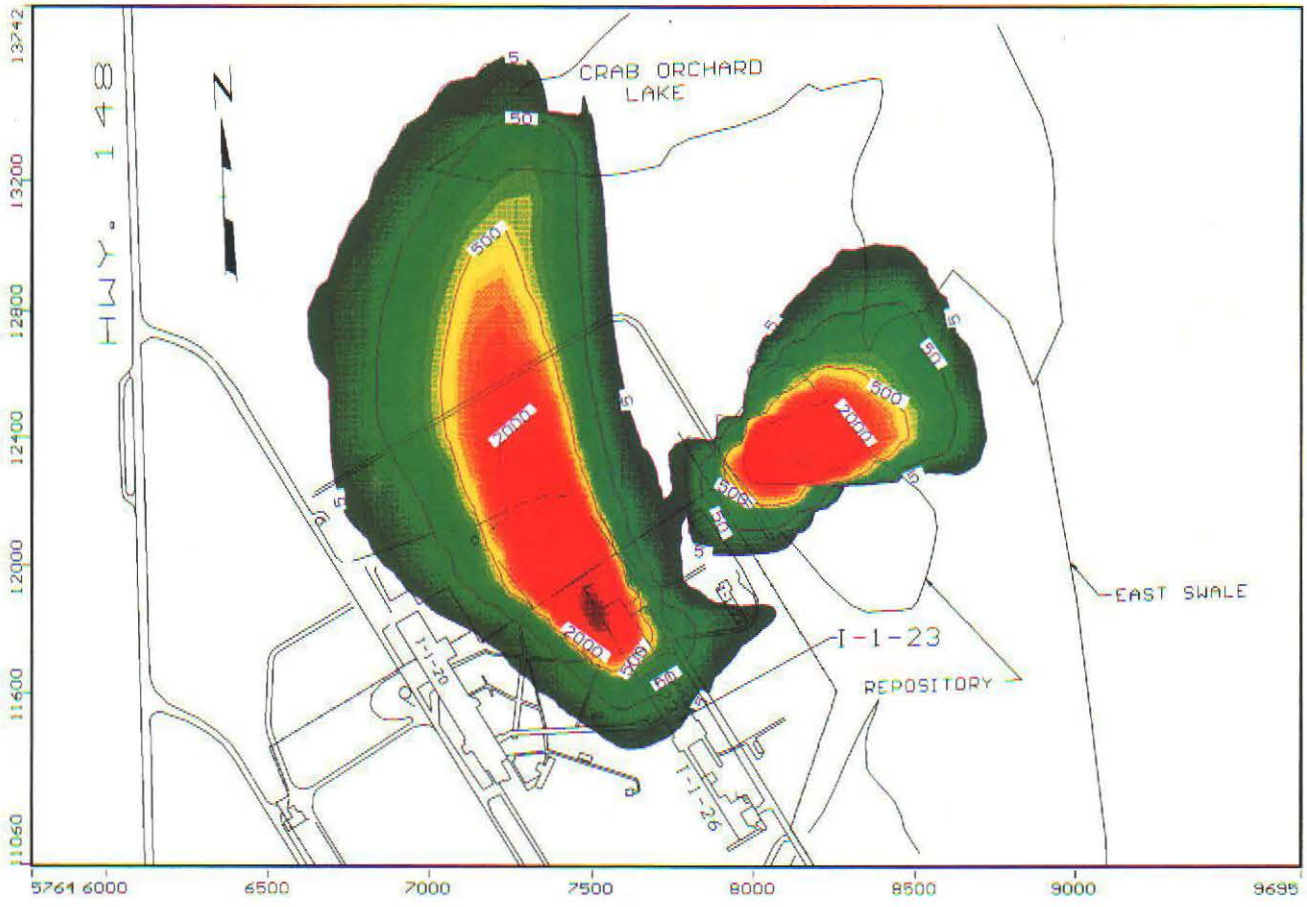


ALTERNATIVE F - THERMAL SOIL TREATMENT WITH MITU,® PHYTOREMEDIATION AND MNA (MPE AT AREA 9 REPOSITORY)

PROJECT: CRAB ORCHARD NWR - PCB O.U. GROUNDWATER INVESTIGATION REPORT & FOCUSED FEASIBILITY STUDY		
SHEET TITLE: CONCEPTUAL DESIGN - REMEDIAL ALTERNATIVES C-F		
DRAWN BY: BREWSTEK	SCALE:	PROJ. NO. 4781.03
CHECKED BY: TEG	1"=400'	FILE NO. 47810328.DWG
APPROVED BY: TEG	DATE PRINTED:	FIGURE 6-1
DATE: JANUARY 2000	JAN 13 2000	

RMT, Inc.
744 Heartland Trail
Madison, WI 53717-1934
P.O. Box 8923
Madison, WI 53708-8923
Phone: 608/831-4444

RMT COMPUTER AIDED DESIGN & DRAFTING



RMT
Project: CRAB ORCHARD Crab210
Description: Natural Attenuation 20yr
Modeller: GK Contours TCE, ppb
10 May 99

Visual MODFLOW v.2.7.2, (C) 1995–1997
Waterloo Hydrogeologic, Inc.
NC: 90 NR: 104 NL: 5
Current Layer: 2

Figure 6-2

Monitored Natural Attenuation - Alternative B
Predicted TCE Concentrations at 20 Years

Figure 6-3

Predicted TCE Concentration in Groundwater Near Crab Orchard Lake (I-1-23 Plume) vs. Time

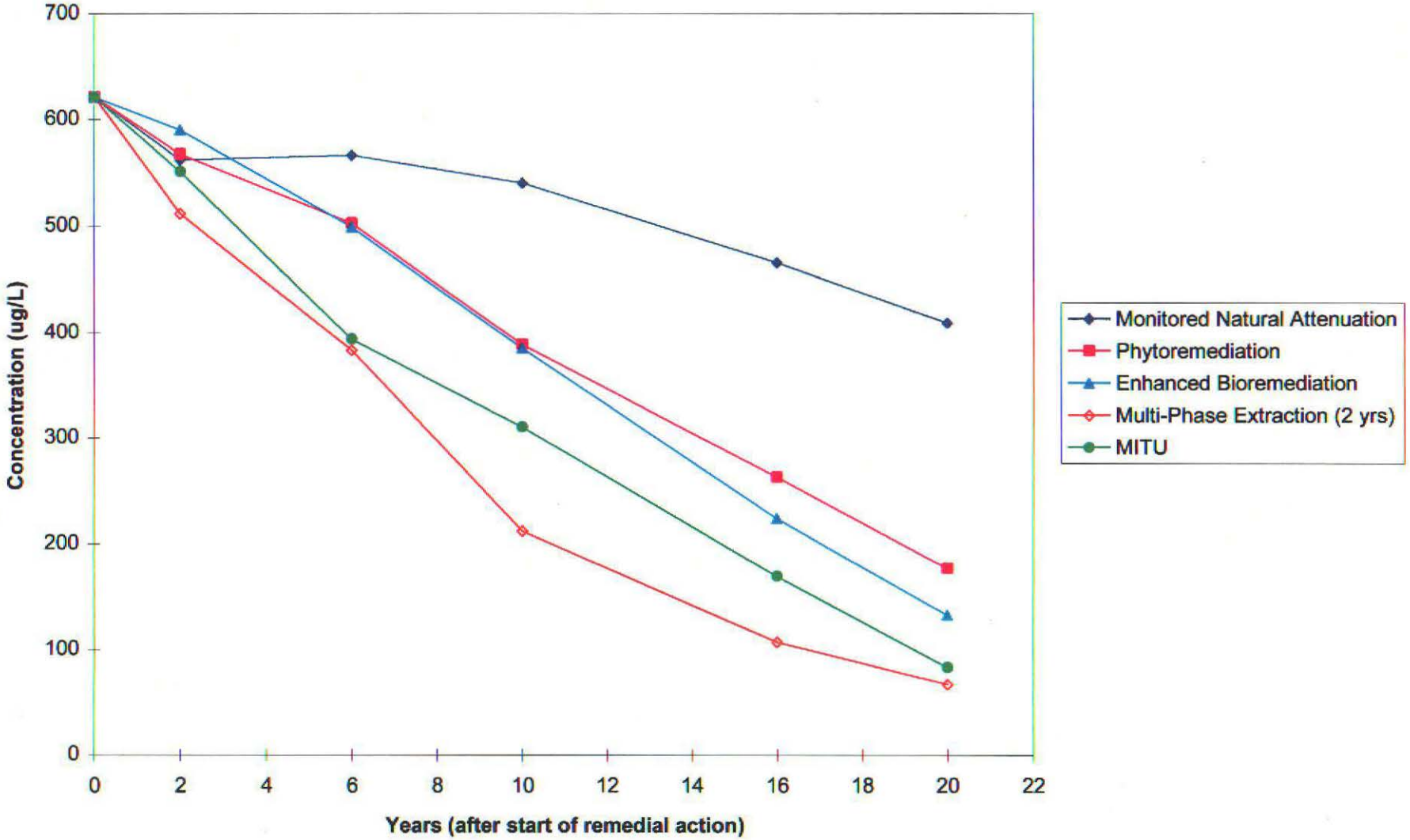
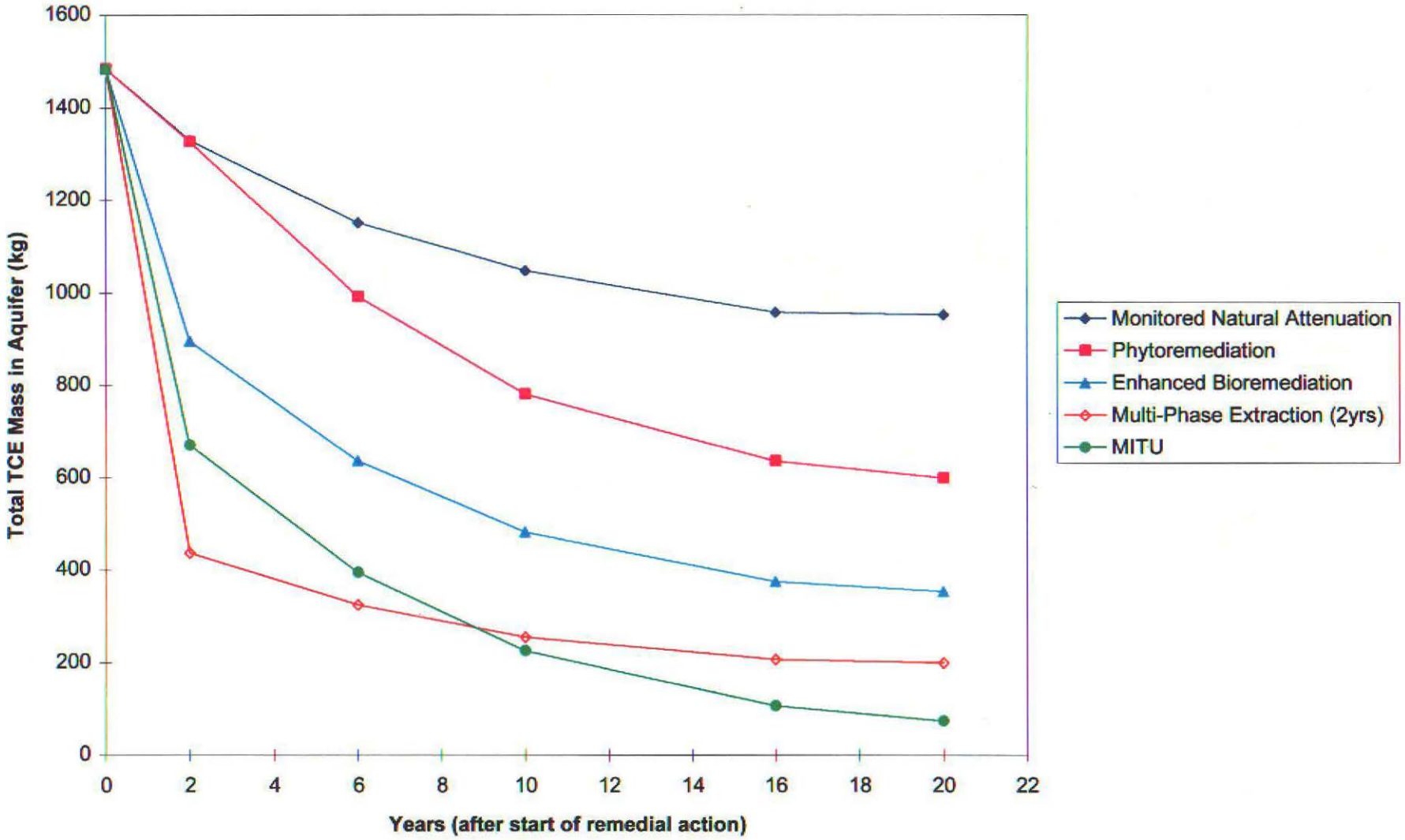
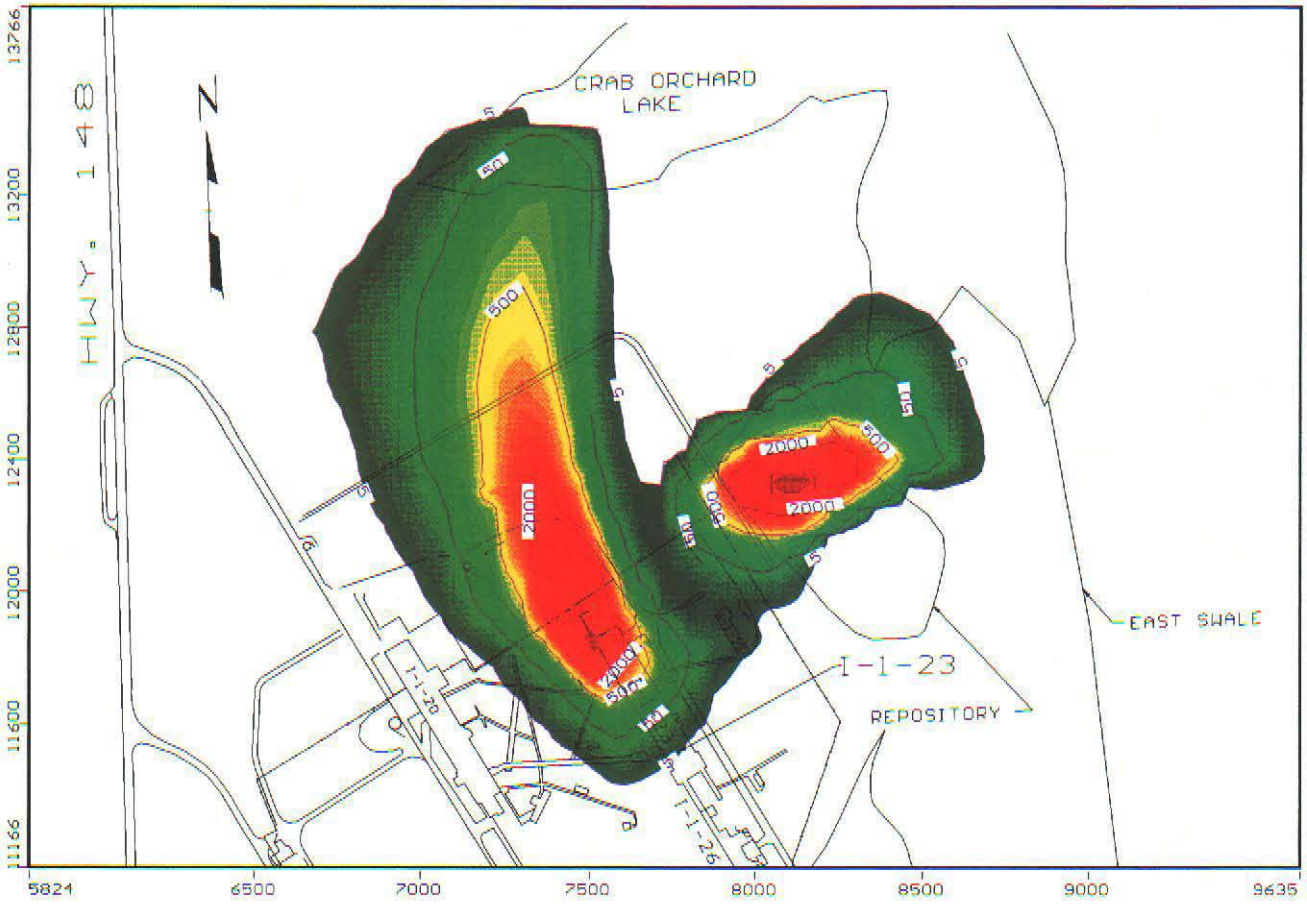


Figure 6- 4

Predicted TCE Mass in Sites 32/33 Aquifer vs. Time

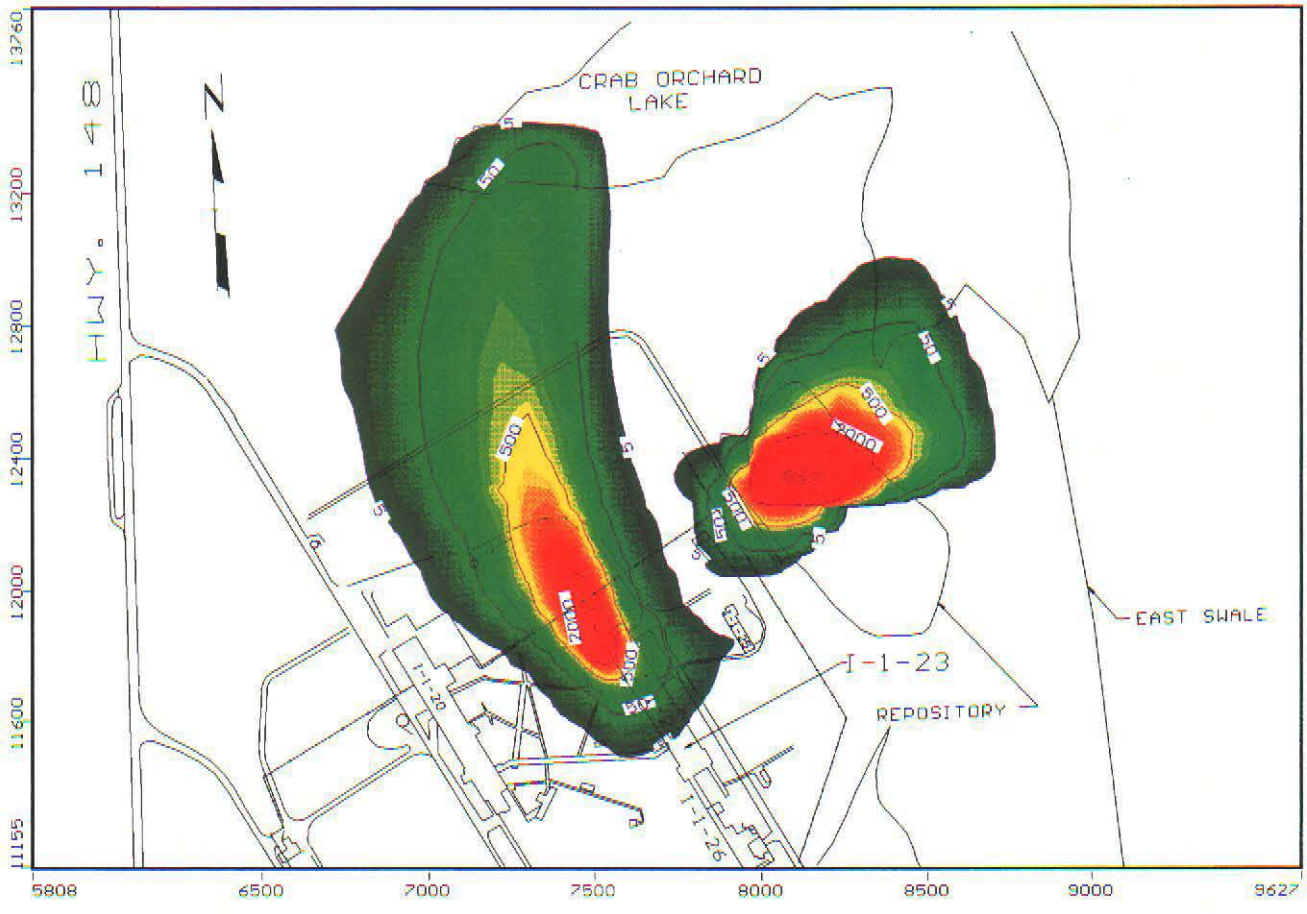




RMT Project: CRAB ORCHARD Crab211 Description: Phytoremediation 20 yrs Modeller: GK Contours TCE, ppb 10 May 99	Visual MODFLOW v.2.7.2, (C) 1995–1997 Waterloo Hydrogeologic, Inc. NC: 90 NR: 104 NL: 5 Current Layer: 2

Figure 6-5

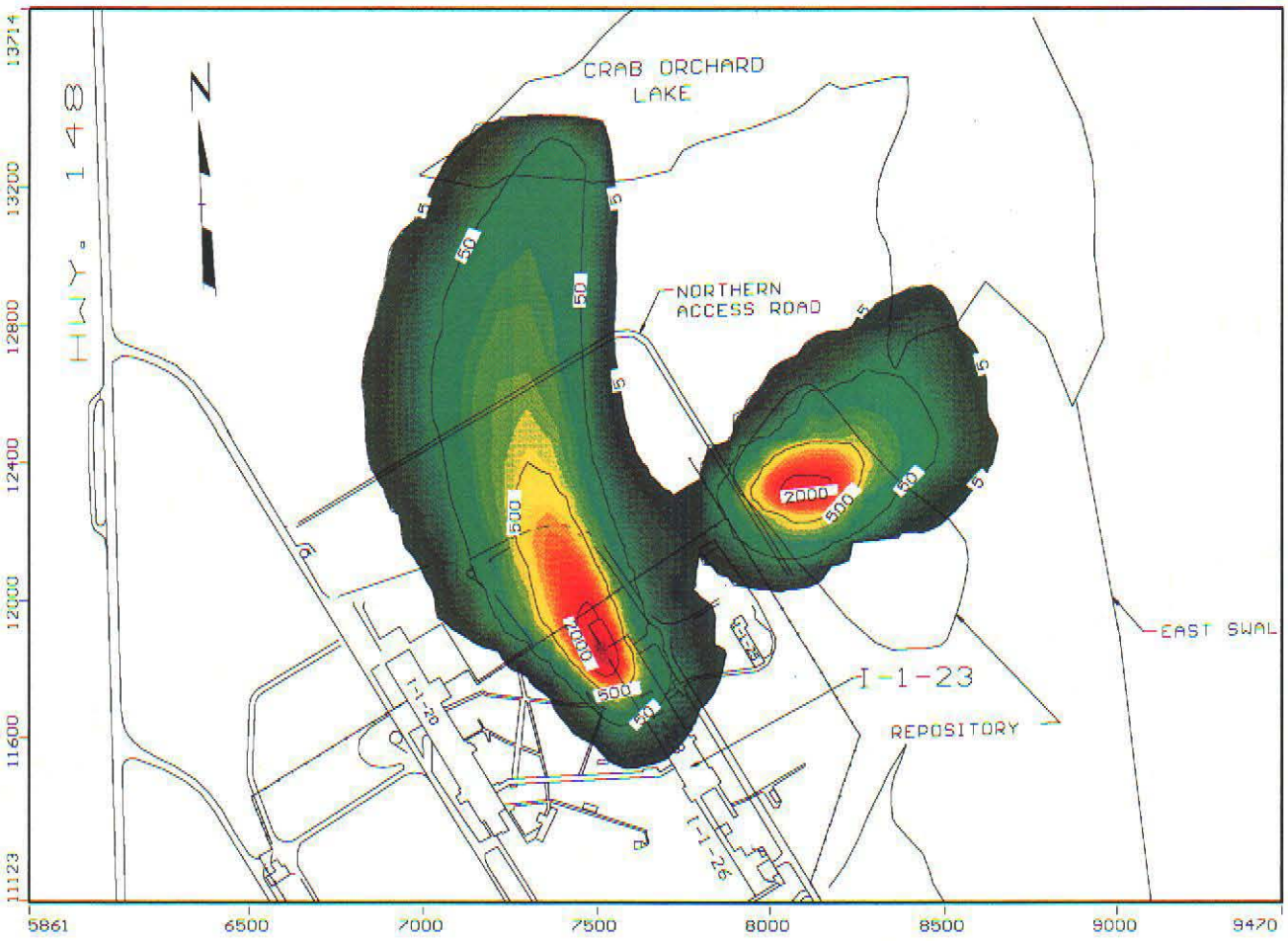
Phytoremediation – Alternative C
Predicted TCE Concentrations at 20 Years



RMT Project: CRAB ORCHARD Crab212bd Description: Enhanced Bioremed., 20 yr Modeller: GK Contours TCE, ppb 10 May 99	Visual MODFLOW v.2.7.2, (C) 1995-1997 Waterloo Hydrogeologic, Inc. NC: 90 NR: 104 NL: 5 Current Layer: 2

Figure 6-6

Enhanced Bioremediation - Alternative D
Predicted TCE Concentrations at 20 Years



rmt Project: CRAB ORCHARD Description: Multi-Phase Extract, 2 yr Modeller: GK Contours TCE, ppb 11 Jan 00	Visual MODFLOW v.2.7.2, (C) 1995-1997 Waterloo Hydrogeologic, Inc. NC: 90 NR: 104 NL: 5 Current Layer: 2

Figure 6-7

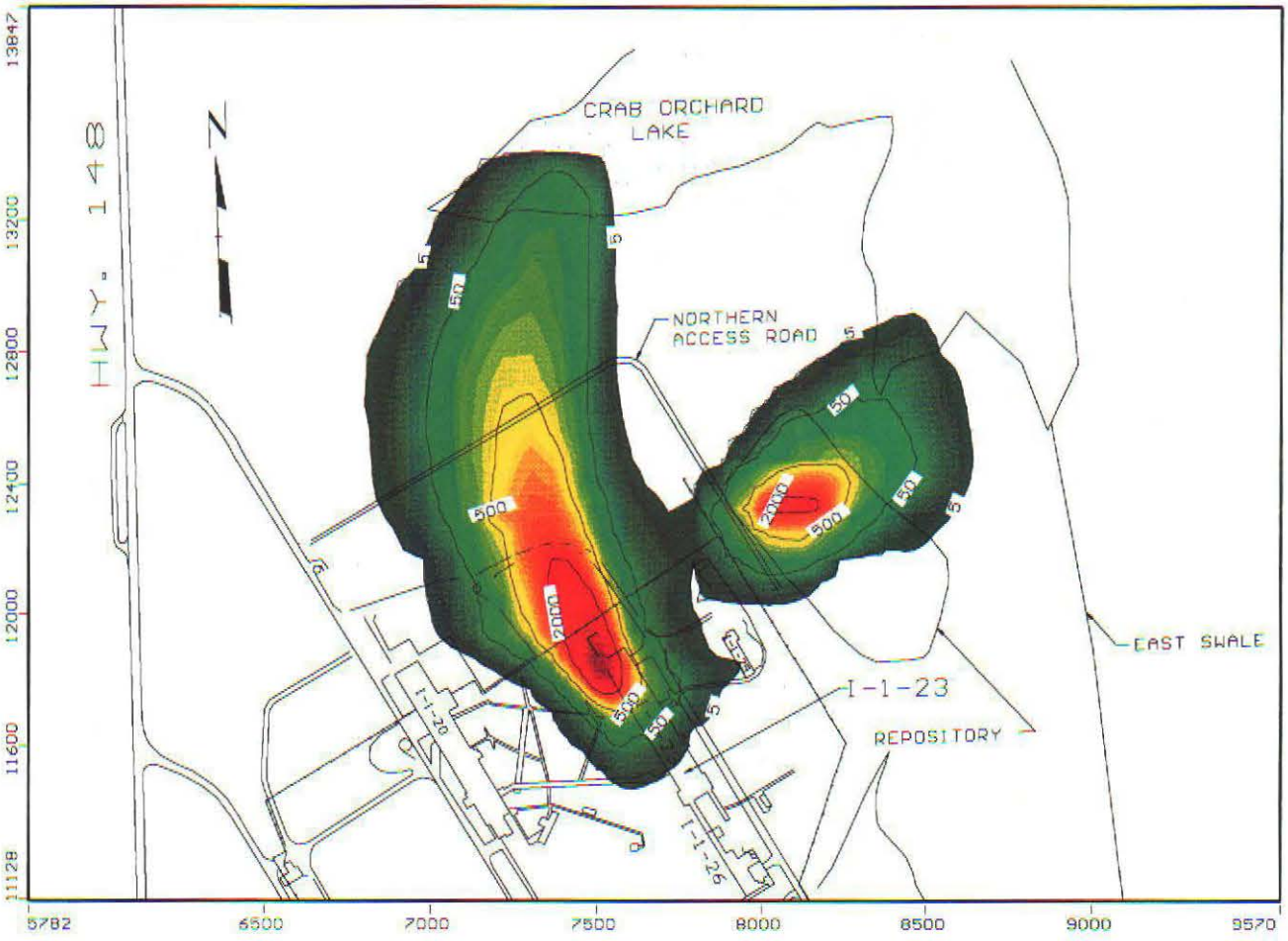
Multi-Phase Extraction – Alternative E,
Predicted TCE Concentrations at 20 years, after 2 years of MPE

RMT
Project: CRAB ORCHARD Crab216
Description: MITU 20 yrs
Modeller: GK Contours TCE, ppb
10 May 99

Visual MODFLOW v.2.7.2, (C) 1995–1997
Waterloo Hydrogeologic, Inc.
NC: 90 NR: 104 NL: 5
Current Layer: 2

Figure 6-8

Mobile Injection Treatment Unit – Alternative F
Predicted TCE Concentrations at 20 Years

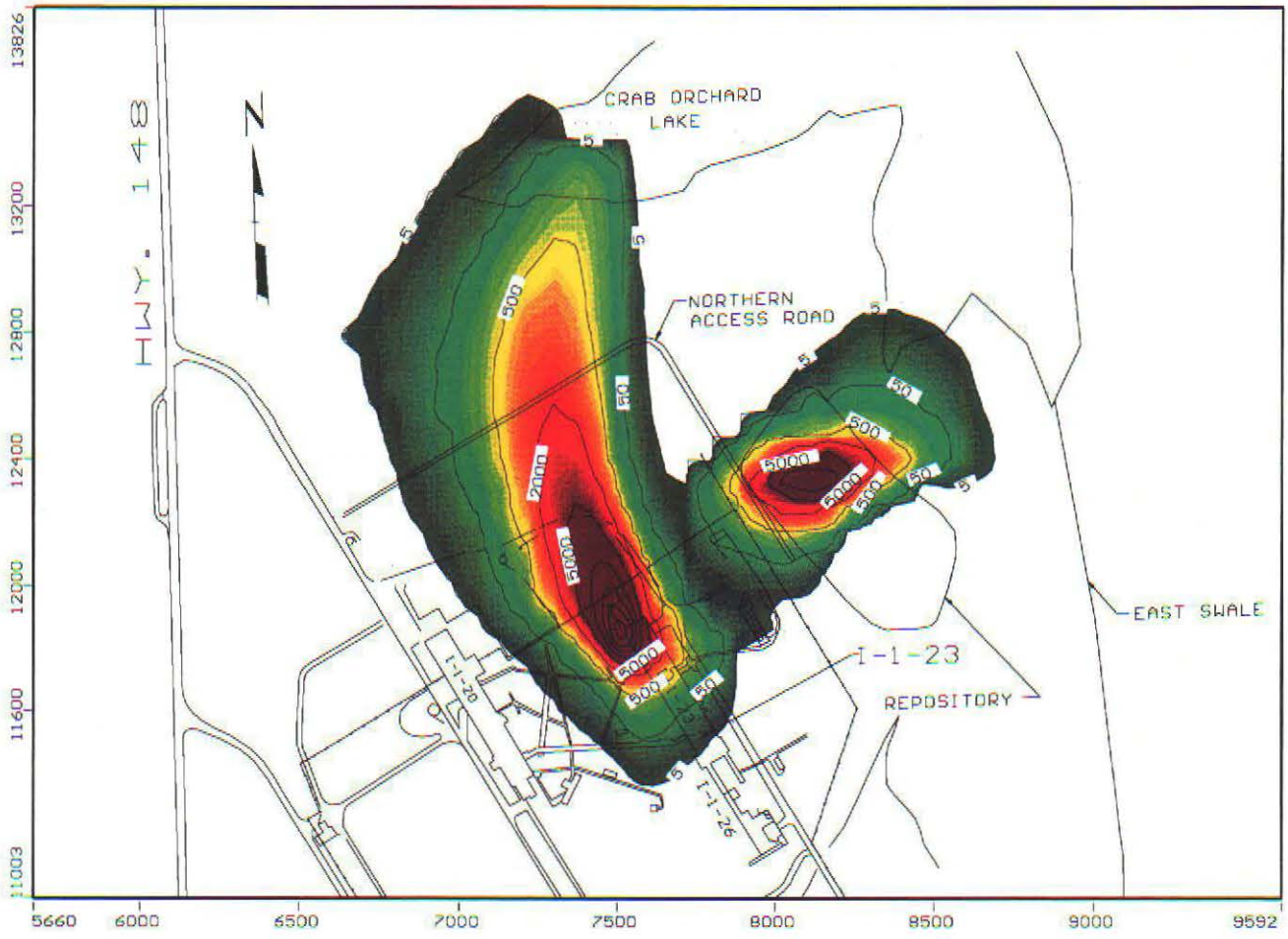


rmt
Project: CRAB ORCHARD
Description: Crab224 MPE, Hi Init Conc
Modeller: GK Contours TCE, ppb
20 Oct 99

Visual MODFLOW v.2.7.2, (C) 1995–1997
Waterloo Hydrogeologic, Inc.
NC: 90 NR: 104 NL: 5
Current Layer: 2

Figure 6-9

Multi-Phase Extraction – Alternative E, Sensitivity Test, High Initial Concentration in Source Areas, Predicted TCE Concentrations at 20 years



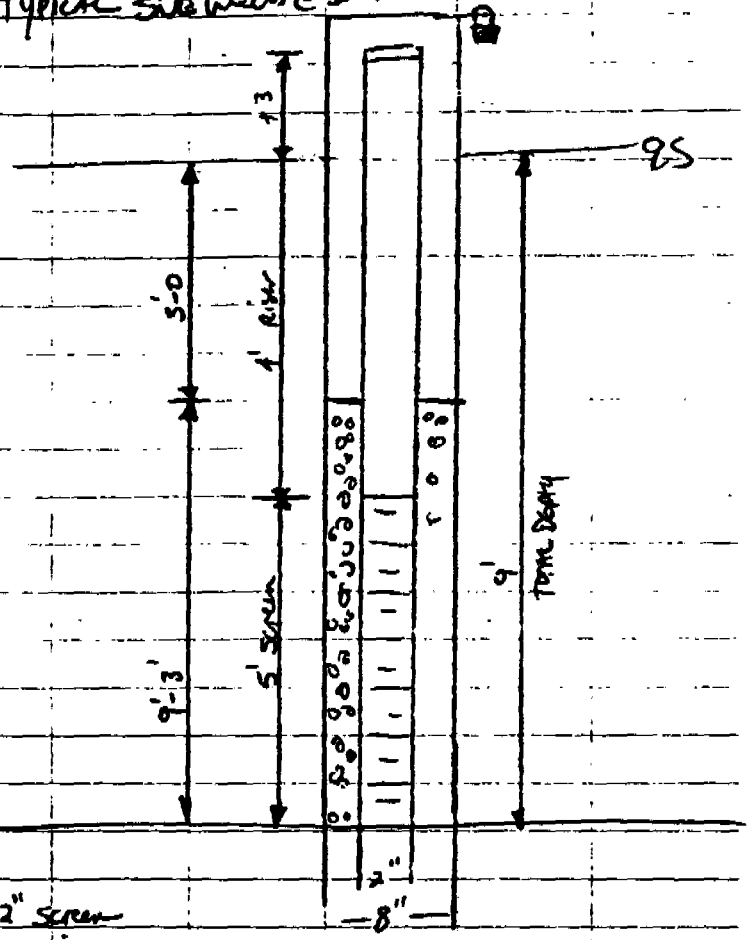
rmt Project: CRAB ORCHARD Crab226 Description: Sens.Test Phyto,decr.disp Modeller: GK Contours TCE, ppb 3 Jan 00	Visual MODFLOW v.2.7.2, (C) 1995-1997 Waterloo Hydrogeologic, Inc. NC: 90 NR: 104 NL: 5 Current Layer: 2

Figure 6-10

Phytoremediation - Alternative C,
Sensitivity Test, High Initial Concentrations in Source Areas, Predicted Concentrations at 20 years

Appendix A
FDGTI Pilot Test Well Construction Field Notes and Pilot Test Well Construction Data Table

TYPICAL SITE WELLS @ I-1-2



1x5' x 2" screen
1x10' x 2" Riser
3 sand
cap/plug
lock

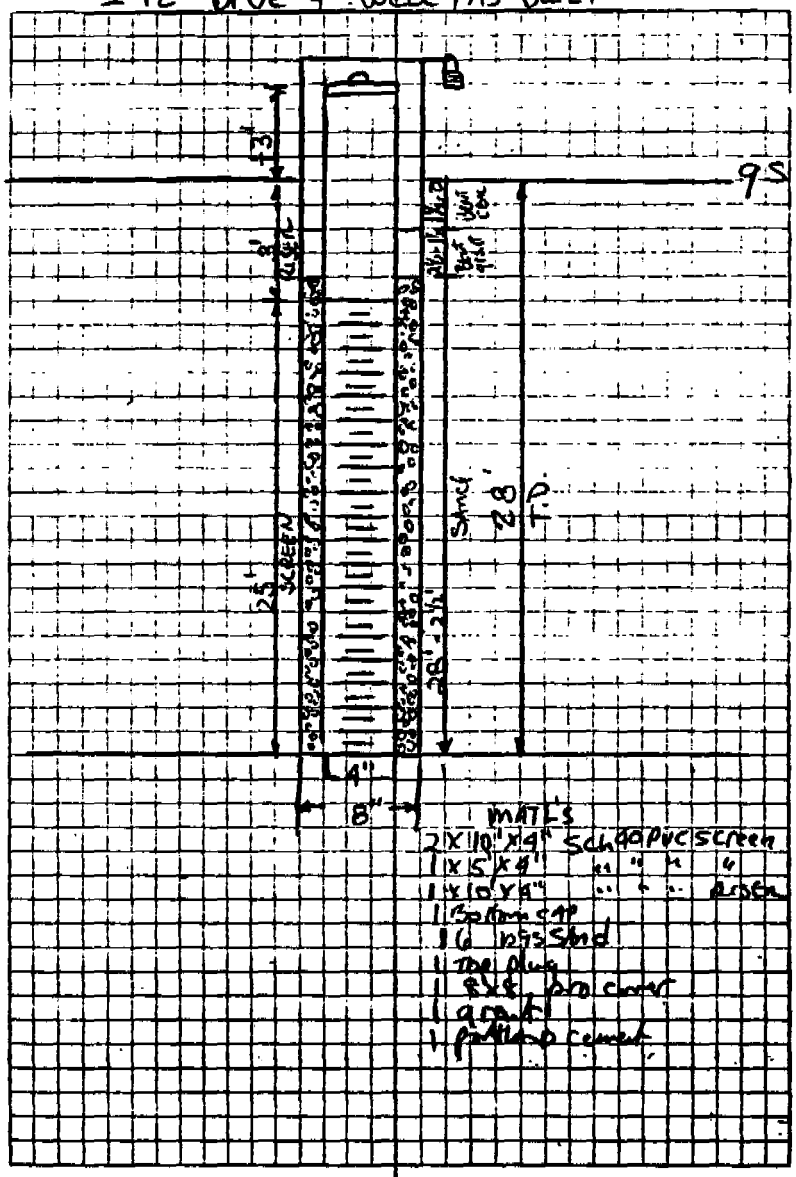
A-3

5-28-98

MP As-Builts typical

5-28-98 Cont

I-12 DPUE 4" WELL / AS-BUILT

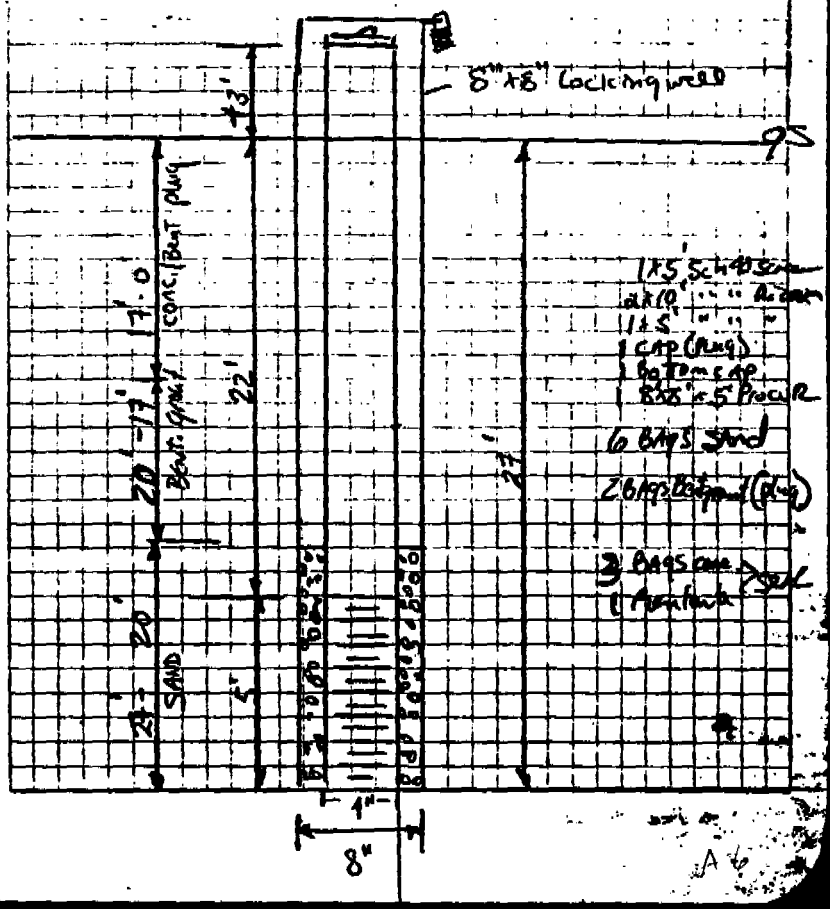


A-5

5-27-96 CONT. COWD 06687410

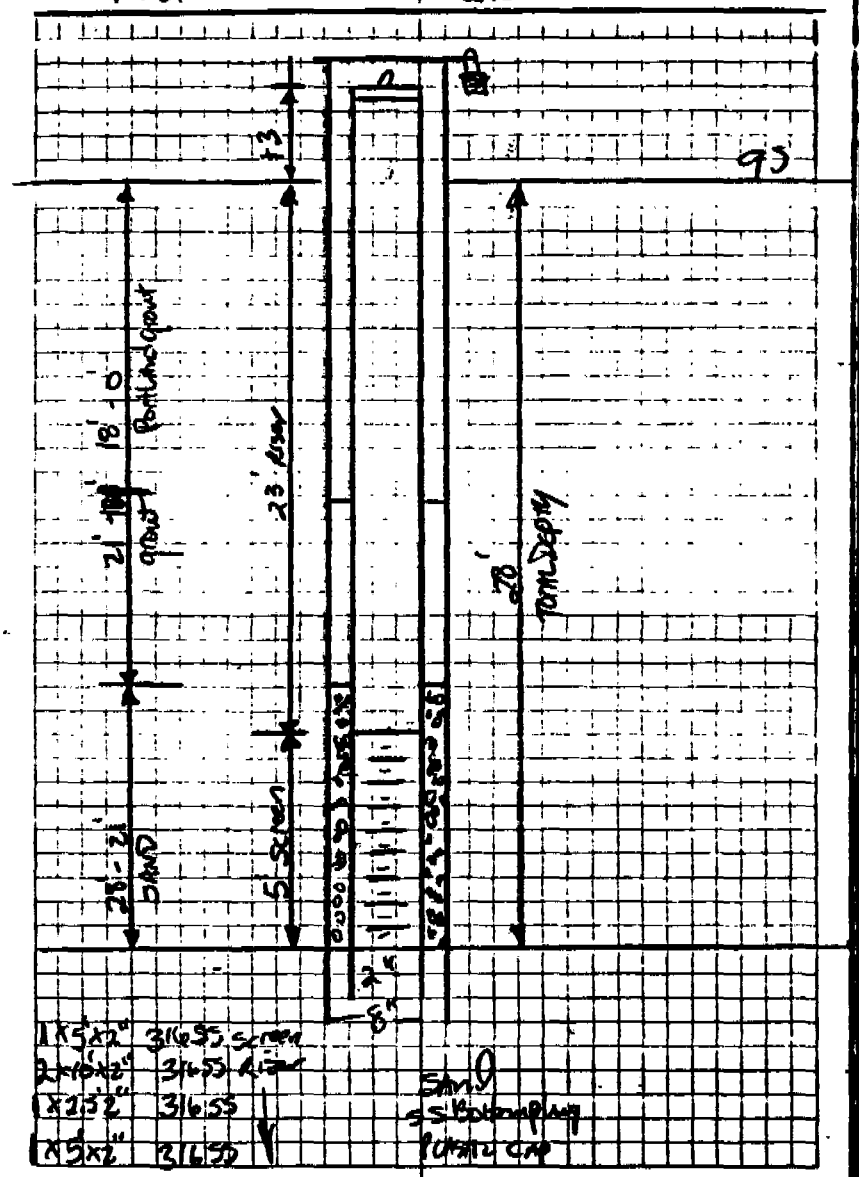
7:15-3:30 SET up GeoTech. 750ATV on sparge well location. Advance boring w/o sampling to 27' as per Timothy log. Cuttings will be placed on VB queen sheeting behind rig. Drilled boring down to 27' bgs. Hole caved a little due to sand blow-up.

I-12 - As-Built SPARGE WELL



A6

Area I-1-2 Shallow GW

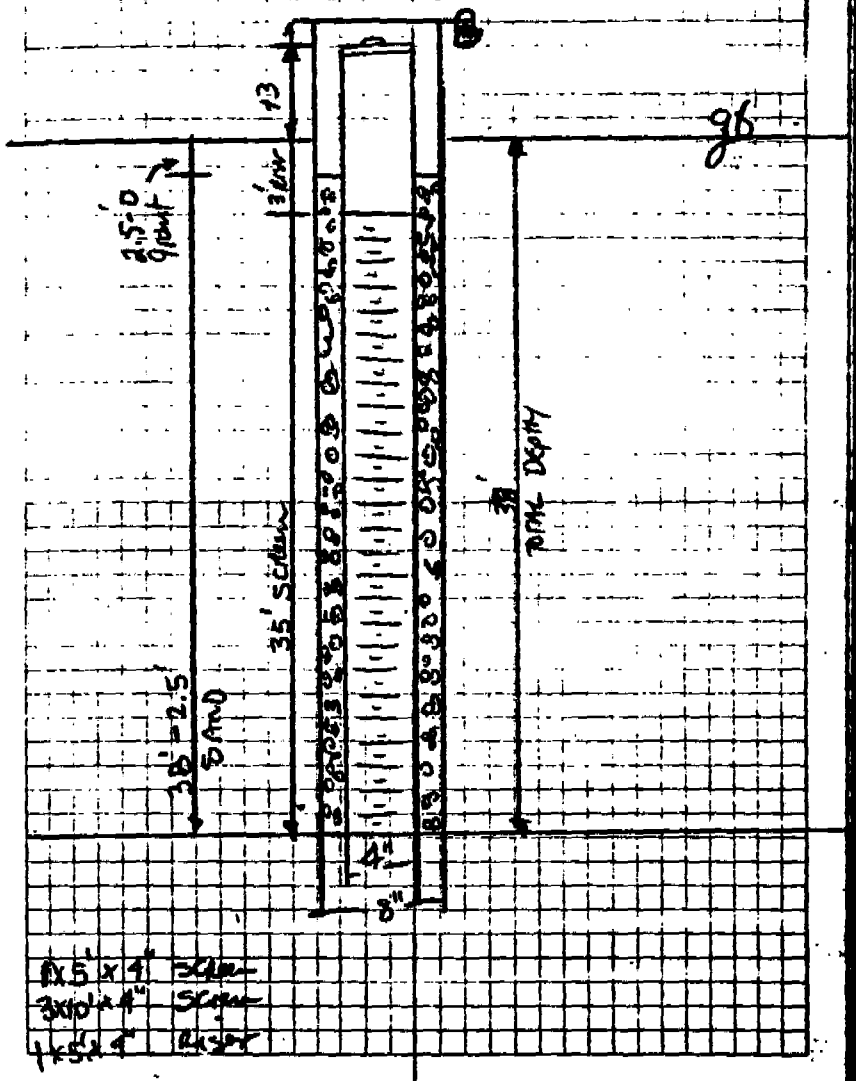


A7

Cont

5-31-98 06687210190 01

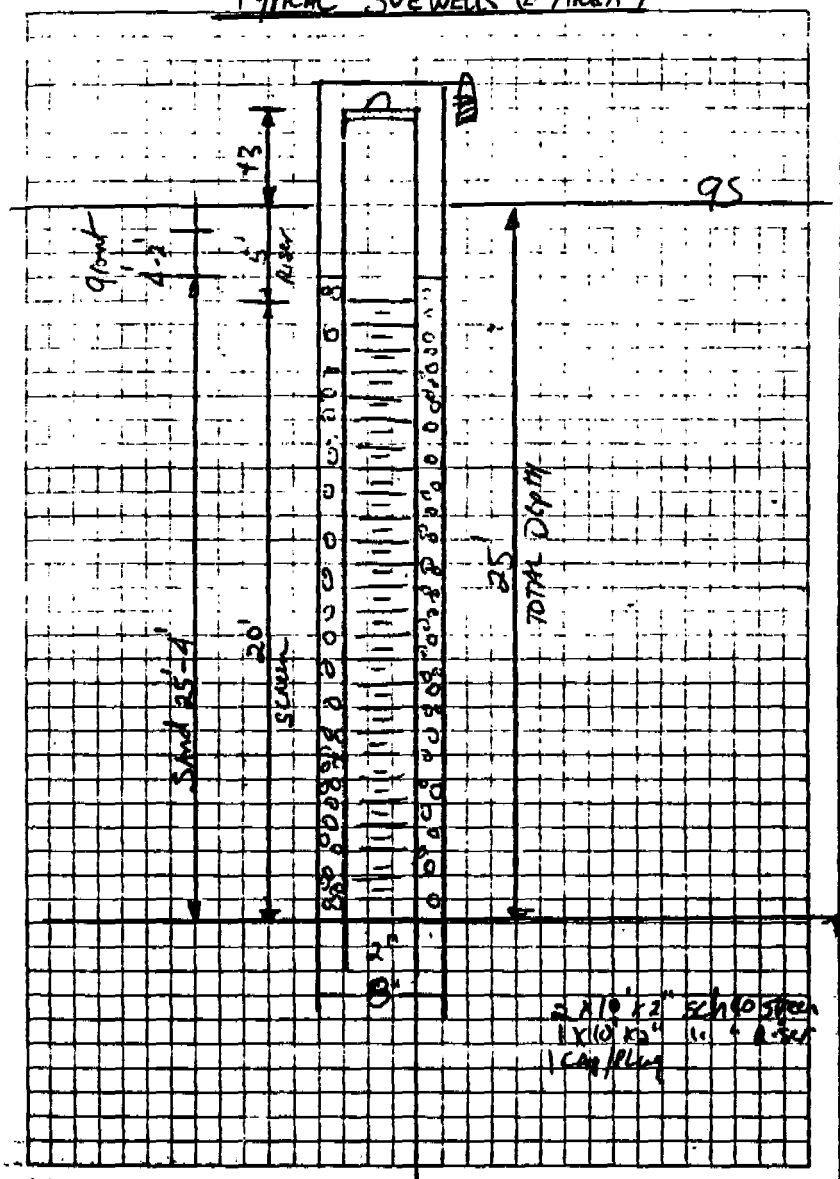
AREA 9 DRIVE WELL CONSTRUCTION



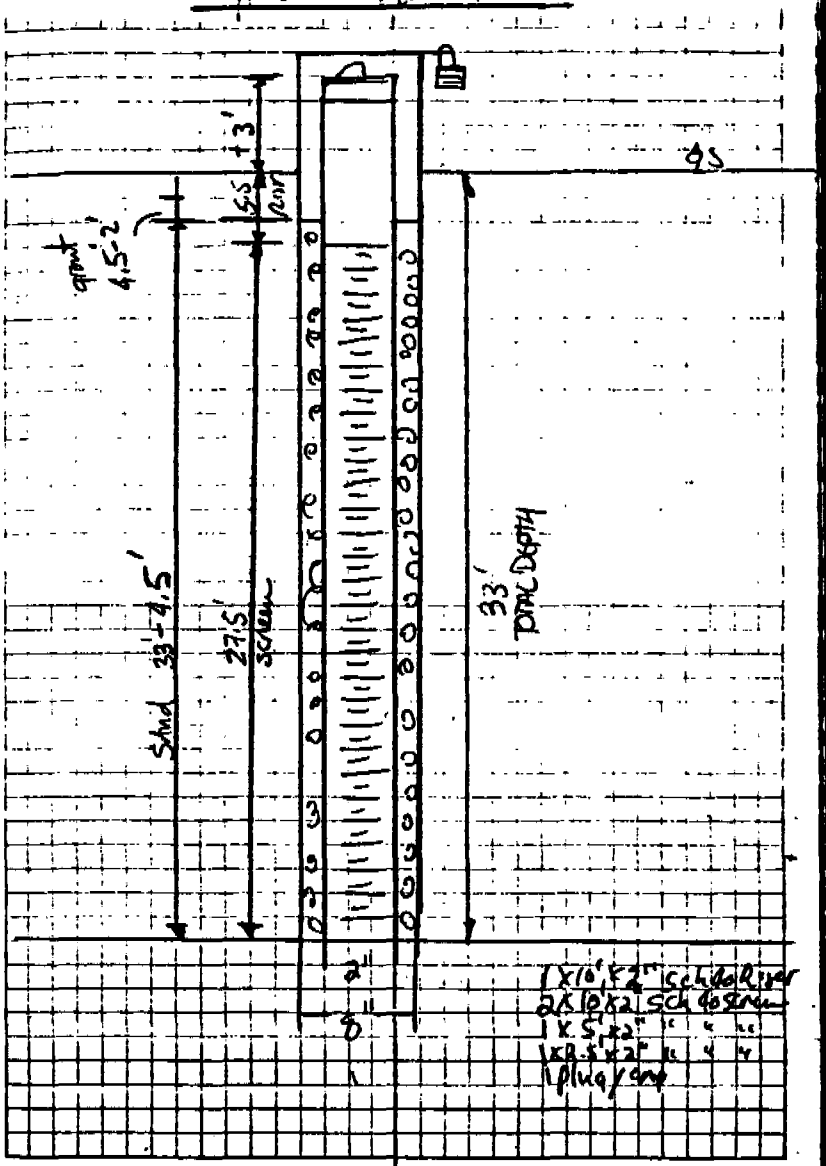
1x5' x 4" Screen
3x10' x 4" Screen
1x5' x 4" Riser

A 8

TYPICAL SVE WELLS @ AREA 9



TYPICAL AREA 9 MP



A-10

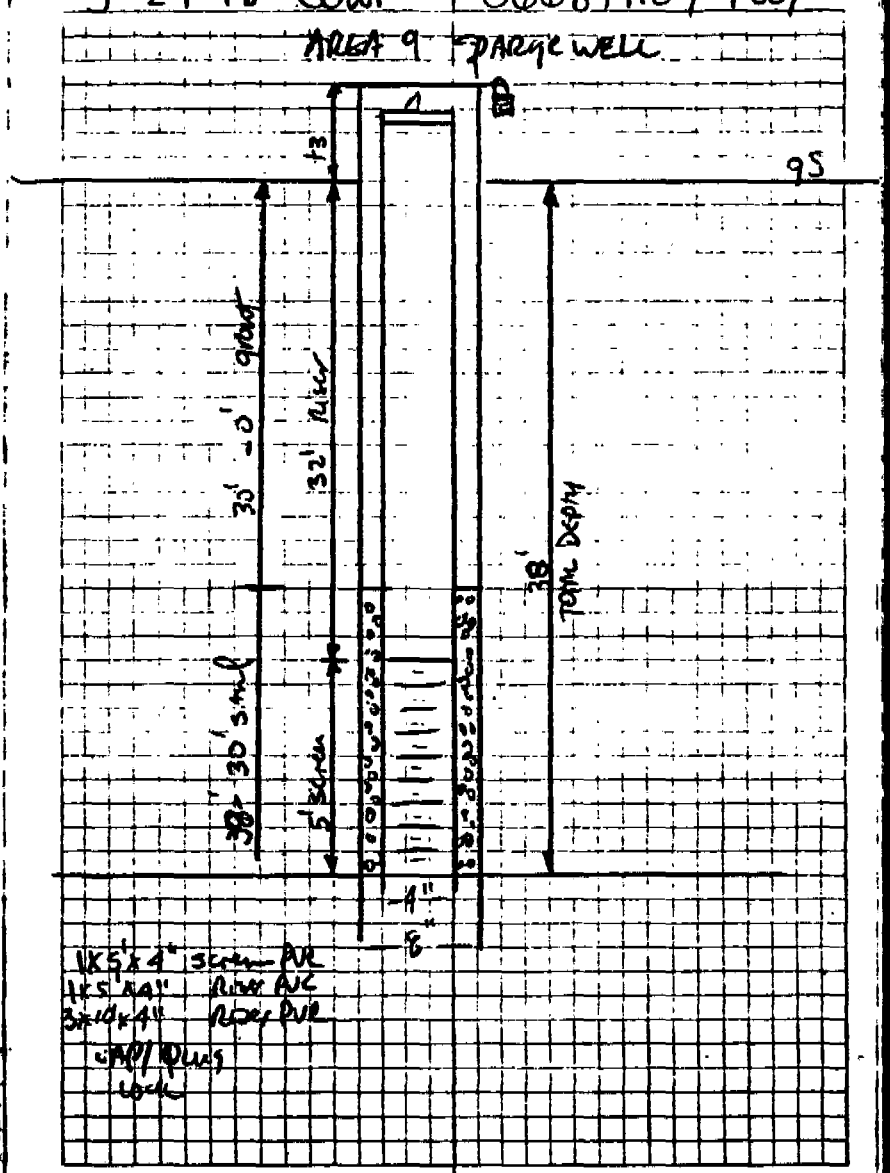
CONT

5-29-98 COWP 060687410 / 9001

D)

D)

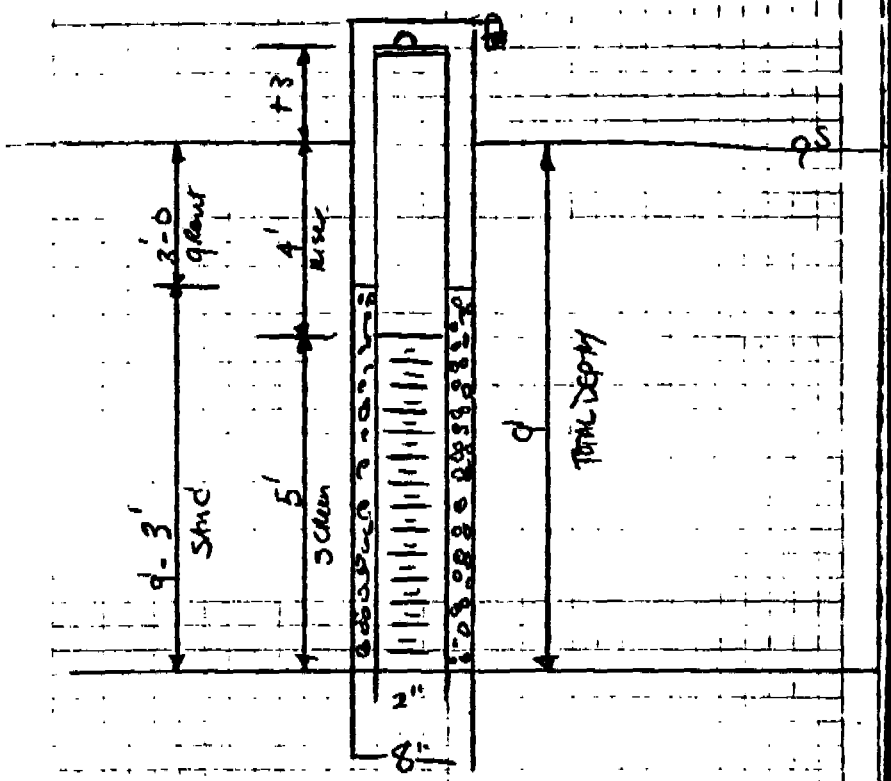
AREA 9 PARGE WELL



A-11

cont

TYPICAL SVE Construction in AREA 23



MATL

1 x 5' x 2" sch 40 PVC screen

1 x 10' x 2" " 4 " " Riser

3 Sand

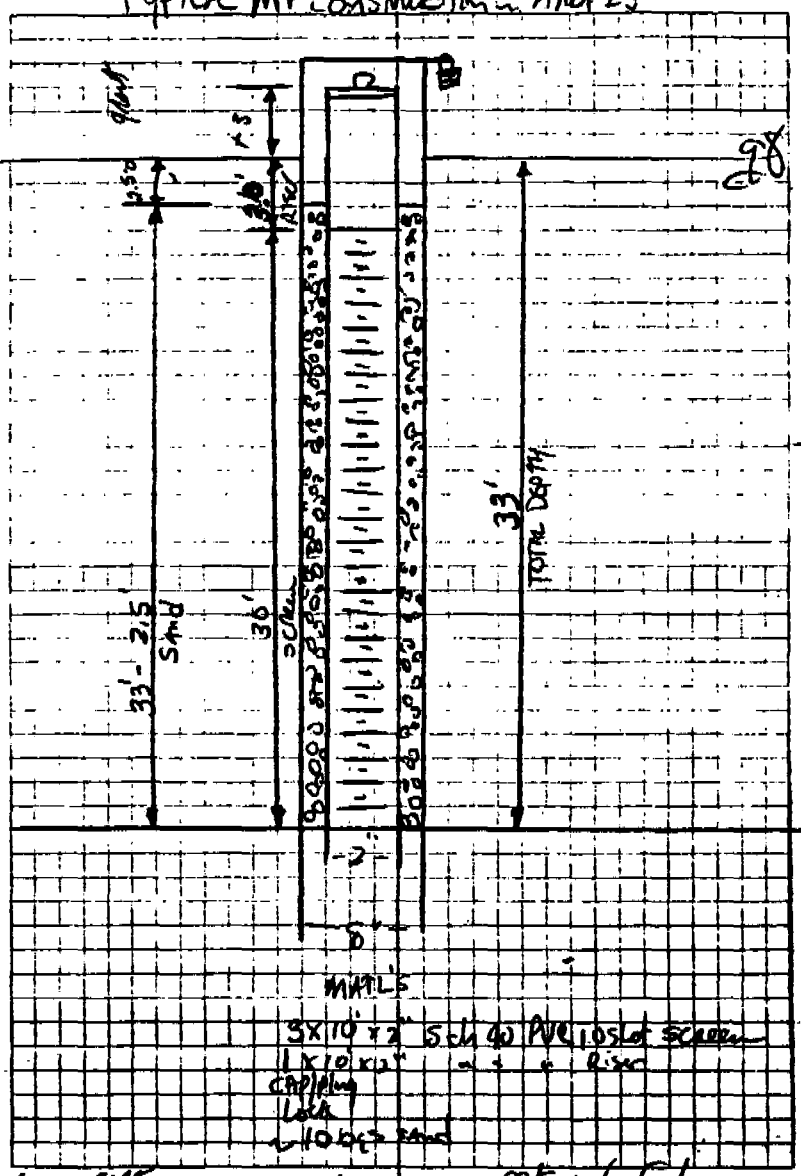
CAP/plug set

Locks

A-12

Cont 6-2-78

Typical MP Construction in Area 23



4:00-5:45 Took supply inventory. Get ready for tomorrow
Talked w/ mr Isley about remaining work

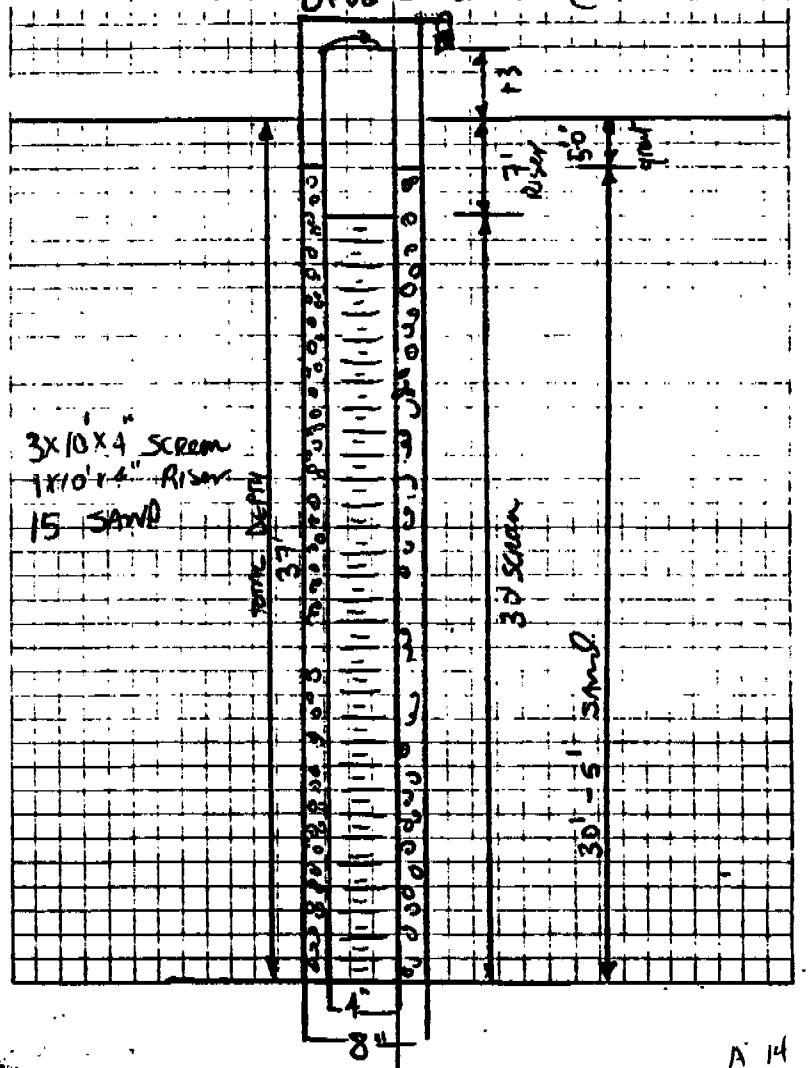
A-13

Cont

6-3-78 COWP 06687910/9001

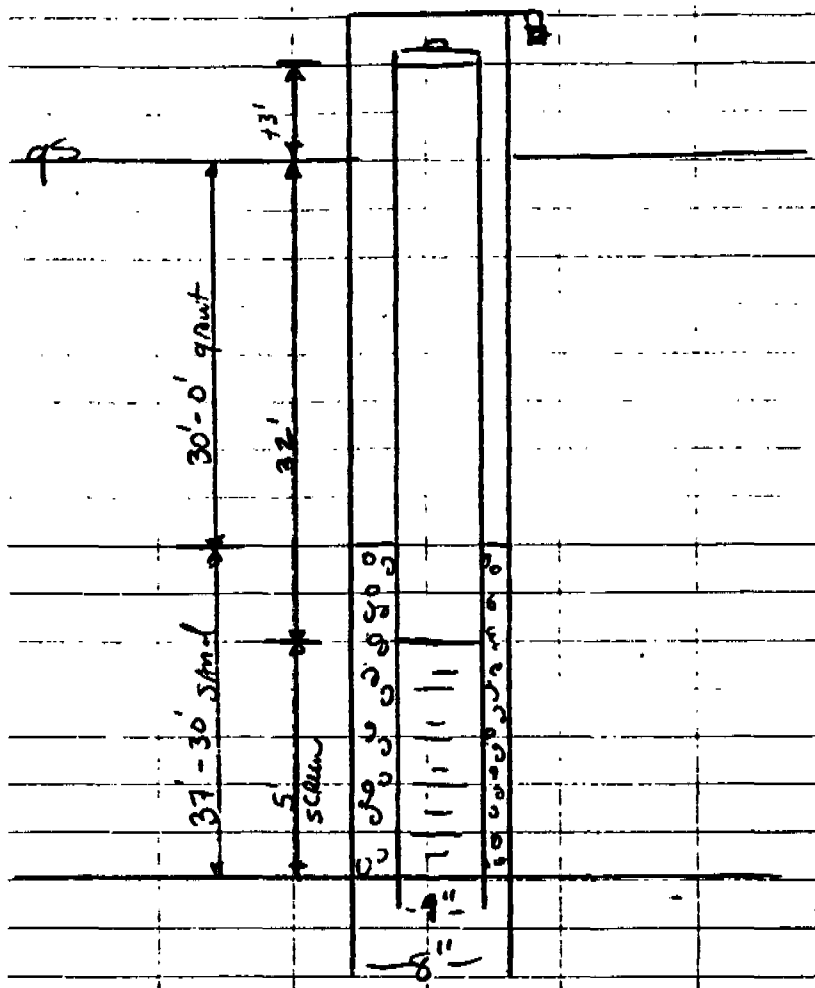
AREA 23, Moved conc to storage area. General site cleanup.

DPUG construction @ Area 23



A 14

AREA 23 Sparge well



1x5'x4" screen PVC 10 slot
1x5'x4" Riser PVC
3x10'x4" " "

A-15

Appendix A
Pilot Testing Wells and Monitoring Probe Construction Data
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

	DISTANCE TO AIR SPARGE WELL (Feet)	DISTANCE TO DUAL PHASE EXTRACTION WELL (Feet)	DEPTH OF SCREENED INTERVAL (Feet, bgs)	DEPTH OF UPPER SAND (Feet, bgs)
Building I-1-2 Area				
MP-1	27.75	43.45	4.5 - 27	24.2 - 26.2
MP-2	19.2	12.0	4.5 - 27	
MP-3	8.25	11.1	4.5 - 27	
MP-4	5.55	16.25	4.5 - 27	
SVE-1	34.05	49.75	4 - 9	
SVE-2	26.8	22.3	4 - 9	
SVE-3	20	24.25	4 - 9	
Air Sparge Well	NA	15.3	22 - 27	
Dual Phase Well	15.3	NA	3 - 28	
Building I-1-23 Area				
MP-1	24.35	34.7	3 - 33	25 - 37.1
MP-2	14.4	12.4	3 - 33	
MP-3	12.05	8.65	3 - 33	
MP-4	5.8	13.0	3 - 33	
SVE-1	29.95	40.25	4 - 9	
SVE-2	16.05	20.2	4 - 9	
SVE-3	20.5	23.85	4 - 9	
Air Sparge Well	NA	10.6	32 - 37	
Dual Phase Well	10.6	NA	7 - 37	
Area 9 Repository				
MP-1	24.8	35.3	5.5 - 33	45.2 - 46.4
MP-2	17.15	15.3	5.5 - 33	
MP-3	10.6	9.45	5.5 - 33	
MP-4	5.7	11.8	5.5 - 33	
SVE-1	29.7	40.25	5 - 25	
SVE-2	16.8	12.7	5 - 25	
SVE-3	20.4	24.25	5 - 25	
Air Sparge Well	NA	10.5	33 - 38	
Dual Phase Well	10.5	NA	3 - 38	

Notes:
NA = Not applicable

Prepared by: MLW 1/21/98
Checked by: PMC 1/26/98

Appendix B
Laboratory Reports – Pilot Test Air and Extraction Well Pump Discharge Samples

Table of Contents

- I-1-23 Area

  Air Samples
  - 141DPVE123
  - 142SPRG123
  - 143SPRG123
  - 143SPRG123DL

  Pump Discharge Samples
  - T16-3233-135-DDH

- I-1-2 Area

  Air Samples
  - 146DPVE12
  - 146DPVE12DL
  - 147SPRC12
  - 148SPRC22

  Pump Discharge Samples
  - T16-3233-144-DPVE

- Area 9 Repository

  Air Samples
  - 150DPVEA9
  - 152SPRC1A9
  - 153SPRC2A9
  - 153SPRC2A9DL

  Pump Discharge Samples
  - T16-3233-149-DPVE-A9

Air Samples

1A
VOLATILE ORGANICS ANALYSIS DATA SHEET

EPA SAMPLE NO.

141DPVE123

Lab Name: SWL-TULSA Contract: FLUORDAN

Lab Code: SWOK Case No.: GPENV SAS No.: SDG No.: 34872

Matrix: AIR Lab Sample ID: 34872.02

Date Received: 07/18/98 Lab File ID: Z7160.D

Date Analyzed: 07/28/98 Dilution Factor: 13.9

GC Column:DB-5 ID: 0.32 (mm)

CAS NO.	COMPOUND	CONCENTRATION UNITS: PPBV	Q
75-71-8	Dichlorodifluoromethane (F12	14	U
74-87-3	Chloromethane	14	U
76-14-2	1,2-DC-1,1,2,2-TFA (F114)	14	U
75-01-4	Vinyl Chloride	14	U
74-83-9	Bromomethane	14	U
75-00-3	Chloroethane	14	U
75-69-4	Trichlorofluoromethane (F11)	14	U
67-64-1	Acetone	200	
75-35-4	1,1-Dichloroethene	14	U
76-13-1	1,1,2-TC-1,2,2-TFA (F113)	28	
75-09-2	Methylene Chloride	590	
75-15-0	Carbon Disulfide	14	U
156-60-5	trans-1,2-Dichloroethene	14	U
75-34-3	1,1-Dichloroethane	14	U
78-93-3	2-Butanone	16	
156-59-2	cis-1,2-Dichloroethene	58	
67-66-3	Chloroform	14	U
71-55-6	1,1,1-Trichloroethane	14	U
107-06-2	1,2-Dichloroethane	14	U
71-43-2	Benzene	14	U
56-23-5	Carbon Tetrachloride	14	U
78-87-5	1,2-Dichloropropane	14	U
79-01-6	Trichloroethene	440	
108-10-1	4-Methyl-2-Pentanone	14	U
10061-01-5	cis-1,3-Dichloropropene	14	U
10061-02-6	trans-1,3-Dichloropropene	14	U
108-88-3	Toluene	56	
79-00-5	1,1,2-Trichloroethane	14	U
591-78-6	2-Hexanone	14	U
106-93-4	1,2-Dibromoethane	14	U
127-18-4	Tetrachloroethene	10	J
108-90-7	Chlorobenzene	16	
100-41-4	Ethylbenzene	14	U

1A
VOLATILE ORGANICS ANALYSIS DATA SHEET

EPA SAMPLE NO.

141DPVE123

Lab Name: SWL-TULSA Contract: FLUORDAN

Lab Code: SWOK Case No.: GPENV SAS No.: SDG No.: 34872

Matrix: AIR Lab Sample ID: 34872.02

Date Received: 07/18/98 Lab File ID: Z7160.D

Date Analyzed: 07/28/98 Dilution Factor: 13.9

GC Column:DB-5 ID: 0.32 (mm)

CAS NO.	COMPOUND	CONCENTRATION UNITS: PPBV	Q
13-302-07	m,p-Xylene	14	U
100-42-5	Styrene	14	U
95-47-6	o-Xylene	14	U
79-34-5	1,1,2,2-Tetrachloroethane	14	U
622-96-8	4-Ethyltoluene	14	U
108-67-8	1,3,5-Trimethylbenzene	14	U
95-63-6	1,2,4-Trimethylbenzene	14	U
541-73-1	1,3-Dichlorobenzene	14	U
100-44-7	Benzyl Chloride	14	U
106-46-7	1,4-Dichlorobenzene	14	U
95-50-1	1,2-Dichlorobenzene	14	U
120-82-1	1,2,4-Trichlorobenzene	14	U
87-68-3	Hexachlorobutadiene	14	U

1E
VOLATILE ORGANICS ANALYSIS DATA SHEET
TENTATIVELY IDENTIFIED COMPOUNDS

EPA SAMPLE NO.

141DPVE123

Lab Name: SWL-TULSA Contract: FLUORDAN

Lab Code: SWOK Case No.: GPENV SAS No.: SDG No.: 34872

Matrix: AIR Lab Sample ID: 34872.02

Date Received: 07/18/98 Lab File ID: Z7160.D

Date Analyzed: 07/28/98 Dilution Factor: 13.9

GC Column:DB-5 ID: 0.32 (mm)

Number TICs found: 6 CONC. UNITS PPBV

CAS NUMBER	COMPOUND NAME	RT	EST. CONC.	Q
1.	UNKNOWN	2.843	44.0	J
2.	UNKNOWN	3.187	68.0	J
3.	UNKNOWN HYDROCARBON	3.693	63.0	J
4.	UNKNOWN	4.699	80.0	J
5.	UNKNOWN HYDROCARBON	5.308	400.0	J
6. 96-37-7	Cyclopentane, methyl-	5.883	56.0	NJ
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1A
VOLATILE ORGANICS ANALYSIS DATA SHEET

EPA SAMPLE NO.

142SPRG123

Lab Name: SWL-TULSA Contract: FLUORDAN

Lab Code: SWOK Case No.: GPENV SAS No.: SDG No.: 34872

Matrix: AIR Lab Sample ID: 34872.03

Date Received: 07/18/98 Lab File ID: Z7158.D

Date Analyzed: 07/28/98 Dilution Factor: 25.1

GC Column:DB-5 ID: 0.32 (mm)

CAS NO.	COMPOUND	CONCENTRATION UNITS: PPBV	Q
75-71-8	Dichlorodifluoromethane (F12	25	U
74-87-3	Chloromethane	25	U
76-14-2	1,2-DC-1,1,2,2-TFA (F114)	25	U
75-01-4	Vinyl Chloride	25	U
74-83-9	Bromomethane	25	U
75-00-3	Chloroethane	25	U
75-69-4	Trichlorofluoromethane (F11)	25	U
67-64-1	Acetone	69	
75-35-4	1,1-Dichloroethene	25	U
76-13-1	1,1,2-TC-1,2,2-TFA (F113)	25	U
75-09-2	Methylene Chloride	25	U
75-15-0	Carbon Disulfide	25	U
156-60-5	trans-1,2-Dichloroethene	25	U
75-34-3	1,1-Dichloroethane	25	U
78-93-3	2-Butanone	1200	
156-59-2	cis-1,2-Dichloroethene	75	
67-66-3	Chloroform	25	U
71-55-6	1,1,1-Trichloroethane	25	U
107-06-2	1,2-Dichloroethane	25	U
71-43-2	Benzene	25	U
56-23-5	Carbon Tetrachloride	25	U
78-87-5	1,2-Dichloropropane	25	U
79-01-6	Trichloroethene	260	
108-10-1	4-Methyl-2-Pentanone	25	U
10061-01-5	cis-1,3-Dichloropropene	25	U
10061-02-6	trans-1,3-Dichloropropene	25	U
108-88-3	Toluene	43	
79-00-5	1,1,2-Trichloroethane	25	U
591-78-6	2-Hexanone	25	U
106-93-4	1,2-Dibromoethane	25	U
127-18-4	Tetrachloroethene	16	J
108-90-7	Chlorobenzene	46	
100-41-4	Ethylbenzene	25	U

1A
VOLATILE ORGANICS ANALYSIS DATA SHEET

EPA SAMPLE NO.

142SPRG123

Lab Name: SWL-TULSA Contract: FLUORDAN

Lab Code: SWOK Case No.: GPENV SAS No.: SDG No.: 34872

Matrix: AIR Lab Sample ID: 34872.03

Date Received: 07/18/98 Lab File ID: Z7158.D

Date Analyzed: 07/28/98 Dilution Factor: 25.1

GC Column:DB-5 ID: 0.32 (mm)

CAS NO.	COMPOUND	CONCENTRATION UNITS: PPBV	Q
13-302-07	m,p-Xylene	25	U
100-42-5	Styrene	25	U
95-47-6	o-Xylene	25	U
79-34-5	1,1,2,2-Tetrachloroethane	25	U
622-96-8	4-Ethyltoluene	25	U
108-67-8	1,3,5-Trimethylbenzene	25	U
95-63-6	1,2,4-Trimethylbenzene	25	U
541-73-1	1,3-Dichlorobenzene	25	U
100-44-7	Benzyl Chloride	25	U
106-46-7	1,4-Dichlorobenzene	25	U
95-50-1	1,2-Dichlorobenzene	25	U
120-82-1	1,2,4-Trichlorobenzene	25	U
87-68-3	Hexachlorobutadiene	25	U

1E
VOLATILE ORGANICS ANALYSIS DATA SHEET
TENTATIVELY IDENTIFIED COMPOUNDS

EPA SAMPLE NO.

142SPRG123

Lab Name: SWL-TULSA Contract: FLUORDAN

Lab Code: SWOK Case No.: GPENV SAS No.: SDG No.: 34872

Matrix: AIR Lab Sample ID: 34872.03

Date Received: 07/18/98 Lab File ID: Z7158.D

Date Analyzed: 07/28/98 Dilution Factor: 25.1

GC Column:DB-5 ID: 0.32 (mm)

Number TICs found: 7

CONC. UNITS
PPBV

CAS NUMBER	COMPOUND NAME	RT	EST. CONC.	Q
1.	UNKNOWN	3.167	120.0	J
2.	UNKNOWN	4.475	51.0	J
3.	UNKNOWN	4.750	77.0	J
4.	UNKNOWN	5.250	35.0	J
5. 109-99-9	Furan, tetrahydro-	5.907	10000.0	NJ
6. 109-99-9	Furan, tetrahydro-	6.176	140.0	NJ
7. 108-94-1	Cyclohexanone	11.589	200.0	NJ
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1A
VOLATILE ORGANICS ANALYSIS DATA SHEET

EPA SAMPLE NO.

143SPRG123

Lab Name: SWL-TULSA Contract: FLUORDAN

Lab Code: SWOK Case No.: GPENV SAS No.: SDG No.: 34872

Matrix: AIR Lab Sample ID: 34872.04

Date Received: 07/18/98 Lab File ID: Z7159.D

Date Analyzed: 07/28/98 Dilution Factor: 223.0

GC Column:DB-5 ID: 0.32 (mm)

CAS NO.	COMPOUND	CONCENTRATION UNITS: PPBV	Q
75-71-8	Dichlorodifluoromethane (F12	220	U
74-87-3	Chloromethane	220	U
76-14-2	1,2-DC-1,1,2,2-TFA (F114)	220	U
75-01-4	Vinyl Chloride	220	U
74-83-9	Bromomethane	220	U
75-00-3	Chloroethane	220	U
75-69-4	Trichlorofluoromethane (F11)	220	U
67-64-1	Acetone	220	U
75-35-4	1,1-Dichloroethene	220	U
76-13-1	1,1,2-TC-1,2,2-TFA (F113)	220	U
75-09-2	Methylene Chloride	220	U
75-15-0	Carbon Disulfide	220	U
156-60-5	trans-1,2-Dichloroethene	220	U
75-34-3	1,1-Dichloroethane	220	U
78-93-3	2-Butanone	900	
156-59-2	cis-1,2-Dichloroethene	790	
67-66-3	Chloroform	220	U
71-55-6	1,1,1-Trichloroethane	220	U
107-06-2	1,2-Dichloroethane	220	U
71-43-2	Benzene	220	U
56-23-5	Carbon Tetrachloride	220	U
78-87-5	1,2-Dichloropropane	220	U
79-01-6	Trichloroethene	7400	
108-10-1	4-Methyl-2-Pentanone	220	U
10061-01-5	cis-1,3-Dichloropropene	220	U
10061-02-6	trans-1,3-Dichloropropene	220	U
108-88-3	Toluene	220	U
79-00-5	1,1,2-Trichloroethane	220	U
591-78-6	2-Hexanone	220	U
106-93-4	1,2-Dibromoethane	220	U
127-18-4	Tetrachloroethene	800	
108-90-7	Chlorobenzene	320	
100-41-4	Ethylbenzene	220	U

1A
VOLATILE ORGANICS ANALYSIS DATA SHEET

EPA SAMPLE NO.

143SPRG123

Lab Name: SWL-TULSA Contract: FLUORDAN

Lab Code: SWOK Case No.: GPENV SAS No.: SDG No.: 34872

Matrix: AIR Lab Sample ID: 34872.04

Date Received: 07/18/98 Lab File ID: Z7159.D

Date Analyzed: 07/28/98 Dilution Factor: 223.0

GC Column:DB-5 ID: 0.32 (mm)

CAS NO.	COMPOUND	CONCENTRATION UNITS: PPBV	Q
13-302-07	m,p-Xylene	220	U
100-42-5	Styrene	220	U
95-47-6	o-Xylene	220	U
79-34-5	1,1,2,2-Tetrachloroethane	220	U
622-96-8	4-Ethyltoluene	220	U
108-67-8	1,3,5-Trimethylbenzene	220	U
95-63-6	1,2,4-Trimethylbenzene	220	U
541-73-1	1,3-Dichlorobenzene	220	U
100-44-7	Benzyl Chloride	220	U
106-46-7	1,4-Dichlorobenzene	220	U
95-50-1	1,2-Dichlorobenzene	220	U
120-82-1	1,2,4-Trichlorobenzene	220	U
87-68-3	Hexachlorobutadiene	220	U

1E
VOLATILE ORGANICS ANALYSIS DATA SHEET
TENTATIVELY IDENTIFIED COMPOUNDS

EPA SAMPLE NO.

143SPRG123

Lab Name: SWL-TULSA Contract: FLUORDAN

Lab Code: SWOK Case No.: GPENV SAS No.: SDG No.: 34872

Matrix: AIR Lab Sample ID: 34872.04

Date Received: 07/18/98 Lab File ID: Z7159.D

Date Analyzed: 07/28/98 Dilution Factor: 223.0

GC Column:DB-5 ID: 0.32 (mm)

Number TICs found: 4

CONC. UNITS
PPBV

CAS NUMBER	COMPOUND NAME	RT	EST. CONC.	Q
1.	UNKNOWN	2.022	440.0	J
2.	UNKNOWN KETONE	3.964	270.0	J
3.	UNKNOWN	4.551	3400.0	J
4. 109-99-9	Furan, tetrahydro-	5.907	7000.0	NJ
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1A
VOLATILE ORGANICS ANALYSIS DATA SHEET

EPA SAMPLE NO.

143SPRG123DL

Lab Name: SWL-TULSA Contract: FLUORDAN

Lab Code: SWOK Case No.: GPENV SAS No.: SDG No.: 34872

Matrix: AIR Lab Sample ID: 34872.04DL

Date Received: 07/18/98 Lab File ID: Z7152.D

Date Analyzed: 07/27/98 Dilution Factor: 2230.0

GC Column: DB-5 ID: 0.32 (mm)

CAS NO.	COMPOUND	CONCENTRATION UNITS: PPBV	Q
75-71-8	Dichlorodifluoromethane (F12	2200	U
74-87-3	Chloromethane	2200	U
76-14-2	1,2-DC-1,1,2,2-TFA (F114)	2200	U
75-01-4	Vinyl Chloride	2200	U
74-83-9	Bromomethane	2200	U
75-00-3	Chloroethane	2200	U
75-69-4	Trichlorofluoromethane (F11)	2200	U
67-64-1	Acetone	2200	U
75-35-4	1,1-Dichloroethene	2200	U
76-13-1	1,1,2-TC-1,2,2-TFA (F113)	2200	U
75-09-2	Methylene Chloride	2200	U
75-15-0	Carbon Disulfide	2200	U
156-60-5	trans-1,2-Dichloroethene	2200	U
75-34-3	1,1-Dichloroethane	2200	U
78-93-3	2-Butanone	2200	U
156-59-2	cis-1,2-Dichloroethene	700	JD
67-66-3	Chloroform	2200	U
71-55-6	1,1,1-Trichloroethane	2200	U
107-06-2	1,2-Dichloroethane	2200	U
71-43-2	Benzene	2200	U
56-23-5	Carbon Tetrachloride	2200	U
78-87-5	1,2-Dichloropropane	2200	U
79-01-6	Trichloroethene	8200	D
108-10-1	4-Methyl-2-Pentanone	2200	U
10061-01-5	cis-1,3-Dichloropropene	2200	U
10061-02-6	trans-1,3-Dichloropropene	2200	U
108-88-3	Toluene	2200	U
79-00-5	1,1,2-Trichloroethane	2200	U
591-78-6	2-Hexanone	2200	U
106-93-4	1,2-Dibromoethane	2200	U
127-18-4	Tetrachloroethene	2200	U
108-90-7	Chlorobenzene	2200	U
100-41-4	Ethylbenzene	2200	U

1A
VOLATILE ORGANICS ANALYSIS DATA SHEET

EPA SAMPLE NO.

143SPRG123DL

Lab Name: SWL-TULSA Contract: FLUORDAN

Lab Code: SWOK Case No.: GPENV SAS No.: SDG No.: 34872

Matrix: AIR Lab Sample ID: 34872.04DL

Date Received: 07/18/98 Lab File ID: Z7152.D

Date Analyzed: 07/27/98 Dilution Factor: 2230.0

GC Column:DB-5 ID: 0.32 (mm)

CAS NO.	COMPOUND	CONCENTRATION UNITS: PPBV	Q
13-302-07	m,p-Xylene	2200	U
100-42-5	Styrene	2200	U
95-47-6	o-Xylene	2200	U
79-34-5	1,1,2,2-Tetrachloroethane	2200	U
622-96-8	4-Ethyltoluene	2200	U
108-67-8	1,3,5-Trimethylbenzene	2200	U
95-63-6	1,2,4-Trimethylbenzene	2200	U
541-73-1	1,3-Dichlorobenzene	2200	U
100-44-7	Benzyl Chloride	2200	U
106-46-7	1,4-Dichlorobenzene	2200	U
95-50-1	1,2-Dichlorobenzene	2200	U
120-82-1	1,2,4-Trichlorobenzene	2200	U
87-68-3	Hexachlorobutadiene	2200	U

1E
VOLATILE ORGANICS ANALYSIS DATA SHEET
TENTATIVELY IDENTIFIED COMPOUNDS

EPA SAMPLE NO.

143SPRG123DL

Lab Name: SWL-TULSA Contract: FLUORDAN

Lab Code: SWOK Case No.: GPENV SAS No.: SDG No.: 34872

Matrix: AIR Lab Sample ID: 34872.04DL

Date Received: 07/18/98 Lab File ID: Z7152.D

Date Analyzed: 07/27/98 Dilution Factor: 2230.0

GC Column:DB-5 ID: 0.32 (mm)

Number TICs found: 2

CONC. UNITS
PPBV

CAS NUMBER	COMPOUND NAME	RT	EST. CONC.	Q
1.	UNKNOWN	3.258	2300.0	JD
2.	UNKNOWN	4.738	27000.0	JD
3.				
4.				
5.				
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1A
VOLATILE ORGANICS ANALYSIS DATA SHEET

EPA SAMPLE NO.

146DPVE12

Lab Name: SWL-TULSA Contract: FLUORDAN

Lab Code: SWOK Case No.: GPENV SAS No.: SDG No.: 34872

Matrix: AIR Lab Sample ID: 34872.01

Date Received: 07/18/98 Lab File ID: Z7147.D

Date Analyzed: 07/27/98 Dilution Factor: 22.3

GC Column:DB-5 ID: 0.32 (mm)

CAS NO.	COMPOUND	CONCENTRATION UNITS: PPBV	Q
75-71-8	Dichlorodifluoromethane (F12	22	U
74-87-3	Chloromethane	22	U
76-14-2	1,2-DC-1,1,2,2-TFA (F114)	22	U
75-01-4	Vinyl Chloride	58	
74-83-9	Bromomethane	22	U
75-00-3	Chloroethane	22	U
75-69-4	Trichlorofluoromethane (F11)	22	U
67-64-1	Acetone	22	U
75-35-4	1,1-Dichloroethene	22	U
76-13-1	1,1,2-TC-1,2,2-TFA (F113)	22000	E
75-09-2	Methylene Chloride	22	U
75-15-0	Carbon Disulfide	22	U
156-60-5	trans-1,2-Dichloroethene	22	U
75-34-3	1,1-Dichloroethane	22	U
78-93-3	2-Butanone	85	
156-59-2	cis-1,2-Dichloroethene	22	U
67-66-3	Chloroform	22	U
71-55-6	1,1,1-Trichloroethane	22	U
107-06-2	1,2-Dichloroethane	22	U
71-43-2	Benzene	22	U
56-23-5	Carbon Tetrachloride	22	U
78-87-5	1,2-Dichloropropane	22	U
79-01-6	Trichloroethene	20	J
108-10-1	4-Methyl-2-Pentanone	22	U
10061-01-5	cis-1,3-Dichloropropene	22	U
10061-02-6	trans-1,3-Dichloropropene	22	U
108-88-3	Toluene	37	
79-00-5	1,1,2-Trichloroethane	22	U
591-78-6	2-Hexanone	22	U
106-93-4	1,2-Dibromoethane	22	U
127-18-4	Tetrachloroethene	22	U
108-90-7	Chlorobenzene	22	U
100-41-4	Ethylbenzene	22	U

1A
VOLATILE ORGANICS ANALYSIS DATA SHEET

EPA SAMPLE NO.

146DPVE12

Lab Name: SWL-TULSA Contract: FLUORDAN

b Code: SWOK Case No.: GPENV SAS No.: SDG No.: 34872

Matrix: AIR Lab Sample ID: 34872.01

Date Received: 07/18/98 Lab File ID: Z7147.D

Date Analyzed: 07/27/98 Dilution Factor: 22.3

GC Column:DB-5 ID: 0.32 (mm)

CAS NO.	COMPOUND	CONCENTRATION UNITS: PPBV	Q
13-302-07	m,p-Xylene	22	U
100-42-5	Styrene	22	U
95-47-6	o-Xylene	22	U
79-34-5	1,1,2,2-Tetrachloroethane	22	U
622-96-8	4-Ethyltoluene	22	U
108-67-8	1,3,5-Trimethylbenzene	22	U
95-63-6	1,2,4-Trimethylbenzene	22	U
541-73-1	1,3-Dichlorobenzene	22	U
100-44-7	Benzyl Chloride	22	U
106-46-7	1,4-Dichlorobenzene	22	U
95-50-1	1,2-Dichlorobenzene	22	U
120-82-1	1,2,4-Trichlorobenzene	22	U
87-68-3	Hexachlorobutadiene	22	U

1E
VOLATILE ORGANICS ANALYSIS DATA SHEET
TENTATIVELY IDENTIFIED COMPOUNDS

EPA SAMPLE NO.

146DPVE12

Lab Name: SWL-TULSA Contract: FLUORDAN

Lab Code: SWOK Case No.: GPENV SAS No.: SDG No.: 34872

Matrix: AIR Lab Sample ID: 34872.01

Date Received: 07/18/98 Lab File ID: Z7147.D

Date Analyzed: 07/27/98 Dilution Factor: 22.3

GC Column:DB-5 ID: 0.32 (mm)

Number TICs found: 14

CONC. UNITS
PPBV

CAS NUMBER	COMPOUND NAME	RT	EST. CONC.	Q
1.	UNKNOWN HYDROCARBON	7.261	180.0	J
2.	UNKNOWN HYDROCARBON	7.563	710.0	J
3. 108-87-2	Cyclohexane, methyl-	7.896	450.0	NJ
4.	Cyclohexane, ethyl-methyl-	11.405	180.0	J
5.	Cyclohexane, trimethyl-	11.819	140.0	J
6.	UNKNOWN HYDROCARBON	12.357	180.0	J
7.	Octene, dimethyl-	12.960	270.0	J
8.	UNKNOWN	13.181	89.0	J
9.	UNKNOWN	13.439	120.0	J
10.	UNKNOWN HYDROCARBON	13.891	290.0	J
11.	UNKNOWN HYDROCARBON	14.219	130.0	J
12.	Cyclohexane, dimethyl-propyl	14.709	99.0	J
13. 91-17-8	Naphthalene, decahydro-	14.994	130.0	NJ
14.	UNKNOWN HYDROCARBON	15.236	210.0	J
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1A
VOLATILE ORGANICS ANALYSIS DATA SHEET

EPA SAMPLE NO.

146DPVE12DL

Lab Name: SWL-TULSA Contract: FLUORDAN

Lab Code: SWOK Case No.: GPENV SAS No.: SDG No.: 34872

Matrix: AIR Lab Sample ID: 34872.01DL

Date Received: 07/18/98 Lab File ID: Z7149.D

Date Analyzed: 07/27/98 Dilution Factor: 4460.0

GC Column:DB-5 ID: 0.32 (mm)

CAS NO.	COMPOUND	CONCENTRATION UNITS: PPBV	Q
75-71-8	Dichlorodifluoromethane (F12	4500	U
74-87-3	Chloromethane	4500	U
76-14-2	1,2-DC-1,1,2,2-TFA (F114)	4500	U
75-01-4	Vinyl Chloride	4500	U
74-83-9	Bromomethane	4500	U
75-00-3	Chloroethane	4500	U
75-69-4	Trichlorofluoromethane (F11)	4500	U
67-64-1	Acetone	4500	U
75-35-4	1,1-Dichloroethene	4500	U
76-13-1	1,1,2-TC-1,2,2-TFA (F113)	120000	D
75-09-2	Methylene Chloride	4500	U
75-15-0	Carbon Disulfide	4500	U
156-60-5	trans-1,2-Dichloroethene	4500	U
75-34-3	1,1-Dichloroethane	4500	U
78-93-3	2-Butanone	4500	U
156-59-2	cis-1,2-Dichloroethene	4500	U
67-66-3	Chloroform	4500	U
71-55-6	1,1,1-Trichloroethane	4500	U
107-06-2	1,2-Dichloroethane	4500	U
71-43-2	Benzene	4500	U
56-23-5	Carbon Tetrachloride	4500	U
78-87-5	1,2-Dichloropropane	4500	U
79-01-6	Trichloroethene	4500	U
108-10-1	4-Methyl-2-Pentanone	4500	U
10061-01-5	cis-1,3-Dichloropropene	4500	U
10061-02-6	trans-1,3-Dichloropropene	4500	U
108-88-3	Toluene	4500	U
79-00-5	1,1,2-Trichloroethane	4500	U
591-78-6	2-Hexanone	4500	U
106-93-4	1,2-Dibromoethane	4500	U
127-18-4	Tetrachloroethene	4500	U
108-90-7	Chlorobenzene	4500	U
100-41-4	Ethylbenzene	4500	U

1A
VOLATILE ORGANICS ANALYSIS DATA SHEET

EPA SAMPLE NO.

146DPVE12DL

Lab Name: SWL-TULSA Contract: FLUORDAN

Lab Code: SWOK Case No.: GPENV SAS No.: SDG No.: 34872

Matrix: AIR Lab Sample ID: 34872.01DL

Date Received: 07/18/98 Lab File ID: Z7149.D

Date Analyzed: 07/27/98 Dilution Factor: 4460.0

GC Column: DB-5 ID: 0.32 (mm)

CAS NO.	COMPOUND	CONCENTRATION UNITS: PPBV	Q
13-302-07	m,p-Xylene	4500	U
100-42-5	Styrene	4500	U
95-47-6	o-Xylene	4500	U
79-34-5	1,1,2,2-Tetrachloroethane	4500	U
622-96-8	4-Ethyltoluene	4500	U
108-67-8	1,3,5-Trimethylbenzene	4500	U
95-63-6	1,2,4-Trimethylbenzene	4500	U
541-73-1	1,3-Dichlorobenzene	4500	U
100-44-7	Benzyl Chloride	4500	U
106-46-7	1,4-Dichlorobenzene	4500	U
95-50-1	1,2-Dichlorobenzene	4500	U
120-82-1	1,2,4-Trichlorobenzene	4500	U
87-68-3	Hexachlorobutadiene	4500	U

1E
VOLATILE ORGANICS ANALYSIS DATA SHEET
TENTATIVELY IDENTIFIED COMPOUNDS

EPA SAMPLE NO.

146DPVE12DL

Lab Name: SWL-TULSA Contract: FLUORDAN

Lab Code: SWOK Case No.: GPENV SAS No.: SDG No.: 34872

Matrix: AIR Lab Sample ID: 34872.01DL

Date Received: 07/18/98 Lab File ID: Z7149.D

Date Analyzed: 07/27/98 Dilution Factor: 4460.0

GC Column:DB-5 ID: 0.32 (mm)

Number TICs found: 2

CONC. UNITS
PPBV

CAS NUMBER	COMPOUND NAME	RT	EST. CONC.	Q
1. 79-38-9	Ethene, chlorotrifluoro-	2.846	13000.0	NJD
2.	UNKNOWN	4.697	63000.0	JD
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1A
VOLATILE ORGANICS ANALYSIS DATA SHEET

EPA SAMPLE NO.

147SPRC12

Lab Name: SWL-TULSA Contract: FLUORDAN

Lab Code: SWOK Case No.: GPENV SAS No.: SDG No.: 34872

Matrix: AIR Lab Sample ID: 34910.01

Date Received: 07/21/98 Lab File ID: Z7191.D

Date Analyzed: 07/30/98 Dilution Factor: 201.0

GC Column:DB-5 ID: 0.32 (mm)

CAS NO.	COMPOUND	CONCENTRATION UNITS: PPBV	Q
75-71-8	Dichlorodifluoromethane (F12	200	U
74-87-3	Chloromethane	200	U
76-14-2	1,2-DC-1,1,2,2-TFA (F114)	200	U
75-01-4	Vinyl Chloride	200	U
74-83-9	Bromomethane	200	U
75-00-3	Chloroethane	200	U
75-69-4	Trichlorofluoromethane (F11)	200	U
67-64-1	Acetone	200	U
75-35-4	1,1-Dichloroethene	200	U
76-13-1	1,1,2-TC-1,2,2-TFA (F113)	8900	
75-09-2	Methylene Chloride	200	U
75-15-0	Carbon Disulfide	200	U
156-60-5	trans-1,2-Dichloroethene	200	U
75-34-3	1,1-Dichloroethane	200	U
78-93-3	2-Butanone	160	J
156-59-2	cis-1,2-Dichloroethene	200	U
67-66-3	Chloroform	200	U
71-55-6	1,1,1-Trichloroethane	200	U
107-06-2	1,2-Dichloroethane	200	U
71-43-2	Benzene	200	U
56-23-5	Carbon Tetrachloride	200	U
78-87-5	1,2-Dichloropropane	200	U
79-01-6	Trichloroethene	200	U
108-10-1	4-Methyl-2-Pentanone	200	U
10061-01-5	cis-1,3-Dichloropropene	200	U
10061-02-6	trans-1,3-Dichloropropene	200	U
108-88-3	Toluene	200	U
79-00-5	1,1,2-Trichloroethane	200	U
591-78-6	2-Hexanone	200	U
106-93-4	1,2-Dibromoethane	200	U
127-18-4	Tetrachloroethene	200	U
108-90-7	Chlorobenzene	200	U
100-41-4	Ethylbenzene	200	U

1A
VOLATILE ORGANICS ANALYSIS DATA SHEET

EPA SAMPLE NO.

147SPRC12

Lab Name: SWL-TULSA Contract: FLUORDAN

Lab Code: SWOK Case No.: GPENV SAS No.: SDG No.: 34872

Matrix: AIR Lab Sample ID: 34910.01

Date Received: 07/21/98 Lab File ID: Z7191.D

Date Analyzed: 07/30/98 Dilution Factor: 201.0

GC Column:DB-5 ID: 0.32 (mm)

CAS NO.	COMPOUND	CONCENTRATION UNITS: PPBV	Q
13-302-07	m,p-Xylene	200	U
100-42-5	Styrene	200	U
95-47-6	o-Xylene	200	U
79-34-5	1,1,2,2-Tetrachloroethane	200	U
622-96-8	4-Ethyltoluene	200	U
108-67-8	1,3,5-Trimethylbenzene	200	U
95-63-6	1,2,4-Trimethylbenzene	200	U
541-73-1	1,3-Dichlorobenzene	200	U
100-44-7	Benzyl Chloride	200	U
106-46-7	1,4-Dichlorobenzene	200	U
95-50-1	1,2-Dichlorobenzene	200	U
120-82-1	1,2,4-Trichlorobenzene	200	U
87-68-3	Hexachlorobutadiene	200	U

1E
VOLATILE ORGANICS ANALYSIS DATA SHEET
TENTATIVELY IDENTIFIED COMPOUNDS

EPA SAMPLE NO.

147SPRC12

Lab Name: SWL-TULSA Contract: FLUORDAN

Lab Code: SWOK Case No.: GPENV SAS No.: SDG No.: 34872

Matrix: AIR Lab Sample ID: 34910.01

Date Received: 07/21/98 Lab File ID: Z7191.D

Date Analyzed: 07/30/98 Dilution Factor: 201.0

GC Column:DB-5 ID: 0.32 (mm)

Number TICs found: 2

CONC. UNITS
PPBV

CAS NUMBER	COMPOUND NAME	RT	EST. CONC.	Q
1.	UNKNOWN	4.603	650.0	JB
2. 109-99-9	Furan, tetrahydro-	6.007	380.0	NJ
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1A
VOLATILE ORGANICS ANALYSIS DATA SHEET

EPA SAMPLE NO.

148SPRC22

Lab Name: SWL-TULSA Contract: FLUORDAN

Lab Code: SWOK Case No.: GPENV SAS No.: SDG No.: 34872

Matrix: AIR Lab Sample ID: 34910.02

Date Received: 07/21/98 Lab File ID: Z7192.D

Date Analyzed: 07/30/98 Dilution Factor: 237.0

GC Column:DB-5 ID: 0.32 (mm)

CAS NO.	COMPOUND	CONCENTRATION UNITS: PPBV	Q
75-71-8	Dichlorodifluoromethane (F12	240	U
74-87-3	Chloromethane	240	U
76-14-2	1,2-DC-1,1,2,2-TFA (F114)	240	U
75-01-4	Vinyl Chloride	240	U
74-83-9	Bromomethane	240	U
75-00-3	Chloroethane	240	U
75-69-4	Trichlorofluoromethane (F11)	240	U
67-64-1	Acetone	240	U
75-35-4	1,1-Dichloroethene	240	U
76-13-1	1,1,2-TC-1,2,2-TFA (F113)	6000	
75-09-2	Methylene Chloride	240	U
75-15-0	Carbon Disulfide	240	U
156-60-5	trans-1,2-Dichloroethene	240	U
75-34-3	1,1-Dichloroethane	240	U
78-93-3	2-Butanone	240	
156-59-2	cis-1,2-Dichloroethene	240	U
67-66-3	Chloroform	240	U
71-55-6	1,1,1-Trichloroethane	240	U
107-06-2	1,2-Dichloroethane	240	U
71-43-2	Benzene	240	U
56-23-5	Carbon Tetrachloride	240	U
78-87-5	1,2-Dichloropropane	240	U
79-01-6	Trichloroethene	240	U
108-10-1	4-Methyl-2-Pentanone	240	U
10061-01-5	cis-1,3-Dichloropropene	240	U
10061-02-6	trans-1,3-Dichloropropene	240	U
108-88-3	Toluene	240	U
79-00-5	1,1,2-Trichloroethane	240	U
591-78-6	2-Hexanone	240	U
106-93-4	1,2-Dibromoethane	240	U
127-18-4	Tetrachloroethene	240	U
108-90-7	Chlorobenzene	240	U
100-41-4	Ethylbenzene	240	U

1A
VOLATILE ORGANICS ANALYSIS DATA SHEET

EPA SAMPLE NO.

148SPRC22

Lab Name: SWL-TULSA Contract: FLUORDAN

b Code: SWOK Case No.: GPENV SAS No.: SDG No.: 34872

Matrix: AIR Lab Sample ID: 34910.02

Date Received: 07/21/98 Lab File ID: Z7192.D

Date Analyzed: 07/30/98 Dilution Factor: 237.0

GC Column:DB-5 ID: 0.32 (mm)

CAS NO.	COMPOUND	CONCENTRATION UNITS: PPBV	Q
13-302-07	m,p-Xylene	240	U
100-42-5	Styrene	240	U
95-47-6	o-Xylene	240	U
79-34-5	1,1,2,2-Tetrachloroethane	240	U
622-96-8	4-Ethyltoluene	240	U
108-67-8	1,3,5-Trimethylbenzene	240	U
95-63-6	1,2,4-Trimethylbenzene	240	U
541-73-1	1,3-Dichlorobenzene	240	U
100-44-7	Benzyl Chloride	240	U
106-46-7	1,4-Dichlorobenzene	240	U
95-50-1	1,2-Dichlorobenzene	240	U
120-82-1	1,2,4-Trichlorobenzene	240	U
87-68-3	Hexachlorobutadiene	240	U

1E
VOLATILE ORGANICS ANALYSIS DATA SHEET
TENTATIVELY IDENTIFIED COMPOUNDS

EPA SAMPLE NO.

148SPRC22

Lab Name: SWL-TULSA Contract: FLUORDAN

.b Code: SWOK Case No.: GPENV SAS No.: SDG No.: 34872

Matrix: AIR Lab Sample ID: 34910.02

Date Received: 07/21/98 Lab File ID: Z7192.D

Date Analyzed: 07/30/98 Dilution Factor: 237.0

GC Column:DB-5 ID: 0.32 (mm)

Number TICs found: 5

CONC. UNITS
PPBV

	CAS NUMBER	COMPOUND NAME	RT	EST. CONC.	Q
1.	79-38-9	Ethene, chlorotrifluoro-	2.832	320.0	NJ
2.		UNKNOWN	3.747	360.0	J
3.		UNKNOWN	4.635	660.0	JB
4.	109-99-9	Furan, tetrahydro-	6.013	550.0	NJ
5.		UNKNOWN HYDROCARBON	7.476	290.0	J
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1A
VOLATILE ORGANICS ANALYSIS DATA SHEET

EPA SAMPLE NO.

150DPVEA9

Lab Name: SWL-TULSA Contract: FLUORDAN

.b Code: SWOK Case No.: GPENV SAS No.: SDG No.: 34872

Matrix: AIR Lab Sample ID: 34910.03

Date Received: 07/21/98 Lab File ID: Z7199.D

Date Analyzed: 07/30/98 Dilution Factor: 3.0

GC Column:DB-5 ID: 0.32 (mm)

CAS NO.	COMPOUND	CONCENTRATION UNITS: PPBV	Q
75-71-8	Dichlorodifluoromethane (F12	3	U
74-87-3	Chloromethane	3	U
76-14-2	1,2-DC-1,1,2,2-TFA (F114)	3	U
75-01-4	Vinyl Chloride	7	
74-83-9	Bromomethane	3	U
75-00-3	Chloroethane	3	U
75-69-4	Trichlorofluoromethane (F11)	3	U
67-64-1	Acetone	14	
75-35-4	1,1-Dichloroethene	3	U
76-13-1	1,1,2-TC-1,2,2-TFA (F113)	3	U
75-09-2	Methylene Chloride	2	J
75-15-0	Carbon Disulfide	2	J
156-60-5	trans-1,2-Dichloroethene	3	U
75-34-3	1,1-Dichloroethane	3	U
78-93-3	2-Butanone	6	
156-59-2	cis-1,2-Dichloroethene	51	
67-66-3	Chloroform	3	U
71-55-6	1,1,1-Trichloroethane	3	U
107-06-2	1,2-Dichloroethane	3	U
71-43-2	Benzene	3	U
56-23-5	Carbon Tetrachloride	3	U
78-87-5	1,2-Dichloropropane	3	U
79-01-6	Trichloroethene	190	
108-10-1	4-Methyl-2-Pentanone	3	U
10061-01-5	cis-1,3-Dichloropropene	3	U
10061-02-6	trans-1,3-Dichloropropene	3	U
108-88-3	Toluene	25	
79-00-5	1,1,2-Trichloroethane	3	U
591-78-6	2-Hexanone	3	U
106-93-4	1,2-Dibromoethane	3	U
127-18-4	Tetrachloroethene	3	U
108-90-7	Chlorobenzene	3	U
100-41-4	Ethylbenzene	3	U

1A
VOLATILE ORGANICS ANALYSIS DATA SHEET

EPA SAMPLE NO.

150DPVEA9

Lab Name: SWL-TULSA Contract: FLUORDAN

Lab Code: SWOK Case No.: GPENV SAS No.: SDG No.: 34872

Matrix: AIR Lab Sample ID: 34910.03

Date Received: 07/21/98 Lab File ID: Z7199.D

Date Analyzed: 07/30/98 Dilution Factor: 3.0

GC Column:DB-5 ID: 0.32 (mm)

CAS NO.	COMPOUND	CONCENTRATION UNITS: PPBV	Q
13-302-07	m,p-Xylene	2	J
100-42-5	Styrene	3	U
95-47-6	o-Xylene	3	U
79-34-5	1,1,2,2-Tetrachloroethane	3	U
622-96-8	4-Ethyltoluene	3	U
108-67-8	1,3,5-Trimethylbenzene	3	U
95-63-6	1,2,4-Trimethylbenzene	3	U
541-73-1	1,3-Dichlorobenzene	3	U
100-44-7	Benzyl Chloride	3	U
106-46-7	1,4-Dichlorobenzene	3	U
95-50-1	1,2-Dichlorobenzene	3	U
120-82-1	1,2,4-Trichlorobenzene	3	U
87-68-3	Hexachlorobutadiene	3	U

1E
VOLATILE ORGANICS ANALYSIS DATA SHEET
TENTATIVELY IDENTIFIED COMPOUNDS

EPA SAMPLE NO.

150DPVEA9

Lab Name: SWL-TULSA Contract: FLUORDAN

Lab Code: SWOK Case No.: GPENV SAS No.: SDG No.: 34872

Matrix: AIR Lab Sample ID: 34910.03

Date Received: 07/21/98 Lab File ID: Z7199.D

Date Analyzed: 07/30/98 Dilution Factor: 3.0

GC Column:DB-5 ID: 0.32 (mm)

Number TICs found: 14

CONC. UNITS
PPBV

CAS NUMBER	COMPOUND NAME	RT	EST. CONC.	Q
1.	UNKNOWN	2.830	14.0	J
2.	UNKNOWN	3.024	8.0	J
3.	UNKNOWN	3.142	9.0	J
4.	UNKNOWN	3.180	10.0	J
5.	UNKNOWN	3.922	9.0	J
6.	Butadiene, methyl-	4.041	11.0	J
7. 123-72-8	Butanal	5.273	10.0	NJ
8. 66-25-1	Hexanal	9.330	6.0	NJ
9.	Cyclotrisilocane, hexamethyl	9.632	16.0	j
10. 111-71-7	Heptanal	11.477	6.0	NJ
11. 556-67-2	Cyclotetrasiloxane, octameth	13.043	5.0	NJ
12. 124-13-0	Octanal	13.522	8.0	NJ
13.	Hexanol, ethyl-	14.109	4.0	[illegible]
14. 124-19-6	Nonanal	15.352	9.0	N[illegible]
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1A
VOLATILE ORGANICS ANALYSIS DATA SHEET

EPA SAMPLE NO.

152SPRC1A9

Lab Name: SWL-TULSA Contract: FLUORDAN

Lab Code: SWOK Case No.: GPENV SAS No.: SDG No.: 34872

Matrix: AIR Lab Sample ID: 34910.04

Date Received: 07/21/98 Lab File ID: Z7200.D

Date Analyzed: 07/30/98 Dilution Factor: 2.5

GC Column:DB-5 ID: 0.32 (mm)

CAS NO.	COMPOUND	CONCENTRATION UNITS: PPBV	Q
75-71-8	Dichlorodifluoromethane (F12	2	U
74-87-3	Chloromethane	2	U
76-14-2	1,2-DC-1,1,2,2-TFA (F114)	2	U
75-01-4	Vinyl Chloride	5	
74-83-9	Bromomethane	2	U
75-00-3	Chloroethane	2	U
75-69-4	Trichlorofluoromethane (F11)	2	U
67-64-1	Acetone	5	
75-35-4	1,1-Dichloroethene	2	U
76-13-1	1,1,2-TC-1,2,2-TFA (F113)	2	U
75-09-2	Methylene Chloride	2	U
75-15-0	Carbon Disulfide	2	U
156-60-5	trans-1,2-Dichloroethene	2	U
75-34-3	1,1-Dichloroethane	2	U
78-93-3	2-Butanone	2	
156-59-2	cis-1,2-Dichloroethene	44	
67-66-3	Chloroform	2	U
71-55-6	1,1,1-Trichloroethane	2	U
107-06-2	1,2-Dichloroethane	2	U
71-43-2	Benzene	2	U
56-23-5	Carbon Tetrachloride	2	U
78-87-5	1,2-Dichloropropane	2	U
79-01-6	Trichloroethene	230	
108-10-1	4-Methyl-2-Pentanone	2	U
10061-01-5	cis-1,3-Dichloropropene	2	U
10061-02-6	trans-1,3-Dichloropropene	2	U
108-88-3	Toluene	7	
79-00-5	1,1,2-Trichloroethane	2	U
591-78-6	2-Hexanone	2	U
106-93-4	1,2-Dibromoethane	2	U
127-18-4	Tetrachloroethene	2	J
108-90-7	Chlorobenzene	2	U
100-41-4	Ethylbenzene	2	U

1A
VOLATILE ORGANICS ANALYSIS DATA SHEET

EPA SAMPLE NO.

152SPRC1A9

Lab Name: SWL-TULSA Contract: FLUORDAN

ıb Code: SWOK Case No.: GPENV SAS No.: SDG No.: 34872

Matrix: AIR Lab Sample ID: 34910.04

Date Received: 07/21/98 Lab File ID: Z7200.D

Date Analyzed: 07/30/98 Dilution Factor: 2.5

GC Column:DB-5 ID: 0.32 (mm)

CAS NO.	COMPOUND	CONCENTRATION UNITS: PPBV	Q
13-302-07	m,p-Xylene	2	U
100-42-5	Styrene	2	U
95-47-6	o-Xylene	2	U
79-34-5	1,1,2,2-Tetrachloroethane	2	U
622-96-8	4-Ethyltoluene	2	U
108-67-8	1,3,5-Trimethylbenzene	2	U
95-63-6	1,2,4-Trimethylbenzene	2	U
541-73-1	1,3-Dichlorobenzene	2	U
100-44-7	Benzyl Chloride	2	U
106-46-7	1,4-Dichlorobenzene	2	U
95-50-1	1,2-Dichlorobenzene	2	U
120-82-1	1,2,4-Trichlorobenzene	2	U
87-68-3	Hexachlorobutadiene	2	U

1E
VOLATILE ORGANICS ANALYSIS DATA SHEET
TENTATIVELY IDENTIFIED COMPOUNDS

EPA SAMPLE NO.

152SPRC1A9

Lab Name: SWL-TULSA Contract: FLUORDAN

Lab Code: SWOK Case No.: GPENV SAS No.: SDG No.: 34872

Matrix: AIR Lab Sample ID: 34910.04

Date Received: 07/21/98 Lab File ID: Z7200.D

Date Analyzed: 07/30/98 Dilution Factor: 2.5

GC Column:DB-5 ID: 0.32 (mm)

Number TICs found: 11

CONC. UNITS
PPBV

CAS NUMBER	COMPOUND NAME	RT	EST. CONC.	Q
1.	UNKNOWN	2.830	20.0	J
2.	UNKNOWN	3.023	12.0	J
3.	Propene, methyl-	3.142	5.0	J
4.	UNKNOWN	3.179	12.0	J
5.	Butene, methyl-	3.551	5.0	J
6.	UNKNOWN	3.680	5.0	J
7.	UNKNOWN HYDROCARBON	3.922	4.0	J
8.	Pentadiene	4.035	6.0	J
9. 541-05-9	Cyclotrisiloxane, hexamethyl	9.637	6.0	NJ
10.	UNKNOWN	12.602	3.0	J
11.	Hexanol, ethyl-	14.103	10.0	J
12.				
13.				
14.				
15.				
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1A
VOLATILE ORGANICS ANALYSIS DATA SHEET

EPA SAMPLE NO.

153SPRC2A9

Lab Name: SWL-TULSA Contract: FLUORDAN

Lab Code: SWOK Case No.: GPENV SAS No.: SDG No.: 34872

Matrix: AIR Lab Sample ID: 34910.05

Date Received: 07/21/98 Lab File ID: Z7201.D

Date Analyzed: 07/30/98 Dilution Factor: 1.9

GC Column:DB-5 ID: 0.32 (mm)

CAS NO.	COMPOUND	CONCENTRATION UNITS: PPBV	Q
75-71-8	Dichlorodifluoromethane (F12	2	U
74-87-3	Chloromethane	2	U
76-14-2	1,2-DC-1,1,2,2-TFA (F114)	2	U
75-01-4	Vinyl Chloride	48	
74-83-9	Bromomethane	2	U
75-00-3	Chloroethane	2	
75-69-4	Trichlorofluoromethane (F11)	2	U
67-64-1	Acetone	15	
75-35-4	1,1-Dichloroethene	3	
76-13-1	1,1,2-TC-1,2,2-TFA (F113)	2	U
75-09-2	Methylene Chloride	2	U
75-15-0	Carbon Disulfide	1	J
156-60-5	trans-1,2-Dichloroethene	34	
75-34-3	1,1-Dichloroethane	2	U
78-93-3	2-Butanone	2	U
156-59-2	cis-1,2-Dichloroethene	1400	E
67-66-3	Chloroform	2	U
71-55-6	1,1,1-Trichloroethane	2	U
107-06-2	1,2-Dichloroethane	2	U
71-43-2	Benzene	4	
56-23-5	Carbon Tetrachloride	2	U
78-87-5	1,2-Dichloropropane	2	U
79-01-6	Trichloroethene	560	E
108-10-1	4-Methyl-2-Pentanone	2	U
10061-01-5	cis-1,3-Dichloropropene	2	U
10061-02-6	trans-1,3-Dichloropropene	2	U
108-88-3	Toluene	5	
79-00-5	1,1,2-Trichloroethane	2	U
591-78-6	2-Hexanone	2	U
106-93-4	1,2-Dibromoethane	2	U
127-18-4	Tetrachloroethene	11	
108-90-7	Chlorobenzene	2	U
100-41-4	Ethylbenzene	2	U

1A
VOLATILE ORGANICS ANALYSIS DATA SHEET

EPA SAMPLE NO.

153SPRC2A9

Lab Name: SWL-TULSA Contract: FLUORDAN

.b Code: SWOK Case No.: GPENV SAS No.: SDG No.: 34872

Matrix: AIR Lab Sample ID: 34910.05

Date Received: 07/21/98 Lab File ID: Z7201.D

Date Analyzed: 07/30/98 Dilution Factor: 1.9

GC Column:DB-5 ID: 0.32 (mm)

CAS NO.	COMPOUND	CONCENTRATION UNITS: PPBV	Q
13-302-07	m,p-Xylene	2	U
100-42-5	Styrene	2	U
95-47-6	o-Xylene	2	U
79-34-5	1,1,2,2-Tetrachloroethane	2	U
622-96-8	4-Ethyltoluene	2	U
108-67-8	1,3,5-Trimethylbenzene	2	U
95-63-6	1,2,4-Trimethylbenzene	4	
541-73-1	1,3-Dichlorobenzene	2	U
100-44-7	Benzyl Chloride	2	U
106-46-7	1,4-Dichlorobenzene	2	U
95-50-1	1,2-Dichlorobenzene	2	U
120-82-1	1,2,4-Trichlorobenzene	2	U
87-68-3	Hexachlorobutadiene	2	U

1E
VOLATILE ORGANICS ANALYSIS DATA SHEET
TENTATIVELY IDENTIFIED COMPOUNDS

EPA SAMPLE NO.

153SPRC2A9

Lab Name: SWL-TULSA Contract: FLUORDAN

Lab Code: SWOK Case No.: GPENV SAS No.: SDG No.: 34872

Matrix: AIR Lab Sample ID: 34910.05

Date Received: 07/21/98 Lab File ID: Z7201.D

Date Analyzed: 07/30/98 Dilution Factor: 1.9

GC Column:DB-5 ID: 0.32 (mm)

Number TICs found: 13

CONC. UNITS
PPBV

CAS NUMBER	COMPOUND NAME	RT	EST. CONC.	Q
1.	UNKNOWN	2.819	9.0	J
2.	Propene, methyl-	3.147	6.0	J
3. 109-99-9	Furan, tetrahydro-	6.112	4.0	NJ
4. 541-05-9	Cyclotrisiloxane, hexamethyl	9.658	2.0	NJ
5.	UNKNOWN	12.596	3.0	J
6.	Hexanol, ethyl-	14.071	18.0	J
7.	UNKNOWN HYDROCARBON	15.206	11.0	J
8.	Benzene, ethyl-dimethyl-	15.798	2.0	J
9.	Benzene, tetramethyl-	15.874	3.0	J
10.	UNKNOWN HYDROCARBON	16.234	3.0	J
11.	UNKNOWN HYDROCARBON	16.772	13.0	J
12.	UNKNOWN HYDROCARBON	16.987	4.0	J
13. 91-20-3	Naphthalene	17.127	4.0	NJ
14.				
15.				
16.				
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1A
VOLATILE ORGANICS ANALYSIS DATA SHEET

EPA SAMPLE NO.

153SPRC2A9D

Lab Name: SWL-TULSA Contract: FLUORDAN

Lab Code: SWOK Case No.: GPENV SAS No.: SDG No.: 34872

Matrix: AIR Lab Sample ID: 34910.05DL

Date Received: 07/21/98 Lab File ID: Z7195.D

Date Analyzed: 07/30/98 Dilution Factor: 187.0

GC Column:DB-5 ID: 0.32 (mm)

CAS NO.	COMPOUND	CONCENTRATION UNITS: PPBV	Q
75-71-8	Dichlorodifluoromethane (F12	190	U
74-87-3	Chloromethane	190	U
76-14-2	1,2-DC-1,1,2,2-TFA (F114)	190	U
75-01-4	Vinyl Chloride	190	U
74-83-9	Bromomethane	190	U
75-00-3	Chloroethane	190	U
75-69-4	Trichlorofluoromethane (F11)	190	U
67-64-1	Acetone	190	U
75-35-4	1,1-Dichloroethene	190	U
76-13-1	1,1,2-TC-1,2,2-TFA (F113)	190	U
75-09-2	Methylene Chloride	190	U
75-15-0	Carbon Disulfide	190	U
156-60-5	trans-1,2-Dichloroethene	190	U
75-34-3	1,1-Dichloroethane	190	U
78-93-3	2-Butanone	190	U
156-59-2	cis-1,2-Dichloroethene	2200	D
67-66-3	Chloroform	190	U
71-55-6	1,1,1-Trichloroethane	190	U
107-06-2	1,2-Dichloroethane	190	U
71-43-2	Benzene	190	U
56-23-5	Carbon Tetrachloride	190	U
78-87-5	1,2-Dichloropropane	190	U
79-01-6	Trichloroethene	1300	D
108-10-1	4-Methyl-2-Pentanone	190	U
10061-01-5	cis-1,3-Dichloropropene	190	U
10061-02-6	trans-1,3-Dichloropropene	190	U
108-88-3	Toluene	190	U
79-00-5	1,1,2-Trichloroethane	190	U
591-78-6	2-Hexanone	190	U
106-93-4	1,2-Dibromoethane	190	U
127-18-4	Tetrachloroethene	190	U
108-90-7	Chlorobenzene	190	U
100-41-4	Ethylbenzene	190	U

1A
VOLATILE ORGANICS ANALYSIS DATA SHEET

EPA SAMPLE NO.

153SPRC2A9DL

Lab Name: SWL-TULSA Contract: FLUORDAN

ab Code: SWOK Case No.: GPENV SAS No.: SDG No.: 34872

Matrix: AIR Lab Sample ID: 34910.05DL

Date Received: 07/21/98 Lab File ID: Z7195.D

Date Analyzed: 07/30/98 Dilution Factor: 187.0

GC Column:DB-5 ID: 0.32 (mm)

CAS NO.	COMPOUND	CONCENTRATION UNITS: PPBV	Q
13-302-07	m,p-Xylene	190	U
100-42-5	Styrene	190	U
95-47-6	o-Xylene	190	U
79-34-5	1,1,2,2-Tetrachloroethane	190	U
622-96-8	4-Ethyltoluene	190	U
108-67-8	1,3,5-Trimethylbenzene	190	U
95-63-6	1,2,4-Trimethylbenzene	190	U
541-73-1	1,3-Dichlorobenzene	190	U
100-44-7	Benzyl Chloride	190	U
106-46-7	1,4-Dichlorobenzene	190	U
95-50-1	1,2-Dichlorobenzene	190	U
120-82-1	1,2,4-Trichlorobenzene	190	U
87-68-3	Hexachlorobutadiene	190	U

1E
VOLATILE ORGANICS ANALYSIS DATA SHEET
TENTATIVELY IDENTIFIED COMPOUNDS

EPA SAMPLE NO.

153SPRC2A9DL

Lab Name: SWL-TULSA Contract: FLUORDAN

b Code: SWOK Case No.: GPENV SAS No.: SDG No.: 34872

Matrix: AIR Lab Sample ID: 34910.05DL

Date Received: 07/21/98 Lab File ID: Z7195.D

Date Analyzed: 07/30/98 Dilution Factor: 187.0

GC Column:DB-5 ID: 0.32 (mm)

Number TICs found: 1

CONC. UNITS
PPBV

CAS NUMBER	COMPOUND NAME	RT	EST. CONC.	Q
1.	UNKNOWN	4.683	340.0	JBD
2.				
3.				
4.				
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Extraction Well Pump Discharge Samples

GPL LABORATORIES, LLLP.
ORGANIC ANALYSIS RESULTS

GP ID: 9807107-01A
Client ID: T16-3233-135-DDH
Collected: 07/13/98
Dilution: 1

Matrix: WATER
Method: OLM03.2
Units: ug/L

Analyst: NEH
Analyzed: 07/16/98
Prepared:

VOLATILE TARGET COMPOUNDS

Parameter	Result	Rep.Lim.	Qualifier
Chloromethane	BQL	10	
Bromomethane	BQL	10	
Vinyl chloride	BQL	10	
Chloroethane	BQL	10	
Methylene chloride	3	10	JB
Acetone	BQL	10	
Carbon Disulfide	BQL	10	
1,1-Dichloroethene	1	10	J
1,1-Dichloroethane	BQL	10	
cis-1,2-Dichloroethene	200	10	
trans-1,2-Dichloroethene	3	10	J
Chloroform	1	10	J
1,2-Dichloroethane	BQL	10	
2-Butanone	BQL	10	
1,1,1-Trichloroethane	BQL	10	
Carbon tetrachloride	BQL	10	
Bromodichloromethane	BQL	10	
1,2-Dichloropropane	BQL	10	
cis-1,3-Dichloropropene	BQL	10	
Trichloroethene	2000	10	-
Benzene	3	10	J
Dibromochloromethane	BQL	10	
trans-1,3-Dichloropropene	BQL	10	
1,1,2-Trichloroethane	BQL	10	
Bromoform	BQL	10	
4-Methyl-2-pentanone	BQL	10	
2-Hexanone	BQL	10	
Tetrachloroethene	130	10	
1,1,2,2-Tetrachloroethane	BQL	10	
Toluene	BQL	10	
Chlorobenzene	180	10	
Ethylbenzene	BQL	10	
Styrene	BQL	10	
Xylene (total)	BQL	10	

GPL LABORATORIES, LLLP.
ORGANIC ANALYSIS RESULTS

GP ID: 9807142-01A
Client ID: T16-3233-144-DPVE
Collected: 07/17/98
Dilution: 1

Matrix: WATER
Method: OLM03.2
Units: ug/L

Analyst: RHC
Analyzed: 07/20/98
Prepared:

VOLATILE TARGET COMPOUNDS

Parameter	Result	Rep.Lim.	Qualifier
Chloromethane	BQL	10	
Bromomethane	BQL	10	
Vinyl chloride	BQL	10	
Chloroethane	BQL	10	
Methylene chloride	BQL	10	
Acetone	BQL	10	
Carbon Disulfide	BQL	10	
1,1-Dichloroethene	BQL	10	
1,1-Dichloroethane	BQL	10	
cis-1,2-Dichloroethene	69	10	
trans-1,2-Dichloroethene	BQL	10	
Chloroform	BQL	10	
1,2-Dichloroethane	BQL	10	
2-Butanone	BQL	10	
1,1,1-Trichloroethane	BQL	10	
Carbon tetrachloride	BQL	10	
Bromodichloromethane	BQL	10	
1,2-Dichloropropane	BQL	10	
cis-1,3-Dichloropropene	BQL	10	
Trichloroethene	230	10	
Benzene	BQL	10	
Dibromochloromethane	BQL	10	
trans-1,3-Dichloropropene	BQL	10	
1,1,2-Trichloroethane	BQL	10	
Bromoform	BQL	10	
4-Methyl-2-pentanone	BQL	10	
2-Hexanone	BQL	10	
Tetrachloroethene	31	10	
1,1,2,2-Tetrachloroethane	BQL	10	
Toluene	BQL	10	
Chlorobenzene	BQL	10	
Ethylbenzene	BQL	10	
Styrene	BQL	10	
Xylene (total)	BQL	10	

GPL LABORATORIES, LLLP.
ORGANIC ANALYSIS RESULTS

GP ID: 9807153-01A
Client ID: T16-3233-149-DPVE-A9
Collected: 07/19/98
Dilution: 1

Matrix: WATER
Method: OLM03.2
Units: ug/L

Analyst: RHC
Analyzed: 07/21/98
Prepared:

VOLATILE TARGET COMPOUNDS

Parameter	Result	Rep.Lim.	Qualifier
Chloromethane	BQL	10	
Bromomethane	BQL	10	
Vinyl chloride	17	10	
Chloroethane	BQL	10	
Methylene chloride	BQL	10	
Acetone	BQL	10	
Carbon Disulfide	BQL	10	
1,1-Dichloroethene	13	10	
1,1-Dichloroethane	1	10	J
cis-1,2-Dichloroethene	3300	10	$
trans-1,2-Dichloroethene	32	10	
Chloroform	4	10	J
1,2-Dichloroethane	13	10	
2-Butanone	BQL	10	
1,1,1-Trichloroethane	BQL	10	
Carbon tetrachloride	BQL	10	
Bromodichloromethane	BQL	10	
1,2-Dichloropropane	BQL	10	
cis-1,3-Dichloropropene	BQL	10	
Trichloroethene	24000	10	$
Benzene	5	10	J
Dibromochloromethane	BQL	10	
trans-1,3-Dichloropropene	BQL	10	
1,1,2-Trichloroethane	44	10	
Bromoform	BQL	10	
4-Methyl-2-pentanone	BQL	10	
2-Hexanone	BQL	10	
Tetrachloroethene	120	10	
1,1,2,2-Tetrachloroethane	2	10	J
Toluene	6	10	J
Chlorobenzene	BQL	10	
Ethylbenzene	2	10	J
Styrene	BQL	10	
Xylene (total)	10	10	

GPL LABORATORIES, LLLP.
ORGANIC ANALYSIS RESULTS

GP ID: 9807107-01C
Client ID: T16-3233-135-DDH
Collected: 07/13/98
Dilution: 1

Matrix: WATER
Method: OLM03.2B
Units: ug/L

Analyst: CJD
Analyzed: 07/16/98
Prepared: 07/14/98

SEMIVOLATILE TARGET COMPOUNDS

Parameter	Result	Rep.Lim.	Qualifier
bis(2-Chloroethyl)ether	BQL	11	
Phenol	4	11	J
2-Chlorophenol	BQL	11	
1,3-Dichlorobenzene	BQL	11	
1,4-Dichlorobenzene	BQL	11	
1,2-Dichlorobenzene	BQL	11	
2,2'-oxybis(1-chloropropane)	BQL	11	
2-Methylphenol	BQL	11	
Hexachloroethane	BQL	11	
N-Nitroso-di-n-propylamine	BQL	11	
4-Methylphenol	BQL	11	
Nitrobenzene	BQL	11	
Isophorone	BQL	11	
2-Nitrophenol	BQL	11	
2,4-Dimethylphenol	BQL	11	
bis(2-Chloroethoxy)methane	BQL	11	
2,4-Dichlorophenol	BQL	11	
1,2,4-Trichlorobenzene	2	11	J
Naphthalene	BQL	11	
4-Chloroaniline	BQL	11	
Hexachlorobutadiene	BQL	11	
4-Chloro-3-methylphenol	BQL	11	
2-Methylnaphthalene	BQL	11	
Hexachlorocyclopentadiene	BQL	11	
2,4,6-Trichlorophenol	BQL	11	
2,4,5-Trichlorophenol	BQL	27	
2-Chloronaphthalene	BQL	11	
2-Nitroaniline	BQL	27	
Acenaphthylene	BQL	11	
Dimethylphthalate	BQL	11	
2,6-Dinitrotoluene	BQL	11	
Acenaphthene	BQL	11	

GPL LABORATORIES, LLLP.
ORGANIC ANALYSIS RESULTS

GP ID: 9807107-01C
Client ID: T16-3233-135-DDH
Collected: 07/13/98
Dilution: 1

Matrix: WATER
Method: OLM03.2B
Units: ug/L

Analyst: CJD
Analyzed: 07/16/98
Prepared: 07/14/98

SEMIVOLATILE TARGET COMPOUNDS

Parameter	Result	Rep.Lim.	Qualifier
3-Nitroaniline	BQL	27	
2,4-Dinitrophenol	BQL	27	
Dibenzofuran	BQL	11	
2,4-Dinitrotoluene	BQL	11	
4-Nitrophenol	BQL	27	
Fluorene	BQL	11	
4-Chlorophenyl-phenylether	BQL	11	
Diethylphthalate	BQL	11	
4-Nitroaniline	BQL	27	
4,6-Dinitro-2-methylphenol	BQL	27	
N-nitrosodiphenylamine	BQL	11	
4-Bromophenyl-phenylether	BQL	11	
Hexachlorobenzene	BQL	11	
Pentachlorophenol	BQL	27	
Phenanthrene	BQL	11	
Anthracene	BQL	11	
Carbazole	BQL	11	
di-n-Butylphthalate	BQL	11	
Fluoranthene	BQL	11	
Pyrene	BQL	11	
Butylbenzylphthalate	2	11	J
3,3'-Dichlorobenzidine	BQL	11	
Benzo[a]anthracene	BQL	11	
Chrysene	BQL	11	
bis(2-Ethylhexyl)phthalate	2	11	JB
di-n-Octylphthalate	BQL	11	
Benzo[b]fluoranthene	BQL	11	
Benzo[k]fluoranthene	BQL	11	
Benzo[a]pyrene	BQL	11	
Indeno[1,2,3-cd]pyrene	BQL	11	
Dibenz[a,h]anthracene	BQL	11	
Benzo[g,h,i]perylene	BQL	11	

GPL LABORATORIES, LLLP.
ORGANIC ANALYSIS RESULTS

GP ID: 9807142-01C
Client ID: T16-3233-144-DPVE
Collected: 07/17/98
Dilution: 1

Matrix: WATER
Method: OLM03.2B
Units: ug/L

Analyst: CJD
Analyzed: 07/25/98
Prepared: 07/22/98

SEMIVOLATILE TARGET COMPOUNDS

Parameter	Result	Rep.Lim.	Qualifier
bis(2-Chloroethyl)ether	BQL	12	
Phenol	BQL	12	
2-Chlorophenol	BQL	12	
1,3-Dichlorobenzene	BQL	12	
1,4-Dichlorobenzene	BQL	12	
1,2-Dichlorobenzene	8	12	J
2,2'-oxybis(1-chloropropane)	BQL	12	
2-Methylphenol	BQL	12	
Hexachloroethane	BQL	12	
N-Nitroso-di-n-propylamine	BQL	12	
4-Methylphenol	BQL	12	
Nitrobenzene	BQL	12	
Isophorone	BQL	12	
2-Nitrophenol	BQL	12	
2,4-Dimethylphenol	BQL	12	
bis(2-Chloroethoxy)methane	BQL	12	
2,4-Dichlorophenol	BQL	12	
1,2,4-Trichlorobenzene	BQL	12	
Naphthalene	BQL	12	
4-Chloroaniline	BQL	12	
Hexachlorobutadiene	BQL	12	
4-Chloro-3-methylphenol	BQL	12	
2-Methylnaphthalene	BQL	12	
Hexachlorocyclopentadiene	BQL	12	
2,4,6-Trichlorophenol	BQL	12	
2,4,5-Trichlorophenol	BQL	29	
2-Chloronaphthalene	BQL	12	
2-Nitroaniline	BQL	29	
Acenaphthylene	BQL	12	
Dimethylphthalate	BQL	12	
2,6-Dinitrotoluene	BQL	12	
Acenaphthene	BQL	12	

GPL LABORATORIES, LLLP.
ORGANIC ANALYSIS RESULTS

GP ID: 9807142-01C
Client ID: T16-3233-144-DPVE
Collected: 07/17/98
Dilution: 1

Matrix: WATER
Method: OLM03.2B
Units: ug/L

Analyst: CJD
Analyzed: 07/25/98
Prepared: 07/22/98

SEMIVOLATILE TARGET COMPOUNDS

Parameter	Result	Rep.Lim.	Qualifier
3-Nitroaniline	BQL	29	
2,4-Dinitrophenol	BQL	29	
Dibenzofuran	BQL	12	
2,4-Dinitrotoluene	BQL	12	
4-Nitrophenol	BQL	29	
Fluorene	BQL	12	
4-Chlorophenyl-phenylether	BQL	12	
Diethylphthalate	BQL	12	
4-Nitroaniline	BQL	29	
4,6-Dinitro-2-methylphenol	BQL	29	
N-nitrosodiphenylamine	BQL	12	
4-Bromophenyl-phenylether	BQL	12	
Hexachlorobenzene	BQL	12	
Pentachlorophenol	BQL	29	
Phenanthrene	BQL	12	
Anthracene	BQL	12	
Carbazole	BQL	12	
di-n-Butylphthalate	14	12	B
Fluoranthene	BQL	12	
Pyrene	BQL	12	
Butylbenzylphthalate	BQL	12	
3,3'-Dichlorobenzidine	BQL	12	
Benzo[a]anthracene	BQL	12	
Chrysene	BQL	12	
bis(2-Ethylhexyl)phthalate	15	12	B
di-n-Octylphthalate	BQL	12	
Benzo[b]fluoranthene	BQL	12	
Benzo[k]fluoranthene	BQL	12	
Benzo[a]pyrene	BQL	12	
Indeno[1,2,3-cd]pyrene	BQL	12	
Dibenz[a,h]anthracene	BQL	12	
Benzo[g,h,i]perylene	BQL	12	

GPL LABORATORIES, LLLP.
ORGANIC ANALYSIS RESULTS

GP ID: 9807153-01C
Client ID: T16-3233-149-DPVE-A9
Collected: 07/19/98
Dilution: 1

Matrix: WATER
Method: OLM03.2B
Units: ug/L

Analyst: CJD
Analyzed: 07/25/98
Prepared: 07/22/98

SEMIVOLATILE TARGET COMPOUNDS

Parameter	Result	Rep.Lim.	Qualifier
bis(2-Chloroethyl)ether	BQL	10	
Phenol	BQL	10	
2-Chlorophenol	BQL	10	
1,3-Dichlorobenzene	BQL	10	
1,4-Dichlorobenzene	BQL	10	
1,2-Dichlorobenzene	BQL	10	
2,2'-oxybis(1-chloropropane)	BQL	10	
2-Methylphenol	BQL	10	
Hexachloroethane	BQL	10	
N-Nitroso-di-n-propylamine	BQL	10	
4-Methylphenol	BQL	10	
Nitrobenzene	BQL	10	
Isophorone	BQL	10	
2-Nitrophenol	BQL	10	
2,4-Dimethylphenol	BQL	10	
bis(2-Chloroethoxy)methane	BQL	10	
2,4-Dichlorophenol	BQL	10	
1,2,4-Trichlorobenzene	BQL	10	
Naphthalene	1	10	J
4-Chloroaniline	BQL	10	
Hexachlorobutadiene	BQL	10	
4-Chloro-3-methylphenol	BQL	10	
2-Methylnaphthalene	BQL	10	
Hexachlorocyclopentadiene	BQL	10	
2,4,6-Trichlorophenol	BQL	10	
2,4,5-Trichlorophenol	BQL	26	
2-Chloronaphthalene	BQL	10	
2-Nitroaniline	BQL	26	
Acenaphthylene	BQL	10	
Dimethylphthalate	BQL	10	
2,6-Dinitrotoluene	BQL	10	
Acenaphthene	BQL	10	

GPL LABORATORIES, LLLP.
ORGANIC ANALYSIS RESULTS

GP ID: 9807153-01C
Client ID: T16-3233-149-DPVE-A9
Collected: 07/19/98
Dilution: 1

Matrix: WATER
Method: OLM03.2B
Units: ug/L

Analyst: CJD
Analyzed: 07/25/98
Prepared: 07/22/98

SEMIVOLATILE TARGET COMPOUNDS

Parameter	Result	Rep.Lim.	Qualifier
3-Nitroaniline	BQL	26	
2,4-Dinitrophenol	BQL	26	
Dibenzofuran	BQL	10	
2,4-Dinitrotoluene	BQL	10	
4-Nitrophenol	BQL	26	
Fluorene	BQL	10	
4-Chlorophenyl-phenylether	BQL	10	
Diethylphthalate	BQL	10	
4-Nitroaniline	BQL	26	
4,6-Dinitro-2-methylphenol	BQL	26	
N-nitrosodiphenylamine	BQL	10	
4-Bromophenyl-phenylether	BQL	10	
Hexachlorobenzene	BQL	10	
Pentachlorophenol	BQL	26	
Phenanthrene	BQL	10	
Anthracene	BQL	10	
Carbazole	BQL	10	
di-n-Butylphthalate	17	10	B
Fluoranthene	BQL	10	
Pyrene	BQL	10	
Butylbenzylphthalate	BQL	10	
3,3'-Dichlorobenzidine	BQL	10	
Benzo[a]anthracene	BQL	10	
Chrysene	BQL	10	
bis(2-Ethylhexyl)phthalate	4	10	JB
di-n-Octylphthalate	BQL	10	
Benzo[b]fluoranthene	BQL	10	
Benzo[k]fluoranthene	BQL	10	
Benzo[a]pyrene	BQL	10	
Indeno[1,2,3-cd]pyrene	BQL	10	
Dibenz[a,h]anthracene	BQL	10	
Benzo[g,h,i]perylene	BQL	10	

Appendix C
FDGTI Pilot Test Schematic Diagrams

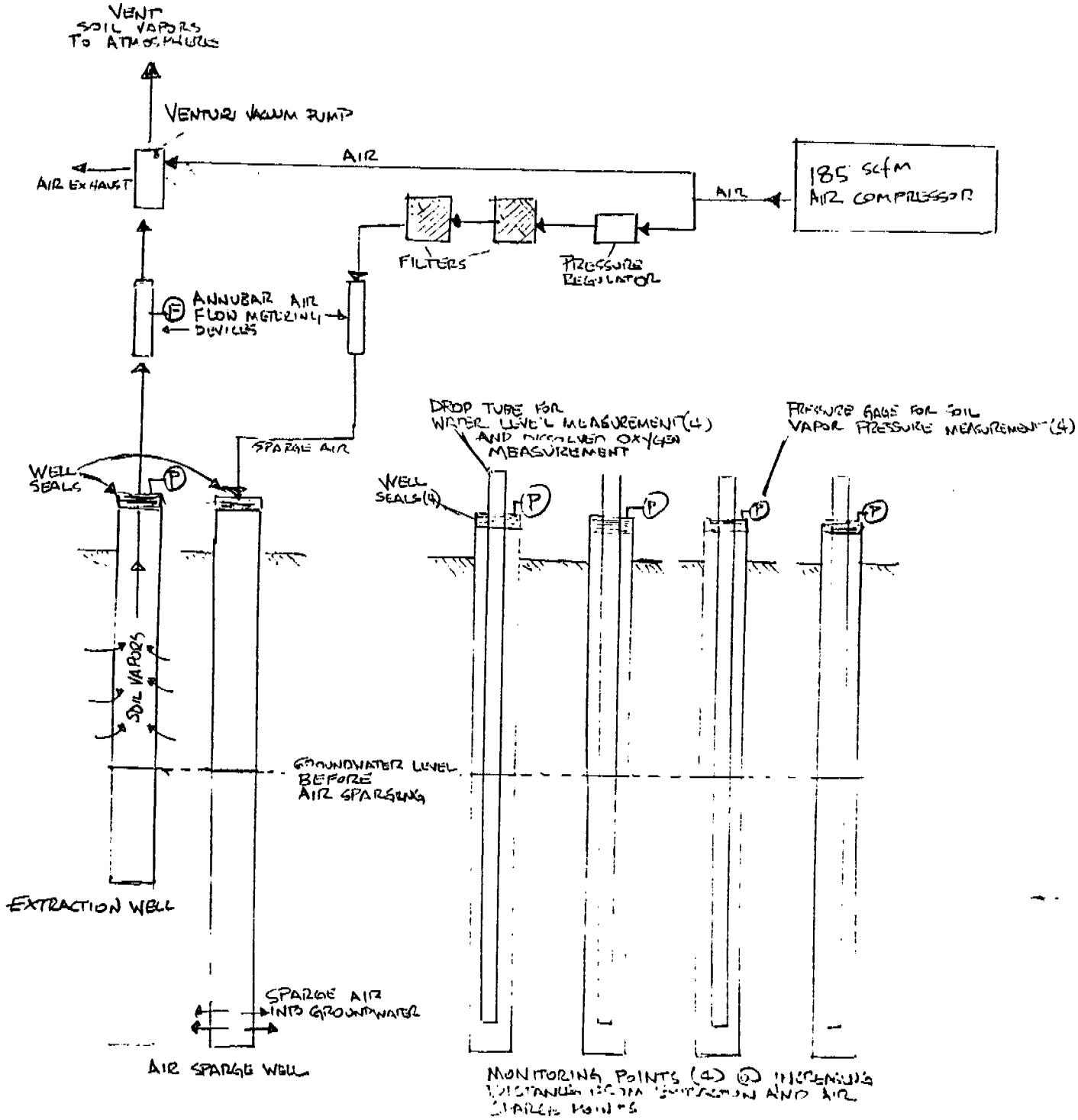
FLUOR DANIEL GTI **ENGINEERING GRID**

PROJECT Crab Orchard Wildlife Refuge PROJECT NUMBER 0668740

SUBJECT Air Sparge Schematic BY Haggard DATE Dec 16, 1998

PAGE ____ OF ____

CHECKED BY ____ DATE ____



200 796AC-170B

FLUOR DANIEL GTI

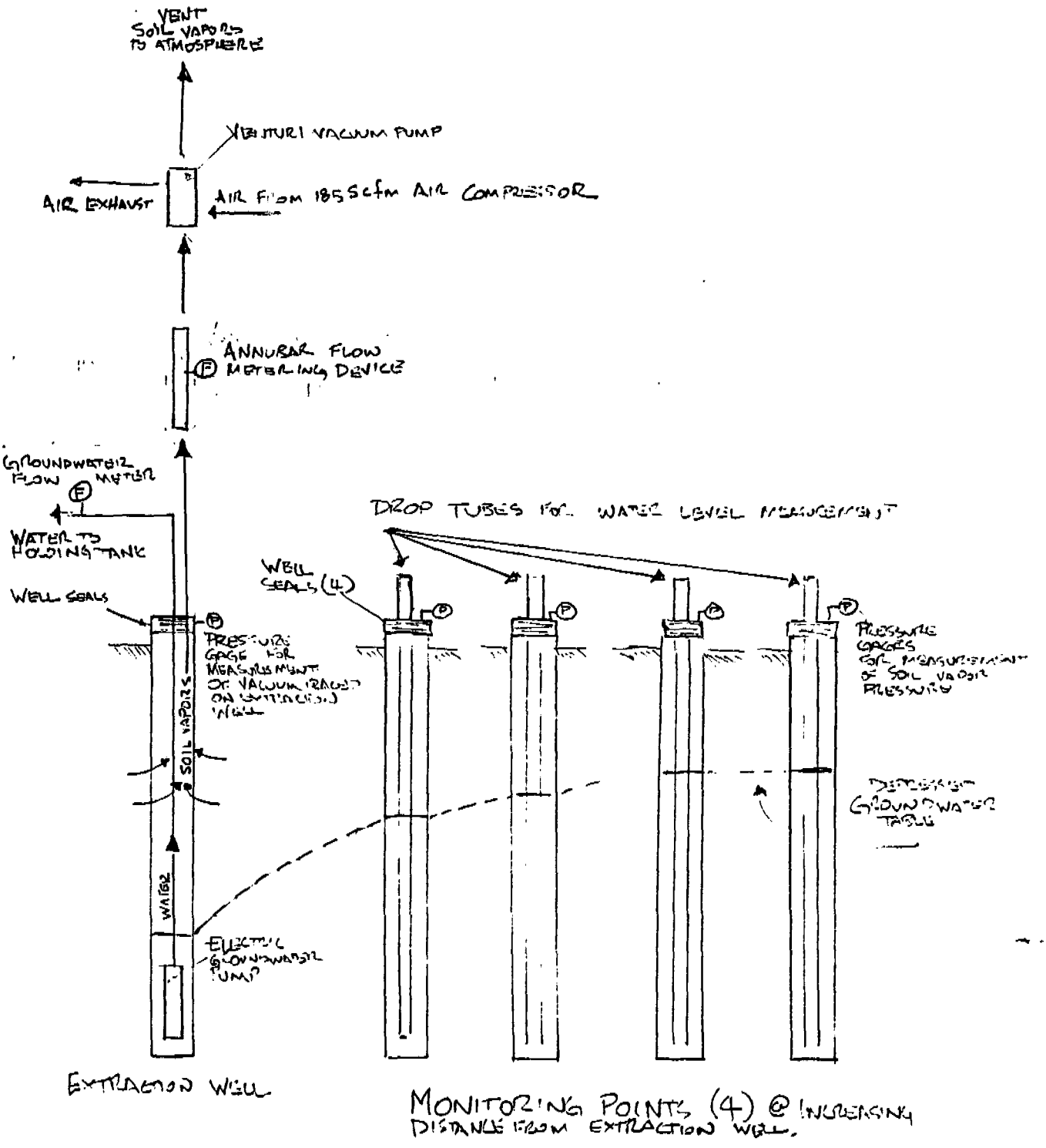
ENGINEERING GRID

PROJECT Crab Orchard Middle Refuse — PROJECT NUMBER 3633-4-3

SUBJECT Dual Phase Extraction [illegible] — BY HAGGARD — DATE DEC 16, 1998

PAGE _____ OF _____

CHECKED BY _____ DATE _____



200-798AC-170R

FLUOR DANIEL GTI

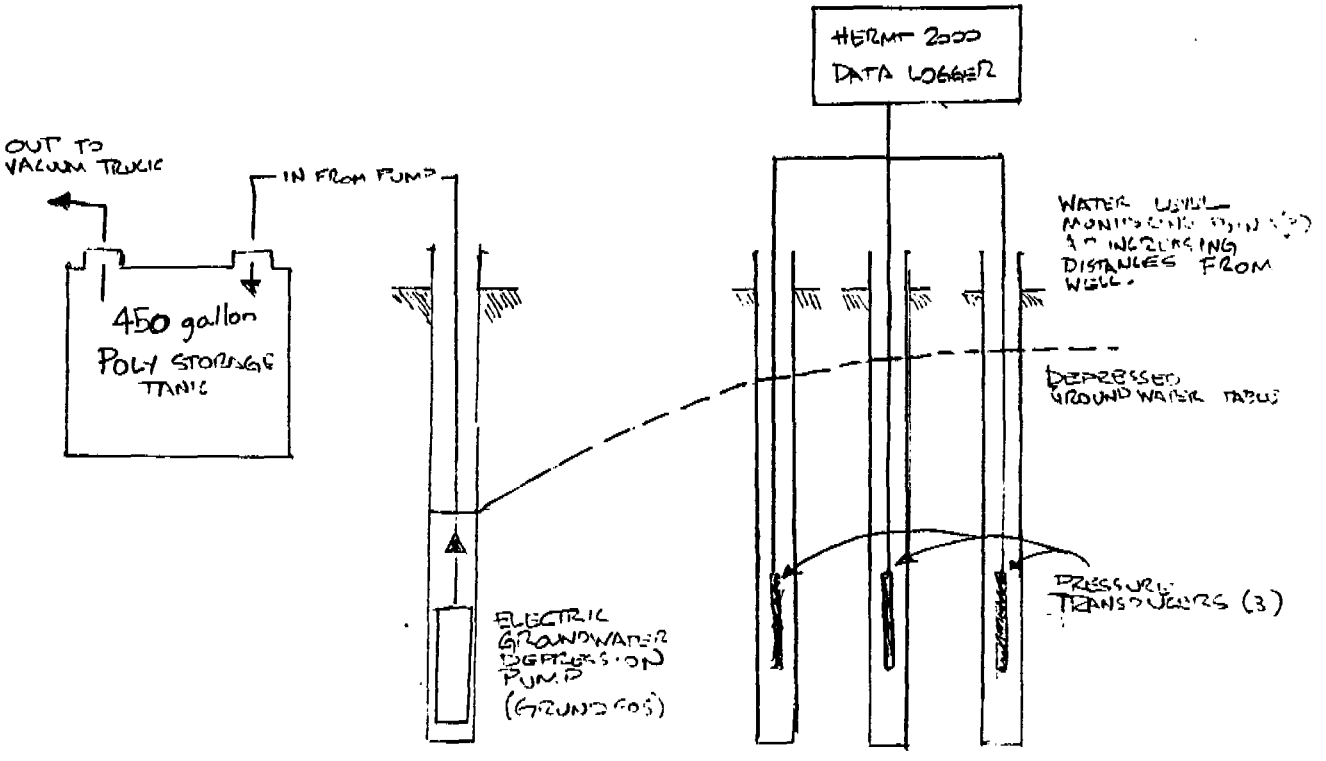
ENGINEERING GRID

PROJECT Crab Orchard Wildlife Refuge — PROJECT NUMBER 0068740

SUBJECT Aquifer Pump Test Schematic — BY Haggard — DATE Dec 16, 1998

PAGE ____ OF ____

CHECKED BY ____ DATE ____



200-796AC-170R

Appendix D
FDGTI Field Data Collection Sheets

Field Logs from SVE/Air Sparge Tests and Dual-Phase Extraction Tests

Logs Prepared by FDGTI

Site: COWR I-423 TEST
Date: 7-13-98
Testers: BRANDON HAGGARD
BILL HARDMAN

Weather: HAZY - HOT

Barometric Pressure:
Temperature:

Well I.D.	MP-1				MP-2				*HERMIT MP-3 (INST 2)				*HERMIT MP-4 (INST 2) (TEST #12)				SVE-1				SVE-2				SVE-3			
Distance	34'5"				12'5"				8'6"				12'11"				39'11"				20'0"				23'3"			
Time	DTW	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC	
Static	10.96				10.31				10.23				10.94															
5	10.97				10.48																							
10	10.98				10.60																							
15	10.99				10.66				HARD (SS)				HARD (SS)															
20	11.00				10.72																							
25	11.01				10.76																							
30	11.02				10.80																							
35	11.03				10.84				.666				.556															
40	11.05				10.86				—				~~.574~~															
45	11.05				10.88				.733				.594															
50	11.07				10.90				—				—															
55	11.08				10.92				.790				.626															
60	11.10				10.94				—				—															
75	11.14				10.97				.860				.670															
90	11.17				11.01				.898				.702															
105	11.21				11.03				.914				.711															
120	11.24				11.05				.914				.711															
135	NT				NT				NT				NT															
150	11.31				11.08				.968				.762															
165	11.34				11.09				.977				~~NT~~ .785															
180	11.38				11.10				1.013				.797															

Blower:
How was Air Flow Measured:
How was Water Flow Measured: HERSEY WATER METER
How were VOCs Measured:

WATER METER READING PRIOR TO TEST START: 155,840 GALLONS

TRANSDUCERS SET IN MP-3 & MP-4 FOR TEST DURATION - TEST #12

155935 @ 32 MIN INTO TEST ≈ 3 GPM
1ST HOUR USED ≈ 40 PSI TO RUN PUMP

156025 @ 60 MIN ≈ 3.08 GPM
156198 @ 120 MIN ≈ 2.98 GPM
156291 @ 180 MIN ≈ 1.55 GPM 2.55 GPM OUTPUT

	DTW	TIME (MIN)
EXTRACTION WELL	14.42	60
	14.54	120
	14.58	180
14.85 MIN 210	~~14.85~~	240
14.86	15.01	300
	15.23	360
	15.44	420

Site: COWR 7723 TEST
Date: 7-13-98
Testers: BRADDON HAGGARD
BILL HARDMAN

Weather: HAZY - HOT

Barometric Pressure:
Temperature:

Well I.D.	MP-1				MP-2				MP-3 (INPUT 2)				MP-4 (INPUT 1)				SVE-1				SVE-2				SVE-3			
Distance									HEAD LOSS (FT)				HEAD LOSS (FT)															
Time	DTW	VAC	VOC		DTW	VAC	VOC		DTW	VAC	VOC		DTW	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC	
Static	—				—				—				—															
210	11.42				11.13				1.028				.807															
240	11.47				11.14				1.041				.820															
270	11.52				11.16				1.060				.842															
300	11.55				11.18				1.082				.864															
330	11.59				11.20				1.095				.879															
360	11.62				11.21				1.114				.889															
390	11.65				11.22				1.114				.896															
420	11.67				11.24				1.124				.905															
450	11.69				11.24				1.136				.915															
480	11.71				11.25				1.143				.924															
510	11.73				11.25				1.149				.931															
540	11.74				11.26				1.162				.940															
* 570	11.76				11.34				1.168				.950															
600	11.78				11.30				1.209				.982															
630	11.80				11.30				1.184				.972															
660	11.80				11.32				1.219				.982															
690	11.82				11.32				1.222				.998															

* VACCUM STARTED

STOPPED PUMP TEST @ 1923 (12 HOURS)

Blower:
How was Air Flow Measured:
How was Water Flow Measured:
How were VOCs Measured:

INITIAL WATER METER 155,840

GALLONS	MINS	GPM LAST HOUR	MINS	GPM
	240	3.0	600	3.1
	300	3.1	660	2.9
	360	3.1		
	~~360~~ 420	3.0		
	480	3.1		
	540	3.1		

EXTRACTION WELL (CONTINUED)

DTW	TIME (MIN)
	540
	600
	660
	720

D-6

Site: COWR I-1-23
Date: ~~7-14-98~~ 7-15-98
Testers: BRANDON HAGGARD
BILL HARDMANT

Weather: OVERCAST - LIGHT DRIZZLE

Barometric Pressure:
Temperature:

SVE TEST

Well I.D.	MP-1				MP-2				MP-3				MP-4				SVE-1				SVE-2				SVE-3			
Distance	34' 5"				12' 5"				8' 6"				12' 11"															
Time	DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC	
Static	11.41				10.79				10.66				11.37															
30	11.66				11.67				11.95				12.40															
60	11.84				11.91				12.24				12.60															
90	12.00				12.02				12.35				12.70															
120	12.12				12.07				12.42				12.77															
150	12.24				12.15				12.48				12.8[illegible]															
180	12.30				12.20				12.52				12.86															
~~210~~	—	—			—	—			—	—			—	—			—	—			—	—			—	—		
~~240~~	—	—			—	—			—	—			—	—			—	—			—	—			—	—		
270	12.52				12.38				12.74	0			13.02	0				0				0				0		
~~300~~ 285	—	0			—	0			—	0			—	0				0				0				0		
300	12.58	0			12.39	0			12.74	0			13.03	0				0				0				0		
~~315~~	—	0			—	0			—	0			—	0				0				0				0		
330	12.63	0			12.38	0			12.76	0			13.06	0				0				0				0		
345	—	0			—	0			—	0			—	0				0				0				0		
360	12.66				12.42				12.78				13.06					0				0				0		
375	—	0			—	0			—	0			—	0				0				0				0		
390	12.72	0			12.42	0			12.80	0			13.08	0				0				0				0		
420	12.74	0			12.47	0			12.82	0			13.12	0				0				0				0		
450	12.76	0			12.47	0			12.86	0			13.21	0				0				0				0		

Blower:
How was Air Flow Measured:
How was Water Flow Measured: MEASURED IN BUCKET + TIMED USED GROUNDED PUMP TO CREATE DRAWDOWN FREQUENCY - 360
How were VOCs Measured:

STARTED TEST @ 0724 USED PUMPING RATE OF 6 GPM (360 FREQUENCY)

CHECKED PUMPING RATE = 5.7 GPM @ 30 MINS INTO TEST
= 6.0 GPM @ 60 MINS INTO TEST
= 6.0 GPM @ 90 MINS " "
= 5.9 GPM @ 120 MINS " "
= 6.0 GPM @ 150 MIN

INCREASED PUMPING RATE TO 6.2 GPM @ 420 to OPEN MORE ~~SCR~~ SCREEN

STARTED SVE @ ≈ 4 hrs 15 min INTO PUMPING TEST

D-7

12 7

Site: COWR I-1-23
Date: 7-15-98
Testers: BRANDON HAGGARD
BILL HARDMANT

Weather: OVERCAST - HAZY - OCCASIONAL DRIZZLE

Page 2 of 2

Barometric Pressure:
Temperature:

SVE TEST

Well I.D.	MP-1				MP-2				MP-3				MP-4				SVE-1				SVE-2				SVE-3			
Distance																												
Time	DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC	
Static	11.41	–			12.79	–			12.46	–			12.32	–				–				–				–		
480	12.80	0			12.54	0			12.92	0			13.20	0				0				0				0		
510	12.84	0			12.61	0			13.01	0			13.38	0				0				0				0		
540	12.88	0			12.61	0			13.01	0			13.38	0				0				0				0		
570	12.89	–			12.46	–			12.75	–			13.08	–				–				–				–		

Blower:
How was Air Flow Measured:
How was Water Flow Measured:
How were VOCs Measured:

COLLECTED AIR SAMPLE SUMA CANISTER @ ~~1400~~ 1600

D-8

I-1-23 7-15-98 S. - TEST

Page 1 of 1

Time	Water Pumping Rate	Air Flow Rate (Annubar IN H_2O)	Vac @ Blower Hg"	Vac. @ Well Hg" (IN H_2O)	Effluent Air LEL	O2	CO2	Tem	Comments: STARTED SVE TEST @ 1145 AFTER PUMPING FOR 4 HOURS 15 MIN.
Initial	6.06 gpm	~~213~~ 0.2	213	~~0.7~~	6.1				
270		~~200~~ 0.2	200		6.0				
285		~~199~~ 0	199		3.1				
300		~~200~~ 0	200		3.1				AFTER MEASUREMENT - INCREASED VAC TO 213 IN H_2O
315		----							
330		* ~~0.5~~ 3	200		2.5				* Annubar reading units changed from in H_2O to mm H_2O to read in small increments.
~~345~~		3	203		2.6				
360		4	218		2.5				
375		* .5	210		2.0				* ANNUBAR READING UNITS CHANGED BACK TO IN" OF H_2O
390		.5-0.2	217		1.5				
420		.5	218		1.5				LOST PUMP @ ≈ 440 MINS. TOO TEST. RESTARTED IT @ 6 GPM
450		0.0	126		1.6				
480		0.5	130		1.6				
510		0.2	187.5		1.3				
540		0.2	205		1.3				
570		—	—		—				LOST VACUUM - PULLED PUMPING HOSE AND WELL - HAD TO SHUT OFF VAC. TO FIX

Notes: * @ 330 min → Annubar reading switched to mm H_2O to read in smaller increments

Site: COWR I-1-23
Date: July 16, 1998
Testers: BRANDON HAGGARD
BILL HARDMANT

Weather: Pt. Cloudy Hot
Barometric Pressure:
Temperature: N95

Page 1 of 1

SPARGE TEST

Well I.D.	MP-1				MP-2				MP-3				MP-4				SPARGE				EXTRACTION						
*Distance	24'-6"				from 14'-6"				to 12'				5'-9"				PRESSURE										
Time	DT	VAC	VOC	DO	DT	VAC	VOC	DO	DT	VAC	VOC	DO	DT	VAC	VOC	DO	DO	VAC	VOC		DO	VAC	VOC		DT	VAC	VOC
Static	11.80	0		0.62	11.14	0		0.70	11.02	0		0.73	11.72	+6		0.55					2.8	295					
~~1150~~																											
1200																	4.8	21									
1215	11.54	0		0.93	10.48	0		.85	10.30	+3.0			10.66	+21		0.8	0.2	21			.2	278					
1230	11.36	0		0.92	10.48	0		.77	10.32	0			10.66	+186		1.70	4.0	21			0	278					
1245	11.34	0		0.86	10.42	+1		.73	10.23	0		0.73	9.79	+555		6.00	.5	21			.8	274					
1300	11.29	0		0.88	10.36	+3		.76	10.20	+3		0.72	8.92	+1483		3.80	1.1	25			.2	272					
1315	11.10	0		0.98	10.12	+11		.74	9.92	+1		0.66	8.82	+937		3.46	1.1	25			.2	274					
1330	11.04	0		0.80	10.06	+29		.64	9.84	+0		0.62	8.85	1256		3.61	1.1	25			.2	275					
1345	10.94	0		0.90	10.15	+66		.66	9.94	+1		0.70	8.99	1580		4.68	1.2	25			.2	297					
1400	10.90	0		0.77	10.14	94		.66	9.96	+6		0.70	9.19	1711		3.55	1.3	25			.1	271					
1430	10.70	0		0.81	9.72	105		.61	9.52	+14		0.55	8.54	2068		5.14	1.6	30			.1	294					
1500	10.55	0		1.21	9.74	330		.92	9.57	19		—	8.30	2395		5.25	1.5	30			.1	279					
1530	10.59	0		0.70	9.87	451		.66	9.70	23		.54	8.39	2573		5.34	1.8	30			.2	273					
1600	10.64	0		0.62	10.04	459		1.77	9.88	21		.64	8.31	2857		5.50	2.3	30			.1	272					
1630																											
1700																											
1730																											
1800																											
1830																											

Blower: VACCON VENTURI -SVE | COMPRESSOR W/ REG. - AS
How was Air Flow Measured: 1½ & ¼ Annular
How was Water Flow Measured: NA
How were VOCs Measured: PID & SUMA

* DISTANCES ARE FROM SPARGE WELL.
VAC is in mm H_2O for Monitoring Point

PID VAPOR READINGS WERE 1.2 ppmv (BACKGROUND)

≈ 2 HOURS INTO TEST INCREASED PRESSURE TO 30 PSI

PREFERENTIAL PATHWAY DETECTED:

The shallow aquifer well was noted as "bubbling" around the well casing. A moderate volume of air was flowing through the well & casing. This caused the lack of sparge effect on MP-1 by short circuiting between MP-1 & AS well.

BACKGROUND READING PID - 1.3 ppm
TEDLAR BAG READING PID 1.6 ppm

Site: COWR I-1-2 AREA
Date: 7-17-88
Testers: BRANDON HAGGARD
BILL HARDMANT

Weather: SUNNY - HOT

Barometric Pressure:
Temperature:

AQUIFER TEST / SVE

Well I.D.	MP-1				MP-2 (INFO 2)				MP-3 (INFO 1)				MP-4				EXTRACTION WELL				PUMPING WELL							
Distance	43'-10"				11'-11"				11'-2"				16'-4"															
Time	DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC	RATE	DT	VAC	VOC	
Static	8.87				9.12				8.98				9.03				9.37							6				
5	8.94				12.16				14.06				12.42				18.40							6				
10	9.03				13.22				15.88				14.02				19.90							6				
15	9.22				15.20				17.53				16.36				21.68							6				
20	9.42				—				—				16.22				—							6				
25	9.67				—				—				17.10				—							6				
30	9.90				16.86				19.66				17.70				23.64							6				
35	10.10				—				—				18.20				—							6				
40	10.40				—				—				18.72				—							6				
45	10.58				18.08				21.12				19.14				25.12							6				
50	10.70				—				—				19.52				—							6				
55	10.82				—				—				19.84				—							6				
60	10.88				19.40				22.14				20.22				26.18							6				
75	10.95				19.71				22.89				20.98				26.97							6				
90	11.63				20.24				23.50				21.62				27.59							6				
105	12.22				20.64				23.90				22.06				28.05							6				
120	12.69				20.99				24.29				22.44				28.42							6				
135	13.04				—				—				22.72				28.65							6				
150	13.33				—				—				23.01				29.01							6				
9:15 165	13.58				—				—				23.22				29.23											

Blower:
How was Air Flow Measured:
How was Water Flow Measured:
How were VOCs Measured:

PUMP RATE IS IN G.P.M.

HERMIT SETUP ON MP-2 & MP-3

D-11

Site: COWR I-1-2 AQUIFER/SVE TEST
Date: 7-17-98
Testers: BRANDON HAGGARD
BILL HARDMANT

Weather:

Barometric Pressure:
Temperature:

Well I.D.	MP-1				MP-2				MP-3				MP-4				EXTRACTION				PUMPING				SVE-2		SVE-3	
Distance					INJ(2)				INJ(1)								WELL				WELL			Pump	22'4"		24' 3"	
Time	DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC	PID	DT	VAC	VOC	Out	DT	VAC	VOC	
Static	8.37				9.12				9.98				9.03				9.37							6		~~0.1~~	0	
Pump 180	13.74			21.84	24.84				25.26				23.42				29.47							6.0				
210	14.18				—				—				23.85				29.89							6.0				
240	14.44				22.44				DRY				24.12				30.16							6.0				
* 270	14.72				—				—				24.32				31.00							6.0				
12 300	14.90				—				—				24.45				29.80							5.0				
330	15.06				—				—				24.44				30.14							5.0				
360	15.17				22.97				DRY				24.47				—							5.0				
375	—	0			—	0.1			—	3.7			—	8.9			—		1.5	1.0				5.0				
390	15.45				24.07	4.7			DRY	5.3			25.79	9.3			—	170	.5	0.9				5.0		0.1	0.0	
405	—	0			—	6.2			—	9.0			—	8.9			—	147	.5	1.0				—		0.0	0.0	
420	15.76	0			24.63	8.5			DRY	12.9			25.82	11.0			—	185	.2	1.0				5.0		0.0	0.0	
435	—	0			—	10.5			—	16.5			—	11.7			—	184	0	1.0				5.0		0.0	0.0	
450	16.02	.3			24.62	12.5			DRY	18.2			25.74	14.0			—	198	.2	1.6				5.0		0.0	0.0	
465	—	0			—	13.6			—	18.2			—	13.4			—	187	.2	1.3				5.0		0.0	0.0	
480	16.24	0			24.44	18.2			DRY	31.7			26.34	[illegible]	14.9		—			1.6				5.0		0.0	0.0	
510	16.42	0			24.51	27.6			DRY	36.9			26.43	16.0			—	187	.2	1.6				5.0		0	0	
540	16.57	0			24.81	28.4			DRY	39.3			26.79	18.6			—	188	0	1.6				5.0		0	0	
570	16.70				24.83	28.6				25.0			26.75	18.2														
600	16.77	0			25.20	28.4				26.2			26.96	18.8				198	.2	1.6						0	0	

Blower:
How was Air Flow Measured:
How was Water Flow Measured:
How were VOCs Measured:

@ 210 MINUTES INTO TEST BACKGROUND PID: 0.9
LOWER PUMP ≈ 1½ FEET

SV-2 .1
SV-3 0

* @ 270 MINS INTO TEST - WATER LEVEL NEAR BOTTOM OF PUMP
SO WE ADJUSTED THE FLOW RATE TO = 5 GPM (FROM 324)

VAC MEASURED IN INCHES OF H_2O

D-12

Site: COWR T-1-2 AQUIFER / SVE TEST
Date: 7-17-98
Testers: BRANDON HAGGARD
BILL HARDMANT

Weather: HOT / SUNNY

Barometric Pressure:
Temperature:

Well I.D.	MP-1				MP-2				MP-3				MP-4				PORT				PUMP			GPM / PUMP	SVE-2		SVE-3	
Distance																												
Time	DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC	PID	DT	VAC	VOC	BAR	DT	VAC	VOC	
Static					24.88					↑			26.42															
630	16.88	0			~~26.07~~	26.7			DRY	41.9			~~24.88~~	20.2			—	188	0.2	.8				5.0		0	0	
660	16.98	0			25.09	28.1			DRY	48.6			26.96	22.7						1.8						0	0	
690	17.11	0			25.13	26.2			DRY	44.8			27.08	~~26.2~~												0	0	

Blower:
How was Air Flow Measured:
How was Water Flow Measured:
How were VOCs Measured:

PID BACKGROUND HAS RANGED FROM 0.9 – 1.3

D13

Site: COWR I-1-2
Date: 7-18-98
Testers: BRANDON HAGGARD
BILL HARDMANT

Weather: SUNNY - HOT

Barometric Pressure:
Temperature:

from sparge well

SPARGE TEST

Well I.D.	MP-1				MP-2				MP-3				MP-4				SPARGE WELL				EXTRACTION							
Distance	27'-10"				19'-5"				8'-2"				5'-6"				AMWBR		PRESSER		AMW	WELL PRESSER						
Time	DTW	VAC	VOC	DO	DTW	VAC	VOC	DO	DTW	VAC	VOC	DO	DTW	VAC	VOC	DO	DT	VAC	VOC		DT	VAC	VOC	PID	DT	VAC	VOC	
Static																			PSI									
0800		0				0				0				0							ND		165					
0815		0				0				0				0							ND		177					
0830		0				0				0				0							ND		177					
0845		0				0				0				0							ND		178					
0900		0				0				0				0							ND		172					
0915		0				0				0				0							ND		178					
0930		0				0				0				0							ND		170					
0945		0				0				0				0							ND		169					
1000	10.65	0		0.86	11.08	0		0.82	10.95	0		1.15	10.99	0		0.64			5		ND		169	1.0				
1015	11.52	-2		2.55	10.69	+6.7		0.81	10.30	-2		4.79	4.20	+.8		3.02	0.3		10		0		179					
1030	10.29	0		0.78	7.56	-.5		0.78	8.38	134		11.00	6.72	98.6		6.53	0.2		10		0		188					
1045	10.13	0		0.79	10.18	-1.8		0.52	9.98	124		10.48	8.32	109.4		5.84	0.2		10		0		174	0.9				
1100	10.11	0		0.77	10.33	0.0		0.48	10.26	116.0		10.64	8.78	123.0		8.28	0.5		10		0		177					
1130	10.16	0		0.90	10.52	0		1.67	[illegible]	84.0	6.1	7.87	9.55	146.9	6.6	10.68	0.5		10		0		179					
1200	10.78	0		0.83	10.82	0.2		0.73	10.68	0.2		9.17	11.94	112.		6.01	0.5		10		0		175	1.0				
1230	10.30	0		2.15	10.65	0.2		0.69	10.05	98.2		10.58	10.58	107.3		8.54	0.5		10		0		178	1.3				
1300	0.22	0		0.94	10.58	[illegible]	1.09	[illegible]	10.10	21.0		12.24	10.60	112.5		5.19	0.2		10		0		177					
1330	10.21	0		0.86	10.57	0		0.91	10.37	29.3		11.86	10.54	109.4		10.97	0.5		10		0		176					
1400	10.22	0		0.87	10.56	0		0.83	10.35	19.7		12.86	10.62	108.5		11.00	0.2		10		0		176					

Blower: VACCON VENTURI - SVE / COMPRESSOR WITH REG.
How was Air Flow Measured: 1/2 - 1/2 AMWBR
How was Water Flow Measured:
How were VOCs Measured: PID & SUMA

* DISTANCES ARE MEASURED FROM SPARGE WELL

AIR SPARGE STARTED @ 1000

PRE-TEST AIR FLOW RESULTS FROM SURROUNDING SVE WELLS

SVE-1/NON RECORDABLE FLOW/No Vac Response
SVE-2/NON RECORDABLE FLOW/No Vac Response
SVE-3/1.5~2.0 AMWBR/No Vac Response

The surrounding SVE wells were used to obtain additional flow data for the shallow zone.

D-14

Site: COWR J-1-2
Date: 7-18-97
Testers: BRANDON HAGGARD
BILL HARDMANT

Weather: SUNNY - HOT

Barometric Pressure:
Temperature:

SVE/SPARGE TEST

Well I.D.	MP-1				MP-2				MP-3				MP-4				SPARGE WELL				EXTRACTION WELL							
Distance											PID				PID		ANNULAR		PSI		ANN							
Time	DT	VAC	VOC	DO	DT	VAC	VOC	DO	DT	VAC	~~VOC~~	DO	DT	VAC	~~VOC~~	DO	DT	VAC	VOC		DT	VAC	VOC	PID	DT	VAC	VOC	
Static	10.65	0	~~0.86~~	0.36	11.08	0	~~0.82~~	0.37	10.55	0	~~DK~~	~~DK~~	10.97	0		0.64	0.3		10		0	175		1.0				
1430	10.18	0		0.89	10.52	0			10.34	20.3	161	12.88	10.50	108.1	69	11.22	0.2 +		10		0	177		1.2				
1500	10.14	0		1.05	10.49	0		0.77	10.28	21.6		12.87	10.45	108.5		11.66	.2-.5		10		0	178		1.1				
1530	10.14	0		0.91	10.48	0.8		0.70	10.27	26.2	7.2	12.27	10.36	106.8	6.6	11.42	0.2		10		0.1	177		1.2				
1600	10.12	0		0.89	10.46	-0.5		0.88	10.22	24.5	3.8	12.82	10.33	107.0	2.2	11.88	0.5		10		0	176		1.2				

Blower:
How was Air Flow Measured:
How was Water Flow Measured:
How were VOCs Measured:

D-15

Site: COWR REPOSITORY
Date: 7-19-98
Testers: BRANDON HAGGARD
BILL HARDMANT

Weather: SUNNY - HOT

Barometric Pressure:
Temperature:

AQUIFER/SUE TEST

Well I.D.	MP-1				MP-2				MP-3 (INJECT I)				MP-4 (INPUT B)				EXTRACTION WELL											
Distance	354'				15'-5"				9'-6"				11'-0"															
Time	DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC	R-DATA	DT	VAC	VOC		DT	VAC	VOC	
Static	23.65				23.16				23.61				23.57				21.14/21.59											
5	23.64				23.18				—				—															
10	23.69				23.16				—				—				26.27											
15	23.66				23.18				—				—				26.90											
20	23.64				23.18				—				—															
25	23.65				23.18				—				—															
30	23.65				23.16				—				—															
35	23.66				23.19				—				—				29.49											
40	23.65				23.18				—				—				30.60											
45	23.66				23.18				—				—															
50	23.66				23.20				—				—															
55	23.66				23.20				—				—				31.36											
60	23.66				23.19				23.78				23.59															
75	23.66				23.20				23.81				23.62				33.16			0.25								
90	23.67				23.22				—				—															
105	23.67				23.23				—								35.85											
120	23.67				23.24				—				—															
135	23.68				23.26				—				—				37.73											
150	23.68				23.27				—																			
165	23.68				23.29				23.84				23.82															

Blower:
How was Air Flow Measured:
How was Water Flow Measured:
How were VOCs Measured:

PUMPING RATE IN GPM ≈ .29 GPM
FREQUENCY SET TO 109
HERMIT SETUP ON MP-4 & MP-3
FREQUENCY INCREASED TO OVERCOME HEAD INCREASES, IN EFFORTS TO MAINTAIN CONSTANT PUMPING RATE.

*SAMPLES (WATER) TAKEN @ 200 minutes.

PUMP TEST STOPPED @ 165 MINS DUE TO NO FLOW

D-16

Site: COWR - Repository
Date: 7-19-90
Testers: Brandon Haggard
Bill Hardmant

Weather: Sunny - Hot

Barometric Pressure:
Temperature:

Aquifer / SVE TRT

Well I.D.	MP-1				MP-2				MP-3				MP-4				DPVE											
Distance																	OVM			PID								
Time	DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC	
Static																												
180																												
~~195~~																												
~~210~~																												
~~225~~																												
~~240~~																												
START EXTRACTION W/ PNEUMATIC PUMP																												
~~215~~	23.67	0			23.36	0			24.42	0			23.97	0			0.8	227										
215																												
230	23.73	0			23.40	0			24.50	0			24.02	0			0.8	227										
245	23.72	0			23.45	-0.1			—	0			—	0			0.8	227		1.0								
260	—	0			—	0			—	0			—	0			0.5	234										
275	23.76	0			23.52	0			24.85	0			24.14	0			0.2	240		1.2								
290	—	-0.1			—	0			—	0			—	0			0.2	238										
305	23.75	0			23.59	0			25.00	0			24.22	0			0.5	238		1.1								
320	—	-0.3			—	0			—	0			—	0			0.2	234										
335	23.78	-0.3			23.62	0.1				0				0			0.5	237		1.2								
350		-0.3				0				0				0			0.5	236										
365	23.79	-0.1			23.69	0			25.21	0			24.47	0			0.8	235		1.1								
360		0.2				0				0				0			0.5	237										

Blower:
How was Air Flow Measured:
How was Water Flow Measured:
How were VOCs Measured:

RESTARTED PUMPING W/ PNEUMATIC PUMP TO MOVE INTO DUAL PHASE TEST @ 200.

4/9

Site: COWR - REPOSITORY
Date: 7-19-98
Testers: BRANDON HAGGARD
BILL HARDMAN

Weather: SUNNY - HOT

Barometric Pressure:
Temperature:

AQUIFER / SVE

Well I.D.	MP-1				MP-2				MP-3 (INPUT 1)				MP-4 (INPUT 2)				DWE											
Distance																	Air			PID								
Time	DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC		DT	VAC	VOC	
Static	23.65				23.16				23.64				23.57															
395	—				—				—				—															
410	23.80	0.3			23.70	0			—	0			—	0			0.5	236		1.1								
425	—	0.4			—	0			—	0			—	0			0.5	236										
440	23.80	0.3			23.72	0			25.29	0			24.54	0			0.5-0.8	235		1.1								
455	—	0.5			—	0.1			—	0			—	0			0.5-0.8	236										
470	23.92	0.4			23.76	0			25.34	0			24.58	0			0.5	237		1.1								
485	—				—				—				—															
500																												

Blower:
How was Air Flow Measured:
How was Water Flow Measured:
How were VOCs Measured:

24.58
25.34

D-18

Site: COWR & DEPOSITORY AREA
Date: 7-20-98
Testers: BRANDON HAGGARD
BILL HARDMANT

Weather: SUNNY - HOT

Barometric Pressure:
Temperature:

Page 1 of 2

FROM SPARGE WELL

SINGLE TEST

Well I.D.	MP-1				MP-2				MP-3				MP-4				SPARGE WELL				EXTRACTION WELL						
Distance	24' 8"				17' 3"				10' 8"				5' 8"				ANNULAR PRESSURE PSI				ANNULAR 10' PSI						
Time	DT	VAC	VOC	DO	DT	VAC	VOC	DO	DT	VAC	VOC	DO	DT	VAC	VOC	DO	DT	VAC	VOC		DT	VAC	VOC	PID	DT	VAC	VOC
Static	23.90				23.95				24.41				24.26														
0800	23.90	0			23.95	0			24.41	0			24.26	0							0.2-0.5	197					
0815	—	—			—	—			—	—			—	—							—	—					
0830	—	-.1			—	0			—	0			—	0							0.2-.5	199					
0845	—	0.2			—	0			—	0			—	0							.5	197					
0900	23.94	-0.1			23.96	0			24.61	0			24.36	0							.5	197		1.0			
0915		-0.1				0				0				0							0.5	197					
0930	23.96	-0.1		0.78	23.99	0		0.72	24.74	0		0.57	24.41	0		0.52					0.5	197					
0945	—	0		—	—	0		—	—	0		—	—	0		—					0.5	200					
1000	23.97	-0.1			23.99	0			24.79	0			24.44	0			0	15			0.5	201					
1015	23.96	0		0.90	23.98	0		0.66	24.79	0		0.50	24.38	0		0.50	0.2	15			0.8	199					
1030	—	+0.6			—	0			—	+0.4			—	0			0.2	15			0.8	201					
1045	23.89	+0.1		0.90	24.10	0.2		0.64	25.44	+1.1		0.44	24.10	0		0.43	0.2	15			0.8	201		1.2			
1100	—	+0.5		—	—	+0.3		—	—	+1.1		—	—	+0.1		—	0.6	20			0.8	200					
1115	23.24	+3.3		0.80	24.24			0.62	25.48	2.1		0.53	24.49	+0.8		0.40	0.8	20			0.8	200					
1130	—	+4.1		—	—	1.0		—	—	2.4		—	—	0.9		—	0.8	20			—	200					
1145	23.70	+4.3		0.97	24.35	+1.1		0.74	25.33	+2.6		0.62	24.15	+0.8		0.44					0.2	110					
1200	—	4.6		—	—	+1.2		—	—	2.8		—	—	0.9		—	1.8	25			0.2	110					
1215	23.57	+6.5		0.95	24.46	+1.8		0.88	25.14	+3.3		0.67	24.46	+1.9		0.56	1.9	25			0.2	110		1.2			
1230	—	+7.0		—	—	+1.9		—	—	+3.5		—	—	+2.0		—	1.8	25			0.2	111					

Blower: VACCON VENTURI - SUE / COMPRESSOR WITH REG
How was Air Flow Measured: 1½ + ½ ANNULAR
How was Water Flow Measured:
How were VOCs Measured: PID + SUMA

0955 - SUMA CANISTER SAMPLE
1000 - START AIR SPARGING GROUNDWATER

D-19

Site: COWR
Date: 7-20-98
Testers: BRANDON HAGGARD
BILL HARDMANT

Weather: SUNNY - HOT

Barometric Pressure:
Temperature:

SPARGE TEST

Well I.D.	MP-1				MP-2				MP-3				MP-4				SPARGE WELL				EXTRACTION WELL							
Distance																	AIR	PRESSURE PSI			AIR							
Time	DT	VAC	VOC	DO	DT	VAC	VOC	DO	DT	VAC	VOC	DO	DT	VAC	VOC	DO			VOC			VAC	VOC	PID	DT	VAC	VOC	
Static	—			0.78	—			0.72	—			0.57	—			0.52	—											
1245	23.53	7.8		1.00	24.39	2.1		0.80	24.49	+3.1		0.56	24.26	+2.1		0.41	2.0	25			0.2	115		1.0				
1300	—	+6.1		—	—	+2.1		—	—	+3.8		—	—	+2.1		—	1.8	25			0.2	120						
1315	23.47	+8.2		1.00	24.34	+2.8		0.92	24.80	+3.7		0.61	24.10	+2.1		0.60	1.9	25			0.2	120		1.0				
1330	—	+4.8		—	—	+2.2		—	—	+3.6		—	—	+1.9		—	1.9	25			0.2	120						
1345	23.45	+8.4		.96	24.24	2.2		.86	24.60	+3.5		.76	23.73	+1.9		.50	2.0	25			0.2	122		1.0				
1400	—	+8.5		—	—	+2.2		—	—	+3.5		—	—	+2.4		—	2.5	30			0.2	122		1.0				
1415	23.45	+8.7		1.50	24.20	+2.6		0.98	24.53	3.8		0.90	24.22	2.9		.70	2.4	30			0.2	121						
1430	-	10.5		-	—	+2.6		—	—	3.5		—	—	3.0		—	2.4	30			0.2	124						
1445	23.36	10.5		1.32	24.24	+2.8		1.15	24.42	3.5		1.00	24.19	3.0		.57	2.4	30			0.2	122		1.0				
1500	23.36	10.20		—	—	2.8		—	—	3.5		—	—	3.1		—	2.4	30			0.2	124						
1515	23.44	9.8		1.04	24.16	2.8		0.88	24.30	3.7		0.75	24.18	3.0		0.31	2.4	30			0.2	124		1.0				
1530	—	10.3		—	—	2.8		—	—	4.0		—	—	2.9		—	2.4	30			0.2	118		—				
1545 1W	23.39	10.8		1.00	24.20	3.0		0.96	24.18	4.1		0.91	24.05	3.0		0.91	2.3	30			0.2	116		1.0				
1600																												

Blower:
How was Air Flow Measured:
How was Water Flow Measured:
How were VOCs Measured:

D-20

Appendix E
FDGTI Field Notes

CRAB ORCHARD NAT'L WILDLIFE REF.

PHASE II : PILOT TESTING (DAY 1)

prepared by: M. Weaver - PMT

JULY 15, 1998 well-activity Day 3-

Mon + Tues FDGTI on site...

Weather: morning fog + drizzle Cloudy, low 70's, Exp. high Mid 80's

6:00 Arrive @ site - talk to Mikey. He shows me latest GP locations in warehouse. Will take photos later. trouble yesterday at I:1-23 - They had problems w/ getting H_2O in air stream - They were using a pneumatic pump. Then pulled vacuum with a VACON venturi pump. They are waiting today for an air water separator. Want to run DP test today, then sparge test tomorrow (had some equipment problems yesterday + Monday). Todays DP test will use Grundfos pump +

6^{20} out at I-1-23 site. Geologists getting set up but waiting for more equipment

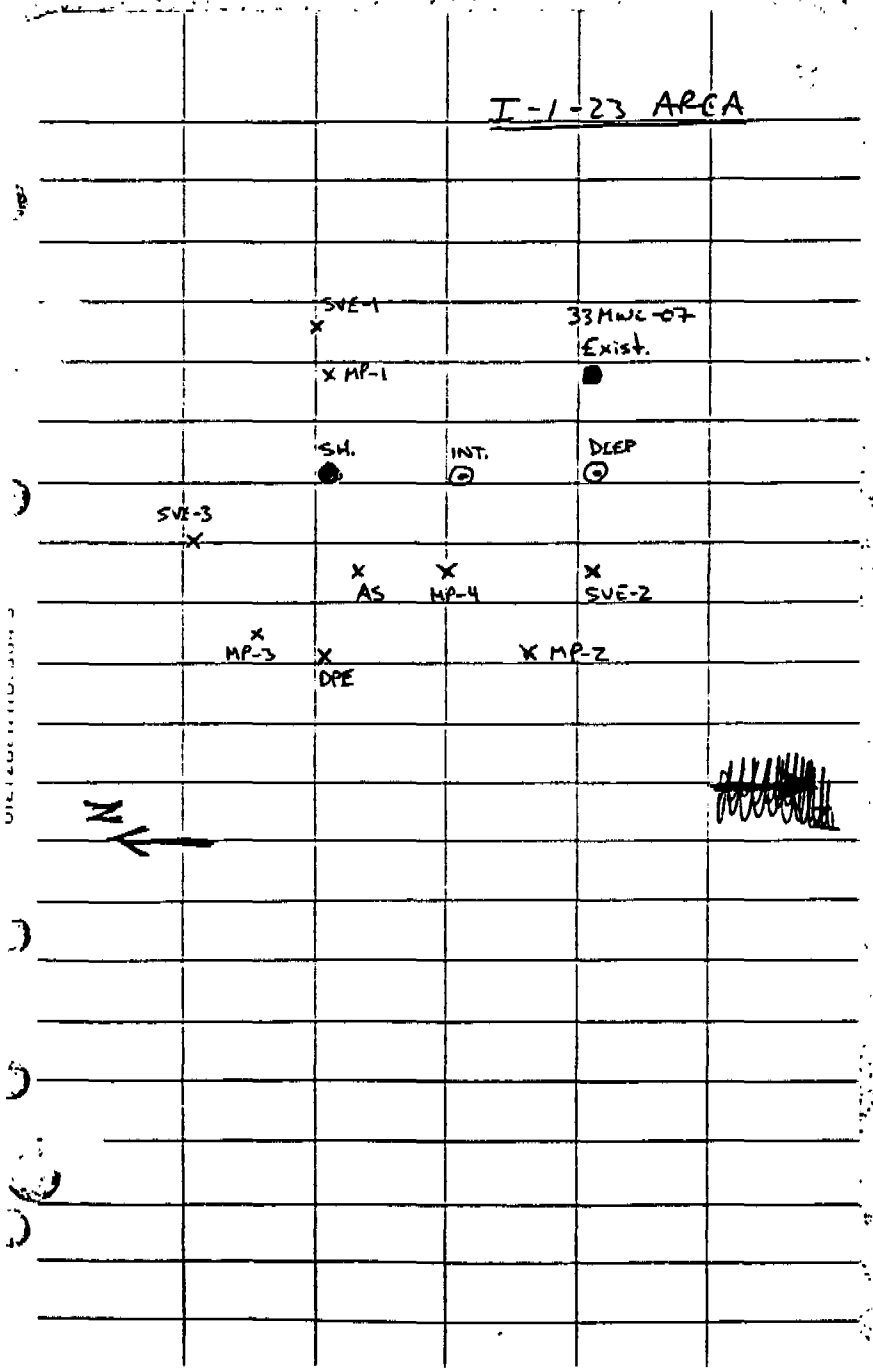
Geologists: Bill (from first week) → Hydro/Seal
and Brandon. - engineer

both engineers → Jameel is here + Mikey is here

Ingersoll Rand Air Compressor
"prestige series"
has AP gauge built in

plate: KHD Deutz

6^{55} Bill just measured H_2O levels at pump well. No measurements at other wells. reasoning (from Brandon) - already done Aq. test. They will take vacuum readings + H_2O levels during test, but primarily to determine amt. of open screen. Mikey has asked me to stay outside of "Restricted Area" (yellow bumper posts) during test. I said "no problem".


I-1-23 AREA
SVE-1
33MWC-07
Exist.
MP-1
SH.
INT.
DEEP
SVE-3
AS
MP-4
SVE-2
MP-3
DPE
MP-2
N

7:15 Ok, They are taking H_2O levels at the MPs - not at wells

start test at about 7:17

Bill measures flow rate with a watch + a bucket. Flowmeter was not hooked up. They haven't checked vacuum yet.

Tuesday - Step tests 2, 4, 6 gpm
1 hour each

Repository 0.9 gpm, 1.2 gpm

J-1-23 A test 3 gpm

pneumatic pump; silted up

2200 gall out flow meter - Ron measured in bucket (each hour.)

DP - 6 gpm

Brandon is the engineer - he is the one running all the tests + setting em up. (so I'll pick his brain)

(747) ok, so Ranjit done step tests for sust. flow rt determination. For I-1-23, run test at 3 gpm. DP test is at 6 gpm to try to get as much drawdown as possible. Aquifer tests - Random does not know if complete round of H_2O levels have been collected. H_2O levels measured by hand in pumping well + w/ Rh hermit at MPs. Hermit log. rt stopped for recovery test (allowed to recover many hours, but not necessarily all the way) Flow rts measured initially w/ gauge, but then hardly in bucket when gauge silted up. Sparge test - will only measure D.O from MPs, not % O_2 DPE test: measuring H_2O levels every hour (approx). use manometer to measure vacuum

up to 50 scfm 40 in of H_2O vacuum
up to 200 in H_2O at reduced flow rt

actual system use more std blowers, etc.

8:20 Call E. Goddell @ AIR + report info to this point. Has interested in whether Geoprobe still here; The warehouse area; more about Venturi pump (how it works); water levels from dishwasher in pumping tests; Grab samples during tests

8:40 I go to "warehouse" area (B-1-1-36A) to take photos

9:30 Return to I-1-23 area - pump still running, still waiting for parts to arrive. Brandon leaves... I'll talk to him when he returns. I'll go find the gate guard. - tells me that Don Hill is the guy I want: Don Hill ex. 224 + I can call from guard house if I want. I told him I may later - I need to watch work for now.

I didn't see any floor drains at I-1-36A; There was a floor "squeegee" but no drains. One pipe drained from loading dock to ditch to south. (outlet not

Some Canister 15/30min mono/H_2O rec

7

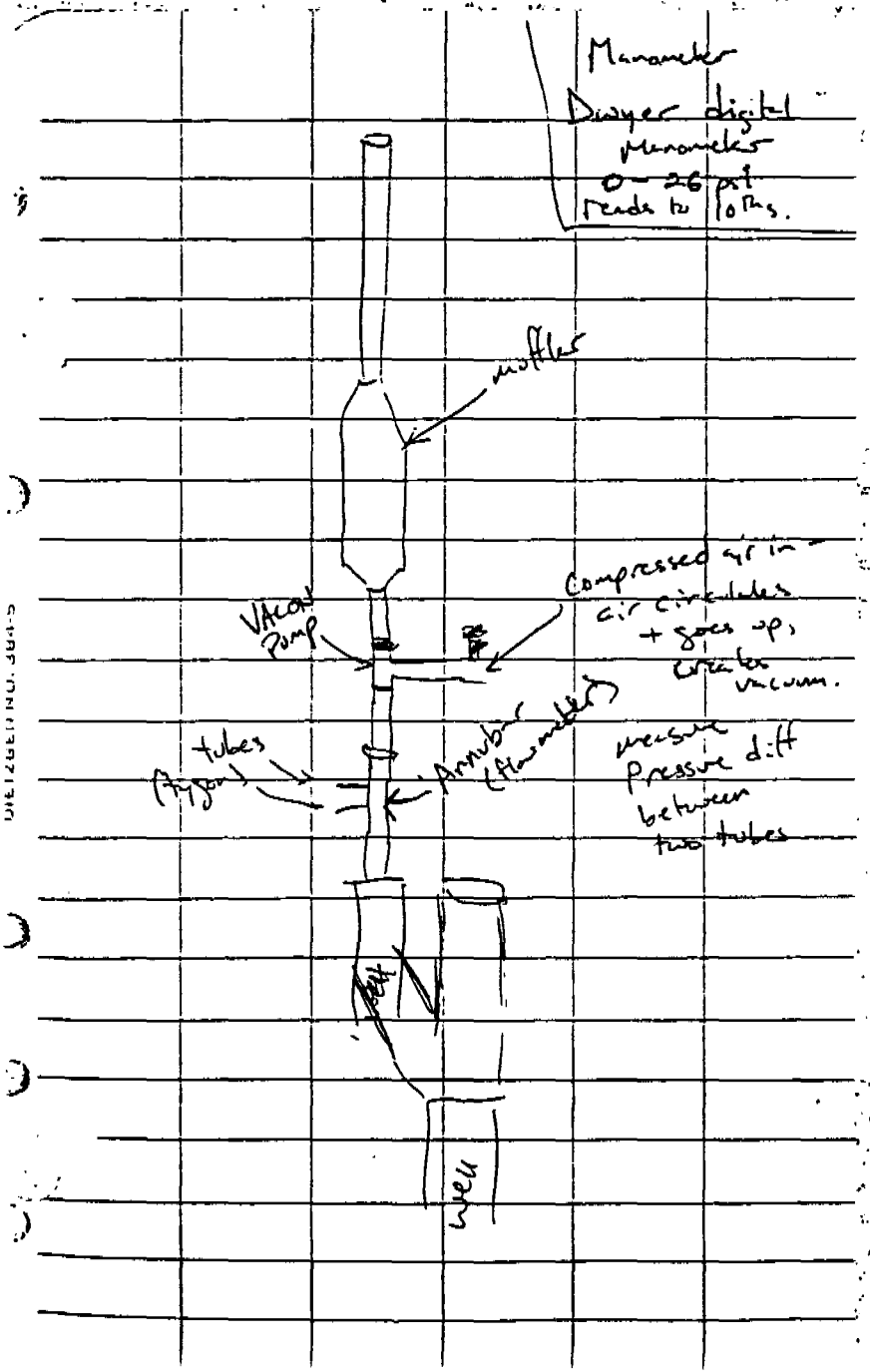
10:10	Ooohh! A box has just arrived. And all jump into "action"
10:15	Brandon returns, take H_2O level readings. Activity dies down. Brandon is on phone.
10:30	Start setting up for DP test - pump line looks like Regina sealing it w/ duct tape.
10:40	Start up compressor.
11:15	Hannah gotten Vapor ext. syst. going yet - something is plugging Venturi pump. Box was a spare meter. The water/air separator isn't here yet. Regina proceeding anyway...
11:35	Got it going! VOCs measured w/ PID. Bill measured abt 5 min into test. Vacuum measured at test well + MPs w/ Manometer.
1145	Bill takes H_2O levels 11:50 - now Manometer. I start grilling Brandon - See attached pages.

They're taking H_2O levels @ 30 min int + Manom. every 15 min. When soil dries out a bit, they'll start cranking the vacuum a bit to try to get higher air flow to get more meaningful PID readings. In an hour or 2, will collect a Summa (sp?) canister of gas for analysis.

During pumping test, 1 gw sample was collected sometime around mid test - collection time will be on COC.

SVE will be done w/ same setup on DPE well, not on SVEs. Brandon says MPs are not in good locations for the SVE locations. More MPs are at better spacing for DPE well.

Compressor they are using is NOT oilless - for extraction does not matter. For sparging, air will be run thru oil filters (Ingersoll-Rand - see photo 2).


Manometer
Dwyer digital manometer
0 - 26 psi
reads to 10 Pa.
muffler
Compressed air in - air circulates + goes up, creates vacuum.
Vacuum Pump
tubes (Pygon)
Annular (Flowmeter)
measure pressure diff between two tubes
well

12^20 Pump hose slips out of tank + has made good size puddle. Mike I directs group to contain spill + dig up saturated dirt. Dirt is placed on a sheet of plastic for disposal.

There's another guy here, driving a pickup truck labeled "ANCO TESTING LABORATORY Geo Technology, Inc." He doesn't seem to be doing much other than help dig wet soil + moving stuff around site. I'll get the story on him later.

One of the drillers.

(Walter) Waste hauler from Central States is also here hanging out + helping a bit.

13^20 Asked Brandon when he was thinking about collecting the air sample - he said he's only pulling abt 10 scfs + would like to get more signif flow first - probably around 4^00 pm.

I'll go try to track down Don Hill when! turns out he's at guard shack. Conversation attached...

Glenn Heil process H2O B-210

1445 return to I-1-23 & check in.
Things were going well... Then the
pump shut off & they got a geyser going.
All was under control when I got back,
but they haven't gotten much Air flow yet.

1540 Vacuum pump disconnected again - They're
back taping something. - Taped a cap
onto top of PVC pipe so they can
send more air thru sampling tube.
cap can be opened & closed.
can get PID reading BUT this is
from above the input from the air
compressor. They'll mostly be getting
air from the compressor, I'd think.
PID reading taken by filling bag for HNU
Geoprobe finished yesterday. Might
come back Friday.

1600 Take some Canister sample & PID
(see photo) PID from upper port,
Sample Can from lowest (can has
its own vacuum).

16⁰⁵ Called office left message for Eric

16¹⁰ Asked few more ?'s of Brad

- No barometric pressure readings taken at any point
- No wells used for H_2O levels during AQ test, just MP's
- Tops of MPs (ref. elevs) not surveyed. They're just looking at drawdown.

GENERAL NOTE:

They're measuring flow rates, but the combination of pump failure, messing w/ the setup, blowing out the pump seal (around pump hose), and adjusting air flow rate, I'm not sure how continuous the vacuum extraction is. They'll be using this setup for the SVE...

16⁴⁰ Seal around pump hose blows out - crew fixes it quickly.

17⁰⁰ stop test. Brad says that H_2O levels stabilized... didn't seem happy about vapor phase. Said he never really got the vacuum back after pump went out.

[redacted]

Miley has some new chem data from Geoprobe borings - found around 600 (?) ppb Vinyl Chloride over by I-1-36A along w/ many other chlorinateds.
He wasn't sure of boring location, however I will get a look at the actual chem data tomorrow.
Looks like they will try out actual SVE wells after all. Prior to starting sparge test they'll do each indiv sparge well to see if they can get air flow. Then start sparge.

1745 Leave site.

CHAT w/DON HILL - PRIMEX 7/15/98 15

13^{20} - 1415 SAFETY + SECURITY SUPERVISOR

About building I-1-36A

I-1-36A is a fairly new building - probably constructed in the 60's (rather than the 40's like most of the plant)

Building consists of two rooms (well... 2 sides...) The North side was a Magazine - Propellant storage and temperature conditioning.

The South room(s) had a Hoffman (sp?) Cyclone dust control Unit

primarily propellant - "double based" → {nitroglycerine + nitrocellulose (+ stabilizer)}

When equip cleaned for maintenance, generally used (probably) Isop. Alcohol

[111-TCA used by Army for mixing stuff, but not used here according to Don]

I asked specifically about solvents and Don couldn't think of any used here.

Actually - probably more strongly stated than that. More along the lines of "to the best of his knowledge, solvents were not used or stored at that building."

A little about site History:

Bldg I-1-23 original use - Melt/pour room for TNT (shut down in (mex) 1945)

Sangamo Electric 1st tenant (sometime between '45 + '59)

might have been only lessee in that time? Unknown.

Olin leased bldg in '57, may not have been used 'til 58 - may not have used I-1-36A

Then Primex

I asked about process water - Don directed me to Glenn Heil at ext. office B-210

I did not contact Glenn immediately - wanted to check on DP test.

7/16/98 CRAB ORCHARD NWR DAY 2

PHASE II Pilot Testing

prepared by: M. Westover - RMT Inc.

weather: Cloudy foggy AM, Low round 70's

6:00 Arrive at site. Geologists arrive

Setting up @ I-1-23.

Bill measures exact dist from SVE 1 to

MP-1 (SVE-1 is first to be tested)

SVE-1 9' deep - They checked H_2O level

+ its at 8.5'. They are still hoping

that moisture separator will arrive

DO measured YSI 50B downhole probe

Jarred calibrate DO meter

6:45 have a big leak in airline.

6:50 seems ok now. Brandon is taking

flow readings continuously initially

+ as he adjusts flow.

Bill measures H_2O levels in MP-1

* This is only to see if they can

produce air flow - not a full SVE test

7:15 Move on to next SVE (SVE-3)
Bill measures exact dist from SVE-3
to MP-3. Grab H_2O level at SVE-3
Again - just trying to see if they
can pull vapors.

8:15 phone office - talk to Eric + report
status. Interested in status of survey,
water levels, + staff gauges

8:40 Setting up VACCON pump at DPE well
will be sparging. Brandon says has got
it going on low vacuum to start - for
abt 1½ hrs, Then start sparge. Will crank
Vacuum (if moisture sep arrives!)
to establish a vacuum

8:45 phone office. Talk to S. Martin RE:
HACCO.

9:30 Moisture separator has arrived. Crew sets it
up

10:00 Went to trailer to update map + talk to
Mike - Mike is busy w/ letter. will talk to
him later. Get Chem data to copy

CHEM DATA as of 7/16

13E	VC	2 J
	cis 12 DCE	25
	TCE	9 J
	Toluene	2 J
15E	VC	5 J
	cis 1,2 DCE	18
	Trans DCE	1 J
	TCE	13
14E	VC	670 E
	1,1 DCE	5 J
	cis 1,2 DCE	850 E
	trans DCE	8 J
	TCE	190
	Benzene	2 J
	PCE	220 E
	Toluene	2 J

9E	TCE		4 J		
10E	VC		9 J		
	Cis		310 E		
	trans		5 J		
	TCE		130		
	PCE		2 J		
11B	ND				
11E	TCE		2 J		
6E	MC		2 JB		
2E	MC		2 JB		
3E	MC		2 JB		
8E	MC		1 JB		

CHEM DATA (WELLS)

31	di-n-Butylphthalate	7 J
	bis (2-ethylhexyl) phthalate	2 J
	4 chloro-3 methyl phenol	14
32	Dimethylphthalate	67
	MC	3 JB
24	bis (2 ethylhexyl) phthalate	2 J
	1,4-Dichlorobenzene	2 J
	1,2-Dichlorobenzene	37
	Dimethylphthalate	2 J
30	VC	2 J
	MC	3 JB
	1,1 DCE	6 J
	cis	400 D
	trans	25
	TCE	2100 D
24	VC	6 J
	cis	84
	TCE	830 D
	PCE	34

31	Mc		4 JB	
	Cis		35	
	trans		2 J	
	TCE		110	
35	4 chloro 3 methylphenol		130 B	
	di n Butylphthalate		19	
	bis (2 Ethylhex) ph.		19	
33	Dimethylphthalate		4 J	
	di-n-Butylph.		8 J	
	bis (2 Ethyh.)		2 J	
35	Mc		4 JB	
	Acet.		11	
	Cis		9 J	
	trans		4 J	
	chloroform		4 J	
	TCE		56	
	PCE		6 J	

WELLS (CONT)

33	VC	7 J
	MC	45B
	Cis	160
	trans	120
	TCE	1100 D
	PCE	65
36	Dimethylphthalate	1 J
	di-n-Butyl phth	10 J
	bis (2 Ethyl h.)	1 J
36 D	Dimeth	3 J
	di-n-B	11
	bis(2 Ethyl.	1 J
39	Dimethyl phthalate	340 D
	diethyl phthalate	1 J
	di-n-Butyl -	17
	bis(2 Ethyl h.)	1 J
41		

36	Acetone		14	
	TCE		6 J	
36D	MC		3 JB	
	Acetone		14	
	TCE		6 J	
39	MC		3 JB	
	cis		3 J	
	TCE		60	
41	MC		3 JB	
	TCE		2 J	
22	Aroclor-1254		0.10 J	
28	VC		4 J	
	MC		1 JB	
	1,1 DCE		4 J	
	cis		1400 D	
	trans		15	
	TCE		15000 D	
	Benz			

WELLS

28	1,1,2- TCA	25
	PCE	38
27	Cis	1 J
	TCE	7 J
29	MC	3 JB
	Cis	1 J
	TCE	18
21	MC	4 JB
	Cis	31
	trans	3 J
	TCE	490 D
	Benzene	1 J
	PCE	5 J
	Chlorobenzene	21
23	MC	4 JB

22	MC	4 JB	
	cis	1 J	
	chloroform	9 J	
	TCE	4 J	
	toluene	210 E	
28	di n BuRgphth	11 B	
	bis(2ERhylh)	14	
27	di-n-B	19 B	
	bis(2-ERhyl)	3 J	
	4 chloro 3 meRhyphen.	110 (qv-1 = ?)	
29	di-n-B	16 B	
	bis (2E)	6 J	
	Dimethylphthe	1 J	
21	di-n-B	11 B	
	bis (2E)	1 J	
23	di-n-B	17 B	
	Bis(2E)	8 J	

22	di-n-B	8 JB
	bis(2E)	1 J
	4chloro 3 methylphen	37

Back To Geoprobes:

5E	MC	1 JB
	cis	1 J
	TCE	44

7E	VC	2 J
	MC	1 JB
	cis	5 J
	TCE	30

1E	MC	2 JB
4E	MC	2 JB
5E Dup	MC	1 JB
	cis	2 J
	TCE	47

11:25 Back to BI-1-23. Moisture Sep.
set up & begin vacuum pump running
again. Tank filled 2/3 almost
immediately, then seems to stabilize
They will have to shut off vacuum
to drain tank! Bought steel cage to go over As well for protection.
Back to conversation w/ Mike - Survey
is still going on apparently. There's been
one change in numbers of Geoprobes -
7B was located further North than
they thought - Its still 7B, but its
really located N. of Tank Lake
inlet. They came back + installed
11B where 7B was supposed to
have gone. 4 Staff gauges have been
installed (will have to locate them)
Mike is still planning to collect full
round of H_2O levels, but probably
not 'til they're ready to demob.
11:40 Bill gets round of H_2O levels prior to
starting test. And downloads D.O.

Mike also said had spoken to Nan Gordon - Nan had declared 1-1-36A site as "Uninvestigated source area" Mike said sort may be an issue.

Note: No decon of probes between holes. – probably doesn't make a difference.

1150 Brandon measures distances from AS well to MPs.

1155 Now taking vacuum air flow at SVE well (the DPE well)?

1200 begin sparging. 20psi, (on gauge + on manometer) doesn't appear to be any flow. Brandon takes reading (flow? vacuum?) at SVE well.

NOTE: official SVE wells all located signif. distant from AS well. DPE well is really only one close enough to AS for this test...

1215 H_2O levels + DO; pressures, MPs; flow + pres @ AS

1230 Collect Sum Canister air sample @ DPE well (SVE), H_2O levels + DO pressures at MPs. Flow + Pressure/vac at DPE + AS

1245 D.H.

1255 Brandon comes over + tells me test is working. H_2O levels have come up in

all the MPs, the closest MP has shown increase in D.O. from 0.8 mg/L to around 8 mg/L (?)

Note: Brandon's initial D.O. readings were < 1.0 mg/L! Something is wrong with the way DO was measured before.

Closest MP also showed a slight positive pressure.

Brandon will be increasing pressure at sparge well now. (1[00])

13[10] I go to take some photos of site + find shaft gauges.

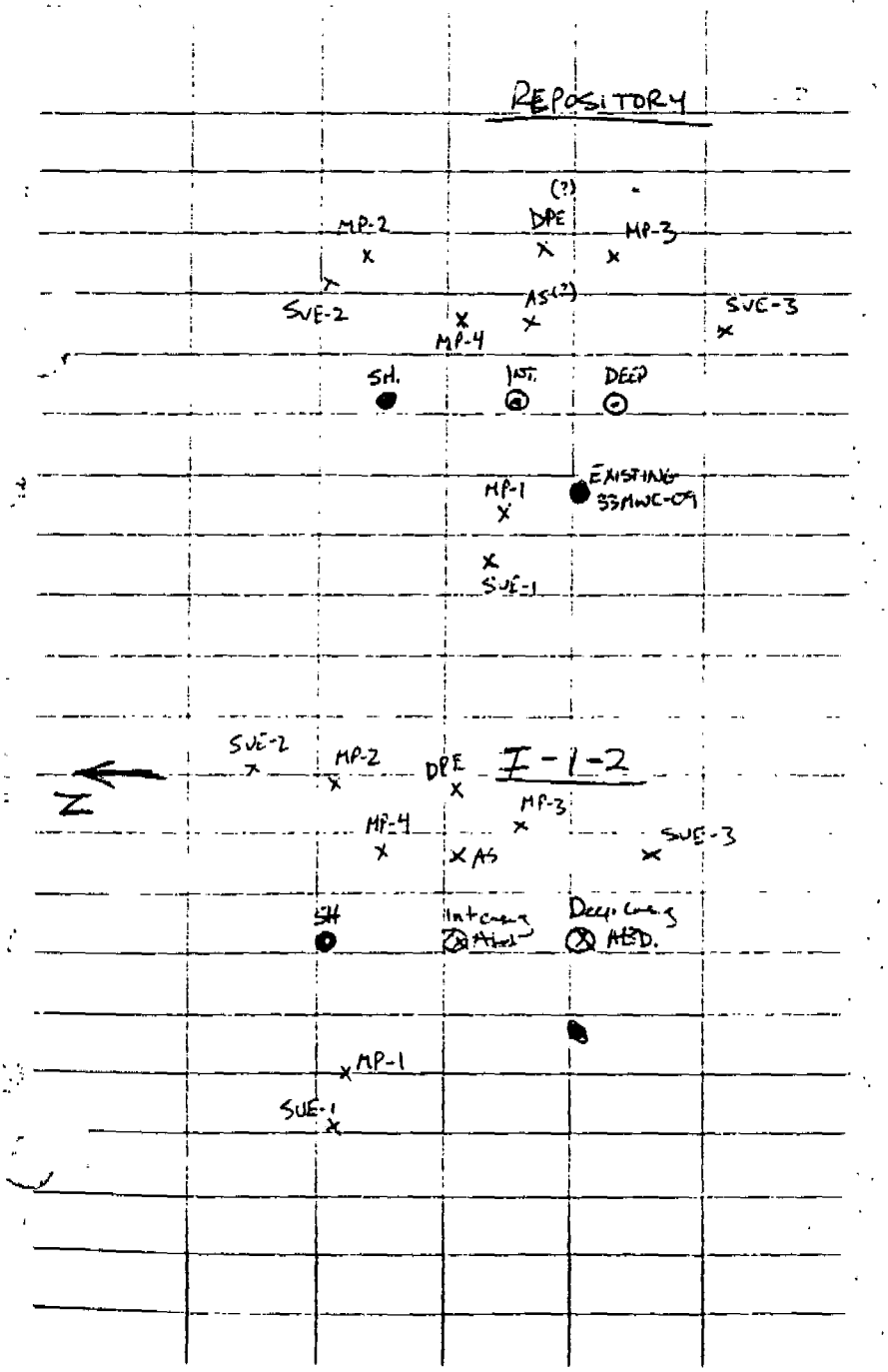
14[50] Found all but 1 gauge - can't see the one off 148. I'll have to try Mike's again. I suggest Weeden to get in 'em - at least to keep the guys from poison oak off. Reminder is I-1-23. Sparge air is going "wild" according to FDCTE - Thursday's sparge. The pressure from 20 to 25 to 50 psi

There seem to be mounding in each of the wells, D.O. readings have increased in all the wells. Positive pressure has developed in at least the closest MP (abt 5' away from AS), and air is coming up thru cap & well seal on new monitoring well. (This isn't good, but the sparging has a pretty good radius of influence)

Now taking readings at MP (Hydraulic pressure, D.O.) every 1/2 hr.

15:20 Back to trailer talk to Mike - he suggests I talk to Jennel abt where last SG is - he placed it. I requested new logs, chem data, and well construct for the pilot test well. They'll all have to be sent. He doesn't have copies now & well construct not readily available.

Got results back from behind 36A - 310 ppb PCE! Hmm... might have been washing stuff down? Its a nice spot area behind there


REPOSITORY
(?)
DPE
MP-2
MP-3
SVE-2
AS(?)
SVE-3
MP-4
SH.
INT.
DEEP
EXISTING
33MWC-09
MP-1
SVE-1
SVE-2
MP-2
DPE
I-1-2
N
MP-3
MP-4
SVE-3
AS
SH
Int
Deep
MED.
MP-1
SVE-1

16⁰⁰ found 4th staff gauge w/ Jimmel.
its in first open water on W side of
148 as you head South (Rt side of
road) Not as far South as the
culvert I looked at the first time.
I tried to mark location w/ paint
stick on white line rt side of line
(won't last) I have no flagging.
Scrubby bush on right is pretty even
w/ stake. I asked Jimmel abt survey
as well --- both he + Mike seemed
to think they were just going to survey
the H_2O interface. I explained again
what the staff gauges were for + what
the ref. elevation needed to be.
Jimmel said he'd tell surveyor to
survey top of yd stick. I also told
him to make sure they note what
the reference elevation is. (top of stick,
zero point, etc

16:10 Call Eric + check in + report days events.

16:30 As turned off - SVE left running. They took 1 more Summa Canister sample. Jameel verified that the Cans are analyzed for VOCs. Jameel had talked to either Mike (who'd spoken to surveyors) or to surveyors themselves. They surveyed H_2O interface and took reading on yd stick. We should be able to get zero pt. (Ref. elev.) from that info. I said goodbye to Jameel + rest of crew - went to go find Mike to let him know I won't be back.

16:50 Chat w/ Mike in Trailer

17:20 Leave site.

Appendix F
Pilot Test Calculations

IT Corporation
One Fluor Daniel Drive
Sugar Land, TX 77478-3899
Tel. 281.263.3439
Fax. 281.263.2118

A Member of The IT Group

REC'D RMT 3-16-99

US AIRBORNE
PRIORITY DELIVERY

March 15, 1999

Attn: Mr. Eric Gredell
RMT
744 Heartland Trail
Madison, WI 53717

Dear Mr. Gredell,

Please find enclosed one set of air flowrate caluclations prepared by the Pilot Test Engineer for the annubar sensors used during the 1998 TCE Investigation. The manufacturer no longer carries the sliding scale that was used on site. They have provided software, which is provided with this package.

Should you have any questions, please don't hesitate to contact me at (281) 263-4156.

Sincerely,

Mike Isley, PE
Environmental Engineer

cc: Project File

To Calculate air flowrate (scfm):

Use Equation 5002: $Q_s = C'\sqrt{hP}$ (see attachment)

$K = 0.6016$ for 1½" Annubar (SVE)
$= 0.9265$ for ½" Annubar (AS)

$D = 1.61''$ for 1½" Annubar (SVE)
$0.622''$ for ½" Annubar (AS)

$F_{Ra} = 1$ for Both

$$Y_A = 1 - \left[0.31424(1-\beta_{ann})^2 - 0.09484\right]\frac{h_w}{27.73\,k_{pf}}$$

$\beta_{ann} = \frac{\text{strut width}}{\text{pipe diameter}}$ Strut Width $= 0.1830^{in}$

$= \frac{0.1830}{1.61} = 0.114$ for 1½" Annubar

$= \frac{0.1830}{0.622} = 0.294$ for ½" Annubar

h_w = differential pressure (in H_2O)

$k_{pf} = 1.4$ for air

$$F_{pb} = \frac{14.69595}{p^b} = \frac{14.69595}{14.7} = 0.99997 \approx 1.00$$

$$F_{tb} = \frac{T_b^{(R)}}{518.67} = 60°F = 519.67°R = F_{tb} = 1.00$$

$$F_{tf} = \sqrt{\frac{518.67}{T_f(°R)}} =$$

$T_f = 60°F = 519.67°R$ for SVE
$= 120°F = 579.67°R$ for AS

$\therefore F_{tf} = 0.999$ for SVE
$F_{tf} = 0.946$ for AS

$F_g = 1.00$ for Air

F_{pv} = Assumed to be 1.00

F_{aa} = Assumed to be 1.00

Sizing

Sensor sizing and selection

General information

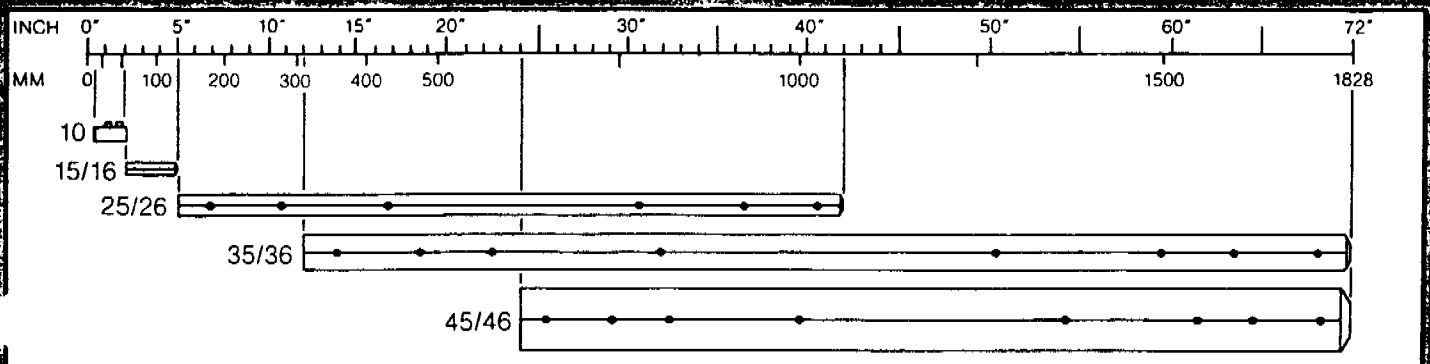
Description		Units
Pipe size, schedule or pipe inside diameter (D), wall		
Tag number		—
Fluid name		—
Maximum piping design pressure		
Maximum piping design temperature		
Minimum piping design temperature (if below −20°F)		

Fluid parameters

2. Flow rate at maximum normal and minimum flow →	Maximum Flow rate	Normal Flow rate	Minimum Flow rate	Units
3. Supply values at the above given flow rates				
Temperature @				
Pressure (gage/abs) @				
Vol. flow-gravity @				
Mass flow-density @				
Viscosity @				
Supercompressibility @				

Sensor selection

Select the Annubar sensor that best fits your nominal pipe size.



Calculate approximate differential pressure (h_w)

Use fluid parameters at maximum flow rate. To calculate the differential pressure, use the equations below. Otherwise Standard flow calculator or Annubar Flow Handbook.

Liquid, gas, steam (mass rate of flow)

$$h_w = \left(\frac{1}{\rho_f}\right)\left(\frac{lb_m/hr}{358.94\ K\ D^2}\right)^2$$

Liquid (volume rate of flow)

$$h_w = \left(G_f\right)\left(\frac{GPM}{5\ 666\ K\ D^2}\right)^2$$

Gas (standard volumetric flow)

$$h_w = \left(\frac{T_f G}{P_f}\right)\left(\frac{SCFH}{7{,}711\ K\ D^2}\right)^2$$

Gas (actual volume rate of flow)

$$h_w = \left(\rho_f\right)\left(\frac{ACFH}{358\ 94\ K\ D^2}\right)^2$$

h_w = differential pressure inches of water at 68° F
K = flow coefficient
D = internal pipe diameter inches
lb_m/hr = pounds mass per hour
GPM = U S gallons per minute
ACFH = Actual cubic feet per hour
SCFH = Standard cubic feet per hour (at 14 73 psia and 60° F)
ρ_f = flowing density, lb_m/ft^3 for gas

$$\frac{P_f}{14\ 73} \times \frac{520}{T_f} \times 076487 \times G$$

076487 lb_m/ft^3 = air density at 14 73 psia and 60°F
G_f = specific gravity of liquid
G = specific gravity of gas (molecular weight of air = 28 9644)
T_f = temperature of flowing gas in degrees Rankine (°R = °F + 460)
P_f = flowing pressure, psia

Flow coefficient-K

Sensor 10

Pipe size Size/Sch	D-in	D-mm	K
1/2" sch 40	622	15 80	4265
3/4" sch 40	824	20 93	5067
1" sch 40	1 049	26 64	5519
1 1/4" sch 40	1 380	35 05	5870
1 1/2" sch 40	1 610	40 89	6016
2" sch 40	2 067	52 50	6197

Sensor 15/16

Pipe size Size/Sch	D-in	D-mm	K
2" sch 40	2 067	52 50	5912
2 1/2" sch 40	2 469	62 71	6026
3" sch 40	3 068	77 93	6134
3 1/2" sch 40	3 548	90 12	6192
4" sch 40	4 026	102 26	6235
5" sch 40	5 047	128 19	6297

Sensor 25/26

Pipe size Size/Sch	D-in	D-mm	K
5" sch 40	5 047	128 19	5934
6" sch 40	6 065	154 05	6047
8" sch 40	7 981	202 72	6173
10" sch 40	10 020	254 51	6250
12" sch std	12 000	304 80	6298
14" sch std	13 250	336 55	6321
16" sch std	15 250	387 35	6349
18" sch std	17 250	438 15	6370
20" sch std	19 250	488 95	6387
24" sch std	23 250	590 55	6411
30" sch std	29 250	742 95	6435
36" sch std	35 250	895 35	6450
42" sch std	41 250	1047 7	6461

Sensor 35/36

Pipe size Size/Sch	D-in	D-mm	K
12" sch std	12 000	304 80	6186
14" sch std	13 250	336 55	6220
16" sch std	15 250	387 35	6263
18" sch std	17 250	438 15	6296
20" sch std	19 250	488 95	6321
24" sch std	23 250	590 55	6357
30" sch std	29 250	742 95	6393
36" sch std	35 250	895 35	6416
42" sch std	41 250	1047 75	6432
48" —	48 00	1219 20	6445
60" —	60 00	1524 0	6461
72" —	72 00	1828 80	6472

Sensor 45/46

Pipe Size Size/Sch	D-in	D-mm	K
24" sch std	23 250	590 55	6247
30" sch std	29 250	742 95	6308
36" sch std	35 250	895 35	6346
42" sch std	41 250	1047 75	6373
48" —	48 00	1219 20	6395
60" —	60 00	1524 0	6422
72" —	72 00	1828 80	6439

Section 1

nglish units

Equation 5002

$$Q_S = C'\sqrt{hP}$$

This equation, used for gases, compensates the standard volume flow whenever there is a significant change in line pressure.

Gas:

Volume rate of flow (Standard conditions)

Rate of Flow	Units Conversion Factor	Annubar Flow Coefficient	Internal Pipe Diameter	Reynolds Number Factor	Annubar Expansion Factor	Pressure Base Factor	Temperature Base Factor	Flowing Temperature Factor	Specific Gravity Factor	Super-Compress. Factor	Thermal Expansion Factor	AT FLOWING CONDITIONS Transmitter Input h = "H_2O @ 68°F P = PSIA
	Annubar Flow Constant C'											
Q_S =	F_{NA} ×	K ×	D^2 ×	F_{RA} ×	Y_A ×	F_{pb} ×	F_{tb} ×	F_{tf} ×	F_g ×	F_{pv} ×	F_{AA} ×	$\sqrt{hP}$
SCFM	5.6362		(in)^2									
SCFH	338.17		(in)^2									
SCFD	8116.1		(in)^2									

Equation 5003

$$Q_S = C'\sqrt{\frac{hP}{T}}$$

This equation, used for gases, compensates the standard volume flow whenever there is a significant change in line pressure and temperature.

as:

Volume rate of flow (Standard conditions)

Rate of Flow	Units Conversion Factor	Annubar Flow Coefficient	Internal Pipe Diameter	Reynolds Number Factor	Annubar Expansion Factor	Pressure Base Factor	Temperature Base Factor	Specific Gravity Factor	Super-Compress. Factor	Thermal Expansion Factor	AT FLOWING CONDITIONS Transmitter Input h = "H_2O @ 68°F P = PSIA T = ° Rankine
	Annubar Flow Constant C'										
Q_S =	F_{NA} ×	K ×	D^2 ×	F_{RA} ×	Y_A ×	F_{pb} ×	F_{tb} ×	F_g ×	F_{pv} ×	F_{AA} ×	$\sqrt{\frac{hP}{T}}$
SCFM	128.52		(in)^2								
SCFH	7711.4		(in)^2								
SCFD	185070		(in)^2								

This equation is used to give the mass rate of flow of gas whenever there is a significant change in line pressure and temperature.

Gas:

$$W = C'\sqrt{\frac{hP}{T}}$$

Mass rate of flow

Rate of Flow	Units Conversion Factor	Annubar Flow Coefficient	Internal Pipe Diameter	Reynolds Number Factor	Annubar Expansion Factor	Thermal Expansion Factor	Specific Gravity	AT FLOWING CONDITIONS Transmitter Input h = "H_2O @ 68°F P = PSIA T = °Rankine
	Annubar Flow Constant C'							
W =	F_{NA} ×	K ×	D^2 ×	F_{RA} ×	Y_A ×	F_{AA} ×	$\sqrt{G}$ ×	$\sqrt{\frac{hP}{T}}$
lb_m/hr	589.70		(in)^2					
lb_m/min	9.8283		(in)^2					
lb_m/sec	.16380		(in)^2					

Air Flow Calculations
Crab Orchard NWR
FDGTI data and calculation assumptions used throughout

Dietrich Annubar Sensor 10

Differential p., in H2O *h*	pressure psia *P*	Int. pipe diameter *D2*	Annubar expansion factor *Ya*	Transmitter input *hP*e-2*	Rate of Flow *Q, SCFM*	Test Area	Test Type
1/2" SCH 40 model (air sparge)							
AS Test							
2.3	30	0.25	0.994875	8.306624	**4.7**	I-1-23	AS
0.5	21	0.25	0.998886	3.240370	**1.8**	I-1-23	AS
0.2	10	0.25	0.999554	1.414214	**0.8**	I-1-2	AS
0.5	10	0.25	0.998886	2.236068	**1.3**	I-1-2	AS
2.5	30	0.25	0.994429	8.660254	**4.9**	REPOS	AS
0.2	15	0.25	0.999554	1.732051	**1.0**	REPOS	AS

Differential p., in H2O *h*	vacuum in H2O *P*	Int. pipe diameter *D2*	Annubar expansion fac *Ya*	Transmitter input *hP*e-2*	Rate of Flow *Q, SCFM*	Test Area	
1 1/2" SCH 40 model (soil vapor extraction)							
DPE Test							
0.2	213	2.25	0.998905	1.239900	**9.4**	I-1-23	DPE
0.5	210	2.25	0.997262	1.946599	**14.8**	I-1-23	DPE
0.5	130	2.25	0.997262	1.531576	**11.6**	I-1-23	DPE
0.2	240	2.25	0.998905	1.316141	**10.0**	REPOS	DPE
0.8	227	2.25	0.995620	2.559998	**19.4**	REPOS	DPE
0.8	235	2.25	0.995620	2.604718	**19.8**	REPOS	DPE
0.5	170	2.25	0.997262	1.751424	**13.3**	I-1-2	DPE
0.2	188	2.25	0.998905	1.164865	**8.9**	I-1-2	DPE
SVE Test							
0.2	278	2.25	0.998905	1.416508	**10.8**	I-1-23	SVE
0.1	271	2.25	0.999452	0.988932	**7.5**	I-1-23	SVE
0.8	201	2.25	0.995620	2.408933	**18.3**	REPOS	SVE
0.2	110	2.25	0.998905	0.891032	**6.8**	REPOS	SVE
0	165	2.25	1.000000	0.000000	**0.0**	I-1-2	SVE
0.1	177	2.25	0.999452	0.799224	**6.1**	I-1-2	SVE

F-8

SVE and DPE Pilot Test- VOC Recovery Rate Calculations - Air
Crab Orchard NWR
FDGTI data used throughout

Test Area	Type of Pilot Test	Rate of Flow *Q, SCFM*	Total VOCs concentration, *ppbv*	VOC Recovery Rate *lb. VOCs/hour*
I-1-23	DPE	**14.8**	1386	0.0004
*I-1-23**	*DPE*	***14.8***	*1414*	*0.0004*
REPOS	DPE	**19.8**	293	0.0001
I-1-2	DPE	**13.3**	222	0.0001
*I-1-2**	*DPE*	***13.3***	*120222*	*0.0326*
I-1-23	SVE	**10.8**	10210	0.0022
REPOS	SVE	**18.3**	1417	0.0005
I-1-2	SVE	**6.1**	160	0.00002
*I-1-2**	*SVE*	***6.1***	*9060*	*0.00112*

** includes 1,1,2-TC-1,2,2-TFA (Freon 113) concentrations in the total VOC figure*

DPE Pilot Test- VOC Recovery Rate Calculations - Groundwater
FDGTI data used throughout

Test Area	Type of Pilot Test	Rate of Flow *Q, GPM*	Total VOCs concentration, *ug/L*	VOC Recovery Rate *lb. VOCs/hour*
I-1-23	DPE	**6.0**	2330	0.007
REPOS	DPE	**0.9**	5937	0.003
I-1-2	DPE	**6.0**	330	0.001

F-9

RMT INC.
744 Heartland Trail PO Box 8923 Madison, WI 53708-8923 (608) 831-4444 FAX (608) 831-3334 VOICE (608) 831-1989

COMPUTATION SHEET

PROJECT / PROPOSAL NAME	PREPARED		CHECKED		PROJECT / PROPOSAL NO
CONWR	By: JWA	Date: 4/25/99	By: RWB	Date: 5/18/99	4791.03

EXAMPLE CALCULATIONS - RECOVERY RATES

AIR 1393 ppbv total VOCs (REPOSITORY AREA)

Assume majority is TCE, (MW = 131)

$$C\ (\mu g/m^3) = (ppbv)(MW)/24.055\ \frac{\mu L}{\mu mole} @\ 1 atm,\ 68°F$$

$$C\ (\mu g/m^3) = (1393\ ppbv)(131)/24.055$$

$$C = 7586.1\ \mu g/m^3$$

Assume air flow rate = 18.3 cfm

$$7586.1\ \frac{\mu g}{m^3} \times \frac{g}{10^6\ \mu g} \times \frac{1\ lb.}{454\ g} \times \frac{1\ m^3}{35.31\ ft^3} \times \frac{18.3\ ft^3}{min} \times \frac{60\ min}{hr} = \underline{0.0005}\ \frac{lb\ VOCs}{hr}$$

SIMPLIFY FOR REPETITIVE CALCS AS:

$$C_a(ppbv) \times Q_a\left(\frac{ft^3}{min}\right) \times 2.0383 \times 10^{-8} = R_a\left(\frac{lb}{hr}\ VOCs\right)$$

RMT INC.
744 Heartland Trail P.O. Box 8923 Madison, WI 53708-8923 (608) 831-4444 FAX (608) 831-3334 VOICE (608) 831-1989

COMPUTATION SHEET

PROJECT / PROPOSAL NAME	PREPARED By:	Date:	CHECKED By:	Date:	PROJECT / PROPOSAL NO
CONWR	JWA	4/25/99	TWB	5/18/99	4781.03

EXAMPLE CALCULATIONS - RECOVERY RATES

WATER

2330 µg/L VOCs @ 6 GPM

$$\frac{2330\ \mu g}{L} \times \frac{1\ g}{10^6\ \mu g} \times \frac{1\ lb}{454\ g} \times \frac{3.78\ L}{1\ gal} \times \frac{6\ gal}{min} \times \frac{60\ min}{hr}$$

$$= 0.007\ lb/hr$$

SIMPLIFY FOR SPREADSHEET CALCS AS:

$$C_w\ \mu g/L \times Q_w\ \frac{gal}{min} \times 4.9956 \times 10^{-7} = R_w\ lb/hr\ VOCs$$

Appendix G
Model Output from Remedial Alternatives Simulations

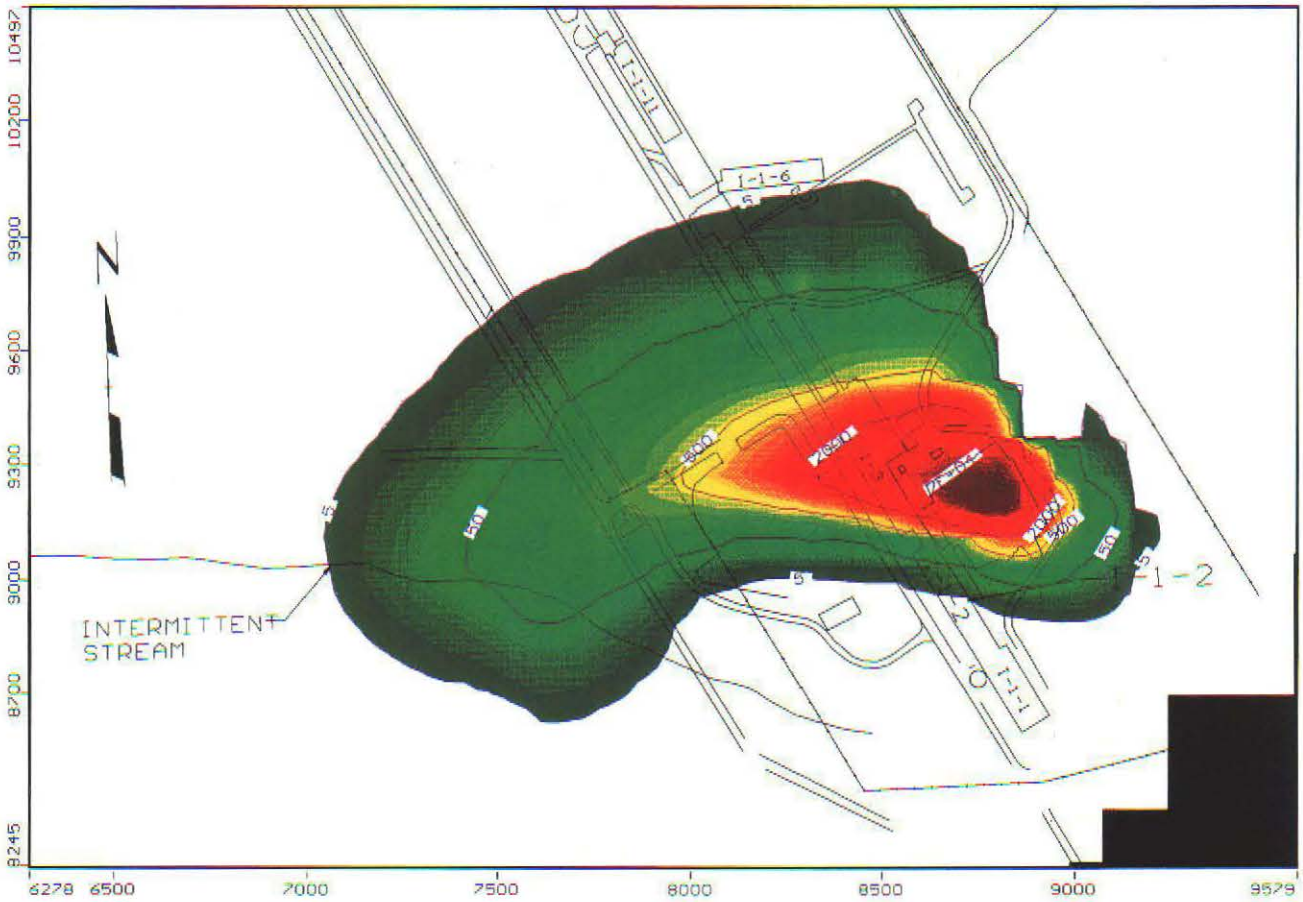
Model Run Crab210 - Monitored Natural Attenuation

Model Input: Calibrated transport model groundwater concentrations

Model Output: Concentrations over 20-year period starting in 1999

No active remediation

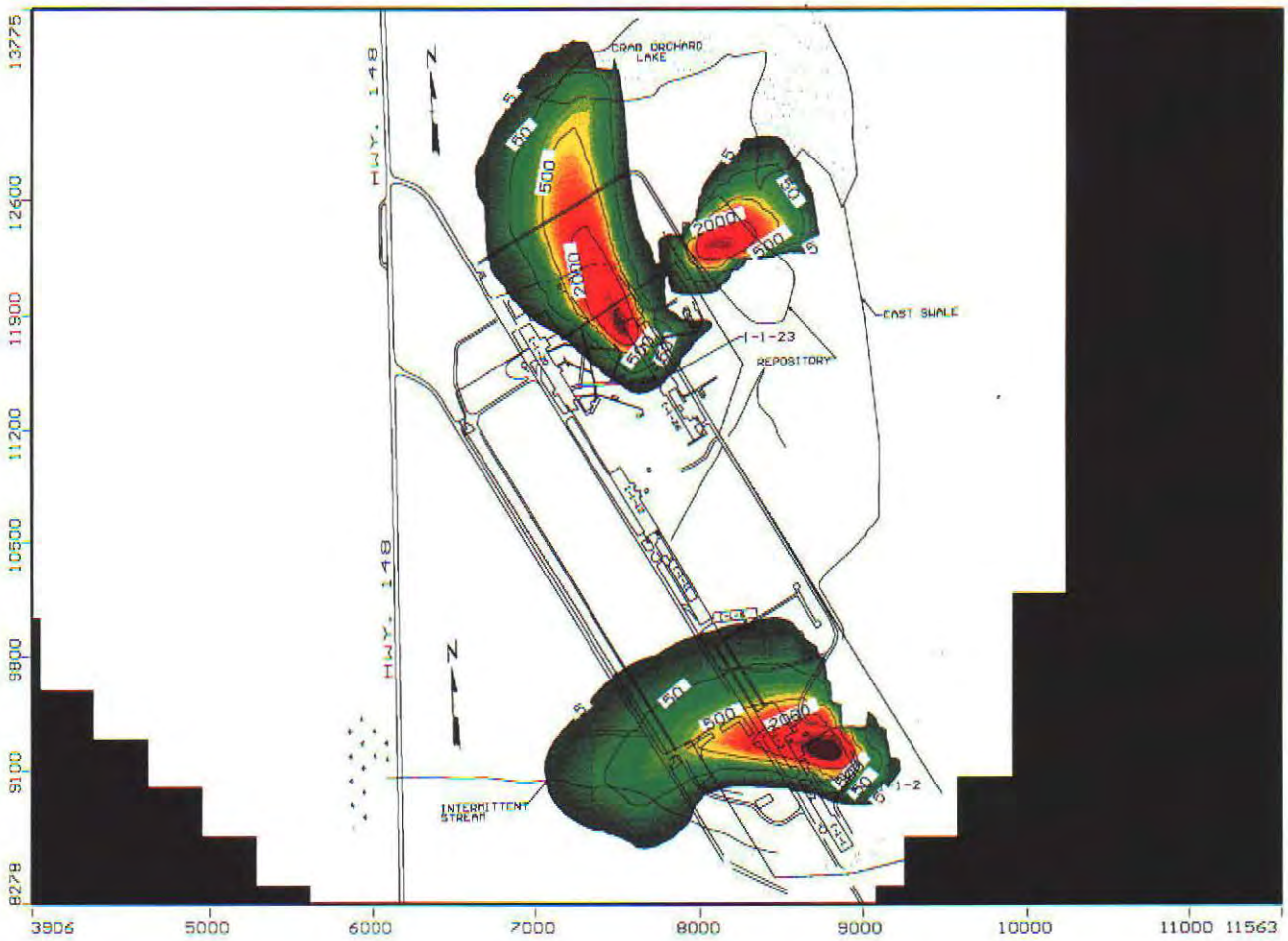
The purpose of this run is to evaluate how concentrations of TCE in the groundwater would change over a 20-year period due to natural attenuation in the groundwater system.



RMT
Project: CRAB ORCHARD Crab210
Description: Natural Attenuation 20yr
Modeller: GK Contours TCE, ppb
10 May 99

Visual MODFLOW v.2.7.2, (C) 1995–1997
Waterloo Hydrogeologic, Inc.
NC: 90 NR: 104 NL: 5
Current Layer: 2

Monitored Natural Attenuation,
Building I-1-2 Plume, Upper Sand, 20 years Future



rmt
Project: CRAB ORCHARD Crab210
Description: Natural Attenuation 20yr
Modeller: GK Contours TCE, ppb
28 Sep 99

Visual MODFLOW v.2.7.2, (C) 1995-1997
Waterloo Hydrogeologic, Inc.
NC: 90 NR: 104 NL: 5
Current Layer: 2

Monitored Natural Attenuation,
Site 32/33, Upper Sand, 20 years Future

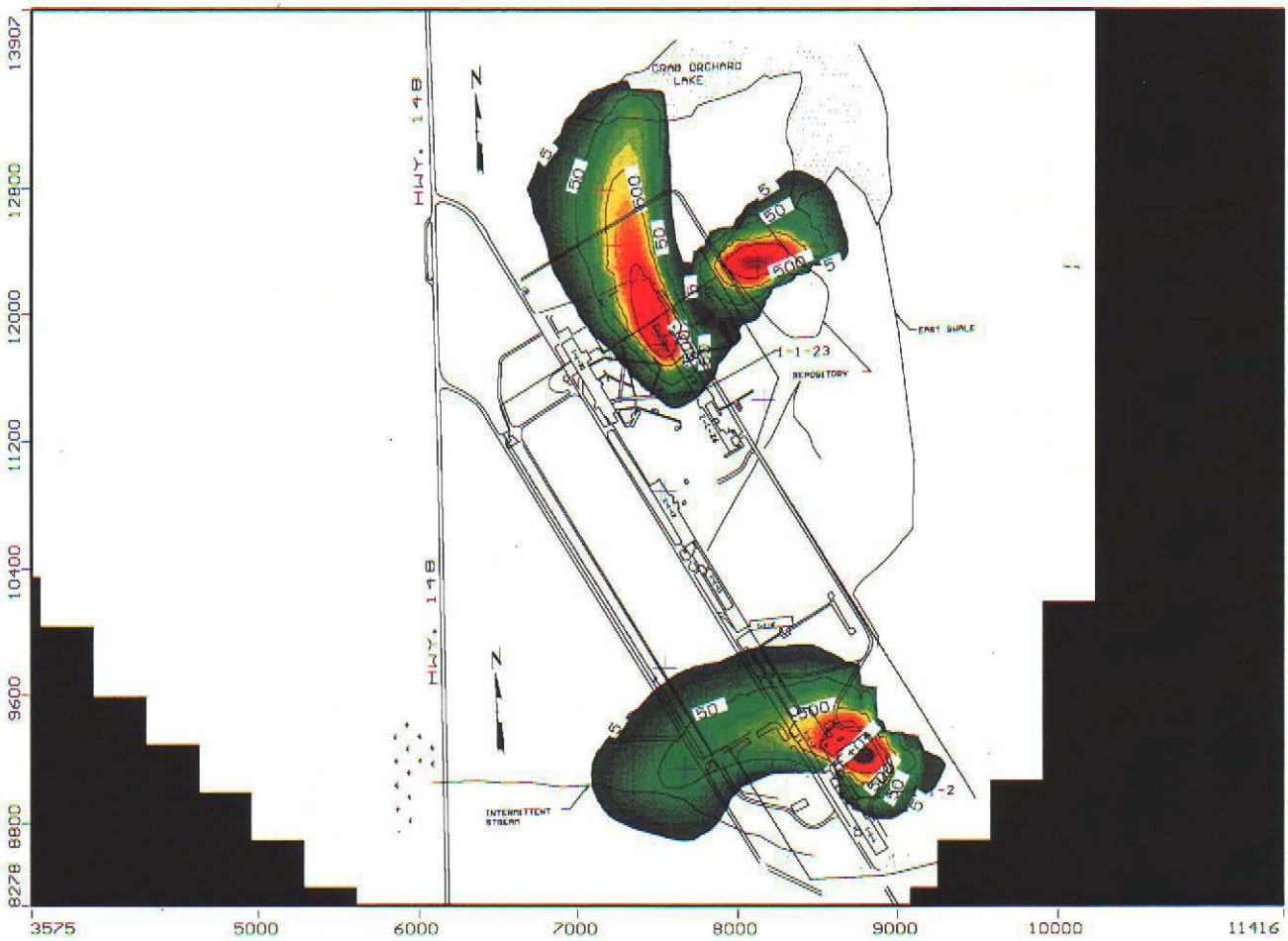
Model Run Crab211 - Phytoremediation

Model Input: Calibrated transport model groundwater concentrations

Model Output: Concentrations over 20-year period after start of this remedial alternative

Remediate groundwater by uptake by hybrid poplar trees in source areas and downgradient groundwater discharge zones

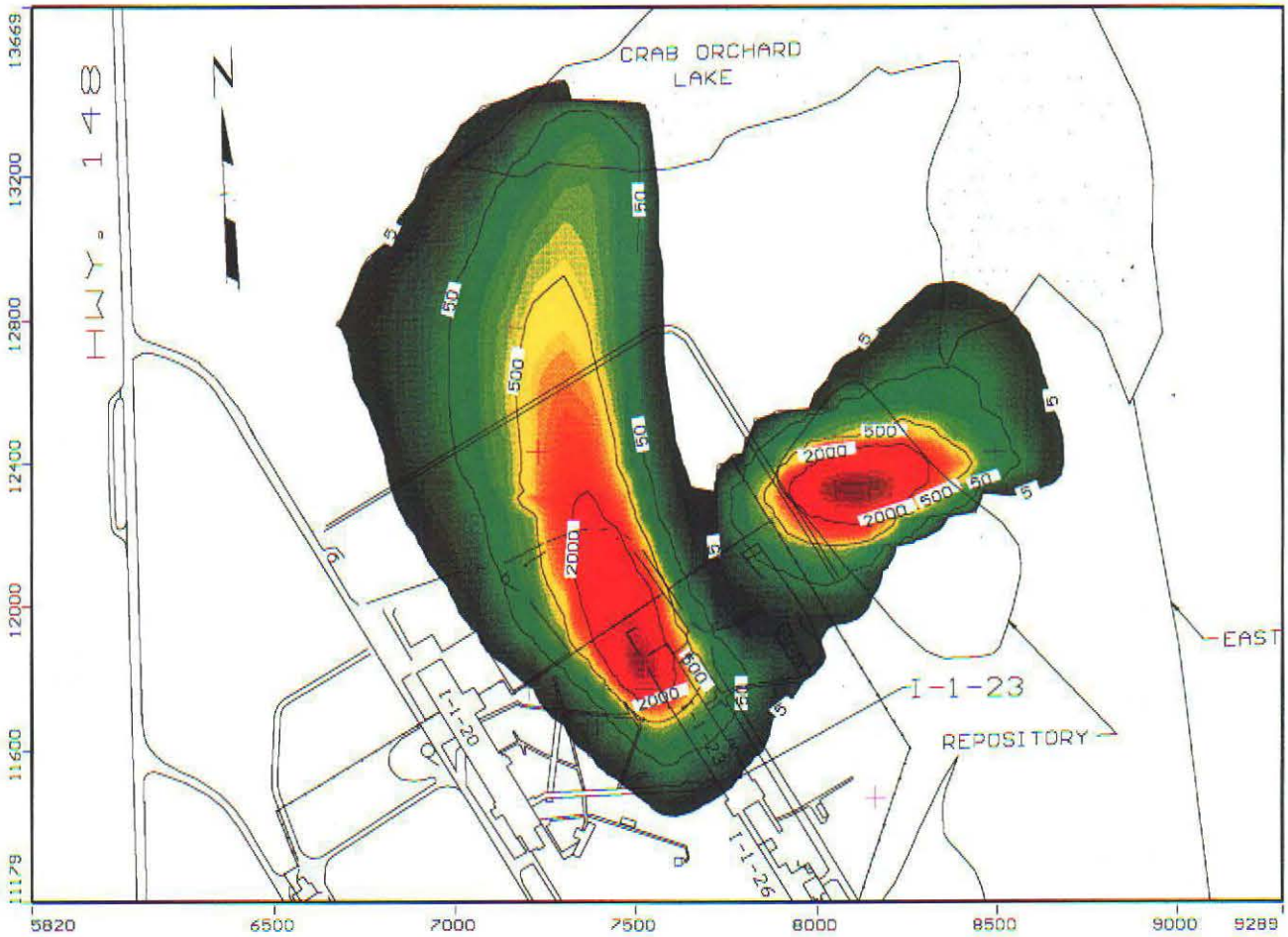
The purpose of this run is to evaluate how concentrations of TCE in the groundwater would change over a 20-year period due to phytoremediation.



rmt
Project: CRAB ORCHARD Crab211
Description: Phytoremediation 20 yrs
Modeller: GK Contours TCE, ppb
28 Sep 99

Visual MODFLOW v.2.7.2, (C) 1995-1997
Waterloo Hydrogeologic, Inc.
NC: 90 NR: 104 NL: 5
Current Layer: 2

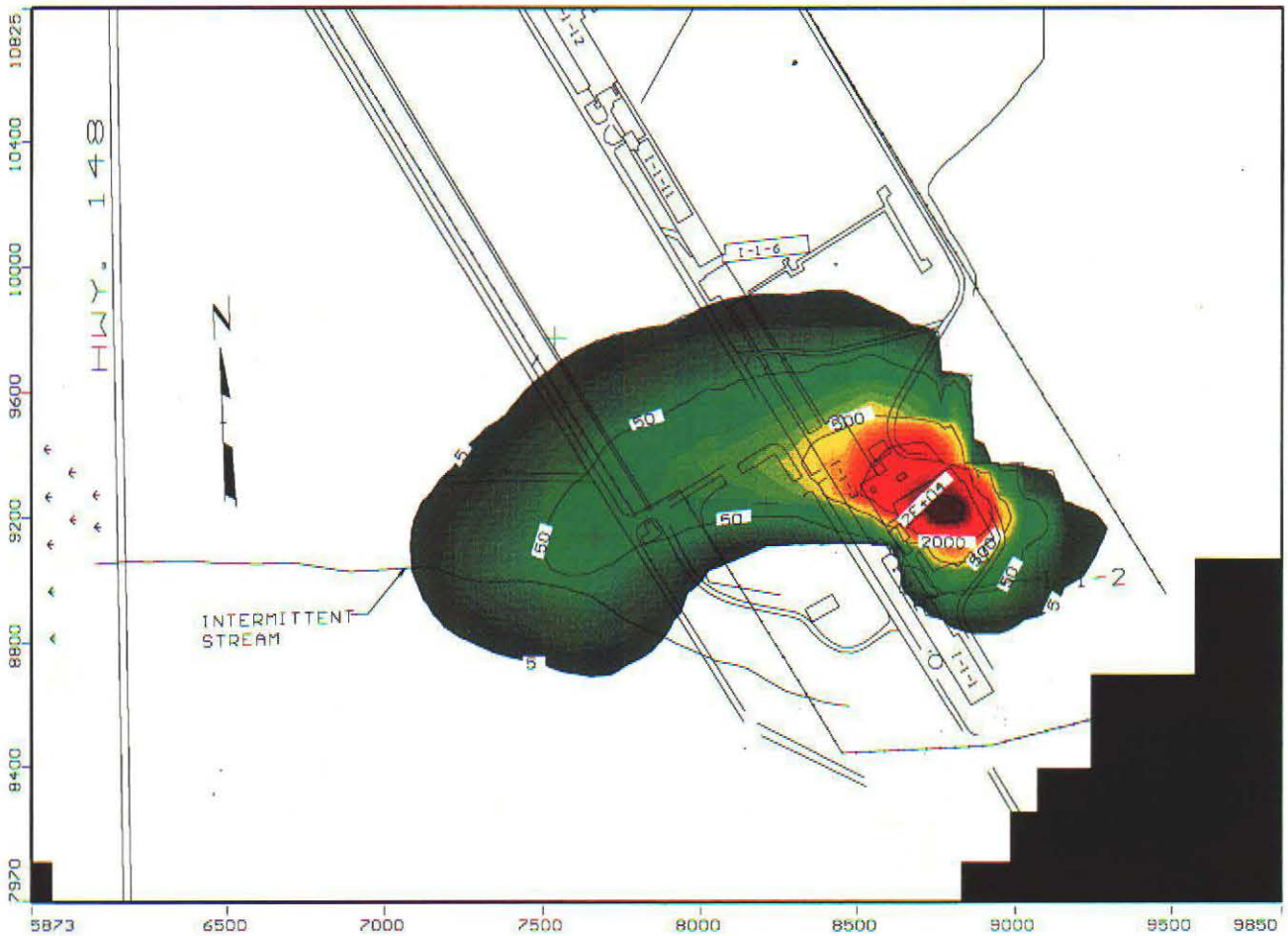
Phytoremediation,
Site 32/33, Upper Sand, 20 years Future



rmt
Project: CRAB ORCHARD Crab211
Description: Phytoremediation 20 yrs
Modeller: GK Contours TCE, ppb
28 Sep 99

Visual MODFLOW v.2.7.2, (C) 1995–1997
Waterloo Hydrogeologic, Inc.
NC: 90 NR: 104 NL: 5
Current Layer: 2

Phytoremediation,
I-1-23/Repository Areas, Upper Sand, 20 years Future



rmt
Project: CRAB ORCHARD Crab211
Description: Phytoremediation 20 yrs
Modeller: GK Contours TCE, ppb
28 Sep 99

Visual MODFLOW v.2.7.2, (C) 1995–1997
Waterloo Hydrogeologic, Inc.
NC: 90 NR: 104 NL: 5
Current Layer: 2

Phytoremediation,
I-1-2 Area, Upper Sand, 20 years Future

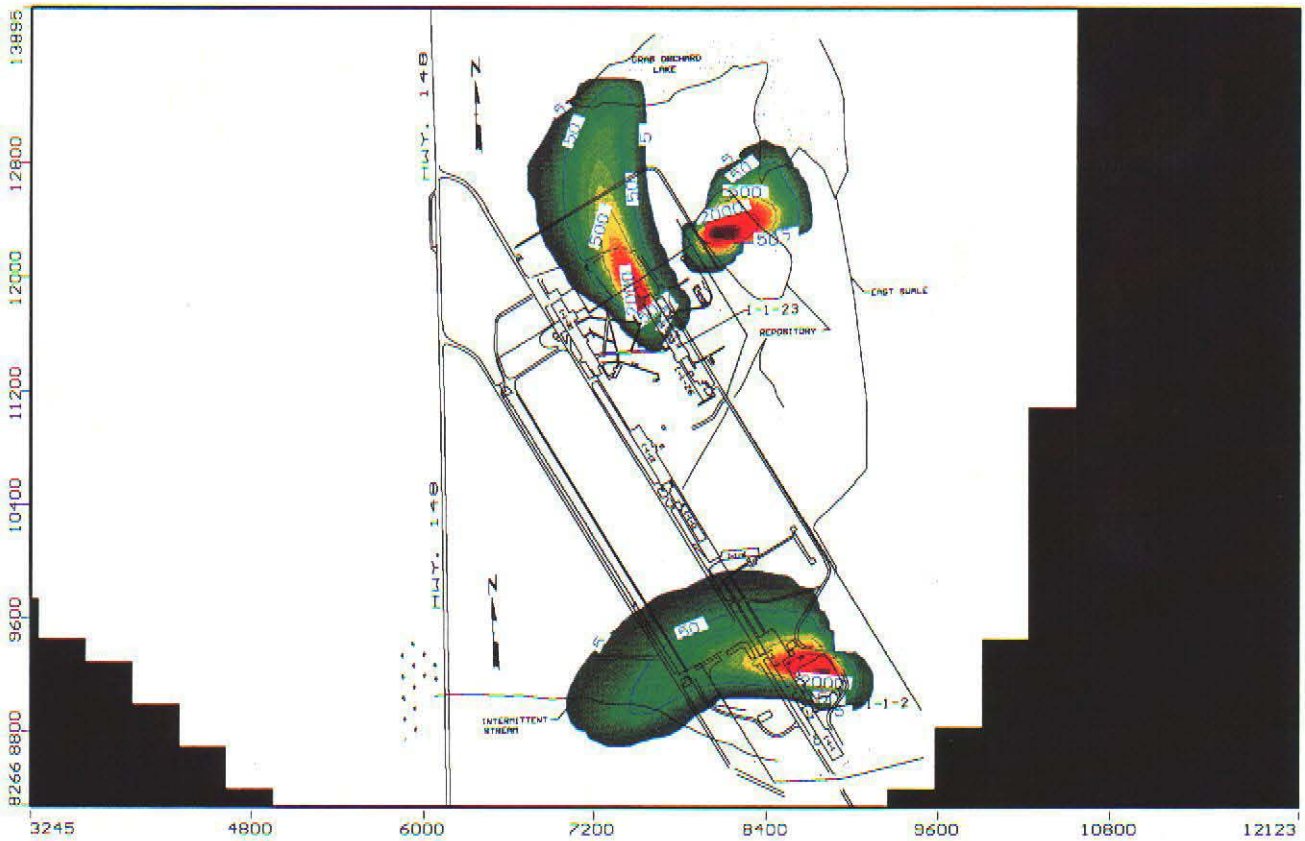
Model Run Crab212bd - Enhanced Bioremediation

Model Input: Calibrated transport model groundwater concentrations

Model Output: Concentrations over 20-year period after start of this remedial alternative

Remediate groundwater by enhanced biodegradation in the source areas. Include phytoremediation in the downgradient groundwater discharge zones.

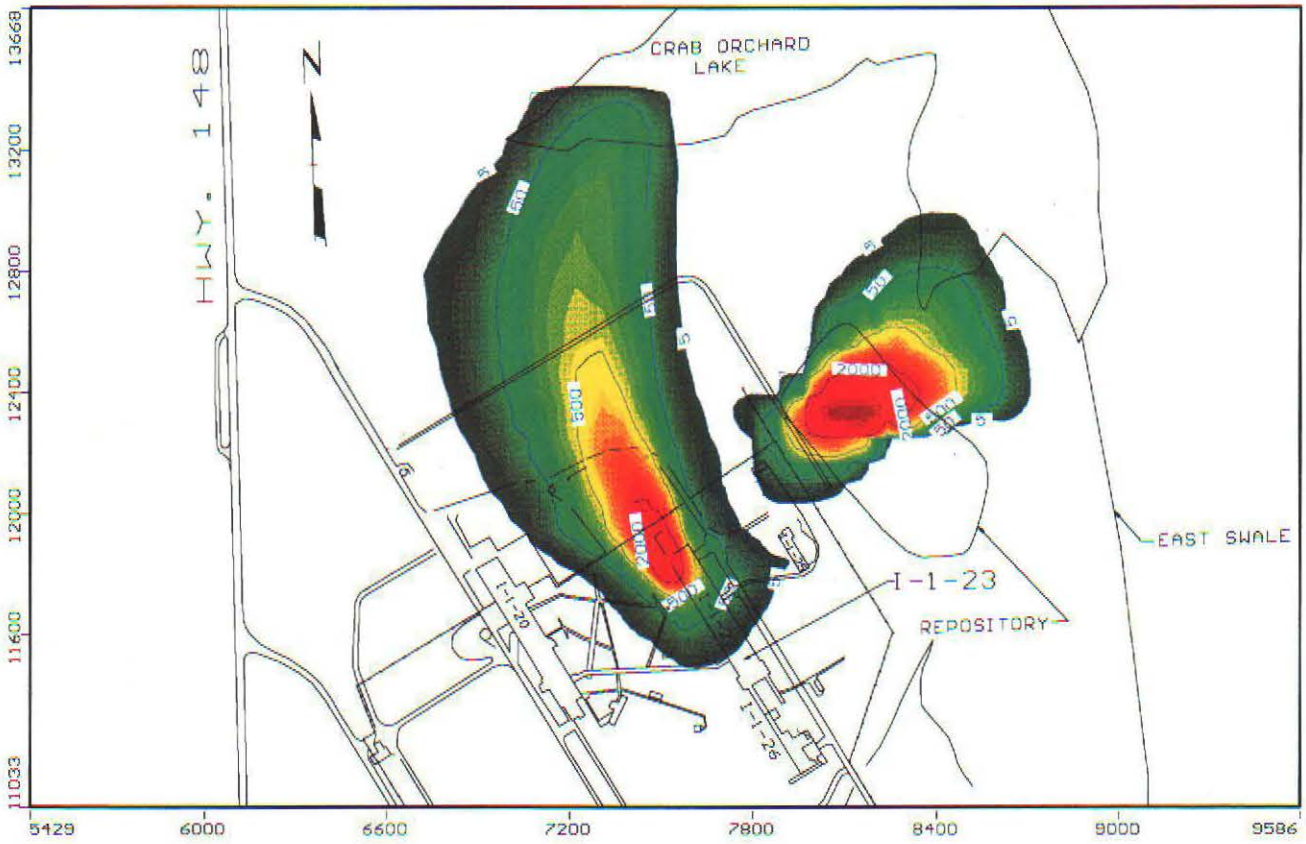
The purpose of this run is to evaluate how concentrations of TCE in the groundwater would change over a 20-year period due to enhanced bioremediation.



rmt
Project: CRAB ORCHARD Crab212bd
Description: Enhanced Biodegrad. 20 yr
Modeller: GK Contours TCE, ppb
7 May 99

Visual MODFLOW v.2.7.2, (C) 1995–1997
Waterloo Hydrogeologic, Inc.
NC: 90 NR: 104 NL: 5
Current Layer: 1

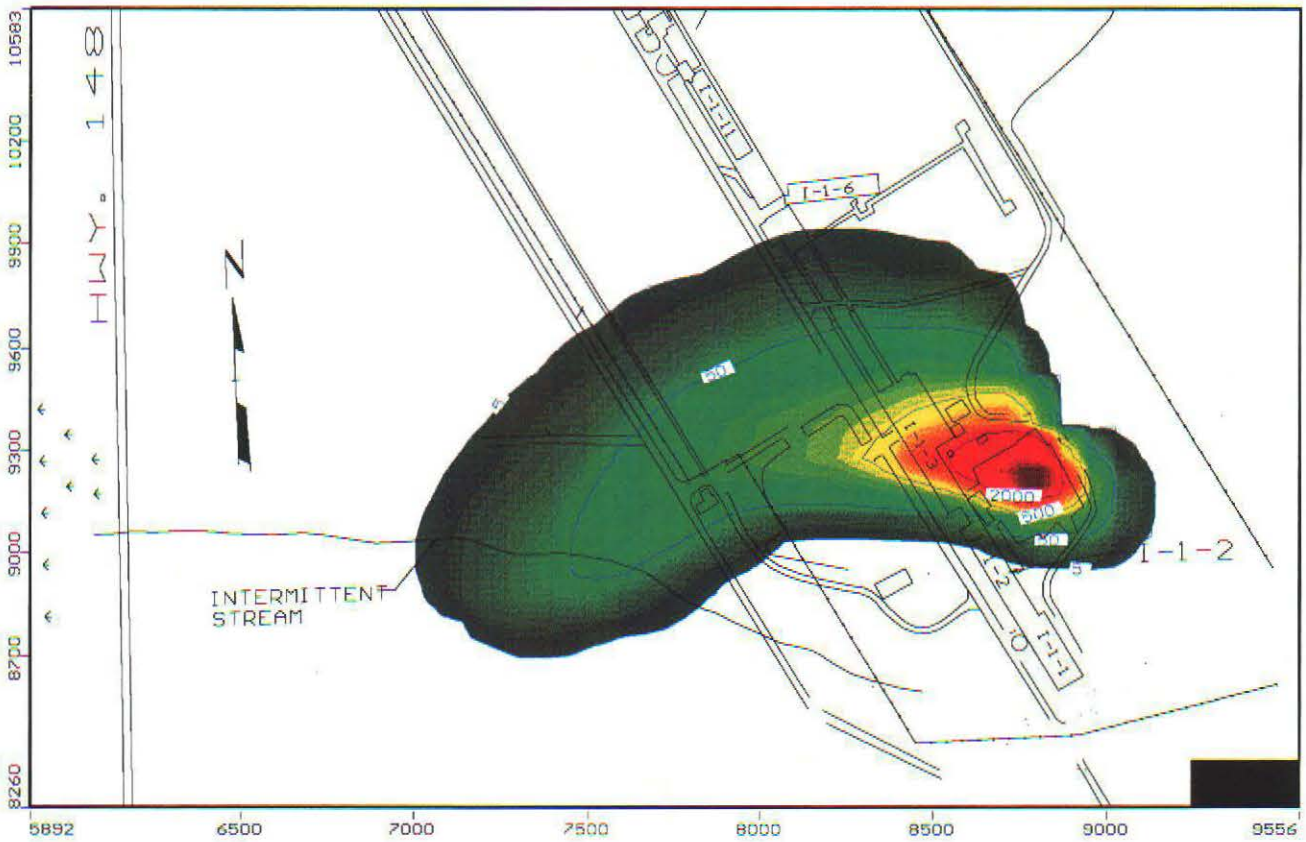
Enhanced Biodegradation,
Site 32/33, Upper Sand, 20 years Future



rmt
Project: CRAB ORCHARD Crab212bd
Description: Enhanced Biodeg. 20 yr
Modeller: GJK Contours in ppb TCE
5 May 99

Visual MODFLOW v.2.7.2, (C) 1995-1997
Waterloo Hydrogeologic, Inc.
NC: 90 NR: 104 NL: 5
Current Layer: 2

Enhanced Biodegradation,
I-1-23/Repository Areas, Upper Sand, 20 years Future



rmt
Project: CRAB ORCHARD Crab212bd
Description: Enhanced Biodegrad. 20 yr
Modeller: GK Contours TCE, ppb
7 May 99

Visual MODFLOW v.2.7.2, (C) 1995–1997
Waterloo Hydrogeologic, Inc.
NC: 90 NR: 104 NL: 5
Current Layer: 1

Enhanced Biodegradation,
I-1-2 Area, Upper Sand, 20 years Future

Model Run Crab213a - Multi-Phase Extraction

Model Input: Calibrated transport model groundwater concentrations

Model Output: Concentrations over 20-year period after start of this remedial alternative

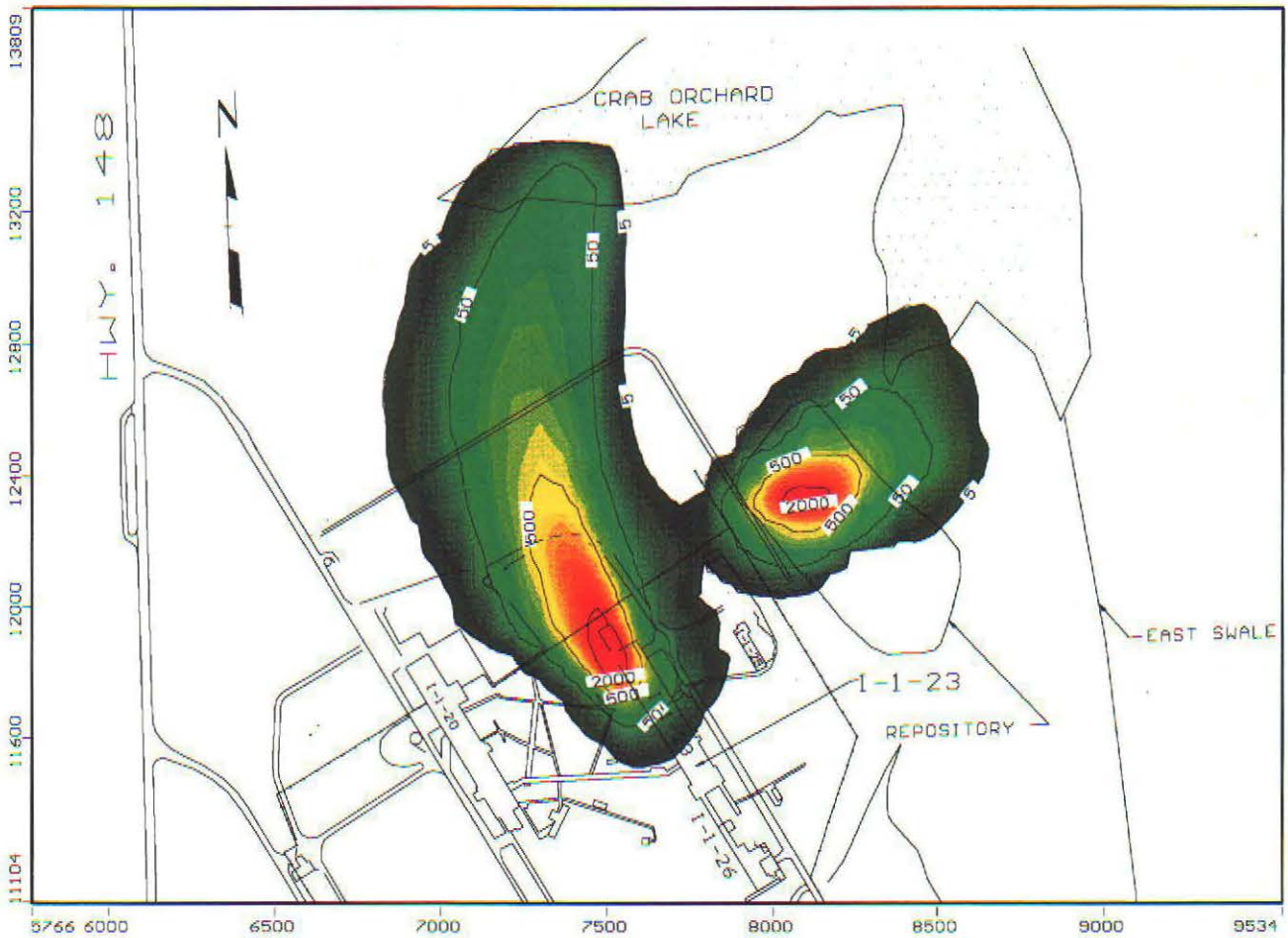
Remediate groundwater by multi-phase extraction (of groundwater and soil vapor) in the source areas. Include phytoremediation in the downgradient groundwater discharge zones.

The purpose of this run is to evaluate how concentrations of TCE in the groundwater would change over a 20-year period due to multi-phase extraction.

rmt
Project: CRAB ORCHARD
Description: Multi-Phase Extract, 2 yr
Modeller: GK Contours TCE, ppb
28 Sep 99

Visual MODFLOW v.2.7.2, (C) 1995-1997
Waterloo Hydrogeologic, Inc.
NC: 90 NR: 104 NL: 5
Current Layer: 2

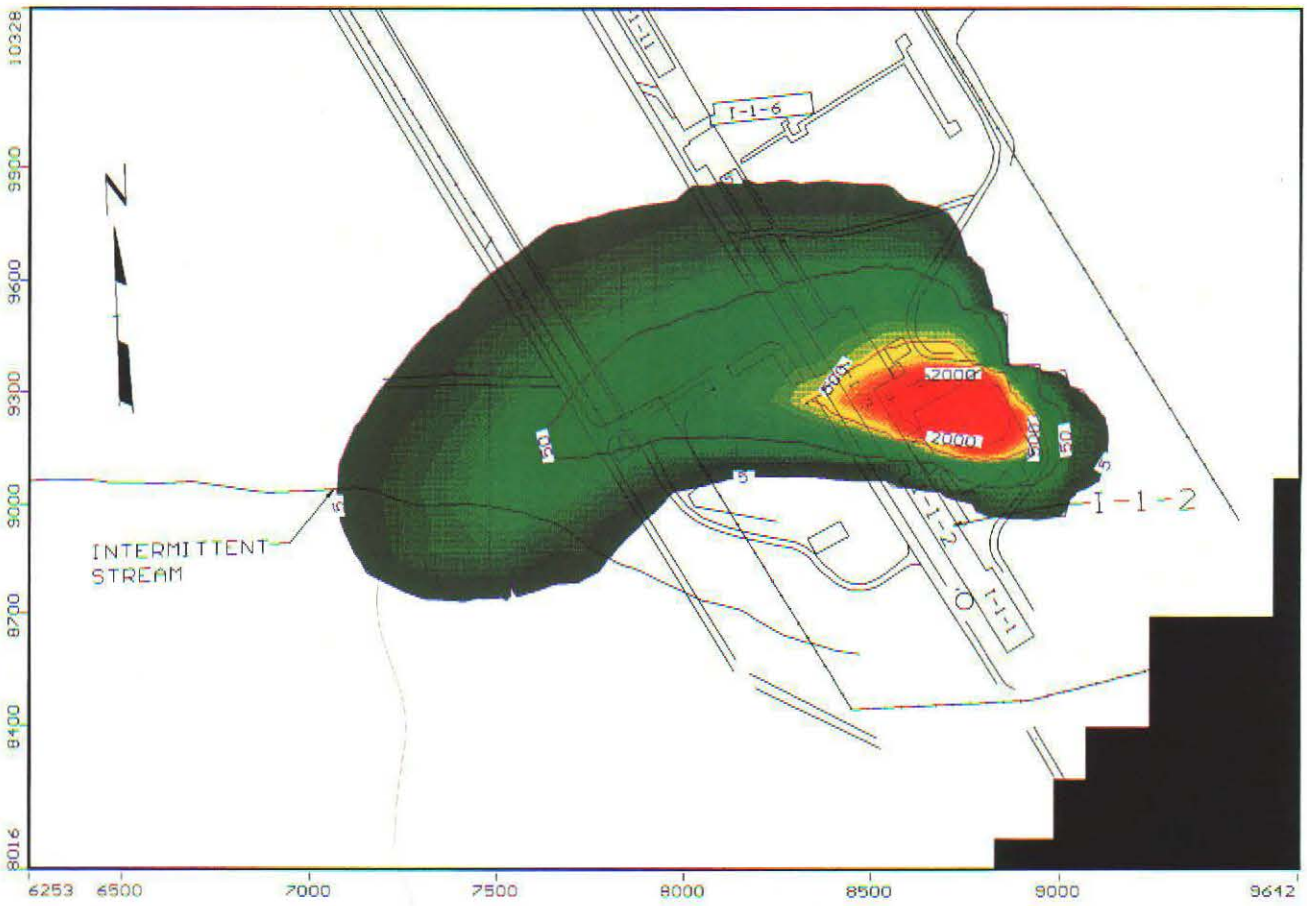
Multi-Phase Extraction,
Site 32/33, Upper Sand, 20 years Future



rmt
Project: CRAB ORCHARD
Description: Multi-Phase Extract, 2 yr
Modeller: GK Contours TCE, ppb
28 Sep 99

Visual MODFLOW v.2.7.2, (C) 1995-1997
Waterloo Hydrogeologic, Inc.
NC: 90 NR: 104 NL: 5
Current Layer: 2

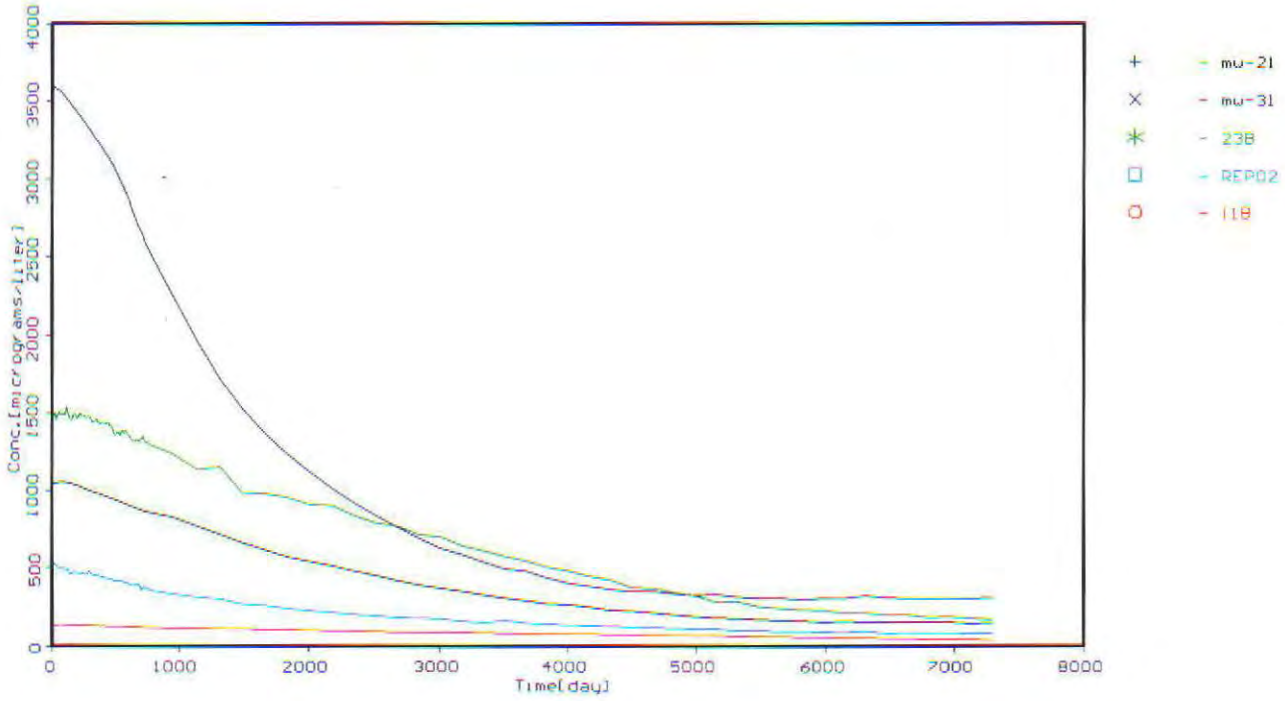
Multi-Phase Extraction, for 2 years,
I-1-23/Repository Areas, Upper Sand, 20 years Future



RMT
Project: CRAB ORCHARD Crab213a
Description: Multi-Phase Extract, 2yrs
Modeller: GK Contours TCE, ppb
10 May 99

Visual MODFLOW v.2.7.2, (C) 1995-1997
Waterloo Hydrogeologic, Inc.
NC: 90 NR: 104 NL: 5
Current Layer: 2

Multi-Phase Extraction, for 2 years,
I-1-2 Area, Upper Sand, 20 years Future



RMT Project: CRAB ORCHARD Description: Crab213 Multi-Phase Extr. Modeller: GJK 29 Apr 99	Visual MODFLOW v.2.7.2, (C) 1995-1997 Waterloo Hydrogeologic, Inc. NC: 90 NR: 104 NL: 5 Current Layer: 2

Multi-Phase Extraction, for 2 years,
Concentration at Monitoring Wells,
Upper Sand, in Future

Model Run Crab216 - MITU

Model Input: Calibrated transport model groundwater concentrations

Model Output: Concentrations over 20-year period after start of this remedial alternative

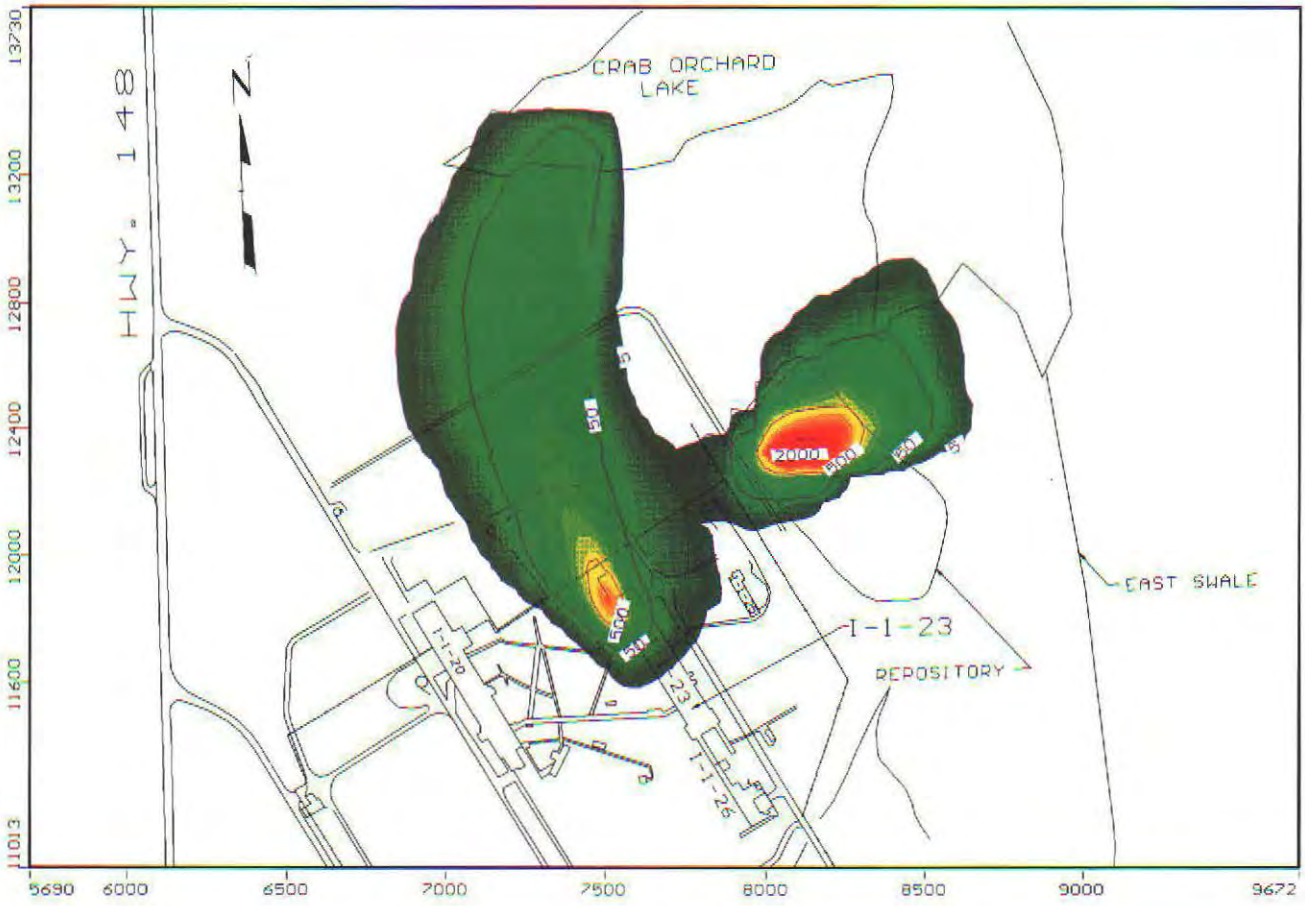
Remediate soil in the source areas by mobile in-situ treatment unit (MITU). Include short-term dewatering of the source areas, and phytoremediation in the downgradient groundwater discharge zones.

The purpose of this run is to evaluate how concentrations of TCE in the groundwater would change over a 20-year period due to treatment of the soil with the MITU .

rmt
Project: CRAB ORCHARD Crab216
Description: MITU 20 yrs
Modeller: GK Contours TCE, ppb
28 Sep 99

Visual MODFLOW v.2.7.2, (C) 1995-1997
Waterloo Hydrogeologic, Inc.
NC: 90 NR: 104 NL: 5
Current Layer: 2

MITU, Site 32/33,
Upper Sand, 20 years Future



RMT
Project: CRAB ORCHARD Crab216
Description: MITU 20 yrs
Modeller: GK Contours TCE, ppb
10 May 99

Visual MODFLOW v.2.7.2, (C) 1995–1997
Waterloo Hydrogeologic, Inc.
NC: 90 NR: 104 NL: 5
Current Layer: 2

MITU, I-1-23/Repository Areas,
Upper Sand, 20 years Future

RMT
Project: CRAB ORCHARD Crab216
Description: MITU 20 yrs
Modeller: GK Contours TCE, ppb
10 May 99

Visual MODFLOW v.2.7.2, (C) 1995-1997
Waterloo Hydrogeologic, Inc.
NC: 90 NR: 104 NL: 5
Current Layer: 2

MITU, I-1-2 Area,
Upper Sand, 20 years Future

Prediction Run Flow Model Output Crab213a

```
1                    MODFLOW

   U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER FLOW MODEL

 Basic Package translator - (c) 1994 Waterloo Hydrogeologic Software

 CRAB213A.BAS Fri Apr 30 09:55:15 1999

   5 LAYERS      104 ROWS      90 COLUMNS

   9 STRESS PERIOD(S) IN SIMULATION

 MODEL TIME UNIT IS DAYS

 BAS5 -- BASIC MODEL PACKAGE, VERSION 5, 1/1/95 INPUT READ FROM UNIT  1

BCF5 -- BLOCK-CENTERED FLOW PACKAGE, VERSION 5, 9/1/93 INPUT READ FROM UNIT 11

 TRANSIENT SIMULATION

 CELL-BY-CELL FLOWS WILL BE SAVED ON UNIT 54

WETTING CAPABILITY IS ACTIVE
LAYER  LAYER-TYPE CODE    INTERBLOCK T

   ----------------------------------------

     1        3        0 -- HARMONIC

     2        3        0 -- HARMONIC

     3        3        0 -- HARMONIC

     4        3        0 -- HARMONIC

     5        3        0 -- HARMONIC

 WEL5 -- WELL PACKAGE, VERSION 5, 9/1/93 INPUT READ FROM UNIT 12

 MAXIMUM OF  106 WELLS

DRN5 -- DRAIN PACKAGE, VERSION 5, 9/1/93 INPUT READ FROM UNIT 13

 MAXIMUM OF  858 DRAINS

 RIV5 -- RIVER PACKAGE, VERSION 5, 9/1/93 INPUT READ FROM UNIT 14

 MAXIMUM OF  699 RIVER REACHES

RCH5 -- RECHARGE PACKAGE, VERSION 5, 6/1/95 INPUT READ FROM UNIT 18

 OPTION 3 -- RECHARGE TO HIGHEST ACTIVE NODE IN EACH VERTICAL COLUMN

0WHS1  - CGSTAB-P PROCEDURE SOLUTION PACKAGE, VERSION 1, 8/4/95 INPUT READ FROM UNIT 31

 MAXIMUM OF  50OUTER ITERATIONS ALLOWED FOR CLOSURE

STRESS PERIOD NO.  1, LENGTH =  1.000000
```

INITIAL TIME STEP SIZE = 0.3852275E-01

36 WELLS

LAYER	ROW	COL	STRESS RATE	WELL NO.
1	27	36	-3.8503	1
1	64	63	-19.251	2
1	18	50	-9.6257	3
1	27	39	-3.8503	4
1	27	41	-3.8503	5
1	28	40	-3.8503	6
1	29	41	-3.8503	7
1	30	40	-3.8503	8
1	31	41	-3.8503	9
1	32	40	-3.8503	10
1	33	41	-3.8503	11
1	34	40	-3.8503	12
1	36	41	-3.8503	13
1	36	39	-3.8503	14
1	34	38	-3.8503	15
1	32	38	-3.8503	16
1	30	38	-3.8503	17
1	28	38	-3.8503	18
1	29	36	-3.8503	19
1	31	36	-3.8503	20
1	33	36	-3.8503	21
1	36	36	-3.8503	22
1	18	51	-9.6257	23
1	18	52	-9.6257	24
1	18	53	-9.6257	25
1	19	53	-9.6257	26
1	20	53	-9.6257	27
1	20	52	-9.6257	28
1	19	52	-9.6257	29
1	19	51	-9.6257	30
1	20	51	-9.6257	31

1	20	50	-9.6257	32
1	19	50	-9.6257	33
1	64	64	-19.251	34
1	65	64	-19.251	35
1	65	63	-19.251	36

0 MAXIMUM INNER ITERATIONS ALLOWED = 25

DAMPING FACTOR = 1.0000

HEAD CHANGE CRITERION FOR CLOSURE = 0.10000E-01

MAXIMUM RESIDUAL FOR LINEAR ITERATION 0.10000E-02

MAXIMUM RELATIVE RESIDUAL FOR LINEAR ITERATION 0.00000E+00

Outer iteration 2 Inner iteration 1 Max. residual -1.713E-08

SOLUTION BY CGSTAB-P

---

0 MAXIMUM ITERATIONS ALLOWED FOR CLOSURE = 50

0 MAXIMUM INNER ITERATIONS ALLOWED = 25

DAMPING FACTOR = 1.0000

HEAD CHANGE CRITERION FOR CLOSURE = 0.10000E-01

MAXIMUM RESIDUAL FOR LINEAR ITERATION 0.10000E-02

MAXIMUM RELATIVE RESIDUAL FOR LINEAR ITERATION 0.00000E+00

Outer iteration 1 Inner iteration 1 Max. residual 2.143E-01

Outer iteration 1 Inner iteration 2 Max. residual 4.242E-05

HEADS AND FLOW TERMS SAVED ON UNIT 75 FOR USE BY MT3D TRANSPORT MODEL

CALIBRATION PACKAGE OUTPUT

CALIBRATION OUTPUT POINTS

1	40	37	0.414410E+03	0.229492E-01
1	32	37	0.414265E+03	0.128174E-02
1	29	37	0.413961E+03	-0.305176E-04
1	40	52	0.416328E+03	-0.305176E-04
2	40	59	0.416223E+03	-0.305176E-04
2	42	37	0.412446E+03	0.227509E+00
2	37	37	0.412795E+03	0.253906E+00
2	32	37	0.413699E+03	0.428162E-01

```
    2    29    37      0.413499E+03      0.305176E-04
    2    39    52      0.415875E+03      0.000000E+00
    2    40    59      0.416223E+03     -0.305176E-04
0


                    SOLUTION BY CGSTAB-P
                    --------------------
0                   MAXIMUM ITERATIONS ALLOWED FOR CLOSURE =     50
0                   MAXIMUM INNER ITERATIONS ALLOWED =     25
                          DAMPING FACTOR =    1.0000
                    HEAD CHANGE CRITERION FOR CLOSURE =   0.10000E-01
MAXIMUM RESIDUAL FOR LINEAR ITERATION   0.10000E-02
MAXIMUM RELATIVE RESIDUAL FOR LINEAR ITERATION    0.00000E+00
Outer iteration   1 Inner iteration   1 Max. residual  2.567E+00
Outer iteration   1 Inner iteration   2 Max. residual  8.049E-03
Outer iteration   1 Inner iteration   3 Max. residual  4.703E-05
0


                    SOLUTION BY CGSTAB-P
                    --------------------
0                   MAXIMUM ITERATIONS ALLOWED FOR CLOSURE =     50
0                   MAXIMUM INNER ITERATIONS ALLOWED =     25
                          DAMPING FACTOR =    1.0000
                    HEAD CHANGE CRITERION FOR CLOSURE =   0.10000E-01
MAXIMUM RESIDUAL FOR LINEAR ITERATION   0.10000E-02
MAXIMUM RELATIVE RESIDUAL FOR LINEAR ITERATION    0.00000E+00
Outer iteration   2 Inner iteration   1 Max. residual -2.352E-04

HEAD/DRAWDOWN PRINTOUT FLAG = 1    TOTAL BUDGET PRINTOUT FLAG = 1
CELL-BY-CELL FLOW TERM FLAG = 1

OUTPUT FLAGS FOR ALL LAYERS ARE THE SAME:
 HEAD   DRAWDOWN  HEAD  DRAWDOWN
```

PRINTOUT PRINTOUT SAVE SAVE

---

0 0 1 1

UBUDSV SAVING " STORAGE" ON UNIT 54 AT TIME STEP 10, STRESS PERIOD 1

UBUDSV SAVING " CONSTANT HEAD" ON UNIT 54 AT TIME STEP 10, STRESS PERIOD 1

UBUDSV SAVING "FLOW RIGHT FACE " ON UNIT 54 AT TIME STEP 10, STRESS PERIOD 1

UBUDSV SAVING "FLOW FRONT FACE " ON UNIT 54 AT TIME STEP 10, STRESS PERIOD 1

UBUDSV SAVING "FLOW LOWER FACE " ON UNIT 54 AT TIME STEP 10, STRESS PERIOD 1

UBUDSV SAVING " WELLS" ON UNIT 54 AT TIME STEP 10, STRESS PERIOD 1

UBUDSV SAVING " DRAINS" ON UNIT 54 AT TIME STEP 10, STRESS PERIOD 1

UBUDSV SAVING " RIVER LEAKAGE" ON UNIT 54 AT TIME STEP 10, STRESS PERIOD 1

UBUDSV SAVING " RECHARGE" ON UNIT 54 AT TIME STEP 10, STRESS PERIOD 1

HEADS AND FLOW TERMS SAVED ON UNIT 75 FOR USE BY MT3D TRANSPORT MODEL

CALIBRATION PACKAGE OUTPUT

CALIBRATION OUTPUT POINTS

1	40	37	0.414379E+03	0.310059E-01
1	32	37	0.414263E+03	0.238037E-02
1	29	37	0.413961E+03	0.000000E+00
1	40	52	0.416328E+03	-0.610352E-04
2	40	59	0.416223E+03	0.000000E+00
2	42	37	0.412197E+03	0.249023E+00
2	37	37	0.412513E+03	0.282837E+00
2	32	37	0.413639E+03	0.602722E-01
2	29	37	0.413499E+03	0.610352E-04
2	39	52	0.415875E+03	0.305176E-04
2	40	59	0.416223E+03	0.000000E+00

HEAD WILL BE SAVED ON UNIT 50 AT END OF TIME STEP 10, STRESS PERIOD 1

DRAWDOWN WILL BE SAVED ON UNIT 51 AT END OF TIME STEP 10, STRESS PERIOD 1

1

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 10 IN STRESS PERIOD 1

CUMULATIVE VOLUMES L**3 RATES FOR THIS TIME STEP L**3/T

IN:		IN:	
STORAGE =	45764.6836	STORAGE =	41311.1055
CONSTANT HEAD =	0.0000	CONSTANT HEAD =	0.0000
WELLS =	0.0000	WELLS =	0.0000
DRAINS =	0.0000	DRAINS =	0.0000
RIVER LEAKAGE =	4.2033	RIVER LEAKAGE =	4.1988
RECHARGE =	128011.3984	RECHARGE =	128011.3906
TOTAL IN =	173780.2812	TOTAL IN =	169326.6875

OUT:		OUT:	
STORAGE =	2935.9463	STORAGE =	1446.6443
CONSTANT HEAD =	29361.6328	CONSTANT HEAD =	29361.5801
WELLS =	269.5184	WELLS =	269.5184
DRAINS =	75600.9922	DRAINS =	72630.4141
RIVER LEAKAGE =	65677.0391	RIVER LEAKAGE =	65677.3125
RECHARGE =	0.0000	RECHARGE =	0.0000
TOTAL OUT =	173845.1250	TOTAL OUT =	169385.4688
IN - OUT =	-64.8438	IN - OUT =	-58.7812
PERCENT DISCREPANCY =	-0.04	PERCENT DISCREPANCY =	-0.03

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 10 IN STRESS PERIOD 9

CUMULATIVE VOLUMES L**3 RATES FOR THIS TIME STEP L**3/T

```
IN:                                IN:
---                                ---
STORAGE =      12882461.0000       STORAGE =        21.2248
CONSTANT HEAD =        0.0000      CONSTANT HEAD =        0.0000
WELLS =      238911.1250           WELLS =        38.5030
DRAINS =        0.0000             DRAINS =        0.0000
RIVER LEAKAGE =      30350.6875    RIVER LEAKAGE =        4.1571
RECHARGE =   934483200.0000        RECHARGE =     128011.3906

TOTAL IN =   947634944.0000        TOTAL IN =     128075.2734

OUT:                               OUT:
---                                ---
STORAGE =      10661528.0000       STORAGE =       104.2827
CONSTANT HEAD =   207751248.0000   CONSTANT HEAD =     28496.5527
WELLS =    16843222.0000           WELLS =      2675.9565
DRAINS =   236637392.0000          DRAINS =     31298.2402
RIVER LEAKAGE =   475741856.0000   RIVER LEAKAGE =     65500.3516
RECHARGE =        0.0000           RECHARGE =        0.0000

TOTAL OUT =   947635200.0000       TOTAL OUT =     128075.3828

IN - OUT =      -256.0000          IN - OUT =       -0.1094

PERCENT DISCREPANCY =        0.00  PERCENT DISCREPANCY =        0.00
TIME SUMMARY AT END OF TIME STEP 10 IN STRESS PERIOD  9
          SECONDS    MINUTES    HOURS     DAYS      YEARS
          ----------------------------------------------
TIME STEP LENGTH 1.25368E+07 2.08946E+05  3482.4     145.10    0.39727
STRESS PERIOD TIME 6.30720E+07 1.05120E+06  17520.     730.00     1.9986
TOTAL TIME 6.30720E+08 1.05120E+07 1.75200E+05  7300.0     19.986
1
```

Prediction Run Transport Model Output Crab213a

```
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
+                                                                      +
+                    MT3D'96                                           +
+        A Modular Three-Dimensional Transport Model                   +
+  For Simulation of Advection, Dispersion and Chemical Reactions      +
+          of Contaminants in Groundwater Systems                      +
+                                                                      +
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
```

```
-----
| M T | MT3D dataset
| 3 D | Translated by Visual MODFLOW
-----
THE TRANSPORT MODEL CONSISTS OF    5 LAYER(S)  104 ROW(S)   90 COLUMN(S)
NUMBER OF STRESS PERIOD(S) IN SIMULATION =   9
UNIT FOR TIME IS day ;  UNIT FOR LENGTH IS ft K;  UNIT FOR MASS IS g
MAJOR TRANSPORT COMPONENTS TO BE SIMULATED:
 1  ADVECTION
 2  DISPERSION
 3  SINK AND SOURCE MIXING
 4  CHEMICAL REACTIONS (DECAY AND/OR SORPTION)

                    EFFECTIVE POROSITY     = 0.2500000    FOR LAYER  1
                EFFECTIVE POROSITY     = 0.2500000    FOR LAYER  2
                EFFECTIVE POROSITY     = 0.2500000    FOR LAYER  3
                EFFECTIVE POROSITY     = 0.2500000    FOR LAYER  4
                EFFECTIVE POROSITY     = 0.2500000    FOR LAYER  5
==============================================
                    TIME STEP NO.  007
              ==============================================

FROM TIME =  6849.2    TO   6933.2
==============================================
```

TIME STEP NO. 010

==========

FROM TIME = 7154.9 TO 7300.0

"THKSAT " FLOW TERMS FOR TIME STEP 10, STRESS PERIOD 9 READ UNFORMATTED ON UNIT 10

"QXX " FLOW TERMS FOR TIME STEP 10, STRESS PERIOD 9 READ UNFORMATTED ON UNIT 10

"QYY " FLOW TERMS FOR TIME STEP 10, STRESS PERIOD 9 READ UNFORMATTED ON UNIT 10

"QZZ " FLOW TERMS FOR TIME STEP 10, STRESS PERIOD 9 READ UNFORMATTED ON UNIT 10

"STO " FLOW TERMS FOR TIME STEP 10, STRESS PERIOD 9 READ UNFORMATTED ON UNIT 10

MAXIMUM STEPSIZE DURING WHICH ANY PARTICLE CANNOT MOVE MORE THAN ONE CELL

= 10.62 (WHEN MIN. R.F.=1) AT K= 2, I= 36, J= 67

MAXIMUM STEPSIZE WHICH MEETS STABILITY CRITERION OF THE ADVECTION TERM

(FOR PURE FINITE-DIFFERENCE OPTION, MIXELM=0)

= 9.048 (WHEN MIN. R.F.=1) AT K= 2, I= 35, J= 67

"CNH " FLOW TERMS FOR TIME STEP 10, STRESS PERIOD 9 READ UNFORMATTED ON UNIT 10

"WEL " FLOW TERMS FOR TIME STEP 10, STRESS PERIOD 9 READ UNFORMATTED ON UNIT
10

"DRN " FLOW TERMS FOR TIME STEP 10, STRESS PERIOD 9 READ UNFORMATTED ON UNIT
10

"RCH " FLOW TERMS FOR TIME STEP 10, STRESS PERIOD 9 READ UNFORMATTED ON UNIT
10

"RIV " FLOW TERMS FOR TIME STEP 10, STRESS PERIOD 9 READ UNFORMATTED ON UNIT
10

TOTAL NUMBER OF POINT SOURCES/SINKS PRESENT IN THE FLOW MODEL = 1415

MAXIMUM STEPSIZE WHICH MEETS STABILITY CRITERION OF THE SINK & SOURCE TERM
= 93.42 (WHEN MIN. R.F.=1) AT K= 2, I= 18, J= 67

MAXIMUM STEPSIZE WHICH MEETS STABILITY CRITERION OF THE DISPERSION TERM
= 0.7365 (WHEN MIN. R.F.=1) AT K= 2, I= 35, J= 67

TRANSPORT STEP NO. 139

TOTAL ELAPSED TIME SINCE BEGINNING OF SIMULATION = 7300.000 day

.....

TOTAL PARTICLES USED IN THE CURRENT STEP = 65105
PARTICLES ADDED AT BEGINNING OF THE STEP = 64
PARTICLES REMOVED AT END OF LAST STEP = 113

CUMMULATIVE MASS BUDGETS AT END OF TRANSPORT STEP 139, TIME STEP 10, STRESS PERIOD 9

	IN	OUT
CONSTANT CONCENTRATION:	457.7350	-204.8549
CONSTANT HEAD:	0.0000000E+00	-32.49475
WELLS:	0.0000000E+00	-43.17962
DRAINS:	0.0000000E+00	-702.6573
RIVERS:	0.0000000E+00	-12.97746
RECHARGE:	0.0000000E+00	0.0000000E+00
DECAY OR BIODEGRADATION:	0.3478015E-06	-783.6318
MASS STORAGE (SOLUTE):	2860.169	-1918.440
MASS STORAGE (SORBED):	1134.509	-793.3218
[TOTAL]:	4452.413 g	-4491.558 g

NET (IN - OUT): -39.14502

DISCREPANCY (PERCENT): -0.8753387

TRANSPORT STEP NO. 140

TOTAL ELAPSED TIME SINCE BEGINNING OF SIMULATION = 7300.001 day

TOTAL PARTICLES USED IN THE CURRENT STEP = 65169

PARTICLES ADDED AT BEGINNING OF THE STEP = 64

PARTICLES REMOVED AT END OF LAST STEP = 0

CUMMULATIVE MASS BUDGETS AT END OF TRANSPORT STEP 140, TIME STEP 10, STRESS PERIOD 9

	IN	OUT
CONSTANT CONCENTRATION:	457.7350	-204.8549
CONSTANT HEAD:	0.0000000E+00	-32.49475
WELLS:	0.0000000E+00	-43.17962
DRAINS:	0.0000000E+00	-702.6573
RIVERS:	0.0000000E+00	-12.97746
RECHARGE:	0.0000000E+00	0.0000000E+00
DECAY OR BIODEGRADATION:	0.3478015E-06	-783.6319
MASS STORAGE (SOLUTE):	2860.173	-1918.444
MASS STORAGE (SORBED):	1134.511	-793.3235
[TOTAL]:	4452.419 g	-4491.564 g

NET (IN - OUT): -39.14453

DISCREPANCY (PERCENT): -0.8753266

| M T |

| 3 D | End of Model Output

Appendix H
Contractor/Vendor's Information – MITU 30

AN ENVIRO HAZ-TECH, INC COMPANY

MOBILE INJECTION TREATMENT UNIT (MITU)

TECHNICAL SPECIFICATIONS
&
CASE STUDIES

CONFIDENTIAL

PREPARED FOR

MR. JACK ANDERSON
RMT, INC.

PREPARED BY

CBA ENVIRONMENTAL SERVICES, INC.
RR#1 BOX 211E, PARK LANE
TRI-VALLEY INDUSTRIAL PARK
HEGINS, PA 17938
(717) 682-8742

APRIL 1996

CBA
ENVIRONMENTAL SERVICES INC.

H3

ENVIRONMENTAL SERVICES INC.

R.R.1 BOX 1T • EAST MOUNTAIN ROAD • HEGINS, PA 17938
(717) 682-8742 • FAX 717-682-8915

April 17, 1996

Mr. Jack Anderson
RMT, Inc.
744 Heartland Trail
Madison, WI 53717

Dear Mr. Anderson:

In response to your request for information regarding our new technology for soil treatment, called Mobile Injection Treatment Unit (MITU), we have enclosed the following information for your review. Please find enclosed three (3) case studies of projects using the MITU 12 and additional information describing the other MITU units that are available for use pending the site conditions and goals. Also included in this information packet is a list of other services made available to you. These services include engineering and design capabilities ~ field construction services, and also management and compliance services. We would like to meet with you in person to further explain our wide range of services.

The success of the MITU units has been attributed to their ability to aggressively treat contaminated soils where they lie. As a direct result of the effectiveness of these units, they have generated tremendous cost savings over conventional remediation technologies. The MITU units have the ability to treat contaminated sites in half the time and generally for half to a third the cost over other treatment technologies.

The MITU units were designed to effectively break up the density of soils , while simultaneously injecting virtually any type reagent. The MITU units are capable of injecting hot air, steam, biotreatment materials, slurry, absorbents, saw dust, hydrogen peroxide, and stabilization compounds just to name a few. To promote compliance with air quality standards, the units have all been equipped with on-board air collection and filter systems, which are constantly monitored with on-board or remote air monitoring devices. The units are totally self contained and depending on size, can usually be in operation 4-6 hours after mobilization to a site.

The MITU units were designed to meet the current and future environmental concerns as well as objectives for effective on-site treatment. Also, make available a technology for treatment of hard to get areas or sites with difficult soil conditions. We have designed a technology that is capable of growing with the future to address

many potential areas of concern that may have been previously dismissed due to actual feasibility.

We would like to extend an invitation to you and your associates for a site visit to one of our remediation sites in the future if you so desire. Thank you again for your interest in the MITU Technology. If I can be of any service to you or to set up a personal meeting, please contact our office.

Sincerely,

Bruce L. Bruso

Bruce L. Bruso
CBA Environmental Services, Inc.

COMPLETED PROJECT B

CS# A11 EHT

SUBJECT

Forced Hot Air Injection (FHAI) with Vapor Recovery - "SUPERFUND" Site - AeroSpace manufacturing facility, North-Eastern Pennsylvania

KEY WORDS

Mobile Injection Treatment Unit (MITU)
Trichloroethene (TCE)
Partitioning Coefficient
Organic Vapor Analyzer (OVA)
Total Leachable Volatile Organic Compounds (VOC's)

BACKGROUND

Slow leakage of TCE from a solvent distillation area resulted in a gradual release and infiltration of TCE and other VOC's into underlying soils. The contamination was last estimated to total 18,000 cubic yards to depths of twelve (12) feet. To date, approximately 10,000 cubic yards have been excavated and treated on-site through land farming to dry out soils initially. Following this process, soils are carried to a "Grizzly" rock crusher and processed to a screener which then separates 20 cubic yard quantities and deposits them into a dump truck. Soils are then transported to a staging area where "grab" samples are procured and analyzed on-site for "Total Leachable VOC's". If treated soils do not meet set criteria, they are returned for further treatment. Soil moisture resulting from early morning temperatures, inclimate weather, and cold temperatures halt processing of soils. The project has been underway for over two (2) years.

TREATMENT OBJECTIVE

To remediate contaminated soils to below 100 ug/Kg Total Leachable VOC's with an emphasis on TCE removal in a relatively short time frame. To eliminate moisture content in soils. To commence treatment directly on a large stockpile contaminated with TCE without having to land farm or separate rocks from the soil. To greatly reduce and/or eliminate any fugitive emissions from the MITU treatment process.

SITE PREPARATION

The stockpile that EHT, Inc. was contracted to perform the pilot test on consisted of approximately 200 cubic yards of soil contaminated with TCE. The soil was very moist and contained rocks of 8" and larger. Prior to soil treatment contaminant ranges were 125.6 ug/Kg to 12,951.4 ug/Kg respectively. Additionally, an IN-SITU area measuring approximately 100 feet by 50 feet was selected for treatment. The IN-SITU area to be treated was located directly over a solid rock glacial tier.

TREATMENT OPERATIONS

EHT, Inc. personnel commenced treatment of the stockpile with the MITU 10 unit injecting forced hot air at temperatures exceeding 700 degrees Fahrenheit. The MITU 10 unit was operated for 90 minutes only on this stockpile that day. The following day, the MITU 10 unit commenced treatment operations on the same stockpile. The MITU 10 unit was allowed to operate only 5 hours that day. Soil samples were collected at 120, 180, 240, and 300 minute intervals and analyzed by the on-site laboratory. At the end of 5 hours of operation, soil samples were procured from the pile. The levels had been reduced to 325.3 ug/Kg and 367.3 ug/Kg respectively. This was an extreme reduction in total leachable VOC's from the starting levels. Summary lab results are attached as Tables' 1-A, 2-A & 3-A.

CASE STUDY (page 2)

CS# A11 EHT (continued)

TREATMENT OPERATIONS (cont.)

EHT, Inc. personnel commenced to begin treatment on the IN-SITU area. The MITU unit penetrated 7.5 feet into the rock when a sample was procured. The results of this sample revealed soil contaminant levels exceeding 103,000 ug/Kg. Due to lack of proper personal protective equipment available for evaluating personnel, treatment in this area was halted.

SITE MONITORING

During the course of treatment operations of the MITU 10 unit, a consistent 20 - 25 mile per hour cross wind was present. On-site personnel performed air monitoring with a portable OVA directly adjacent to and around the perimeter of the MITU unit while it was operating. The down wind side measured less than .5 ppb of organic vapor. The remaining perimeter of the unit did not create any detectable emissions. Backround levels were above 5 ppb during routine operations at the site.

Soil samples were analyzed using a Gas Chromatograph, Mass Spectrometer (GC/MS). Analysis included the use of a partitioning coefficient to determine Total Leachable VOC's.

Field GC Concentration		**Partitioning Coefficient**		**Leachable Concentration**
Cs	+	**Kd**	=	**Cl**
(ug/Kg)		**(L/Kg)**		**(ug/Kg)**

In addition, the site was monitored by the United States Environmental Protection Agency Region III (US EPA) and the Pennsylvania Department of Environmental Resources (PADER) during operations with the MITU technology.

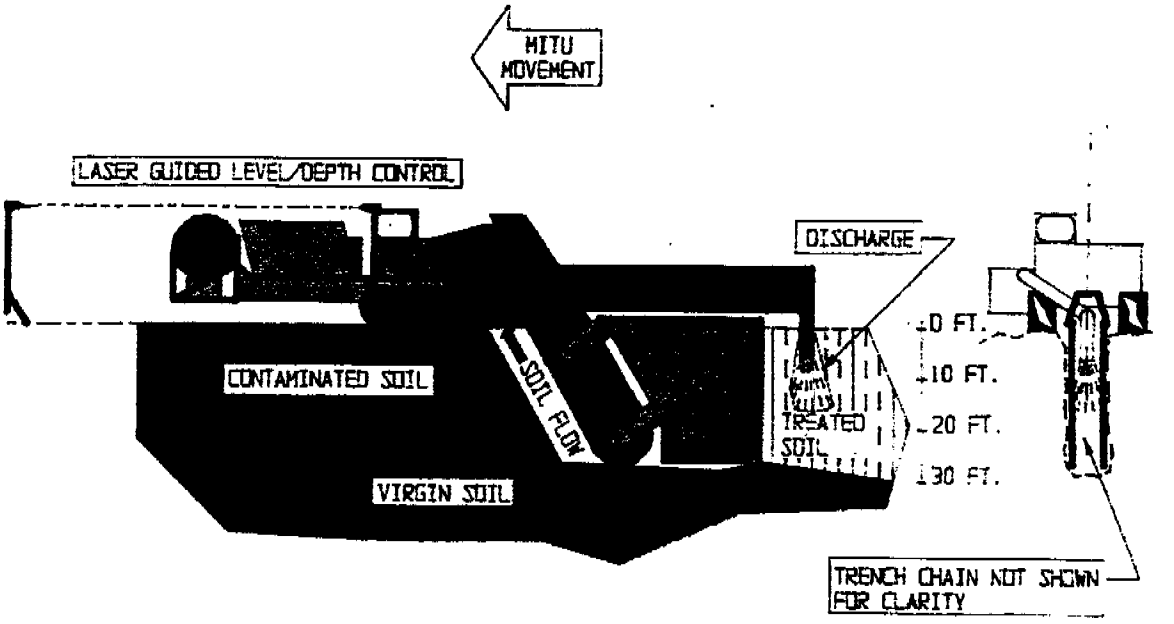
RESULTS

Enviro Haz-Tech, Inc mobilized the MITU 10 technology to demonstrate the agressive ability of the unit to significantly eliminate organic compounds in all soil types while collecting and eliminating any toxic fugitive emissions. The MITU technology was operated for a total of 6.5 hours at this "Superfund" site and reduced TCE contaminants from a high of 12,951.4 ug/Kg to 325.3 ug/Kg respectively.

The MITU technology demonstrated its ability to treat 200 cubic yards in 6.5 hours of operation. It is estimated that the MITU unit could decontaminate the remaining 8000 cubic yards in 8 - 9 weeks of operation generating a tremendous cost savings and site closure

For further information regarding other VOC's that were decontaminated from the soils at this site, contact our corporate office

PROJECT PROFILE: MITU 30: CBA ENVIRONMENTAL SERVICES, INC.
CASE STUDY A13 EHT: UTICA, MICHIGAN



In the winter of 1994, the MITU 30 was utilized to cut through an existing concrete slurry stoppage wall that had been installed some years prior. The stoppage wall was installed around a portion of the Landfill perimeter. A deficiency had developed with the current wall. The MITU 30 cut into the existing solid concrete to depths ranging from 16' to 30' and 32" wide. During the process debris such as engine blocks and guard rail material was encountered. The MITU 30 penetrated this debris and following completion of the cut, a bentonite slurry was installed to reinforce the stoppage wall. Previous to the mobilization of the MITU 30, the "MILLGARD" (Large Diameter Auger), technology was applied with <u>no success.</u>

During installation of the bentonite slurry, extraction wells were placed in intermitent locations throughout the cut to facilitate recovery of leachate water from landfill operations.

For further information or details regarding this project, contact CBA Environmental Services/EHT at (717) 682-8742.

ENVIRONMENTAL SERVICES INC.

R.R.1 BOX 1T • EAST MOUNTAIN ROAD • HEGINS, PA 17938
(717) 682-8742 • FAX 717-682-8915

MOBILE INJECTION TREATMENT UNIT

Specifically, the technologies are the design of the Mobile Injection Treatment Unit ("MITU"). MITU is a highly mobile unit designed for application of IN-SITU (In-Ground) and EX-SITU (Above-ground) contaminated soil and sludge treatment applications. Each unit can easily and logistically be mobilized to any location or climate. The unit's primary function is to conduct single or multiple subsurface or surface injection of chemical reagents, mixing operations and air contaminant emission recovery.

Prior Environmental Technologies have had limited performance due to dense soil and rock. The MITU units are capable of penetrating very dense soil as well as rock. As a result of this penetration, sufficient breakdown and mixing of these soil and rock types with various reagents including liquids, solids, and slurries is excellent thereby producing maximum IN-SITU and EX-SITU remediation results.

The unit is self-contained, with all controls operated from within the enclosed cab. The operator can run the trencher type soil cutting device at three speeds plus reverse to control mixture ratios, treatment time, and soil conditioning. All injection occurs at pre-determined adjustable locations inside the primary and secondary air emission collection hood. The trencher cutting devise is completely enclosed and equipped with primary and secondary air emission collection systems that transfer all vapors, dust, and emissions to the on-board treatment system. The cab of each unit is fitted with a removable low-pressure grade "D" breathing air system to protect the operator in hazardous airborne environments.

One example process that is enhanced by the MITU is Bioremediation. IN-SITU Bioremediation efforts traditionally have been successful only when applied to porous and semi-porous soils. Due to the combination of soil density breakdown, homogeneous mixing, proper aeration, and accurate microbial injection, Bioremediation is now not only possible but also enhanced thereby expediting the cleanup and reduction in contaminant levels. Another example of soil treatment enhancement is forced hot air injection with vapor recovery for volatile and semi-volatile organic contaminated soils. Typically, industrial sites contaminated with chlorinated solvents, aromatic/aliphatic hydrocarbons or residual petroleum compounds are selected for soil vapor extraction. This is a conventional treatment process that can take several years to remediate with no absolute cost expenditure guarantee. The MITU technology deploys a forced hot air injection system at temperatures ranging from 1,000 to 1,600 degrees Fahrenheit depending on unit size. A powerful vacuum recovery system for the volatiles is used in conjunction with the heat injection to create a tremendously aggressive soil cleanup. Treatment time frame is reduced by years! Refer to attached "projects completed" section for full details.

As the soil is treated, it is dispersed through the undercarriage or immediately backfilled emerging as a fine grained topsoil. Municipal and Hazardous sludges can be dried and chemically stabilized to greatly reduce or eliminate off-site disposal costs. Depending on site conditions and MITU size, the unit can treat up to fifty-five (55) metric tons per hour, saving up to 60 percent over conventional remediation costs. Depending on the MITU model, injection and mixing treatment operations can be applied beneath building and basement floors.

There are currently three (3) MITU unit sizes available. The technology is similar for all units.

MITU MINI - This unit is capable of soil treatment operations beneath basement floors for contaminated areas which may exist under buildings and present difficult treatment solutions. Depths of eight (8) to twelve (12) feet can be treated based on building size.

MITU 10 - This is the most popular MITU unit in that it is the only one that can perform subsurface (IN-SITU) treatment operations to a depth of twelve (12) feet as well as surface (EX-SITU) treatment operations on above-ground stockpiles as high as eight (8) feet without moving the pile. The unit can also treat contaminated areas within close proximity of building foundations.

MITU 30 - This unit is capable of deep sub-surface treatment operations IN-SITU to a maximum depth of thirty (30) feet, while simultaneously performing immediate backfill and compaction operations. This unit can also be operated to transfer treated soils immediately to a dump truck for placement to another area of the site.

Applications

The MITU units are capable of several different injection applications including all types of liquids, solids, slurries, gasses, and forced hot air. Examples include the following:

- Hazardous Waste Fixation
- Microbial - IN-SITU/EX-SITU Bioremediation
- Portland Cement/Fly Ash - Heavy Metal Stabilization
- Kiln Dust - Sludge Solidification
- Forced Hot Air - Volatile/Semi-Volatile Organic Extraction
- Cement Slurry - Slurry Wall Construction/Landfill Application
- Absorbents - Major Spill Stoppage
- Municipal & Hazardous Sludge treatment
- Horizontal Well installation - ground water recovery and treatment

Performance/Operation

Since there is a growing concern with air quality, the MITU units have all been equipped with air emission and dust collection hoods which are completely sealed and rest on the surface of the area where the injection/mixing operations are taking place. The air collection hood is powered by an on-board vacuum unit which transfers vapors, emissions, and dust to an appropriate filter system. Contained within this vacuum hood is an air monitoring probe which is directly connected to a direct reading instrument including but not limited to a portable GC, Oxygen/CGI indicator, or a PID.

Pre-Treatment Requirements

A complete site delineation to determine vertical and horizontal contaminate location, contaminate type, and soil type are required prior to mobilization of the MITU units.

Advantages

Soil or sludge does not have to be excavated thereby eliminating the cost of backfill, transportation, and disposal. Elimination of these elements commonly used in remediation, generates a significant cost savings to the client. In addition, future liabilities to the client are eliminated as well as limited disruption to the site. The MITU units can also be used to enhance a full circle soil washing or pump and treat system.

Limitations

The MITU units are not capable on IN-SITU treatment greater than 30 feet deep.

If you should have any questions or would like more information, please contact:

CBA Environmental Services, Inc.
Enviro Haz-Tech, Inc.
R.R. # 1 Box 1T
East Mountain Road
Hegins, PA 17938
(717) 682-8742

Appendix A - MITU Specifications

MITU - MINI

Drive Power:	50 - 75 HP Diesel
Height:	75 - 1/2 "
Width:	5 ft.
Weight:	5,232 lbs. Plus 1,500 lbs. with Trencher
Drive:	Tire or Tracks
Cutting Depth:	Up to 8' - 12' depending on building size
Treatment Rate:	500 CU. FT./HR.
Treatment:	Forced hot air/slurry/liquid spray/solid injection Air - 50 CFM Vacuum Filter Media

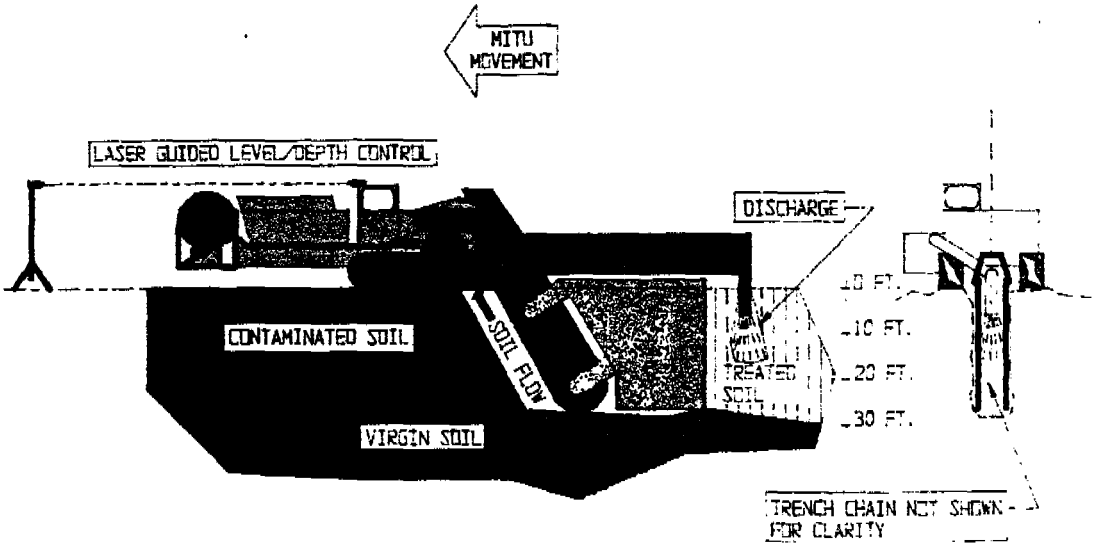
MITU - 12

Drive Power:	140 HP & 130 HP Diesel (dual)
Length:	Approximately 30' plus 9' 6" arm and 14' trencher
Width:	10' 5" with 32" tracks
Weight:	Approximately 52,500 lbs.
Drive:	32" Tracks
Cutting Depth:	Up to 12' sub-surface and up to 8' on above-ground piles
Treatment Rate:	1,500 CU. FT./HR.
Treatment:	Forced hot air/slurry/liquid spray/solid injection Air - 50 - 75 CFM with optional 400 CFM Vacuum Filter Media

MITU - 30

Drive Power:	750 HP Diesel
Length:	Approximately 54'
Width:	11' 6" plus 6' to 7' auxiliary equipment to one side
Weight:	Approximately 200,000 to 240,000 lbs.
Drive:	30" Tracks
Cutting Depth:	0 to 30'
Treatment Rate:	7,500 - 10,000 CU. FT./HR.
Treatment:	Forced hot air/slurry/liquid spray/solid injection Air - 400 CFM Vacuum Filter Media

MOBILE INJECTION TREATMENT UNIT 30 (MITU 30)



Comparative Technologies

It is important to note that the MITU system is capable of handling a variety of remediation media and waste applications, which is not found in other vendors applications. This is clearly shown when comparing the MITU system with two other reputable vendors, using the popular "Soil Vapor Extraction" process.

Soil Vapor Extraction

Most environmental companies continue to use the conventional methods of "treating" contaminated soil by either displacing it for extensive treatment or trucking it to landfills or incinerators. One process displaces the contamination for future considerations (landfills) and the other requires significant time and money.

According to information provided by the Office of Solid Waste and Emergency Response Technology Innovation Office, a division of the EPA, there are over 277 technologies listed with the EPA that addresses all forms of remediation. Of those 277 processes, only forty-two (42) processes dealt with IN SITU SOIL (17) and SOLID PHASE (25) processing. Most of these technologies were designed for a specific contaminant for a specific site and therefore have limited value and associated extensive limitations. Some of the more obvious limitations that are experienced with other remediation processing and not with the MITU process include:

- Concentration levels below certain levels usually less than 1,000 PPM.
- Incapable of handling viscous materials that have the same size and specific gravity as the soil particles.
- Capable of remediating only a limited number of contaminants.

In reviewing the information provided by the Office of Solid Waste and Emergency Response Technology Innovation Office, there are only two other Vendors that have a working process for Soil Vapor Extraction. They are Geo-Con, Inc. of Monroeville, PA and Terra Vac, Inc. of Newport Beach, CA. While these two firms use a vapor extraction process, the Terra Vac process uses labor intense "vapor extraction wells" that require considerable monitoring and excessive amount of time to process a site. The vapor extraction wells are connected via manifold of piping to a gas liquid separator, a blower capable of inducing a vacuum in the system of vapor extraction wells and their surrounding soils and finally to an air stream treatment device. The Geo-Con technology uses a large mixing auger which penetrates the soil while the Volatile Organic Compounds are then removed through wells and through a special movable shroud which covers the work area during mixing.

The following Table provides an overview of the three technologies and their capable further highlights the extensive advantages of the MITU process.

Table 1
Comparison of Remediation Technologies

	MITU	GEO CON	TERRA VAC
MEDIA			
SOIL (IN SITU)	X	X	X
SOIL (EX SITU)	X		
SLUDGE	X		
SOLID (SLAG)		X	
DENSE NONAQUEOUS PHASE LIQ[1]			
NATURAL SEDIMENT (IN SITU)	X	X	
NATURAL SEDIMENT (EX SITU)	X		
LIGHT NONAQUEOUS PHASE LIQ[2]			X
WASTE APPLICATIONS			
HALOGENATED VOLATILES	X	X	X
HALOGENATED SEMIVOLATILES	X	X	X
NONHALOGENATED VOLATILES	X	X	X
NONHALOGENATED SEMI "	X	X	X
ORGANIC PESTICIDES/HERBICIDES	X	X	X
DIOXINS/FURANS	X		X
PCBs	X		
POLYNUCLEAR AROMATIC (PNA's)	X		X
SOLVENTS	X	X	X
BENZENE	X		X
ORGANIC CYANIDE	X	X	X
ORGANIC ACIDS	X	X	
INORGANICS			
HEAVY METAL	X		
NONMETALLIC TOXIC ELEMENTS	X	X	
RADIOACTIVE METALS	X		

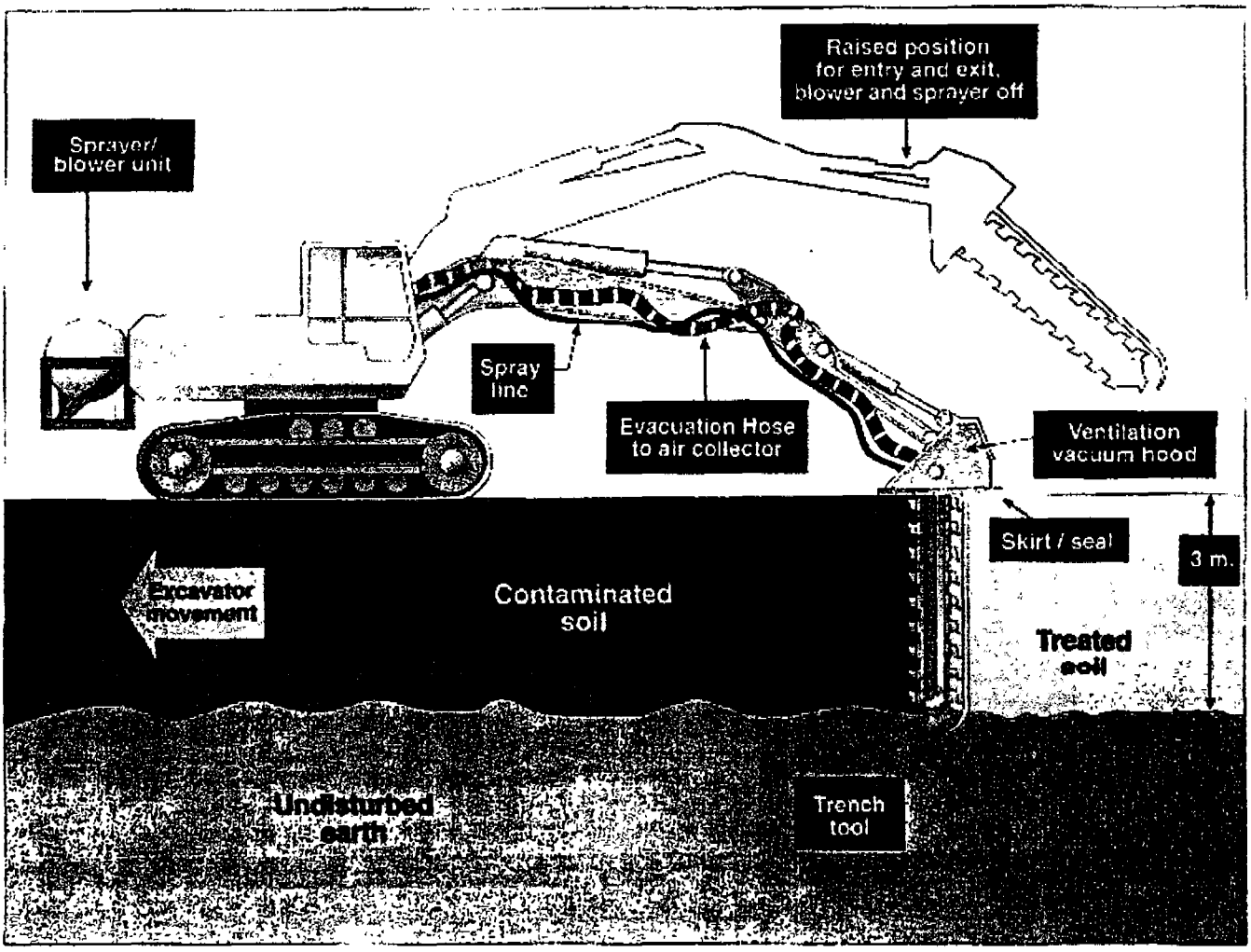
[1] While the MITU isn't designed for Ground Water treatment, it is capable of installing horizontal recovery well systems.

[2] Same as footnote 1

	MITU	GEO CON	TERRA VAC
ASBESTOS	X		
INORGANIC CYANIDES	X		
INORGANIC CORROSIVES	X		
MISCELLANEOUS			
EXPLOSIVES/PROPELLANTS	X		
ORGANOMETALLIC PESTICIDES	X		
VENDOR SERVICE			
EQUIPMENT MANUFACTURER	X		
SUB-CONTRACTOR/CLEANUP SVS.	X	X	X
PRIME CONTRACTOR-FULL SVS.	X		
FULL SCALE FACILITY IS			
TRANSPORTABLE	X		
FIXED			
IN-SITU		X	X
HOLDING TANK			

HERE'S HOW IT WORKS...

Enviro Haz-Tech Mobile Injection Treatment Units



● Enviro Haz-Tech Environmental Services, Hegins, Pa., has developed a series of Mobile Injection Treatment Units (MITUs) to conduct subsurface, in situ or surface, ex situ treatments. The unit can penetrate dense soils, as well as rock and mix in all types of treatment reagents—slurry, solid, liquid or hot air—to depths of 9 meters. The major component of the unit is a modified hydraulic excavator mounted to a custom fabricated trenching unit and fitted with a series of interchangeable injection systems with full vapor recovery systems. To ensure compliance with air quality standards, the unit has on-board, computerized air monitoring to record organic and inorganic vapors, as well as combustible and toxic vapor emissions.The units are equipped with rotary carbide cutting blades, which can penetrate even solid rock. The MITU Mini model is designed to inject and mix soils up to 2.5 meters beneath buildings, basement floors and other structures. The model 10 can treat to depths up to 3.6 meters and stockpiles as high as 4.5 meters. The model 30 can penetrate depths to 9 meters. The carbide teeth rotate at three speeds to chew into the soil formation in up to 46 centimeter widths. When the unit is at the desired depth, one of several types of injection units disburse the reagent into the soil as the unit is breaking it down. Soil is pulled into the sealed housing, which can deliver microbial and nutrient mixtures to enhance bioremediation, liquid or dry lime to stabilize the area, hot air for volatile stripping applications, cement slurry for slurry wall construction or absorbants to collect free product. As soil is treated, it is dispersed through the undercarriage of the unit, emerging as a fine grained, clean topsoil. Depending on site conditions, the unit can treat up to 55 metric tons per hour, saving up to 60 percent over conventional remediation option costs.■

Write in 575 for more information

A-17

Enviro Haz Tech of Pa.

Mobile Injection Treatment For Dense Contaminated Soil

By *Elena Marcheso Moreno*

Turning contaminated land into usable construction sites has great appeal in the competitive world of building development. Enviro Haz-Tech, an environmental remediation company in Hegins, Pa., has developed a series of Mobile Injection Treatment Units (MITUs) that can help remediate difficult soil conditions, both on unbuilt and built sites.

Enviro Haz-Tech specializes in treatment of all types of soils contaminated with petroleum or other hazardous materials. The patented MITU technology particularly appeals to building developers because it can handle dense subsurface contaminated soils under buildings. Cleaning the soil in place saves developers the costs of transportation and disposal associated with the alternative solution of dumping the contaminated soil into landfills, or incinerating it.

Huge Cost Savings

By actually treating the soil on-site, the MITU system can help a land owner save between 40 percent and 60 percent compared to removing it, Enviro Haz-Tech estimates. Once the treatment is completed, new soils are not required in order to develop and build on the site.

Enviro Haz-Tech's soil treatment unit is comprised of a John Deere modified hydraulic excavator mounted on a custom trenching unit equipped with a series of interchangeable injection systems and full vapor recovery. It includes proprietary manifolds, pumps, storage tanks, computers, monitors, and hydraulic controls. The operator can manipulate all controls from within the cab of the self-contained unit.

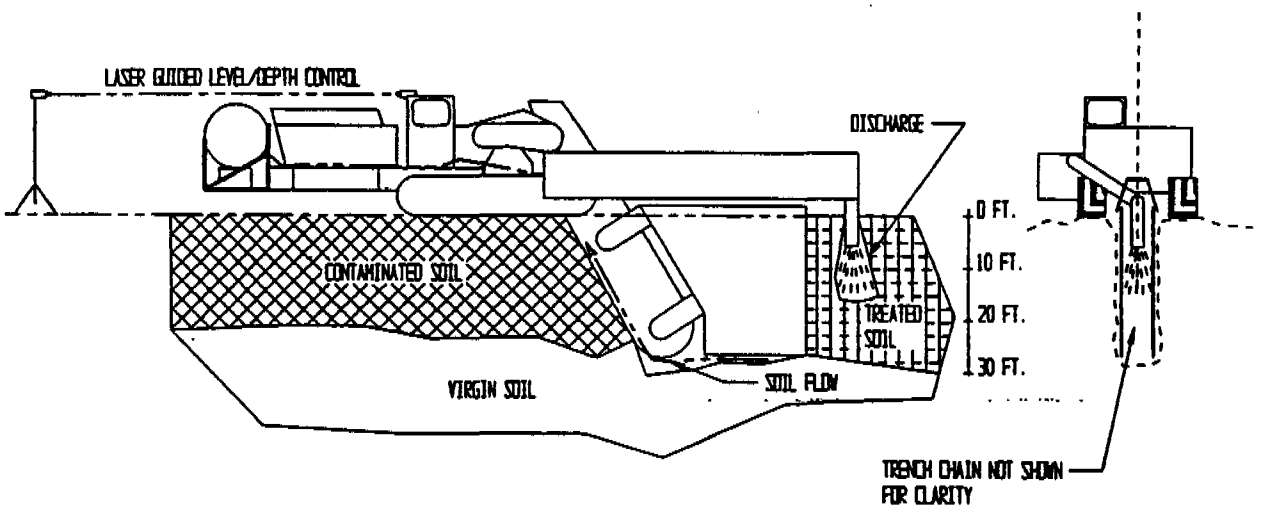
In addition, the trencher is completely enclosed and has air emission collection systems that transfer vapors to on-board treatment equipment. Compliance with air-quality standards is achieved through computerized monitoring of organic and inorganic vapors, and other toxic or combustible emissions.

Soil Injection

The MITU operator excavates contaminated land within a predetermined grid, trenching contaminated soil and injecting it with hot-air, biochemicals, slurries, and stabilization compounds, as required for remediation. All units use rotary carbide cutting blades that can penetrate all soils, even dense rock, to depths of 9 meters. A MITU Mini model was also developed to inject and mix soils to a maximum depth of 2.5 meters beneath building basements, concrete slabs, and other structures.

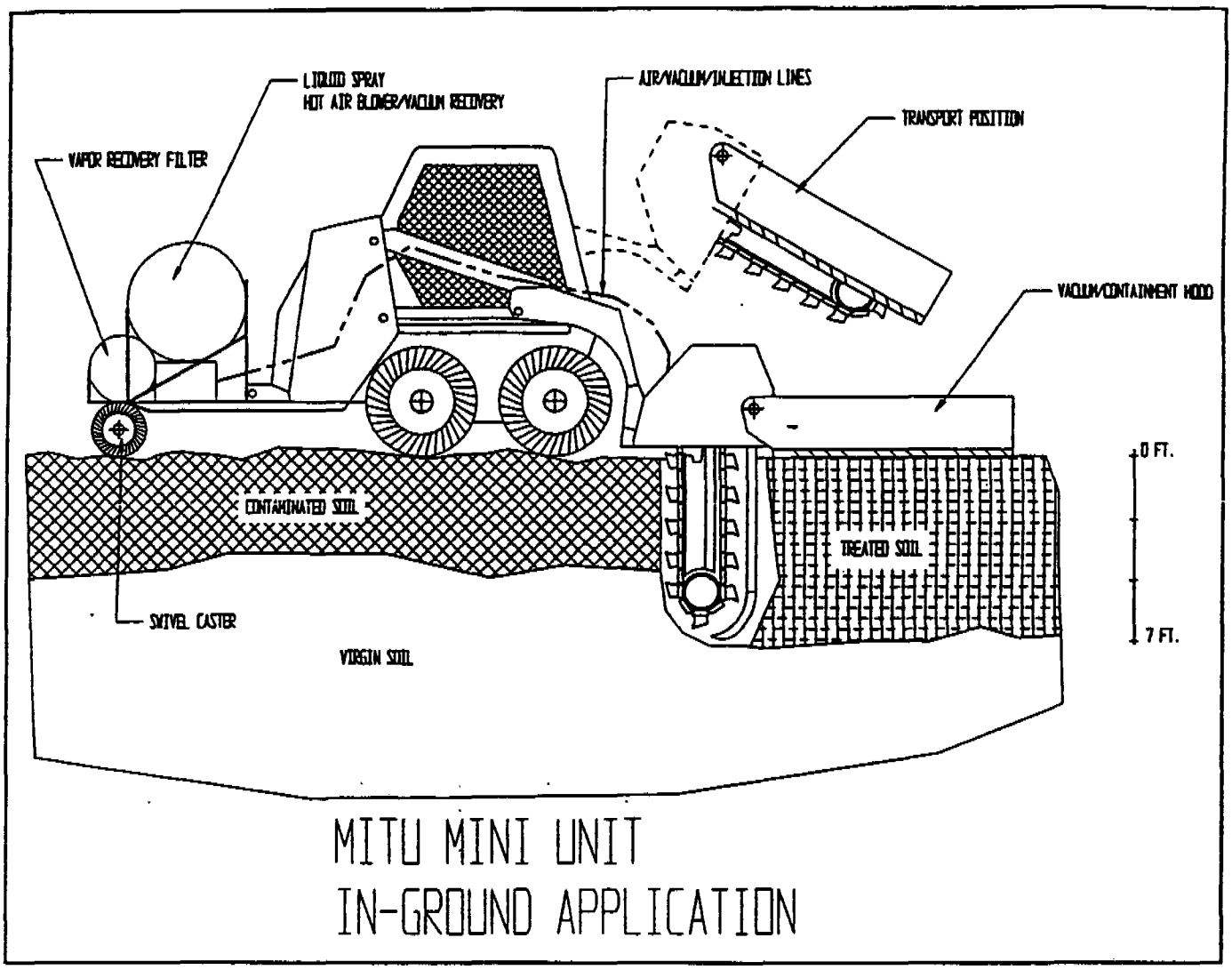
The unit's carbide teeth rotate at three speeds to break up soil formations in 46-centimeter

(Continued)



LARGE SCALE REMEDIATOR - MITU-30
SHOWN WITH AIR/LIQUID/SOLID INJECTION AND VACUUM RECOVERY

H-9



Enviro Haz-Tech *(Cont.)*

widths. Once it has reached the required depth, one of a variety of injection units distributes the Enviro mitigating agent into the soil. Soil passes through the sealed housing, where it is treated. Microbial and nutrient mixtures are delivered into the chamber to enhance bioremediation; hot air to encourage volatile stripping; cement slurry for slurry wall construction; and absorbants to collect free product. Once the soil is treated, it is pushed through the undercarriage of the MITU, reappearing as a clean, fine-grained topsoil. In all but the most difficult site conditions, the MITU can treat up to 55 metric tons per hour.

MITU Versatility

In the past, bioremediation strategies have succeeded only when employed on porous or semi-porous soils. The new MITU approach handles all types of soils, according to Enviro Haz-Tech. In addition to vapor recovery, oils contaminated with metals or pesticides can be cleaned with this multiple injection system, which has the ability to inject remediation agents in the necessary form-solid, liquid, gas, or slurry.

When the MITU completes its job, the land left can immediately be used for buildings that will be occupied by people. The company recently completed a clean-up project in Pottsville, Pa., on a site when petroleum had been distributed. Although the storage tanks were no longer present, the site was contaminated by past seepage of petroleum, kerosene, and bunker fuel. Enviro Haz-Tech cleaned upthe site, which is now being developed for a 100,000 mixed-use warehouse and shopping mall project.

For more information about the MITU system, or to inquire about domestic and international joint ventures. *Contact:* Bruce Bruso at EHT/CBA (717) 682-8742.

IN-SITU HOT AIR INJECTION USING MITU-12 TECHNOLOGY
PENNSYVANIA DEPARTMENT OF ENVIRONMENTAL PROTECTION
STATE HSCA (HAZARDOUS SITE CLEANUP AGENCY) PROJECT
ZIEGLERVILLE, MONTGOMERY COUNTY, PENNSYLVANIA
JANUARY 1997

COMPOUND	PRE-TREATMENT CONC. (ppb)	POST TREATMENT CONC. (ppb)	PADEP CLEANUP STANDARD
TCE	24,900	<5 to 500	2,000 ppb
BENZENE	5,619	nd	100 ppb
XYLENE	113,100	2000	5,000 ppb
1,1 DCE	1,023	<5	1,000 ppb
TOLUENE	270,000	nd to 53	100,000 ppb
1,1,2 TCEA	3,990	<5	800 ppb

* Total treatment time was 50 hours
* Total soil volume 200 cubic yards
* Soil moisture content 90% - 100% constant
* Initial investigation revealed TCE levels as high as 270,000 ppb
* Soil type was dense clay and silts with groundwater at 9 feet
* Treatment depth - 9 feet

Appendix I
Opinion of Probable Cost for Remedial Alternatives – Cost Breakdown Tables

OPINION OF PROBABLE COST
CRAB ORCHARD NWR - PCBOU - Sites 32/33
MARION, ILLINOIS
PROJECT NO. 4781.03

REMEDIAL ALTERNATIVE "A"

NO ACTION / COMPLIANCE MONITORING ONLY

	UNIT	UNIT $	QUANT.	TOTAL	COMMODITY COSTS	CONSULTANT COSTS
DIRECT CAPITAL COSTS:						
No capital costs	ls	$0	0	$0	$0	$0
SUBTOTAL DIRECT CAPITAL COSTS				**$0**		
INDIRECT CAPITAL COSTS:						
Proj. Mg'mt/Scheduling	hr	$125	24	$3,000	$0	$3,000
Administration	ls	$2,000	1	$2,000		$2,000
SUBTOTAL INDIRECT CAPITAL COSTS				**$5,000**		
SUBTOTAL DIRECT & INDIRECT CAPITAL COSTS				**$5,000**		
CONTINGENCY ON TOTAL CAPITAL COSTS (15				$750		
TOTAL CAPITAL & STARTUP O&M COSTS				**$5,750**	**$0**	**$5,000**
ANNUAL COMPLIANCE MONITORING COSTS:						
Proj. Mg'mt	hr	$125	24	$3,000	$0	$3,000
Semi-Annual Compliance Sampling (14 MWs, 5 SW, 1 leach, 1 WW, 9 QA/QC)						
Labor - prep & sample coll. (160 hr @ $65/	visit	$10,400	2	$20,800	$0	$20,800
Monitoring Equipment	visit	$1,000	2	$2,000	$0	$2,000
Lab Analysis						
(VOCs, SVOCs, PCB/Pest,Metals; CLP)	ea	$915	60	$54,900	$54,900	$0
Purge water disposal	gal	$0.50	700	$350	$350	$0
Data evaluation	ls	$4,000	2	$8,000	$0	$8,000
Reporting	ls	$8,000	2	$16,000	$0	$16,000
Miscellaneous expenses	ls	$1,000	2	$2,000	$0	$2,000
SUBTOTAL ANNUAL OM&M COSTS				**$107,050**	**$55,250**	**$51,800**

PRESENT WORTH OF ANNUAL COSTS	**30**	**years @**	**7 %**	**$1,329,000**

TOTAL COSTS (TOTAL CAPITAL PLUS PRESENT WORTH)	**$1,335,000**

-30% TOTAL COST=	**$935,000**
+50% TOTAL COST=	**$2,003,000**

ASSUMPTIONS AND CLARIFICATIONS

1. Cost totals rounded to the nearest thousand dollars.
2. Costs determined from vendor quotes, Means construction cost data, and estimates from other similar projects.
3. Contingency is assumed to be 15% of total capital cost.
4. Discount rate of 7.0% used for present worth estimate, per OSWER Directive No. 9355.3-20 (1993).
5. All costs are based on preliminary concepts. They are intended for comparison among options, and not for final budgeting.

OPINION OF PROBABLE COST
CRAB ORCHARD NWR - PCBOU - Sites 32/33
MARION, ILLINOIS
PROJECT NO. 4781.03

REMEDIAL ALTERNATIVE "B"

MONITORED NATURAL ATTENUATION (MNA)

	UNIT	UNIT $	QUANT.	TOTAL	COMMODITY COSTS	CONSULTANT COSTS
DIRECT CAPITAL COSTS:						
No capital costs	ls	$0	0	$0	$0	$0
SUBTOTAL DIRECT CAPITAL COSTS				**$0**		
INDIRECT CAPITAL COSTS:						
Proj. mg'mt/Scheduling	hr	$125	50	$6,250	$0	$6,250
Workplan prep./approvals	ls	$15,000	1	$15,000		$15,000
Administration	ls	$2,500	1	$2,500		$2,500
SUBTOTAL INDIRECT CAPITAL COSTS				**$23,750**		
SUBTOTAL DIRECT & INDIRECT CAPITAL COSTS				**$23,750**		
CONTINGENY ON TOTAL CAPITAL COSTS (15				$3,563		
TOTAL CAPITAL COSTS				**$27,313**	**$0**	**$23,750**
ANNUAL MNA MONITORING COSTS (YEARS 1&2):						
Proj. Mg'mt	hr	$125	48	$6,000	$0	$6,000
Natural Attenuation monitoring						
Semi-Annual MNA GW Sampling (20 wells + 4 QC)						
Labor - sample collection (add'l 40 mh @	visit	$2,600	2	$5,200	$0	$5,200
Monitoring Equipment	visit	$1,000	2	$2,000	$0	$2,000
Lab Analysis						
GW MNA (VOCs, CLP)	ea	$150	48	$7,200	$7,200	$0
GW (MNA parameters)	ea	$295	48	$14,160	$14,160	$0
Purge water disposal	gal	$0.50	1000	$500	$500	$0
Data evaluation	ls	$4,000	2	$8,000	$0	$8,000
Reporting	ls	$8,000	2	$16,000	$0	$16,000
Miscellaneous expenses	ls	$1,000	2	$2,000	$0	$2,000
SUBTOTAL ANNUAL MNA MONITORING (YEARS 1&2)				$61,060	$21,860	$39,200
SEMI-ANNUAL COMPLIANCE MONITORING						
Sampling, analysis, limited data eval/repor	year	$82,000	1	$82,000	$0	$82,000
SUBTOTAL COMPLIANCE MONITORING ANNUAL COST (YEARS 1&2)				$82,000		$82,000
SUBTOTAL ANNUAL MONITORING COSTS (YEARS 0-2)				**$143,060**	**$21,860**	**$121,200**
ANNUAL MNA MONITORING COSTS - (YEARS 3 to 30):						
Proj. mg'mt	hr	$125	24	$3,000	$0	$3,000
Natural Attenuation monitoring						
Semi-Annual MNA GW Sampling (20 wells + 4 QC)						

Labor - sample collection (add'l 40 hr @ $	visit	$2,600	1	$2,600	$0	$2,600
Monitoring Equipment	visit	$1,000	1	$1,000	$0	$1,000
Lab Analysis						
GW MNA (VOCs, CLP)	ea	$150	24	$3,600	$3,600	$0
GW (MNA parameters)	ea	$295	24	$7,080	$7,080	$0
Purge water disposal	gal	$0.50	500	$250	$250	$0
Data evaluation	ls	$4,000	2	$8,000	$0	$8,000
Reporting	ls	$8,000	2	$16,000	$0	$16,000
Miscellaneous expenses	ls	$500	1	$500	$0	$500
SUBTOTAL ANNUAL MNA MONITORING (YRS. 3-30)				$42,030	$10,930	$31,100
SEMI-ANNUAL COMPLIANCE MONITORING						
Sampling, analysis, limited data eval/repo	year	$82,000	1	$82,000	$0	$82,000
SUBTOTAL COMPL. MONIT. ANNUAL COST (YRS. 3-30)				$82,000	$0	$82,000
SUBTOTAL ANNUAL MONITORING COSTS (YEARS 3-30)				**$124,030**	**$10,930**	**$113,100**

PRESENT WORTH OF ANNUAL COSTS	**30**	**years @**	**7 %**	**$1,574,000**

TOTAL COSTS (TOTAL CAPITAL PLUS PRESENT WORTH)	**$1,602,000**

-30% TOTAL COST=	**$1,122,000**
+50% TOTAL COST=	**$2,403,000**

ASSUMPTIONS AND CLARIFICATIONS

1. Cost totals rounded to the nearest thousand dollars.
2. Costs determined from vendor quotes, Means construction cost data, and estimates from other similar projects.
3. Contingency is assumed to be 15% of total capital cost.
4. Discount rate of 7.0% used for present worth estimate, per OSWER Directive No. 9355.3-20 (1993).
5. All costs are based on preliminary concepts. They are intended for comparison among options, and not for final budgeting.

OPINION OF PROBABLE COST
CRAB ORCHARD NWR - PCBOU - Sites 32/33
MARION, ILLINOIS
PROJECT NO. 4781.03

REMEDIAL ALTERNATIVE "C"

PHYTOREMEDIATION WITH MNA

	UNIT	UNIT $	QUANT.	TOTAL	COMMODITY COSTS	CONSULTANT COSTS
DIRECT CAPITAL COSTS:						
Phytoremediation						
Pre-design site visit	ls	$5,000	1	$5,000	$5,000	$0
Vendor design fee	ls	$50,000	1	$50,000	$50,000	$0
Site Preparation	ls	$5,000	1	$5,000	$5,000	$0
Drill waste disposal	cy	$216	1100	$237,600	$237,600	$0
Hybrid poplar trees; procure & install	acre	$15,000	25.58	$383,700	$383,700	$0
Contingency (15%)				$102,195	$102,195	$0
SUBTOTAL DIRECT CAPITAL COSTS				**$783,495**		
INDIRECT CAPITAL COSTS:						
Proj. mg'mt/Scheduling	hr	$125	100	$12,500	$0	$12,500
Design	ls	$15,000	1	$15,000	$0	$15,000
Construction Management	ls	$25,000	1	$25,000	$0	$25,000
Permitting	ls	$5,000	1	$5,000	$0	$5,000
On-site observe/documentation	day	$1,000	21	$21,000	$0	$21,000
Documentation Report	ls	$10,000	1	$10,000	$0	$10,000
Administration	ls	$3,000	1	$3,000		$3,000
Contingency (15%)				$13,725		
SUBTOTAL INDIRECT CAPITAL COSTS				**$105,225**		
TOTAL CAPITAL COSTS				**$888,720**	**$783,495**	**$91,500**
ANNUAL OM&M COSTS (YEARS 1 & 2):						
Tree maintenance (fertilize, water, pruning)	acre	$1,700	26	$44,200	$0	$44,200
Proj. mg'mt	hr	$125	40	$5,000	$0	$5,000
Annual site visit	ls	$1,000	1	$1,000	$0	$1,000
Data evaluation	ls	$2,500	1	$2,500	$0	$2,500
Reporting	ls	$5,000	1	$5,000	$0	$5,000
Miscellaneous	ls	$1,000	1	$1,000	$0	$1,000
Compliance Monitoring - S/A	year	$82,000	1	$82,000	$0	$82,000
MNA Sampling - S/A	year	$60,000	1	$60,000	$0	$60,000
SUBTOTAL ANNUAL OM&M COSTS (YRS. 1&2)				**$200,700**	**$0**	**$200,700**
ANNUAL O&M COSTS (YEARS 3 thru 30):						
Tree Maintenance (fertilize, water, pruning)	acre	$1,700	26	$44,200	$0	$44,200
Proj. mg'mt	hr	$124	40	$4,960	$0	$4,960
Annual site visit	ls	$1,000	1	$1,000	$0	$1,000
Data Evaluation	ls	$2,500	1	$2,500	$0	$2,500

Reporting	ls	$5,000	1	$5,000	$0	$5,000
Miscellaneous	ls	$1,000	2	$2,000	$0	$2,000
Compliance Monitoring - S/A	year	$82,000	1	$82,000	$0	$82,000
MNA Sampling (annually)	year	$42,000	1	$42,000	$0	$42,000
SUBTOTAL ANNUAL OM&M COSTS (YRS. 3-30)				**$183,660**	**$0**	**$183,660**

PRESENT WORTH OF ANNUAL COSTS	**30**	**years @**	**7 %**	**$2,310,000**

TOTAL COSTS (TOTAL CAPITAL PLUS PRESENT WORTH)	**$3,198,720**

-30% TOTAL COST=	**$2,240,000**
+50% TOTAL COST=	**$4,799,000**

ASSUMPTIONS AND CLARIFICATIONS

1. Cost totals rounded to the nearest thousand dollars.
2. Costs determined from vendor quotes, Means construction cost data, and estimates from other similar projects.
3. Contingency is assumed to be 15% of total capital cost.
4. Discount rate of 7.0% used for present worth estimate, per OSWER Directive No. 9355.3-20 (1993).
5. All costs are based on preliminary concepts. They are intended for comparison among options, and not for final budgeting.
6. Assumes planting density of 1500 poplar trees per acre, using a trencher to plant trees.
7. Assumes 20% of native contaminated material can't be backfilled, so must be disposed offsite as characteristically hazardous waste.

OPINION OF PROBABLE COST
CRAB ORCHARD NWR - PCBOU - Sites 32/33
MARION, ILLINOIS
PROJECT NO. 4781.03

REMEDIAL ALTERNATIVE "D"

IN SITU ENHANCED BIOREMEDIATION WITH MNA AND LIMITED PHYTOREMEDIATION

	UNIT	UNIT $	QUANT.	TOTAL	COMMODITY COSTS	CONSULTANT COSTS
DIRECT CAPITAL COSTS:						
Mobilization	ls	$5,000	1	$5,000	$5,000	$0
Drill injection wells - 4" dia. PVC	ft	$50	600	$30,000	$30,000	$0
Wellhead completion	ea	$300	15	$4,500	$4,500	$0
Construction/site work	--	--	--			
Excavate infiltration pits - 3 each	cy	$5	13500	$67,500	$67,500	$0
Backfill infiltration pits - washed gravel	cy	$15	10200	$153,000	$153,000	$0
Topsoil/grade infiltration galleries	cy	$6	4000	$24,000	$24,000	$0
Trenching & piping	lf	$25	1500	$37,500	$37,500	$0
Polyethylene cover (3 galleries)	sf	$0.50	100000	$50,000	$50,000	$0
Tankage (2 poly tanks/site, 2500 gal)	ls	$5,000	4	$20,000	$20,000	$0
Transfer pump & metering pump	ls	$4,000	4	$16,000	$16,000	$0
Misc. equipment	ls	$2,500	4	$10,000	$10,000	$0
Equipment shelters	ls	$1,500	4	$6,000	$6,000	$0
Electrical install. work - 4 sites	ls	$3,000	4	$12,000	$12,000	$0
Electrical service (Repos. & So. Repos. onl	ls	$5,000	2	$10,000	$10,000	$0
Plumbing - water line & equip. connections	ls	$5,000	4	$20,000	$20,000	$0
Sump & level controls installation	ls	$5,000	3	$15,000	$15,000	$0
Control panels	ls	$5,000	4	$20,000	$20,000	$0
Site restoration	ls	$15,000	1	$15,000	$15,000	$0
Limited Phytoremediation						
Vendor design fees	ls	$50,000	1	$50,000	$50,000	$0
Pre-design/site prep	ls	$10,000	1	$10,000	$10,000	$0
Hybrid poplar trees; procure & install	acre	$15,000	14	$210,000	$210,000	$0
Contingency (25%)				$196,375	$196,375	$0
SUBTOTAL DIRECT CAPITAL COSTS				**$981,875**		
INDIRECT CAPITAL COSTS:						
Proj. mg'mt/Scheduling	hr	$125	120	$15,000	$0	$15,000
Pre-design - pilot test	ls	$15,000	1	$15,000	$0	$15,000
Design	ls	$40,000	1	$40,000	$0	$40,000
Construction Management	ls	$75,000	1	$75,000	$0	$75,000
Permitting	ls	$5,000	1	$5,000	$0	$5,000
On-site observe/documentation	day	$1,000	14	$14,000	$0	$14,000
Documentation Report	ls	$10,000	1	$10,000	$0	$10,000
Administration	ls	$3,000	1	$3,000		$3,000

Contingency (15%)				$26,550		
SUBTOTAL INDIRECT CAPITAL COSTS				**$203,550**		
SUBTOTAL DIRECT & INDIRECT CAPITAL COSTS				**$1,185,425**		
STARTUP OM&M COSTS: (5 days to do initial charges and injections)						
Labor	days	$800	5	$4,000	$0	$4,000
Monitoring equipment	days	$200	5	$1,000	$0	$1,000
Chemicals						
Lactate	lb	$5	1295	$6,475	$6,475	$0
Sodium sulfite	lb	$0.50	776	$388	$388	$0
Data evaluation	ls	$1,000	1	$1,000	$0	$500
Proj. mg'mt	hr	$125	24	$3,000	$0	$3,000
Reporting	ls	$2,500	1	$2,500	$0	$2,500
Miscellaneous	ls	$1,000	1	$1,000	$0	$1,000
SUBTOTAL STARTUP OM&M COSTS				**$19,363**		
TOTAL CAPITAL & STARTUP OM&M COSTS				**$1,204,788**	**$988,738**	**$189,000**
ANNUAL OM&M COSTS YEARS 1 & 2:						
Proj. mg'mt	hr	$125	60	$7,500	$0	$7,500
OM&M labor (monthly)	visit	$1,200	12	$14,400	$0	$14,400
Monitoring equipment	visit	$150	12	$1,800	$0	$1,800
Data evaluation	qtr	$800	4	$3,200	$0	$3,200
Reporting	hr	$80	50	$4,000	$0	$4,000
Miscellaneous	ls	$1,000	1	$1,000	$0	$1,000
Chemicals						
Lactate	lb	$5	6560	$32,800	$32,800	$0
Sodium sulfite	lb	$0.50	3910	$1,955	$1,955	$0
Utilities	mo	$100	12	$1,200	$1,200	$0
Compliance Monitoring - S/A	year	$82,000	1	$82,000	$0	$82,000
MNA Sampling - S/A	year	$60,000	1	$60,000	$0	$60,000
Ltd Phytoremediation maintenance	acre	$2,500	15	$37,500	$37,500	$0
SUBTOTAL ANNUAL OM&M COSTS (YRS. 1&2)				**$247,355**	**$73,455**	**$173,900**
ANNUAL OM&M COSTS (YEARS 3 - 30).						
Proj. mg'mt	hr	$125	24	$3,000	$0	$3,000
Compliance monitoring - S/A	year	$82,000	1	$82,000	$0	$82,000
MNA Sampling (annually)	year	$42,000	1	$42,000	$0	$42,000
Ltd Phytoremediation maintenance	acre	$2,500	15	$37,500	$37,500	$0
SUBTOTAL ANNUAL OM&M COSTS (YRS. 3-30)				**$164,500**	**$37,500**	**$127,000**
PRESENT WORTH OF ANNUAL COSTS	**30**	**years @**	**7 %**	**$2,192,000**		
TOTAL COSTS (TOTAL CAPITAL PLUS PRESENT WORTH)				**$3,397,000**		

-30% TOTAL COST=	**$2,378,000**
+50% TOTAL COST=	**$5,096,000**

ASSUMPTIONS AND CLARIFICATIONS

1. Cost totals rounded to the nearest thousand dollars.
2. Costs determined from vendor quotes, Means construction cost data, and estimates from other similar projects.
3. Contingency is assumed to be 25% of total capital cost due to uncertainties regarding injection frequency and total injectate volume.
4. Discount rate of 7.0% used for present worth estimate, per OSWER Directive No. 9355.3-20 (1993).
5. All costs are based on preliminary concepts. They are intended for comparison among options, and not for final budgeting.
6. Assumes injection/infiltration of lactate solution on a quarterly basis. The gallery is recharged daily with de-oxygenated water.
7. Assumes dosage rate for lactate=200 mg/L
8. Assume 3 injection wells @8460 gal/(well*injection) at I-1-2.
9. Assume 3 injection wells @50,758 gal/(well*injection) at I-1-23.
10. Assume 6 wells at Repository operating at 8460 gal/(well*injection)
11. Assume 3 wells south of Repository operating at 25,379 gal/(well*injection)

OPINION OF PROBABLE COST
CRAB ORCHARD NWR - PCBOU - Sites 32/33
MARION, ILLINOIS
PROJECT NO. 4781.03

REMEDIAL ALTERNATIVE "E"

MULTIPLE-PHASE EXTRACTION WITH MNA AND LIMITED PHYTOREMEDIATION

	UNIT	UNIT $	QUANT.	TOTAL	COMMODITY COSTS	CONSULTANT COSTS
DIRECT CAPITAL COSTS:						
Mobilization	ls	$10,000	1	$10,000	$10,000	$0
Site preparation	ls	$6,000	1	$6,000	$6,000	$0
Clearing and grubbing	acre	$4,000	0.25	$1,000	$1,000	$0
MPE skid	ea	$25,000	4	$100,000	$100,000	$0
Airstripper skid	ea	$20,000	2	$40,000	$40,000	$0
Transfer pump and equalization tank	ea	$5,000	3	$15,000	$15,000	$0
Control panel	ea	$15,000	3	$45,000	$45,000	$0
Air-phase carbon - treatment systems	ea	$10,000	2	$20,000	$20,000	$0
Air-phase carbon - transfer station	ea	$5,000	1	$5,000	$5,000	$0
Liquid-phase carbon - treatment systems	ea	$15,000	2	$30,000	$30,000	$0
Extraction well - vertical	vf	$60	3185	$191,100	$191,100	$0
Extraction well - horizontal	lf	$150	1080	$162,000	$162,000	$0
Extraction line piping - individual, 1" dia.	lf	$3	2500	$7,500	$7,500	$0
Extraction line piping -manifolded, 2" dia.	lf	$4	1600	$6,400	$6,400	$0
Discharge line piping	lf	$6	2230	$13,603	$13,603	$0
Utility trenching	lf	$35	4750	$166,250	$166,250	$0
Potable/seal water line	lf	$13	1600	$21,360	$21,360	$0
Wellheads	ea	$300	109	$32,700	$32,700	$0
Mechanical connections	hr	$50	400	$20,000	$20,000	$0
Electrical connections	hr	$60	300	$18,000	$18,000	$0
Treatment building	lf wall	$445	200	$89,000	$89,000	$0
Transfer station	lf wall	$445	80	$35,600	$35,600	$0
Drill waste disposal	cy	$216	100	$21,600	$21,600	$0
Site restoration	ls	$15,000	1	$15,000	$15,000	$0
Limited Phytoremediation						
Vendor design fees	ls	$50,000	1	$50,000	$50,000	$0
Pre-design/site prep	ls	$10,000	1	$10,000	$10,000	$0
Hybrid poplar trees; procure & install	acre	$15,000	14	$210,000	$210,000	$0
Contingency (15%)				$201,317	$201,317	$0
SUBTOTAL DIRECT CAPITAL COSTS				**$1,543,430**		
INDIRECT CAPITAL COSTS:						
Project management (10% of indirect capital c	ls	$271,949	1	$27,195	$0	$27,195
Pre-design - Pilot Test	ls	$15,000	1	$15,000	$0	$15,000

Design (5% of direct capital costs)	ls	$1,543,430	1	$77,171	$0	$77,171
Bidding (1% of direct capital costs)	ls	$1,543,430	1	$15,434	$0	$15,434
Contracting (1% of direct capital costs)	ls	$1,543,430	1	$15,434	$0	$15,434
Permitting (2% of direct capital costs)	ls	$1,543,430	1	$30,869	$0	$30,869
Construction Observation/Documentation (7% of direct capital costs)	ls	$1,543,430	1	$108,040	$0	$108,040
Documentation Report	ls	$10,000	1	$10,000	$0	$10,000
SUBTOTAL INDIRECT CAPITAL COSTS				**$299,144**		
Contingency (15%)				$276,386		
SUBTOTAL DIRECT & INDIRECT CAPITAL COSTS				**$2,118,960**		
STARTUP OM&M COSTS: (6 visits in 60 days following implementation)						
Labor	visit	$1,200	6	$7,200	$0	$7,200
Monitoring equipment	visit	$300	6	$1,800	$0	$1,800
Water sample analysis	round	$825	12	$9,900	$9,900	$0
Off-gas analysis	round	$250	18	$4,500	$4,500	$0
Data evaluation	ls	$1,500	1	$1,500	$0	$500
Project management (10% of s/u costs)	ls	$13,700	1	$1,370	$0	$1,370
Documentation report	ls	$5,000	1	$5,000	$0	$5,000
SUBTOTAL STARTUP OM&M COSTS				**$31,270**		
TOTAL CAPITAL & STARTUP OM&M COSTS				**$2,150,230**	**$1,557,830**	**$315,014**
ANNUAL OM&M COSTS (YRS. 1&2)						
Operation and maintenance labor	visit	$1,000	12	$12,000	$0	$12,000
Monitoring equipment	visit	$150	12	$1,800	$0	$1,800
Water sample analysis	round	$825	24	$19,800	$19,800	$0
Off-gas analysis	round	$250	36	$9,000	$9,000	$0
Data evaluation	mo	$600	12	$7,200	$0	$7,200
Reporting	qtr	$5,000	1	$5,000	$0	$5,000
Project Management	hr	$125	50	$6,250	$0	$6,250
Equipment replacement	mo	$500	12	$6,000	$6,000	$0
Carbon usage/replacement - air	mo	$1,000	12	$12,000	$12,000	$0
Carbon usage/replacement - liquid	yr	$2,000	1	$2,000	$2,000	$0
Groundwater monitoring	--	--	--	--	--	--
labor for collection	visit			$0	$0	$0
laboratory analysis	ea			$0	$0	$0
Compliance Monitoring - S/A	year	$82,000	1	$82,000	$0	$82,000
MNA Sampling -S/A	year	$60,000	1	$60,000	$0	$60,000
Ltd. Phytoremediation maintenance	acre	$2,500	15	$37,500	$37,500	$0
SUBTOTAL ANNUAL OM&M COSTS (YRS. 1&2)				**$260,550**	**$48,800**	**$32,250**
ANNUAL OM&M COSTS (YRS. 3 - 30)						
Project Management	hr	$125	24	$3,000	$0	$3,000
Compliance Monitoring - S/A	year	$82,000	1	$82,000	$0	$82,000
MNA Sampling - S/A	year	$42,000	1	$42,000	$0	$42,000
Ltd. Phytoremediation maintenance	acre	$2,500	15	$37,500	$37,500	$0

SUBTOTAL ANNUAL OM&M COSTS (YRS 3-30)	$164,500	$0	$3,000

PRESENT WORTH OF ANNUAL COSTS	30	years @	7%	$2,215,000

TOTAL COSTS (TOTAL CAPITAL + PRESENT WORTH)	$4,366,000

-30% TOTAL COST=	$3,057,000
+50% TOTAL COST=	$6,549,000

ASSUMPTIONS AND CLARIFICATIONS

1. Cost totals rounded to the nearest thousand dollars.
2. Costs determined from vendor quotes, Means construction cost data, and estimates from other similar projects.
3. Contingency is assumed to be 15% of total capital cost.
4. Discount rate of 7.0% used for present worth estimate, per OSWER Directive No. 9355.3-20 (1993).
5. All costs are based on preliminary concepts. They are intended for comparison among options, and not for final budgeting.
6. Assume I-1-2 consists of 25 wells drilled to a vertical depth of 25 ft and 2 horizontal wells of 140 ft adjusted length.
7. I-1-23 consists of 20 wells drilled to a vertical depth of 20 ft and 2 horizontal wells of 100 ft adjusted length.
8. Repository consists of 44 wells drilled to a vertical depth of 40 ft and 2 horizontal wells of 240 ft adjusted length.
9. Assume 20 wells south of Repository drilled to a vertical depth of 20 ft.
10. Assume 2 separate treatment systems: one at I-1-2, and one encompassing I-1-23, Repository, and s.of Repository (pump and transfer system only at I-1-23).

OPINION OF PROBABLE COST
CRAB ORCHARD NWR - PCBOU - Sites 32/33
MARION, ILLINOIS
PROJECT NO. 4781.03

REMEDIAL ALTERNATIVE "F"

IN SITU PHYSICAL/THERMAL REMOVAL USING MITU WITH MNA AND LTD PHYTOREMEDIATION

	UNIT	UNIT $	QUANT.	TOTAL	COMMODITY COSTS	CONSULTANT COSTS
DIRECT CAPITAL COSTS:						
Dewatering (CBA / Winzeler)						
Install dewatering casings 40' deep, 16" dia	ea	$3,500	12	$42,000	$42,000	$0
Labor, pumps & equipment	mo	$70,000	3	$210,000	$210,000	$0
Mobilization - GW treatment system (CBA)	ls	$16,000	1	$16,000	$16,000	$0
Mobile GW treatment system & frac tank	mo	$8,000	3	$24,000	$24,000	$0
Carbon regeneration	lb	$5	5000	$25,000	$25,000	$0
Wellhead Completion	ea	$750	15	$11,250	$11,250	$0
Mobil./demob. - MITU-30 unit	ls	$120,000	1	$120,000	$120,000	$0
Thermal treatment w/ MITU-30 unit	cy	$70	26240	$1,836,800	$1,836,800	$0
Thermal re-treatment w/ MITU-30 unit	cy	$70	13000	$910,000	$910,000	$0
Misc. earthmoving/benching	ls	$25,000	1	$25,000	$25,000	$0
Multi-phase extraction system @ Repository						
Vertical extraction wells	ft	$25	1760	$44,000	$44,000	$0
Horizontal extraction wells	ft	$50	450	$22,500	$22,500	$0
Trenching & piping	ft	$40	1000	$40,000	$40,000	$0
Treatment equipment (LR pump, stripper,	ls	$50,000	1	$50,000	$50,000	$0
Installation (plumbing & electrical)	ls	$25,000	4	$100,000	$100,000	$0
Building w/ elec & HVAC	ls	$35,000	4	$140,000	$140,000	$0
Electrical service	ls	$5,000	4	$20,000	$20,000	$0
Control panel	ls	$10,000	4	$40,000	$40,000	$0
Site restoration	ls	$15,000	1	$15,000	$15,000	$0
Limited Phytoremediation						
Vendor design fees	ls	$50,000	1	$50,000	$50,000	$0
Pre-design/site prep	ls	$10,000	1	$10,000	$10,000	$0
Hybrid poplar trees; procure & install	acre	$15,000	14	$210,000	$210,000	$0
Contingency (25%)				$990,388	$990,388	$0
SUBTOTAL DIRECT CAPITAL COSTS				**$4,951,938**		
INDIRECT CAPITAL COSTS:						
Proj. mg'mt/Scheduling	hr	$125	240	$30,000	$0	$30,000
Pre-design - MPE pilot test	ls	$15,000	1	$15,000	$0	$15,000
Pre-design-refine geo/chem characterization	ls	$30,000	1	$30,000	$0	$30,000

Design	ls	$50,000	1	$50,000	$0	$50,000
Construction Management	ls	$75,000	1	$75,000	$0	$75,000
Permitting	ls	$10,000	1	$10,000	$0	$10,000
On-site observe/documentation	day	$1,000	75	$75,000	$0	$75,000
Documentation Report	ls	$15,000	1	$15,000	$0	$15,000
Administration	ls	$3,000	1	$3,000		$3,000
Contingency (15%)				$45,450		
SUBTOTAL INDIRECT CAPITAL COSTS				**$348,450**		
SUBTOTAL DIRECT & INDIRECT CAPITAL COSTS				**$5,300,388**		
STARTUP OM&M COSTS: (5 days to do initial gallery charges and injections)						
Labor	days	$1,000	5	$5,000	$0	$5,000
Monitoring equipment	days	$200	5	$1,000	$0	$1,000
Lab analysis						
Influent	ea	$165	10	$1,650	$1,650	$0
Effluent	ea	$675	10	$6,750	$6,750	$0
Off-gas (VOCs by TO-14)	ea	$250	10	$2,500	$2,500	$0
Data evaluation	ls	$1,000	1	$1,000	$0	$500
Proj. mg'mt	hr	$125	24	$3,000	$0	$3,000
Reporting	ls	$5,000	1	$5,000	$0	$5,000
Miscellaneous	ls	$1,000	1	$1,000	$0	$1,000
SUBTOTAL STARTUP OM&M COSTS				**$26,900**		
TOTAL CAPITAL & STARTUP OM&M COSTS				**$5,327,288**	**$4,962,838**	**$318,500**
ANNUAL OM&M COSTS YEARS 1 & 2:						
O&M Labor	days	$1,000	5	$5,000	$0	$5,000
O&M monitoring equipment	days	$200	5	$1,000	$0	$1,000
Lab analysis						
Influent	ea	$165	10	$1,650	$1,650	$0
Effluent	ea	$675	10	$6,750	$6,750	$0
Off-gas (VOCs by TO-14)	ea	$250	10	$2,500	$2,500	$0
Data evaluation	ls	$1,000	1	$1,000	$0	$500
Proj. mg'mt	hr	$125	24	$3,000	$0	$3,000
Reporting	ls	$5,000	1	$5,000	$0	$5,000
Carbon regeneration (vapor)	lb	$2.50	2000	$5,000	$5,000	$0
Utilities - electricity (50 hp, $0.07/KWH)	mo	$2,000	12	$24,000	$24,000	$0
Miscellaneous	ls	$1,000	1	$1,000	$0	$1,000
Compliance Monitoring - S/A	year	$82,000	1	$82,000	$0	$82,000
MNA Sampling - S/A	year	$60,000	1	$60,000	$0	$60,000
Ltd. Phytoremediation maintenance	acre	$2,500	15	$37,500	$37,500	$0
SUBTOTAL ANNUAL OM&M COSTS (YRS. 1&2)				**$235,400**	**$77,400**	**$157,500**
ANNUAL O&M COSTS (YRS. 3 - 30)						
Proj. mg'mt	hr	$125	24	$3,000	$0	$3,000
Compliance monitoring - S/A	year	$82,000	1	$82,000	$0	$82,000

MNA Sampling (annually)	year	$42,000	1	$42,000	$0	$42,000
Ltd. Phytoremediation maintenance	acre	$2,500	15	$37,500	$37,500	$0
SUBTOTAL ANNUAL OM&M COSTS (YRS. 3-30)				**$164,500**	**$37,500**	**$127,000**

PRESENT WORTH OF ANNUAL COSTS	**30**	**years @**	**7 %**	**$2,170,000**

TOTAL COSTS (TOTAL CAPITAL PLUS PRESENT WORTH)	**$7,498,000**

-30% TOTAL COST=	**$5,249,000**
+50% TOTAL COST=	**$11,247,000**

ASSUMPTIONS AND CLARIFICATIONS

1. Cost totals rounded to the nearest thousand dollars.
2. Costs determined from vendor quotes, Means construction cost data, and estimates from other similar projects.
3. Contingency is assumed to be 25% of total capital cost due to uncertainties with dewatering and MITU treatment effectiveness.
4. Discount rate of 7.0% used for present worth estimate, per OSWER Directive No. 9355.3-20 (1993).
5. All costs are based on preliminary concepts. They are intended for comparison among options, and not for final budgeting.
6. Assumes equal treatment depth of 35 ft for all areas, except at Repository, where MPE will be implemented.
7. Assumes 6 months of dewatering and treatment time for MITU.
8. Assumes MPE system at Repository with 44 vertical wells and 2 horizontal wells to operate 2 years.
9. Assumes refined geologic and chemical characterization, using direct-push technology, as a pre-design requirement.