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Intrinsic Remediation Engineering Evaluation/Cost Analysis for the FT-002 Site

Plattsburgh Air Force Base
New York

Prepared For

Air Force Center for Environmental Excellence
Technology Transfer Division
Brooks Air Force Base
San Antonio, Texas

and

Plattsburgh Air Force Base
New York

April 1995

EXECUTIVE SUMMARY

This report presents the results of an Engineering Evaluation/Cost Analysis (EE/CA) performed by Parsons Engineering Science, Inc. (Parsons ES) at Plattsburgh Air Force Base, New York, to evaluate if naturally occurring attenuation mechanisms would be sufficient to reduce dissolved fuel-related compounds in shallow ground water at and migrating from the former Fire Training Area (Site FT-002) to levels that meet federal- and state-specified ground water protection standards. Several site investigations completed at Site FT-002 under the Department of Defense (DOD) Installation Restoration Program (IRP) indicate that the soil and ground water associated with and downgradient of the former fire training area is contaminated with JP-4-related compounds and chlorinated solvents. Significant light nonaqueous phase liquid (LNAPL) still exists at the site, which acts as a continuing source of contaminant mass to the ground water.

The main emphasis of the work described herein was to quantitatively investigate the fate and transport of dissolved benzene, toluene, ethylbenzene, and total xylenes (BTEX) in the shallow ground water at the site. The fate and transport of dissolved chlorinated solvents [i.e., trichloroethene (TCE), cis- and trans-dichloroethene (DCE), and vinyl chloride] in shallow ground water was qualitatively considered to evaluate whether remedial technologies that may be appropriate for the BTEX compounds would also be effective on these other site-related contaminants.

Site characterization data was collected under this program in December 1993 and May 1994 by Parsons ES and the United States Environmental Protection Agency (USEPA) Robert S. Kerr Environmental Research Laboratory (RSKERL). These additional data were used to supplement existing data collected under the IRP on the nature and extent of ground water contamination at and migrating from the site. Data collected under this program were also used to investigate if naturally occurring attenuation mechanisms were occurring at the site, and, if so, whether these processes alone were sufficient to minimize plume migration and ensure that no exposure pathway involving ground water could be completed. A limited air sparging treatability test was also conducted in May 1994 to assess the effectiveness of this remedial technology on dissolved chlorinated solvent compounds.

Analytical data on the contaminants and other geochemical parameters that are relevant to documenting the potential for biodegradation of site-related contaminants suggest that BTEX

is biodegrading at Site FT-002 via aerobic respiration, nitrate reduction, ferric iron reduction, sulfate reduction, and methane fermentation. TCE appears to be biodegrading at Site FT-002 via anaerobic cometabolic mechanisms. Theoretical capacity estimates and equilibrium considerations suggest that BTEX mass will be completely eliminated from the shallow ground water at Site FT-002 before reaching potential human receptors. Available site data imply that dissolved chlorinated organic compounds are not being effectively attenuated once these compounds migrate beyond the existing BTEX contamination.

The numerical model Bioplume II was employed to simulate the fate and transport of BTEX in the shallow ground water over time under the influence of advection, hydrodynamic dispersion, adsorption, and aerobic biodegradation. Because the Bioplume II model developed for Site FT-002 was based on several conservative assumptions and input parameters, the reduction in BTEX mass actually expected to occur at the site should exceed model predictions. These predictive simulations demonstrate that naturally occurring attenuation mechanisms will be sufficient to prevent further migration of the dissolved BTEX plume so that federal- and state-regulated ground water protection standards can be attained before any exposure pathway involving ground water can be completed. Model simulations predict that the dissolved BTEX plume will decrease in size in the next 10 years. Implementation of source removal activities such as product recovery and bioventing, should further expedite the reduction in the size of the BTEX plume. The fate and transport of the chlorinated organic compounds were not simulated under this effort.

A comparative analysis of remedial technologies showed that a combination of continued source reduction using bioventing and product recovery, intrinsic remediation, institutional controls, and long-term monitoring was the most cost-effective remedial alternative for dissolved BTEX contamination at Site FT-002. Expanded source removal activities would expedite this remediation. However, these technologies alone would not be sufficient to remediate dissolved chlorinated organic contamination. Although the limited air sparging treatability test suggested that this technology may be effective at reducing the mass of chlorinated organic compounds in the ground water, Parsons ES recommends that an extended pilot test be completed on this technology before full-scale implementation is considered.

A long-term monitoring plan was developed for Site FT-002, which identifies the proposed location of long-term monitoring wells and proposed point-of-compliance wells, and the site-specific, annual sampling requirements to verify contaminant attenuation.

TABLE OF CONTENTS

Page

Executive Summary ES-1

1 Introduction 1-1
- 1.1 Scope and Objectives 1-1
- 1.2 Facility Background 1-4
  - 1.2.1 Operational History 1-5
  - 1.2.2 Current Remedial Activities 1-8

2 Site Characterization Activities 2-1
- 2.1 CPT and Geoprobe® Sampling 2-3
  - 2.1.1 First-Phase Instrumented Cone Penetrometer Testing 2-9
    - 2.1.1.1 Pore Pressure Measurements 2-9
    - 2.1.1.2 LIF CPT Measurements 2-10
    - 2.1.1.3 Resistivity 2-12
  - 2.1.2 Second-Phase Instrumented Cone Penetration Testing 2-12
- 2.2 Confirmatory Soil Sampling 2-13
- 2.3 Ground Water Sampling 2-14
  - 2.3.1 CPT Water Sampling 2-15
  - 2.3.2 Sampling Existing Monitoring Wells and New Ground Water Monitoring Points 2-16
  - 2.3.3 Geoprobe® Water Sampling 2-17
- 2.4 Chemical Parameter Measurement and Sample Analysis 2-18
  - 2.4.1 Onsite Dissolved Oxygen Measurements 2-19
  - 2.4.2 Onsite pH and Temperature Measurements 2-19
  - 2.4.3 Reduction/Oxidation Potential Measurements 2-20
  - 2.4.4 Onsite Mobile Laboratory Chemical Analysis Methods 2-20
    - 2.4.4.1 Indicator Analytes 2-20
    - 2.4.4.2 Soil Analysis 2-21
  - 2.4.5 Offsite Laboratory Chemical Analysis Methods 2-21
    - 2.4.5.1 Soil Analyses 2-21
    - 2.4.5.2 Ground Water Analyses 2-22
- 2.5 CPT Data Interpretation 2-22
- 2.6 Sampling Location Survey 2-23
- 2.7 Results of Air Sparging Treatability Test 2-24

3 Physical Characteristics of the Study Area 3-1
- 3.1 Introduction 3-1
- 3.2 Surface Features 3-1
  - 3.2.1 Topography and Surface Water Hydrology 3-3
  - 3.2.2 Manmade Features 3-4

TABLE OF CONTENTS (continued)

3.3 Site Geology and Hydrogeology 3-4
3.3.1 Lithology and Stratigraphic Relationship 3-5
3.3.2 Grain-Size Distribution 3-9
3.3.3 Ground Water Hydraulics 3-10
3.3.3.1 Flow Direction and Gradient 3-10
3.3.3.2 Hydraulic Conductivity 3-12
3.3.3.3 Effective Porosity (n_e) 3-14
3.3.3.4 Advective Ground Water Velocity 3-14
3.3.3.5 Estimation of BTEX Retardation 3-14
3.3.3.6 Confining Layers 3-15
3.3.3.7 Surface Discharge of Ground Water 3-16
3.3.4 Previous Ground Water Modeling 3-18
3.3.5 Ground Water Use 3-18
3.4 Climatological Characteristics 3-19

4 Nature and Extent of Contamination 4-1
4.1 Source of Contamination 4-1
4.2 Soil Gas Contamination 4-2
4.3 Soil Contamination 4-4
4.3.1 LNAPL Contamination 4-4
4.3.2 Unsaturated Soil Contamination 4-6
4.3.2.1 Soil BTEX Contamination 4-6
4.3.2.2 Soil TPH Contamination ..... 4-1[illegible]
4.3.2.3 Soil Solvent Contamination 4-22
4.4 Ground Water Contamination 4-22
4.4.1 Dissolved BTEX Contamination 4-24
4.4.2 Dissolved Chlorinated Solvent Contamination 4-39

5 Defining Effects of Destructive Attenuation Mechanisms 5-1
5.1 Introduction 5-1
5.2 Overview 5-2
5.2.1 Availability of Appropriate Microbial Consortia 5-3
5.2.2 Applicability of Thermodynamics 5-3
5.2.3 Why and How BTEX Biodegrades 5-4
5.2.4 Approach 5-10
5.3 Observed Plume Migration Patterns 5-11
5.3.1 Spatial and Temporal Differences in the Extent of BTEX Contamination 5-11
5.3.2 Spatial and Temporal Differences in the Extent of Chlorinated Solvent Contamination 5-13
5.4 Apparent Reduction in Contaminant Mass 5-13
5.4.1 Correcting for Dispersion and Adsorption 5-13
5.4.2 Estimating Actual Contaminant Mass Loss 5-14
5.5 Destruction of Contaminant Mass Via Microbially Catalyzed Redox Reactions 5-16

TABLE OF CONTENTS (continued)

5.5.1 Analytical Data on Oxidized and Reduced Chemical Species 5-16
5.5.1.1 Dissolved Oxygen 5-16
5.5.1.2 Nitrate 5-17
5.5.1.3 Ferrous Iron 5-29
5.5.1.4 Sulfate 5-33
5.5.1.5 Methane 5-37
5.5.1.6 Correlation Between Observed Redox Processes and Measured Eh Levels 5-37
5.5.1.7 Cometabolism of Trichloroethene 5-43
5.5.2 Theoretical Assimilative Capacity Estimates 5-48
5.5.2.1 Relevant Stoichiometric Relationship 5-48
5.5.2.2 Total Assimilative Capacity 5-49
5.5.2.3 Apparent Distribution and Contribution of Redox Processes 5-49
5.5.3 Correlation Between Theoretical Assimilative Capacity and Observed Contaminant Mass Reduction 5-54
5.5.4 Equilibrium Limitations 5-57
5.6 Other Considerations 5-57
5.7 Summary 5-57

6 Ground Water Flow and Contaminant Transport Model 6-1
6.1 General Overview and Model Description 6-1
6.2 Conceptual Model Design and Assumptions 6-2
6.3 Initial Model Setup 6-3
6.3.1 Grid Design and Boundary Conditions 6-3
6.3.2 Ground Water Elevation and Gradient 6-6
6.3.3 BTEX Concentrations 6-7
6.3.4 Dissolved Oxygen 6-7
6.4 Model Calibration 6-8
6.4.1 Water Table Calibration 6-8
6.4.2 BTEX Plume Calibration 6-12
6.4.2.1 Discussion of Parameters Varied During BTEX Plume Calibration 6-14
6.4.2.1.1. Contaminant Source Concentration 6-14
6.4.2.1.2 Dispersivity 6-16
6.4.2.1.3 Reaeration Coefficient 6-17
6.4.2.1.4 Coefficient of Retardation 6-17
6.5 Sensitivity Analysis 6-17
6.6 Model Results 6-24
6.6.1 Continuation of Calibrated Conditions (Model PLATCAL) 6-24
6.6.2 Reduced BTEX Source (Model PLATPRD) 6-24
6.7 Conclusions and Discussions 6-26

TABLE OF CONTENTS (continued)

7 Comparative Analysis of Remedial Alternatives 7-1
7.1 Remedial Alternative Evaluation Criteria 7-1
7.1.1 Long-Term Effectiveness and Permanence 7-2
7.1.2 Implementability 7-2
7.1.3 Cost 7-2
7.2 Factors Influencing Alternatives Development 7-3
7.2.1 Program Objectives 7-3
7.2.2 Contaminant Properties 7-4
7.2.3 Site-Specific Conditions 7-6
7.2.3.1 Ground Water and Soil Characteristics 7-6
7.2.3.2 Potential Exposure Pathways Involving Shallow Ground Water 7-8
7.2.3.3 Potential Remediation Goals for Shallow Ground Water 7-10
7.2.4 Summary of Remedial Technology Screening 7-12
7.3 Brief Description of Remedial Alternatives 7-17
7.3.1 Alternative 1 - Intrinsic Remediation, Institutional Controls, and Long-Term Ground Water Monitoring 7-17
7.3.2 Alternative 2 - Source Removal via Continued/Expanded Product Recovery, Bioventing, Intrinsic Remediation, Institutional Controls, and Long-Term Ground Water Monitoring 7-19
7.3.3 Alternative 3 - Source Removal via Continued/Expanded Product Recovery and Bioventing, Intrinsic Remediation Supplemented with Air Sparging, Institutional Controls, and Long-Term Ground Water Monitoring 7-20
7.3.4 Alternative 4 - Source Removal via Continued/Expanded Product Recovery and Bioventing, Intrinsic Remediation Supplemented with an *In Situ* Permeable Reaction Wall, Institutional Controls, and Long-Term Ground Water Monitoring 7-23
7.4 Evaluation of Alternatives 7-24
7.4.1 Alternative 1 - Intrinsic Remediation, Institutional Controls, and Long-Term Monitoring 7-24
7.4.1.1 Effectiveness 7-24
7.4.1.2 Implementability 7-25
7.4.13 Cost 7-26
7.4.2 Alternative 2 - Source Removal via Continued/Expanded Product Recovery, Bioventing, Intrinsic Remediation, Institutional Controls, and Long-Term Ground Water Monitoring 7-26
7.4.2.1 Effectiveness 7-26
7.4.2.2 Implementability 7-28
7.4.2.3 Cost 7-28

TABLE OF CONTENTS (continued)

7.4.3 Alternative 3 - Source Removal via Continued/Expanded Product Recovery and Bioventing, Intrinsic Remediation Supplemented with Air Sparging, Institutional Controls, and Long-Term Ground Water Monitoring 7-30
7.4.3.1 Effectiveness 7-30
7.4.3.2 Implementability 7-31
7.4.3.3 Cost 7-32
7.4.4 Alternative 4 - Source Removal via Continued/Expanded Product Recovery and Bioventing, Intrinsic Remediation Supplemented with an *In Situ* Permeable Reaction Wall, Institutional Controls, and Long-Term Ground Water Monitoring 7-32
7.4.4.1 Effectiveness 7-32
7.4.4.2 Implementability 7-34
7.4.4.3 Cost 7-34

7.5 Recommended Remedial Approach 7-34

8 Long-Term Monitoring Plan 8-1
8.1 Overview 8-1
8.2 Monitoring Networks 8-2
8.2.1 Long-Term Monitoring Wells 8-2
8.2.2 Proposed POC or Sentry Wells 8-10
8.3 Ground Water Sampling 8-12
8.3.1 Analytical Protocol 8-12
8.3.2 Sampling Frequency 8-12

9 Conclusions and Recommendations 9-1

10 References 10-1

APPENDIX A CPT Profiles and Soil Boring Logs

APPENDIX B Available Soil and Ground Water Data

APPENDIX C Bioplume II Model Input and Related Calculations

APPENIDX D Bioplume II Model Output Files

APPENDIX E Estimating Non-Destructive Attenuation Effects

TABLE OF CONTENTS (continued)

LIST OF TABLES

		Page
2.1	December 1993 Sample Location Information	2-5
2.2	May 1994 Sampling Location Information	2-8
2.3	Summary of Test Sparging System Data, May 1994	2-25
3.1	Vertical Hydraulic Gradients	3-13
4.1	May 1994 Soil Gas Data	4-3
4.2	Mobile LNAPL Thickness Estimates Based on December 1993 and May 1994 LIF and Monitoring Well Data	4-7
4.3	Chemical Analysis of LNALP Sample Collected from MW-02-015 in December 1993	4-8
4.4	Soil Data for the BTEX Compounds and Total Petroleum Hydrocarbons	4-9
4.5	Soil Data for Chlorinated Solvents and Other Fuel-Related Compounds	4-14
4.6	Summary of Previous Ground Water Quality Data	4-25
4.7	Ground Water Quality Data for BTEX and TMB Compounds	4-26
4.8	Ground Water Quality Data for Chlorinated Solvents and Other Fuel-Related Compounds	4-40
5.1	Electron Acceptor and Electron Donor Half-Cell Reactions	5-5
5.2	Coupled Redox Reactions Involving the BTEX Compounds	5-6
5.3	Calculation of Expected Contaminant Travel Times	5-1[illegible]
5.4	Defining Nondestructive Attenuation Effects	5-15
5.5	Ground Water Quality Data for Geochemical Indicators	5-18
5.6	Ground Water Quality Data for Additional Chemical Parameters	5-26
5.7	Calculation of Intrinsic Assimilative Capacity	5-50
6.1	Bioplume II Model Input Parameters	6-9
7.1	Potential Ground Water Remediation Goal	7-12
7.2	Initial Technical Implementability Screening of Technologies and Process Options for Ground Water Remediation	7-13
7.3	Cost Estimate for Alternative 1	7-27
7.4	Cost Estimate for Alternative 2	7-29
7.5	Cost Estimate for Alternative 3	7-33
7.6	Cost Estimate for Alternative 4	7-35
7.7	Summary of Remedial Alternatives Evaluation Ground Water Remediation	7-36
8.1	Long-Term Monitoring Analytical Protocol	8-3
8.2	Point-of-Compliance Monitoring Analytical Protocol	8-7

TABLE OF CONTENTS (continued)

LIST OF FIGURES

		Page
1.1	FT-002 Location Map	1-6
1.2	FT-002 Surface Features Map	1-7
2.1	Sampling Locations (December 1993)	2-4
2.2	Sampling Locations (May 1994)	2-7
3.1	Site Map	3-2
3.2	Location of Hydrogelogic Profiles	3-6
3.3	Northwest-Southeast Hydrogeologic Profile A-A'	3-7
3.4	North-South Hydrogeologic Profile B-B'	3-8
3.5	Ground Water Table Elevation Map	3-11
3.6	Location of Downgradient Surface Water Bodies	3-17
4.1	LNAPL Isopach Map	4-5
4.2	Extent of Total BTEX Contamination in Soil	4-18
4.3	Northwest-Southeast Extent of Contamination	4-20
4.4	Extent of Soil Total Petroleum Hydrocarbon Contamination	4-21
4.5	Extent of Soil TCE Contamination	4-23
4.6	Areal Extent of Dissolved BTEX at Depth of Maximum Concentration	4-28
4.6b	Vertical Extent of Dissolved Total BTEX Along Plum Centerline	4-30
4.7a	Area Extent of Dissolved Benzene at Depth of Maximum Concentration	4-31
4.7b	Vertical Extent of Dissolved Benzene Along Plume Centerline	4-32
4.8a	Areal Extent of Dissolved Toluene at Depth of Maximum Concentration	4-33
4.8b	Vertical Extent of Dissolved Toluene Along Plume Centerline	4-34
4.9a	Areal Extent of Dissolved Ethylbenzene at Depth of Maximum Concentration	4-35
4.9b	Vertical Extent of Dissolved Ethylbenzene Along Plume Centerline	4-36
4.10a	Areal Extent of Dissolved Total Xylenes at Depth of Maximum Concentration	4-37
4.10b	Vertical Extent of Dissolved Total Xylenes Along Plume Centerline	4-38
4.11a	Areal Extent of Dissolved Total Chlorinated Solvents at Depth of Maximum Concentration	4-45
4.11b	Vertical Extent of Dissolved Total Chlorinated Solvents Along Plume Centerline	4-46
4.12a	Areal Extent of Dissolved Trichloroethene at Depth of Maximum Concentration	4-48
4.12b	Vertical Extent of Dissolved Trichloroethene Along Plume Centerline	4-49
4.13a	Areal Extent of Dissolved Vinyl Chloride at Depth of Maximum Concentration	4-50
4.13b	Vertical Extent of Dissolved Vinyl Chloride Along Plume Centerline	4-51
5.1	Sequence of Microbially Mediated Redox Processes	5-9
5.2a	Areal Extent of Dissolved Oxygen at Depth of Maximum BTEX Concentration	5-20
5.2b	Vertical Extent of Dissolved Oxygen Along Plume Centerline	5-21

TABLE OF CONTENTS (continued)

5.3	Comparison of Total BTEX and Dissolved Oxygen	5-22
5.4a	Areal Extent of Nitrate/Nitrite as N at Depth of Maximum BTEX Concentration	5-23
5.4b	Vertical Extent of Nitrate/Nitrite as N Along Plume Centerline	5-24
5.5	Comparison of Total BTEX and Nitrate as N	5-25
5.6a	Areal Extent of Ferrous Iron at Depth of Maximum BTEX Concentration	5-30
5.6b	Vertical Extent of Ferrous Iron Along Plume Centerline	5-31
5.7	Comparison of Total BTEX and Ferrous Iron	5-32
5.8a	Areal Extent of Sulfate at Depth of Maximum BTEX Concentration	5-34
5.8b	Vertical Extent of Sulfate Along Plume Centerline	5-35
5.9	Comparison of total BTEX and Sulfate	5-36
5.10a	Areal Extent of Methane at Depth of Maximum BTEX Concentration	5-38
5.10b	Vertical Extent of Methane Along Plume Centerline	5-39
5.11	Comparison of Total BTEX and Methane	5-40
5.12a	Areal Extent of Hypothetical Electron Activity at Equilibrium Relative to the Hydrogen Scale at Depth of Maximum BTEX Concentration	5-41
5.12b	Vertical Extent of Hypothetical Electron Activity at Equilibrium Relative to the Hydrogen Scale Along Plume Centerline	5-42
5.13	Comparison of Microbially Mediated Oxidation and Reduction Reactions	5-44
5.14	Evidence Suggesting Cometabolic TCE Degradation	5-46
5.15	Distribution of Ground Water Assimilative Capacity	5-5
5.16	Relative Contribution of Redox Processes	5-5
5.17	Comparison of Theoretical Assimilative Capacity to Observed BTEX Mass Reduction	5-55
5.18	Cometabolic Degradation of TCE	5-56
6.1	Model Grid	6-4
6.2	Calibrated Water Table Map	6-11
6.3	Calibrated BTEX Plume	6-13
6.4	Location of Simulated Injection Wells for Model Calibration and Prediction	6-15
6.5	Model Sensitivity to Variations in Transmissivity	6-19
6.6	Model Sensitivity to Variations in Longitudinal Dispersivity	6-20
6.7	Model Sensitivity to Variations in Solute Retardation	6-21
6.8	Model Sensitivity to Variations in Reaeration Coefficient	6-22
6.9	Simulated BTEX Plume in the Year 2003	6-25
6.10	Simulated BTEX Plume in the Year 2003 with Source Reduction (T=48 years)	6-27
7.1	Proposed Location of Downgradient Air Sparing Network	7-22
8.1	Proposed Locations of LTM and POC Wells	8-11

SECTION 1

INTRODUCTION

This report was prepared by Parsons Engineering Science, Inc. (Parsons ES), formerly Engineering Science, Inc. (ES), and presents the results of an Engineering Evaluation/Cost Analysis (EE/CA) conducted to evaluate whether intrinsic remediation (natural attenuation) is an appropriate remedial option for shallow ground water contaminated with fuel hydrocarbons at the former Fire Training Area (FT-002) at Plattsburgh Air Force Base (AFB), Plattsburgh, New York. Site FT-002 was used to train base fire-fighting personnel from the mid- to late-1950s until the site was permanently closed to dedicated fire training activities in 1989. Previous investigations indicate that JP-4 jet fuel, solvents, and other chemicals that were sometimes mixed with the fuel before being used in the four unlined fire training pits have contaminated soil and shallow ground water at the site.

The main emphasis of the work described herein was to evaluate if naturally occurring attenuation mechanisms would be sufficient to reduce dissolved fuel-related compounds in ground water to levels that meet federal- and state-specified ground water protection standards. The potential for these mechanisms to effectively reduce the concentration of chlorinated solvents at the site, which is outside the scope of this program, was also qualitatively considered.

1.1 SCOPE AND OBJECTIVES

Parsons ES, in conjunction with researchers from the United States Environmental Protection Agency (USEPA) Robert S. Kerr Environmental Research Laboratory (RSKERL), was retained by the United States Air Force Center for Environmental Excellence (AFCEE) to conduct site characterization and ground water modeling to evaluate if intrinsic remediation with long-term monitoring would be a scientifically defensible remedial option for contaminated ground water at the FT-002 site.

There were two primary objectives of this project:

- Determine whether naturally occurring attenuation processes for fuel hydrocarbons are occurring in ground water at the site, and, if so,
- Investigate if these processes are sufficient to minimize the expansion of the fuel hydrocarbon plume using the Bioplume II model to ensure that federal- and state-specified ground water protection standards will be met at a downgradient point of compliance (POC).

These objectives were accomplished by:

- Reviewing existing hydrogeological and soil and ground water quality data for the site;
- Conducting additional site characterization activities to determine the nature and extent of soil and ground water contamination and to collect the geochemical data necessary to document the occurrence of intrinsic remediation;
- Developing a conceptual hydrogeological model of the shallow saturated zone, including the current distribution of contaminants;
- Evaluating site-specific data to determine whether fuel hydrocarbon contamination is being attenuated in ground water;
- Designing and setting up the Bioplume II model for site hydrogeologic conditions;
- Simulating the fate and transport of fuel hydrocarbons in ground water under the influence of advection, dispersion, adsorption, and biodegradation using the Bioplume II model;
- Performing sensitivity analyses using the Bioplume II model with a range of feasible input parameters to ensure that several contaminant fate and transport scenarios were considered;
- Comparing the predicted effectiveness of intrinsic remediation to other viable ground water remediation strategies to identify the most cost-effective remedial option; and
- Developing a 30-percent (conceptual) remedial design for contaminated ground water using the most appropriate remedial technology or combination of remedial technologies, as necessary.

Site characterization activities completed as part of this project included use of a standard cone penetrometer testing (CPT) device and a Geoprobe® to sample ground water, use of a laser-induced fluorescence (LIF) CPT tool to delineate the extent of the light nonaqueous-phase liquid (LNAPL) source in soil and ground water, sampling of existing ground water monitoring wells, and installation and testing of an air sparging network.

Site-specific data were used to assess the potential effectiveness of naturally occurring attenuation mechanisms, develop a fate and transport model for the site using Bioplume II,

and determine if any ground water exposure pathway could be completed. The Bioplume II model developed for the FT-002 site as part of this project focused on simulating the fate and transport of benzene, toluene, ethylbenzene, and xylenes (BTEX) in the shallow saturated zone under the influence of advection, dispersion, adsorption, and biodegradation. Model results were used to help assess the potential for completion of exposure pathways involving ground water and to identify whether intrinsic remediation with long-term monitoring is an appropriate and defensible remedial option for contaminated ground water. Site-specific data were also used to qualitatively evaluate the potential fate and transport of trichloroethene (TCE), cis-dichloroethene (cis-DCE), trans-dichloroethene (trans-DCE), vinyl chloride, and ethene in the presence of fuel hydrocarbons. Potential biological degradation of these chlorinated solvents via cometabolic processes was addressed qualitatively.

Several remedial options were considered to identify the major advantages and disadvantages associated with different ground water remedial strategies. Other remedial technology options briefly considered in this document include free product removal, ground water extraction and treatment (i.e., pump and treat), air sparging, and a gate-and-funnel system coupled with an *in situ* reactive barrier system. Much of the hydrogeological and ground water chemical data necessary to evaluate the various remedial options were available from previous investigations conducted at this site or at other sites with similar characteristics, or in the technical literature. The field work conducted under this program was oriented toward the collection of hydrogeological data necessary to document and model the effectiveness of intrinsic remediation with long-term monitoring for fuel-hydrocarbon-contaminated ground water. Data collected on the effectiveness of air sparging on chlorinated solvents in ground water at the site are included in the comparative analysis.

This report contains 10 sections, including this introduction, and 5 appendices. Section 2 summarizes site characterization activities. Section 3 summarizes the physical characteristics of the study area. Section 4 describes the nature and extent of soil and ground water contamination at the site. Section 5 describes the observed relationships between site contamination and geochemical parameters that suggest that microbial-mediated contaminant degradation is occurring. Section 6 describes the Bioplume II model, summarizes the conceptual model for the site, lists model assumptions and input parameters, describes sensitivity analyses, model output, and the results of the Bioplume II modeling. Section 7 presents a comparative analysis of remedial alternatives for ground water. Section 8

identifies a 30-percent remedial design for the most appropriate and cost-effective remedial technology for contaminated ground water at, and migrating from, the site. Section 9 presents the conclusions of this work and provides recommendations for further work at the site. Section 10 lists the references used to develop this document. Appendix A contains LIF CPT profile logs and confirmatory soil borehole logs. Appendix B contains soil and ground water analytical data. Appendix B also contains data on the seasonal variation in ground water elevation and ground water flow direction at the site. Appendix C contains gridded model input parameters. Appendix D contains model output. Appendix E contains free product/ground water partitioning calculations.

1.2 FACILITY BACKGROUND

Plattsburgh AFB is located in northeastern New York State and is bor[illegible] on the north by the City of Plattsburgh, on the south and west by the Town of Plattsbur[illegible]d on the east by Lake Champlain. The base is approximately 26 miles south of the Canadian border and 167 miles north of Albany, New York. The Adirondack Mountains lie 20 to 30 miles west of Plattsburgh AFB. A portion of the base has been a military installation since 1812. The current configuration of Plattsburgh AFB, which was developed in 1954 by the Strategic Air Command (SAC), consists of the old military installation (i.e., the Plattsburgh Barracks) and the Main Base that includes housing facilities, the flightline, and support areas. The base currently covers 4,795 acres, 3,365 of which are federally owned and controlled by the military, and 1,430 of which are registered as easement tracts (ABB Environmental Services, Inc., and URS Consultants, Inc., 1993).

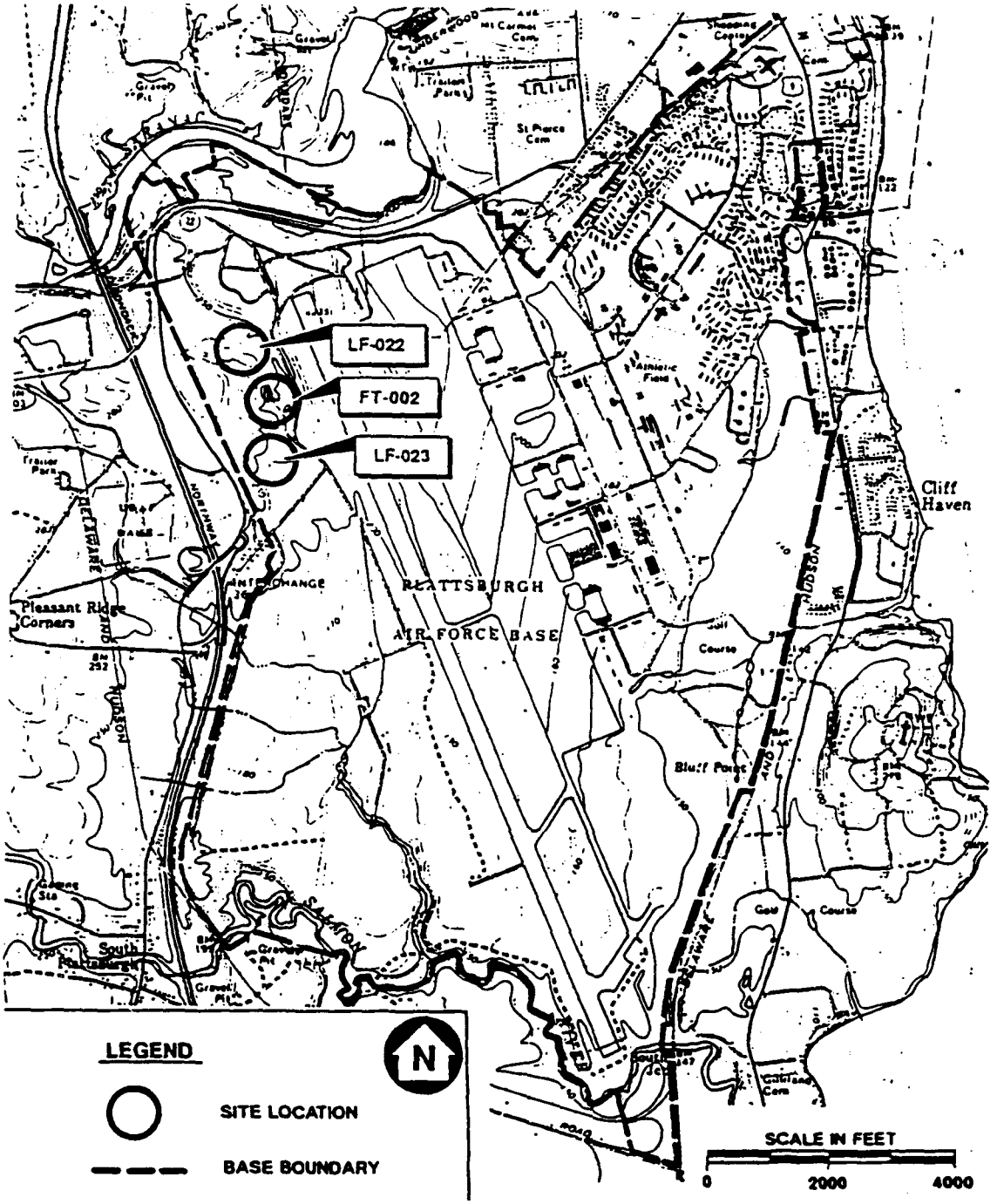
Site FT-002, formerly designated FT-001, is located in the northwest corner of the base and is approximately 700 feet wide and 800 feet long. The FT-002 site is located approximately equidistant (500 feet) between the Plattsburgh AFB runway to the east and the base boundary on the west. Site FT-002 is located south of domestic waste landfill LF-022 and north of domestic waste/spent munitions landfill LF-023. Previous remedial investigation studies suggested that these sites are not contributing an appreciable mass of contamination to ground water affected by FT-002 operations. Both source areas (LF-022 and LF-023) are to be covered under separate remedial action implementation programs to minimize exposure risks from the surface soil pathway.

Figure 1.1 is a site location map showing the position of the site relative to Plattsburgh AFB and the surrounding area. The site is located on a land surface that slopes gently eastward toward the confluence of the Saranac and the Salmon Rivers, which is located approximately 1.9 miles east of the site. Figure 1.2 is a site map showing the FT-002 site and the immediately adjacent area in detail. The site consists of four bermed pits that range in diameter from approximately 60 to 160 feet. The surface of the site is transected by several unpaved roads. Site FT-002 is situated in a limited-access area. Access from the east is restricted by the controlled-access areas of the active runway to the east; access from the west is somewhat less restricted, although the area is bounded by a 4-foot-high, three-wire fence. Access from the north and south is generally limited by the LF-022 and LF-023 areas, respectively. The following sections describe the previous and current uses of the FT-002 site.

1.2.1 Operational History

Site FT-002 was used to train base and municipal fire-fighting personnel from the mid- to late-1950s until the site was permanently closed to standard fire training activities on May 22, 1989. However, limited emergency rescue training has been allowed at the site since 1989. During fire training exercises, fires were ignited in four fire training pits located in the FT-002 area. Prior to 1980, the fire pits consisted of sand and gravel depressions. In 1980, cement-stabilized soil liners were added to active Pits 2 and 3. Pits 1 and 4 had been since removed from service.

For the purposes of fire training exercises, the pits were typically saturated with water before adding approximately 75 to 100 gallons of fuel, which was then ignited (ABB Environmental Services, Inc., and URS Consultants, Inc., 1993). Pits 2 and 3 were supplied with fuel from a partially buried fuel storage tank. The fuel was fed to the pits via underground gravity feed lines. The fuel for the fire pits consisted mainly of off-specification waste jet fuel (JP-4) mixed with waste oil. Solvents and other chemicals were sometimes mixed with the fuel. A single training exercise usually consisted of four consecutive cycles of igniting and extinguishing fires in the training pits. Prior to the 1980s, a maximum of 2,000 gallons of fuel was burned weekly fire training exercises (Radian, 1985). Previous site investigations have suggested training activities may also have been



Taken from ABB Environmental, Inc. and URS Consultants, Inc., 1993

FIGURE 1.1

FT-002 LOCATION MAP

Fire Training Area, FT-002
Intrinsic Remediation EE/C,
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC
Denver, Colorado

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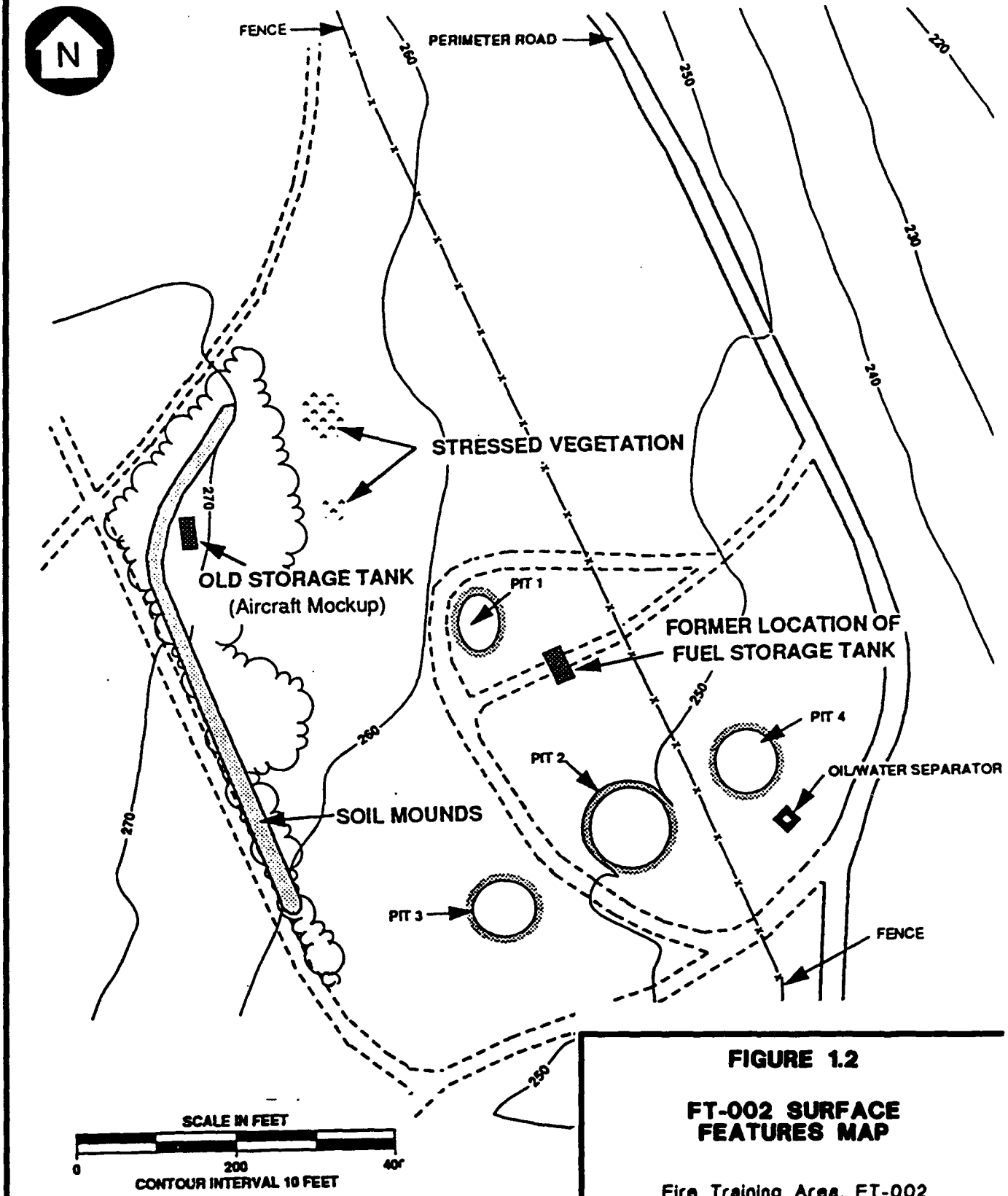

Taken from ABB Environmental, Inc., 1992

FIGURE 1.2

FT-002 SURFACE FEATURES MAP

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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conducted in an area north and west of the pits (ABB Environmental Services, Inc., and URS Consultants, Inc., 1993).

Several site investigations have been conducted since the spring of 1984 to characterize soil and ground water contamination at FT-002. A preliminary assessment of the site was completed in 1985 (Radian, 1985); a site inspection (E.C. Jordon, Co., 1989a) and a Phase I remedial investigation (E.C. Jordan, Co., 1990) were completed in 1988; a free product recovery pilot test was conducted in 1989 (E.C. Jordan, Co., 1989b and 1991a); a drainage flow study was completed in 1990 (E.C. Jordan, Co., 1991b); a soil remedial investigation was completed in 1991 (ABB Environmental, Inc., 1992); and a Phase II ground water remedial investigation was completed in 1991 (ABB Environmental Services, Inc. and URS Consultants, Inc., 1993). A Phase II feasibility study report for the site also has been prepared (URS Consultants, Inc., 1993).

The results of these investigations suggest that the soil and ground water associated with and downgradient of the fire training area is contaminated with JP-4-related compounds and chlorinated solvents. The unburned fuel mixture seeped beneath the pits and, over years of training exercises, contaminated the soil column and ground water underlying the pit area. In some areas, the soil is saturated with fuel. LNAPL is present in the capillary fringe and floating on top of the ground water table in some areas (e.g., downgradient of Pit 1, Pit 4, and the oil/water separator). The former fuel storage tank and oil/water separator that served Pits 2 and 3 have also been identified as potential sources of soil and ground water contamination. The site-specific data presented in Sections 3 and 4 are based on a review of these documents and on data collected by Parsons ES and researchers from the RSKERL under this program. A synopsis of site characterization activities conducted prior to implementation of field work under this program is provided in the Phase I and Phase II remedial investigation reports (ABB Environmental, Inc., 1992; ABB Environmental, Inc. and URS Consultants, Inc., 1993).

1.2.2 Current Remedial Activities

Plattsburgh AFB has initiated several investigations at the FT-002 site to identify, evaluate, and remediate hazardous contamination as part of the Department of Defense (DOD) Installation Restoration Program (IRP). Since initiation of the IRP, Plattsburgh AFB

has been placed on the National Priorities List (NPL) of sites to be remediated through the USEPA Superfund Program. The FT-002 site has been divided into two operable units. Operable Unit 1 consists of surface and subsurface soil above the zone of water table fluctuation. Operable Unit 2 consists of ground water and deep subsurface soil, including soil within the zone of water table fluctuation. Separate remedial investigations (RIs) and feasibility studies (FSs) have been completed for each operable unit. Site FT-002 has also been selected as a test site for a pilot study of the bioventing technology as part of the AFCEE Bioventing Test Initiative.

Current remedial activities at the FT-002 site include operation of an active LNAPL recovery system as a source control/removal action and installation and testing of pilot-scale bioventing systems at each of the four pits as part of a treatability study. The LNAPL recovery system, which went into continuous operation in 1993, consists of a network of four wells, each equipped with a pump and an oil-sensing skimmer. Product and aqueous-phase liquid are pumped to a treatment facility located between FT-002 and LF-023. The treatment system consists of metals pretreatment, air stripping, and carbon polishing. System capacity is 100 gallons per minute (gpm). The treatment system discharges from between 20 to 80 gpm of treated effluent to the Salmon River drainage basin. The LNAPL recovery system has been effective at removing free product from the ground water at a rate of 30 to 65 gallons per day. However, free product still remains in several ground water monitoring wells northeast and east of Pits 1, 2, and 4. The rate of product recovery of this system has decreased significantly, and plans for additional recovery wells are under development.

A bioventing treatability study also is being conducted at the FT-002 site. Pilot-scale demonstration systems have been installed at each of the four fire training pits. The objectives of this demonstration are 1) to assess the treatability of fuel-contaminated unsaturated soils by supplying oxygen throughout the contaminated soil depth, 2) to determine the rate at which indigenous microorganisms degrade fuel when stimulated by oxygen-rich soil gas, and 3) to evaluate the potential for sustaining these rates of biodegradation until fuel contamination is remediated to concentrations below regulatory standards. A single bioventing well was constructed near the center of each of the four bermed fire training pits in 1993 and 1994 (ES, 1993a). Three multiple-depth vapor monitoring points also were installed within a 60-foot radius of each of these central bioventing wells at the time of their construction. Initial pilot test results involving soil gas chemistry, air permeability, radius of oxygen influence, and *in situ* respiration rates at all pits

suggest that naturally occurring oxygen has been depleted in the contaminated soils, and that air injection will likely be an effective method of stimulating aerobic fuel biodegradation. A 1-year extended test period has been completed for the bioventing system constructed at Pit 3 (ES, 1993a). Although results from the Pit 3 test have been encouraging, the New York State Department of Environmental Conservation (NYSDEC) has not yet approved the operation of the systems at Pits 1, 2, and 4 for the extended test phase of the treatability study.

SECTION 2

SITE CHARACTERIZATION ACTIVITIES

To meet the requirements of the intrinsic remediation demonstration at the FT-002 site, several investigative techniques, including soil and ground water sampling, were utilized. There were two objectives of the site characterization activities completed at this site under this program. The first was to supplement existing data on the nature and extent of ground water contamination at, or migrating from, the site. The second was to investigate if naturally occurring attenuation mechanisms are occurring at the site, and, if so, whether these processes are sufficient to warrant intrinsic remediation for remediation of contaminated ground water. Activities included 1) delineating the areal extent of the LNAPL source, and 2) defining the physical and chemical characteristics of areas upgradient of the suspected source (i.e., background), within the source (i.e., affected by the LNAPL), within the dissolved-plume, and downgradient of detectable contamination (i.e., outside the current range of contamination).

Soil profiling and sampling was accomplished during this investigation using tip resistance, friction ratio, pore pressure values, and fluorescence measurements of LNAPL generated by laser light from an instrumented CPT tool and 5-foot and 2-foot Mostap® soil samplers as part of a conventional CPT system. Soil gas data were collected during several CPT pushes. Previous soil investigations conducted at the site included a soil gas survey, a magnetometer survey, ground-penetrating radar mapping, seismic refraction, terrain conductivity, laboratory clay testing, grain size analysis, and standard hollow-stem auger (HSA) drilling and soil sampling, as well as a CPT survey. Ground water sampling was accomplished during this investigation with a modified CPT tool equipped with a discrete-depth sampling chamber, a Geoprobe® water sampling apparatus, and previously existing monitoring wells. Previous investigations utilized monitoring wells installed in HSA boreholes, the HydroPunch® sampler, and discrete-depth samplers used as part of the earlier CPT survey. Aquifer tests previously conducted at the site included pumping, slug, and rising head testing. A network of five ground water monitoring points and one air sparging

well was installed during this investigation at various depths to test the treatability of ground water contaminated with chlorinated solvents.

This section presents the methods that were used by Parsons ES and researchers from the RSKERL to collect site-specific data at the FT-002 site. Site characterization data obtained under this program were collected in two phases. The first phase was completed in December 1993, by Parsons ES staff and researchers from the RSKERL. During this effort, soil and ground water profiling was completed using the instrumented CPT tool. Several continuous soil samples were collected to confirm the data from the instrumented CPT tool. Ground water samples were also collected both using the discrete-depth sampler on the CPT tool and from existing monitoring wells. The second phase of field work was completed by RSKERL personnel in May 1994, and consisted of soil gas, soil, and ground water sampling using Geoprobe® and an instrumented CPT tool. One air sparge well and five ground water monitoring points were also installed and tested to assess the treatability of ground water contaminated with chlorinated solvents. In addition, soil and ground water data collected under the IRP and Bioventing Test Initiative Program at the site were used to help develop the conceptual site model and to aid interpretation of the physical setting (Section 3) and contaminant distribution (Section 4).

Target site-related chemical contamination at the FT-002 site has been defined by investigations conducted as part of the IRP. Site-related contaminants in soil and ground water include the BTEX compounds, TCE, cis-DCE, trans-DCE, naphthalene, carbon disulfide, 2-methylnaphthalene, and vinyl chloride (ABB Environmental, Inc., 1992; ABB Environmental, Inc. and URS Consultants, Inc., 1993). Chemical data collected under this program focused on the BTEX compounds and chlorinated solvents. Supplemental data on the other target compounds are provided when available.

In summary, the physical and chemical hydrogeological data listed below were collected during the field work phase of the EE/CA:

- Depth from measurement datum to the ground water table in monitoring wells and monitoring points;
- Location of potential ground water recharge and discharge areas;
- Detailed stratigraphic analysis of subsurface media;
- Estimation of extent and thickness of free-phase product (LNAPL);

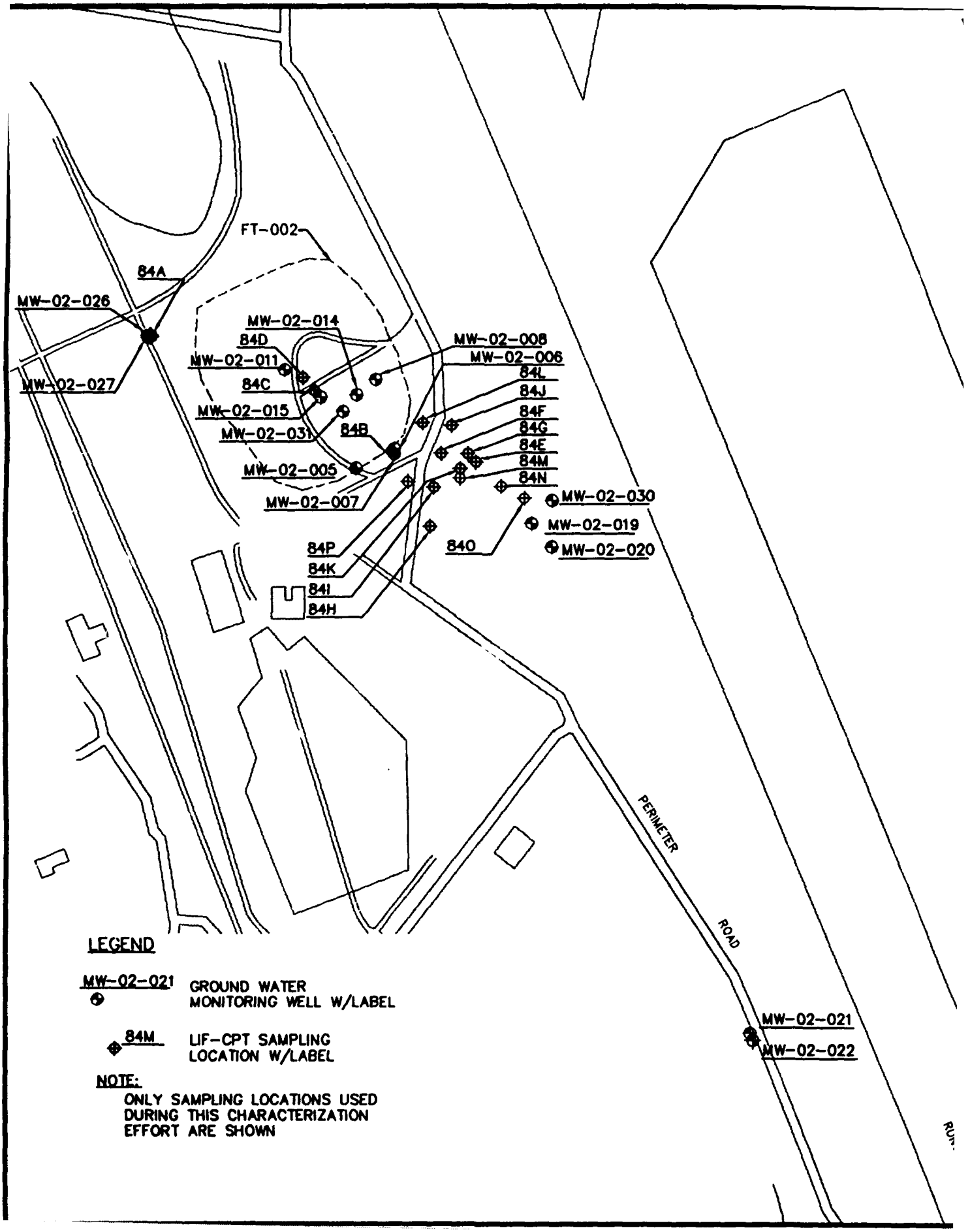
- Dissolved oxygen (DO), nitrate (NO_3^-), nitrite (NO_2^-), ferrous iron (Fe^{2+}), sulfate (SO_4^{2-}), methane (CH_4), carbon dioxide ($CO_{2(gas)}$), chloride (Cl^-), ammonia (NH_3), total phosphate (PO_4^{3-} and HPO_4^{2-}), and total organic carbon (TOC) concentrations in ground water;
- Temperature, specific conductance, redox potential, total alkalinity, and pH of ground water;
- BTEX, trimethylbenzene (TMB), total petroleum hydrocarbon (TPH), trans-DCE, cis-DCE, TCE, and vinyl chloride concentrations in ground water;
- BTEX, TMB, TPH, trans-DCE, cis-DCE, TCE, and vinyl chloride concentrations in soil; and
- Chemical analysis of an LNAPL sample to determine the mass fraction of fuel hydrocarbons (BTEX) and chlorinated solvents.

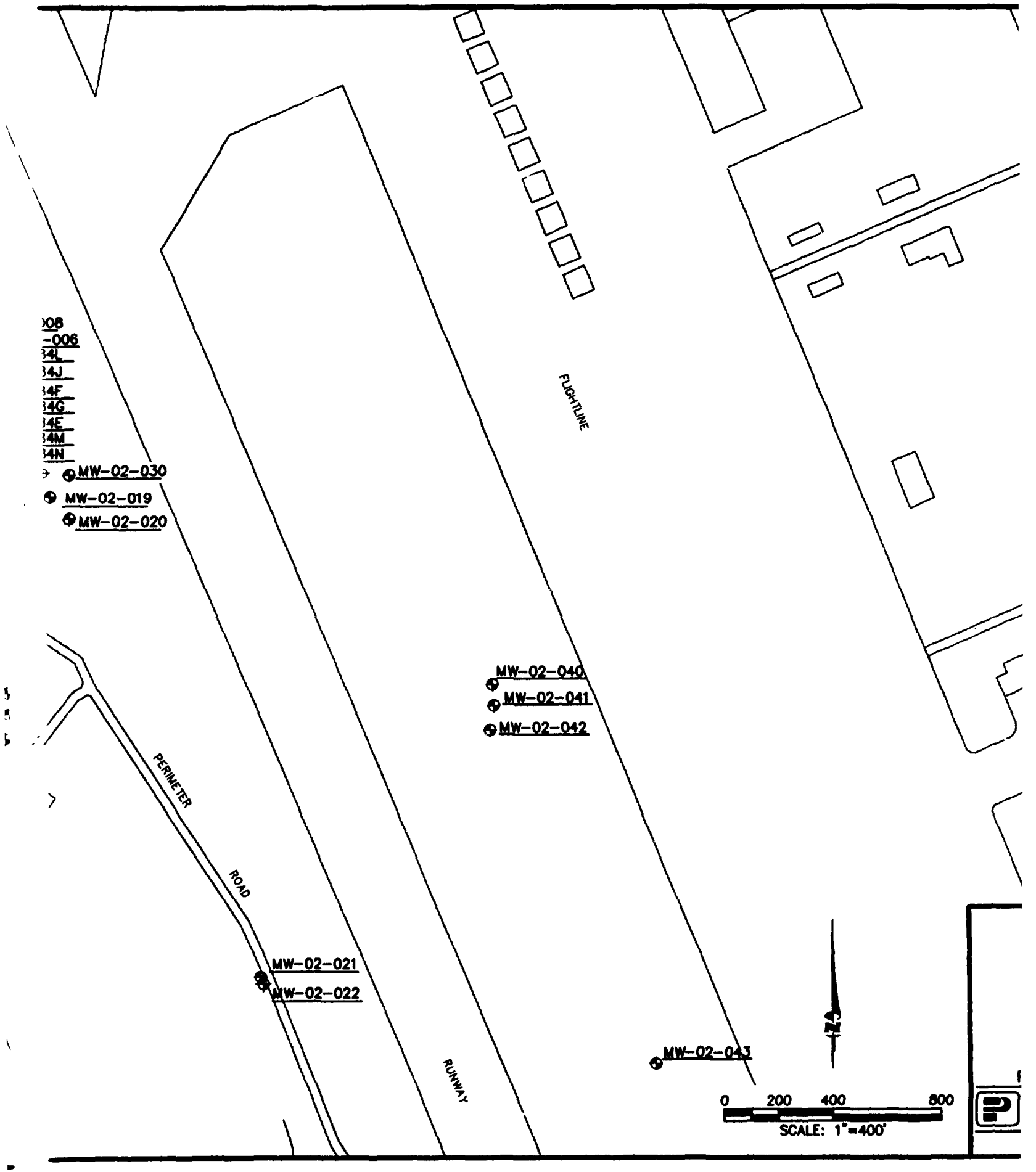
The following sections summarize the procedures that were followed when collecting site-specific data. The soil and ground water profiling and sampling and lithologic logging procedures using the instrumented CPT tool and Geoprobe® are described in Section 2.1. Confirmatory soil sampling procedures are described in Section 2.2. Ground water sampling procedures for existing wells are described in Section 2.3. Details on the sampling strategy and approach are presented in the work plan developed in support of these site characterization activities at the FT-002 site (ES, 1993). Sample analysis procedures are presented in Section 2.4. CPT data interpretation approaches are presented in Section 2.5.

2.1 CPT AND GEOPROBE® SAMPLING

Soil and ground water profiling and sampling using either an instrumented CPT tool or the Geoprobe® were accomplished in two phases under this program. The first phase of the soil and ground water sampling was initiated during the first week of December 1993, and consisted of soil and ground water characterization at 26 locations using an improved, instrumented CPT tool.

Figure 2.1 shows the first phase soil and ground water sampling locations. Table 2.1 summarizes relevant data, including the sample matrix, for each location. CPT tip resistance, friction ratio, and pore pressure measurements were completed at five locations (84B, 84C-1, 84C-2, 84D, and 84E). 84C-2 was completed after cone refusal was encountered at a depth


FT-002
84A
MW-02-026
MW-02-027
MW-02-014
84D
MW-02-011
84C
MW-02-015
MW-02-031
84B
MW-02-005
MW-02-007
MW-02-008
MW-02-006
84L
84J
84F
84G
84E
84M
84N
MW-02-030
MW-02-019
MW-02-020
840
84P
84K
84I
84H
PERIMETER
ROAD
MW-02-021
MW-02-022
LEGEND
MW-02-021
GROUND WATER
MONITORING WELL W/LABEL
84M
LIF-CPT SAMPLING
LOCATION W/LABEL
NOTE:
ONLY SAMPLING LOCATIONS USED
DURING THIS CHARACTERIZATION
EFFORT ARE SHOWN


)08
-006
14L
14J
14F
14G
14E
14M
14N
MW-02-030
MW-02-019
MW-02-020
FLIGHTLINE
MW-02-040
MW-02-041
MW-02-042
PERIMETER
ROAD
MW-02-021
MW-02-022
RUNWAY
MW-02-043
0
200
400
800
SCALE: 1"=400'

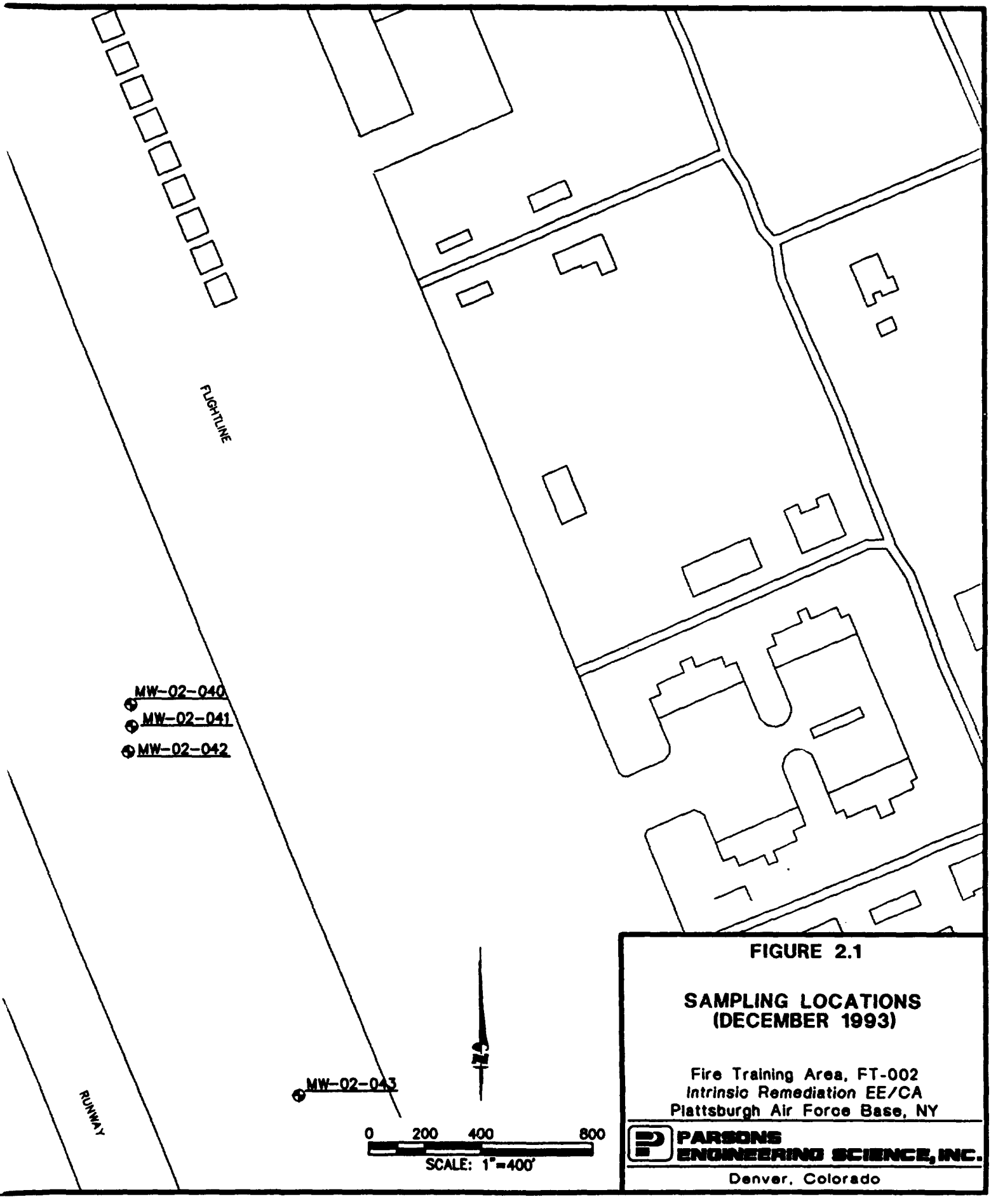


FIGURE 2.1

SAMPLING LOCATIONS (DECEMBER 1993)

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

TABLE 2.1
DECEMBER 1993 SAMPLE LOCATION INFORMATION
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Sample Location	Easting	Northing	Sampled Interval(s) (ft bgs)[a]	Matrix	Sampling Method
MW-02-005	722393.85	1700306.02	37.5	Ground Water	Bailer
MW-02-006	722521.64	1700372.17	34	Ground Water	Bailer
MW-02-007	722521.41	1700354.16	69	Ground Water	Bailer
MW-02-014	722146.23	1700554.89	38	Ground Water	Bailer
MW-02-015	722023.54	1700547.37	39	Ground Water	Bailer
MW-02-019	722797.86	1700166.45	16.5	Ground Water	Bailer
MW-02-020	722807.69	1700165.37	35	Ground Water	Bailer
MW-02-021	723492.61	1698394.41	12	Ground Water	Bailer
[redacted]	721429.01	1700757.23	54.5	Ground Water	Bailer
[redacted]	721430.77	1700751.15	87.5	Ground Water	Bailer
MW-02-030	722808.70	1700172.70	50	Ground Water	Bailer
MW-02-040	724351.63	1699361.02	25	Ground Water	Bailer
MW-02-041	724363.83	1699363.58	40	Ground Water	Bailer
MW-02-042	724368.43	1699352.83	55.5	Ground Water	Bailer
MW-02-043	724953.42	1698070.12	20	Ground Water	Bailer
MW-02-044	725474.64	1697178.35	24	Ground Water	Bailer
[redacted]	721440.00	1700760.00	53' Continuous	Soil	LIF CPT
84B	722267.00	1700360.00	61' Continuous	Soil	LIF CPT
84B	722267.00	1700360.00	34.3, 55.5	Ground Water	CPT-water
84C	722001.00	1700570.00	52' Continuous	Soil	LIF CPT
84D	721963.00	1700610.20	62' Continuous	Soil	LIF CPT
84E	722556.00	1700320.00	31, 51, 67	Soil; Ground Water	LIF CPT, CPT-water
84F	722437.00	1700360.00	56' Continuous	Soil	LIF CPT
84F	722437.00	1700360.00	37, 47, 52, 67	Ground Water	CPT-water
84G	722528.00	1700360.00	46' Continuous	Soil	LIF CPT
84H	722400.00	1700097.09	39' Continuous	Soil	LIF CPT
84I	722411.00	1700240.00	40' Continuous	Soil	LIF CPT
84J	722471.00	1700450.00	43' Continuous	Soil	LIF CPT
84K	722502.00	1700300.10	38' Continuous	Soil	LIF CPT
84L	722373.00	1700460.00	39' Continuous	Soil	LIF CPT
84M	722502.00	1700270.00	40, 60	Ground Water	CPT-water
84N	722643.00	1700250.00	36, 56	Ground Water	CPT-water
84O	722723.00	1700210.00	31, 46	Ground Water	CPT-water
84P	722302.00	1700310.00	26-29.5	Soil	LIF CPT

[a] ft bgs = feet below ground surface

Shading indicates background sampling locations

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of 17.2 feet below ground surface (bgs) at 84C-1. The remaining four pushes were advanced approximately 5 to 10 feet into the water table, with total completion depths ranging from 35.6 to 48.3 feet bgs. Ten LIF-CPT soundings were completed at the site during the first phase of field work to profile the areal and vertical extent of LNAPL contamination in the soil and ground water at the FT-002 site. Emphasis was placed on delineating the areal extent of the LNAPL. LIF CPT soundings were completed at sampling locations 84A, 84B, 84D, 84F, 84G, 84H, 84I, 84J, 84K, and 84L. Sampling location 84A represents the background location for LIF CPT soundings. The depths of these soundings ranged from 38 to 61.7 feet bgs. Soil samples were collected from five locations within 10 feet of LIF CPT sampling locations to confirm the presence and vertical extent of LNAPL contamination suggested by the LIF probe data. Discrete soil samples were collected from sampling locations 84B, 84D, 84F, 84L, and 84P. Discrete ground water samples were collected at various depths from six sample locations (84B, 84E, 84F, 84M, 84N, and 84O) using the discrete-depth ground water sampling apparatus on the CPT tool. The purpose of this ground water sampling strategy was to characterize the nature and extent of ground water contamination within and immediately downgradient from the source LNAPL.

The second phase of site characterization completed under this program was conducted by RSKERL personnel in May 1994, and focused on further defining the nature and extent of the source area for the chlorinated solvent plume. Thirty-three additional sampling locations were completed at the site using the US Army Corps of Engineers (USACE) Site Characterization and Analysis Penetrometer System (SCAPS) to supplement the LIF CPT survey completed in December 1993. Figure 2.2 shows these sampling locations, and Table 2.2 summarizes details of the sampling strategy by sampling location. These additional data confirmed the areal extent of LNAPL present at the site. Ground water samples were also collected from a sampling location (84Q) between Perimeter Road and the runway and the test ground water monitoring points. The Geoprobe® ground water sampling apparatus was used at 84Q; small bailers were used at the ground water monitoring points. Collected ground water samples were analyzed for TCE, trans-DCE, cis-DCE, vinyl chloride, and some of the geochemical parameters indicative of biodegradation.

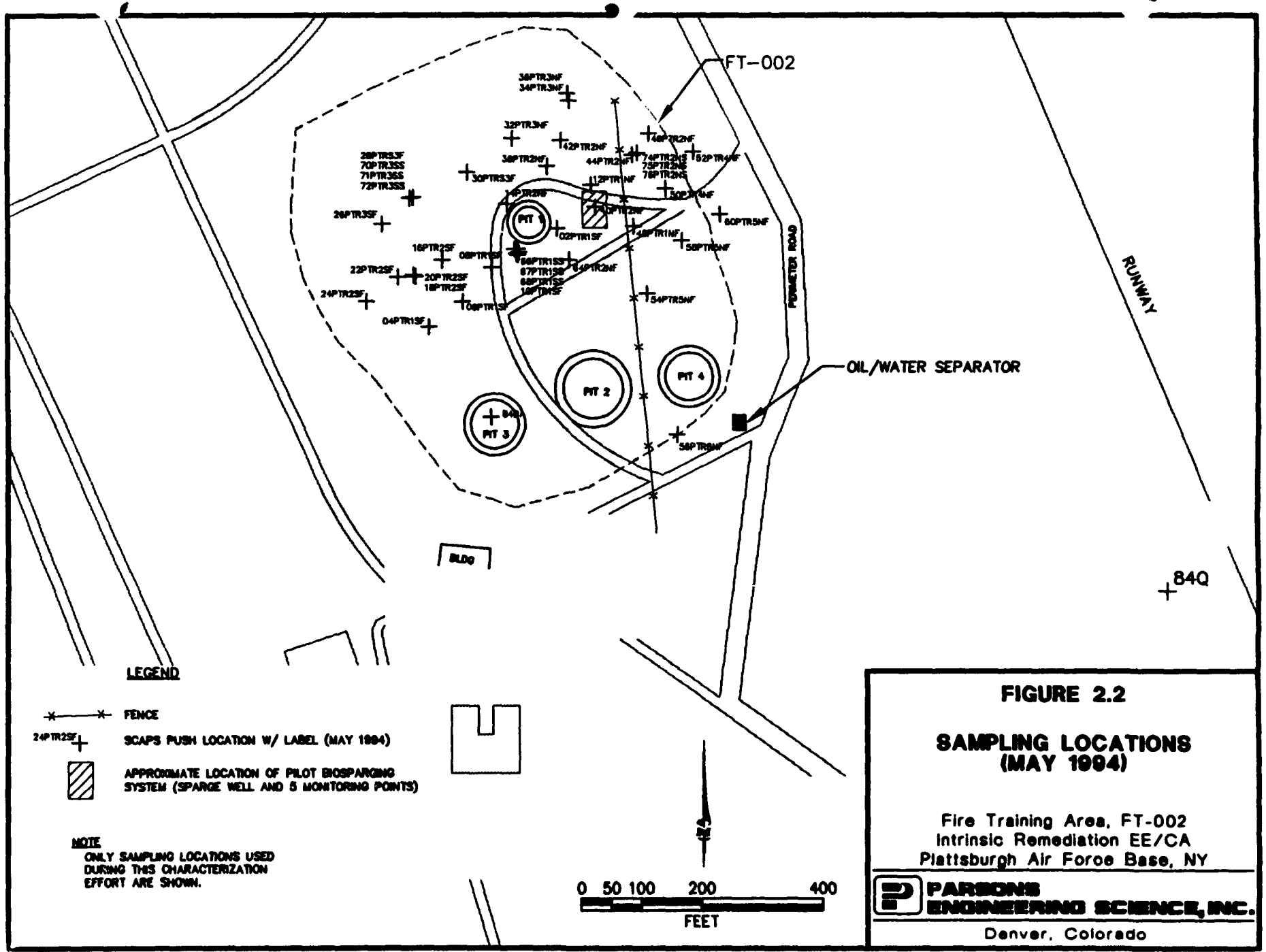
FT-002
OIL/WATER SEPARATOR
PIT 1
PIT 2
PIT 3
PIT 4
BLDG
PERIMETER ROAD
RUNWAY
84Q
LEGEND
FENCE
SCAPS PUSH LOCATION W/ LABEL (MAY 1994)
APPROXIMATE LOCATION OF PILOT BIOSPARGING SYSTEM (SPARGE WELL AND 5 MONITORING POINTS)
NOTE
ONLY SAMPLING LOCATIONS USED DURING THIS CHARACTERIZATION EFFORT ARE SHOWN.
0 50 100 200 400
FEET
FIGURE 2.2
SAMPLING LOCATIONS (MAY 1994)
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY
PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado
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TABLE 2.2
MAY 1994 SAMPLING LOCATION INFORMATION
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Sample Location	Easting	Northing	Sampled Interval(s) (ft bgs)[a/]	Matrix	Sampling Method
O2PTR1SF	722229.65	1700634.14	48' Continuous	Soil; Soil Gas	SCAPS
04PTR1SF	722368.38	1700529.91	52' Continuous	Soil	SCAPS
06PTR1SF	722235.56	1700640.59	49' Continuous	Soil; Soil Gas	SCAPS
08PTR1SF	722310.06	1700642.44	49' Continuous	Soil; Soil Gas	SCAPS
10PTR1SF	722258.87	1700617.55	46' Continuous	Soil; Soil Gas	SCAPS
12PTR1NF	722114.04	1700809.79	47' Continuous	Soil; Soil Gas	SCAPS
14PTR2SF	722309.98	1700739.54	49.5' Continuous	Soil; Soil Gas	SCAPS
16PTR2SF	722433.46	1700596.39	50' Continuous	Soil; Soil Gas	SCAPS
18PTR2SF	722436.94	1700595.86	49' Continuous	Soil	SCAPS
20PTR2SS	722464.36	1700594.83		Soil	SCAPS
22PTR2SF	722538.86	1700583.67	54' Continuous	Soil	SCAPS
24PTR2SF	722433.76	1700505.22	54' Continuous	Soil	SCAPS
26PTR3SF	722385.23	1700607.73	46' Continuous	Soil	SCAPS
28PTR3SF	722464.4	1700688.02	50' Continuous	Soil	SCAPS
30PTR3SF	722407.32	1700719.86	46' Continuous	Soil	SCAPS
32PTR3NF	722181.16	1700795.05	35' Continuous	Soil; Soil Gas	SCAPS
34PTR3NF	722145.85	1700755.28	46' Continuous	Soil	SCAPS
36PTR3NS	722117.35	1700815.19		Soil	SCAPS
38PTR2NF	722203.81	1700619.3	50' Continuous	Soil	SCAPS
40PTR2NF	722109.45	1700671.61	50' Continuous	Soil; Soil Gas	SCAPS
42PTR3NF	722219.28	1700776	50' Continuous	Soil	SCAPS
44PTR2NF	722091.79	1700640.1	46' Continuous	Soil; Soil Gas	SCAPS
46PTR2NF	722061.92	1700855.92	46' Continuous	Soil	SCAPS
48PTR4NF	722089.7	1700520.93	45' Continuous	Soil; Soil Gas	SCAPS
50PTR4NF	721998.1	1700731.56	45' Continuous	Soil	SCAPS
52PTR4NF	721990.07	1700637.78	39' Continuous	Soil	SCAPS
54PTR5NF	721790.69	1700268.34	40' Continuous	Soil	SCAPS
56PTR6NF	722083.24	1700138.63	40' Continuous	Soil	SCAPS
58PTR5NF	721910.2	1700571.23	40' Continuous	Soil	SCAPS
60PTR5NF	721905.83	1700640.5	40' Continuous	Soil	SCAPS
62PTR6NF	721984.14	1700544.05	34' Continuous	Soil	SCAPS
64PTR2NF	722154.26	1700647.03	50' Continuous	Soil	SCAPS
66,67,68PTR1SS	722258.06	1700592.93	11, 20, 39.5	Soil	SCAPS
70,71,72PTR3SS	722405.19	1700718.93	10, 21, 43	Soil	SCAPS
74,75,76PTR2NS	722061.56	1700697.71	13, 33.8, 38	Soil	SCAPS
84Q	N/A	N/A	7.5, 20, 27, 36.5, 44	Ground Water	SCAPS-water
Monitoring Point 1	N/A	N/A	14, 24	Ground Water	Bailer
Monitoring Point 2	N/A	N/A	14	Ground Water	Bailer
Monitoring Point 3	N/A	N/A	14	Ground Water	Bailer
Monitoring Point 4	N/A	N/A	14, 24	Ground Water	Bailer
Monitoring Point 5	N/A	N/A	14	Ground Water	Bailer

a/ ft bgs = feet below ground surface

2.1.1 First-Phase Instrumented Cone Penetrometer Testing

The instrumented CPT tool used during the first phase of soil and ground water characterization activities was originally developed for use in consolidated clay soils. The instrumented CPT tool used in this effort consisted of a probe that is forced into the ground using a hydraulic load frame mounted on a heavy truck, with the weight of the truck providing the necessary reaction mass. The penetrometer equipment was mounted inside an 18-foot van body attached to a 10-wheel truck chassis with a turbo-charged diesel engine. Ballast in the form of metal weights and a steel water tank, which can hold 5,000 pounds of water, can be added to the truck to achieve an overall push capability of 45,000 pounds. This push capability can be limited in tight soils by the structural bending capacity of the push rods, rather than by the weight of the truck. Penetration force was supplied by a pair of large hydraulic cylinders bolted to the truck frame.

A 15-square-centimeter (cm^2) penetrometer probe was used at this site. The penetrometer probe was normally advanced vertically into the soil at a constant rate of 48 inches per minute, although this rate was reduced when the LIF probe was in use. The instrumented probe consisted of a pressure transducer, a resistivity module, and a friction sleeve which independently measured vertical resistance beneath the penetrometer tip as well as frictional resistance on the side of the probe as a function of depth. The depth of each penetration was measured by an extensiometer within the truck. Each depth measurement was verified in the field against a tape measure. All push rods were cleaned and decontaminated with a pressurized steam-cleaning system attached to the CPT truck. Pressurized steam was not applied to the LIF module. All holes generated by the CPT during this phase of the investigation were filled with 0.25-inch bentonite pellets at the end of each day, as specified by Plattsburgh AFB.

2.1.1.1 Pore Pressure Measurements

The instrumented CPT tool was equipped with two load cells to independently measure the vertical resistance against the tip and the side friction along the sleeve. Each load cell was a cylinder of uniform cross section inside the tool, which was instrumented with four strain gauges in a full-bridge circuit. Forces are sensed by the load cells, and the data are transmitted from the probe assembly via a cable running through the push tubes. The analog data were digitized, recorded, and plotted by a computer in the truck. A set of data was

recorded each second, for a minimum resolution of about one data point every 0.8 inch of probe advance into the soil.

Thus instrumented, the probe could sense the pore pressure immediately behind the tip. The sensing element (a pressure transducer) was located behind the probe tip so that the filter was protected from the direct thrust of the penetrometer and the measured pore pressure could be used to correct the tip resistance data. The water pressures in the soil were sensed through a 250-micron porous polyethylene filter that was 0.25-inch high and 0.202-inch thick. The filter and pressure port were saturated with oil to enable the pressure transducer to respond rapidly and correctly to changing pore pressures upon penetration. The magnitude of the penetration pore pressure was a function of the soil compressibility and, most importantly, permeability. In freely draining soil layers, such as those encountered at the FT-002 site, the measured pore pressures were very close to the hydrostatic pressure computed from the elevation of the ground water table. The pore pressure measurements made at the FT-002 site were used to qualitatively determine the degree of saturation and to classify soil. Location-specific penetration profiles that include pore pressure values are presented in Appendix A of this document.

Probe response to saturation was verified with daily field calibrations. For each calibration, the lead penetrometer push rod was placed into the push frame and loaded onto a precision reference load cell. The reference load cell had been calibrated against National Institute of Standards and Technology (NIST) traceable standards prior to mobilizing to the field. The pore pressure transducer was also calibrated daily by inserting it into a pressure chamber with air pressure supplied by the truck-mounted compressor. The reference transducer in the pressure chamber was also calibrated against NIST-traceable standards prior to mobilizing to the field. During calibration of each instrument, the output from the reference device was checked for linearity and repeatability. The calibration results were maintained to develop calibration factors using a linear regression algorithm prior to development of final results. Spikes in the pore pressure data could be (and were) caused by stopping the penetrometer to add another section of push tube.

2.1.1.2 LIF CPT Measurements

The LIF CPT tool measured the fluorescence emitted by hydrocarbon-contaminated soil that had been excited by a beam of laser light focused on the soil. The fluorescence

measurements were recorded as the LIF CPT tool was pushed into the soil. This tool takes advantage of a unique property of hydrocarbon compounds, in that they fluoresce when excited by high-frequency light. The spectral emission is then used to identify the type of contamination at a site. The laser light was generated inside the penetrometer truck using a full-wavelength, tunable dye laser system developed by North Dakota State University (NDSU). The laser system consisted of a neodymium:yttrium aluminum garnet laser (Nd:YAG), a single tunable dye laser, and the necessary optics to focus the light into a fiber optic bundle. The fiber optic bundle consisted of one transmission line surrounded by six collection lines used to capture the soil fluorescence. The fiber optic bundle was used to guide light to and from the LIF module attached to the CPT probe. The LIF system measured the intensity of fluorescence coming into the probe at a wavelength of 340 nanometers (nm). The time delay of this light was recorded by the laser central processing unit (CPU), and averaged over 20 pulses of the laser. The area under the average time-delay curve was then integrated to determine an intensity value. These intensity values were then averaged every 2 seconds as the CPT was advanced, and the average intensity value was then transferred to the CPT computer where it was stored for later use. Intensity values were recorded versus depth for each of the LIF CPT locations.

The LIF probe was calibrated after the potentiometer and the extensiometer calibrations by placing a cuvette containing 1 percent JP-4 on sand next to the measurement window. The fluorescence response was then set to 2,048 on the CPU. Thus, the LIF "count" was set to represent 1/2,048 (1 bit) of the area under the time-delay curve of the calibration mixture. The LIF was used only to qualitatively locate BTEX (JP-4) in soil and ground water. No quantitative correlation between intensity response and degree of contamination was established.

A minimum of 41 points were used to establish a baseline value for the LIF data to eliminate hole-to-hole variance in the laser intensity. This baseline value was then subtracted from all measurements so that LIF profiles from different locations could be compared directly (i.e., equipment variances were eliminated). LIF profiles completed during the first phase of this field effort are presented in Appendix A of this document.

2.1.1.3 Resistivity

Resistivity measurements are based on the ease with which an electrical current can pass through the soil, rock, and fluid within the subsurface. Resistivity is a function of the soil type, degree of consolidation, pore fluid, and ion concentration (conductivity). Soil resistivity is influenced primarily by the water content and ion concentration within the pore space. Saturated soils and clay soils with high ion concentrations will have lower resistivities than unsaturated soils or sands and gravels. Hydrocarbon compounds will have higher resistivities than pore water, which allows a distinction between contaminated and uncontaminated soil. The contrast in resistivity was used to locate mobile LNAPL at the FT-002 site and to distinguish lithology. Location-specific penetration profiles that incorporate resistivity data and soil classification results are presented in Appendix A of this document.

The CPT tool used in the first phase of this field effort was equipped with a resistivity probe to enable direct contact with the soil and pore fluid. This assembly minimizes data errors associated with the intrusion of drilling fluids into borehole walls, which can change the resistivity of the adjacent medium, and complicating influences from any casing material. The resistivity probe consisted of four electrodes separated by high-strength Kevlar® plastic-reinforced insulators. The outer two electrodes induced an electrical current into the soil and the inner two electrodes measured the return current and the associated voltage drop between the electrodes, which is proportional to the resistivity of the soil. The four-electrode array was operated at a frequency of 40 hertz to avoid polarization effects. The current and potential measurement signals were modulated and demodulated during operation. The resistivity probe was calibrated in the field before each individual site was measured. The calibration was performed using a water solution in which conductivity was varied over a known range. The data from each calibration were used to determine the location-specific calibration factor, which is also dependent upon probe geometry.

2.1.2 Second-Phase Instrumented Cone Penetration Testing

The second phase of the field activities completed at the FT-002 site was conducted by researchers from the RSKERL. The emphasis of site characterization activities at this time was delineating the nature and extent of the chlorinated solvent plume within the suspected source area and augmenting existing data on the extent and degree of LNAPL contamination at the site.

A SCAPS from the USACE was used during this sampling event to measure reflectance of LIF and resistivity of soil and ground water at the FT-002 site. The SCAPS is similar to the LIF CPT used in the first phase of the field work. The conical rods used in the SCAPS were equipped with LIF, resistivity, and pore pressure sensors to identify the areal and vertical extent of the LNAPL source. As during the first phase of the field work, the LIF sensor on the SCAPS was used to make fluorescence measurements of the soil and ground water as the SCAPS was advanced. The spectral emission can be used to identify the type of contamination at a site. The basic premise and operating characteristics of an LIF probe are described earlier in section 2.1.1.2. The SCAPS used during this second phase of field work also was equipped to make resistivity and pore pressure measurements to aid in soil classification and contamination profiling. Location-specific penetration profiles develop during the SCAPS effort, which incorporate LIF data, resistivity data, and soil classification results, are presented in Appendix A of this document.

The SCAPS was also used to collect and analyze soil gas samples for oxygen (O_2), total hydrocarbons, carbon dioxide (CO_2), methane (CH_4), and total halogens. Gaseous concentrations of CO_2 and O_2 were analyzed using a GasTech® model 32520X CO_2/O_2 analyzer. Meters were calibrated each day prior to use against purchased CO_2 and O_2 calibration standards. These standards were selected to closely match the concentration range of the soil gas expected at the FT-002 site. The CO_2 calibration was performed against atmospheric CO_2 (0.05-percent) and a 5-percent standard. The O_2 calibration was completed using atmospheric O_2 (20.9-percent) and 5-percent and 0-percent O_2 standard. Petroleum hydrocarbon concentrations were analyzed using a GasTech TraceTechtor™ hydrocarbon analyzer.

2.2 CONFIRMATORY SOIL SAMPLING

The first phase of the field effort at the FT-002 site also included collecting and analyzing soil samples from continuous cores to compare with data provided by the instrumented CPT tool. Emphasis was placed on verifying the vertical extent of contamination, ground water surface elevation, and soil classification. Continuous soil cores were taken at five locations (84B, 84D, 84F, 84L, and 84P) with the intent of providing approximately 0.5-foot resolution on the LIF CPT data. The 2-foot Mostap® sampler was used at this site to collect relatively undisturbed soil samples at discrete depths. The sampler was attached to the CPT push rods,

and locked into position to prevent soil from entering the soil sample tube during penetration. The sampler was pushed to the beginning of the 2-foot interval at which the soil sample was to be collected, and the sampler was unlocked to allow soil to enter the soil sample tube. The sampler was then pushed through the length of the sample interval to capture the soil core, and then pulled to the ground surface as quickly as possible. All soil samples were collected in split-spoon samplers that were decontaminated by pressurized steam cleaning prior to each sampling event.

Samples were collected continuously to the same depth as the initial CPT penetration. The soil samples collected were removed from the sampler in two foot intervals and placed on clean aluminum foil. Confirmatory lithologic logging was completed in the field. An aliquot of each 2-foot sample was then packed into clean glass jars for laboratory analysis. Care was taken to not disturb sample integrity.

In addition, another aliquot of the soil sample was placed in a second clean glass jar for photoionization detector (PID) headspace measurements for volatile organic compounds (VOCs). This sample was sealed with aluminum foil and held for 15 minutes at an ambient temperature of 65 degrees Fahrenheit (°F) or greater. Semiquantitative measurements were made by puncturing the aluminum foil seal with the PID probe and reading the concentration of the headspace gases. The PID relates the concentration of total VOCs in the sample to an isobutylene calibration standard. Calibration of the PID to the isobutylene standard was completed daily before soil sampling commenced. The PID was also used to monitor the worker breathing zone.

A detailed descriptive log of subsurface materials recovered was maintained to compare to the soil classification data obtained from the CPT tool. Representative samples were also photographed. Final lithologic logs of these confirmatory samples are presented in Appendix A.

2.3 GROUND WATER SAMPLING

This section describes the procedures used during both phases of the field work for collecting ground water quality samples using the CPT sampling apparatus and Geoprobe®, and from existing ground water monitoring wells and new ground water monitoring points. In order to maintain a high degree of quality control during each sampling event, the

procedures described in the following sections were followed. Details on sampling procedures are also presented in the work plan developed by Parsons ES (ES, 1993b).

The procedures used to collect ground water samples using the CPT sampling apparatus during the first phase of the field work are described in Section 2.3.1. The procedures used to collect ground water samples from existing ground water monitoring wells and newly installed ground water monitoring points are described in Section 2.3.2. Ground water quality samples were also collected by RSKERL personnel during the second phase of field work using a Geoprobe®. These procedures are presented in Section 2.3.3. In addition to the sampling events conducted under this program, several other ground water sampling events have been previously completed at this site. Ground water screening data collected during the CPT survey completed in 1991 by ABB Environmental, Inc. (1992) were used to supplement data collected under this program.

2.3.1 CPT Water Sampling

Ground water samples were collected using the CPT water sampling apparatus at six different locations near previous CPT locations (84B, 84E, 84F, 84M, 84N, and 84O) at various depths to characterize the existing nature and extent of ground water contamination and the potential effectiveness of naturally occurring attenuation mechanisms within and immediately downgradient of the suspected source area.

The CPT was equipped with a water sampling apparatus that was locked into place to prevent water from entering the sample collection chamber during penetration. The CPT water sampling apparatus consisted of an air-tight and water-tight sealed intake screen and sample chamber that was isolated from the surrounding environment as the tool was advanced. The tight seal, which is created as the soil is displaced and compacted during penetration, allows for the collection of a discrete sample from a specific depth.

The CPT data from previous pushes were consulted to determine the depth to ground water at the sample location. The penetrometer rods were pushed to the desired depth, and the water sampler was unlocked. The penetrometer rod was then withdrawn approximately 1 foot to allow ground water to enter the perforated intake screen and sample collection chamber. The water table was allowed to equilibrate to the static water level as indicated by earlier CPT data within the sampling chamber. An electric water level indicator was used to

monitor water recovery rates. Equilibration occurred rapidly in these sandy soils, and was complete in all cases in less than 10 minutes.

A pre-cleaned Teflon® bailer was used to collect ground water samples from the CPT sampling chamber. No purging was performed. A new pair of disposable, nitrile gloves were worn by the sampler at each new sample location and depth. Collected ground water samples were carefully transferred to labeled sample containers (preservatives were added onsite, as necessary), and transferred to the onsite laboratory staffed by RSKERL personnel. Details on analytical methods performed onsite are presented in Section 2.4. No chemical parameters were measured in the field at these locations. The electric water level probe, the Teflon® bailer, and all components of the CPT sampling apparatus were thoroughly cleaned prior to each penetration and sample collection event first using the pressurized steam cleaner (potable water) and subsequently rinsed with de-ionized water.

2.3.2 Sampling Existing Monitoring Wells and New Ground Water Monitoring Points

Ground water samples were collected from 16 existing ground water monitoring wells (MW-02-005, MW-02-006, MW-02-007, MW-02-014, MW-02-015, MW-02-019, MW-02-020, MW-02-021, MW-02-026, MW-02-027, MW-02-030, MW-02-040, MW-02-041, MW-02-042, MW-02-043, MW-02-044) in December 1993, to characterize the existing nature and extent of ground water contamination at and migrating from the FT-002 site and to assess the potential effectiveness of naturally occurring attenuation mechanisms at removing contaminant mass from the aquifer and minimizing plume expansion (Figure 2.1). Ground water sampling locations MW-02-026 and MW-02-027 were identified as background locations because the wells are upgradient from and apparently unaffected by site-related contamination. Several existing ground water wells in the source area were not sampled during this investigation because it was determined that source area contamination would be adequately defined by using analytical data from specific wells supplemented with analytical data taken during CPT-water sampling. Five newly installed ground water monitoring located within the suspected source area at depths of 14 feet and 24 feet bgs [point 1 (shallow and deep), point 2 (shallow only), point 3 (shallow only), point 4 (shallow and deep), and point 5 (shallow only)] were used to collect ground water samples in May 1994 to supplement existing contaminant data and to assess the treatability of ground water contaminated with chlorinated solvents (Figure 2.2).

The static water level in the well and monitoring point was measured with an ORS® oil/water interface electric probe. The depth to ground water was measured from the measurement datum (north side of well casing) to the nearest 0.01 foot. After measurement of the static water level, the oil/water interface probe was lowered to the bottom of the well to measure the total well depth (recorded to the nearest 0.01 foot). The DO content of each well and monitoring point was measured before purging and after sample collection using a portable YSI® Model 50B DO meter. The procedures followed during this measurement are presented in Section 2.4.1.

Only existing ground water wells were purged prior to sampling. Newly installed monitoring points were not purged. The total volume of water to be purged from each existing ground water monitoring well was based on the saturated length of the well casing. Three times the calculated saturated casing volumes were removed from each well prior to sampling. A dedicated disposable, polyethylene bailer with a dedicated lifting line was used for well purging and sampling. The well was allowed to recharge to within 10 percent of the initial static water level before a sample was collected for analysis. No samples were composited.

To obtain a sample for analysis of chemical parameters, the disposable polyethylene bailer was gently lowered into the well or monitoring point to prevent splashing and to avoid creating a vacuum in the well. The bailer was allowed to fill, and then pulled smoothly to the ground surface. Collected water samples were transferred directly to the appropriate sample containers, which were prepared with the necessary preservatives at the sample location. All water samples were transferred from the bailer to the sample container by discharging the sample from the top. The water was carefully poured down the inner walls of the sample container to minimize aeration of the sample. Details on sample analysis procedures and onsite measurement procedures (e.g., for DO) are presented in Section 2.4.

2.3.3 Geoprobe® Water Sampling

The second phase of ground water sampling conducted at the FT-002 under this program was completed by researchers from the RSKERL using a Geoprobe®. Ground water samples were collected at one sampling location (84Q) at various depths to supplement existing data on the extent and degree of chlorinated solvent contamination in ground water downgradient of the site. One ground water sample was also collected from existing ground water

monitoring well MW-02-043 during this phase of the field work. All of these ground water samples were analyzed for trans-DCE, cis-DCE, TCE, and vinyl chloride. No onsite measurement of physical or chemical parameters was completed.

Prior to taking a sample of ground water using the Geoprobe®, the static water level was measured using a manometer. The manometer was inserted into the high-density polyethylene (HDPE) tubing through which the ground water sample would be acquired. The manometer tube was then marked at the level of the ground surface and removed from the ground. Depth to ground water was determined by placing a tape measure next to the HDPE tubing and measuring the length from the base of the tubing to the ground level mark to the nearest 0.1 foot. Sampling depth was measured to the nearest 0.1 foot by noting the length of each section of Geoprobe® sampling rod placed in the ground.

A peristaltic pump was used to extract ground water samples from the Geoprobe® sampling point. Prior to sample collection, ground water was purged using the peristaltic pump until DO and temperature readings, which were monitored in the field, stabilized. The samples were transferred directly to the appropriate sample container, which contained the necessary preservatives. The water was carefully poured down the inner walls of the sample bottle to minimize aeration of the sample. A clean pair of disposable, nitrile gloves was worn at each sampling location by the sampler. Details on chemical analysis procedures used to develop analytical results on chlorinated solvents are presented in Section 2.4.5.

2.4 CHEMICAL PARAMETER MEASUREMENT AND SAMPLE ANALYSIS

DO, temperature, and pH were measured at each ground water sampling location at the time of sample collection, in addition to the depth to ground water. All other parameters measured under this program were completed in the onsite mobile laboratory, staffed by RSKERL personnel, or shipped to the RSKERL analytical laboratory, located in Ada, Oklahoma. The following discussion summarizes the methods used to make onsite measurements and to quantitatively analyze both soil and ground water samples for specific chemical characteristics.

2.4.1 Onsite Dissolved Oxygen Measurements

DO measurements were taken at existing ground water monitoring well sample locations using a YSI® Model 50B DO meter equipped with a YSI® Model 5739 DO probe with KCl solution and membrane. DO was not measured for use in site characterization activities at CPT water and Geoprobe® sampling locations under this effort. The DO meter was calibrated daily relative to air-saturated water. The calibration of the DO meter was occasionally verified in the field, and adjusted as necessary. The DO probe was lowered gently into the first 2 feet below the ground water surface, both before purging and after sample collection for analysis, to measure the DO concentration at the sample point. The probe was slowly agitated within the water column at a rate of about 2 feet per minute to develop the necessary oxygen differential across the probe membrane. DO concentrations were recorded in the field notebook and on the sampling form after the readings stabilized within 0.02 milligrams per liter (mg/L), and in all cases, the final recorded values represented the lowest DO measurement observed.

2.4.2 Onsite pH and Temperature Measurements

The pH and temperature of the ground water was measured at existing ground water monitoring wells and CPT water sampling locations using an Orion® 290A portable pH/ISE meter and an optional Orion® Ross 8165BN pH probe. The pH meter was calibrated daily using two standards at pHs of 7 and 10 standard units, given the expected pH of the ground water samples. The temperature was measured using the temperature function of the DO meter described previously. The pH was measured onsite using a sample of ground water collected from the sample location after all sample containers had been filled. The sample to be measured was poured into a clean glass container. The pH probe was placed in the container, and the solution was slowly swirled around the probe until the readings stabilized within 0.1 pH unit. The measured value was recorded in the field notebook and on the sampling forms. Care was taken to ensure that the sample was not subject to temperature changes during pH measurement. The temperature of the ground water was measured using the procedures described in Section 2.4.1.

2.4.3 Reduction/Oxidation Potential Measurements

Biotic microenvironments can be characterized by reduction/oxidation (redox) levels that are different from those prevalent in the surrounding environment. Direct redox measurements were made at the FT-002 site to provide boundary conditions on redox patterns. The goal of these measurements was to predict equilibration states of redox-sensitive reactions. Although absolute Eh measurements are problematic, relative differences between observed and computed equilibria can provide valuable information on the system's properties and the potential for biological activity. The sample to be measured was poured into a clean glass container, capped, and transported to the onsite mobile RSKERL laboratory. The net potential of collected ground water samples was directly measured in millivolts in the onsite mobile laboratory staffed by the RSKERL researchers. These data have been converted to pE, which gives the hypothetical electron activity at equilibrium and expresses the relative tendency of a solution to transfer or accept electrons, to facilitate interpretation of site characterization data.

2.4.4 Onsite Mobile Laboratory Chemical Analysis Methods

The following sections briefly describe the analytical procedures and methods used to measure chemical compounds in soil and ground water samples collected during the first phase of FT-002 site investigation.

2.4.4.1 Indicator Analytes

An onsite mobile laboratory staffed by RSKERL personnel was used to determine several indicator analytes in ground water samples taken from existing ground water monitoring wells and CPT water sample locations.. The laboratory used colorimetric (i.e., HACH™) methods and portable meters to measure ferrous iron and specific conductance. These analyses were completed for each sample of ground water collected from the sampling location after all sample containers had been filled. The sample to be analyzed was poured into a clean glass container, capped, and transported to the RSKERL onsite mobile laboratory for analysis. The field holding time for each sample did not exceed 0.5 hour. Care was taken to prevent the samples from temperature changes and exposure to sunlight. Indicator analytes were not quantitatively characterized in soil samples.

2.4.4.2 Soil Analysis

Each of the collected soil samples were analyzed onsite for TPH and JP-4 concentrations. A modified USEPA Method 418.1 was used to quantify TPH and JP-4 concentrations. Organic vapor meter (OVM) measurements were also completed. All other soil analytical work was completed offsite.

2.4.5 Offsite Laboratory Chemical Analysis Methods

Samples were packaged onsite and sent to the RSKERL laboratory in Ada, Oklahoma. Water samples to be sent offsite were preserved with H_2SO_4 at the time of sample collection. All samples were placed into a cooler containing ice to maintain a shipping temperature of 4 degrees centigrade (°C).

2.4.5.1 Soil Analyses

Soil core extracts were analyzed for 15 compounds of interest, including, benzene, toluene, ethylbenzene, p-xylene, m-xylene, o-xylene, 1,3,5-trimethylbenzene (1,3,5-TMB), 1,2,4-trimethylbenzene (1,2,4-TMB), 1,2,3-trimethylbenzene (1,2,3-TMB), 1,3-dichlorobenzene (1,2-DCB), 1,4-dichlorobenzene (1,4-DCB), 1,2-dichlorobenzene (1,2-DCB), naphthalene, 2-methylnaphthalene, and 1-methylnaphthalene. Dichloroethene (DCE) was not quantified due to its presence as an impurity in the methylene chloride extraction solvent. The analytical method used for soil extracts was a modification of RSKSOP-124, using a gas chromatograph/mass spectrometer (GC/MS). Quantitation was based on calibration curves of a single target ion for each compound with the addition of up to two qualifier ions recorded to verify chromatographic separation or purity. The ions chosen were those listed in USEPA Method 524.2, revision 3.0, except for the methylnaphthalenes, which are not listed in any USEPA Method. The lower limit of quantitation was 0.1 part per million (ppm) except for the naphthalenes where the lower limit of quantitation was 0.5 ppm due to carryover between injections. Dilution of some sample extracts was necessary to keep concentrations within the upper level of the calibration curve.

2.4.5.2 Ground Water Analyses

Collected ground water samples were analyzed by RSKERL using a number of methods. Aqueous samples were analyzed by purge-and-trap/GC:flame ionization detector(FID)-PID for BTEX, TMBs, and total fuel hydrocarbons. All samples were stored at 4°C until analyzed. The method of analysis was RSKSOP-133, "Simultaneous Analysis of Aromatics and Total Fuel Carbon by Dual Column-dual Detector for Ground Water Samples." Aqueous TOC was analyzed using the RSKSOP-102 method.

Water samples were also analyzed for carbon dioxide, methane, and ethylene. The samples were prepared as per RSKSOP-175. Analysis and calculations of carbon dioxide were performed as per RSKSOP-114; and analysis and calculations for methane and ethylene were performed as per RSKSOP-147 (FID).

Several water samples were also analyzed for nitrite and nitrate (USEPA Method 353.1), ammonia (USEPA Method 350.1), total phosphate (USEPA Method 360.1), and total alkalinity (USEPA Method 150.1). Chloride and sulfate concentrations were analyzed using Water's capillary electrophoresis method N-601. The "floating product" sample collected from MW 02-015 was analyzed for identification and semiquantitation of organic compounds using GC/MS. Chromatographic separation was performed using 30 meter (m) X 0.25 millimeter (mm) Restek® Stabilwax capillary column in series with a 100 m X 0.25 mm J&W® DB-1 Petrocol capillary column (total length = 130 m).

The chlorinated solvents were analyzed using headspace GC/MS for vinyl chloride, trans-DCE, cis-DCE, and TCE. RSKSOP-148 ["Determination of Volatile Organic Compounds in Water by Automated Headspace Gas Chromatography/Mass Spectrometry (Saturn II Ion Trap Detector)"] was used for this analysis. An internal standard calibration method was established for the four compounds. The standard curves for vinyl chloride, trans-DCE, and TCE ranged from 1.0 to 2,000 parts per billion (ppb). The standard curve for cis-DCE ranged from 1.0 to 10,000 ppb. The lower quantitation limit for all compounds was 0.5 ppb. The internal standard was fluorobenzene at a concentration of 100 ppb in the headspace vial.

2.5 CPT DATA INTERPRETATION

The data collected using the instrumented CPT probe and the SCAPS were used to determine soil classification as a function of depth. The methodology employed was based

on specific empirical correlations developed by Timian *et al.*, (1992). Clean, coarse-grained soils generally have high strengths with relatively low sleeve friction, whereas finer-grained soils show low strength and greater cohesion (high sleeve friction). A correlation also exists between soil type and the ratio of tip stress to pore pressure response. Clean, coarse-grained soils are high strength, permeable, and develop little or no excess pore pressure during penetration. Fine-grained soils are weaker, impermeable, and develop high excess pore pressure during penetration.

Soil classification was developed from CPT and SCAPS data by comparing normalized tip resistance to both the pore pressure ratio and the normalized friction ratio. Both comparisons result in a classification zone number, which can be used to determine the Unified Soil Classification System (USCS) profile. The soil types that can be classified using these methods are as follow: sensitive clay, soft clay, clay, silty clay, clayey clay, sandy fine grained, sand mixture, sand, gravelly sand, and over consolidated.

The two methods were then reconciled into a single unified classification by accounting for both the similarities and differences between the two types of data comparisons. A point-by-point weighted average was the preferred method of reconciliation for soil classification. A vertical resolution of 1 foot was achieved on the CPT and SCAPS data for the FT-002 site. Layer thicknesses and soil types were determined based on the mean of the soil classification number. In some instances, the CPT and SCAPS data fell outside the range of the classification chart. When this occurred, no data were plotted, and a break in the classification profile was noted. Appendix A presents the resulting soil classification stratigraphy for the FT-002 site from the CPT and SCAPS data collected under this program.

2.6 SAMPLING LOCATION SURVEY

The location and elevation of new sampling locations were surveyed by Applied Research Associates (ARA) following the first phase of the field work, and by a registered surveyor provided by USACE following the second phase of the field work. The newly installed air sparging system was not surveyed. Horizontal locations were measured relative to established monuments. Horizontal coordinates were measured to the nearest 1 foot. Vertical location of the ground surface adjacent to the well casing and the measurement datum (top of the PVC well casing) were measured relative to a US Geological Survey

(USGS) mean sea level datum. The ground surface elevation was measured to the nearest 0.1 foot, and the measurement datum elevation was measured to the nearest 0.01 foot.

2.7 RESULTS OF AIR SPARGING TREATABILITY TEST

A limited air sparging treatability test was conducted within the source area at Site FT-002 in May 1994 to assess the potential effectiveness of this remedial technology on dissolved chlorinated solvents. An air sparging well (ASW) was installed at the suspected source area for the injection of atmospheric air within the zone of contaminated ground water. Five multiple-depth ground water monitoring points were also installed at distances from the ASW ranging from 3 to 20 feet for the collection of ground water samples during testing.

Air was injected into the ASW for 6 days at an air pressure of about 15 pounds per square inch (psi) and an air flow rate of 80 cubic feet per hour (scfh). Ground water samples were collected every other day and analyzed for TCE, cis-DCE, trans-DCE, and vinyl chloride to assess the effectiveness of the pilot system in removing these VOCs from groundwater. Table 2.3 summarizes the results of the ground water analytical sampling.

Concentrations of dissolved chlorinated compounds were reduced at all sampling points during the 6-day pilot test. TCE concentrations were reduced by an average of 15 percent. Generally, the highest removal rates occurred in the monitoring points that contained the highest initial concentrations of dissolved constituents. For example, the TCE concentration in ground water monitoring point 84SP2 at a depth of 14 bgs, which contained the highest initial TCE concentration in the pilot test area, was reduced by 69 percent. Concentrations of both DCE isomers were reduced by approximately 30 percent, and vinyl chloride concentrations dropped by 19 percent during the pilot test. A conservative radius of influence of 20 feet was observed during the pilot test.

These results suggest that air sparging could facilitate remediation of the chlorinated solvent concentrations. The dissolved constituents could be stripped from the ground water into the vadose zone, where they could then be recovered and treated using a SVE system with off-gas treatment, if required. However, due to the short duration of this initial air sparging treatability test, the reduction in the concentration of dissolved chlorinated solvents could also be the result of the outward displacement of the contaminated ground water rather than remediation. Thus, Parsons ES recommends that a long-term (i.e., 90-day) pilot test be

TABLE 2.3
SUMMARY OF TEST SPARGING SYSTEM DATA, MAY 1994
Fire Traning Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Ground Water Monitoring Point	Depth of Screened Interval (feet bgs)	Distance from Air Sparging Well (feet)	TCE Concentration (ppb)[a]			Percent Change	cis-DCE[b] Concentration (ppb)			Percent Change
			15-May	17-May	21-May		15-May	17-May	21-May	
Monitoring Point 1	14	10	4.44	4.58	5.29	19%	840	834	847	1%
Monitoring Point 1	24	10	23.10	21.80	15.80	-32%	187	167	167	-11%
Monitoring Point 2	14	20	162.00	131.00	49.50	-69%	731	433	193	-74%
Monitoring Point 3	14	3	10.40	6.66	8.38	-19%	578	529	465	-20%
Monitoring Point 4	14	10	9.87	17.80	9.62	-3%	848	751	817	-4%
Monitoring Point 4	24	10	14.80	18.60	14.00	-5%	3460	1590	1590	-54%
Monitoring Point 5	14	20	4.73	5.99	4.99	5%	324	220	154	-52%
			Average Concentration Change			-15%	Average Concentration Change			-30%

Ground Water Monitoring Point	Depth of Screened Interval (feet bgs)	Distance from Air Sparging Well (feet)	trans-DCE[c] Concentration (ppb)			Percent Change	Vinyl Chloride (ppb)			Percent Change
			15-May	17-May	21-May		15-May	17-May	21-May	
Monitoring Point 1	14	10	34.90	37.60	33.10	-5%	233.00	217.00	230.00	-5%
Monitoring Point 1	24	10	228.00	281.00	177.00	-22%	167.00	194.00	146.00	-13%
Monitoring Point 2	14	20	137.00	89.50	20.90	-85%	29.90	15.90	4.44	-85%
Monitoring Point 3	14	3	52.50	47.00	27.30	-48%	537.00	505.00	484.00	-10%
Monitoring Point 4	14	10	67.10	60.60	67.00	0%	459.00	468.00	473.00	3%
Monitoring Point 4	24	10	233.00	229.00	170.00	-27%	195.00	190.00	176.00	-10%
Monitoring Point 5	14	20	55.80	59.20	54.70	-2%	717.00	634.00	611.00	-15%
			Average Concentration Change			-27%	Average Concentration Change			-19%

a/ TCE = trichloroethene; ppb = parts per billion in ground water.
b/ cis-DCE = cis-dichloroethene.
c/ trans-DCE = trans-dichloroethene.

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conducted to verify the radius of influence and uniformity of treatment. This long-term pilot test is discussed further in Section 7.3 as part of the comparative analysis of remedial alternatives.

SECTION 3

PHYSICAL CHARACTERISTICS OF THE STUDY AREA

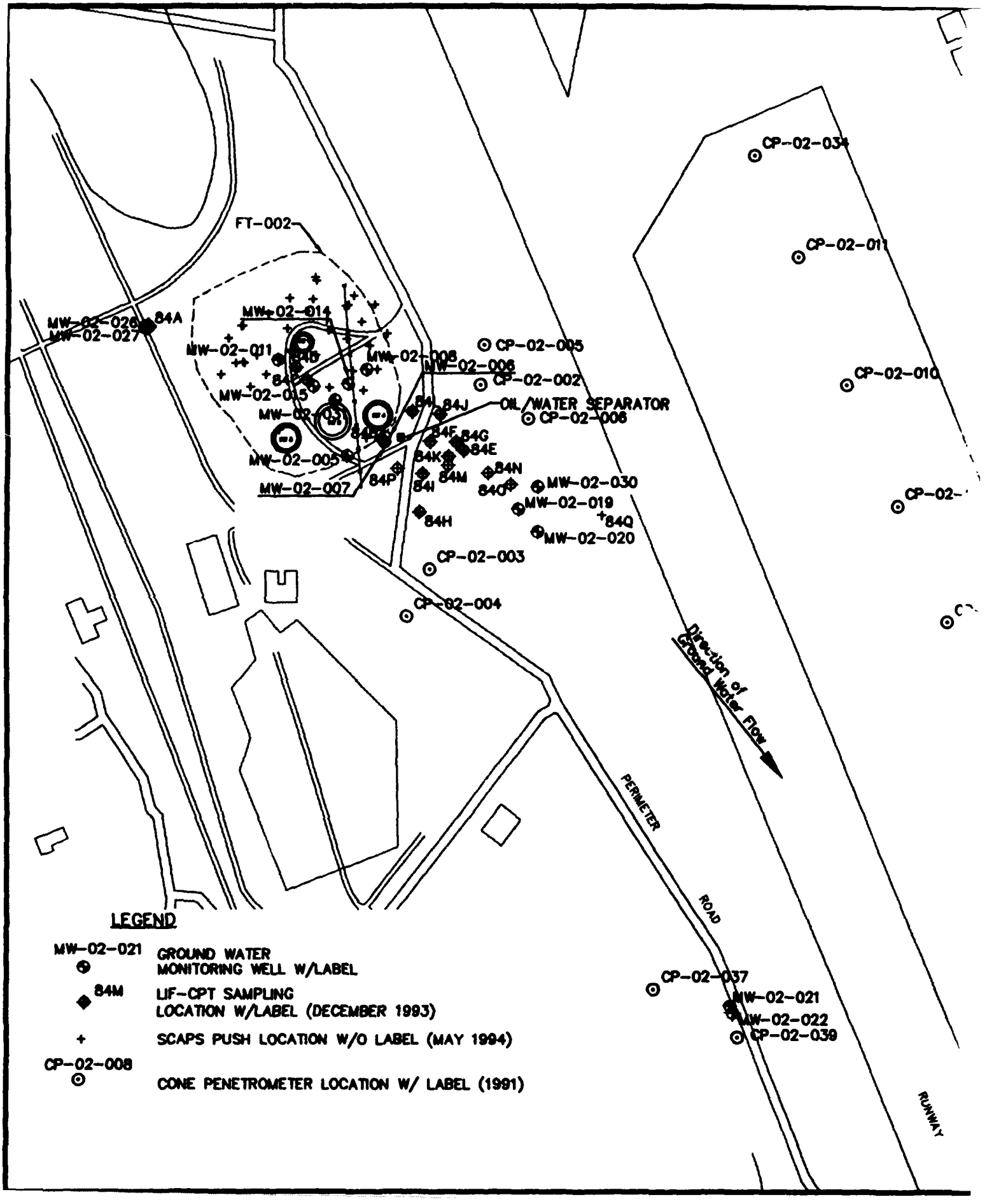
3.1 INTRODUCTION

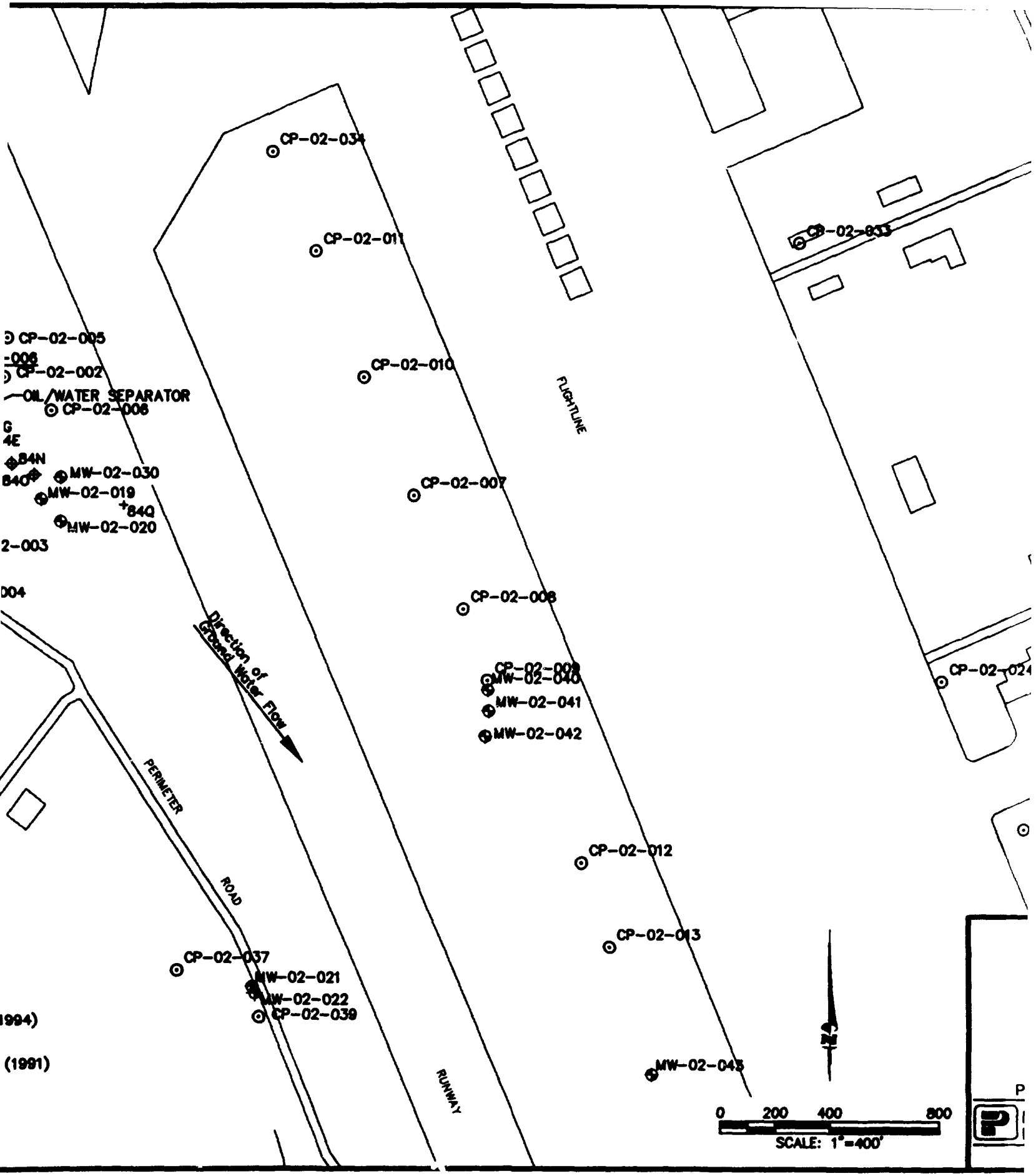
This section describes the physical characteristics of the FT-002 site as determined from data collected during previous investigations conducted under the IRP and by Parsons ES in conjunction with RSKERL in December 1993 and May 1994. The investigative techniques used in previous investigations to characterize soil and ground water at the site are summarized in the relevant data reports (Radian, 1985; E.C. Jordan, Co., 1989a, 1989b, 1990, 1991a, and 1991b; ABB Environmental Services, Inc., 1992; ABB Environmental Services, Inc., and URS Consultants, Inc., 1993; URS Consultants, Inc., 1993). The investigative techniques used by Parsons ES and RSKERL to determine the physical characteristics of the FT-002 site are presented in Section 2.

3.2 SURFACE FEATURES

Figure 3.1 is a generalized map showing the major features at and downgradient of FT-002. The general surface features on and adjacent to the FT-002 site consist of the fire training area proper, paved and dirt roads, the runway and flightline, and the drainage area between the runway and the flightline. Three fire training pits can be identified by surface features at the site. Pits 2 and 3 are easily recognized by the presence of berms and cement-stabilized soil liners. Pit 1 has no visible lining or berm, but can be identified from distressed vegetation on its north side and from aerial photographs as a slight land surface depression. The fourth fire training pit, Pit 4, was the most difficult to discern and was not located until the Phase II RI. Pit 4 still has a slight berm, which can be identified on a 2-foot contour interval topographic map (ABB Environmental Services, Inc., 1992).

A partially buried fuel storage tank, which was located south of Pit 1, was removed in the fall of 1990. The soil and gravel ramp built up and over this former tank are still present at the site. Underground fuel supply lines that run from the former tank area to Pits 2 and 3 and


FT-002
MW-02-014
MW-02-026
MW-02-027
84A
MW-02-011
84B
MW-02-015
MW-02-013
MW-02-005
MW-02-007
MW-02-006
MW-02-008
84C
84D
84J
84F
84G
84E
84K
84P
84I
84M
84N
84O
84H
84Q
CP-02-005
CP-02-002
OIL/WATER SEPARATOR
CP-02-006
MW-02-030
MW-02-019
MW-02-020
CP-02-003
CP-02-004
CP-02-034
CP-02-011
CP-02-010
CP-02-
Direction of Ground Water Flow
PERIMETER
ROAD
CP-02-037
MW-02-021
MW-02-022
CP-02-039
RUNWAY
LEGEND
MW-02-021
GROUND WATER MONITORING WELL W/LABEL
84M
LIF-CPT SAMPLING LOCATION W/LABEL (DECEMBER 1993)
SCAPS PUSH LOCATION W/O LABEL (MAY 1994)
CP-02-008
CONE PENETROMETER LOCATION W/ LABEL (1991)


CP-02-034
CP-02-011
CP-02-033
CP-02-005
CP-02-002
OIL/WATER SEPARATOR
CP-02-006
CP-02-010
FLIGHTLINE
MW-02-030
MW-02-019
MW-02-020
CP-02-007
CP-02-008
Direction of Ground Water Flow
CP-02-009
MW-02-040
MW-02-041
MW-02-042
CP-02-024
PERIMETER
ROAD
CP-02-012
CP-02-013
CP-02-037
MW-02-021
MW-02-022
CP-02-039
MW-02-043
RUNWAY
0 200 400 800
SCALE: 1"=400'

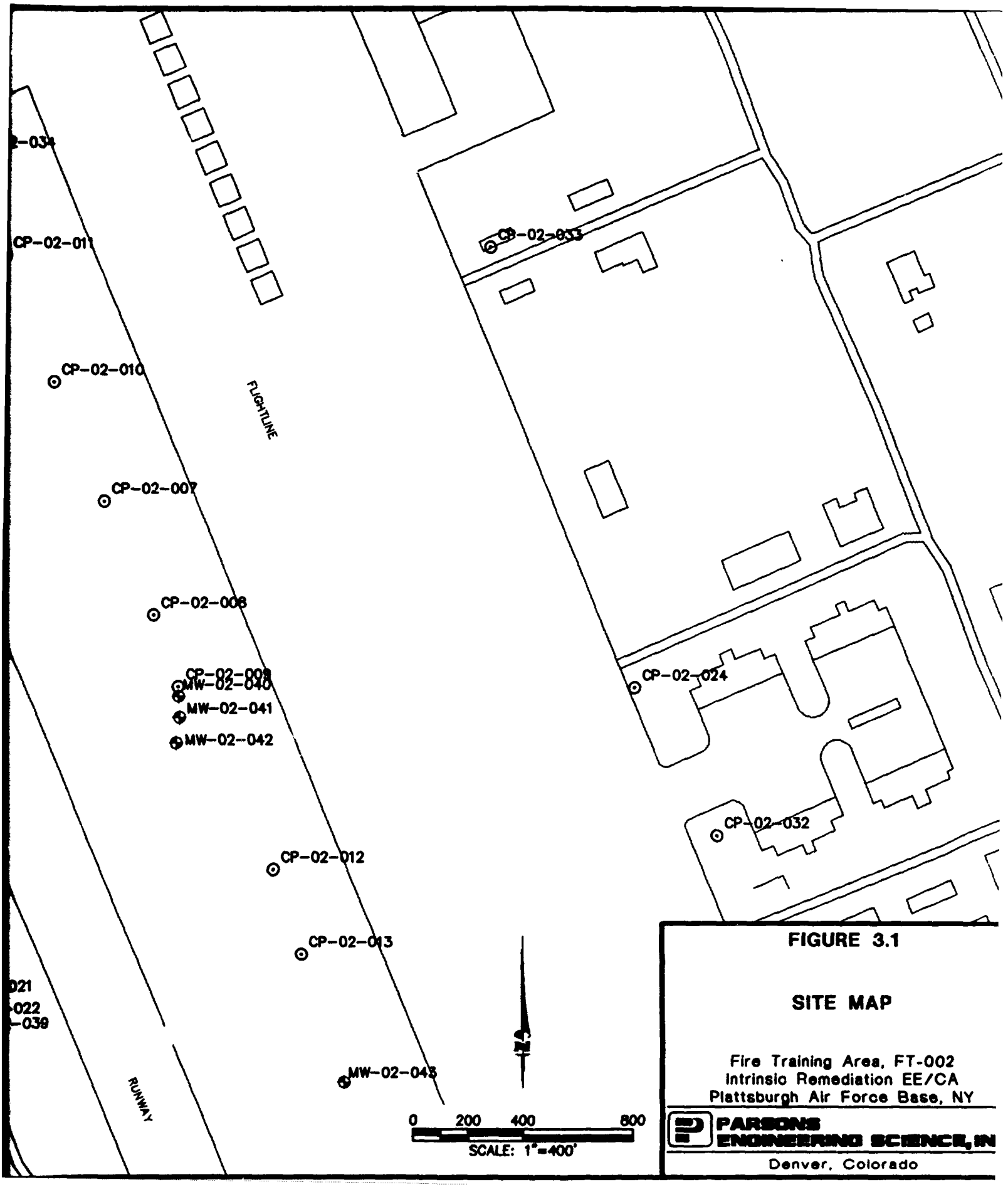


FIGURE 3.1

SITE MAP

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

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Denver, Colorado

underground drainage lines that run from Pits 2 and 3 to the oil/water separator east of Pit 2 are still intact.

The FT-002 site was graded from east to west at some time during its operational history, as indicated by mounds of dirt and debris along the western edge of the site. The Phase I RI report identifies the presence of a large storage tank, approximately 30 feet long and 7 feet in diameter, at the northwestern edge of the site (E.C. Jordan, Co., 1990). This large storage tank was removed from the site under the IRP effort. No other site features of note were identified during the 1993 field investigation.

3.2.1 Topography and Surface Water Hydrology

The land at Plattsburgh AFB slopes gradually downward toward the east and southeast, with elevations ranging from a high of approximately 270 feet above mean sea level (MSL) in the area of FT-002 to approximately 180 feet above MSL at the flightline. The elevation at the FT-002 site ranges from 248 to 270 feet above MSL. A topographic low exists at approximately 150 feet above MSL in the southwest portion of the base near the Weapons Storage Area.

The topography of the base and the FT-002 site has been significantly altered during base construction and operations. A steep hill was created to the east of the FT-002 site when soil was removed to construct the runway. A deep gully was created between the runway and the flightline during the construction of the runway and flightline. The modifications to the terrain, presence of buried features, and the variability between borrow, fill, and undisturbed soil may locally affect infiltration and ground water flow.

Lake Champlain is located east of the base, and the Saranac and Salmon Rivers are located to the north and south of the base, respectively. All of these large surface water bodies influence the ground water flow system at Plattsburgh AFB. The local hydraulic gradient and ground water flow direction suggest that the ground water underlying Plattsburgh AFB could possibly discharge into the Salmon River and/or Lake Champlain.

There are no surface water features at the FT-002 site. Because the soils are highly permeable and the ground water surface is located approximately 35 feet bgs, water does not accumulate at the surface. However, two surface water bodies are located just south of FT-002 (ABB Environmental Services, Inc., and URS Consultants, Inc., 1993). The first is a

drainageway between the runway and the flightline, which can intercept ground water during periods of high ground water table elevation. This water is routed through a pipeline and discharged into a stream west of the runway. The second surface water body near the FT-002 site is a stream that flows through the Weapons Storage Area and eventually discharges into the Salmon River. The FT-002 site lies above the 500-year flood plain. No wetlands regulated by NYSDEC are present on or adjacent to the FT-002 site (ABB Environmental Services, Inc., 1992).

3.2.2 Manmade Features

The major manmade features at the site consist of the fire training pits, paved and unpaved roads, a warehouse building, and a 4-foot-high, three-wire fence. The FT-002 site is situated in the limited-access area of the base. The nearest paved road is Perimeter Road, which is in a controlled-access area. Only military personnel who need to work within the controlled area and civilians (e.g., contractors) who obtain prior clearance from security personnel are allowed access to Perimeter Road. Underground fuel supply and drainage lines are not noticeable at the surface (see Figure 3.1).

The nearest on-base housing unit is more than 6,000 feet southeast (downgradient) of the FT-002 site. The nearest off-base residential area is the cluster of mobile homes located approximately 2,000 feet south of the site. Various light industries are located about 800 feet to the west, and Interstate 87 is about 1,600 feet west of the site.

The fire training pits at the FT-002 site are essentially barren of vegetation. Surrounding environs can be described as successional old field and successional shrubland. Trees have overgrown the soil mounds created during surface grading activities on the western perimeter of the site (Figure 1.2).

3.3 SITE GEOLOGY AND HYDROGEOLOGY

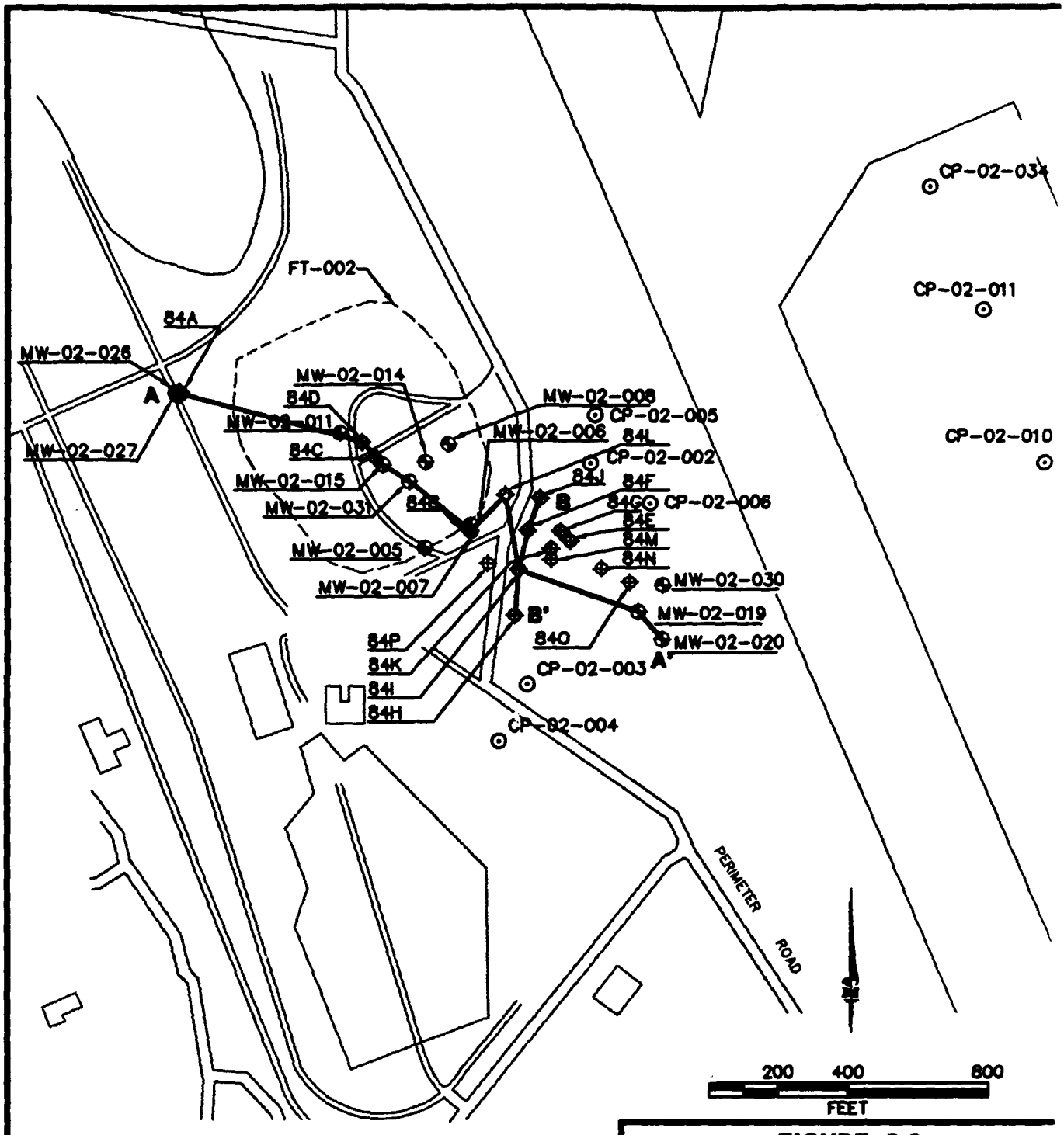
The geology and subsurface conditions at FT-002 were characterized as part of the initial site investigation (E.C. Jordan, Co., 1989a), the Phase I RI (E.C. Jordan, Co., 1990), and this work. Figures 2.1 and 2.2 show the location of the sampling sites used during both the December 1993 and May 1994 field efforts to characterize site conditions, including the nature and extent of site-related contamination, and to assess the potential effectiveness of naturally occurring attenuation mechanisms.

Four distinct stratigraphic units underlie the FT-002 site: sand, clay, till, and carbonate bedrock. The sand unit generally extends from ground surface up to 90 feet bgs in the vicinity of the FT-002 site. A 7-foot-thick clay unit has been identified on the eastern side of the site. The thickness of the clay on the western side of the site has not been determined. A 30- to 40-foot thick clay/till unit is also present from 80 to 105 feet bgs in the vicinity of the FT-002 site. Bedrock is located approximately 120 feet bgs. Ground water occurs in the sand unit approximately 0 to 35 feet bgs. Interpretative profiles were generated from soil borings, soil samples collected during the installation of monitoring wells, CPT explorations, laboratory grain-size analyses, and geophysical surveys. The locations of the geologic profiles are shown in Figure 3.2. The northwest-southeast profile (parallel to the direction of ground water flow) and the north-south profile (perpendicular to the direction of ground water flow) are shown in Figures 3.3 and 3.4, respectively.

3.3.1 Lithology and Stratigraphic Relationships

The upper sand unit consists of well-sorted, medium-to fine-grained sand, with a trace to some silt. Gravel and cobbles are only occasionally encountered, and fine sands and silts become more predominant at the base of the sand unit. The bottom 5 to 10 feet of the sand unit consists of silty sand with silt lenses (ABB Environmental, Inc., 1992). The CPT data collected under this program confirm the presence of fine-grained sand and silt at the bottom of the sand unit (see Appendix A). The sand was observed to change from light brown to gray at the water table, which could be attributable to a change from a generally oxidizing environment (unsaturated soil) to a reducing environment (saturated soil).

The next lower unit in the profile is a deep water glacial lacustrine clay deposit. The extent and depth of the clay layer are based on data obtained during previous CPT explorations and during installation of deep ground water monitoring wells. No CPT or SCAPS pushes were completed into the clay unit at the site during the field activities recently conducted by Parsons ES and researchers from RSKERL. Previous data suggest that the clay layer is located approximately 90 feet bgs on the west side of the FT-002 site and 20 feet bgs on the east side of the flightline (ABB Environmental, Inc. and URS Consultants, Inc., 1993). Although few borings have completely penetrated the clay layer, seismic survey results from the eastern side of the FT-002 site suggest that the clay layer is 7 feet thick. Together the clay and overlying sands represent a regressive sequence caused by retreating shorelines related to the shrinkage of the former Champlain Sea. The sea receded due to of isostatic



LEGEND

MW-02-021 GROUND WATER MONITORING WELL W/LABEL

84M LIF-CPT SAMPLING LOCATION W/LABEL (DECEMBER 1993)

CP-02-039 EXISTING CONE PENETROMETER LOCATION W/ LABEL (1991)

NOTE:
ONLY SAMPLING LOCATIONS USED DURING THIS CHARACTERIZATION EFFORT ARE SHOWN

FIGURE 3.2

LOCATION OF HYDROGEOLOGIC PROFILES

Fire Training Area, FT-002
Intrinsic Remediation EE/C
Plattsburgh Air Force Base, N.

PARSONS ENGINEERING SCIENCE, INC
Denver, Colorado

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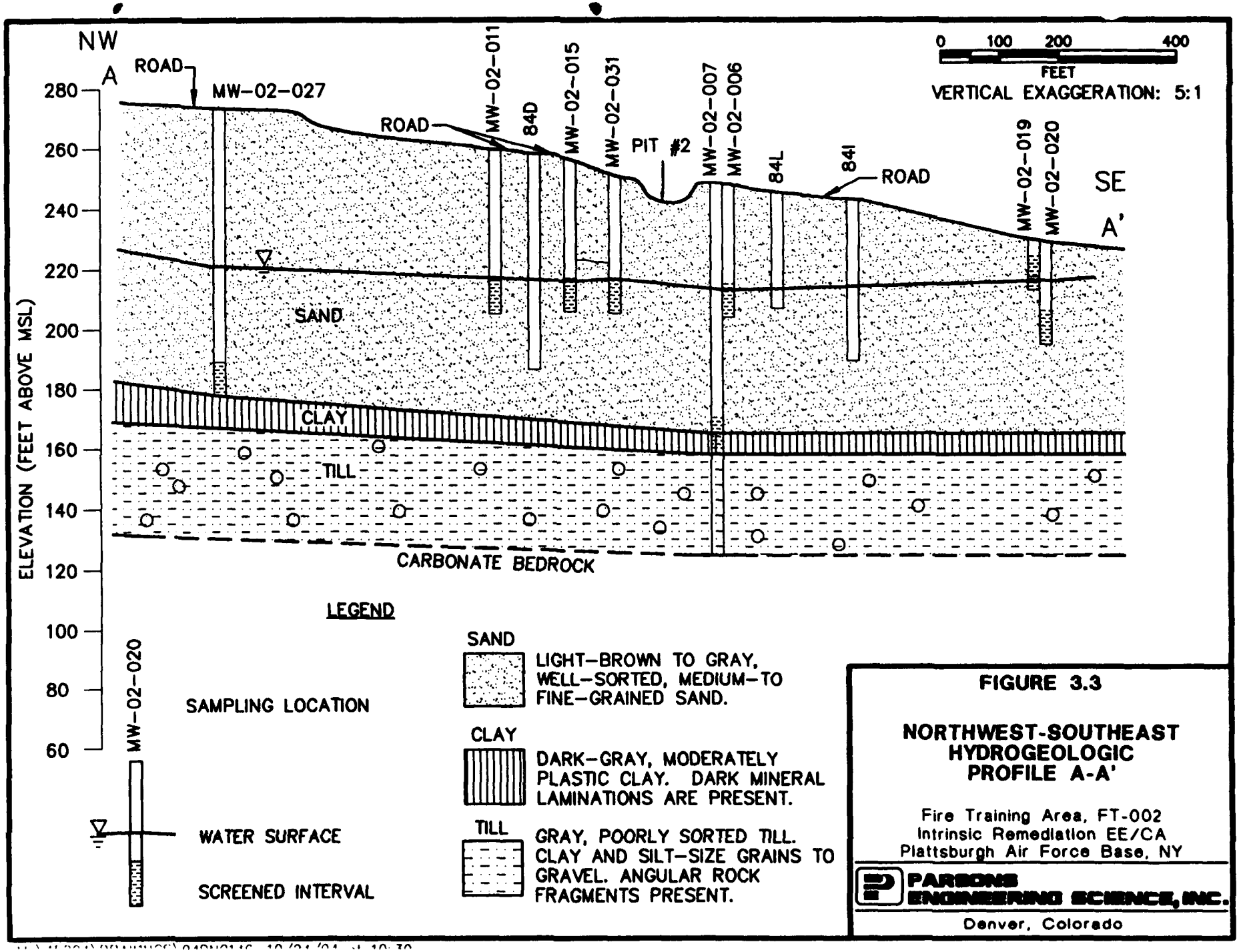

FIGURE 3.3

NORTHWEST-SOUTHEAST HYDROGEOLOGIC PROFILE A-A'

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

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Denver, Colorado

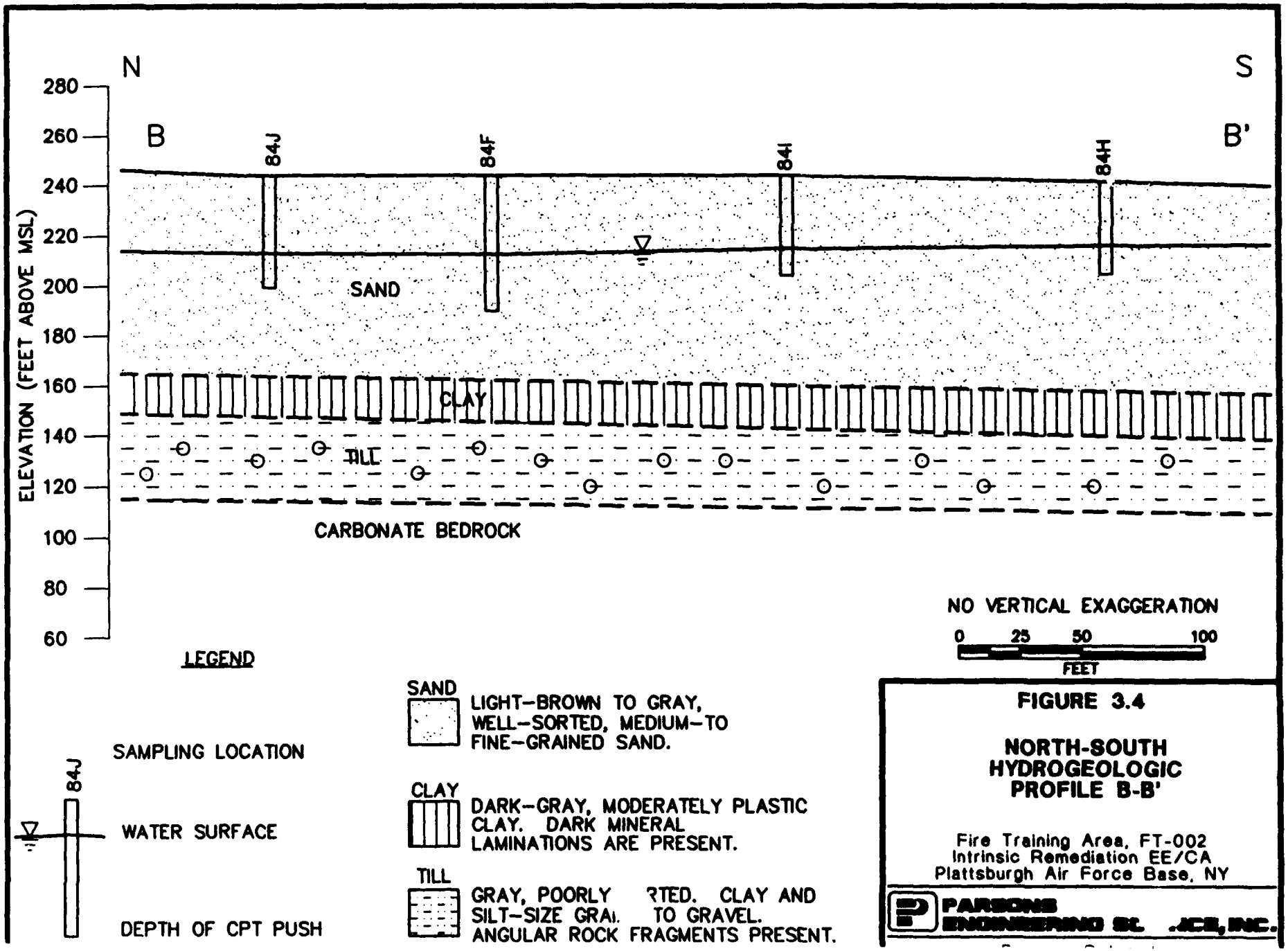


FIGURE 3.4

NORTH-SOUTH HYDROGEOLOGIC PROFILE B-B'

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SC. ..CE, INC.

rebound of the crust after the melting of the glaciers (Fisher, 1968; ABB Environmental, Inc. and URS Consultants, Inc., 1993).

Gray till was found on the east side of FT-002 at an estimated depth of 88 feet bgs during the installation of MW-02-007 (Figure 3.3). This boring completely penetrated the 37-foot thick till. Till was also encountered at 58 feet bgs south of the site at the Weapons Storage Area, and at a depth of 60 feet at CP-02-007 (Figure 3.2). The till is poorly sorted, with particle sizes ranging from clay and silt to gravel and cobbles. The till near the base of the unit has the characteristics of basal till, whereas the upper portions of the unit contain sediments more massive in structure (ABB Environmental, Inc., 1992; ABB Environmental, Inc. and URS Consultants, Inc., 1993).

The elevation of the fourth geologic unit, limestone bedrock, was determined by previous seismic surveys and auger refusal during the installation of MW-02-007 (ABB Environmental, Inc., 1992; ABB Environmental, Inc. and URS Consultants, Inc., 1993). The bedrock unit is located approximately 120 feet bgs at the FT-002 site, and slopes downward to a depth of 140 feet bgs on the east side of the flightline. No bedrock has been cored during the site investigation or remedial investigation, but outcrops on the eastern side of Plattsburgh AFB have been identified as Ordovician Period limestone (Fisher, 1968).

3.3.2 Grain-Size Distribution

No samples from the sand unit were collected during the RI for physical characterization data. However, grain-size distribution, Atterburg limits, water content, and specific gravity were measured on samples of the confining clay unit during previous site characterization efforts (E.C. Jordan, Co., 1991b; ABB Environmental, Inc., 1992). Clay samples used for these types of analyses were collected using a 3-foot, thin-wall tube to prevent significant disturbance of soil core integrity (ABB Environmental, Inc. and URS Consultants, Inc., 1993).

Grain-size distribution was determined using the standard American Society for Testing Materials (ASTM) sieve analysis methodology (ASTM D 422). Classification ranged from a gray clay with a trace of sand and silt to a gray fine sand with some silt and clay. The grain size distribution was as follows: sand-size particles ranged from 0.8 to 35.3 percent, silt-size

particles ranged from 4.9 to 33.9 percent, and clay- size particles ranged from 31.6 to 89.8 percent (ABB Environmental, Inc. and URS Consultants, Inc., 1993).

Water content of the confining clay layer ranged from 40 to 56 percent using ASTM Method ASTM D 2216. Results of the Atterburg limit tests completed using ASTM method D 4318 showed that, in general, the clay samples could be classified as a plastic clay with a Unified Soil Classification System (USCS) classification of CH. The specific gravity of the tested clay samples ranged from 2.65 to 2.85. Higher specific gravities were likely attributable to the presence of greater amounts of clay-sized particles in the particular sample (ABB Environmental, Inc. and URS Consultants, Inc., 1993).

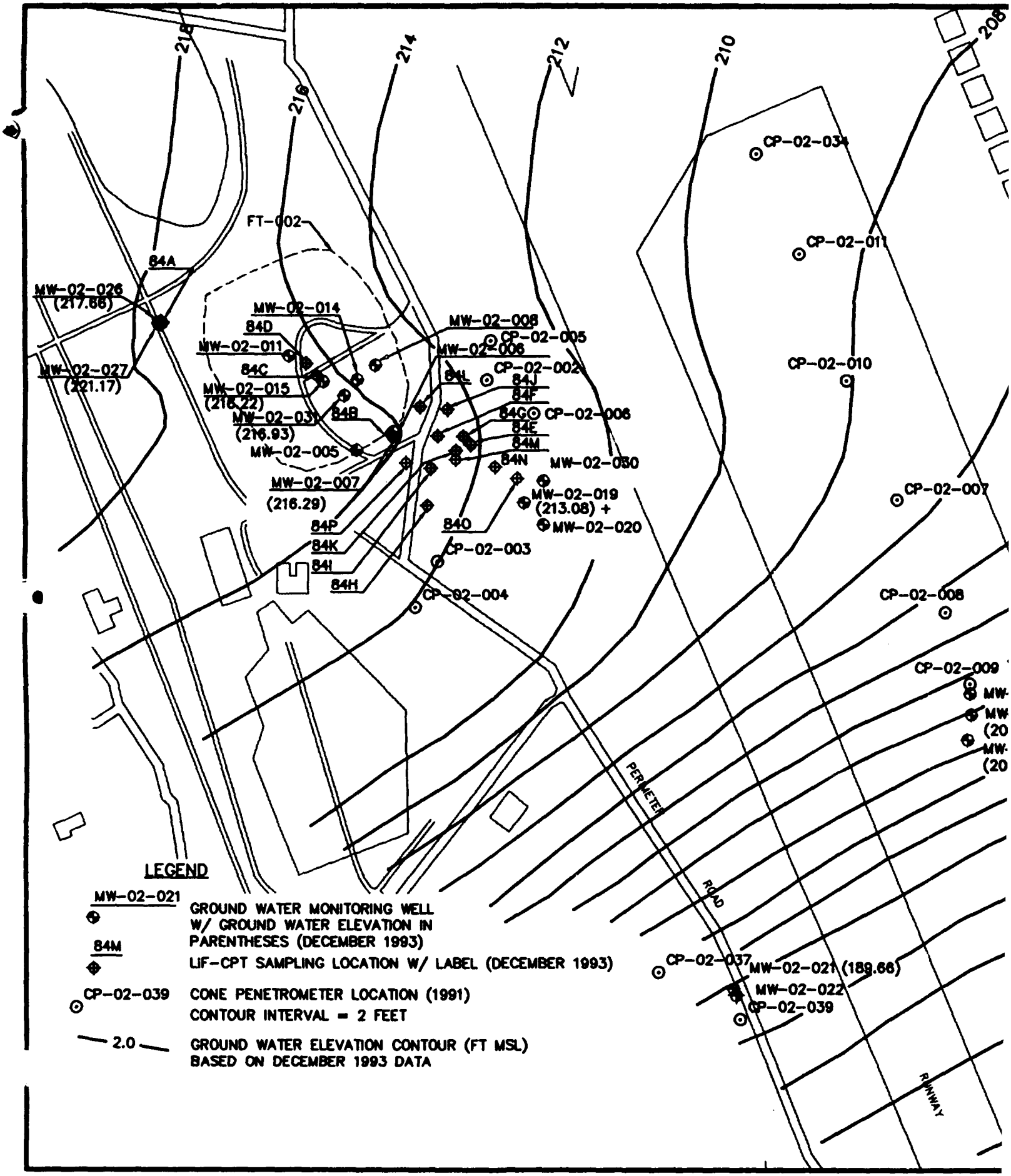
3.3.3 Ground Water Hydraulics

Three distinct hydrogeologic units have been identified beneath the FT-002 site. Data collected during this program and during previous site investigations suggest that the upper most aquifer is unconfined and exists in the shallow sand unit described in Section 3.3.1. The depth to ground water in the sand aquifer ranges from 45 feet bgs on the west side of the site to almost zero between the flightline and runway.

The second unit is a series of aquitards and aquicludes consisting of silts, clays, and glacial till (i.e., the confining layers). The third hydrogeologic unit is a confined aquifer within the limestone bedrock unit (Giese and Hobba, 1970; ABB Environmental, Inc. and URS Consultants, Inc., 1993). This bedrock aquifer is unconfined to the west of Plattsburgh AFB near the Adirondack Mountains, which act as a recharge area. Ground water then flows to the east under Plattsburgh AFB toward Lake Champlain. Water from this confined bedrock aquifer discharges to topographic lows, the Salmon and Saranac Rivers, and eventually to Lake Champlain. Ground water from the confined portion of this bedrock aquifer also leaks upward into the unconfined aquifer in the overlying sand unit.

3.3.3.1 Flow Direction and Gradient

Ground water flow in the vicinity of the FT-002 site is to the southeast (generally toward Lake Champlain). The average gradient along the ground water flow lines emanating from the FT-002 site to 8,200 feet downgradient is approximately 0.010 foot per foot (ft/ft) (Figure 3.5). Available data show that ground water elevations in the unconfined sand aquifer typically vary by about 2 feet across the site. Some wells displayed seasonal variations of 4



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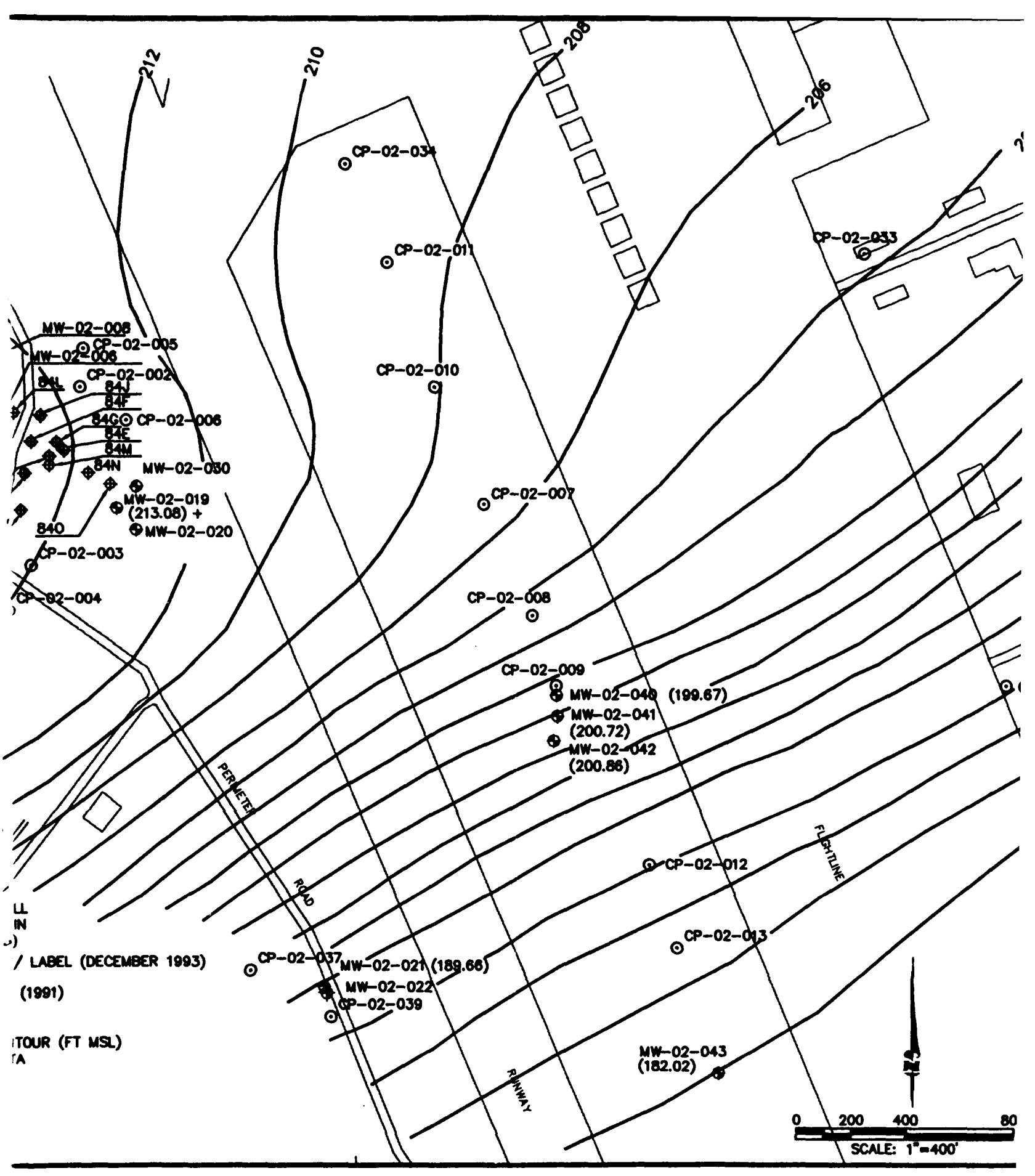
212
210
208
206
CP-02-034
CP-02-011
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MW-02-005
CP-02-005
MW-02-006
CP-02-002
84L
84J
84F
84G
CP-02-006
84E
84M
84N
MW-02-030
MW-02-019
(213.08) +
MW-02-020
840
CP-02-003
CP-02-004
CP-02-010
CP-02-007
CP-02-008
CP-02-009
MW-02-040 (199.67)
MW-02-041
(200.72)
MW-02-042
(200.86)
PERIMETER
ROAD
CP-02-012
FLIGHTLINE
CP-02-013
CP-02-037
MW-02-021 (189.66)
MW-02-022
CP-02-039
MW-02-043
(182.02)
RUNWAY
0 200 400 80
SCALE: 1"=400'
/ LABEL (DECEMBER 1993)
(1991)
TOUR (FT MSL)

t 10:00

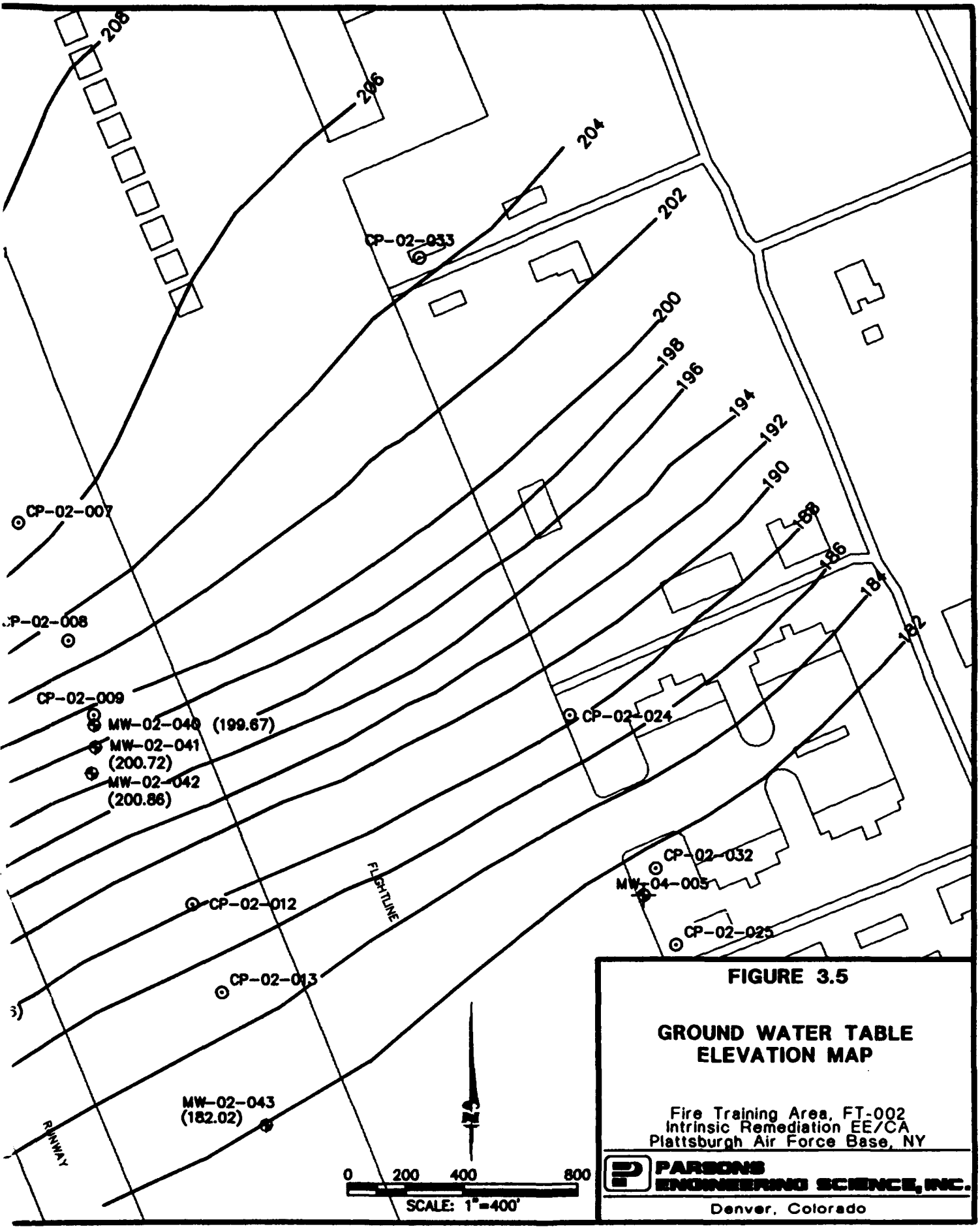


FIGURE 3.5

GROUND WATER TABLE ELEVATION MAP

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

to 5 feet, depending on the time of year the measurement is taken. Water level measurements are not available for each season for a full year, but these fluctuations reflect seasonal or annual trends. Available ground water elevation data for the wells referenced in this document are presented in Appendix B.

Vertical hydraulic gradients have been calculated from water surface elevation data for monitoring well clusters within and downgradient of the FT-002 site collected under this program and during previous site investigations. These results are presented in Table 3.1. The monitoring well cluster at MW-02-019/MW-02-020/MW-02-030 demonstrates a consistent upward gradient ranging from 0.0064 to 0.193 ft/ft. A maximum upward vertical gradient of about 0.193 ft/ft was also calculated for well cluster MW-02-040/MW-02-041. Calculated downward vertical gradients ranged from 0.007 to 0.156 ft/ft for well clusters MW-02-021/MW-02-022 and MW-02-041/MW-02-042, respectively. The variable nature of these vertical hydraulic gradients suggests possible localized influences, including the presence of surface discharge features and vertical heterogeneity of the sediments.

3.3.3.2 Hydraulic Conductivity

Hydraulic conductivity (K) of the upper sand aquifer was measured by E.C. Jordan Co. (1989) during the site investigation using constant drawdown tests and by ABB Environmental, Inc. during the Phase II RI using rising head tests (ABB Environmental, Inc. and URS Consultants, Inc., 1993). Because K values determined from these two separate investigations are generally comparable, no additional data on hydraulic conductivity were collected under this program. Results from these previous investigations are summarized herein.

Hydraulic conductivity values for the unconfined sand aquifer underlying the FT-002 site ranged from 0.059 to 90.7 feet per day (ft/day) [2.1×10^{-5} to 3.2×10^{-2} centimeters per second (cm/sec)]. The average K for the FT-002 site has been determined to be 11.6 ft/day (4.1×10^{-3} cm/sec). K values were observed to decrease slightly with depth, probably due to a decrease in grain size and/or compaction of soils. Use of empirical relationships between grain-size distributions and K (Hazen method, Freeze and Cherry, 1979) yields K values of 8.49 to 84.9 ft/day (3×10^{-3} to 3×10^{-2} cm/sec). These values compare well with those measured during *in situ* testing.

TABLE 3.1
VERTICAL HYDRAULIC GRADIENTS
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburg Air Force Base, NY

WELL ID #	ELEVATION OF SCREEN MIDPOINT (FEET MSL)[a/]	VERTICAL HYDRAULIC GRADIENT (FT/FT)			
		1/19/89	9/91-10/91	11/19/91	12/5/93
MW-02-019	211.43	-0.152	-0.152	-0.152	-0.193
MW-02-020	195.16	-0.013	-0.0064	-0.0064	-0.176
MW-02-030	179.55				
MW-02-021	181.85	NA	+0.0066	+0.013	NA
MW-02-022	164.50				
MW-02-037	197.90	NA	-0.005	-0.005	NA
MW-02-038	177.80				
MW-02-040	184.02	NA	-0.133	0.112	-0.193
MW-02-041	169.05	NA	+0.028	+0.011	+0.156
MW-02-042	153.26				
MW-04-006	186.40	NA	+0.0073	NA	NA
MW-02-023	159.00				

a/ feet msl = feet above mean sea level
NA = Not Available
- = Indicates upward vertical gradient
+ = Indicates downward vertical hydraulic gradient

3.3.3.3 Effective Porosity (n_e)

Because of the difficulty involved in accurately determining effective porosity, accepted literature values for the type of soil comprising the unconfined sand aquifer were used. Freeze and Cherry (1979) give a range of effective porosity for sand of 0.25 to 0.50. Chow (1964) cites an effective porosity range of 0.30 to 0.40 for an unconsolidated deposit composed predominantly of sand, silty sand, or sandy silt. Effective porosity is used with K values and hydraulic gradients to calculate ground water seepage velocity. Effective porosity was conservatively assumed to be 0.30. This value is consistent with that used to estimate travel times and model contaminant fate and transport at the FT-002 site as part of the Phase II remedial investigation and feasibility study (ABB Environmental, Inc. and URS Consultants, Inc., 1993; URS Consultants, Inc., 1993).

3.3.3.4 Advective Ground Water Velocity

Average advective ground water velocity (seepage velocity) in the direction parallel to ground water flow can be computed by multiplying the horizontal gradient by K and dividing by the effective porosity. Using a horizontal gradient of 0.010 ft/ft, the average K value of 11.6 ft/day, and an effective porosity of 0.30 yields an average advective ground water velocity for the unconfined sand aquifer of 0.38 ft/day or approximately 139 ft/year.

However, considering the range in hydraulic conductivity values obtained from tests conducted at the site, the linear ground water velocity could locally range from 0.002 to 3.02 ft/day (i.e., 0.73 to 1,102 ft/year). From the results of the unconfined aquifer hydraulic conductivity analyses (see Appendix B), maximum ground water velocities would be expected to occur within the upper portion of the sand aquifer, which is characterized by coarser deposits, near and immediately downgradient of the source area. These data also imply that ground water velocity decreased substantially (e.g., an order of magnitude below the site average) immediately east of the runway at well cluster MW-02-040/MW-02-041/MW-02-042.

3.3.3.5 Estimation of BTEX Retardation

Total organic carbon (TOC) concentrations in soil are used to estimate the amount of organic matter available in the soil matrix that can act as a sorbent for site-related contaminants. Measured TOC concentrations in soil samples taken from the saturated zone

can be used to estimate the amount of contaminant that could potentially be sorbed to the aquifer matrix (i.e., estimating the amount of solute that can be removed from solution and attached to the surface of the solid sorbent). Hydrophobic compounds, such as the BTEX compounds and other organic compounds, tend to adsorb well to the solid soil matrix under both unsaturated and saturated conditions. Adsorption results in slowing (retardation) of the contaminant plume relative to the average advective ground water velocity.

Soil samples collected during the Phase I remedial investigation (ABB Environmental, Inc., 1992) were analyzed for fraction organic content. The fraction organic carbon content of deeper, unsaturated soils from locations not affected by petroleum contamination (i.e., suspected background locations) was about 0.03. Soil samples from below the ground water table could not be collected due to poor recovery. The organic carbon measurements obtained from the unsaturated sandy soils at the FT-002 site should result in large site distribution coefficients (K_D). This suggests that the sandy soils at FT-002 could have a strong affinity for site-related contamination and could effectively retard dissolved contaminant migration. However, the K_D value derived from this site data and K_{oc} values for each site contaminant (see Appendix E) is large in comparison to K_D values derived using literature values of fraction organic carbon content for saturated sandy soils, which range from 0.001 to 0.01. The difference between the measured fraction organic carbon content and the range of fraction organic carbon content usually found in similar soil medium could be attributable to the presence of humic materials, clays, and silts, which can be characteristic of unsaturated soils but not saturated soils at the site (ABB Environmental, Inc., 1992). Use of the literature values of fraction organic carbon content for sandy soils will result in a more conservative estimate of potential retardation effects for site-related contamination, and is consistent with the actual migration observed at this site (ABB Environmental, Inc., 1992; ABB Environmental, Inc. and URS Consultants, Inc., 1993). Calculation of compound-specific retardation values are presented in Appendix E.

3.3.3.6 Confining Layers

Permeability testing was completed in accordance with the procedures outlined in EM-1110-2-1906, Appendix VII, on each of the samples collected from the clay geologic unit (ABB Environmental, Inc. and URS Consultants, Inc., 1993). The objective of these analyses was to explore the effect, if any, of organic solvents on the permeability of these confining materials. Two permeants were used: pure de-ionized water, and a mixture of 100

ppb TCE, 100 ppb DCE, and de-ionized water. Details on test methodology are presented in Appendix E of the Phase II RI Report (ABB Environmental, Inc. and URS Consultants, Inc., 1993).

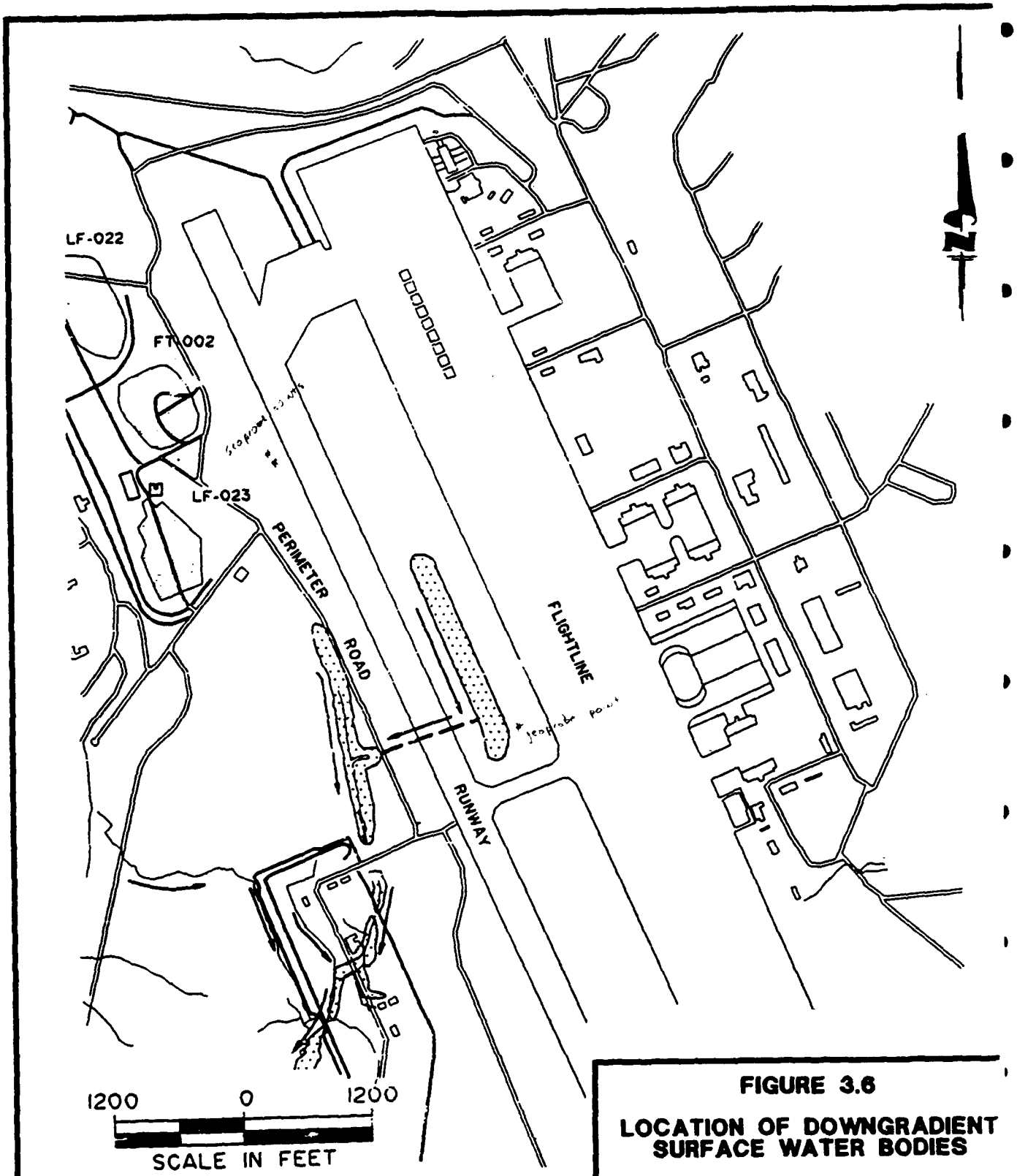
The permeability tests yielded very consistent results for each of the clay samples, regardless of the duration of material exposure to the permeants, changes in test pressure, and differential heads. The permeability of the clay to the de-ionized water ranged from 1.19 x 10^{-8} to 4.49 x 10^{-8} cm/sec. The permeability of the clay to the TCE/DCE mixture ranged from 1.21 x 10^{-8} to 4.05 x 10^{-8} cm/sec. These results suggest that the clay unit should be characterized as a low-permeability confining unit, even under sustained contact with low concentrations of organic solvents. These results suggest no appreciable hydrologic communication between the aquifer and the lower bedrock aquifer, although ground water apparently leaks upward from the confined bedrock aquifer into the unconfined sandy aquifer (Giese and Hobba, 1970).

3.3.3.7 Surface Discharge of Ground Water

Ground water is suspected to discharge into the two surface water bodies directly downgradient of the FT-002 site. Ground water may discharge directly into the drainageway between the runway and flightline; ground water may also discharge directly and via the drainageway into the stream that flows south of the FT-002 site through the Weapons Storage Area. This stream eventually discharges into the Salmon River. These surface water bodies and their flow paths are shown in Figure 3.6.

Several surface water and sediment samples were collected from the drainageway and the stream as part of the Phase I RI to determine if contaminated ground water discharges to this area and to assess the potential for preferential contaminant transport via these surface water pathways (ABB Environmental, Inc., 1992; ABB Environmental Inc. and URS Consultants, Inc., 1993). Measurable concentrations of TCE and DCE were detected in three of the six surface water samples collected from the drainageway and the stream. No target compounds were detected in sediment samples.

Subsequently, surface water and sediment samples were collected monthly from two locations upgradient of the stream south of the FT-002 site during the 8-month 1990 drainage flow study to pinpoint the probable source of the surface water contaminants (E.C. Jordan,



TAKEN FROM ABB ENVIRONMENTAL, INC. and URS CONSULTANTS, INC. , 1993

FIGURE 3.6

LOCATION OF DOWNGRADIENT SURFACE WATER BODIES

Fire Training Area, FT-0C
Intrinsic Remediation EE/C
Plattsburgh Air Force Base, NY

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Denver, Colorado

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Co., 1991b). The maximum concentration of TCE and DCE detected in surface water was consistently measured during this 1990 study at the point where the drainageway discharges to the stream. The Phase II RI report concluded that contaminated ground water from the FT-002 site is discharging to the drainageway between the flightline and runway and is being diverted to the stream (ABB Environmental, Inc. and URS Consultants, Inc., 1993). TCE and DCE were not detected in sediment samples collected during the drainage flow study program. BTEX compounds were not analyzed for in surface water samples.

3.3.4 Previous Ground Water Modeling

A ground water flow model was developed for the 6,200 acres that encompass Plattsburgh AFB as a tool for the analysis and design of remedial alternatives. The USGS MODFLOW code, developed by McDonald and Harbaugh, was used to simulate ground water flow in the upper unconfined aquifer based on available hydrogeological and hydrological information. Calibration of the MODFLOW model for the site was optimized using MODINV, an inverse problem algorithm program developed by J. Doherty of the Australian Centre for Tropical Freshwater Research to optimize model parameters to match observed hydraulic heads. Optimized model parameters were reconciled with field-determined parameters. The USACE Waterways Experiment Station Hydrologic Evaluation of Landfill Performance (HELP) code, which was developed for the USEPA, was used to estimate recharge from precipitation.

The direction of ground water flow near the FT-002 area used in these larger scale (i.e., base-wide) MODFLOW simulations compares well with all available site-specific data. The MODFLOW model for the site also incorporated both of the surface drainage features that may be receiving ground water affected by operations at the FT-002 site (see Section 3.3.3.6). Satisfactory model calibrations were achieved by simulating discharge of ground water into the onsite surface water bodies. Details on the modeled area, input parameters, and calibration results are presented in the Phase II RI Report (ABB Environmental Inc. and URS Consultants, Inc., 1993).

3.3.5 Ground Water Use

The source of potable water for Plattsburgh AFB is the municipal water supply from the City of Plattsburgh, which is derived from the Westbrook, Patterson, and Mead Reservoirs

located about 7.5 miles west of the base. The majority of private homes and industries located north of the base are supplied by municipal water. However, there are a number of private residences located along Kemp Lane (adjacent the base's north gate) which obtain their potable water supply from private water supply wells. Residences and industries located south of the base, between Clinton Community College and Lake Champlain, rely on private wells or Lake Champlain for potable water. Residences and industries located to the immediate south and west of Plattsburgh AFB also rely on private water wells, including a cluster of homes on Old NY Route 22, located on the western boundary of the base (ABB Environmental, Inc., 1992). A mobile home development directly southwest of the FT-002 site uses ground water as a source of potable water (ABB Environmental, Inc. and URS Consultants, Inc., 1993).

The ground water beneath the FT-002 site is not currently used to meet domestic water needs, although the aquifer has been classified as GA by NSYDEC (i.e., a potential future residential drinking water source). The baseline risk assessment completed for the FT-002 site included unrestricted (i.e., residential) use of ground water resources in potential future exposure scenarios(ABB Environmental, Inc. and URS Consultants, Inc., 1993).

3.4 CLIMATOLOGICAL CHARACTERISTICS

Because Plattsburgh AFB is located in the rain shadow of the Adirondack Mountains, it experiences one of the driest climates in the State of New York. The average annual precipitation is about 28.9 inches in equivalent rainfall, which includes about 63 inches of snow. The maximum recorded 24-hour rainfall was 3.1 inches; the maximum recorded 24-hour snowfall was 21 inches. Infiltration rates in the local vicinity of the FT-002 site were estimated using the HELP model as part of the Phase II RI modeling effort. Estimated infiltration for the area ranged from 0.0006 to 0.0033 ft/day through unsaturated soil (ABB Environmental, Inc. and URS Consultants, Inc., 1993).

Plattsburgh AFB is also located in the coldest region of New York State. Average daily maximum temperature is 53 degrees Fahrenheit (°F), and the average daily minimum is 35°F. The highest and lowest temperatures on record for the base are 98°F and -34°F, respectively. The predominant wind directions at the base are north and southeast. Wind speeds are typically less than 10 knots, and rarely exceed 27 knots. All meteorological data cited herein were obtained from the Phase II RI Report (ABB Environmental, Inc. and URS Consultants,

Inc., 1993). The Phase II RI Report cites the Plattsburgh AFB weather station as its source (US Air Force, 1989).

SECTION 4

NATURE AND EXTENT OF CONTAMINATION

4.1 SOURCE OF CONTAMINATION

Possible sources of contamination at the FT-002 site include the four former fire training pits, a partially buried fuel storage tank (removed in the fall of 1990), a network of underground fuel supply and drainage lines, and an intact oil/water separator. The former fire training pits were used during weekly fire training exercises from the mid-1950s until May 22, 1989. Based on historical information, the unlined pits were typically saturated with water before adding approximately 75 to 100 gallons of off-specification waste jet fuel (JP-4), which was then ignited. Solvents, waste oil, and other chemicals were sometimes mixed with the waste jet fuel prior to being used in these exercises. A single training exercise usually consisted of four consecutive cycles of igniting and extinguishing fires in the training pits. Previous estimates indicate that up to 2,000 gallons of fuel was burned during the weekly exercises from the mid-1950s until the late 1980s (ABB Environmental, Inc. and URS Consultants, Inc., 1993). Two of the pits were upgraded with cement-stabilized liners in 1980; the other two pits have been deactivated (ABB Environmental, Inc., 1992; ABB Environmental, Inc. and URS Consultants, Inc., 1993).

The presence of distressed vegetation and soil contamination suggest that fire training exercises may also have been conducted in an area north and west of the pits (ABB Environmental, Inc., 1992). Additionally, the network of underground fuel supply and drainage lines that exist at Site FT-002 may have contributed to contamination of the soil column and underlying ground water. This underground fuel-feed system is still intact at the site. The Phase I RI report identifies the former fuel storage tank and the oil/water separator, both of which received liquid drainage from Pits 2 and 3, as possible sources of soil and ground water contamination (E.C. Jordan, Co., 1990).

4.2 SOIL GAS CONTAMINATION

Several soil gas surveys have been conducted at the FT-002 site under the IRP to assess the nature and extent of volatile organic hydrocarbon contamination in shallow subsurface soil. Soil gas samples were also collected at the site during the AFCEE Bioventing Test Initiative program. These soil gas samples were analyzed for total volatile hydrocarbons (TVH) and the BTEX compounds. Data on the oxygen and carbon dioxide content of the soils were also collected during the initial bioventing test program to assess the relationship between depleted oxygen levels/elevated carbon dioxide levels (as indicators of fuel biodegradation) and contaminated soils. These soil gas data can be found in the relevant reports produced under the IRP and AFCEE Bioventing Test Initiative.

Data from the IRP soil gas surveys suggested that most deeper soil contamination (i.e., several feet bgs) is associated with previously identified source areas, namely, Pits 1, 2, and 3, and the area north of the pits (ABB Environmental, Inc., 1992). VOC contamination was typically not found in shallow soil, which can be attributed to migration, volatilization, and biodegradation. Soil gas samples taken in Pits 1, 2, and 3 during the initial bioventing sample event show measurable BTEX concentrations in samples from 12 and 38 feet bgs. The concentration of the BTEX compounds appeared to increase with depth, which can also be attributed to downward migration and/or enhanced volatilization and degradation at and near the ground surface. As noted in Section 1, data collected under the bioventing program also suggested that native microorganisms have completely depleted soil gas oxygen supplies while metabolizing fuel hydrocarbons in the soil. The inverse relationship between soil gas oxygen levels and hydrocarbon concentrations suggests that natural microbial degradation of fuel hydrocarbon contamination in unsaturated soil would be stimulated by air (oxygen) injection. Further details on these data can be found in the interim test results reports for each of the former fire training pits (ES, 1992 and ES, 1993b).

Soil gas samples collected during the second phase of the field work conducted under this program confirm the relationship between depleted oxygen levels/elevated carbon dioxide levels and elevated hydrocarbon concentrations. Table 4.1 summarizes these results by sample location. Additionally, these soil gas data suggest methane fermentation of site contamination in the unsaturated soil, as the methane content increases in direct relation to hydrocarbon and carbon dioxide content. These data will be revisited in Section 5, which focuses on determining whether site characterization data indicate microbial degradation of site-related contamination.

TABLE 4.1
MAY 1994 SOIL GAS DATA
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Sample Location	Depth (ft bgs)[a/]	Oxygen (%)	Carbon Dioxide (%)	Methane (%)	Hydrocarbons (ppmv as hexane)[b/]	Halogen Sniffer (relative)
06PTR1S	7.0	19.0	0.2	<0.1	310	0
06PTR1S	16.0	18.1	1.7	<0.1	360	0
06PTR1S	25.0	11.0	5.2	<0.1	420	0
06PTR1S	34.0	0.1	9.7	11.1	1800	0
08PTR1S	7.0	15.3	3.4	<0.1	340	0
08PTR1S	16.0	13.5	4.2	<0.1	410	0
08PTR1S	25.0	8.6	6.4	<0.1	580	0
08PTR1S	34.0	4.2	7.7	8.7	2500	0
10PTR1S	7.0	2.0	9.3	4.4	1400	0
10PTR1S	16.0	3.6	11.5	6.8	1400	0
10PTR1S	25.0	2.5	10.4	6.2	1800	4
10PTR1S	34.0	0.9	10.9	46.7	4600	7
12PTR1N	7.0	18.8	1.1	<0.1	320	0
12PTR1N	16.0	17.3	1.8	<0.1	180	0
12PTR1N	25.0	13.7	3.3	<0.1	260	0
12PTR1N	34.0	0.0	10.4	0.6	1000	3
14PTR2S	7.0	2.5	8.7	22.1	4700	5
14PTR2S	16.0	0.0	11.0	24.2	>4000	6
14PTR2S	25.0	0.0	11.3	38.7	*	7
14PTR2S	34.0	0.0	11.4	63.0	*	5
16PTR2S	7.0	14.2	4.4	<0.1	370	0
16PTR2S	16.0	1.8	10.5	0.3	1200	0
16PTR2S	25.0	1.7	10.1	28.8	4100	0
16PTR2S	34.0	1.0	10.5	43.8	4600	0
30PTR3S	7.0	13.0	4.9	<0.1	490	0
30PTR3S	16.0	8.6	7.3	<0.1	360	0
30PTR3S	25.0	4.9	8.6	<0.1	320	0
30PTR3S	34.0	0.0	11.2	<0.1	850	0
40PTR2N	7.0	15.8	3.4	<0.1	100	0
40PTR2N	16.0	12.5	5.3	<0.1	150	0
40PTR2N	25.0	1.8	10.4	4.1	2000	0
40PTR2N	34.0	0.0	11.3	66.3	6000	3
44PTR2N	7.0	18.0	1.0	<0.1	290	0
44PTR2N	16.0	14.5	2.7	<0.1	285	0
44PTR2N	25.0	7.3	6.3	<0.1	320	0/+1
44PTR2N	34.0	4.6	7.8	<0.1	330	3
48PTR4N	7.0	17.7	1.3	<0.1	270	0
48PTR4N	16.0	16.5	2.1	<0.1	300	0
48PTR4N	25.0	2.1	8.7	<0.1	750	0
48PTR4N	34.0	0.0	10.2	28.7	3000	3

a/ ft bgs = feet below ground surface
b/ ppmv as hexane = parts per million, volume per volume, in terms of hexane
* cannot be determined

4.3 SOIL CONTAMINATION

The site-related compounds targeted in this program are the BTEX compounds, although a qualitative analysis of TCE, DCE, and vinyl chloride have been included to adequately assess the nature and extent of ground water contamination that may affect remediation at Site FT-002. Significant LNAPL is present in the soil column and on the ground water at and immediately downgradient of the suspected source areas. The following sections summarize available soil quality data. Soil data from previous site investigations activities have been incorporated into this discussion.

4.3.1 LNAPL Contamination

LNAPL refers to product that is present at saturation, can percolate through unsaturated soil under the influence of gravity, and can migrate into flowing ground water. LNAPL is also possibly present in soils at residual or insular saturation, which will prohibit downward percolation. The site characterization methods employed at this site cannot directly distinguish between mobile and residual LNAPL. However, LNAPL that was present within permanent ground water monitoring wells is, by definition, LNAPL. Additionally, resistivity profiles and LIF data can be coupled with soil analytical data to semi-quantitatively define the extent of LNAPL at the site. The methodology used to make this type of correlation is discussed in Section 2 of this report..

Although previous data suggest that approximately 5,000 to 50,000 gallons of LNAPL is within the capillary fringe soils or on the ground water table at the FT-002 site (URS Consultants, Inc., 1993), the amount of LNAPL in the subsurface at a site can be extremely difficult to quantify. Based on resistivity profiles, CPT LIF data, SCAPS data, and product thickness measurements taken in December 1993 at permanent ground water monitoring wells MW-02-014 and MW-02-015, approximately 39,000 gallons of LNAPL is estimated to be present within the source area at the FT-002 site. The LIF CPT surveys completed at this site in December 1993 and May 1994, respectively, show a LNAPL plume that is about 350,000 square feet (ft^2) in areal extent with a maximum thickness of 10 feet within and immediately downgradient of the suspected source areas at the FT-002 site.

Figure 4.1 is an isopach map showing the distribution and measured thickness of LNAPL at the site as of May 1994. This map was prepared using the greatest LNAPL thickness measured at each location during this program (December 1993 and May 1994). LNAPL was found near or floating on the water table at sample locations 84B, 84D, 84F, 84L, MW-02-006, MW-02-

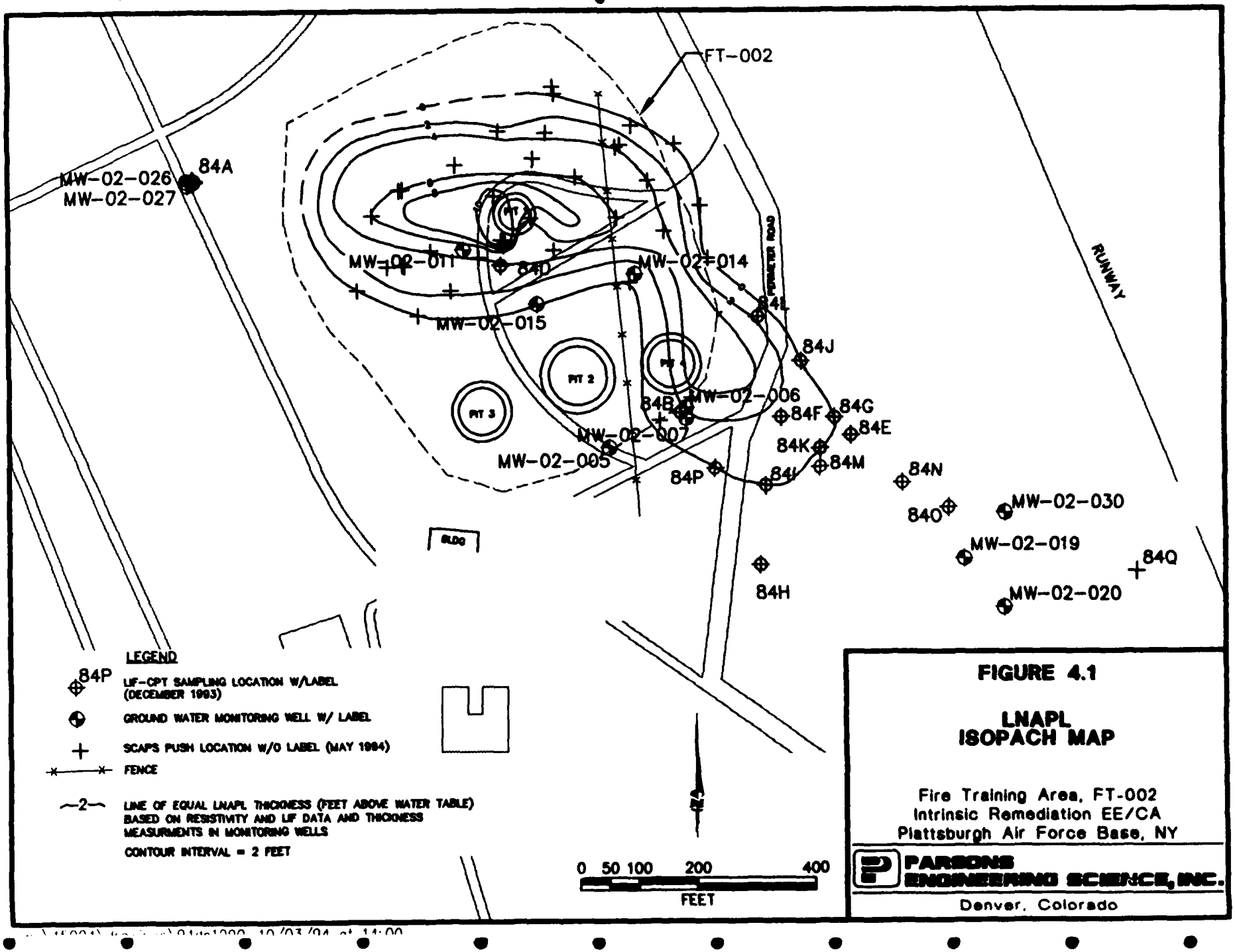

FIGURE 4.1

LNAPL ISOPACH MAP

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

014, and MW-02-015 in December 1993 (Figure 4.1). LNAPL was found near or floating on the water table at sample locations 06PTR1SF, 08PTR1SF, 10PTR1SF, 12PTR1NF, 14PTR2SF, 16PTR2SF, 18PTR2SF, 22PTR2SF, 26PTR3SF, 28PTR3SF, 30PTR3SF, 38PTR2NF, 40PTR2NF, 42PTR3NF, 44PTR2NF, 48PTR4NF, 50PTR4NF, 02PTR1SF, 56PTR6NF, 58PTR5NF, and 64PTR2NF in May 1994. The presence of LNAPL in shallower soils also was suggested by LIF data collected during both field efforts completed under this program at sample locations, 84D, 10PTR1SF, 14PTR2SF, 16PTR2SF, and 28PTR3SF. Table 4.2 summarizes LNAPL thickness estimates by sampling location. Appendix A presents raw LIF profiles.

The LNAPL plume is comprised predominately of comingled BTEX compounds and TCE. Table 4.3 summarizes the relative concentration of the major compounds measured semiquantitatively using GC/MS in a sample of free product collected from MW-02-015. Soil data collected during the LIF CPT and SCAPS surveys completed in December 1993 and May 1994, respectively, indicate that the concentration of TCE in soil saturated with LNAPL is significantly elevated in the portion of the LNAPL plume adjacent to and downgradient from Pit 1. Soil samples taken from within Pit 3 at several depths showed no detectable concentrations of any of the target compounds, suggesting that this pit may not be a direct source of contamination.

4.3.2 Unsaturated Soil Contamination

Previous soil sampling efforts at the FT-002 site focused on defining the nature and extent of fuel-related contamination in vadose zone (unsaturated) soils (ABB Environmental, Inc., 1992). Earlier soil core data showed that fuel-related compounds, especially the BTEX compounds, generally increased in concentration in soil with depth. The maximum concentration of these compounds were typically measured within the capillary fringe near the ground water surface. Tables 4.4 and 4.5 present soil data collected at the FT-002 site in December 1993 and May 1994.

4.3.2.1 Soil BTEX Contamination

Figure 4.2 shows the extent of total BTEX soil contamination at the site as identified during confirmatory soil sampling. Details on the nature and extent of soil contamination are described in previous reports (ABB Environmental, Inc., 1992). A limited number of soil samples were collected and analyzed for BTEX contamination during this program. From these data, soil BTEX contamination appears to extend downgradient to at least Perimeter Road. The highest measured concentration of total BTEX in soil collected during this effort was 2,051 milligrams

TABLE 4.2
MOBILE LNAPL THICKNES ESTIMATES
Based on December 1993 and May 1994 LIF and Monitoring Well Data
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Sample Location	Method	Date	LNAPL Thickness (feet)[a/]
84 B	LIF CPT	Dec-93	4.5
84 C	CPT TEST	Dec-93	-
84 D	LIF CPT	Dec-93	8.5
84 F	LIF CPT	Dec-93	1.3
84 L	LIF CPT	Dec-93	2.3
MW-02-006	Downhole Probe	Dec-93	0.1
MW-02-014	Downhole Probe	Dec-93	1.5
MW-02-015	Downhole Probe	Dec-93	0.6
06PTR1SF	SCAPS	May-94	1.5
08PTR1SF	SCAPS	May-94	3.0
10PRT1SF	SCAPS	May-94	10.0
12PTR1NF	SCAPS	May-94	6.0
14PTR2SF	SCAPS	May-94	12.2
16PTR2SF	SCAPS	May-94	4.3
18PTR2SF	SCAPS	May-94	3.0
22PTR2SF	SCAPS	May-94	4.2
26PTR3SF	SCAPS	May-94	6.4
28PTR3SF	SCAPS	May-94	3.5
30PTR3SF	SCAPS	May-94	5.0
38PTR2NF	SCAPS	May-94	5.0
40PTR2NF	SCAPS	May-94	7.9
42PTR3NF	SCAPS	May-94	2.7
44PTR2NF	SCAPS	May-94	4.8
48PTR4NF	SCAPS	May-94	4.6
50PTR4NF	SCAPS	May-94	4.0
02PTR1SF	SCAPS	May-94	4.3
56PTR6NF	SCAPS	May-94	1.0
58PTR5NF	SCAPS	May-94	2.8
64PTR2NF	SCAPS	May-94	5.3

a/ Actual, estimated thickness in feet above water table based on resistivity and LIF data and thickness measurements in monitoring wells.

TABLE 4.3
CHEMICAL ANALYSIS OF LNALP SAMPLE
COLLECTED FROM MW-02-015 IN DECEMBER 1993
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Compound	Measured Concentration[a] (ppm)[b]	Mass Fraction (%)
Benzene	1,400	0.83
Toulene	8,970	5.32
Ethylbenzene	5,440	3.23
m-Xylene	13,700	8.13
o-Xylene	4,570	2.71
p-Xylene	4,920	2.92
1,2,3-trimethylbenzene	3,560	2.11
1,2,4-trimethylbenzene	6,960	4.13
1,3,5-trimethylbenzene	4,110	2.44
1-methylnapthalene	1,400	0.83
2-methylnapthalene	1,990	1.18
Decane	17,600	10.45
Dodecane	11,100	6.59
Heptane	1,170	0.70
Hexane	4,090	2.43
Napthalene	1,370	0.81
Nonane	15,300	9.10
Octane	14,600	8.67
Pentadecane	2,980	1.77
Tetradecane	5,490	3.26
Trichloroethene(TCE)	16,400	9.74
Tridecane	9,320	5.53
Undecane	12,000	7.12

a/ GC/MS Semiquantitative Estimate, USEPA RSKERL, 2/11/94
b/ ppm = parts per million

TABLE 4.4
SOIL DATA FOR THE BTEX COMPOUNDS AND TOTAL PETROLEUM HYDROCARBONS
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Sample Location	Sample Date	Sample Interval(' bgs)[c]	JP-4 (mg/kg)	TPH[a] (mg/kg)	OVM[a]	Benzene (mg/kg)	Toluene (mg/kg)	Ethylbenzene (mg/kg)	m-xylene (mg/kg)	o-xylene (mg/kg)	p-xylene (mg/kg)	Total BTEX (mg/kg)
84B	Dec. '93	31-32.5	1550	1890	NR[d]	BLQ[e]	1.73	5.01	18.2	7.91	6.91	39.76
84D	Dec. '93	3-3.5	NR	BLQ	NR	NR	NR	NR	NR	NR	NR	NR
84D	Dec. '93	3.5-4	NR	BLQ	NR	NR	NR	NR	NR	NR	NR	NR
84D	Dec. '93	4-4.5	NR	BLQ	NR	NR	NR	NR	NR	NR	NR	NR
84D	Dec. '93	4.5-5	NR	BLQ	NR	NR	NR	NR	NR	NR	NR	NR
84D	Dec. '93	5-5.5	NR	BLQ	NR	NR	NR	NR	NR	NR	NR	NR
84D	Dec. '93	5.5-6	NR	BLQ	NR	NR	NR	NR	NR	NR	NR	NR
84D	Dec. '93	6-6.5	NR	176	NR	NR	NR	NR	NR	NR	NR	NR
84D	Dec. '93	7-7.5	NR	BLQ	NR	NR	NR	NR	NR	NR	NR	NR
84D	Dec. '93	7.5-8	NR	BLQ	0	NR	NR	NR	NR	NR	NR	NR
84D	Dec. '93	8-8.5	NR	BLQ	3	NR	NR	NR	NR	NR	NR	NR
84D	Dec. '93	8.5-9	NR	BLQ	2	NR	NR	NR	NR	NR	NR	NR
84D	Dec. '93	9-9.5	NR	BLQ	1	NR	NR	NR	NR	NR	NR	NR
84D	Dec. '93	9.5-10	NR	BLQ	NR	NR	NR	NR	NR	NR	NR	NR
84D	Dec. '93	10-10.5	NR	BLQ	NR	NR	NR	NR	NR	NR	NR	NR
84D	Dec. '93	10.5-11	NR	BLQ	2	NR	NR	NR	NR	NR	NR	NR
84D	Dec. '93	11-11.5	NR	BLQ	3	NR	NR	NR	NR	NR	NR	NR
84D	Dec. '93	11.5-12	NR	BLQ	1	NR	NR	NR	NR	NR	NR	NR
84D	Dec. '93	12-12.5	NR	BLQ	3	NR	NR	NR	NR	NR	NR	NR
84D	Dec. '93	12.5-13	NR	BLQ	2	NR	NR	NR	NR	NR	NR	NR
84D	Dec. '93	13-13.5	NR	BLQ	1	NR	NR	NR	NR	NR	NR	NR
84D	Dec. '93	13.5-14	NR	BLQ	1	NR	NR	NR	NR	NR	NR	NR
84D	Dec. '93	14-14.5	2.09	BLQ	0	ND[f]	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
84D	Dec. '93	14.5-15	NR	BLQ	1	NR	NR	NR	NR	NR	NR	NR
84D	Dec. '93	15-15.5	19.4	94	45	ND	0.0585	BLQ	0.0369	BLQ	BLQ	0.095
84D	Dec. '93	15.5-16	4370	4120	297	0.262	5.35	3.89	13.6	8.81	6.01	37.92
84D	Dec. '93	16-16.5	1330	2080	655	0.0738	2.58	2.65	8.98	5.22	3.76	23.26
84D	Dec. '93	16.5-17	3140	5180	584	0.351	9.31	7.98	26.6	14.8	11	70.04
84D	Dec. '93	17-17.5	2880	5400	663	0.263	8.41	7.6	26.1	14.3	10.5	67.17

TABLE 4.4 (continued)
SOIL DATA FOR THE BTEX COMPOUNDS AND TOTAL PETROLEUM HYDROCARBONS
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Sample Location	Sample Date	Sample Interval(' bgs)[c]	JP-4 (mg/kg)	TPH[a] (mg/kg)	OVM[b]	Benzene (mg/kg)	Toluene (mg/kg)	Ethylbenzene (mg/kg)	m-xylene (mg/kg)	o-xylene (mg/kg)	p-xylene (mg/kg)	Total BTEX (mg/kg)
84D	Dec. '93	17.5-18	3000	4480	591	0.162	6.53	6.9	24.4	13.4	9.77	61.16
84D	Dec. '93	18-18.5	3290	4230	709	0.388	11	9.49	32.9	17.6	13.2	84.58
84D	Dec. '93	18.5-1	2340	3450	616	0.21	6.52	5.91	20.9	11.2	8.29	53.03
84D	Dec. '93	19-19.5	2200	3030	610	0.163	6.39	6.12	21.8	11.5	8.58	54.55
84D	Dec. '93	19.5-20	1810	2880	673	0.131	4.78	4.5	1.61	8.52	6.37	25.91
84D	Dec. '93	20-20.5	1740	2360	481	0.177	5.93	5	17.7	9.26	6.93	45.00
84D	Dec. '93	20.5-21	795	1150	631	0.035	1.89	2.03	7.37	4.04	2.88	18.25
84D	Dec. '93	21-21.5	1310	1790	558	0.13	3.99	3.49	12.4	6.59	4.9	31.5
84D	Dec. '93	21.5-22	2410	2340	448	0.275	8.55	7.31	26	13.9	10.2	66.24
84D	Dec. '93	22-22.5	1940	2220	584	0.158	6.11	5.55	19.7	10.5	7.76	49.78
84D	Dec. '93	22.5-23	2240	3240	562	0.24	8.14	6.98	24.7	13.2	9.8	63.06
84D	Dec. '93	23-23.5	1860	3710	713	0.31	7.9	5.95	20.6	11	8.19	53.95
84D	Dec. '93	23.5-24	79.6	194	501	BLQ	0.131	0.125	0.457	0.271	0.179	1.16
84D	Dec. '93	28-28.5	ND		NR	ND	ND	BLQ	ND	ND	ND	ND
84D	Dec. '93	35-35.5	19.1	112	42	BLQ	0.132	0.0369	0.131	0.0633	0.0509	0.414
84D	Dec. '93	35.5-36	10.9	99	38	BLQ	0.145	0.0275	0.0951	0.0469	0.0408	0.355
84D	Dec. '93	36-36.5	1750	3380	219	0.812	13.5	6.55	22.4	9.87	8.25	61.38
84D	Dec. '93	36.5-37	3440	4780	471	1.47	25.8	12.5	45.8	19	16.6	121.17
84D	Dec. '93	37-37.5	7840	7570	408	4.9	64.2	31.4	94	39.4	38.3	272.2
84D	Dec. '93	37.5-38	12600	10100	490	9.63	109	51.4	161	62.4	68.1	461.53
84D	Dec. '93	38-38.5	8000	18800	521	6.01	80.1	40.5	139	49.7	47.7	363.01
84D	Dec. '93	38.5-39	22500	39400	414	20.5	236	128	390	137	135	1046.5
84D	Dec. '93	39-39.5	39000	75300	454	32.9	412	239	697	245	244	1869.9
84D	Dec. '93	39.5-40	52700	125000	340	48	547	313	899	318	320	2445
84D	Dec. '93	40-40.5	44300	120000	490	42.6	470	260	751	262	265	2050.6
84D	Dec. '93	40.5-41	28800	78700	348	27.4	303	168	499	173	171	1341.4
84D	Dec. '93	41-41.5	7900	19400	521	7.38	77.2	44.8	134	46	45.7	355.08
84D	Dec. '93	44-44.3	2.73	BLQ	5	ND	BLQ	0.04	0.0978	0.0438	0.0356	0.217
84F	Dec. '93	25.5-26	NR	BLQ	2	NR	NR	NR	NR	NR	NR	NR

TABLE 4.4 (continued)
SOIL DATA FOR THE BTEX COMPOUNDS AND TOTAL PETROLEUM HYDROCARBONS
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Sample Location	Sample Date	Sample Interval(' bgs)[c]	JP-4 (mg/kg)	TPH[a] (mg/kg)	OVM[b]	Benzene (mg/kg)	Toluene (mg/kg)	Ethylbenzene (mg/kg)	m-xylene (mg/kg)	o-xylene (mg/kg)	p-xylene (mg/kg)	Total BTEX (mg/kg)
84F	Dec. '93	26-26.5	NR	BLQ	1	NR	NR	NR	NR	NR	NR	NR
84F	Dec. '93	26.5-27	NR	BLQ	3	NR	NR	NR	NR	NR	NR	NR
84F	Dec. '93	27-27.5	NR	BLQ	1	NR	NR	NR	NR	NR	NR	NR
84F	Dec. '93	27.5-28	NR	BLQ	1	NR	NR	NR	NR	NR	NR	NR
84F	Dec. '93	28-28.5	NR	BLQ	1	NR	NR	NR	NR	NR	NR	NR
84F	Dec. '93	28.5-29	NR	BLQ	1	NR	NR	NR	NR	NR	NR	NR
84F	Dec. '93	29-29.5	NR	64	6	NR	NR	NR	NR	NR	NR	NR
84F	Dec. '93	29.5-30	NR	106	44	NR	NR	NR	NR	NR	NR	NR
84F	Dec. '93	30-30.5	591	762	208	0.119	0.917	1.52	4.69	2.06	1.83	11.14
84F	Dec. '93	30.5-31	618	812	408	0.122	2.89	2.07	6.77	3.23	2.51	17.59
84F	Dec. '93	31-31.5	1770	2050	236	0.315	9.2	7.38	24	11.6	8.7	61.20
84L	Dec. '93	31-32.5	NR	1890	NR	NR	NR	NR	NR	NR	NR	NR
84L	Dec. '93	31.5-32.5	NR	34	NR	NR	NR	NR	NR	NR	NR	NR
84P	Dec. '93	26-26.5	NR	BLQ	1	NR	NR	NR	NR	NR	NR	NR
84P	Dec. '93	26.5-27	NR	BLQ	1	NR	NR	NR	NR	NR	NR	NR
84P	Dec. '93	27-27.5	NR	BLQ	1	NR	NR	NR	NR	NR	NR	NR
84P	Dec. '93	27.5-28	NR	39	1	NR	NR	NR	NR	NR	NR	NR
84P	Dec. '93	28-28.5	NR	BLQ	33	NR	NR	NR	NR	NR	NR	NR
84P	Dec. '93	28.5-29	NR	BLQ	14	NR	NR	NR	NR	NR	NR	NR
84P	Dec. '93	29-29.5	NR	35	11	NR	NR	NR	NR	NR	NR	NR
36PTR3NS	May'94	35.5	1.6	NR	NR	ND	BLQ	BLQ	0.0117	BLQ	BLQ	0.01
66PTR1SS	May'94	11	3440	6950	NR	0.0323	0.548	1.52	16.9	9.23	7.38	35.61
67PTR1SS	May'94	20	0.95	<70	NR	ND	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
68PTR1SS	May'94	39.5	14500	22500	NR	4.75	84.7	12	433	90	114	738.45
70PTR3SS	May'94	10	5.84	151	NR	ND	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
71PTR3SS	May'94	21	3430	3380	NR	BLQ	2.64	7.06	34.4	18.2	11.7	74.00
72PTR3SS	May'94	43	3900	8020	NR	0.085	11.5	11.3	43.7	15.3	16.5	98.39
74PTR2NS	May'94	13	0.65	<70	NR	ND	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
75PTR2NS	May'94	33.8	0.75	<70	NR	ND	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ

TABLE 4.4 (continued)
SOIL DATA FOR THE BTEX COMPOUNDS AND TOTAL PETROLEUM HYDROCARBONS
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Sample Location	Sample Date	Sample Interval(' bgs)[c]	JP-4 (mg/kg)	TPH[a] (mg/kg)	OVM[b]	Benzene (mg/kg)	Toluene (mg/kg)	Ethylbenzene (mg/kg)	m-xylene (mg/kg)	o-xylene (mg/kg)	p-xylene (mg/kg)	Total BTEX (mg/kg)
76PTR2NS	May'94	38	2120	NR	NR	BLQ	5.23	11.1	26	11.2	8.04	61.57
84BA	May'94	10.1-10.5	NR	<70	NR	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
84BA	May'94	10.5-10.9	NR	<70	NR	ND	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
84BA	May'94	10.9-11.3	NR	<70	NR	ND	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
84BA	May'94	11.3-11.7	NR	<70	NR	ND	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
84BA	May'94	11.7-12.1	NR	<70	NR	ND	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
84BA	May'94	12.1-12.5	NR	<70	NR	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
84BA	May'94	31.5-31.6	NR	<70	NR	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
84BA	May'94	31.6-32	NR	<70	NR	ND	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
84BA	May'94	32-32.4	NR	<70	NR	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
84BA	May'94	32.4-32.4	NR	<70	NR	ND	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
84BA	May'94	32.8-33.2	NR	<70	NR	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
84BA	May'94	33.2-33.6	NR	<70	NR	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
84BA	May'94	33.6-34	NR	<70	NR	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
84BA	May'94	34-34.1	NR	<70	NR	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
84BA	May'94	34.1-34.5	NR	<70	NR	ND	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
84BA	May'94	34.5-34.9	NR	<70	NR	ND	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
84BA	May'94	34.9-35.3	NR	<70	NR	ND	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
84BA	May'94	35.3-35.7	NR	<70	NR	ND	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
84BA	May'94	35.7-36.1	NR	<70	NR	ND	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
84BA	May'94	36.1-36.5	NR	<70	NR	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
84CA	May'94	38.1-38.5	NR	NR	NR	0.0162	64.3	70.2	228	46.1	62.7	471.32
84S	May'94	7.5-8.0	12.7	229	NR	ND	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
84S	May'94	7.0-7.5	17.5	<70	NR	BLQ	0.083	0.0115	0.0514	0.0226	0.0187	0.19
84S	May'94	17.0-17.5	0.76	<70	NR	BLQ	BLQ	BLQ	0.0086	BLQ	BLQ	0.01
84S	May'94	16.5-17.0	0.78	<70	NR	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
84S	May'94	24.7-25.0	76.8	<70	NR	0.0256	0.193	0.1	0.458	0.258	0.17	1.20
84S	May'94	35.2-35.5	9750	9150	NR	2.84	53.7	40	124	37.5	41.7	299.74
84S	May'94	34.4-34.8	4690	3090	NR	1.16	26.6	19.5	65.6	20.4	21.7	154.96

TABLE 4.4 (concluded)
SOIL DATA FOR THE BTEX COMPOUNDS AND TOTAL PETROLEUM HYDROCARBONS
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Sample Location	Sample Date	Sample Interval(' bgs)[c]	JP-4 (mg/kg)	TPH[a] (mg/kg)	OVM[b]	Benzene (mg/kg)	Toluene (mg/kg)	Ethylbenzene (mg/kg)	m-xylene (mg/kg)	o-xylene (mg/kg)	p-xylene (mg/kg)	Total BTEX (mg/kg)
84S	May'94	33.6-34.0	4390	3810	NR	1.32	25.7	18.8	62	19.7	20.5	148.02
84S	May'94	33.2-33.0	611	<70	NR	0.0475	2.1	2.1	7.43	2.67	2.37	16.72
84S	May'94	38.2-38.6	20600	19900	NR	9.95	108	79	357	73.1	67.1	694.15
84S	May'94	37.4-37.8	8780	15900	NR	4.25	59.3	41.6	204	40.8	42.7	392.65
84S	May'94	37.2-37.4	7960	NR	NR	2.26	29.8	28.4	85.4	24.6	28.1	198.56
84S	May'94	41.1-41.5	2410	3400	NR	2.04	21.6	15.4	44.5	14	14.8	112.34
84S	May'94	40.7-41.1	4090	NR	NR	3.47	37.3	26.3	73.3	23.2	25	188.57
84S	May'94	40.3-40.7	32.2	<70	NR	0.481	1.29	0.349	1.06	0.378	0.327	3.89
84S	May'94	39.7-39.9	15400	13800	NR	7.05	67.4	53	229	46.6	53.3	456.35
84S	May'94	42.7-43.1	16.4	<70	NR	0.031	1.71	0.245	0.725	0.2665	0.229	3.21
84S	May'94	42.3-42.7	39	NR	NR	0.0431	2.05	0.416	1.19	0.458	0.385	4.54
84S	May'94	41.9-42.3	9990	3850	NR	4.73	126	75.3	227	73.8	71.2	578.03
06PTR1SF	May'94		NR	NR	NR	BLQ	BLQ	0.0787	0.014	0.059	0.074	0.23
B8133384	May'94		NR	NR	NR	BLQ	BLQ	7.38	24.5	0.04	8.9	40.82

a/ TPH = total petroleum hydrocarbons
b/ OVM =organic vapor meter
c/ ' bgs = feet below ground surface
d/ NR = not reported
e/ BLQ = below practical limit of quantitation
f/ ND = not detected

TABLE 4.5
SOIL DATA FOR CHLORINATED SOLVENTS AND OTHER FUEL-RELATED COMPOUNDS
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Sample Location	Sample Date	Sample Interval(' bgs)[y]	TCE[w] (mg/kg)	1,2,3-TMB[b] (mg/kg)	1,2,4-TMB[d] (mg/kg)	1,3,5-TMB[d] (mg/kg)	1,3-DCB[e] (mg/kg)	1,4-DCB[e] (mg/kg)	1,2-DCB[e] (mg/kg)	Napthalene (mg/kg)	2-methylnapth[v] (mg/kg)	1-methylnapth[v] (mg/kg)
84B	Dec. '93	31-32.5' bgs	BLQ[w]	6.37	16.3	6.26	BLQ	0.0398	BLQ	2.79	4.03	2.69
84D	Dec. '93	14-14.5' bgs	ND[v]	BLQ	BLQ	0.034	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
84D	Dec. '93	15-15.5' bgs	ND	0.0347	BLQ	BLQ	ND	ND	ND	BLQ	BLQ	BLQ
84D	Dec. '93	15.5-16' bgs	ND	11.3	15.5	10.3	0.05	0.127	ND	1.71	3.93	4.02
84D	Dec. '93	16-16.5' bgs	BLQ	4.83	11.3	4.61	BLQ	0.0672	0.142	1.24	1.38	1.33
84D	Dec. '93	16.5-17' bgs	BLQ	12	28.3	11.7	0.053	0.123	NR[w]	6.33	8.3	6.33
84D	Dec. '93	17-17.5' bgs	BLQ	11.6	28.2	11.1	0.047	0.113	0.451	8.03	9.56	6.92
84D	Dec. '93	17.5-18' bgs	ND	12.1	29.2	11.1	0.0048	0.116	0.497	8.97	10.7	7.75
84D	Dec. '93	18-18.5' bgs	BLQ	13.6	33.3	13	0.053	0.127	0.567	9.49	11.1	7.99
84D	Dec. '93	18.5-19' bgs	BLQ	9.09	22.8	8.39	0.036	0.0871	0.36	6.68	7.94	5.63
84D	Dec. '93	19-19.5' bgs	BLQ	9.05	22.6	8.39	0.036	0.0858	0.413	6.59	7.89	5.59
84D	Dec. '93	19.5-20' bgs	BLQ	6.92	17.5	6.32	0.029	0.0673	0.304	5.2	6.48	4.59
84D	Dec. '93	20-20.5' bgs	BLQ	6.94	17.7	6.31	BLQ	0.0665	0.308	4.95	5.99	4.23
84D	Dec. '93	20.5-21' bgs	ND	3.44	8.84	3.02	BLQ	0.0361	0.146	2.58	3.14	2.16
84D	Dec. '93	21-21.5' bgs	BLQ	5.37	13.6	4.7	BLQ	0.0511	0.241	3.95	4.98	3.54
84D	Dec. '93	21.5-22' bgs	BLQ	11.1	27.3	9.7	0.043	0.103	0.496	8.13	10.1	7.27
84D	Dec. '93	22-22.5' bgs	BLQ	8.75	21.8	7.61	BLQ	0.08	0.38	6.45	8.17	5.77
84D	Dec. '93	22.5-23' bgs	BLQ	10.5	26	9.28	0.041	0.0965	0.451	7.54	9.74	6.99
84D	Dec. '93	23-23.5' bgs	BLQ	8.33	20.4	7.26	0.033	0.077	0.407	5.82	7.43	5.28
84D	Dec. '93	23.5-24' bgs	ND	0.311	0.759	0.25	BLQ	BLQ	BLQ	0.275	BLQ	BLQ
84D	Dec. '93	35-35.5' bgs	BLQ	0.0392	0.0941	0.0317	ND	ND	BLQ	BLQ	BLQ	BLQ
84D	Dec. '93	35.5-36' bgs	ND	BLQ	0.0347	BLQ	BLQ	ND	BLQ	BLQ	BLQ	BLQ
84D	Dec. '93	36-36.5' bgs	5.06	7.62	19.2	6.8	0.078	0.307	1.48	5.15	6.81	4.79
84D	Dec. '93	36.5-37' bgs	17.4	14.8	35.4	13.9	0.121	0.367	2.34	9.73	11.7	8.36
84D	Dec. '93	37-37.5' bgs	57.2	29.3	62.6	30.5	0.295	0.879	5.09	18.6	22.3	16.4
84D	Dec. '93	37.5-38' bgs	169	38.2	82.5	44.5	0.923	2.68	11.7	23.9	30.3	22.2
84D	Dec. '93	38-38.5' bgs	210	28.6	76.2	26.9	0.876	2.57	11.7	15.5	20.1	12.5
84D	Dec. '93	38.5-39' bgs	615	73.5	193	71.4	2.76	8.01	36.1	39.7	52.9	35.3

TABLE 4.5 (continued)
SOIL DATA FOR CHLORINATED SOLVENTS AND OTHER FUEL-RELATED COMPOUNDS
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Sample Location	Sample Date	Sample Interval(' bgs)[y]	TCE[a] (mg/kg)	1,2,3-TMB[b] (mg/kg)	1,2,4-TMB[c] (mg/kg)	1,3,5-TMB[d] (mg/kg)	1,3-DCB[e] (mg/kg)	1,4-DCB[f] (mg/kg)	1,2-DCB[g] (mg/kg)	Napthalene (mg/kg)	2-methylnapth[w] (mg/kg)	1-methylnapth[v] (mg/kg)
84D	Dec. '93	39-39.5' bgs	931	127	328	127	5.25	14.9	66.6	67.4	90.3	61.5
84D	Dec. '93	39.5-40' bgs	1280	164	425	165	692	19.8	88.2	86.3	116	78.7
84D	Dec. '93	40-40.5' bgs	1130	133	343	134	5.82	16.7	73.4	69.8	92.7	62.6
84D	Dec. '93	40.5-41' bgs	876	89.9	239	89.5	3.97	11.4	51.4	47.9	62.3	40.1
84D	Dec. '93	41-41.5' bgs	314	26.4	67.1	24.6	1.36	3.91	18.3	13.7	18.4	11.9
84D	Dec. '93	44-44.3' bgs	ND	BLQ	BLQ	BLQ	ND	ND	ND	BLQ	BLQ	BLQ
84F	Dec. '93	28-28.5' bgs	BLQ	ND	ND	ND	ND	ND	ND	BLQ	BLQ	BLQ
84F	Dec. '93	30-30.5' bgs	ND	2.37	5.28	1.9	ND	ND	ND	0.615	1.45	0.82
84F	Dec. '93	30.5-31' bgs	ND	2.29	5.91	2.31	ND	ND	ND	0.821	1.6	0.96
84F	Dec. '93	31-31.5' bgs	ND	7.16	19.4	8.21	ND	ND	ND	2.45	6.24	3.88
36PTR3N	May'94	35.5' bgs	0.13	BLQ	0.00849	BLQ	NR	NR	NR	NR	NR	NR
66PTR1S	May'94	11' bgs	0.00979	7.28	15.9	7.1	NR	NR	NR	NR	NR	NR
67PTR1S	May'94	20' bgs	BLQ	BLQ	BLQ	BLQ	NR	NR	NR	NR	NR	NR
68PTR1S	May'94	39.5' bgs	0.705	40	106	48.2	NR	NR	NR	NR	NR	NR
70PTR3S	May'94	10' bgs	BLQ	BLQ	BLQ	BLQ	NR	NR	NR	NR	NR	NR
71PTR3S	May'94	21' bgs	BLQ	13.1	33.9	17.5	NR	NR	NR	NR	NR	NR
72PTR3S	May'94	43' bgs	0.0334	8.12	24.9	11.6	NR	NR	NR	NR	NR	NR
74PTR2N	May'94	13' bgs	0.0198	ND	BLQ	ND	NR	NR	NR	NR	NR	NR
75PTR2N	May'94	33.8' bgs	0.0766	BLQ	BLQ	BLQ	NR	NR	NR	NR	NR	NR
76PTR2N	May'94	38' bgs	33.2	7.97	18.8	7.88	NR	NR	NR	NR	NR	NR
84BA	May'94	10.1-10.5' bgs	BLQ	BLQ	BLQ	BLQ	NR	NR	NR	NR	NR	NR
84BA	May'94	10.5-10.9' bgs	BLQ	BLQ	BLQ	BLQ	NR	NR	NR	NR	NR	NR
84BA	May'94	10.9-11.3' bgs	BLQ	BLQ	BLQ	BLQ	NR	NR	NR	NR	NR	NR
84BA	May'94	11.3-11.7' bgs	BLQ	BLQ	BLQ	BLQ	NR	NR	NR	NR	NR	NR
84BA	May'94	11.7-12.1' bgs	BLQ	BLQ	BLQ	BLQ	NR	NR	NR	NR	NR	NR
84BA	May'94	12.1-12.5' bgs	BLQ	BLQ	BLQ	BLQ	NR	NR	NR	NR	NR	NR
84BA	May'94	31.5-31.6' bgs	BLQ	BLQ	BLQ	BLQ	NR	NR	NR	NR	NR	NR
84BA	May'94	31.6-32' bgs	BLQ	BLQ	ND	BLQ	NR	NR	NR	NR	NR	NR

TABLE 4.5 (continued)
SOIL DATA FOR CHLORINATED SOLVENTS AND OTHER FUEL-RELATED COMPOUNDS
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Sample Location	Sample Date	Sample Interval(' bgs)[y]	TCE[w] (mg/kg)	1,2,3-TMB[b] (mg/kg)	1,2,4-TMB[c] (mg/kg)	1,3,5-TMB[d] (mg/kg)	1,3-DCB[e] (mg/kg)	1,4-DCB[f] (mg/kg)	1,2-DCB[g] (mg/kg)	Napthalene (mg/kg)	2-methylnapth[h] (mg/kg)	1-methylnapth[i] (mg/kg)
84BA	May'94	32-32.4' bgs	BLQ	ND	BLQ	BLQ	NR	NR	NR	NR	NR	NR
84BA	May'94	32.4-32.4' bgs	BLQ	ND	BLQ	ND	NR	NR	NR	NR	NR	NR
84BA	May'94	32.8-33.2' bgs	BLQ	BLQ	BLQ	BLQ	NR	NR	NR	NR	NR	NR
84BA	May'94	33.2-33.6' bgs	BLQ	BLQ	BLQ	BLQ	NR	NR	NR	NR	NR	NR
84BA	May'94	33.6-34' bgs	BLQ	BLQ	BLQ	BLQ	NR	NR	NR	NR	NR	NR
84BA	May'94	34-34.1' bgs	BLQ	ND	BLQ	BLQ	NR	NR	NR	NR	NR	NR
84BA	May'94	34.1-34.5' bgs	BLQ	BLQ	BLQ	BLQ	NR	NR	NR	NR	NR	NR
84BA	May'94	34.5-34.9' bgs	BLQ	ND	ND	ND	NR	NR	NR	NR	NR	NR
84BA	May'94	34.9-35.3' bgs	BLQ	ND	BLQ	ND	NR	NR	NR	NR	NR	NR
84BA	May'94	35.3-35.7' bgs	BLQ	ND	ND	ND	NR	NR	NR	NR	NR	NR
84BA	May'94	35.7-36.1' bgs	BLQ	ND	ND	BLQ	NR	NR	NR	NR	NR	NR
84BA	May'94	36.1-36.5' bgs	BLQ	ND	BLQ	BLQ	NR	NR	NR	NR	NR	NR
84CA	May'94	38.1-38.5' bgs	144	19.5	42.3	22.6	NR	NR	NR	NR	NR	NR
84S	May'94	7.5-8.0' bgs	BLQ	BLQ	BLQ	BLQ	NR	NR	NR	NR	NR	NR
84S	May'94	7.0-7.5'bgs	BLQ	0.0236	0.0671	0.0271	NR	NR	NR	NR	NR	NR
84S	May'94	17.0-17.5' bgs	0.00756	BLQ	0.00833	BLQ	NR	NR	NR	NR	NR	NR
84S	May'94	16.5-17.0' bgs	BLQ	BLQ	BLQ	BLQ	NR	NR	NR	NR	NR	NR
84S	May'94	24.7-25.0' bgs	0.00778	0.285	0.796	0.245	NR	NR	NR	NR	NR	NR
84S	May'94	35.2-35.5' bgs	19.1	24.4	53.7	25.3	NR	NR	NR	NR	NR	NR
84S	May'94	34.4-34.8' bgs	8.03	13.4	31	14.2	NR	NR	NR	NR	NR	NR
84S	May'94	33.6-34.0' bgs	7.78	12.7	30.9	13.6	NR	NR	NR	NR	NR	NR
84S	May'94	33.2-33.0' bgs	0.408	2.02	5.39	2.07	NR	NR	NR	NR	NR	NR
84S	May'94	38.2-38.6' bgs	83.8	42.4	102	39.8	NR	NR	NR	NR	NR	NR
84S	May'94	37.4-37.8' bgs	29.1	0.26	58.8	22.8	NR	NR	NR	NR	NR	NR
84S	May'94	37.2-37.4' bgs	20.7	15.7	35.5	16.7	NR	NR	NR	NR	NR	NR
84S	May'94	41.1-41.5' bgs	15.4	6.62	16.7	7.72	NR	NR	NR	NR	NR	NR
84S	May'94	40.7-41.1' bgs	30.2	10.4	26.8	12.2	NR	NR	NR	NR	NR	NR
84S	May'94	40.3-40.7' bgs	1.25	0.116	0.243	0.108	NR	NR	NR	NR	NR	NR

TABLE 4.5 (concluded)
SOIL DATA FOR CHLORINATED SOLVENTS AND OTHER FUEL-RELATED COMPOUNDS
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Sample Location	Sample Date	Sample Interval(' bgs)[j]	TCE[a] (mg/kg)	1,2,3-TMB[b] (mg/kg)	1,2,4-TMB[c] (mg/kg)	1,3,5-TMB[d] (mg/kg)	1,3-DCB[e] (mg/kg)	1,4-DCB[f] (mg/kg)	1,2-DCB[g] (mg/kg)	Napthalene (mg/kg)	2-methylnapth[h] (mg/kg)	1-methylnapth[i] (mg/kg)
84S	May'94	39.7-39.9' bgs	60.4	25.8	66	28	NR	NR	NR	NR	NR	NR
84S	May'94	42.7-43.1' bgs	0.117	0.0639	0.141	0.0498	NR	NR	NR	NR	NR	NR
84S	May'94	42.3-42.7' bgs	0.251	0.124	0.288	0.118	NR	NR	NR	NR	NR	NR
84S	May'94	41.9-42.3' bgs	70.1	32.8	90.9	38.1	NR	NR	NR	NR	NR	NR
06PTR1SF	May'94		BLQ	BLQ	0.00542	BLQ	NR	NR	NR	NR	NR	NR
B8133384	May'94		BLQ	7.74	19.9	8.47	NR	NR	NR	NR	NR	NR

a/ TCE = trichloroethene
b/ 1,2,3-TMB = 1,2,3-trimethylbenzene
c/ 1,2,4-TMB = 1,2,4-trimethylbenzene
d/ 1,3,5-TMB = 1,3,5-trimethylbenzene
e/ 1,3-DCB = 1,3-dichlorobenzene
f/ 1,4-DCB = 1,4-dichlorobenzene
g/ 1,2-DCB = 1,2-dichlorobenzene
h/ 2-methylnapth = 2-methylnapthalene
i/ 1-methylnapth = 1-methylnapthalene
j/ ' bgs = feet below ground surface
k/ BLQ = below limit of practical quantitation
l/ ND = not detected
m/ NR = not reported

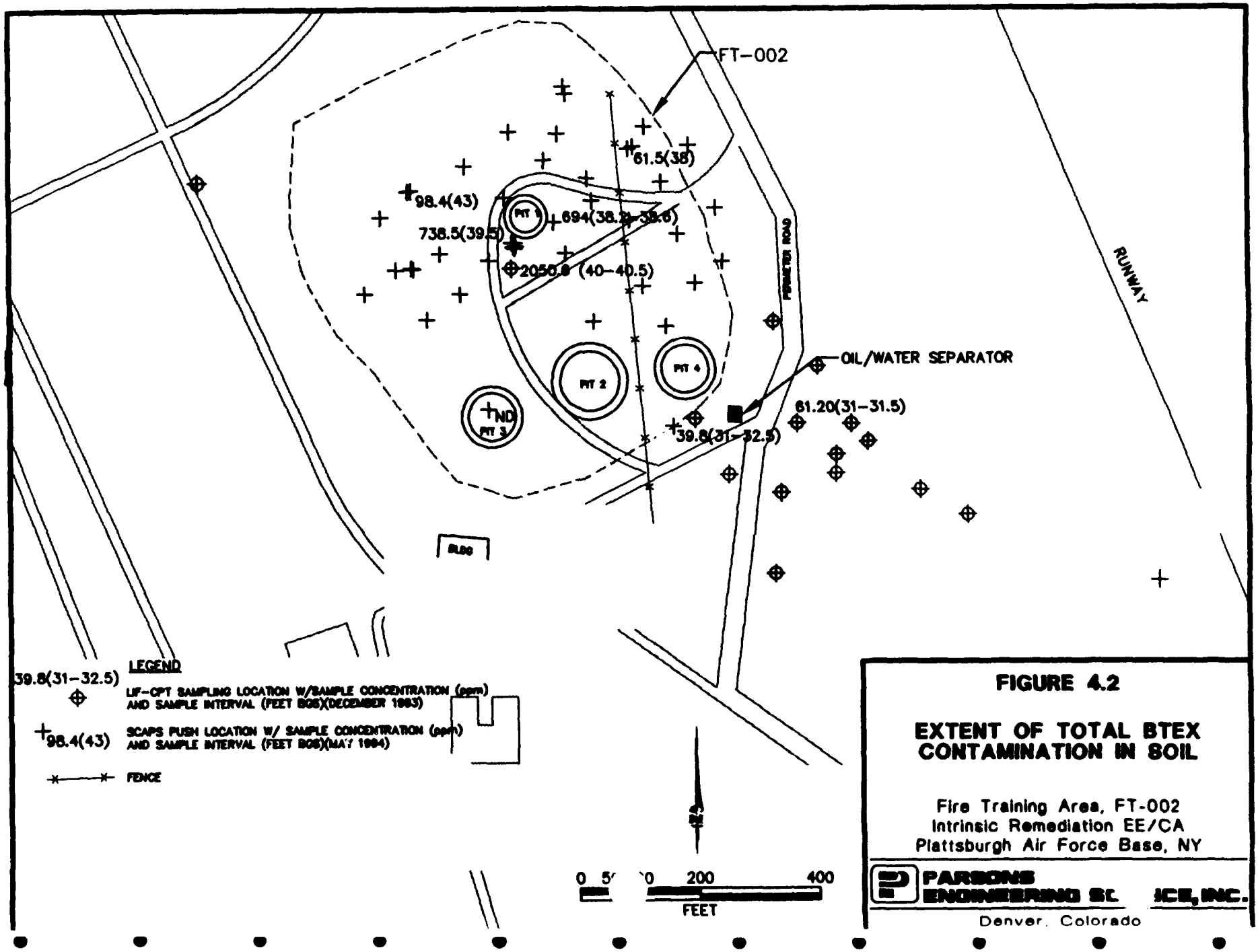

FIGURE 4.2

EXTENT OF TOTAL BTEX CONTAMINATION IN SOIL

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

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per kilogram (mg/kg). This maximum total BTEX concentration was observed in a soil core sample taken from approximately 40 feet bgs at sample location 84D, which is within or at least immediately adjacent to the suspected source area of JP-4 contamination. The JP-4 and TPH concentrations for this sample location and depth (44,300 and 120,000 mg/kg, respectively) are indicative of LNAPL source contamination.

Figure 4.3 schematically illustrates the probable vertical extent of vadose zone BTEX contamination along a line parallel to ground water flow based on soil data collected in December 1993 and May 1994. These data suggest that most of the LNAPL traveled at saturation to the water table, and little fuel-related contamination is held at residual saturation above the capillary fringe. Measured concentration of total BTEX in soil samples generally increased with depth. However, as noted in Section 4.2.1, data from the LIF CPT and SCAPS surveys conducted at this site under this program indicated some level of soil contamination in shallow soils at select sample locations. The presence of fuel-related contamination in shallow soils can probably be attributed to either recent surface spills or subsurface heterogeneities that have impeded downward migration.

Assuming that the former fire training pits are the only source of contamination at the site, the soil data also indicate that fuel-related contamination has spread laterally. Lateral spreading within the capillary fringe can result from seasonal water table fluctuations, the chemical and physical properties of the contaminants themselves, and the effects of capillary forces (ABB Environmental, Inc., 1992). Additionally, some degree of lateral spreading is consistent with a slow release, such as is indicated at FT-002 given the operational history of the site (Farmer, 1983).

4.3.2.2 Soil TPH Contamination

Figures 4.2 and 4.4 show that elevated TPH concentrations are closely associated with elevated BTEX concentrations in soil. The distribution of soil contamination at the site is consistent with the suspected sources. Measured TPH concentrations exceeded 120,000 mg/kg at 84D in saturated soil near the water table within the source area. Measured TPH concentrations at 84F, which is located at the outer fringe of the suspected area of LNAPL, reached a maximum of 2,051 mg/kg of soil. The vertical thickness of TPH contamination that equals or exceeds 100 mg/kg in soil is approximately 25 feet above the water table within the source area. The vertical thickness of TPH contamination decreases and then disappears in areas downgradient of the source area.

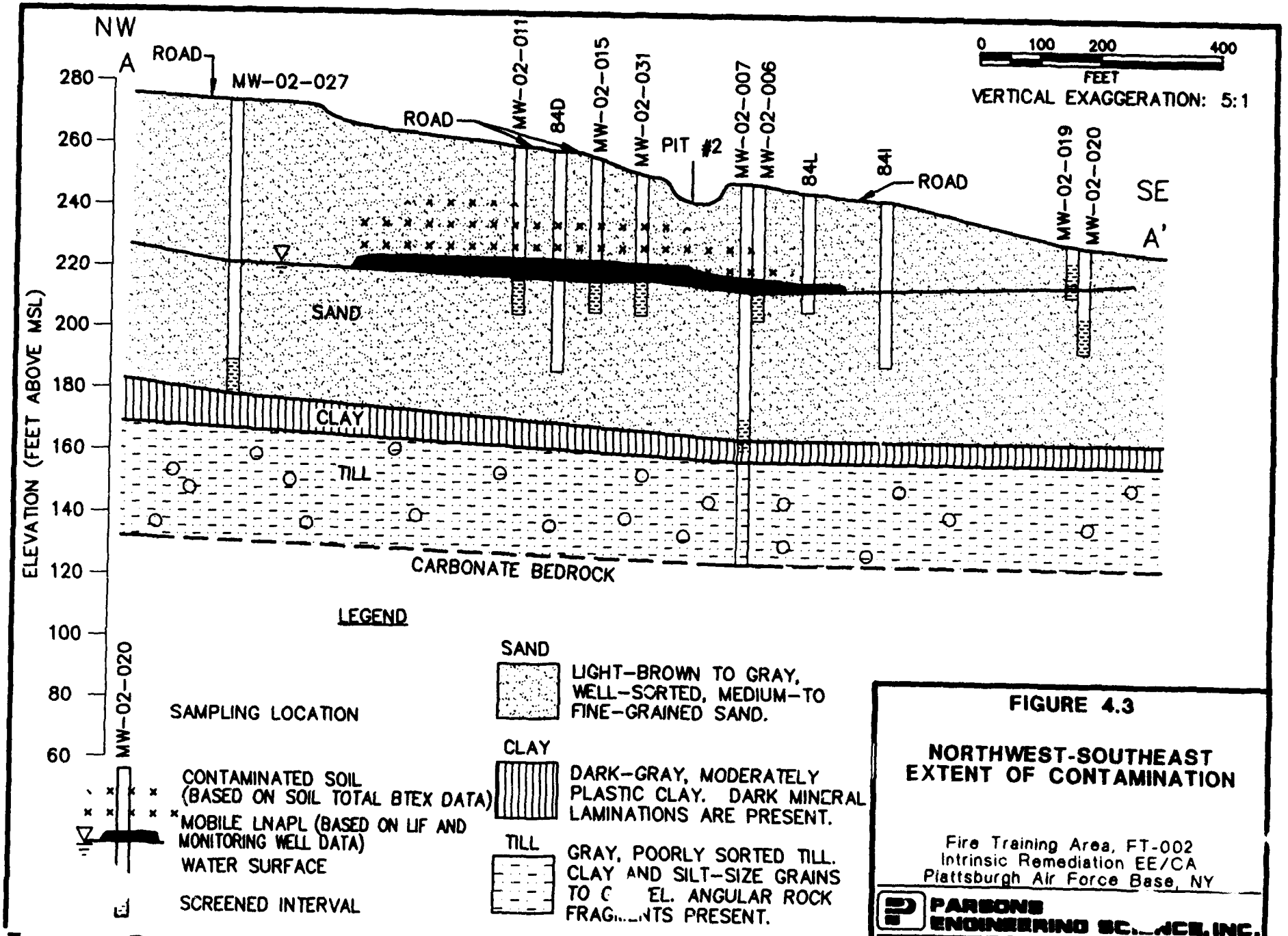

FIGURE 4.3

NORTHWEST-SOUTHEAST EXTENT OF CONTAMINATION

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SC...CE, INC.

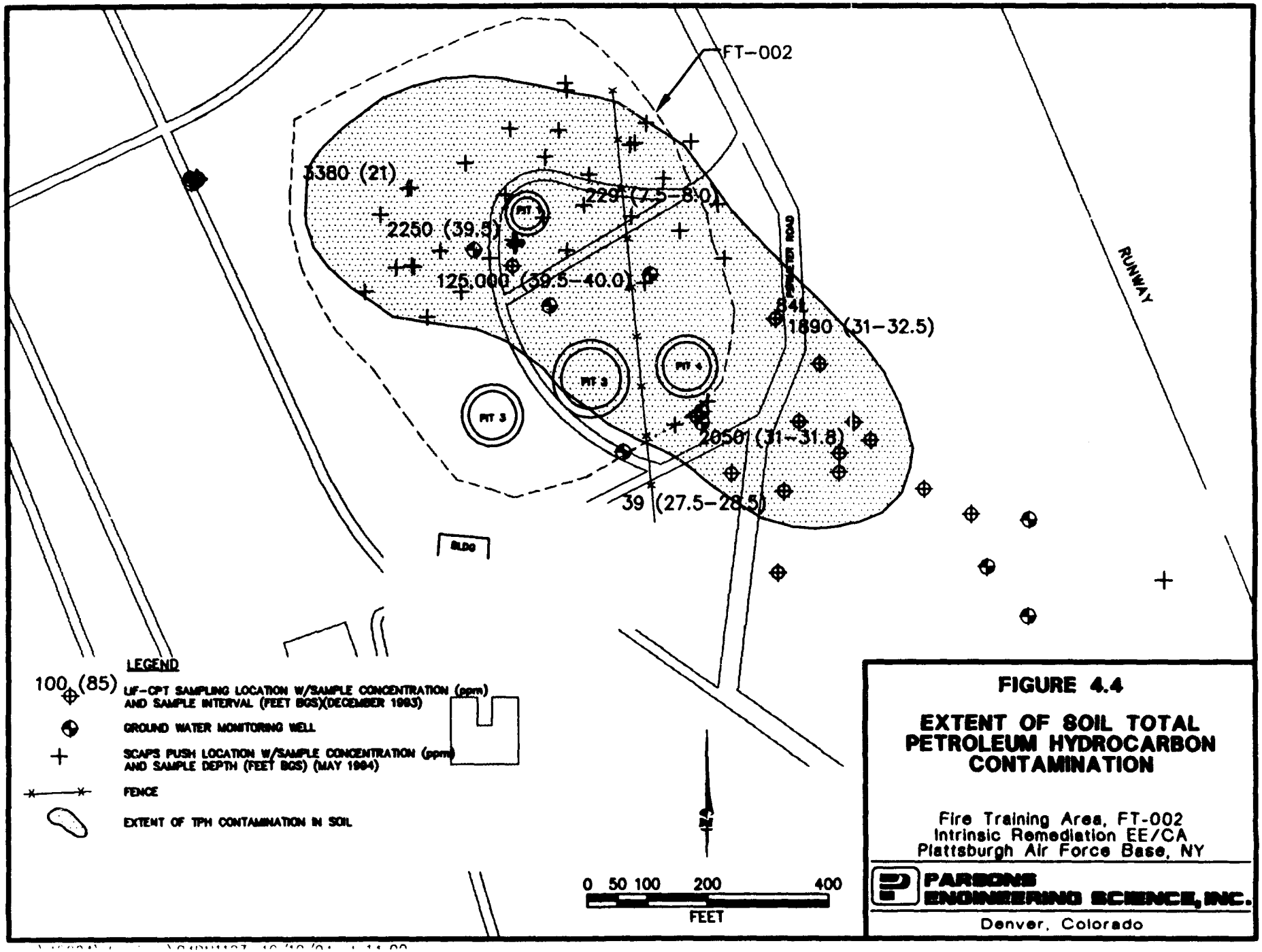

FIGURE 4.4

EXTENT OF SOIL TOTAL PETROLEUM HYDROCARBON CONTAMINATION

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

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Denver, Colorado

Elevated concentrations of TPH in soil did not extend significantly below the ground water table. Existing data suggest that the winter water table levels may represent a seasonal low (see Appendix B). Because soils below this minimum water table level did not appear to be affected by site-related contamination, it appears that the total depth of soil contamination is due to contact with LNAPL. Dissolved contamination in ground water does not appear to be a significant source of soil contamination.

4.3.2.3 Soil Solvent Contamination

Chlorinated solvents were mixed with the JP-4 fuel used in fire training exercises at the site. The Phase I RI report for soils identified TCE, DCE, 1,3-DCB, and 1,4-DCB as fuel-related contamination based on the operational history of the site. Figure 4.5 describes the probable extent of TCE contamination in soil, as measured in December 1993 and May 1994. Table 4.5 presents soil data for other solvents measured in soil samples collected under this program. Elevated TCE concentrations were measured in the same soil samples that exhibited elevated BTEX and TPH concentrations. TCE was not measured in soil samples determined to be uncontaminated with regard to other fuel-related compounds. This correlation of contamination distribution in soil suggests that solvent compounds were mixed with fuel before release and that these solvent compounds have not separated significantly from the source fuel during downward migration via percolation.

4.4 GROUND WATER CONTAMINATION

The chemical composition of ground water at the FT-002 site was determined from water samples taken from permanent ground water monitoring wells in December 1993 and from water samples taken at temporary sampling locations using the CPT water sampling apparatus and Geoprobe® in December 1993 and May 1994, respectively. All ground water samples were analyzed as described in Section 2 of this report. Emphasis was placed on defining the extent and nature of ground water contamination and collecting data on geochemical parameters used to evaluate whether naturally occurring attenuation mechanisms are operating at the site. Ground water data collected in 1990 under a separate ground water investigation have been included to supplement data collected under this program.

The upper, unconfined aquifer underlying the FT-002 site is contaminated with dissolved fuel-related compounds and solvents consistent with those identified in the LNAPL and vadose zone soils. Previous ground water investigations conducted at the site have defined a

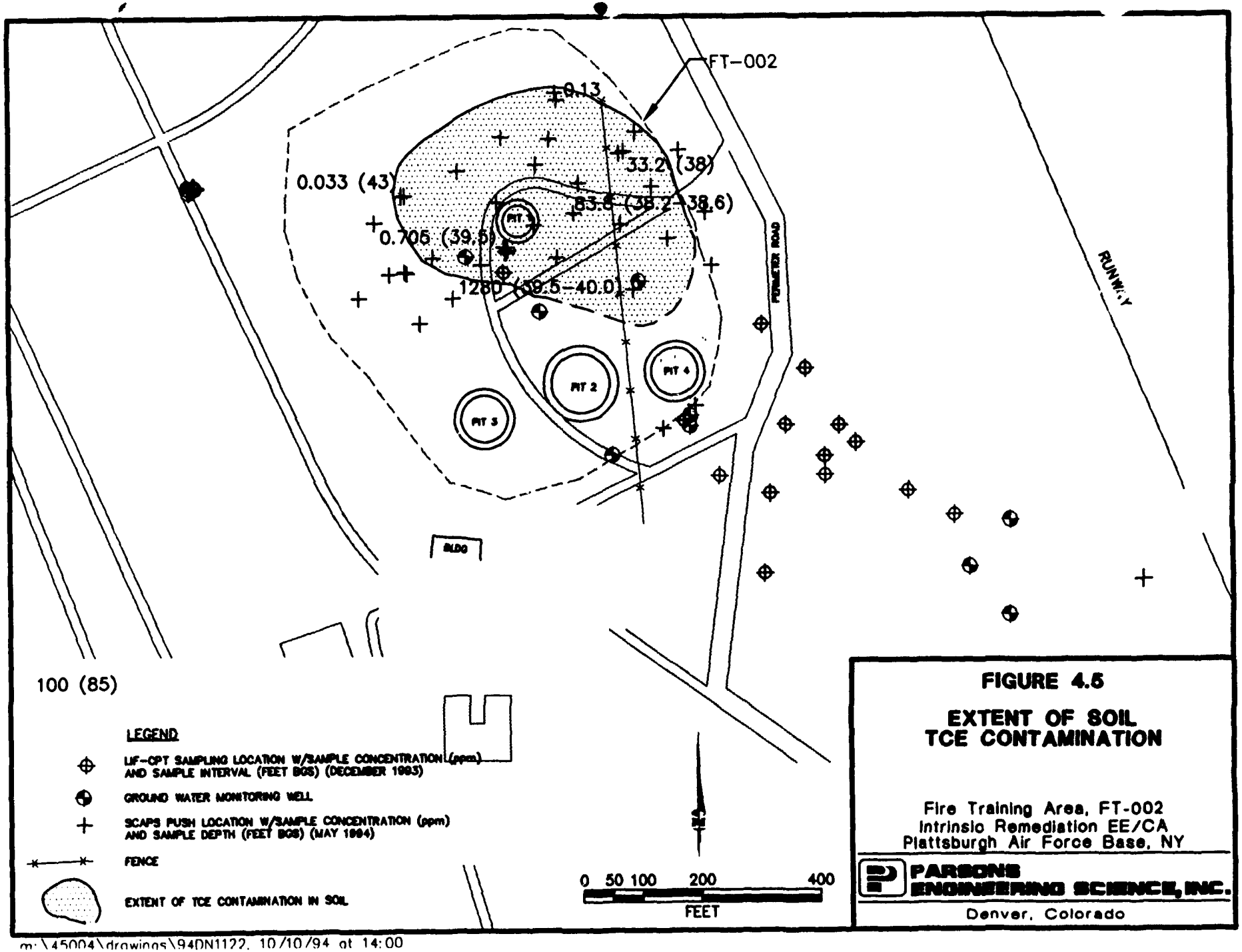

FIGURE 4.5

EXTENT OF SOIL TCE CONTAMINATION

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

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Denver, Colorado

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contaminant distribution pattern based on contaminant concentrations (ABB Environmental, Inc. and URS Consultants, Inc., 1993). The primary site-related contaminants that were measured at elevated concentrations in ground water near the suspected source area as part of previous investigation efforts were the BTEX compounds, TCE, cis-DCE, trans-DCE, napthalene, carbon disulfide, and 2-methylnapthalene. The primary site-related contaminants measured at detectable concentrations in ground water downgradient of the FT-002 site were identified as the BTEX compounds, TCE, cis-DCE, trans-DCE, and vinyl chloride. The vertical and horizontal extent of the fuel-related BTEX compounds and the solvents differed significantly. These differences will be discussed in detail in subsequent sections. Table 4.6 summarizes the ground water quality data from previous site investigations for the primary site-related contaminants.

4.4.1 Dissolved BTEX Contamination

Table 4.7 presents the analytical results for the BTEX compounds measured in ground water samples collected in December 1993 and May 1994 by Parsons ES and RSKERL. Dissolved BTEX compounds are present within and downgradient from the suspected source area at FT-002. Ground water analytical results indicate that the dissolved BTEX ground water plume currently extends approximately 2,800 feet downgradient from Site FT-002, and has a maximum width of about 500 feet. These data are consistent with ground water data on the BTEX compounds collected in 1991 as part of earlier characterization efforts (ABB Environmental, Inc., 1992).

The analytical results for several ground water samples collected from the source area during the December 1993 sampling event showed maximum total BTEX concentrations ranging from 3.14 ppm in MW-02-021 to 6.01 ppm in MW-02-014. These data suggest equilibrium partitioning calculations may overestimate the mass of total BTEX in the ground water at Site FT-002 (see Appendix E).

Figure 4.6a is an isopleth map that shows the areal distribution of total BTEX dissolved in ground water as of December 1993. No ground water samples were collected and analyzed for BTEX compounds during the May 1994 sampling event. This isopleth map was constructed using the maximum total BTEX concentrations identified at each sample location to provide a conservative estimate of the nature and extent of dissolved BTEX contamination. This figure also includes data collected during the 1991 CPT survey conducted between the runway and flightline. These sample locations are used to confirm the lateral width of the dissolved BTEX plume at its furthest downgradient edges. These data represent the only data available for this

TABLE 4.6
SUMMARY OF PREVIOUS GROUND WATER QUALITY DATA
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY*

Sample Compound	Range of Concentration(ppb)[a]	Frequency of Detection	Maximum Concentration(ppb)	Sample Location of Maximum Concentration
Benzene	ND[b] to 720	20/31	720	MW-02-031
Toluene	ND to 2100 D[c]	25/31	2100 D	MW-02-031
Ethylbenzene	ND to 1400	26/31	1400	MW-02-006
Xylenes	ND to 9300	26/31	9300	MW-02-006
Vinyl Chloride	ND to 1000 U[d]	17/31	1000 U	MW-02-031
DCE Total	ND to 9800	27/31	9800	MW-02-031
TCE	ND to 390 D	21/31	390 D	MW-02-011

* Source: Ground water data from Phase I and II RI sampling events
a/ ppb = parts per billion
b/ ND = not detected
c/ D = concentration was established by dilution of original sample
d/ U = nondetect at the associated detection limit

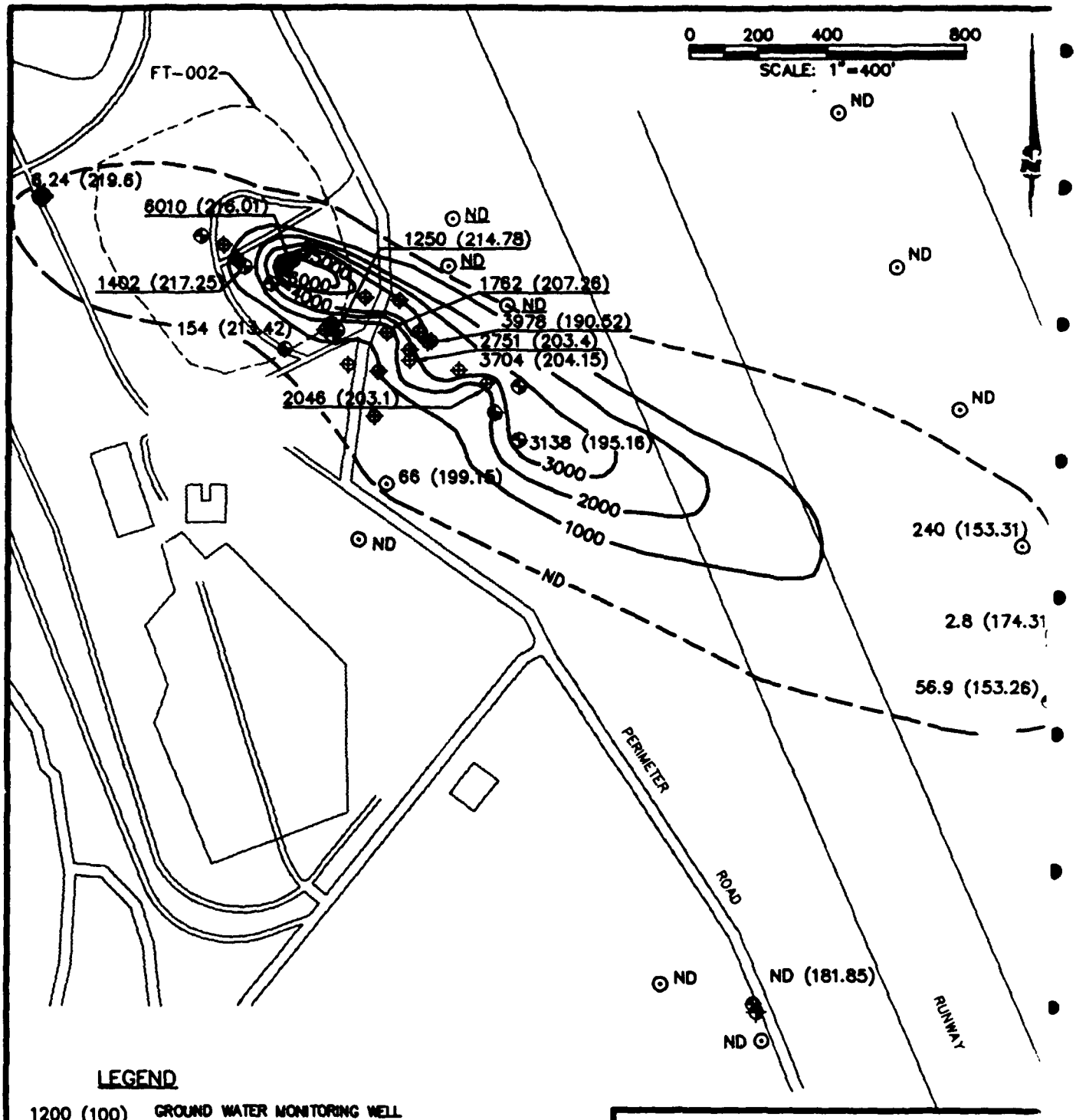
TABLE 4.7
GROUND WATER QUALITY DATA FOR BTEX AND TMB COMPOUNDS
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Sample Location	Sample Date	Sample Elevation (feet msl)[e]	Benzene (ppb)[e]	Toluene (ppb)	Ethylbenzene (ppb)	p-xylene (ppb)	m-xylene (ppb)	o-xylene (ppb)	Total Xylenes (ppb)	Total BTEX (ppb)	1,3,5-TMB[e] (ppb)	1,2,4-TMB[e] (ppb)	1,2,3-TMB[e] (ppb)
84B	Dec. 1993	207.22	71	52.9	16.2	8.53	24.7	14.9	48.13	188.23	< 0.5f/	2.24	2.46
84B	Dec. 1993	186.02	< 0.5g/	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
84E	Dec. 1993	210.52	264	525	354	303	671	268	1242	2385	54	149	60.6
84E	Dec. 1993	190.52	448	944	606	553	979	448	1980	3978	78.6	227	120
84E	Dec. 1993	174.52	6.65	< 0.5	7.26	< 0.5	< 0.5	< 0.5	< 0.5	13.91	< 0.5	< 0.5	< 0.5
84F	Dec. 1993	207.26	178	443	263	255	374	249	878	1762	57.4	159	80.7
84F	Dec. 1993	197.26	151	363	250	219	461	164	844	1618	29.7	97.1	49.6
84F	Dec. 1993	192.26	83.4	107	166	136	226	78.2	440.2	796.6	17.3	65.6	33.2
84F	Dec. 1993	177.26	1.59	< 0.5	11.3	< 0.5	< 0.5	< 0.5	< 0.5	12.89	< 0.5	< 0.5	< 0.5
84M	Dec. 1993	203.4	183	277	449	480	1010	352	1842	2751	88.6	242	130
84M	Dec. 1993	183.4	16.3	1.03	15.7	6.25	< 0.5	< 0.5	< 0.5	39.28	< 0.5	< 0.5	< 0.5
84N	Dec. 1993	204.15	416	1090	488	429	902	379	1710	3704	70.8	198	99.6
84N	Dec. 1993	184.15	287	241	316	278	607	223	1108	1954	37.8	102	56.8
84O	Dec. 1993	203.1	296	309	329	294	574	244	1112	2046	56.9	149	71.9
84O	Dec. 1993	188.1	242	78.7	273	233	512	193	938	1531.7	32.6	89.9	50
MW-02-005	Dec. 1993	213.42	1.27	< 0.5	107	37.1	7.69	1.27	46.06	154.33	2.57	5.48	7.65
MW-02-006	Dec. 1993	214.78	7.32	101	144	200	515	283	998	1250.32	180	588	306
MW-02-006 (dup)	Dec. 1993	214.78	7.96	263	139	147	367	187	701	1110.96	43.5	122	66.3
MW-02-007	Dec. 1993	179.69	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
MW-02-014	Dec. 1993	216.01	342	1560	808	795	1790	715	3300	6010	111	352	189
MW-02-015	Dec. 1993	217.25	30.2	303	161	183	512	213	908	1402.2	93	255	145
MW-02-019	Dec. 1993	211.43	321	327	433	352	703	263	1318	2399	65.9	179	93.2
MW-02-020	Dec. 1993	195.16	286	148	563	534	1190	419	2143	3138	116	322	157
MW-02-021	Dec. 1993	181.85	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
MW-02-026	Dec. 1993	219.6	< 0.5	< 0.5	< 0.5	< 0.5	3.69	2.55	6.24	6.24	1.19	1.98	1.66
MW-02-027	Dec. 1993	186.72	< 0.5	< 0.5	< 0.5	< 0.5	0.997	< 0.5	0.997	0.997	< 0.5	< 0.5	< 0.5
MW-02-030	Dec. 1993	179.55	16.5	1.06	19.9	3	4.72	1.48	9.2	46.66	< 0.5	1.1	< 0.5
MW-02-030 (dup)	Dec. 1993	179.55	19.6	1.05	21.6	2.37	3.04	0.969	6.379	48.639	< 0.5	< 0.5	< 0.5

TABLE 4.7 (concluded)
GROUND WATER QUALITY DATA FOR BTEX AND TMB COMPOUNDS
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Sample Location	Sample Date	Sample Elevation (feet msl)[a/]	Benzene (ppb)[b/]	Toluene (ppb)	Ethylbenzene (ppb)	p-xylene (ppb)	m-xylene (ppb)	o-xylene (ppb)	Total Xylenes (ppb)	Total BTEX (ppb)	1,3,5-TMB[c/] (ppb)	1,2,4-TMB[d/] (ppb)	1,2,3-TMB[e/] (ppb)
MW-02-040	Dec. 1993	184.02	1.93	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	1.93	< 0.5	< 0.5	< 0.5
MW-02-041	Dec. 1993	169.05	40.7	< 0.5	< 0.5	< 0.5	< 0.5	0.914	0.914	41.614	< 0.5	< 0.5	< 0.5
MW-02-042	Dec. 1993	153.26	56.9	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	56.9	< 0.5	< 0.5	< 0.5
MW-02-043	Dec. 1993	165.47	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
MW-02-043 (dup)	Dec. 1993	165.47	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
MW-02-044	Dec. 1993	166.24	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Field Blank	Dec. 1993		2.42	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
CP-02-003	1991	217.15	2	NR[h/]	NR	NR	NR	NR	NR	2	NR	NR	NR
CP-02-003	1991	208.15	15	NR	15	NR	NR	NR	NR	30	NR	NR	NR
CP-02-003	1991	199.15	NR	NR	66	NR	NR	NR	NR	66	NR	NR	NR
CP-02-003	1991	185.15	NR	NR	16	NR	NR	NR	NR	16	NR	NR	NR
CP-02-008	1991	153.31	240	NR	NR	NR	NR	NR	NR	240	NR	NR	NR
CP-02-009	1991	174.31	2.8	NR	NR	NR	NR	NR	NR	2.8	NR	NR	NR

a/ feet msl = feet above mean sea level
b/ ppb = parts per billion
c/ 1,3,5 TMB = 1,3,5 trimethylbenzene
d/ 1,2,4 TMB = 1,2,4 trimethylbenzene
e/ 1,2,3 TMB = 1,2,3 trimethylbenzene
f/ < 0.5 = below practical limit of quantitation
g/ < 0.5 = not detected
h/ NR = not reported
Note: Background sampling locations are placed in boldface



LEGEND

1200 (100) ◆	GROUND WATER MONITORING WELL W/SAMPLE CONCENTRATION IN ppb (DECEMBER 1993) SAMPLE ELEV (feet above msl) IN PARENTHESES
1200 (100) ◆	LIF-CPT SAMPLING LOCATION W/SAMPLE CONCENTRATION IN ppb (DECEMBER 1993) SAMPLE ELEV (feet above msl) IN PARENTHESES
⊙ 1000	CONE PENETROMETER W/SAMPLE CONCENTRATION IN ppb (1991) SAMPLE ELEVATION (FEET ABOVE MSL) IN PARENTHSES
2.0	LINE OF EQUAL TOTAL BTEX CONCENTRATION (ppb)
ND	NOT DETECTED
	CONTOUR INTERVAL = 1000 ppb

FIGURE 4.6a

AREAL EXTENT OF DISSOLVED BTEX AT DEPTH OF MAXIMUM CONCENTRATION

Fire Training Area, FT-002
Intrinsic Remediation EE/C
Plattsburgh Air Force Base, N.Y.

PARSONS ENGINEERING SCIENCE, INC
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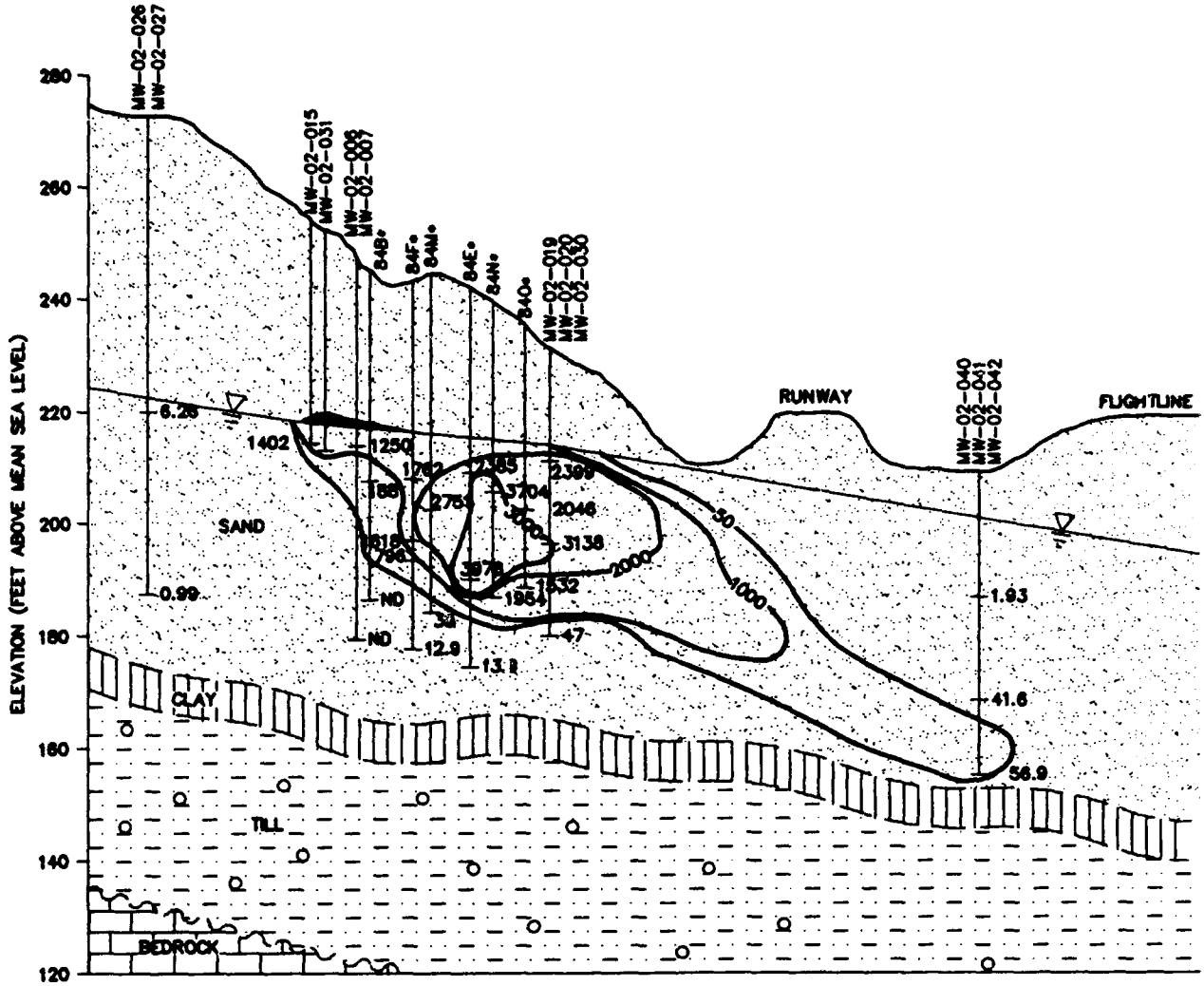
area. As indicated on this map, dissolved BTEX contamination is migrating to the southeast in the direction of ground water flow.

Figure 4.6b is an isopleth map that shows the vertical distribution of total BTEX dissolved in ground water along the plume centerline as of December 1993. The maximum concentration of dissolved total BTEX was measured immediately downgradient of the area with LNAPL contamination. Concentrations of dissolved total BTEX generally were elevated at approximately 40 feet bgs and decreased with depth beneath and immediately downgradient of the suspected source area. The data suggest the presence of a preferential pathway or strong vertical hydraulic gradients as the dissolved total BTEX plume migrates downgradient beneath the runway.

Figures 4.7a through 4.10b map the areal and vertical extent of each of the BTEX compounds. Benzene and o-xylene were measured in ground water samples from well cluster MW-02-040/MW-02-41/MW-02-042, which represents the leading edge of the dissolved BTEX plume. None of the other BTEX compounds were detected at this location. Benzene represented the largest fraction of the total BTEX concentration measured at the downgradient edge of the dissolved plume (o-xylene was measured in well MW-02-041 at a concentration of 0.914 ppb). Dissolved toluene and total xylenes extend about 1,500 feet downgradient of the source area. Measurable concentrations of ethylbenzene are found about 1,800 feet downgradient of the FT-002 site.

The vertical nature and extent of ground water BTEX contamination also is characterized by this compound-specific distribution pattern. In general, toluene and total xylenes were not detected in ground water samples taken from deeper portions of the unconfined, sandy aquifer. Ethylbenzene and particularly benzene appear to have migrated deeper within the aquifer. This vertical distribution pattern is identical to that described in the Phase II RI Report (ABB Environmental, Inc. and URS Consultants, Inc., 1993).

This horizontal and vertical contaminant distribution pattern suggests that benzene is more mobile (less attenuated) in the ground water compared to toluene, ethylbenzene, or the xylenes. Ground water quality data on the BTEX compounds collected during the Phase I and Phase II RI sampling events are comparable (ABB Environmental, Inc. and URS Consultants, Inc., 1993). No significant change in the concentration or extent of BTEX contamination in ground water was identified. Although this comparability between data sets from 1991 and 1993/1994 does not document the mass loss of BTEX contamination over this time period, the data demonstrate



LEGEND

⊥	SAMPLE ELEVATION (ft above msl)
16.4	MEASURED CONCENTRATION OF TOTAL BTEX (ppb)
—20—	LINE OF EQUAL ESTIMATED CONCENTRATION OF TOTAL BTEX (ppb)
ND	NOT DETECTED
	ESTIMATED EXTENT OF LNAPL
▽	SURFACE OF GROUND WATER TABLE
	UNCONFORMITY
	LIGHT-BROWN TO GRAY, WELL-SORTED, MEDIUM-TO FINE-GRAINED SAND
	DARK-GRAY, MODERATELY PLASTIC CLAY. DARK MINERAL LAMINATIONS ARE PRESENT
	GRAY, POORLY SORTED TILL. CLAY AND SILT-SIZE GRAINS TO GRAVEL. ANGULAR ROCK FRAGMENTS PRESENT
	CARBONATE BEDROCK

• WATER ELEVATION DATA FROM CPT POINTS ARE ESTIMATED VALUES

VERTICAL EXAGGERATION = 20X

HORIZ 0 300 600 1200

VERT 0 15 30 60

FIGURE 4.6b

VERTICAL EXTENT OF DISSOLVED TOTAL BTEX ALONG PLUME CENTERLINE

Fire Training Area, FT-00'
Intrinsic Remediation EE/C.
Plattsburgh Air Force Base, NY

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Denver, Colorado

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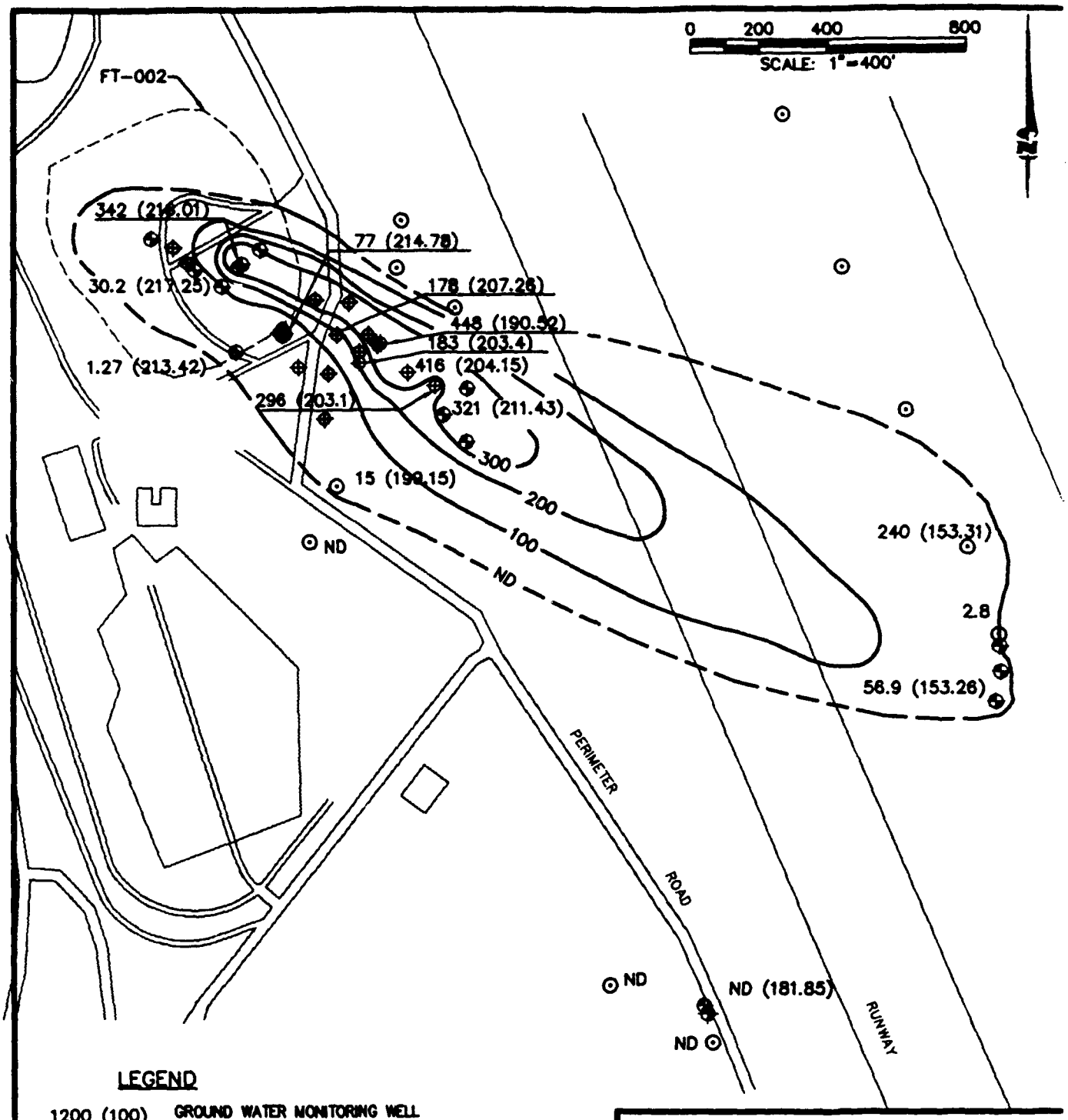

LEGEND

1200 (100) ◆	GROUND WATER MONITORING WELL W/SAMPLE CONCENTRATION IN ppb (DECEMBER 1993) SAMPLE ELEV (feet above msl) IN PARENTHESES
1200 (100) ◆	LIF-CPT SAMPLING LOCATION W/SAMPLE CONCENTRATION IN ppb (DECEMBER 1993) SAMPLE ELEV (feet above msl) IN PARENTHESES
⊙ 1000	CONE PENETROMETER W/SAMPLE CONCENTRATION IN ppb (1991) SAMPLE ELEVATION (FEET ABOVE MSL) IN PARENTHESES
ND	NOT DETECTED
	CONTOUR INTERVAL = 100 ppb
— 2.0 —	LINE OF EQUAL BENZENE CONCENTRATION (ppb)

FIGURE 4.7a

AREAL EXTENT OF DISSOLVED BENZENE AT DEPTH OF MAXIMUM CONCENTRATION

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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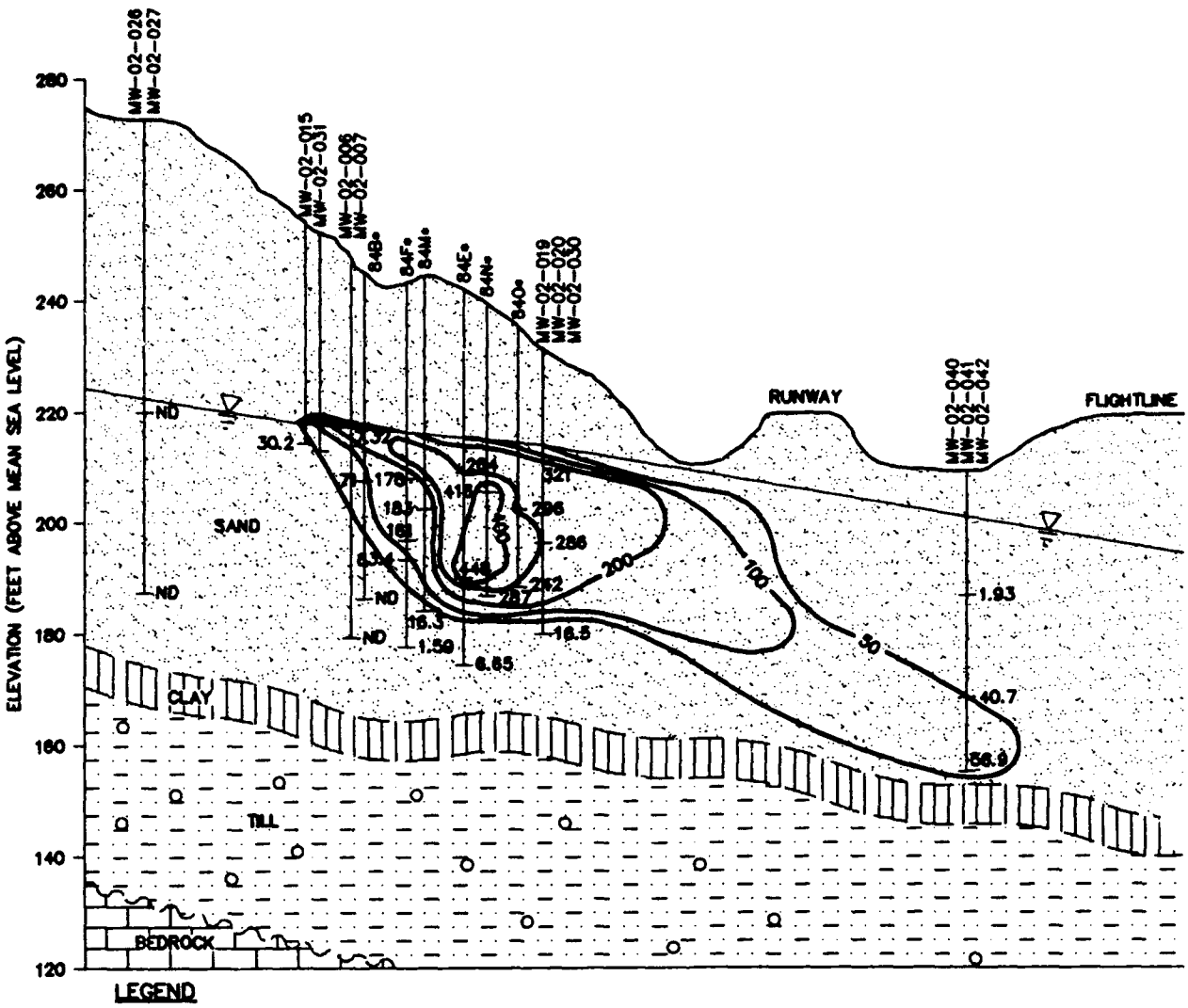

LEGEND

⊥	SAMPLE ELEVATION (ft above msl)
16.4	MEASURED CONCENTRATION OF BENZENE (ppb)
—20—	LINE OF ESTIMATED EQUAL CONCENTRATION OF BENZENE (ppb)
ND	NOT DETECTED
	ESTIMATED EXTENT OF LNAPL
▽	SURFACE OF GROUND WATER TABLE
	UNCONFORMITY
	LIGHT-BROWN TO GRAY, WELL-SORTED, MEDIUM-TO FINE-GRAINED SAND
	DARK-GRAY, MODERATELY PLASTIC CLAY. DARK MINERAL LAMINATIONS ARE PRESENT
	GRAY, POORLY SORTED TILL. CLAY AND SILT-SIZE GRAINS TO GRAVEL. ANGULAR ROCK FRAGMENTS PRESENT
	CARBONATE BEDROCK

* WATER ELEVATION DATA FROM CPT POINTS ARE ESTIMATED VALUES

VERTICAL EXAGGERATION = 20X

HORIZ 0 300 600 1200

VERT 0 15 30 60

FIGURE 4.7b

VERTICAL EXTENT OF DISSOLVED BENZENE ALONG PLUME CENTERLINE

Fire Training Area, FT-002
Intrinsic Remediation EE/C
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC
Denver, Colorado

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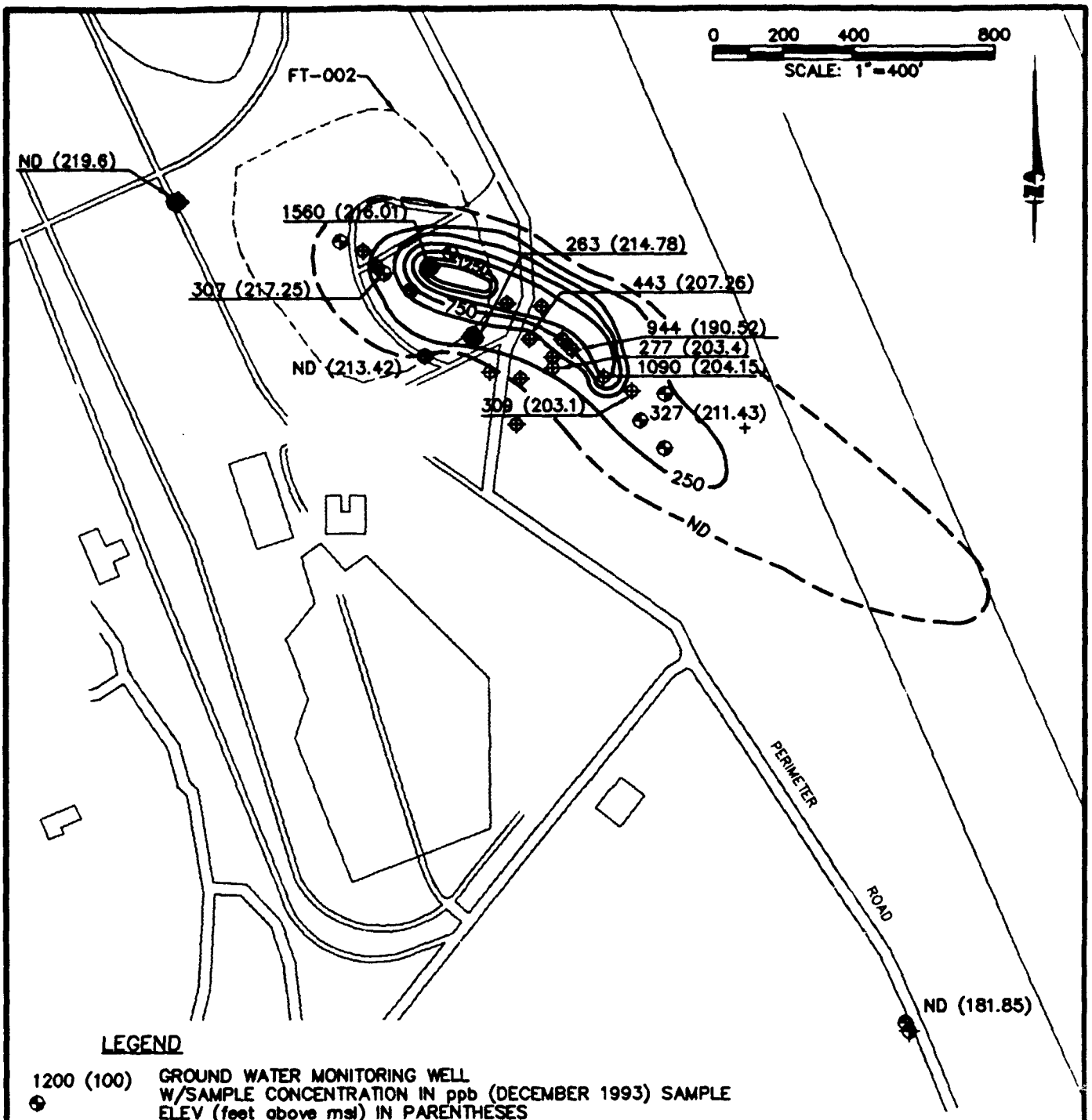

LEGEND

1200 (100) ◆	GROUND WATER MONITORING WELL W/SAMPLE CONCENTRATION IN ppb (DECEMBER 1993) SAMPLE ELEV (feet above msl) IN PARENTHESES
1200 (100) ◆	LIF–CPT SAMPLING LOCATION W/SAMPLE CONCENTRATION IN ppb (DECEMBER 1993) SAMPLE ELEVATION(feet above msl) IN PARENTHESES
— 2.0 —	LINE OF EQUAL TOLUENE CONCENTRATION (ppb)
ND	NOT DETECTED

CONTOUR INTERVAL = 250 ppb

FIGURE 4.8a

AREAL EXTENT OF DISSOLVED TOLUENE AT DEPTH OF MAXIMUM CONCENTRATION

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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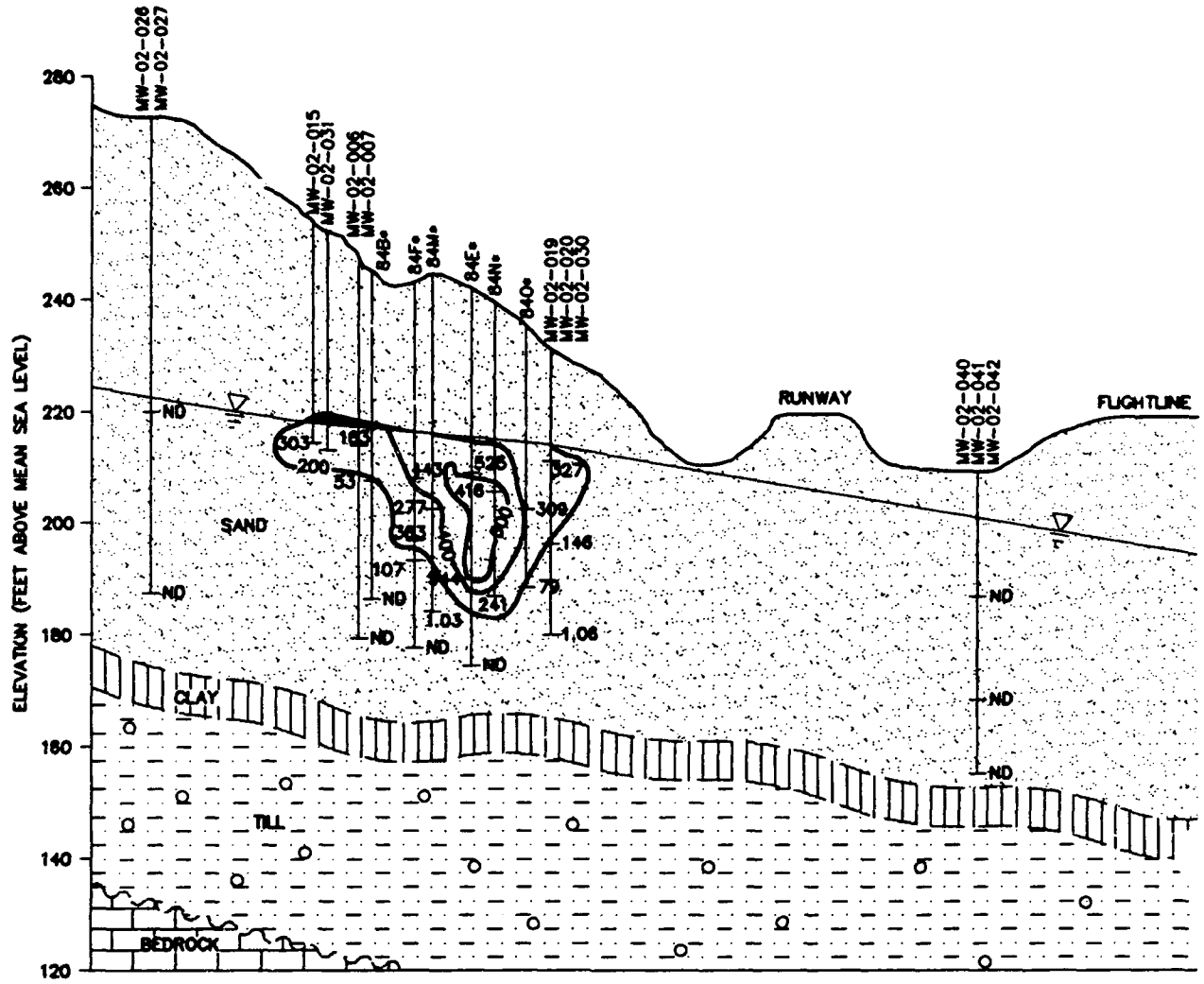

LEGEND

⊥	SAMPLE ELEVATION (ft above msl)
16.4	MEASURED CONCENTRATION OF TOLUENE (ppb)
—20—	LINE OF ESTIMATED EQUAL CONCENTRATION OF TOLUENE (ppb)
ND	NOT DETECTED
	ESTIMATED EXTENT OF LNAPL
▽	SURFACE OF GROUND WATER TABLE
	UNCONFORMITY
	LIGHT-BROWN TO GRAY, WELL-SORTED, MEDIUM-TO FINE-GRAINED SAND
	DARK-GRAY, MODERATELY PLASTIC CLAY. DARK MINERAL LAMINATIONS ARE PRESENT
	GRAY, POORLY SORTED TILL. CLAY AND SILT-SIZE GRAINS TO GRAVEL. ANGULAR ROCK FRAGMENTS PRESENT
	CARBONATE BEDROCK

* WATER ELEVATION DATA FROM CPT POINTS ARE ESTIMATED VALUES

VERTICAL EXAGGERATION = 20X

HORIZ 0 300 600 1200

VERT 0 15 30 60

FIGURE 4.8b

VERTICAL EXTENT OF DISSOLVED TOLUENE ALONG PLUME CENTERLINE

Fire Training Area, FT-00
Intrinsic Remediation EE/C
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC
Denver, Colorado

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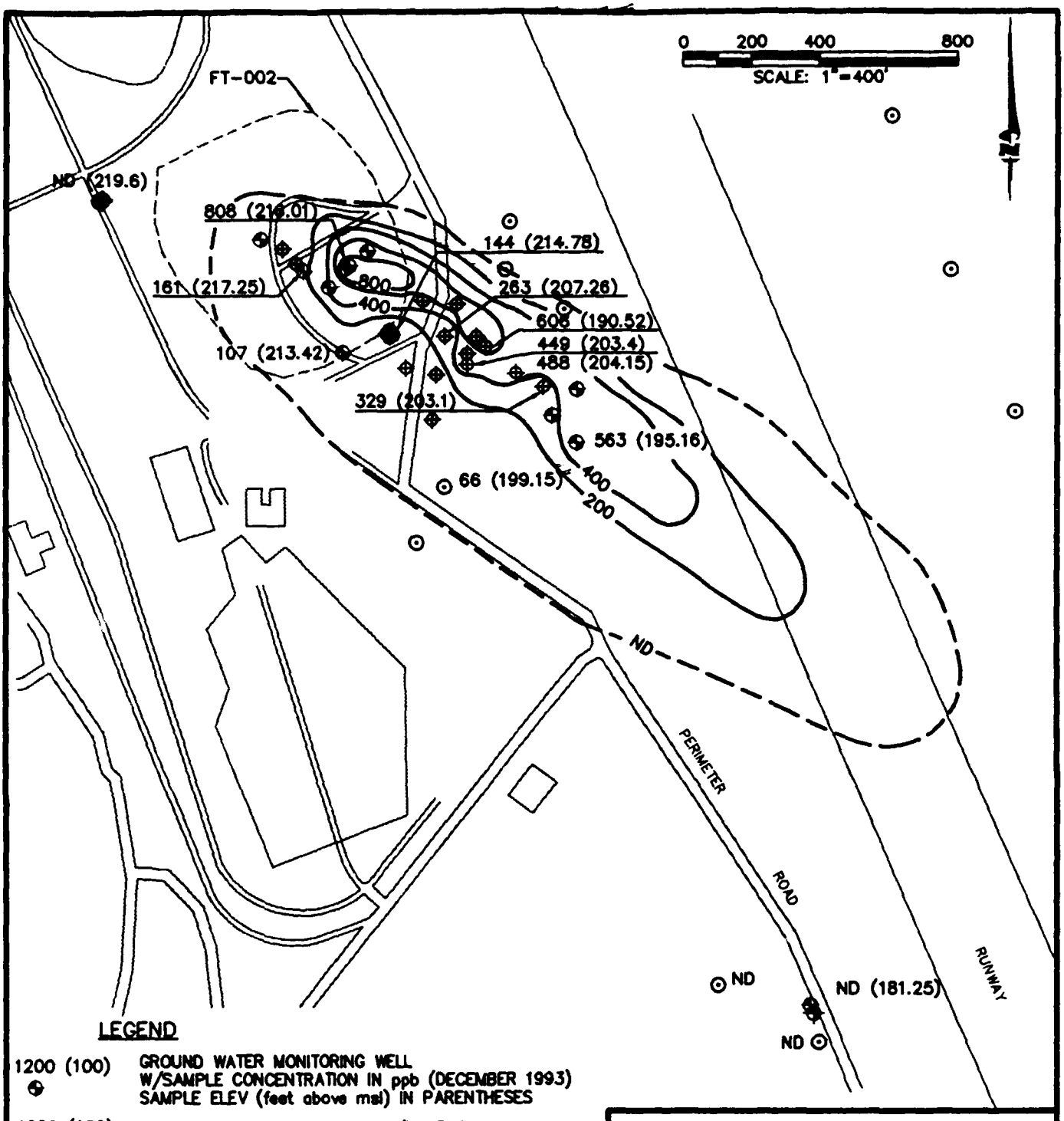

FIGURE 4.9a

AREAL EXTENT OF DISSOLVED ETHYLBENZENE AT DEPTH OF MAXIMUM CONCENTRATION

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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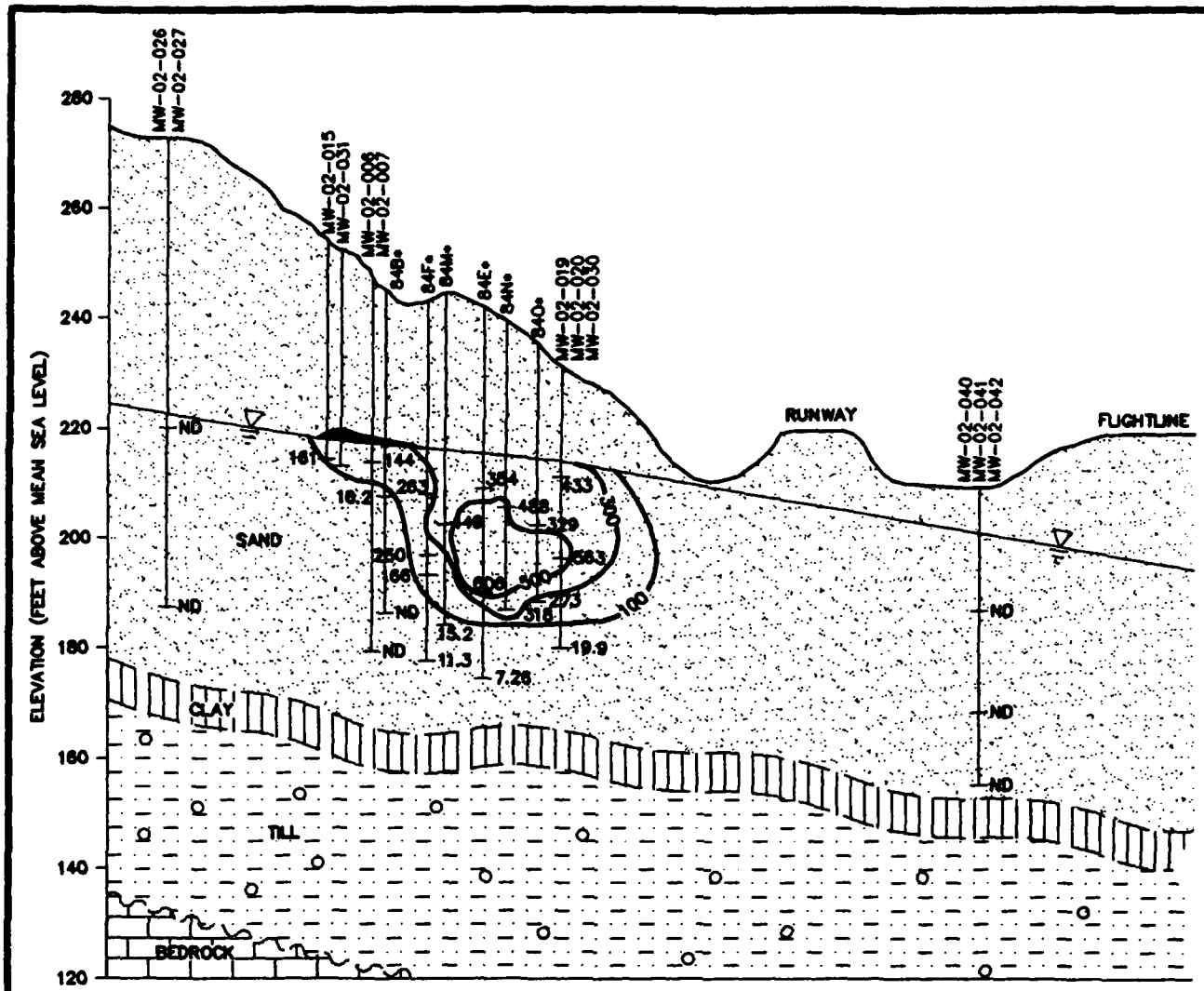

LEGEND

⊥	SAMPLE ELEVATION (ft above msl)
16.4	MEASURED CONCENTRATION OF ETHYLBENZENE (ppb)
—20—	LINE OF ESTIMATED EQUAL CONCENTRATION OF ETHYLBENZENE (ppb)
ND	NOT DETECTED
	ESTIMATED EXTENT OF LNAPL
▽	SURFACE OF GROUND WATER TABLE
	UNCONFORMITY
	LIGHT-BROWN TO GRAY, WELL-SORTED, MEDIUM-TO FINE-GRAINED SAND
	DARK-GRAY, MODERATELY PLASTIC CLAY. DARK MINERAL LAMINATIONS ARE PRESENT
	GRAY, POORLY SORTED TILL. CLAY AND SILT-SIZE GRAINS TO GRAVEL. ANGULAR ROCK FRAGMENTS PRESENT
	CARBONATE BEDROCK

* WATER ELEVATION DATA FROM CPT POINTS ARE ESTIMATED VALUES

VERTICAL EXAGGERATION = 20X

HORIZ 0 300 600 1200

VERT 0 15 30 60

FIGURE 4.9b

VERTICAL EXTENT OF DISSOLVI ETHYLBENZENE ALONG PLUME CENTERLINE

Fire Training Area, FT-00^
Intrinsic Remediation EE/C
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, IN
Denver, Colorado

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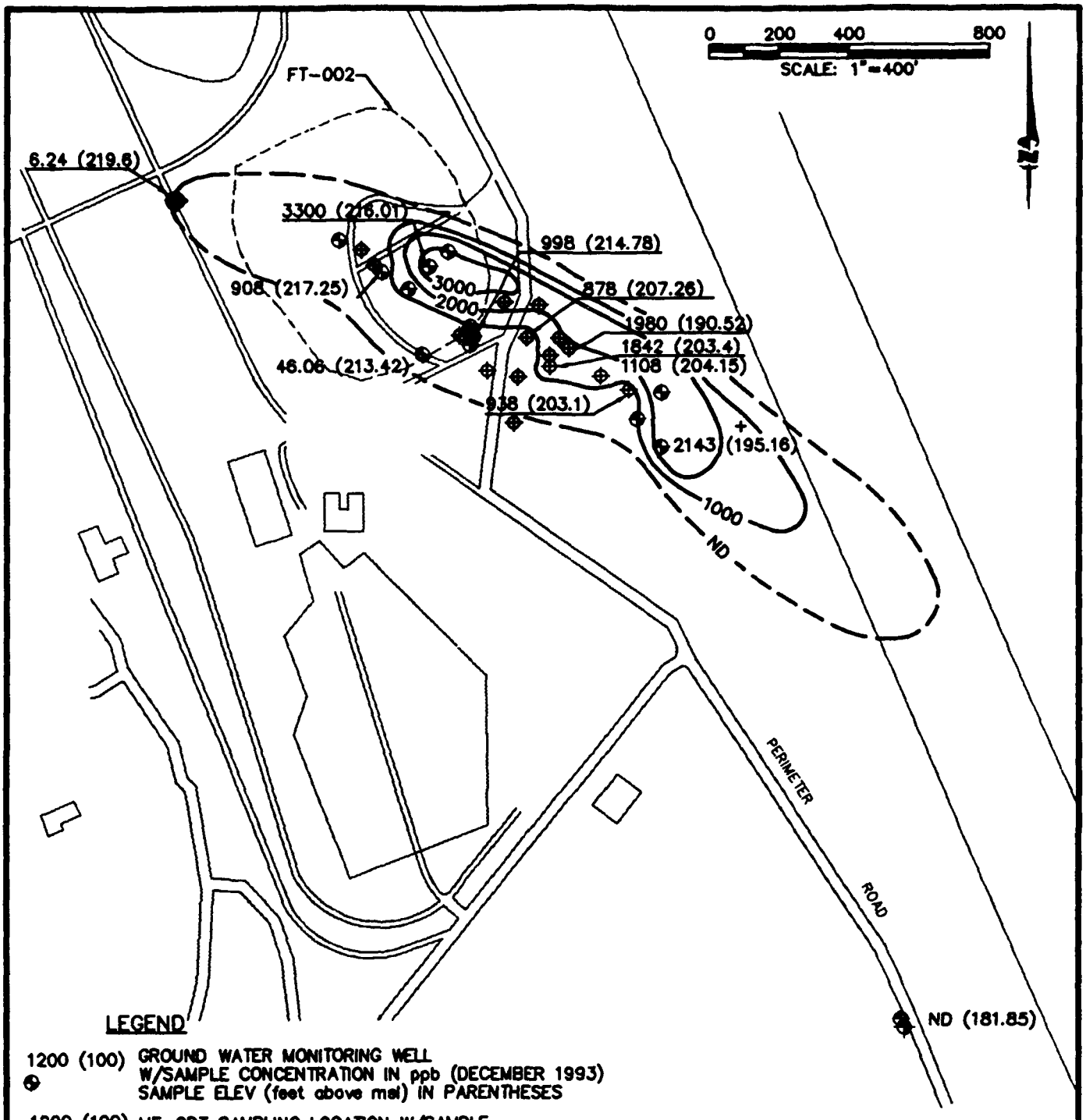

FIGURE 4.10a

AREAL EXTENT OF DISSOLVED TOTAL XYLENES AT DEPTH OF MAXIMUM CONCENTRATION

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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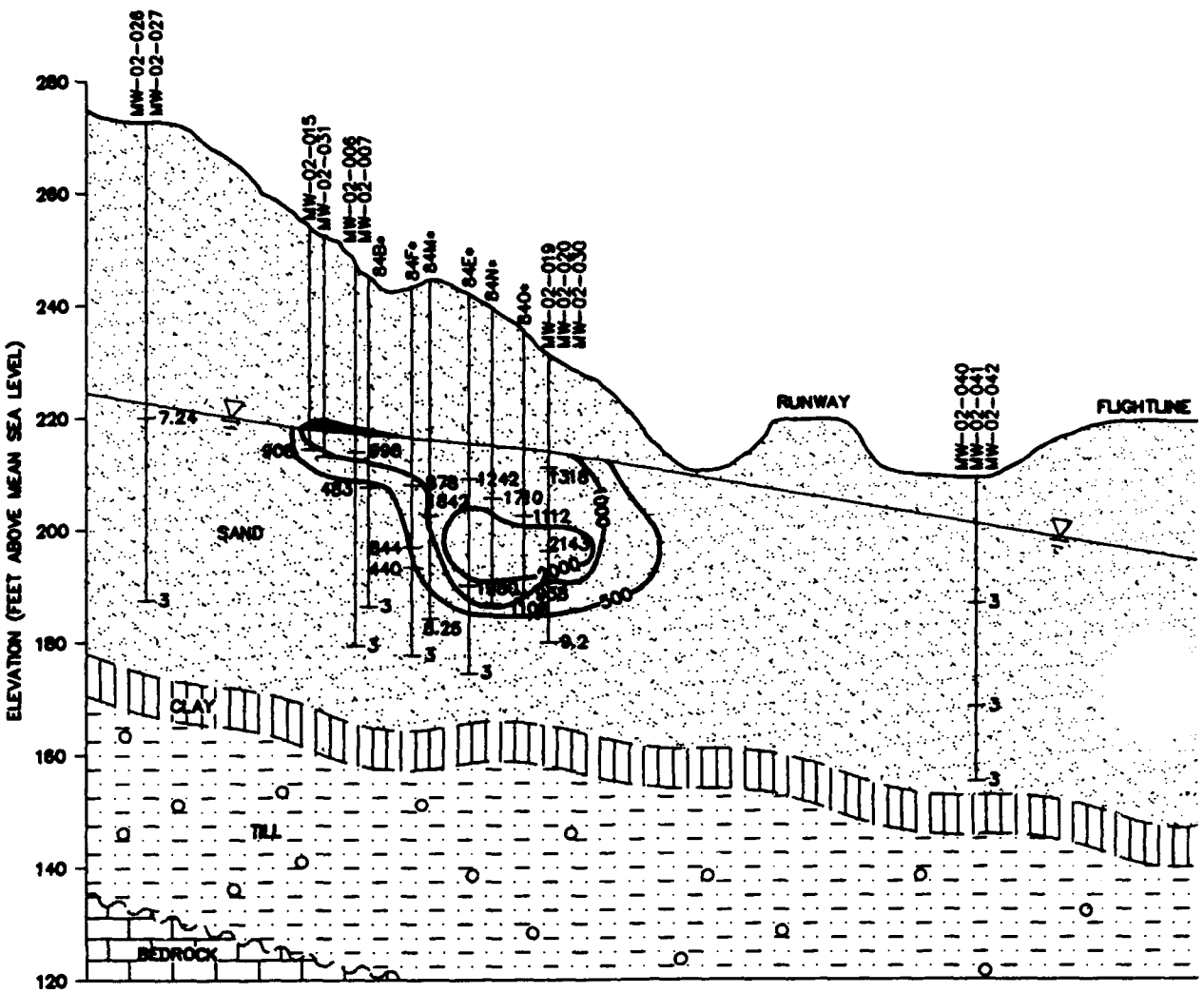

LEGEND

- SAMPLE ELEVATION (ft above msl)
- 16.4 — MEASURED CONCENTRATION OF TOTAL XYLENES (ppb)
- 20 — LINE OF ESTIMATED EQUAL CONCENTRATION OF TOTAL XYLENES (ppb)
- ESTIMATED EXTENT OF LNAPL
- SURFACE OF GROUND WATER TABLE
- UNCONFORMITY
- LIGHT-BROWN TO GRAY, WELL-SORTED, MEDIUM-TO FINE-GRAINED SAND
- DARK-GRAY, MODERATELY PLASTIC CLAY. DARK MINERAL LAMINATIONS ARE PRESENT
- GRAY, POORLY SORTED TILL. CLAY AND SILT-SIZE GRAINS TO GRAVEL. ANGULAR ROCK FRAGMENTS PRESENT
- CARBONATE BEDROCK

* WATER ELEVATION DATA FROM CPT POINTS ARE ESTIMATED VALUES

VERTICAL EXAGGERATION = 20X

HORIZ 0 300 600 1200
VERT 0 15 30 60

FIGURE 4.10b

VERTICAL EXTENT OF DISSOLVED TOTAL XYLENES ALONG PLUME CENTERLINE

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC
Denver, Colorado

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minimal plume migration over the past two or three years. This is suggestive that natural attenuation processes are occurring at the periphery of the dissolved BTEX plume.

4.4.2 Dissolved Chlorinated Solvent Contamination

Ground water samples were collected in December 1993 and May 1994 to characterize the nature and extent of chlorinated solvent contamination at the FT-002. Analytical results for these samples and those collected in 1991 are presented in Table 4.8. The source of contamination at the site is known to include chlorinated and nonchlorinated solvents mixed with off-specification JP-4 fuel. Figures 4.11a and 4.11b illustrate the areal extent of the current dissolved chlorinated solvent plume. Measured concentrations of chlorinated solvents in collected ground water samples indicate that these contaminants are present in dissolved form. Observed concentrations do not suggest the presence of chlorinated solvents as dense non-aqueous phase liquids (DNAPLs).

The measured horizontal extent of the total chlorinated solvents plume was about 4,800 feet downgradient of the suspected source area (Figure 4.11a). The maximum lateral width of the chlorinated plume is approximately 2,000 feet. There appears to be a good correlation between the horizontal extent of the chlorinated solvent plume and the direction of ground water flow in the immediate area. Data on the horizontal extent of total chlorinated solvent contamination in ground water collected under this program compare well with data collected in 1991, under the IRP. The maximum horizontal extent of the chlorinated solvent plume as of September 1991 was determined to be about 6,000 feet (ABB Environmental, Inc. and URS Consultants, Inc., 1993). Comparison of these two data sets suggests that the chlorinated solvent plume may have decreased by about 20 percent in areal extent from September 1991 to May 1994. However, the maximum measured concentration within the source area apparently increased from 10,000 ppb to 10,323.7 ppb from 1991 to 1994 (Table 4.8). This increase in concentration may be a result of sampling methodology rather than an actual change in site conditions.

The vertical extent of the total chlorinated solvents plume measured in December 1993 and May 1994 is different than that shown by the BTEX compounds (Figure 4.6b and 4.11b). Chlorinated solvent contamination was measured at greater depth in the unconfined aquifer within the source area than BTEX contamination. Further, chlorinated solvents showed greater vertical stratification at sample locations downgradient of the source area. The difference in vertical distribution patterns between the BTEX compounds and total chlorinated solvents was documented in the Phase II RI report (ABB Environmental, Inc. and URS Consultants, Inc.,

TABLE 4.8
GROUND WATER QUALITY DATA FOR CHLORINATED SOLVENTS AND OTHER FUEL-RELATED COMPOUNDS
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Sample Location	Sample Date	Sample Elevation (feet msl)[a]	Vinyl Chloride (ppb)[b]	trans-DCE[c] (ppb)	cis-DCE[d] (ppb)	Lab Qual. Flag	TCE[e] (ppb)	Total Chlorinated Solvents (ppb)	Fuel Carbon (ppb)
84B	Dec. 1993	207.22	< 0.5[f]	< 0.5	300		5.6	305.6	296
84B	Dec. 1993	186.02	< 0.5	< 0.5	3.1		< 0.5	3.1	< 0.5
84E	Dec. 1993	210.52	1020	1.2	752		< 0.5	1773.7	3060
84E (dup)	Dec. 1993	210.52	1010	1.1	710		< 0.5	1721.1	NR
84E	Dec. 1993	190.52	25.7	1.3	10000	>	0.7	10027.7	7560
84E (dup)	Dec. 1993	190.52	22.4	1.3	10900	1/2 dil[g]	1	10924.7	NR
84E	Dec. 1993	174.52	< 0.5	< 0.5	160		20.6	180.6	74.3
84F	Dec. 1993	207.26	2080	< 0.5	9.1		< 0.5	2089.1	2570
84F (dup)	Dec. 1993	207.26	1610	< 0.5	8.3		< 0.5	1618.3	NR
84F	Dec. 1993	197.26	3.6	< 0.5	6370		< 0.5	6373.6	3360
84F	Dec. 1993	192.26	5.7	< 0.5	4310		0.6	4316.3	1930
84F	Dec. 1993	177.26	< 0.5	< 0.5	69		12.8	81.8	53.1
84M	Dec. 1993	203.4	1050	< 0.5	1320		< 0.5	2370	4300
84M (lab dup)	Dec. 1993	203.4	995	< 0.5	1250		< 0.5	2245	NR
84M	Dec. 1993	183.4	< 0.5	< 0.5	240		9.1	249.1	124
84N	Dec. 1993	204.15	1710	< 0.5	208		< 0.5	1918	4620
84N (dup)	Dec. 1993	204.15	1550	< 0.5	209		< 0.5	1759	NR
84N	Dec. 1993	184.15	3.1	1	5850		< 0.5	5854.1	4200
84O	Dec. 1993	203.1	486	< 0.5	3140		2.8	3628.8	3370
84O	Dec. 1993	188.1	< 0.5	< 0.5	6710		< 0.5	6710	3280
84O (lab dup)	Dec. 1993	188.1	< 0.5	< 0.5	6650		< 0.5	6650	NR
84-Field Blank	Dec. 1993	N/A[f]	< 0.5	< 0.5	< 0.5		< 0.5	< 0.5	4.77
MW-02-005	Dec. 1993	213.42	< 0.5	< 0.5	4		0.6	4.6	844
MW-02-006	Dec. 1993	214.78	< 0.5	< 0.5	28.7		0.6	29.3	3620
MW-02-007	Dec. 1993	179.69	< 0.5	< 0.5	< 0.5		< 0.5	< 0.5	< 0.5
MW-02-007 (dup)	Dec. 1993	179.69	< 0.5	< 0.5	< 0.5		< 0.5	< 0.5	NR

TABLE 4.8 (Continued)
GROUND WATER QUALITY DATA FOR CHLORINATED SOLVENTS AND OTHER FUEL-RELATED COMPOUNDS
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Sample Location	Sample Date	Sample Elevation (feet msl)[a]	Vinyl Chloride (ppb)[b]	trans-DCE[c] (ppb)	cis-DCE[d] (ppb)	Lab Qual. Flag	TCE[e] (ppb)	Total Chlorinated Solvents (ppb)	Fuel Carbon (ppb)
MW-02-014	Dec. 1993	216.01	4.5	< 0.5	9050		1030	10084.5	9940
MW-02-014 (dup)	Dec. 1993	216.01	3.7	< 0.5	9760		560	10323.7	NR
MW-02-015	Dec. 1993	217.25	< 0.5	< 0.5	110		1330	1440	2800
MW-02-019	Dec. 1993	211.43	384	< 0.5	3540		1.9	3925.9	4410
MW-02-020	Dec. 1993	195.16	9.8	< 0.5	8530		1.4	8541.2	7580
MW-02-021	Dec. 1993	181.85	< 0.5	< 0.5	2		4.6	6.6	< 0.5
MW-02-021 (lab dup)	Dec. 1993	181.85	< 0.5	< 0.5	2.1		4.5	6.6	NR
MW-02-026	**Dec. 1993**	**219.6**	**< 0.5**	**< 0.5**	**< 0.5**		**< 0.5**	**< 0.5**	**25.7**
MW-02-027	**Dec. 1993**	**186.72**	**< 0.5**	**< 0.5**	**< 0.5**		**< 0.5**	**< 0.5**	**< 0.5**
MW-02-030	Dec. 1993	179.55	< 0.5	0.7	185		79.7	265.4	145
MW-02-040	Dec. 1993	184.02	0.8	< 0.5	339		3.1	342.9	92
MW-02-041	Dec. 1993	169.05	< 0.5	< 0.5	5230		30.7	5260.7	18500
MW-02-042	Dec. 1993	153.26	2.2	1.1	1570		98.5	1671.8	469
MW-02-042 (lab dup)	Dec. 1993	153.26	2.3	1	1570		91	1664.3	NR
MW-02-043	Dec. 1993	165.47	< 0.5	< 0.5	10.6		373	383.6	< 0.5
MW-02-044	Dec. 1993	166.24	< 0.5	< 0.5	2.9		135	137.9	< 0.5
MW-02-043	May 1994	165.47	1.65	2.49	11.4		303	318.5	NR
MW-02-043 (dup)	May 1994	165.47	2.14	3.32	13.9		321	340.4	NR
84Q-2	May 1994	211.92	1.18	1.08	156		2.79	161.1	NR
84Q-2 (dup)	May 1994	211.92	< 0.5	1.79	155		3.07	159.9	NR
84Q-3	May 1994	199.42	488	25.6	601		6.94	1121.5	NR
84Q-4	May 1994	192.42	161	228	3150		21.5	3560.5	NR
84Q-5	May 1994	182.92	32.3	33.8	908		129	1103.1	NR
84Q-6	May 1994	175.42	28.5	11.9	1120		104	1264.4	NR
Sparge Pt 1 (1)	May 1994	14' bgs*	233	34.9	840		4.44	1112.3	NR
Sparge Pt 1 (1) (dup)	May 1994	14' bgs*	232	37.4	837		5.12	1111.5	NR

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TABLE 4.8 (Continued)
GROUND WATER QUALITY DATA FOR CHLORINATED SOLVENTS AND OTHER FUEL-RELATED COMPOUNDS
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Sample Location	Sample Date	Sample Elevation (feet msl)[a]	Vinyl Chloride (ppb)[b]	trans-DCE[c] (ppb)	cis-DCE[d] (ppb)	Lab Qual. Flag	TCE[e] (ppb)	Total Chlorinated Solvents (ppb)	Fuel Carbon (ppb)
Sparge Pt 1 (2)	May 1994	24' bgs*	167	228	1870		23.1	2288.1	NR
Sparge Pt 2	May 1994	14' bgs*	29.9	137	731		162	1059.9	NR
Sparge Pt 3	May 1994	14' bgs*	537	52.5	578		10.4	1177.9	NR
Sparge Pt 4 (1)	May 1994	14' bgs*	459	67.1	848		9.87	1383.9	NR
Sparge Pt 4 (2)	May 1994	24' bgs*	195	233	3460		14.8	3902.8	NR
Sparge Pt 5	May 1994	14' bgs*	717	55.8	324		4.73	1101.5	NR
CP-02-002	1991	230.92	NR[f]	NR	NR		47	47	NR
CP-02-002	1991	198.92	NR	NR	1.1		21	22.1	NR
CP-02-002	1991	192.92	NR	NR	< 0.5		< 0.5	< 0.5	NR
CP-02-003	1991	217.15	NR	NR	120		NR	120	NR
CP-02-003	1991	208.15	NR	NR	210		NR	210	NR
CP-02-003	1991	199.15	NR	NR	160		NR	160	NR
CP-02-003	1991	185.15	NR	NR	84		NR	84	NR
CP-02-003	1991	173.15	NR	NR	1.2		NR	1.2	NR
CP-02-004	1991	210.15	NR	NR	NR		1	1	NR
CP-02-004	1991	194.15	NR	NR	NR		20	20	NR
CP-02-004	1991	184.15	NR	NR	NR		< 0.5	< 0.5	NR
CP-02-004	1991	176.15	NR	NR	NR		< 0.5	< 0.5	NR
CP-02-005	1991	237.68	NR	NR	NR		6.6	6.6	NR
CP-02-005	1991	226.68	NR	NR	NR		< 0.5	< 0.5	NR
CP-02-005	1991	210.68	NR	NR	NR		< 0.5	< 0.5	NR
CP-02-005	1991	206.68	NR	NR	NR		< 0.5	< 0.5	NR
CP-02-005	1991	202.68	NR	NR	NR		< 0.5	< 0.5	NR
CP-02-006	1991	247.37	NR	NR	NR		630	630	NR
CP-02-006	1991	238.37	NR	NR	180		3400	3580	NR
CP-02-006	1991	229.37	NR	NR	850		3500	4350	NR

TABLE 4.8 (Continued)
GROUND WATER QUALITY DATA FOR CHLORINATED SOLVENTS AND OTHER FUEL-RELATED COMPOUNDS
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Sample Location	Sample Date	Sample Elevation (feet msl)[a]	Vinyl Chloride (ppb)[b]	trans-DCE[c] (ppb)	cis-DCE[d] (ppb)	Lab Qual. Flag	TCE[e] (ppb)	Total Chlorinated Solvents (ppb)	Fuel Carbon (ppb)
CP-02-006	1991	218.37	NR	NR	NR		430	430	NR
CP-02-006	1991	207.37	NR	NR	NR		330	330	NR
CP-02-007	1991	187.81	NR	NR	NR		12	12	NR
CP-02-007	1991	178.81	NR	NR	NR		54	54	NR
CP-02-007	1991	164.81	NR	NR	240		4900	4900	NR
CP-02-007	1991	153.81	NR	NR	NR		26	26	NR
CP-02-008	1991	182.31	NR	NR	670		52	722	NR
CP-02-008	1991	167.31	NR	NR	2000		1500	3500	NR
CP-02-008	1991	158.31	NR	NR	1700		3200	4900	NR
CP-02-008	1991	153.31	NR	NR	510		3300	3810	NR
CP-02-009	1991	193.31	NR	NR	14		NR	14	NR
CP-02-009	1991	181.31	NR	NR	19		NR	19	NR
CP-02-009	1991	174.31	NR	NR	700	1/20 dil	NR	700	NR
CP-02-009	1991	165.31	NR	NR	10000	1/1000 dil	NR	10000	NR
CP-02-009	1991	155.31	NR	NR	790	1/100 dil	NR	790	NR
CP-02-009	1991	149.31	NR	NR	20	1/10 dil	NR	20	NR
CP-02-010	1991	179.76	NR	NR	NR		5.3	5.3	NR
CP-02-010	1991	163.76	NR	NR	19		5.5	24.5	NR
CP-02-011	1991	174.51	NR	NR	NR		1.4	1.4	NR
CP-02-011	1991	161.5	NR	NR	17		6.2	23.2	NR
CP-02-012	1991	194.87	NR	NR	42		19	61	NR
CP-02-012	1991	184.87	NR	NR	2100		1500	3600	NR
CP-02-012	1991	175.87	NR	NR	8.7		6.4	15.1	NR
CP-02-013	1991	189.99	NR	NR	NR		190	190	NR
CP-02-013	1991	181.99	NR	NR	3.7		8.4	12.1	NR
CP-02-024	1991	N/A	NR	NR	< 0.5		< 0.5	< 0.5	NR

TABLE 4.8 (Concluded)
GROUND WATER QUALITY DATA FOR CHLORINATED SOLVENTS AND OTHER FUEL-RELATED COMPOUNDS
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Sample Location	Sample Date	Sample Elevation (feet msl)[a/]	Vinyl Chloride (ppb)[b/]	trans-DCE[c/] (ppb)	cis-DCE[d/] (ppb)	Lab Qual. Flag	TCE[e/] (ppb)	Total Chlorinated Solvents (ppb)	Fuel Carbon (ppb)
CP-02-025	1991	212.9	NR	NR	< 0.5		< 0.5	< 0.5	NR
CP-02-025	1991	202.9	NR	NR	< 0.5		50	50	NR
CP-02-025	1991	195.9	NR	NR	< 0.5		< 0.5	< 0.5	NR
CP-02-032	1991	212.3	NR	NR	< 0.5		< 0.5	< 0.5	NR
CP-02-032	1991	202.3	NR	NR	< 0.5		23	23	NR
CP-02-032	1991	195.3	NR	NR	< 0.5		< 0.5	< 0.5	NR
CP-02-033	1991	N/A	< 0.5	< 0.5	< 0.5		< 0.5	< 0.5	NR
CP-02-037	1991	183.85	< 0.5	< 0.5	< 0.5		< 0.5	< 0.5	NR
CP-02-037	1991	173.85	< 0.5	< 0.5	< 0.5		< 0.5	< 0.5	NR
CP-02-037	1991	161.85	< 0.5	< 0.5	< 0.5		< 0.5	< 0.5	NR
CP-02-039	1991	173.55	< 0.5	< 0.5	500		30	530	NR

a/ feet msl = feet above mean sea level
b/ ppb = parts per billion
c/ trans-DCE = trans-dichloroethlene
d/ cis-DCE = cis-dichloroethlene
e/ TCE = trichloroethlene
f/ < 0.5 = below practical limit of quantitation
g/ NR = not reported
h/ dil = dilution factor
i/ N/A = not applicable
* estimated feet below ground surface
Note: Background sampling locations placed in boldface

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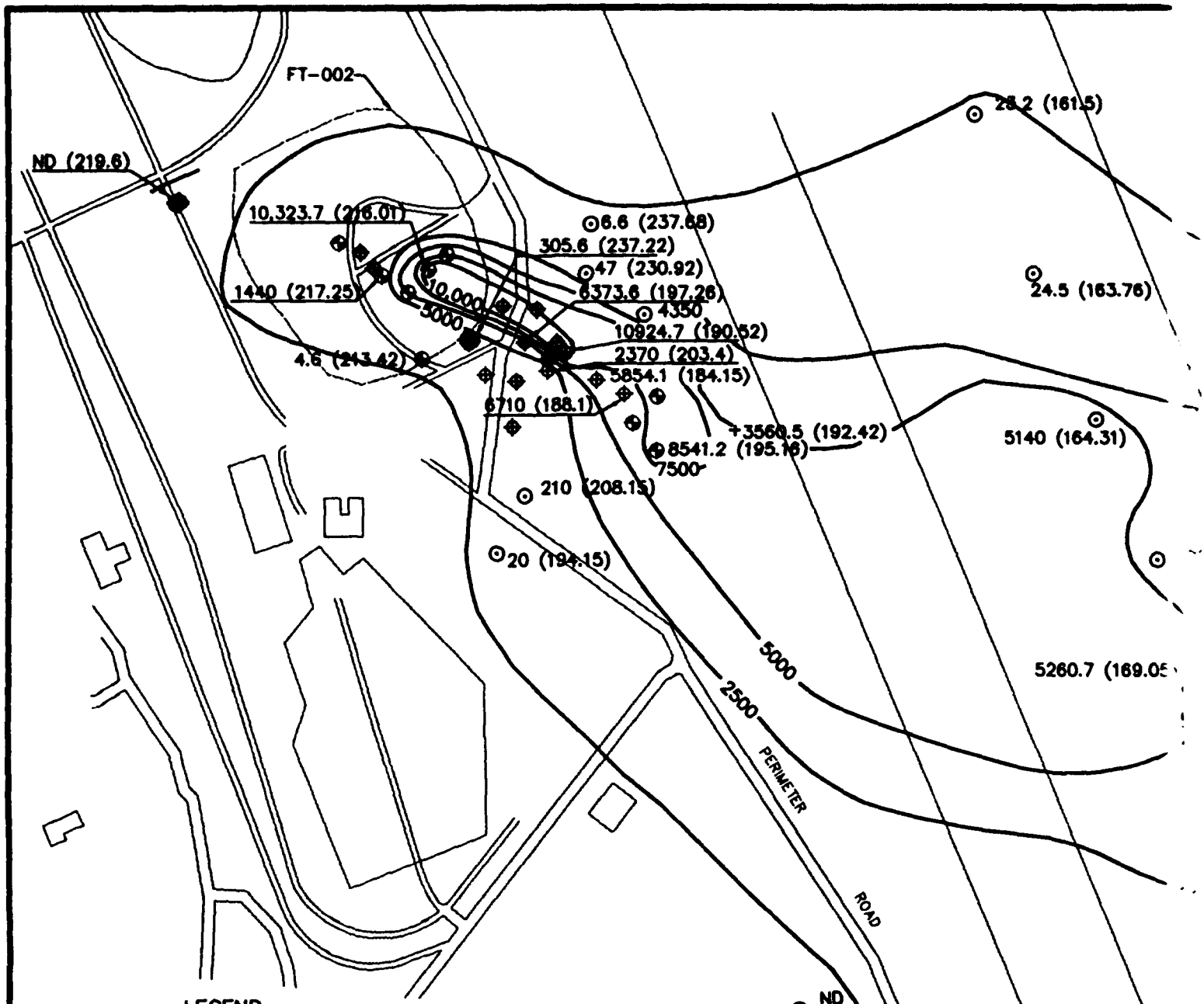

LEGEND

1200 (100) ◆	GROUND WATER MONITORING WELL W/SAMPLE CONCENTRATION IN ppb (DECEMBER 1993) SAMPLE ELEV (feet above msl) IN PARENTHESES
1200 (100) ◆	LIF-CPT SAMPLING LOCATION W/SAMPLE CONCENTRATION IN ppb (DECEMBER 1993) SAMPLE ELEV (feet above msl) IN PARENTHESES
⊙ 530	CONE PENETROMETER LOCATION W/SAMPLE CONCENTRATION IN ppb (1991) SAMPLE ELEV (FEET ABOVE MSL) IN PARENTHESES
— 2.0 —	LINE OF EQUAL TOTAL CHLORINATED SOLVENTS CONCENTRATION (ppb)
ND	NOT DETECTED
	CONTOUR INTERVAL = 2500 ppb
+	SCAPS PUSH LOCATION W/ SAMPLE CONCENTRATION IN ppb (MAY 1994)

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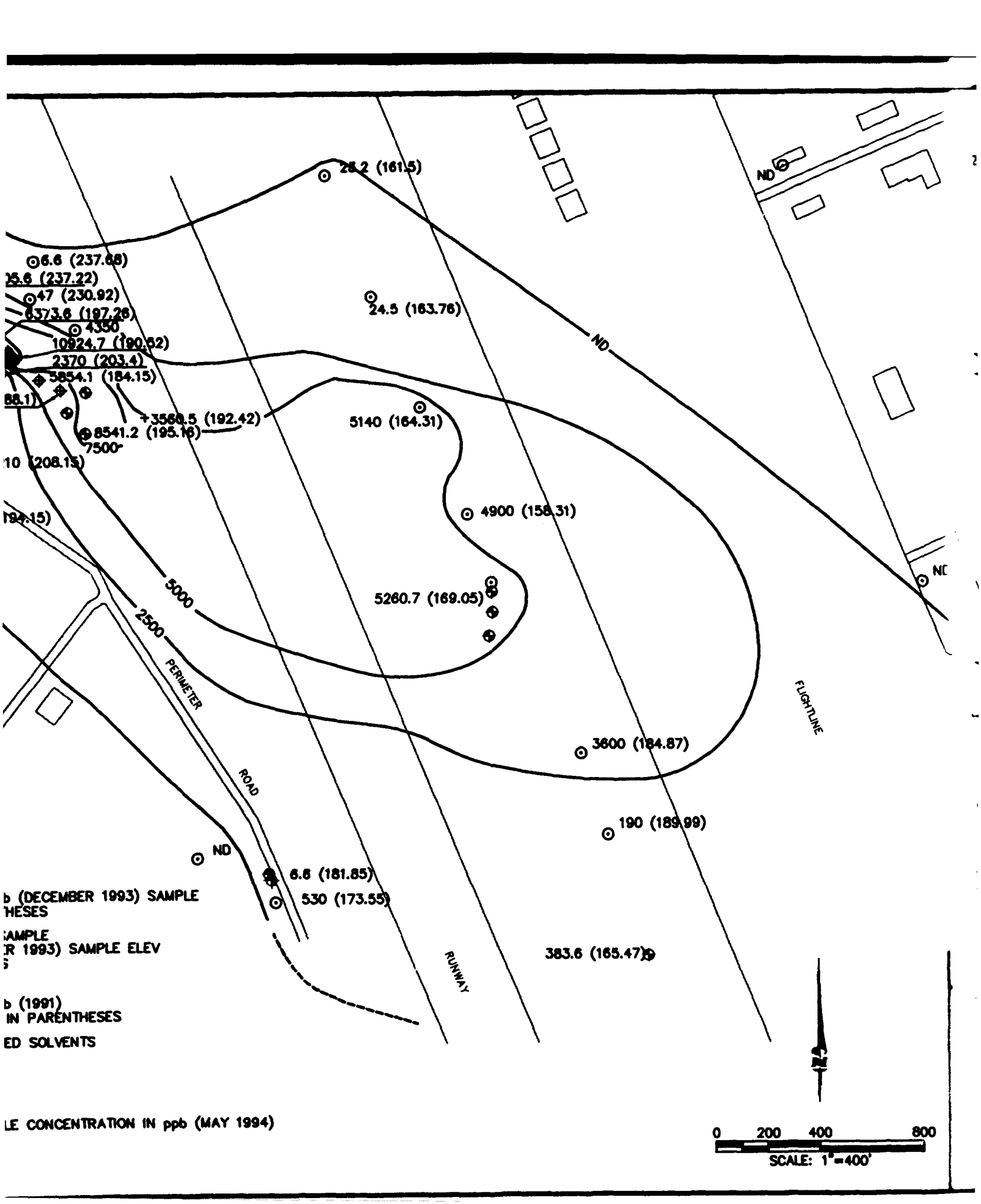

25.2 (161.5)
ND
6.6 (237.68)
25.6 (237.22)
47 (230.92)
24.5 (163.76)
4350
10924.7 (190.52)
2370 (203.4)
3854.1 (184.15)
ND
+3560.5 (192.42)
5140 (164.31)
8541.2 (195.16)
7500
4900 (158.31)
5260.7 (169.05)
5000
2500
PERIMETER
ROAD
FLIGHTLINE
3600 (184.87)
190 (189.99)
ND
6.6 (181.85)
530 (173.55)
383.6 (165.47)
RUNWAY
0
200
400
800
SCALE: 1"=400'
b (DECEMBER 1993) SAMPLE
HESES
AMPLE
R 1993) SAMPLE ELEV
b (1991)
IN PARENTHESES
ED SOLVENTS
LE CONCENTRATION IN ppb (MAY 1994)

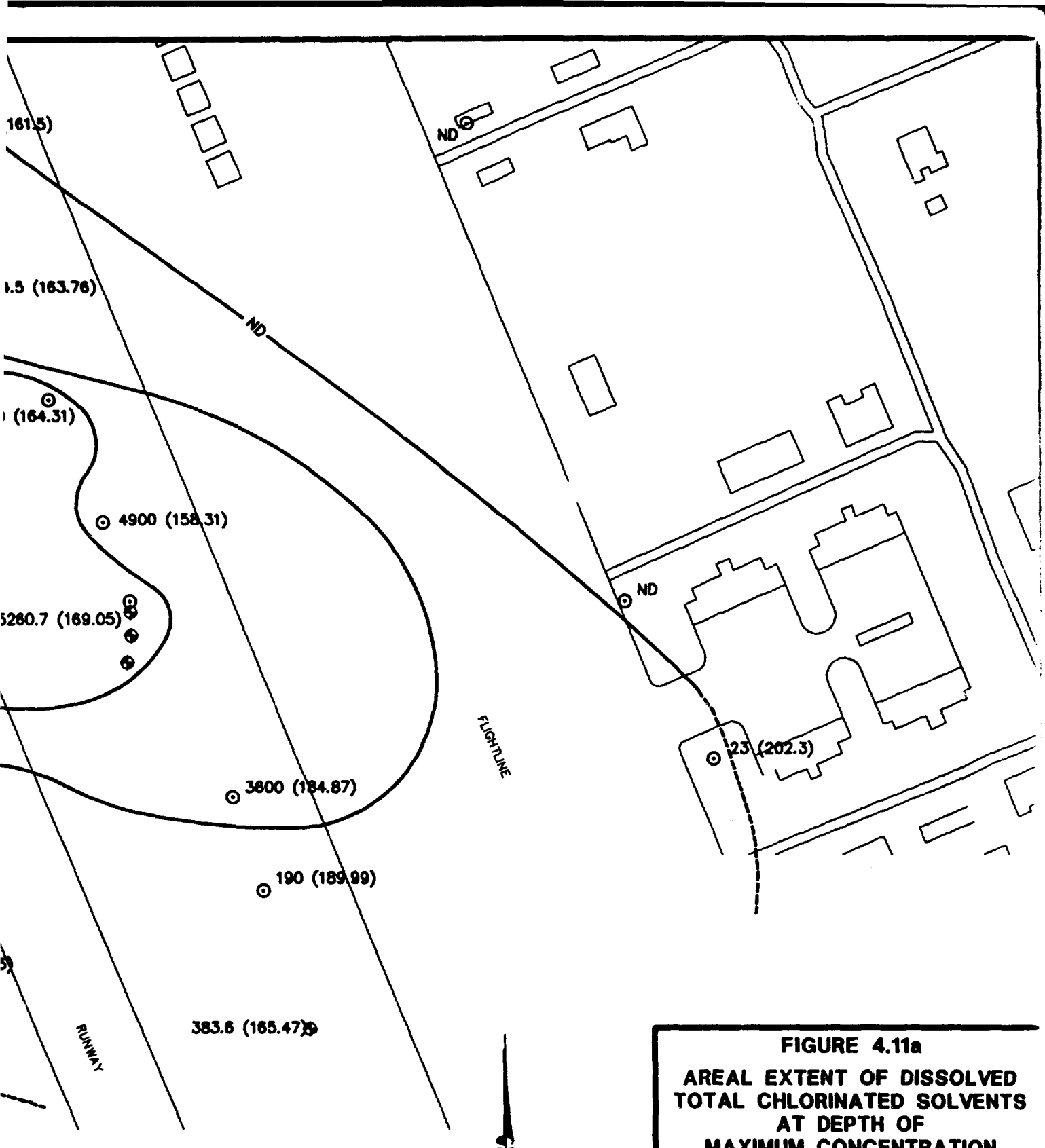
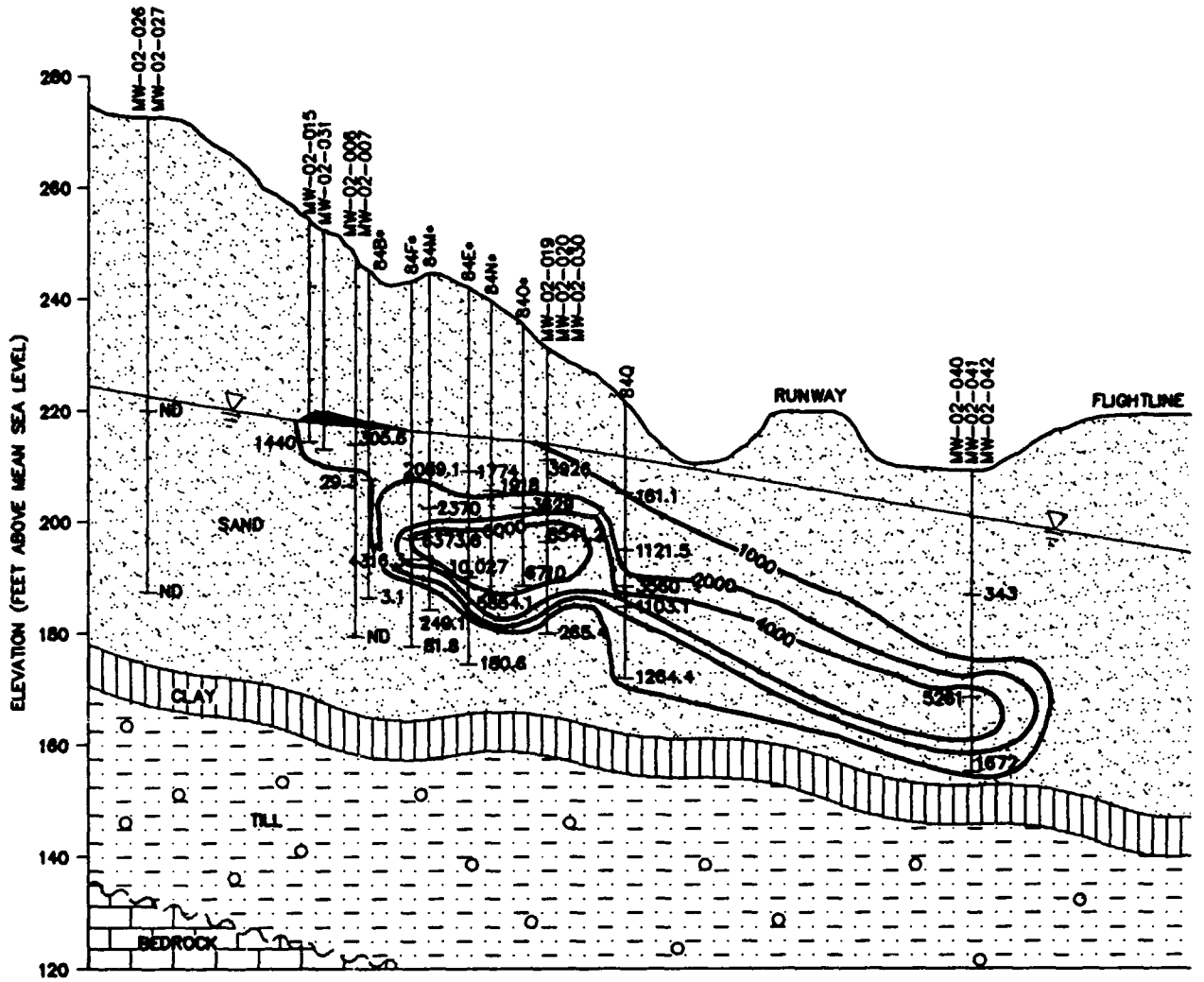


FIGURE 4.11a

AREAL EXTENT OF DISSOLVED TOTAL CHLORINATED SOLVENTS AT DEPTH OF MAXIMUM CONCENTRATION

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado



LEGEND

⊥	SAMPLE ELEVATION (ft above msl)
16.4	MEASURED CONCENTRATION OF TOTAL CHLORINATED SOLVENTS (ppb)
—20—	LINE OF ESTIMATED EQUAL CONCENTRATION OF TOTAL CHLORINATED SOLVENTS (ppb)
ND	NOT DETECTED
	ESTIMATED EXTENT OF LNAPL
▽	SURFACE OF GROUND WATER TABLE
	UNCONFORMITY
	LIGHT-BROWN TO GRAY, WELL-SORTED, MEDIUM-TO FINE-GRAINED SAND
	DARK-GRAY, MODERATELY PLASTIC CLAY. DARK MINERAL LAMINATIONS ARE PRESENT
	GRAY, POORLY SORTED TILL. CLAY AND SILT-SIZE GRAINS TO GRAVEL. ANGULAR ROCK FRAGMENTS PRESENT
	CARBONATE BEDROCK

* WATER ELEVATION DATA FROM CPT POINTS ARE ESTIMATED VALUES

VERTICAL EXAGGERATION = 20X

HORIZ 0 300 600 1200

VERT 0 15 30 60

FIGURE 4.11b

VERTICAL EXTENT OF DISSOLVED TOTAL CHLORINATED SOLVENTS ALONG PLUME CENTERLINE

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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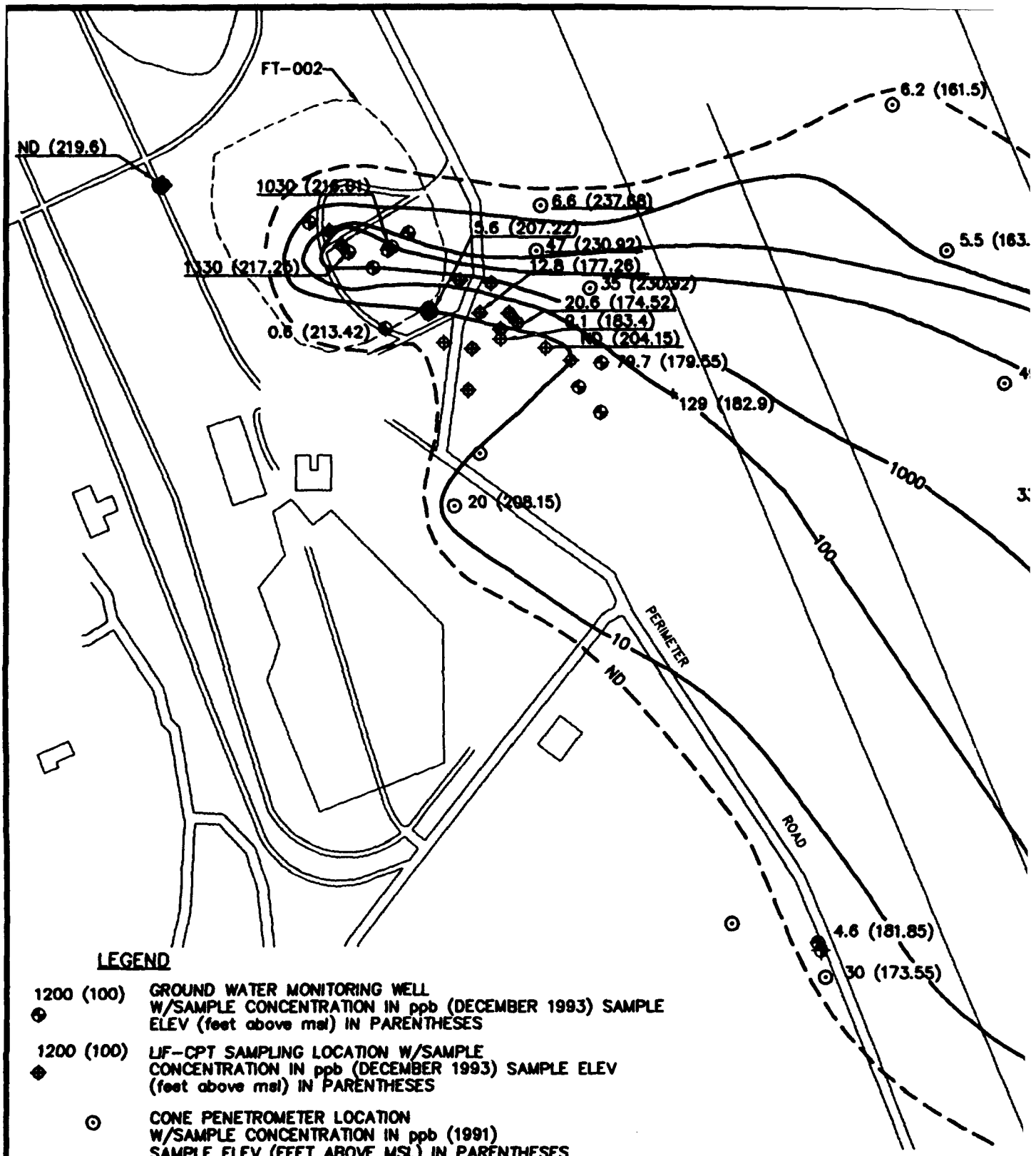
1993). However, the differences between the two plumes with respect to vertical distribution appear more pronounced in data collected under this program.

Figures 4.12a and 4.12b illustrate the horizontal and vertical extent of TCE contamination measured at the site in December 1993 and May 1994. These data have been supplemented with field screening data collected in 1991 under the IRP. The maximum horizontal extent of the dissolved TCE plume was estimated to be about 4,700 feet downgradient of the FT-002 site in the general direction of ground water flow. It is important to note, however, that the focus of this program was on the BTEX compounds. Efforts did not extend to defining the full extent of the chlorinated solvent (i.e., TCE) plume. The vertical extent of TCE contamination at the site is identical to that exhibited by total chlorinated solvents, particularly at sample locations situated near the suspected fringe of the chlorinated solvent plume (Figures 4.11b and 4.12b). TCE is the major chlorinated solvent measured within these fringe areas.

TCE can degrade via chemical and biological processes to a variety of chlorinated aliphatic hydrocarbons (CAHs), including cis-DCE, trans-DCE, vinyl chloride, and ethylene (McCarty, 1994). The transformation of TCE and its intermediate CAH degradation products to these other compounds can be brought about through cometabolism or interactions of these compounds with enzymes or cofactors produced by microorganisms for other purposes. Cometabolism of TCE and the intermediate CAHs can occur provided other organic compounds, such as BTEX, are present to serve as the primary substrate to satisfy microbial energy requirements. Data were collected under this program to determine whether cometabolic degradation of chlorinated solvents could be occurring at the site.

In general, TCE is amenable to reductive transformations under anaerobic conditions. One of the most common indicators of intrinsic reductive transformation of TCE in ground water is the presence of intermediate products. Vinyl chloride and ethylene are two of the primary products of reductive dechlorination of TCE. Figures 4.13a and 4.13b show the horizontal and vertical extent of vinyl chloride contamination measured at the site in December 1993 and May 1994. The measured concentrations of ethylene are summarized in Section 5.5. The absence of ethylene at most sampling locations suggests that transformation of TCE or the CAHs to ethylene is likely of little significance at this site.

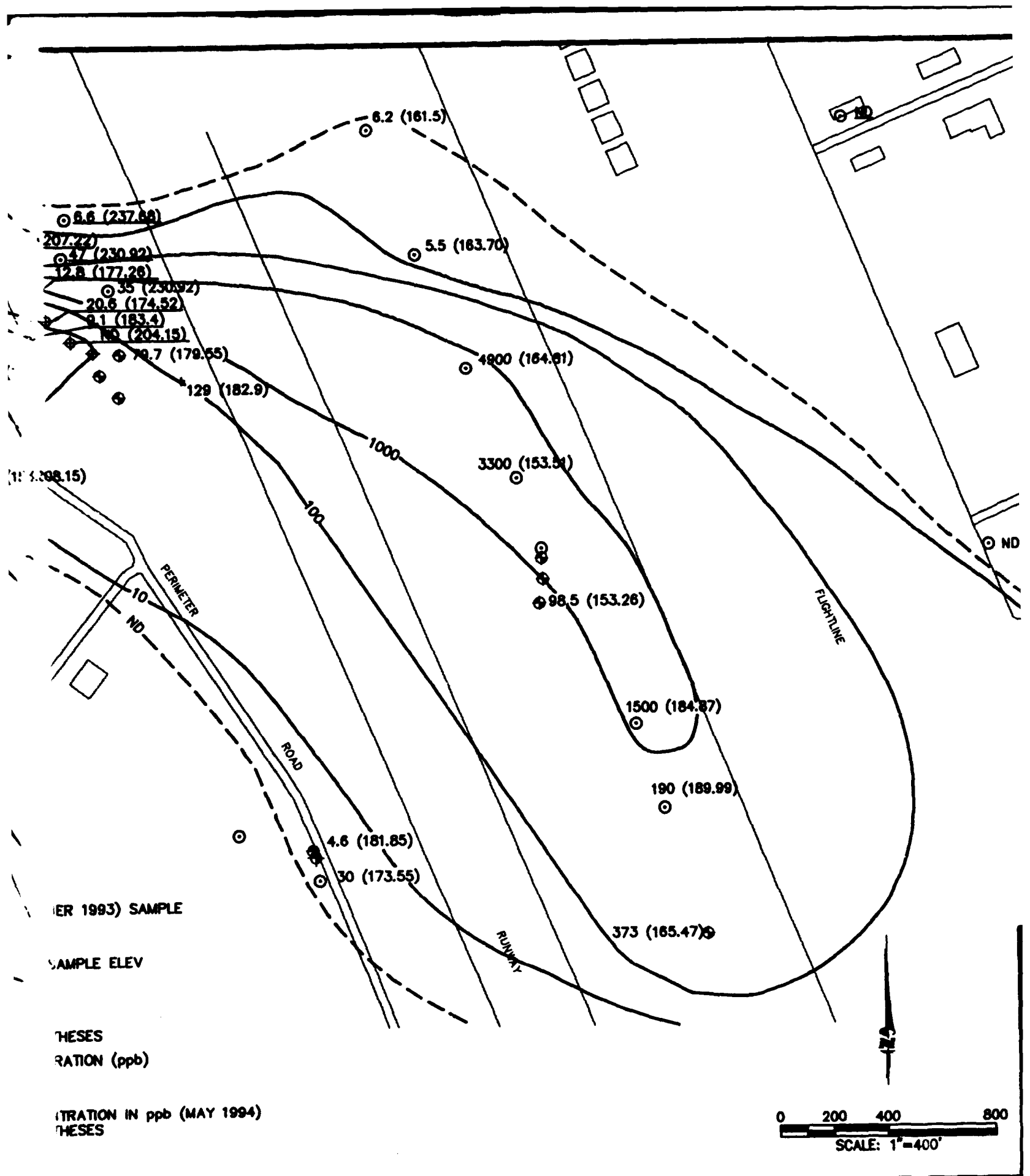
The observed concentrations of vinyl chloride correlate well with the areas exhibiting high levels of both BTEX and chlorinated solvents. The vinyl chloride plume is limited in horizontal extent in comparison to the total chlorinated solvent plume. The leading edge of the vinyl chloride plume is about 1,800 feet downgradient from the source area in the direction of ground



LEGEND

1200 (100) ⊕	GROUND WATER MONITORING WELL W/SAMPLE CONCENTRATION IN ppb (DECEMBER 1993) SAMPLE ELEV (feet above msl) IN PARENTHESES
1200 (100) ◆	LIF–CPT SAMPLING LOCATION W/SAMPLE CONCENTRATION IN ppb (DECEMBER 1993) SAMPLE ELEV (feet above msl) IN PARENTHESES
⊙	CONE PENETROMETER LOCATION W/SAMPLE CONCENTRATION IN ppb (1991) SAMPLE ELEV (FEET ABOVE MSL) IN PARENTHESES
— 2.0 —	LINE OF EQUAL TRICHLOROETHENE CONCENTRATION (ppb)
ND	NOT DETECTED
+	SCAPS PUSH LOCATION W/ SAMPLE CONCENTRATION IN ppb (MAY 1994) SAMPLE ELEV (FEET ABOVE MSL) IN PARENTHESES

CONTOUR INTERVAL = VARIABLE


6.2 (161.5)
ND
5.5 (163.70)
4900 (164.91)
129 (182.9)
1000
3300 (153.51)
100
ND
PERIMETER
10
ND
98.5 (153.26)
FLIGHTLINE
1500 (184.87)
ROAD
190 (189.99)
4.6 (181.85)
30 (173.55)
373 (165.47)
RUNWAY
ER 1993) SAMPLE
AMPLE ELEV
HESES
RATION (ppb)
TRATION IN ppb (MAY 1994)
HESES
0 200 400 800
SCALE: 1"=400'

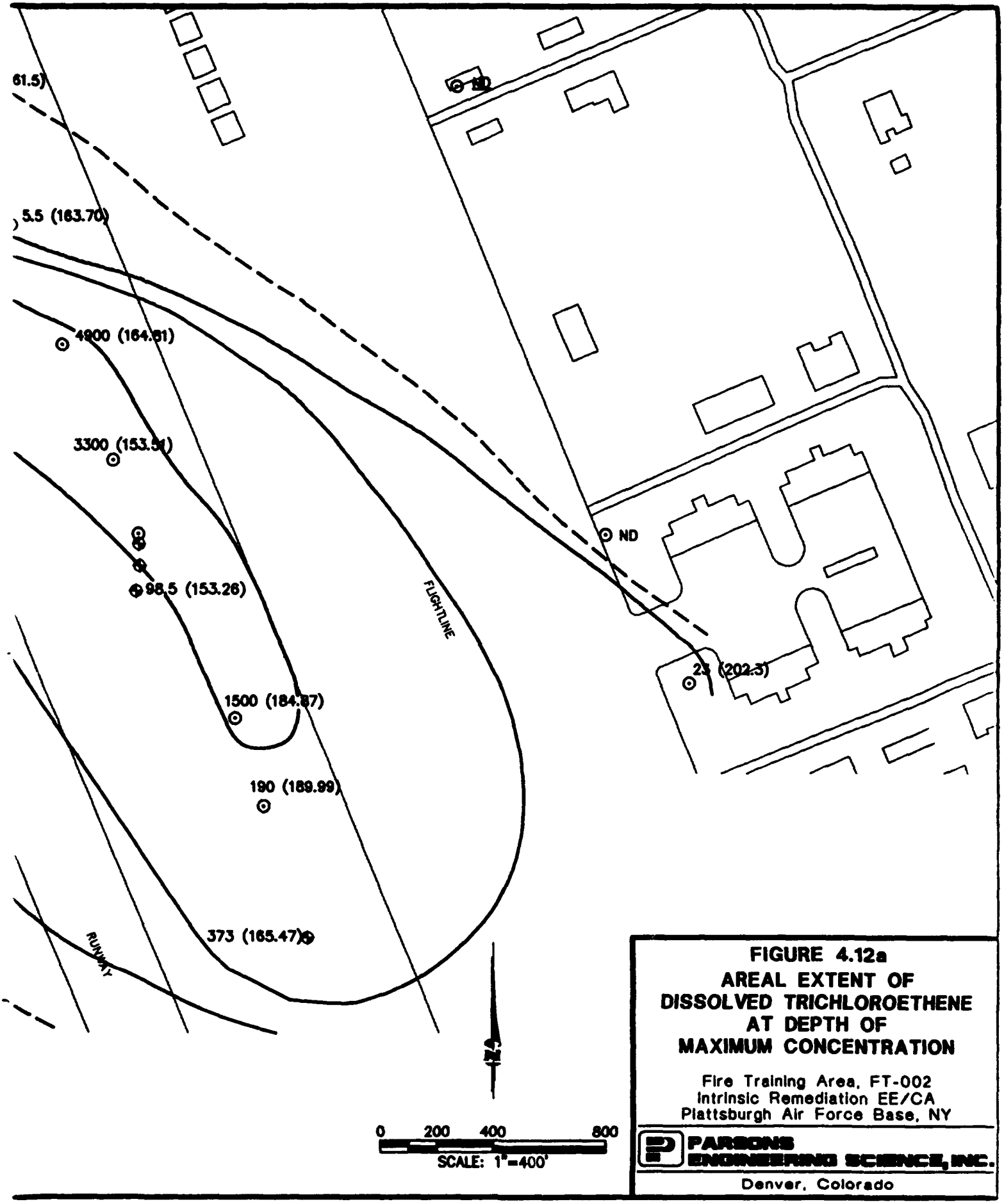
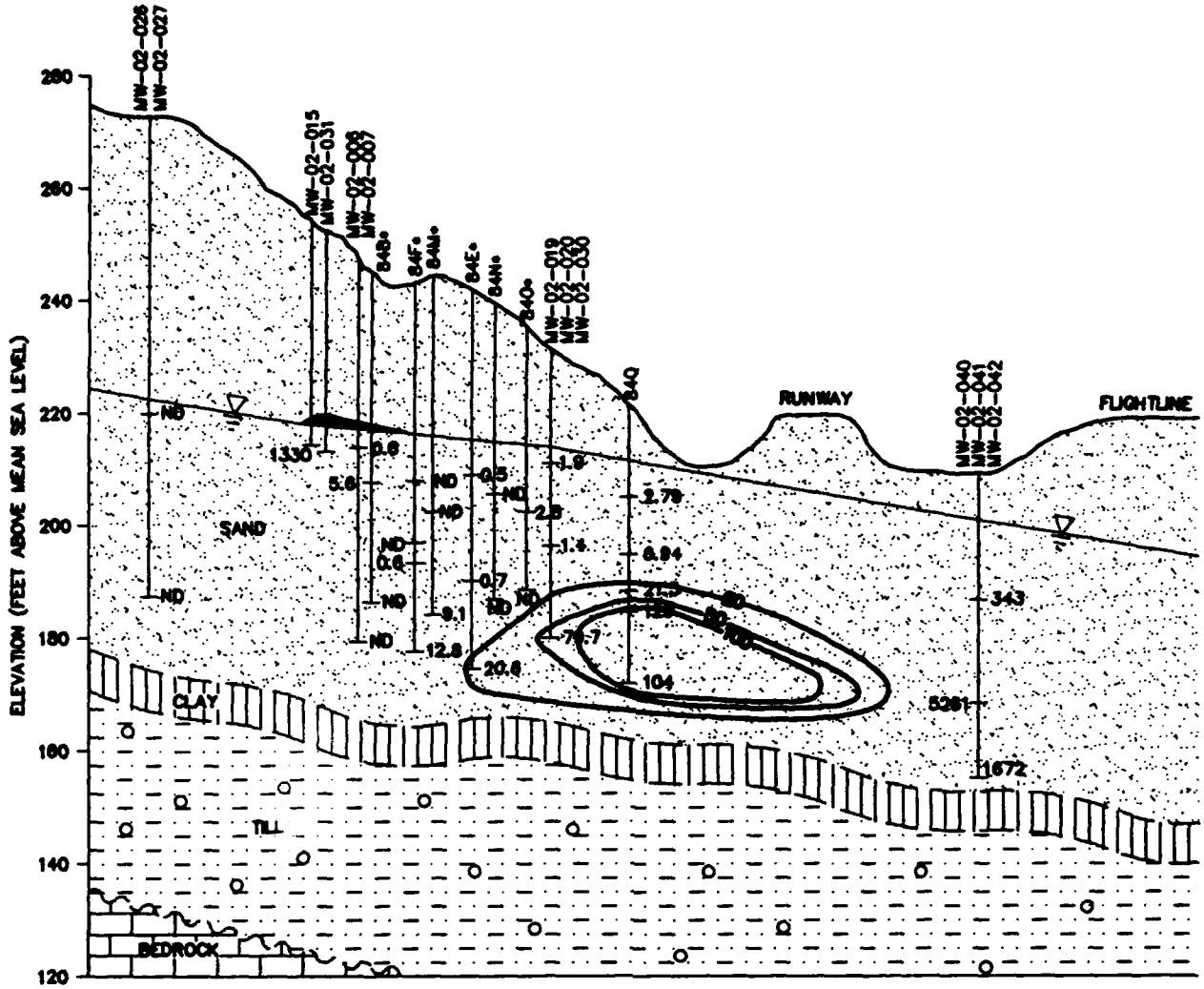


FIGURE 4.12a
AREAL EXTENT OF DISSOLVED TRICHLOROETHENE AT DEPTH OF MAXIMUM CONCENTRATION

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado



LEGEND

⊥	SAMPLE ELEVATION (ft above msl)
16.4	MEASURED CONCENTRATION OF TCE (ppb)
—20—	LINE OF ESTIMATED EQUAL CONCENTRATION OF TCE (ppb)
ND	NOT DETECTED
	ESTIMATED EXTENT OF LNAPL
▽	SURFACE OF GROUND WATER TABLE
	UNCONFORMITY
	LIGHT-BROWN TO GRAY, WELL-SORTED, MEDIUM-TO FINE-GRAINED SAND
	DARK-GRAY, MODERATELY PLASTIC CLAY. DARK MINERAL LAMINATIONS ARE PRESENT
	GRAY, POORLY SORTED TILL. CLAY AND SILT-SIZE GRAINS TO GRAVEL. ANGULAR ROCK FRAGMENTS PRESENT
	CARBONATE BEDROCK

* WATER ELEVATION DATA FROM CPT POINTS ARE ESTIMATED VALUES

VERTICAL EXAGGERATION = 20X

HORIZ 0 300 600 1200

VERT 0 15 30 60

FIGURE 4.12b

VERTICAL EXTENT OF DISSOLVED TRICHLOROETHENE ALONG PLUME CENTERLINE

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

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Denver, Colorado

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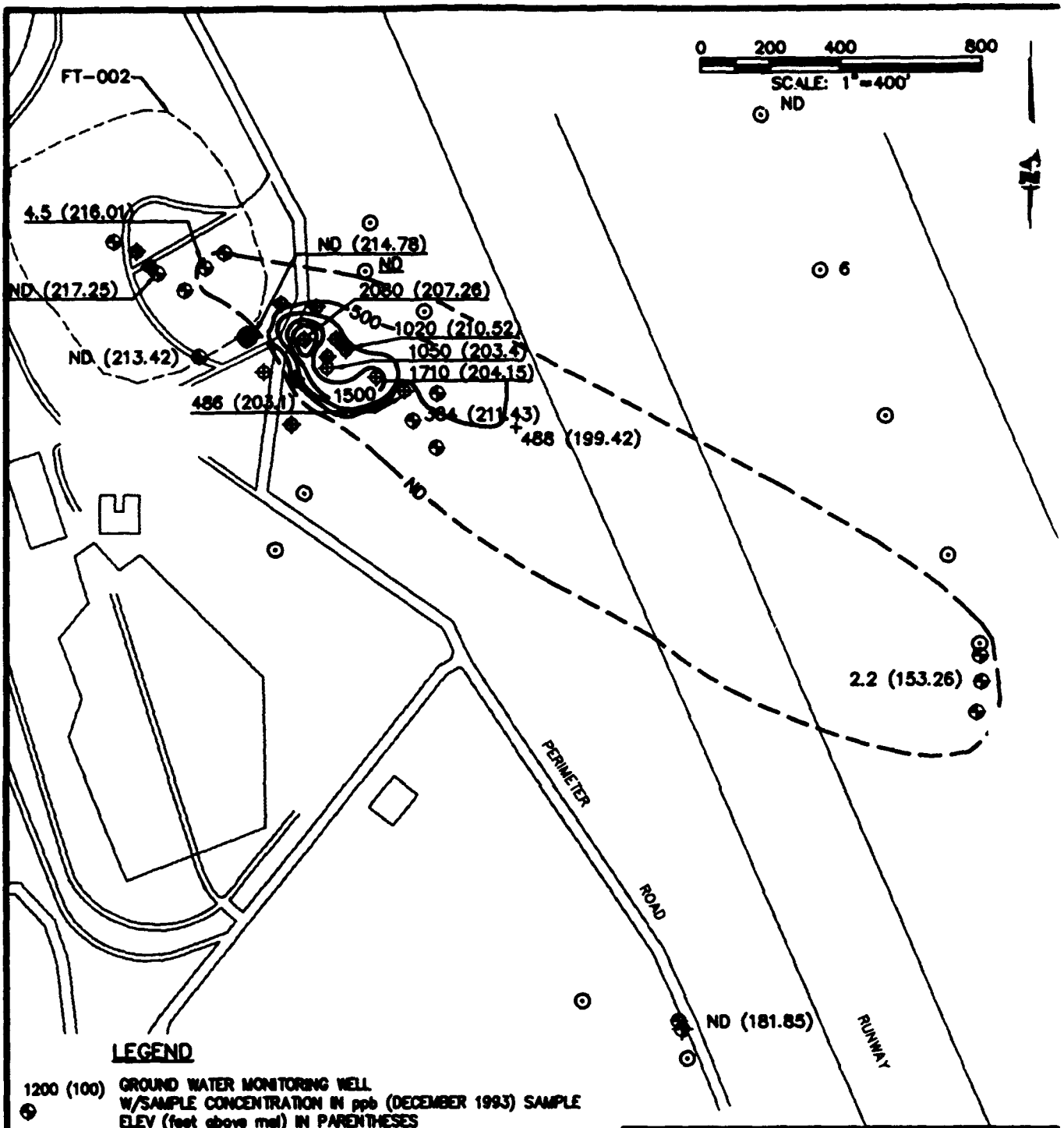

FIGURE 4.13a

AREAL EXTENT OF DISSOLVED VINYL CHLORIDE AT DEPTH OF MAXIMUM CONCENTRATION

Fire Training Area, FT-002
Intrinsic Remediation EE/C
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC
Denver, Colorado

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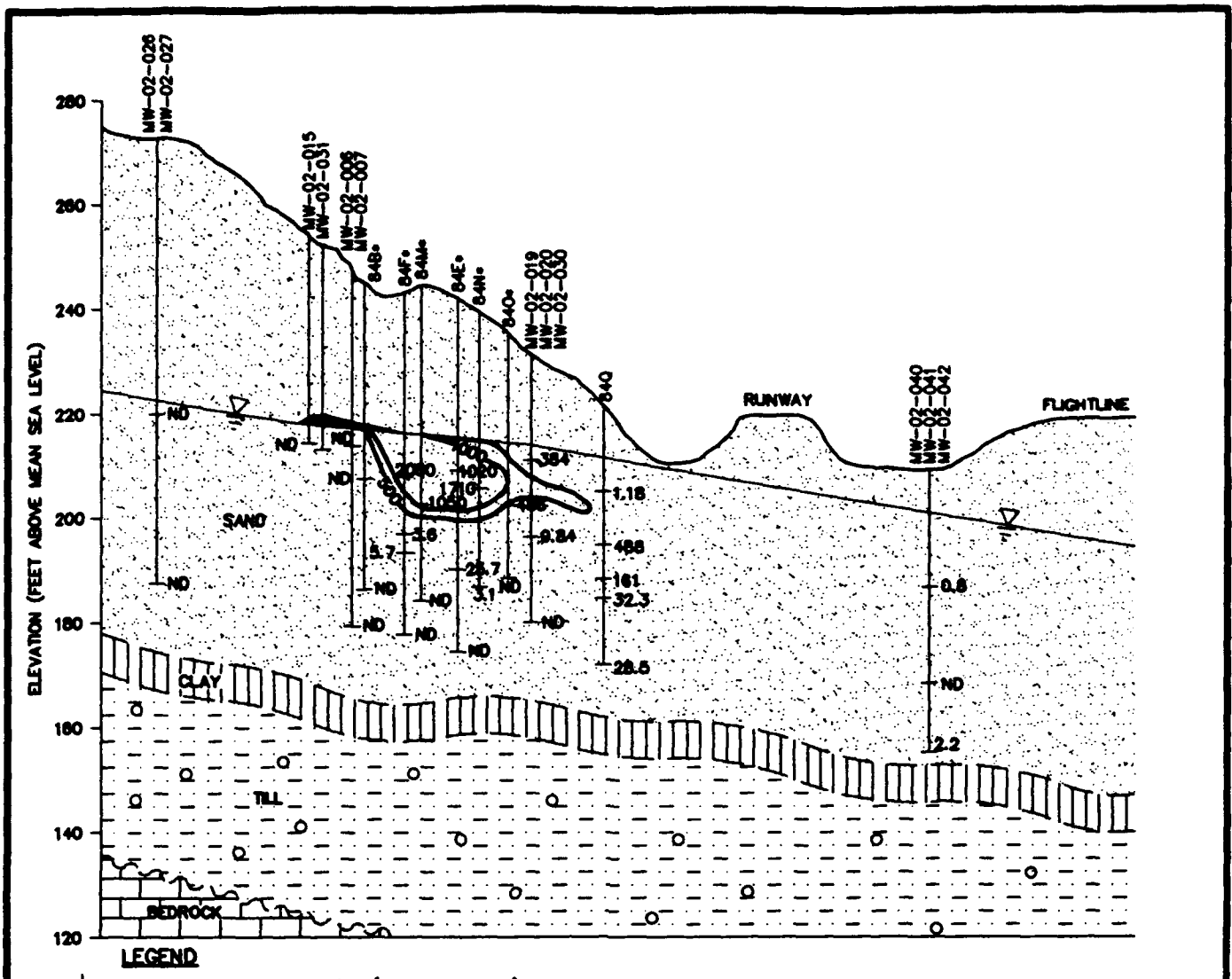

LEGEND

⊥	SAMPLE ELEVATION (ft above msl)
16.4	MEASURED CONCENTRATION OF VINYL CHLORIDE (ppb)
—20—	LINE OF ESTIMATED EQUAL CONCENTRATION OF VINYL CHLORIDE (ppb)
ND	NOT DETECTED
	ESTIMATED EXTENT OF LNAPL
▽	SURFACE OF GROUND WATER TABLE
	UNCONFORMITY
	LIGHT-BROWN TO GRAY, WELL-SORTED, MEDIUM-TO FINE-GRAINED SAND
	DARK-GRAY, MODERATELY PLASTIC CLAY. DARK MINERAL LAMINATIONS ARE PRESENT
	GRAY, POORLY SORTED TILL. CLAY AND SILT-SIZE GRAINS TO GRAVEL. ANGULAR ROCK FRAGMENTS PRESENT
	CARBONATE BEDROCK

* WATER ELEVATION DATA FROM CPT POINTS ARE ESTIMATED VALUES

VERTICAL EXAGGERATION = 20X

HORIZ 0 300 600 1200
VERT 0 15 30 60

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FIGURE 4.13b

VERTICAL EXTENT OF DISSOLVED VINYL CHLORIDE ALONG PLUME CENTERLINE

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

water flow. The vertical extent of the vinyl chloride plume is similar to (and almost mirrors) the BTEX plume (Figures 4.7b and 4.13b). The vinyl chloride plume was limited to the upper portions of the unconfined aquifer. The vinyl chloride plume does not appear to be as affected by vertical hydraulic gradients or dispersion as the total chlorinated solvent or TCE plumes.

Section 5 of this document explores the relationships between site contamination patterns and other geochemical parameters that are relevant to documenting the occurrence of biologically-mediated degradation of fuel hydrocarbons. That section also investigates the observed relationships between BTEX, chlorinated solvents, and likely degradation products to determine whether anaerobic or aerobic cometabolism is occurring.

SECTION 5

DEFINING EFFECTS OF DESTRUCTIVE ATTENUATION MECHANISMS

5.1 INTRODUCTION

Section 3 of this document was devoted to describing the physical site conditions. Section 4 focused on identifying the nature and extent of site-related contaminants to estimate the total mass and spatial distribution of reactive fuel hydrocarbons that may be present in the unconfined aquifer. This section explores whether the compounds of concern, namely the BTEX compounds and the chlorinated solvents, are actually biodegrading in the aquifer.

As discussed in Section 1, the first objective of this demonstration was to determine if naturally occurring contaminant attenuation mechanisms are operating at the site. Supporting the use of intrinsic remediation as a scientifically defensible and attractive remedial option for ground water contamination hinges on documenting loss of contaminant mass at the field scale. To evaluate the potential for intrinsic remediation processes to bring about a continual reduction in contaminant concentrations over time, it is important to distinguish between contaminant mass loss due to nondestructive attenuation mechanisms, such as mechanical dispersion, diffusion, adsorption, and volatilization, and destructive attenuation mechanisms, such as biodegradation, abiotic oxidation, and hydrolysis (Wilson, 1993; Wiedemeier *et al.*, 1994). This section presents data used to define that fraction of contaminant loss within the unconfined aquifer at Site FT-002 that can potentially be attributed to destructive attenuation mechanisms. This information must be developed before predictions about the performance of intrinsic remediation can be evaluated using a numerical model such as Bioplume II.

This section also describes the mechanism of permanent contaminant mass removal in the shallow unconfined aquifer at Site FT-002. The oxidation of BTEX compounds is accompanied by a reduction of other chemical species. Thus, analytical data on oxidized and reduced chemical species can be used as secondary indicators of BTEX degradation. This section presents analytical data on these indicator parameters for the FT-002 site, and discusses how these data are relevant to documenting the destruction of contaminant mass over time.

5.2 OVERVIEW

Numerous laboratory and field studies have shown that hydrocarbon-degrading bacteria can participate in the degradation of many of the chemical components of jet fuel and gasoline, including the BTEX compounds (e.g., Jamison *et al.*, 1975; Atlas, 1981, 1984, 1988; Gibson, 1984; Reinhard *et al.*, 1984; Young, 1984; Bartha, 1986; Wilson *et al.*, 1986, 1987; 1990; Barker *et al.*, 1987; Baedecker *et al.*, 1988; Lee, 1988; Chiang *et al.*, 1989; Grbic-Galic, 1989, 1990; Cozzarelli *et al.*, 1990; Leahy and Colwell, 1990; Altenschmidt and Fuchs, 1991; Alvarez and Vogel, 1991; Baedecker and Cozzarelli, 1991; Ball *et al.*, 1991; Bauman, 1991; Borden, 1991; Brown and McFarland, 1991; Edwards *et al.*, 1991, 1992; Evans *et al.*, 1991a, 1991b; Haag *et al.*, 1991; Hutchins and Wilson, 1991; Hutchins *et al.*, 1991a, 1991b; Beller *et al.*, 1992; Bouwer, 1992; Edwards and Grbic-Galic, 1992; Edwards *et al.*, 1992; Thierrin *et al.*, 1992; Malone *et al.*, 1993; Davis *et al.*, 1994). Biodegradation of fuel hydrocarbons theoretically can occur when an indigenous population of hydrocarbon-degrading microorganisms is present in the aquifer and sufficient concentrations of electron acceptors and nutrients, including fuel hydrocarbons, are available to these organisms. The potential of these organisms to convert site contaminants (i.e., the BTEX compounds and chlorinated solvents) into harmless byproducts ultimately determines the feasibility and expected performance of intrinsic remediation (Godsey, 1994; Reinhard, 1994).

Microorganisms obtain energy to replenish enzymatic systems and to reproduce by oxidizing organic matter. Biodegradation of the BTEX compounds is the result of a series of reduction-oxidation (redox) reactions which maintain the charge balance within the natural environment. The introduction of fuel hydrocarbons within the shallow ground water at the FT-002 site disrupted the chemical equilibrium by increasing its reduction capacity. Microorganisms obtain energy and reproduce by facilitating thermodynamically possible redox reactions involving BTEX compounds and available electron acceptors. Consequently, these microorganisms help to restore equilibrium by facilitating energy-yielding redox reactions. It is important to note that microbial degradation of BTEX compounds cannot be strictly classified as catalysis because the process results in useable energy for the microorganisms. The impetus for facilitating these redox processes is the energy yield, which is used to meet cell maintenance requirements and increase microbial mass.

Microorganisms facilitate the degradation of the BTEX compounds by transferring electrons from benzene, toluene, ethylbenzene, and the xylenes to available electron acceptors. Electron acceptors are elements or compounds that occur in relatively oxidized states and can participate in redox reactions involving the BTEX compounds. Laboratory and field studies suggest that

oxygen, nitrate, ferric iron, sulfate, and carbon dioxide can act as electron acceptors during the oxidation of the BTEX compounds (Reinhard *et al.*, 1984; Kuhn *et al.*, 1985, 1988; Zeyer *et al.*, 1986; Grbic-Galic and Vogel, 1987; Wilson *et al.*, 1987; Major *et al.*, 1988; Michelcic and Luthy, 1988; Kukor and Olsen, 1989; Lovley *et al.*, 1989; Dolfing *et al.*, 1990; Grbic-Galic, 1990; Lovley and Lonergan, 1990; Altenschmidt and Fuchs, 1991; Baedecker and Cozzarelli, 1991; Ball *et al.*, 1991; Beller *et al.*, 1991, 1992; Edwards *et al.*, 1991; Evans *et al.*, 1991a, 1991b, and 1992; Flyvbjerg *et al.*, 1991, Hutchins *et al.*, 1991; Lovley, 1991). Analytical data on these potential electron acceptors can be chemical indicators of BTEX degradation.

5.2.1 Availability of Appropriate Microbial Consortia

The ability of microorganisms to oxidize a variety of fuel hydrocarbons, including the BTEX compounds, is well documented in the literature. An early review of hydrocarbon-degrading consortia indicated that over 100 microbial species from 30 genera can degrade some or several types of fuel hydrocarbons (Zobell, 1946). Hydrocarbon-degrading microorganisms are found in most aquifers, particularly those contaminated with fuel hydrocarbons (McKee *et al.*, 1972; Litchfield and Clark, 1973; Ridgeway *et al.*, 1990; Borden, 1994). Although no soil or water samples were collected and tested for microbial activity, chemical data indicate that hydrocarbon-degrading microorganisms are present in the immediate vicinity of the contamination at Site FT-002 and that these microorganisms have the capability to participate in the oxidation of the dissolved BTEX compounds. Field data on environmental conditions and limiting factors that may affect the types of microorganism populations that can exist in the ground water and/or the capabilities of the microbial consortia are briefly discussed below.

5.2.2 Applicability of Thermodynamics

Microorganisms are constrained by the laws of thermodynamics. They can only facilitate those redox reactions that are thermodynamically possible (Chapelle, 1993). Most of the reactions involved in BTEX oxidation cannot proceed abiotically, even though they are thermodynamically favorable. These reactions require microorganisms to proceed. The microorganisms facilitate these redox reactions by providing the necessary activation energy. Without this input, these redox reactions would not spontaneously occur in the ground water at Site FT-002. Additionally, it has been assumed that biological mediation of redox processes can be described by metastable steady-state conditions that approximate partial equilibrium (Stumm and Morgan, 1981). Equilibrium models can be used to predict the thermodynamically stable

state and to describe the direction and extent of processes tending toward it. Thus, equilibrium calculations for the predominant redox components can be used to deduce the potential for intrinsic remediation of the contaminated ground water system at Site FT-002.

5.2.3 Why and How BTEX Biodegrades

The driving force of BTEX degradation is electron transfer and is quantified by the free energy of the reaction (Stumm and Morgan, 1981; Bouwer, 1994; Godsey, 1994). The Gibbs free energy of a reaction (ΔG_r) defines the maximum, useful energy change for a chemical reaction at a constant temperature and pressure. The state of a redox reaction relative to equilibrium is defined by the sign of ΔG_r. Negative values indicate that the reaction will proceed from left to right (i.e., reactants will be transformed into products). Positive values indicate that the reaction will proceed from right to left (i.e., products will be transformed into reactants). Reactions will tend to proceed in the direction that minimizes the Gibbs free energy (i.e., $\Delta G_r = 0$ at equilibrium). The value of ΔG_r estimates how much free energy is consumed or can be yielded to the system during the reaction. Microorganisms will facilitate only those redox reactions that will *yield* some energy (i.e., $\Delta G_r < 0$). These energy-releasing reactions are called exergonic. Microorganisms will not invest more energy into the system than can be released.

Table 5.1 presents the calculated ΔG_r values for the oxidation reactions for each of the BTEX compounds. The positive calculated ΔG_r values indicate that these oxidation reactions are endergonic (i.e., energy-consuming). Thus, to derive energy for cell maintenance and production from the BTEX compounds, the microorganisms must couple an exergonic reaction and an endergonic reaction. Table 5.1 also presents the calculated ΔG_r values for the reduction of potential electron acceptors that are available in the ground water at Site FT-002 . All of these ΔG_r values are negative, indicating that they yield energy when they go to completion.

Microorganisms are able to utilize electron transport systems and chemiosmosis to combine energetically favorable and unfavorable reactions to produce energy for life processes. Table 5.2 shows how microorganisms chemically combine endergonic and exergonic reactions to release useful energy for cell maintenance and production. By coupling the oxidation of the BTEX compounds to the reduction of other compounds (e.g., oxygen, nitrate, ferric iron, sulfate, and

TABLE 5.1

ELECTRON ACCEPTOR AND ELECTRON DONOR HALF-CELL REACTIONS

Fire Training Area, FT-002

Intrinsic Remediation EE/CA

Plattsburgh Air Force Base, NY

...ALF-CELL REACTIONS	$\Delta G°_r$ (kcal/ equiv)*	$G°_r$ (kJ/ equiv)*	$E°$ (mV)	Eh (mV)	pE	Conditions for Eh and pE §
ELECTRON-ACCEPTOR (REDUCTION) HALF CELL REACTIONS						
$5e^- + 6H^+ + NO_3^- \Rightarrow 0.5N_2 + 3H_2O$ *Denitrification*	-28.7	-120.	+1.24	+0.712	+12.0	pH = 7 $\Sigma[N]=10^{-3}$ $P_{N_2}=0.77$ atm
$4e^- + 4H^+ + O_2 \Rightarrow 2H_2O$ *Aerobic Respiration*	-28.3	-119.	+1.23	+0.805	+13.6	pH = 7 $P_{O_2}=0.21$ atm
$2e^- + 4H^+ + \underline{MnO_2} \Rightarrow Mn^{2+} + 2H_2O$ *Pyrolusite Dissolution/Reduction*	-28.3	-119	+1.23	+0.550	+9.27	pH = 7 $\Sigma[Mn]=10^{-5}$
$e^- + H^+ + CO_2 + \underline{MnOOH} \Rightarrow \underline{MnCO_3} + H_2O$ *a Manganite Carbonation/Reduction*	-23.1	-96.8	+1.00	+0.412	+6.96	pH = 8 $P_{CO_2}=10^{-2}$
$e^- + H^+ + \underline{MnO_2} \Rightarrow \underline{MnOOH}$ *Pyrolusite Hydrolysis/Reduction*	-22.1	-92.5	+0.959	+0.545	+9.21	pH = 7
$e^- + 3H^+ + \underline{Fe(OH)_{3,amph.}} \Rightarrow Fe^{2+} + 3H_2O$ *Amorphous "Goethite" Dissolution/Reduction*	-21.5	-89.9	+0.932	+0.163	+2.75	pH = 6
$8e^- + 10H^+ + NO_3^- \Rightarrow NH_4^+ + 3H_2O$ *Nitrate Reduction*	-20.3	-84.9	+0.879	+0.362	+6.12	pH = 6 $\Sigma[Fe]=10^{-5}$
$2e^- + 2H^+ + NO_3^- \Rightarrow NO_2^- + H_2O$ *Nitrate Reduction*	-18.9	-78.9	+0.819	+0.404	+6.82	pH = 7
$1e^- + 3H^+ + \underline{FeOOH} \Rightarrow Fe^{2+} + 2H_2O$ *"Ferric oxyhydroxide" Dissolution/Reduction*	-15.0	-62.9	+0.652	-0.118	-1.99	pH = 6 $\Sigma[Fe]=10^{-5}$
$e^- + 3H^+ + \underline{Fe(OH)_{3,xline.}} \Rightarrow Fe^{2+} + 3H_2O$ *Crystallized "Goethite" Dissolution/Reduction*	-11.8	-49.2	+0.510	-0.259	-4.38	pH = 6 $\Sigma[Fe]=10^{-5}$
$e^- + H^+ + CO_{2,g} + \underline{Fe(OH)_{3,amph.}} \Rightarrow \underline{FeCO_3} + 2H_2O$ *Amorphous "Goethite" Carbonation/Reduction*	-11.0	-46.2	+0.479	-0.113	-1.90	pH = 8 $P_{CO_2}=10^{-2}$ atm
$8e^- + 9H^+ + SO_4^{2-} \Rightarrow HS^- + 4H_2O$ *Sulfate Reduction*	-5.81	-24.3	+0.252	-0.281	-4.74	pH = 8
$8e^- + 10H^+ + SO_4^{2-} \Rightarrow H_2S^\circ + 4H_2O$ *Sulfate Reduction*	-6.93	-28.9	+0.301	-0.143	-2.42	pH = 6
$8e^- + 8H^+ + CO_{2,g} \Rightarrow CH_{4,g} + 2H_2O$ *Methanogenesis*	-3.91	-16.4	+0.169	-0.259	-4.39	pH = 7 $P_{CO_2}=10^{-2}$ $P_{CH_4}=10^{0}$
ELECTRON-DONOR (OXIDATION) HALF CELL REACTIONS						
$12H_2O + C_6H_6 \Rightarrow 6CO_2 + 30H^+ + 30e^-$ *Benzene Oxidation*	+2.83	+11.8	+0.122	-0.316	-5.34	pH = 7 $P_{CO_2}=10^{-2}$
$14H_2O + C_6H_5CH_3 \Rightarrow 7CO_2 + 36H^+ + 36e^-$ *Toluene Oxidation*	+2.96	+12.4	+0.128	-0.309	-5.22	pH = 7 $P_{CO_2}=10^{-2}$
$16H_2O + C_6H_5C_2H_5 \Rightarrow 8CO_2 + 42H^+ + 42e^-$ *Ethylbenzene Oxidation*	+2.95	+12.4	+0.128	-0.308	-5.21	pH = 7 $P_{CO_2}=10^{-2}$
$16H_2O + C_6H_4(CH_3)_2 \Rightarrow 8CO_2 + 42H^+ + 42e^-$ *m-Xylene Oxidation*	+3.02	+12.7	+0.131	-0.305	-5.88	pH = 7 $P_{CO_2}=10^{-2}$

NOTES:

* = $\Delta G°_r$ for half-cell reaction as shown divided by the number of electrons involved in reaction.

§ = Conditions assumed for the calculation of Eh and pE (pE = Eh/0.05916). Where two dissolved species are involved, other than those mentioned in this column, their activities are taken as equal. Note, this does not affect the free energy values listed.

TABLE 5.2

COUPLED REDOX REACTIONS INVOLVING THE BTEX COMPOUNDS

Fire Training Area, FT-002

Intrinsic Remediation EE/CA

Plattsburgh Air Force Base, NY

Coupled Benzene Oxidation Reactions	$\Delta G°_r$ (kcal/mole Benzene)	$\Delta G°_r$ (kJ/mole Benzene)	Stoichiometric Mass Ratio of Electron Acceptor to Compound
$7.5O_2 + C_6H_6 \Rightarrow 6CO_{2,g} + 3H_2O$ *Benzene oxidation /aerobic respiration*	-765.34	-3202	3.07:1
$6NO_3^- + 6H^+ + C_6H_6 \Rightarrow 6CO_{2,g} + 6H_2O + 3N_{2,g}$ *Benzene oxidation / denitrification*	-775.75	-3245	4.77:1
$30H^+ + 15\underline{MnO_2} + C_6H_6 \Rightarrow 6CO_{2,g} + 15Mn^{2+} + 18H_2O$ *Benzene oxidation / manganese reduction*	-765.45	-3202	10.56:1
$3.75\,NO_3^- + C_6H_6 + 7.5\,H^+ + 0.75\,H_2O \Rightarrow 6\,CO_2 + 3.75\,NH_4^+$ *Benzene oxidation / nitrate reduction*	-524.1	-2193	2.98:1
$60H^+ + 30\underline{Fe(OH)_{3,a}} + C_6H_6 \Rightarrow 6CO_2 + 30Fe^{2+} + 78H_2O$ *Benzene oxidation / iron reduction*	-560.10	-2343	21.5:1
$7.5H^+ + 3.75SO_4^{2-} + C_6H_6 \Rightarrow 6CO_{2,g} + 3.75H_2S° + 3H_2O$ *Benzene oxidation / sulfate reduction*	-122.93	-514.3	4.61:1
$4.5H_2O + C_6H_6 \Rightarrow 2.25CO_{2,g} + 3.75CH_4$ *Benzene oxidation / methanogenesis*	-32.40	-135.6	0.77:1 a/

Coupled Toluene Oxidation Reactions	$\Delta G°_r$ (kcal/mole Toluene)	$\Delta G°_r$ (kJ/mole Toluene)	Stoichiometric Mass Ratio of Electron Acceptor to Compound
$9O_2 + C_6H_5CH_3 \Rightarrow 7CO_{2,g} + 4H_2O$ *Toluene oxidation /aerobic respiration*	-913.76	-3823	3.13:1
$7.2NO_3^- + 7.2H^+ + C_6H_5CH_3 \Rightarrow 7CO_{2,g} + 7.6H_2O + 3.6N_{2,g}$ *Toluene oxidation / denitrification*	-926.31	-3875	4.85:1
$36H^+ + 18\underline{MnO_2} + C_6H_5CH_3 \Rightarrow 7CO_{2,g} + 18Mn^{2+} + 22H_2O$ *Toluene oxidation / manganese reduction*	-913.89	-3824	10.74:1
$72H^+ + 36\underline{Fe(OH)_{3,a}} + C_6H_5CH_3 \Rightarrow 7CO_2 + 36Fe^{2+} + 94H_2O$ *Toluene oxidation / iron reduction*	-667.21	-2792	21.86:1
$9H^+ + 4.5SO_4^{2-} + C_6H_5CH_3 \Rightarrow 7CO_{2,g} + 4.5H_2S° + 4H_2O$ *Toluene oxidation / sulfate reduction*	-142.86	-597.7	4.7:1
$5H_2O + C_6H_5CH_3 \Rightarrow 2.5CO_{2,g} + 4.5CH_4$ *Toluene oxidation / methanogenesis*	-34.08	-142.6	0.78:1

TABLE 5.2 (concluded)
COUPLED REDOX REACTIONS INVOLVING THE BTEX COMPOUNDS
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Coupled Ethylbenzene Oxidation reactions	$\Delta G°_r$ (kcal/mole Ethylbenzene)	$\Delta G°_r$ (kJ/mole Ethylbenzene)	Stoichiometric Mass Ratio of Electron Acceptor to Compound
$10.5O_2 + C_6H_5C_2H_5 \Rightarrow 8CO_{2,g} + 5H_2O$ *Ethylbenzene oxidation /aerobic respiration*	-1066.13	-4461	3.17:1
$8.4NO_3^- + 8.4H^+ + C_6H_5C_2H_5 \Rightarrow 8CO_{2,g} + 9.2H_2O + 4.2N_{2,g}$ *Ethylbenzene oxidation / denitrification*	-1080.76	-4522	4.92:1
$46H^+ + 22\underline{MnO_2} + C_6H_5C_2H_5 \Rightarrow 8CO_{2,g} + 22Mn^{2+} + 28H_2O$ *Ethylbenzene oxidation / manganese reduction*	-1066.27	-4461	11.39:1
$84H^+ + 42\underline{Fe(OH)_{3,a}} + C_6H_5C_2H_5 \Rightarrow 8CO_2 + 42Fe^{2+} + 110H_2O$ *Ethylbenzene oxidation / iron reduction*	-778.48	-3257	22:1
$10.5H^+ + 5.25SO_4^{2-} + C_6H_5C_2H_5 \Rightarrow 8CO_{2,g} + 5.25H_2S^o + 5H_2O$ *Ethylbenzene oxidation / sulfate reduction*	-166.75	-697.7	4.75:1
$5.5H_2O + C_6H_5C_2H_5 \Rightarrow 2.75CO_{2,g} + 5.25CH_4$ *Ethylbenzene oxidation / methanogenesis*	-39.83	-166.7	0.79:1

Coupled m-Xylene Oxidation Reactions	$\Delta G°_r$ (kcal/mole *m*-xylene)	$\Delta G°_r$ (kJ/mole *m*-xylene)	Stoichiometric Mass Ratio of Electron Acceptor to Compound
$10.5O_2 + C_6H_4(CH_3)_2 \Rightarrow 8CO_{2,g} + 5H_2O$ *m-Xylene oxidation /aerobic respiration*	-1063.25	-4448	3.17:1
$8.4NO_3^- + 8.4H^+ + C_6H_4(CH_3)_2 \Rightarrow 8CO_{2,g} + 9.2H_2O + 4.2N_{2,g}$ *m-Xylene oxidation / denitrification*	-1077.81	-4509	4.92:1
$46H^+ + 22\underline{MnO_2} + C_6H_4(CH_3)_2 \Rightarrow 8CO_{2,g} + 22Mn^{2+} + 28H_2O$ *m-Xylene oxidation / manganese reduction*	-1063.39	-4449	11.39:1
$84H^+ + 42\underline{Fe(OH)_{3,a}} + C_6H_4(CH_3)_2 \Rightarrow 8CO_2 + 42Fe^{2+} + 110H_2O$ *m-Xylene oxidation / iron reduction*	-775.61	-3245	22:1
$10.5H^+ + 5.25SO_4^{2-} + C_6H_4(CH_3)_2 \Rightarrow 8CO_{2,g} + 5.25H_2S^o + 5H_2O$ *m-Xylene oxidation / sulfate reduction*	-163.87	-685.6	4.75:1
$5.5H_2O + C_6H_4(CH_3)_2 \Rightarrow 2.75CO_{2,g} + 5.25CH_4$ *m-Xylene oxidation / methanogenesis*	-36.95	-154.6	0.79:1

(a/ mass of methane produced during microbial respiration.)

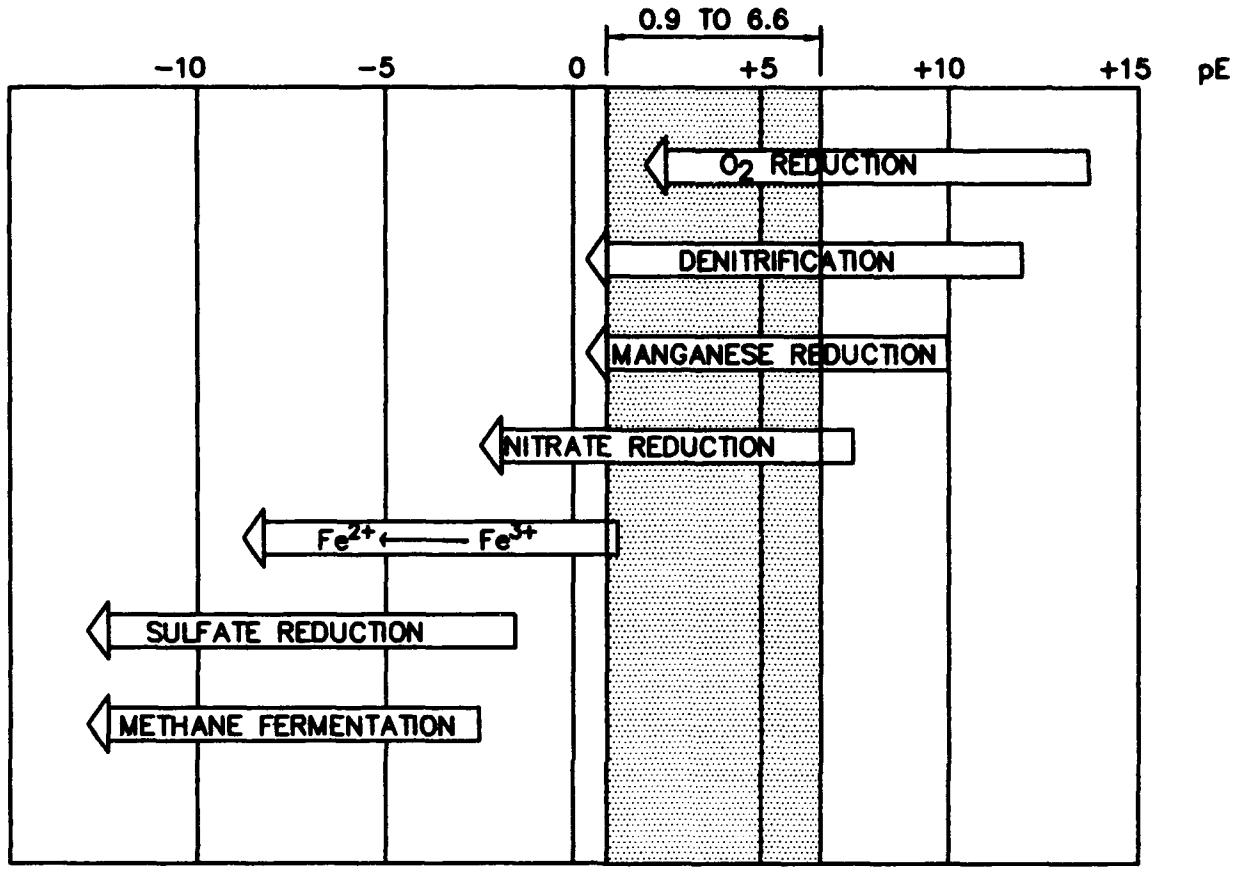
carbon dioxide), the overall reaction becomes energy yielding. For example, the oxidation of 1 mole of benzene via oxygen reduction would make 765.34 kilocalories of free energy available to the microorganisms. The microorganisms would derive a significant source of energy by facilitating this coupled reaction.

Coupled redox reactions would be expected to occur in order of their thermodynamic energy yield assuming that there are organisms capable of facilitating each pertinent redox reaction and that there is an available supply of oxidants (i.e., electron acceptors) (Stumm and Morgan, 1981; Chapelle, 1993). Figure 5.1 illustrates the sequence of microbially mediated redox processes based on ΔG_r. In general, more energy-yielding reactions tend to take precedence over processes that are less energy-yielding (Stumm and Morgan, 1981; Godsey, 1994; Reinhard, 1994). Thus, oxygen reduction would be expected to occur in an aerobic environment with microorganisms capable of aerobic respiration because oxygen reduction yields significant energy (Bouwer, 1992; Chapelle, 1993). However, once the available oxygen is depleted and anaerobic conditions dominate the interior regions of the BTEX plume, anaerobic microorganisms can utilize other electron acceptors in the following order of preference: nitrate, manganese, ferric iron, sulfate and finally carbon dioxide. Each successive redox reaction provides less energy to the system, and each step down in redox energy yield would have to be paralleled by an ecological succession of microorganisms capable of facilitating the pertinent redox reactions.

The expected sequence of redox processes is also a function of the oxidizing potential of the ground water. The oxidizing potential measures the relative tendency of a solution or chemical reaction to accept or transfer electrons. The oxidizing potential of the ground water can be measured in the field (Eh). This measurement can be used as a crude indicator of which redox reactions may be operating at a site. This field measurement can then be expressed as pe, which is the hypothetical measure of the electron activity associated with a specific Eh. High pe means that the solution or redox couple has a relatively high oxidizing potential.

Microorganisms can only facilitate the oxidation of the BTEX compounds using compounds or redox couples that have a higher oxidizing potential than the BTEX compounds. Table 5.1 also presents the calculated pe values for each of the redox reactions that may be pertinent at Site FT-002. This table shows that redox couples including nitrate, oxygen, manganese, ferric iron, and sulfate all have a higher oxidizing potential than the redox couples including the BTEX compounds. Thus, these electron acceptors can be used to oxidize BTEX compounds.

The reduction of highly oxidized species results in an overall decrease in the oxidizing potential of the ground water. As shown in Figure 5.1, the reduction of oxygen and nitrate will



NOTES

RANGE OF pE MEASURED AT FT-002

1. THESE REACTIONS WOULD BE EXPECTED TO OCCUR IN SEQUENCE IF THE SYSTEM IS MOVING TOWARD EQUILIBRIUM.

2. THESE REDOX PROCESSES OCCUR IN ORDER OF THEIR ENERGY-YIELDING POTENTIAL (PROVIDE MICROORGANISMS ARE AVAILABLE TO MEDIATE A SPECIFIC REACTION). REDUCTION OF A HIGHLY OXIDIZED SPECIES DECREASE THE pE OF THE SYSTEM.

3. THE pE OF THE SYSTEM DETERMINES WHICH ELECTRONS ACCEPTORS ARE AVAILABLE FOR BTEX OXIDATION.

4. REDOX SEQUENCE IS PARALLELED BY AN ECOLOGICAL SUCCESSION OF BIOLOGICAL MEDIATORS.

FIGURE 5.1

SEQUENCE OF MICROBIALLY MEDIATED REDOX PROCESSES

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

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reduce the oxidizing potential to levels where manganese and ferric iron (Fe^{3+}) reduction can occur. As each chemical species that can be used to oxidize the BTEX compounds is exhausted, the microorganisms are forced to use other available electron acceptors with lower oxidizing capacity. When sufficiently negative pe levels have been developed by these redox reactions, sulfate reduction and methane fermentation can occur almost simultaneously (Stumm and Morgan, 1981). Thus, the succession of expected redox reactions can also be explained by the charge balance. Figure 5.1 shows the range of pe in the ground water at Site FT-002 based on Eh measurements. These data imply that oxygen, nitrate, manganese, and ferric iron may be available to be used to biodegrade BTEX at Site FT-002. Analytical data on oxidized and reduced species are presented in Section 5.5 to verify which electron acceptors may be operating at Site FT-002.

5.2.4 Approach

A four step process was used during this investigation to determine if BTEX compounds are degrading at Site FT-002. The first step was to compare analytical data on the nature and extent of site contamination collected in September 1991 to analytical data on the nature and extent of site contamination collected in December 1993. The purpose of this comparison was to assess the evidence of field-scale contaminant mass loss. Additionally, details about plume dynamics as a function of time could also be examined. Section 5.3 presents the results of this analysis.

The second step was to define how much of the observed contaminant mass loss was attributable to destructive contaminant attenuation mechanisms. A biologically recalcitrant tracer was employed to correct analytical field data for the effects of dispersion, diffusion, and adsorption. Volatilization was assumed to be an insignificant mechanism of contaminant mass loss at Site FT-002. Section 5.4 also presents the results of this analysis.

The third step was to determine the predominant electron acceptors that are being used to oxidize the BTEX compounds at the site. Thermodynamically possible redox processes are described in terms of oxidizing intensity. Analytical data on reduced and oxidized chemical species are presented to assess which redox processes are likely occurring at the site. The potential for cometabolism of TCE in the presence of BTEX is also discussed. This data is described in Section 5.5.

The fourth and final step in this process was to evaluate the theoretical and actual capacity of the ground water and resident microorganisms to oxidize the BTEX compounds. An estimate of

the theoretical assimilative capacity of the ground water was developed by coupling stoichiometric equations and analytical data on electron acceptors. The theoretical distribution and relative contribution of each of the redox processes at Site FT-002 was then determined. This analysis is described in Section 5.5.

5.3 OBSERVED PLUME MIGRATION PATTERNS

One of the primary methods used to document contaminant mass loss at the field scale is comparison of historical site characterization data to more recent site characterization data on the nature and spatial distribution of site-related contaminants. Those changes in the nature and extent of contamination at a site over time that cannot be explained by ground water flow and contaminant transport may be an indication that other mechanisms, such as biodegradation, are operating at the site. Existing site characterization data for Site FT-002 site collected in September 1991 under the IRP were comparable to data collected in December 1993 as part of this demonstration project (Appendix E). The types of contaminants at the site have not changed over the time period for which data are available (i.e., September 1991 to December 1993/May 1994). The BTEX compounds, TCE, cis-DCE, trans-DCE, and vinyl chloride were and still are the primary ground water contaminants. Additionally, site data indicate that sufficient LNAPL and soil contamination persist in the suspected source area to be a continuing source of dissolved ground water contamination.

5.3.1 Spatial and Temporal Differences in the Extent of BTEX Contamination

No significant change in dissolved concentrations of the BTEX compounds was observed between data collected in 1991 (Appendix E) and data collected in December 1993 and May 1994. Additionally, the horizontal and lateral extent of the dissolved BTEX plume did not change over this time period. Contaminant attenuation mechanisms are likely to be limiting plume migration because the hydraulic properties of the aquifer would permit greater plume migration than observed. The average distance that the dissolved BTEX plume would have been expected to migrate since September 1991 was 60 feet. Data collected in 1993/1994 suggest that the BTEX has not migrated more than 20 feet since 1991. Table 5.3 summarizes the expected contaminant velocities for each of the BTEX compounds based on the average advective ground water velocity and contaminant retardation coefficients (see Appendix E).

TABLE 5.3
CALCULATION OF EXPECTED CONTAMINANT TRAVEL TIMES
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Compound	Average Ground Water Velocity (feet/year) [a]	Average Contaminant Velocity (feet/year) [b]	Expected Average Distance Traveled 1991 to 1993 (feet)
Benzene	139	41.867	136
Toluene	139	21.157	69
Ethylbenzene	139	9.437	31
m-Xylene	139	10.792	35
o-Xylene	139	10.389	34
p-Xylene	139	12.119	39
AVERAGE	139	18	57
TCE	139	36.675	119
DCE	139	50.916	165
Vinyl Chloride	139	129.907	422

[a] Based on measured K values and an assumed effective porosity of 0.3.
[b] Based on retardation coefficient calculations presented in Appendix E.

5.3.2 Spatial and Temporal Differences in the Extent of Chlorinated Solvent Contamination

In contrast to the BTEX compounds, the horizontal extent of the dissolved chlorinated solvents plume appeared to have decreased since September 1991 (Appendix E). As noted in Section 4, the areal extent of the dissolved chlorinated solvent plume was observed to be approximately 20 percent larger in 1991 than estimated from 1993/1994 data. This decrease in spatial extent is probably real and not the result of an inadequate data set, as 1991 CPT data were conservatively used to supplement 1993/1994 data (see Section 4). The decrease could be due either to greater resolution of the spatial distribution of contaminants in the unconfined aquifer or to effects of naturally occurring attenuation mechanisms.

This reduction in the horizontal extent of the dissolved chlorinated solvent plume is even more pronounced when compared to the distance that the plume was expected to migrate. Table 5.3 also presents the expected distance that the chlorinated solvents could have migrated since September 1991. Based on these estimates, the dissolved chlorinated solvent plume could have migrated between 120 and 420 feet downgradient toward the runway and flightline since 1991. The observed reduction in the horizontal extent of the dissolved chlorinated solvent plume may be attributable to both nondestructive and destructive contaminant attenuation mechanisms.

5.4 APPARENT REDUCTION IN CONTAMINANT MASS

Available site data suggest that dissolved site contaminants may be attenuating. To accurately determine the mass of reactive organic compounds that has or could be transformed to innocuous products, it is important to correct site characterization data with respect to other non-destructive processes that can cause an apparent reduction in contaminant mass (Wilson, 1993; Wiedemeier *et al.*, 1994).

5.4.1 Correcting for Dispersion and Adsorption

Hydrodynamic dispersion, molecular diffusion, and adsorption can cause an apparent loss of contaminants at the field scale. Hydrodynamic dispersion can be viewed as a form of dilution if contaminated ground water mixes with uncontaminated ground water with no actual loss of contaminant mass. The existing contaminant mass is merely diluted as the dissolved plume disperses both horizontally and vertically. Adsorption of the contaminants to the aquifer matrix can slow plume migration relative to the advective transport velocity of the ground water. If not

corrected, retardation of contaminant mass resulting from adsorption could be mistaken for contaminant mineralization by destructive contaminant attenuation processes.

The use of a conservative tracer has been proposed to distinguish between contaminant mass losses caused by dispersion and adsorption and contaminant mass losses caused by destructive attenuation mechanisms. The trimethylbenzenes (1,2,3-TMB, 1,2,4-TMB, and 1,3,5-TMB) have been proposed as conservative tracers for fuel hydrocarbon plumes because they are fairly recalcitrant under anaerobic conditions and have sorptive properties similar to the BTEX compounds (Cozzarelli *et al.*, 1990, and 1994; Wiedemeier, 1994; Wiedemeier *et al.*, 1994; Wilson *et al.*, 1994). Although the TMBs appeared to be an adequate tracer for the BTEX plume under anaerobic conditions, this suite of chemicals does not appear to be appropriate to use to correct chlorinated solvent data for these nondestructive attenuation effects. Appendix E shows how site data was corrected for dispersion, diffusion, and adsorption using TMB as a conservative tracer under anaerobic conditions (Wiedemeier *et al.*, 1994).

5.4.2 Estimating Actual Contaminant Mass Loss

Once corrected for the effects of dispersion and adsorption, the BTEX data for sample locations located within and immediately downgradient of the suspected source area still showed a measurable decrease in concentration with distance from the source. This observed decrease in concentration can be attributed to destruction of contaminant mass. The calculations presented in Appendix E suggest that 27 percent of the observed benzene mass loss, 67 percent of the observed toluene mass loss, 25 percent of the observed ethylbenzene mass loss, and 26 percent of the observed total xylenes mass loss at the field scale is likely the result of destructive attenuation mechanisms such as microbially-mediated degradation. Toluene comprises the largest mass fraction of total BTEX at the source, accounting for 43 percent of the total mass of contamination at and near the source. In comparison, benzene, ethylbenzene, and total xylenes accounted for about 16 percent, 20.5 percent, and 20.5 percent of the total BTEX mass, respectively. This means that approximately 45 percent of total BTEX on a mass fraction basis has been eliminated from the aquifer via mechanisms other than dispersion and adsorption. Table 5.4 summarizes these results.

Normalizing the measured concentrations of chlorinated solvents to TMB data proved inconclusive (see Appendix E). Although the failure of the TMBs as a tracer for the effects of dilution and adsorption on chlorinated solvents was not anticipated, it may be attributable to significant differences in tracer/contaminant sorptive properties and transport mechanisms.

TABLE 5.4
DEFINING NONDESTRUCTIVE ATTENUATION EFFECTS
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

COMPOUND	Percent Observed Mass Loss Due To Nondestructive Attenuation Mechanisms	Percent Observed Mass Loss Due To Destructive Attenuation	Mass Fraction of Total BTEX	Mass Fraction of Total BTEX Lost Due to Destructive Attenuation Mechanisms
Benzene	73%	27%	16%	4.30%
Toluene	23%	67%	43%	28.80%
Ethylbenzene	75%	25%	20.50%	5.10%
Total Xylenes	74%	26%	20.50%	6.70%
			Total	45%

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TMBs are significantly more retarded with respect to ground water advective transport than the chlorinated solvents. The data did demonstrate a good correlation between the observed reduction in the mass loss of TCE and the observed production of DCE and vinyl chloride, which are both products of TCE degradation. Use of DCE and vinyl chloride as indicators of cometabolic degradation of TCE is described in Section 5.5.3.

5.5 DESTRUCTION OF CONTAMINANT MASS VIA MICROBIALLY CATALYZED REDOX REACTIONS

The major destructive attenuation mechanism that was evaluated at the FT-002 site during this demonstration was biodegradation of the BTEX compounds. Section 5.2.3 described both why and how these microorganisms facilitate the degradation of BTEX compounds through electron transfer.

5.5.1 Analytical Data on Oxidized and Reduced Chemical Species

Having established why and how microorganisms facilitate the degradation of BTEX compounds, it is necessary to determine if such reactions are occurring at Site FT-002. The following sections summarize analytical data on reduced and oxidized chemical species and other relevant parameters that were collected to investigate BTEX biodegradation. The importance of these data in documenting the occurrence of microbially mediated BTEX degradation is also discussed.

5.5.1.1 Dissolved Oxygen

Almost all types of fuel hydrocarbons can be biodegraded under aerobic conditions (Borden, 1994). Mineralization of fuel hydrocarbons to carbon dioxide and water under aerobic conditions involves the use of oxygen as a cosubstrate during the initial stages of metabolism and as a terminal electron acceptor during the later stages of metabolism for energy production (Higgins and Gilbert, 1978; Gibson and Subramanian, 1984; Young, 1984). As shown earlier, the O_2-H_2O redox couple has a high oxidizing potential and, when coupled with endergonic reactions involving the BTEX compounds, can be used by microorganisms to release a large amount of free energy (see Tables 5.1 and 5.2). In fact, reduction of molecular oxygen is one of the most energetically favorable of the redox reactions potentially involved in BTEX degradation (i.e., denitrification and manganese reduction are more thermodynamically favorable redox reactions).

Dissolved oxygen (DO) concentrations were measured at ground water wells and CPT ground water sampling locations in December 1993 and at the Geoprobe® sample locations and newly installed ground water monitoring points in May 1994. Table 5.5 presents analytical results for DO by sample location. Figures 5.2a and 5.2b show the areal and vertical distribution of DO concentrations measured in ground water at Site FT-002. No data on DO in ground water were collected under the IRP program.

Figure 5.3 compares measured concentrations of total BTEX in the ground water with measured levels of DO. There is a strong correlation between areas of high BTEX levels and areas depleted of DO relative to measured background levels. The absence of DO from contaminated ground water indicates that oxygen may be functioning as an electron acceptor during microbially mediated degradation of fuel hydrocarbons. Use of this electron acceptor during microbial degradation of BTEX is consistent with the measured Eh (pe) levels at the site. However, the reduction of molecular oxygen will cause anaerobic conditions, reduce the oxidizing tendency of the aquifer, and bring about a change in the types of microorganisms that facilitate the degradation of BTEX.

5.5.1.2 Nitrate

Once anaerobic conditions prevail in the ground water, nitrate can be used as an electron acceptor by facultative anaerobic microorganisms to mineralize the BTEX compounds via either denitrification or nitrate reduction processes. Denitrification results in the formation of nitrogen as gas; nitrate reduction results in the production of NH_4^+ (see Table 5.3). Denitrification is the most thermodynamically favorable of the redox reactions likely to be involved in the oxidation of the BTEX compounds (see Table 5.2). Although the oxidation of the BTEX compounds by nitrate reduction will also yield significant amounts of free energy for microbial use, nitrate reduction is not as thermodynamically favorable as other potential redox reactions. However, nitrate reduction may take precedence over denitrification at Site FT-002 as the ground water becomes more reducing. As conditions become more reducing, nitrate is used as an electron acceptor via nitrate reduction to NH_4^+ rather than denitrification to nitrogen gas.

Concentrations of nitrate plus nitrite expressed as nitrogen (N) were measured at ground water wells and CPT ground water sampling locations in December 1993. No data on nitrate/nitrite concentrations were collected in May 1994. Table 5.5 presents analytical data for nitrate/nitrite as N by sampling location. Figures 5.4a and 5.4b show the areal and vertical distribution of observed nitrate/nitrite concentrations (expressed as N) in ground water. Figure 5.5 compares

TABLE 5.5
GROUND WATER QUALITY DATA FOR GEOCHEMICAL INDICATORS
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Sample Location	Sample Date	Sample Elevation (feet msl)[a]	Dissolved Oxygen (ppm)[b]	NO_2+NO_3 as N[c] (ppm)	Sulfate (ppm)	Ferrous Iron (ppm)	Methane (ppm)	Carbon Dioxide (ppm)	pE	pH	Temp. (°C)
84B	Dec. 1993	207.22	NR[d]	0.19	5.49	0.5	0.03	176	3.72	NR	NR
84B	Dec. 1993	186.02	NR	0.19	18.8	BLQ[e]	0.016	121	6.66	NR	NR
84E	Dec. 1993	210.52	NR	BLQ	5.78	1.2	0.099	490	3.28	7.4	NR
84E	Dec. 1993	190.52	NR	0.05	7.15	1.2	0.322	426	2.86	7.5	NR
84E	Dec. 1993	174.52	NR	0.15	20.3	BLQ	0.008	124	6.27	7.8	NR
84F	Dec. 1993	207.26	NR	0.06	5.43	2.6	0.512	550	2.94	7.1	NR
84F (dup)	Dec. 1993	207.26	NR	NR	NR	NR	0.501	549	NR	NR	NR
84F	Dec. 1993	197.26	NR	0.06	BLQ	5.3	0.134	356	2.57	7.4	NR
84F	Dec. 1993	192.26	NR	BLQ	BLQ	2.3	0.088	323	2.69	7.3	NR
84F	Dec. 1993	177.26	NR	BLQ	22	BLQ	0.011	138	5.65	7.8	NR
84M	Dec. 1993	203.4	NR	0.12	3.44	8.9	0.121	899	2.43	7.2	NR
84M	Dec. 1993	183.4	NR	0.14	14.6	BLQ	0.02	369	4.24	8.4	NR
84N	Dec. 1993	204.15	NR	0.12	0.21	2.9	0.1	484	2.94	7.1	NR
84N	Dec. 1993	184.15	NR	0.16	0.34	0.8	0.162	374	2.87	7.6	NR
84O	Dec. 1993	203.1	NR	0.17	0.33	3.70	0.092	618	2.43	7.20	NR
84O(dup)	Dec. 1993	203.1	NR	NR	NR	4.60	NR	NR	2.60	7.00	NR
84O	Dec. 1993	188.1	NR	0.13	0.5	NR	0.123	303	NR	NR	NR
84-Field Blank	Dec. 1993	N/A[f]	NR	NR	NR	NR	0.0002	0.902	NR	NR	NR
MW-02-005	Dec. 1993	213.42	2.1	0.1	9.73	NR	0.005	250	NR	NR	7.4
MW-02-005(dup)	Dec. 1993	213.42	NR	NR	NR	NR	0.004	229	NR	NR	NR
MW-02-006	Dec. 1993	214.78	0.8	0.12	25.1	3.5	0.007	117	1.76	NR	9.9
MW-02-007	Dec. 1993	179.69	1.1	0.1	11.7	NR	0.204	80	NR	NR	9.3
MW-02-014	Dec. 1993	216.01	1.2	BLQ	BLQ	NR	0.307	319	NR	NR	9.31
MW-02-014 (lab dup)	Dec. 1993	216.01	NR	BLQ	NR	NR	0.293	293	NR	NR	NR
MW-02-015	Dec. 1993	217.25	1	BLQ	23.1	NR	0.0004	107	NR	NR	9.3
MW-02-019	Dec. 1993	211.43	0.9	0.11	0.08	10.3	0.111	278	1.93	7.4	10
MW-02-019 (lab dup)	Dec. 1993	211.43	0.7	NR	NR	NR	0.103	260	NR	NR	8.5
MW-02-020	Dec. 1993	195.16	1.3	0.12	BLQ	10.7	0.295	381	2.10	7.3	9.4
MW-02-020 (dup)	Dec. 1993	195.16	0.8	NR	BLQ	NR	NR	NR	NR	NR	8.5
MW-02-021	Dec. 1993	181.85	1.4	0.55	22	NR	0.075	290	NR	NR	9.4
MW-02-021 (lab dup)	Dec. 1993	181.85	NR	0.53	NR	NR	NR	NR	NR	NR	NR
MW-02-026	**Dec. 1993**	**219.6**	**10**	**0.44**	**19.6**	**BLQ**	**ND[g]**	**102**	**6.66**	**7.8**	**7.2**

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TABLE 5.. oncluded)
GROUND WATER QUALITY DATA FOR GEOCHEMICAL INDICATORS
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Sample Location	Sample Date	Sample Elevation (feet msl)[a/]	Dissolved Oxygen (ppm)[b/]	NO_2+NO_3 as N[c/] (ppm)	Sulfate (ppm)	Ferrous Iron (ppm)	Methane (ppm)	Carbon Dioxide (ppm)	pE	pH	Temp. (°C)
MW-02-027	**Dec. 1993**	**186.72**	**5.5**	**0.51**	**1.79**	**NR**	**0.004**	**ND**	**2.60**	**12.1**	**6.4**
MW-02-027(dup)	Dec. 1993	186.72	NR	NR	1.88	NR	NR	NR	NR	NR	NR
MW-02-030	Dec. 1993	179.55	2.2	0.09	11.5	BLQ	0.168	102	2.27	7.7	9.4
MW-02-030 (dup)	Dec. 1993	179.55	1.3	NR	NR	NR	0.16	101	NR	NR	7.8
MW-02-040	Dec. 1993	184.02	2.2	26.5	5.53	BLQ	0.009	119	4.29	8.2	8
MW-02-041	Dec. 1993	169.05	3	0.69	1.66	BLQ	0.16	334	4.21	7.9	8.4
MW-02-042	Dec. 1993	153.26	2.4	0.13	0.26	BLQ	0.503	164	3.45	7.9	7.6
MW-02-042 (lab dup)	Dec. 1993	153.26	NR	NR	NR	NR	NR	NR	NR	NR	8.1
MW-02-043	Dec. 1993	165.47	1.4	31.1	13	NR	0.001	225	NR	NR	9.4
MW-02-044	Dec. 1993	166.24	2.5	94.9	9	BLQ	0.001	294	1.08	6.9	8.9
MW-02-043	May 1994	165.47	0.3	NR	NR	NR	NR	NR	6.14	8	9
84Q	May 1994	211.92	1.5	NR	BLQ	NR	NR	NR	3.53	8.5	7.6
84Q	May 1994	199.42	0.1	NR	BLQ	NR	NR	NR	3.23	7.5	10.7
84Q	May 1994	192.42	0.5	NR	BLQ	NR	NR	NR	4.01	7.5	NR
84Q	May 1994	189.92	0.2	NR	BLQ	NR	NR	NR	3.16	8.2	NR
84Q	May 1994	175.42	0.2	NR	BLQ	NR	NR	NR	3.70	5.2	NR
Sparge Pt 1 (1)	May 1994	14' bgs*	0.4	NR	NR	NR	NR	NR	NR	8.1	9.6
Sparge Pt 1 (2)	May 1994	24' bgs*	0.2	NR	NR	NR	NR	NR	NR	7.9	9.5
Sparge Pt 2	May 1994	14' bgs*	0.4	NR	NR	NR	NR	NR	NR	7.7	9.3
Sparge Pt 3	May 1994	14' bgs*	0.1	NR	NR	NR	NR	NR	NR	7.8	9
Sparge Pt 4 (1)	May 1994	14' bgs*	0.2	NR	NR	NR	NR	NR	NR	7.9	8.2
Sparge Pt 4 (2)	May 1994	24' bgs*	0.4	NR	NR	NR	NR	NR	NR	7.7	9.3
Sparge Pt 5	May 1994	14' bgs*	0.4	NR	NR	NR	NR	NR	NR	8	9.5

a/ feet msl = feet above mean sea level
b/ ppm = parts per million
c/ NO_2+NO_3 as N = nitrite and nitrate reported as ppm of nitrogen
d/ NR = not reported
e/ BLQ = below practical limits of quantitation
f/ N/A = not applicable
g/ ND = not detected
* ' bgs = estimated feet below ground surface
Note: Background sampling locations placed in boldface

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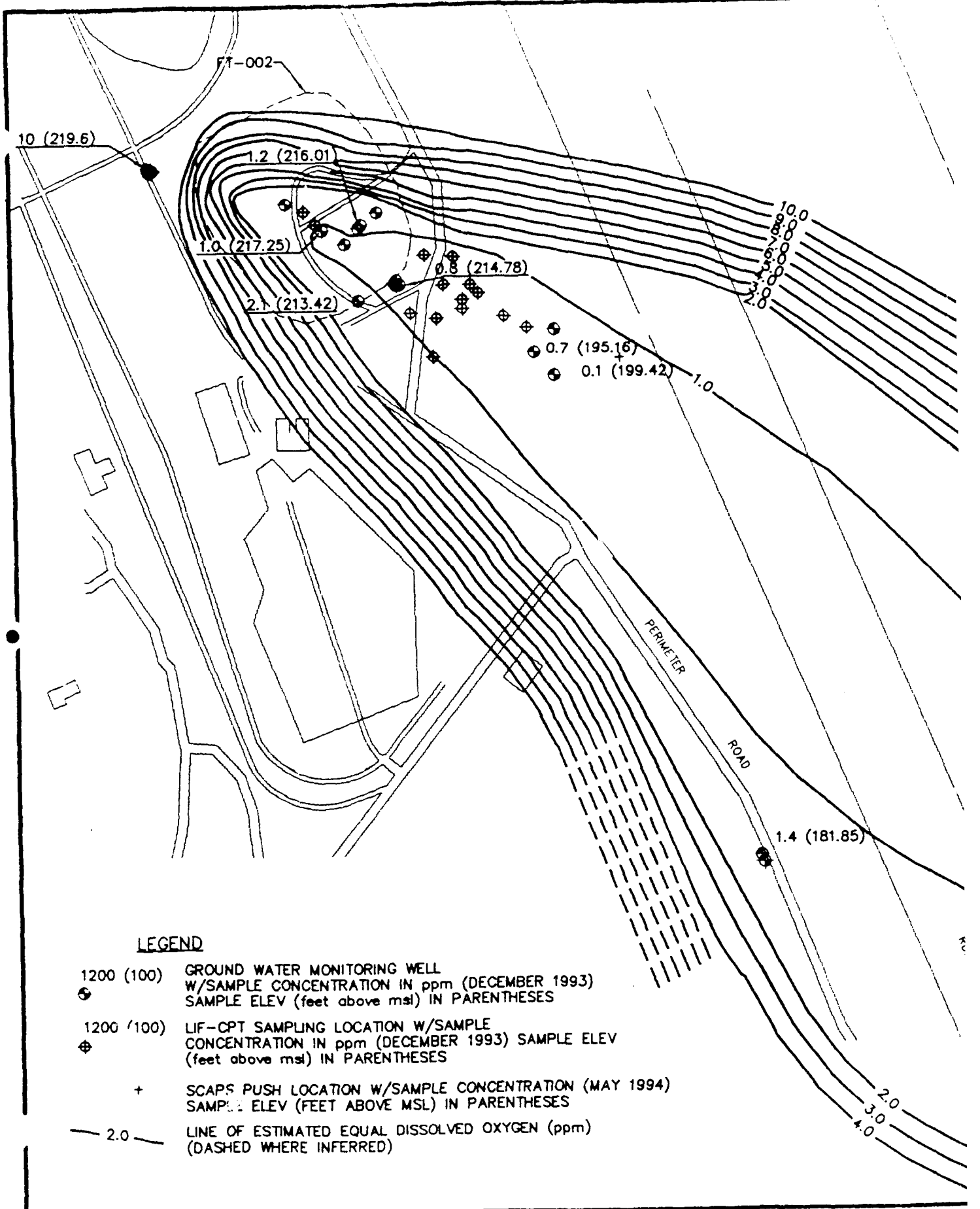

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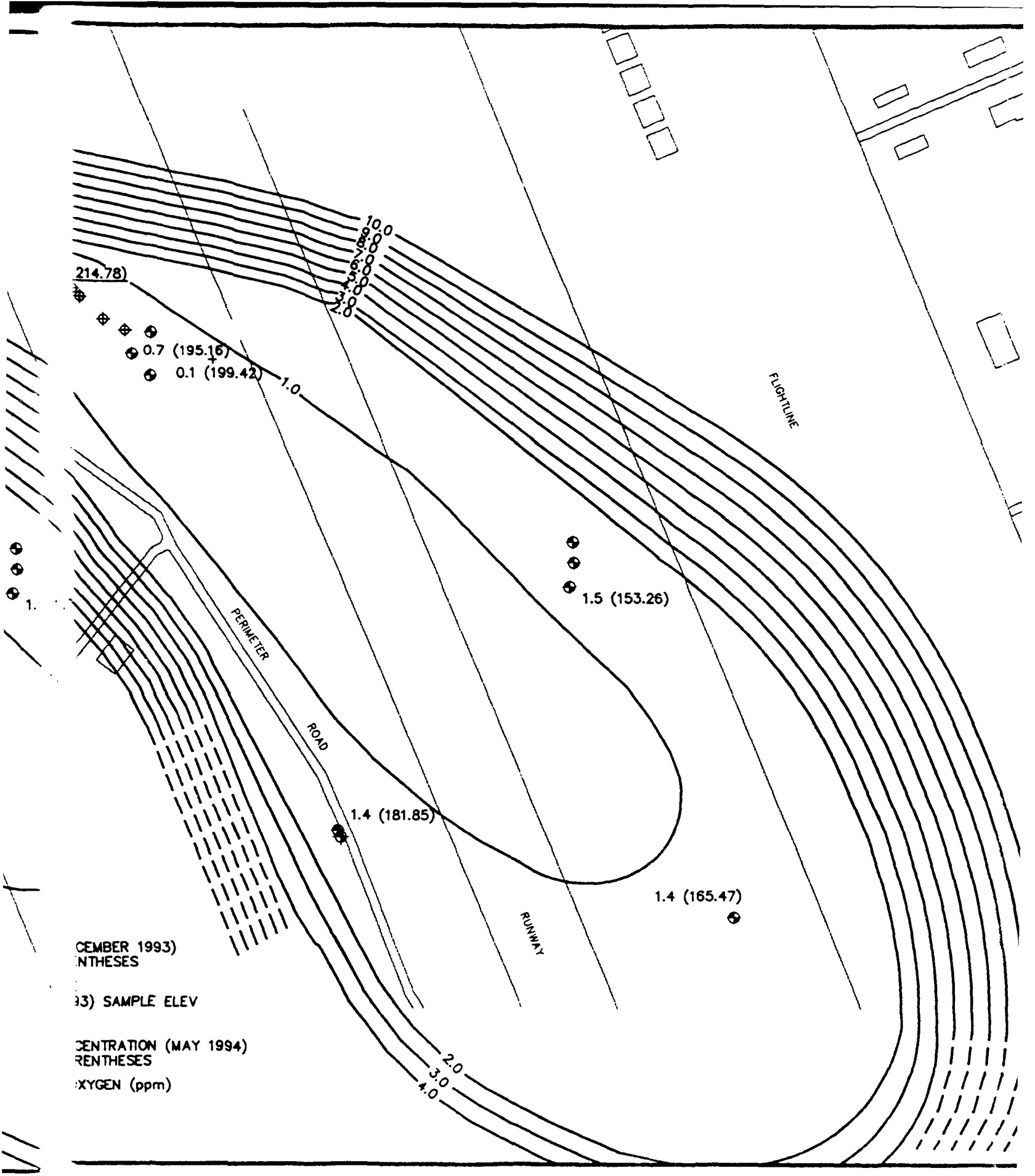

214.78)
0.7 (195.16)
0.1 (199.42)
1.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.5 (153.26)
1.4 (181.85)
1.4 (165.47)
PERIMETER
ROAD
RUNWAY
FLIGHTLINE
2.0
3.0
4.0
CEMBER 1993)
NTHESES
33) SAMPLE ELEV
CENTRATION (MAY 1994)
RENTHESES
XYGEN (ppm)

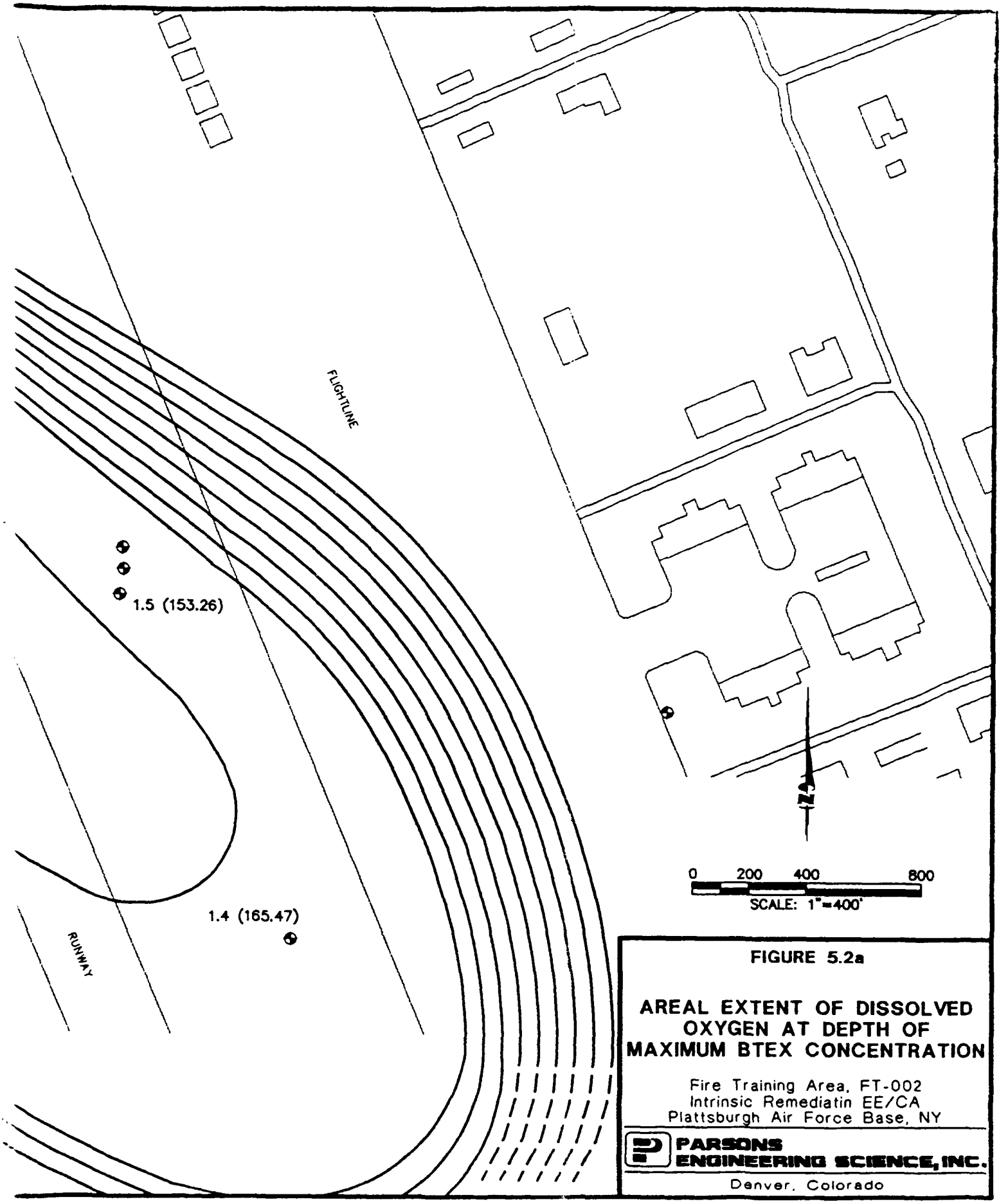
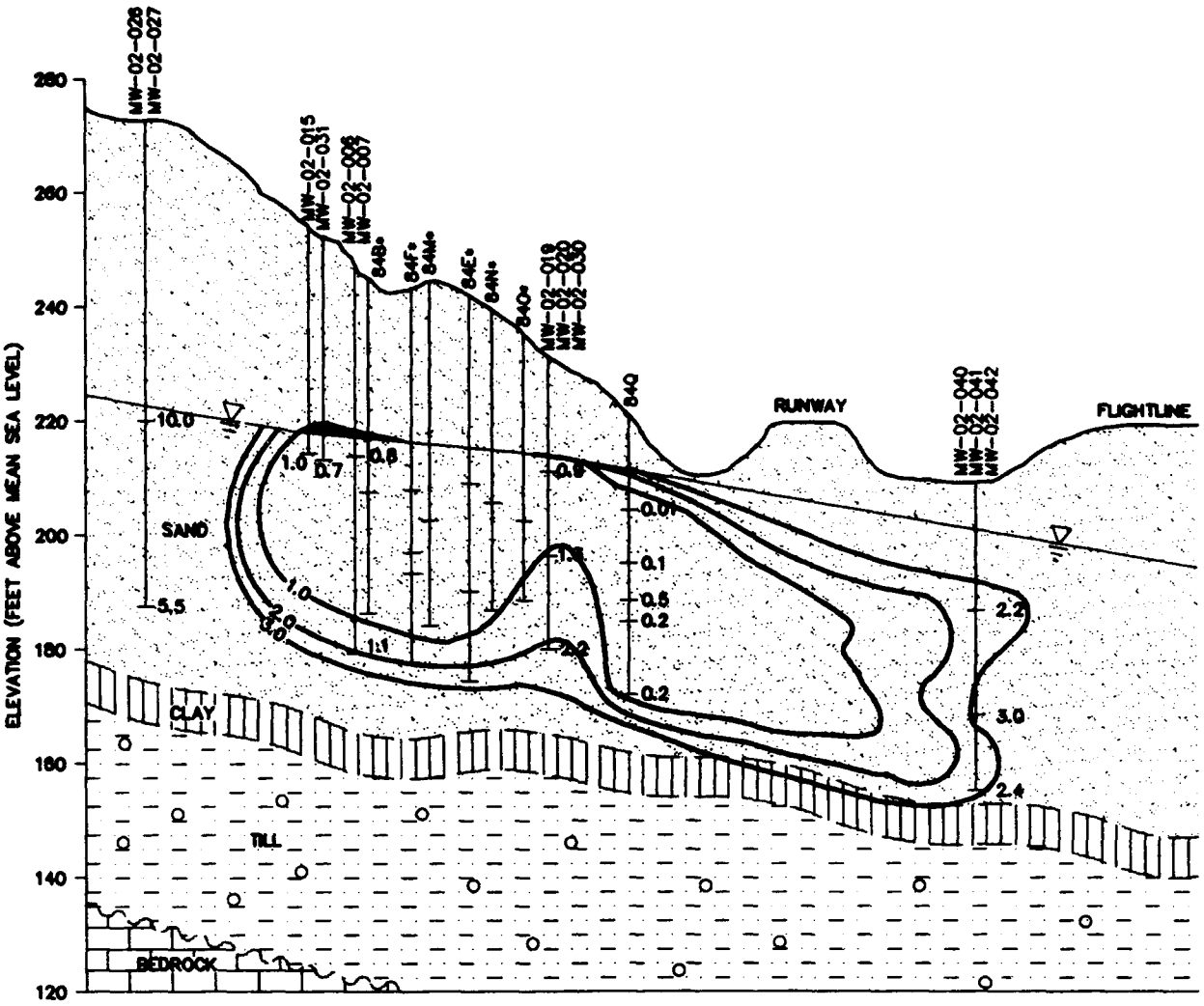


FIGURE 5.2a

AREAL EXTENT OF DISSOLVED OXYGEN AT DEPTH OF MAXIMUM BTEX CONCENTRATION

Fire Training Area, FT-002
Intrinsic Remediatin EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado



• WATER ELEVATION DATA FROM CPT POINTS ARE ESTIMATED VALUES

VERTICAL EXAGGERATION = 20X

LEGEND

- SAMPLE ELEVATION (ft above msl)
- 16.4 — MEASURED CONCENTRATION OF DISSOLVED OXYGEN (ppm)
- 20 — LINE OF ESTIMATED EQUAL CONCENTRATION OF DISSOLVED OXYGEN (ppm)
- ESTIMATED EXTENT OF LNAPL
- SURFACE OF GROUND WATER TABLE
- UNCONFORMITY
- LIGHT BROWN TO GRAY, WELL-SORTED, MEDIUM-TO FINE-GRAINED SAND
- DARK GRAY, MODERATELY PLASTIC CLAY. DARK MINERAL LAMINATIONS ARE PRESENT
- GRAY, POORLY-SORTED TILL. CLAY AND SILT-SIZE GRAINS TO GRAVEL. ANGULAR ROCK FRAGMENTS PRESENT
- CARBONATE BEDROCK

HORIZ 0 300 600 1200
VERT 0 15 30 60

FIGURE 5.2b

VERTICAL EXTENT OF DISSOLVED OXYGEN ALONG PLUME CENTERLINE

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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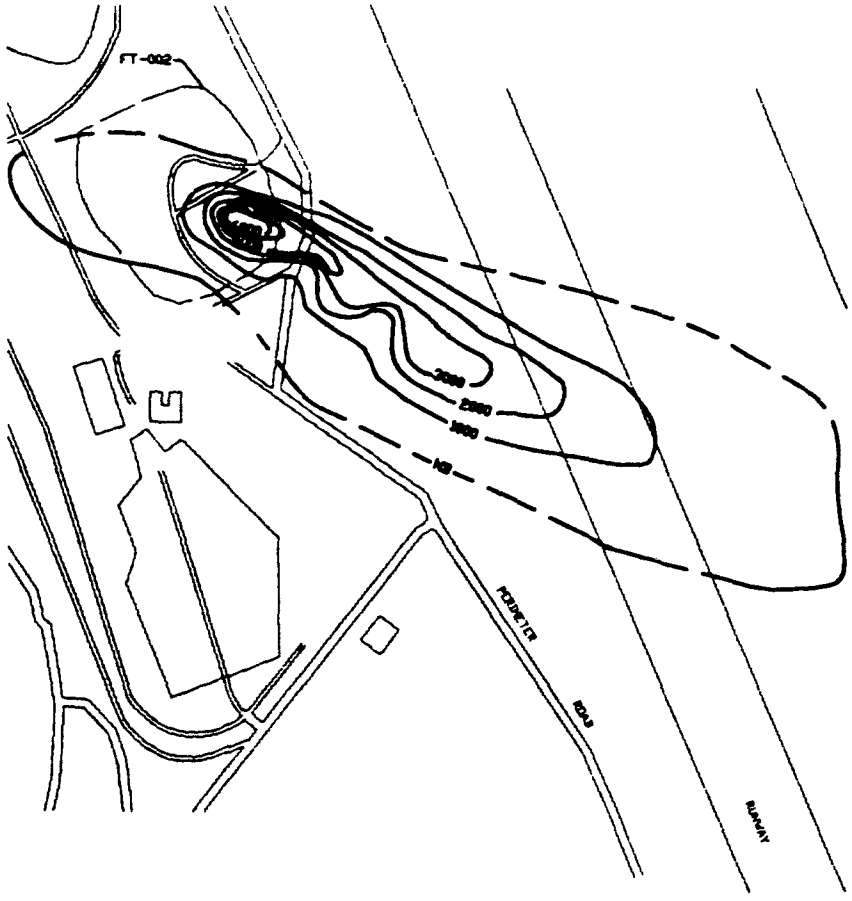

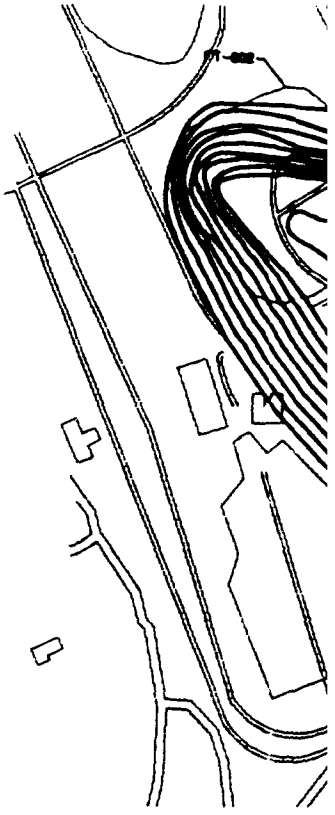

TOTAL BTEX (ppb)

NOTES

1. Areas of high dissolved total BTEX correspond to areas depleted in dissolved oxygen.

2. Oxygen is generally considered a strong oxidant if the reduction of fuel hydrocarbons occurs via sequential electron steps. Oxygen is likely one of the primary participants in the metabolic reactions taking place at this site.

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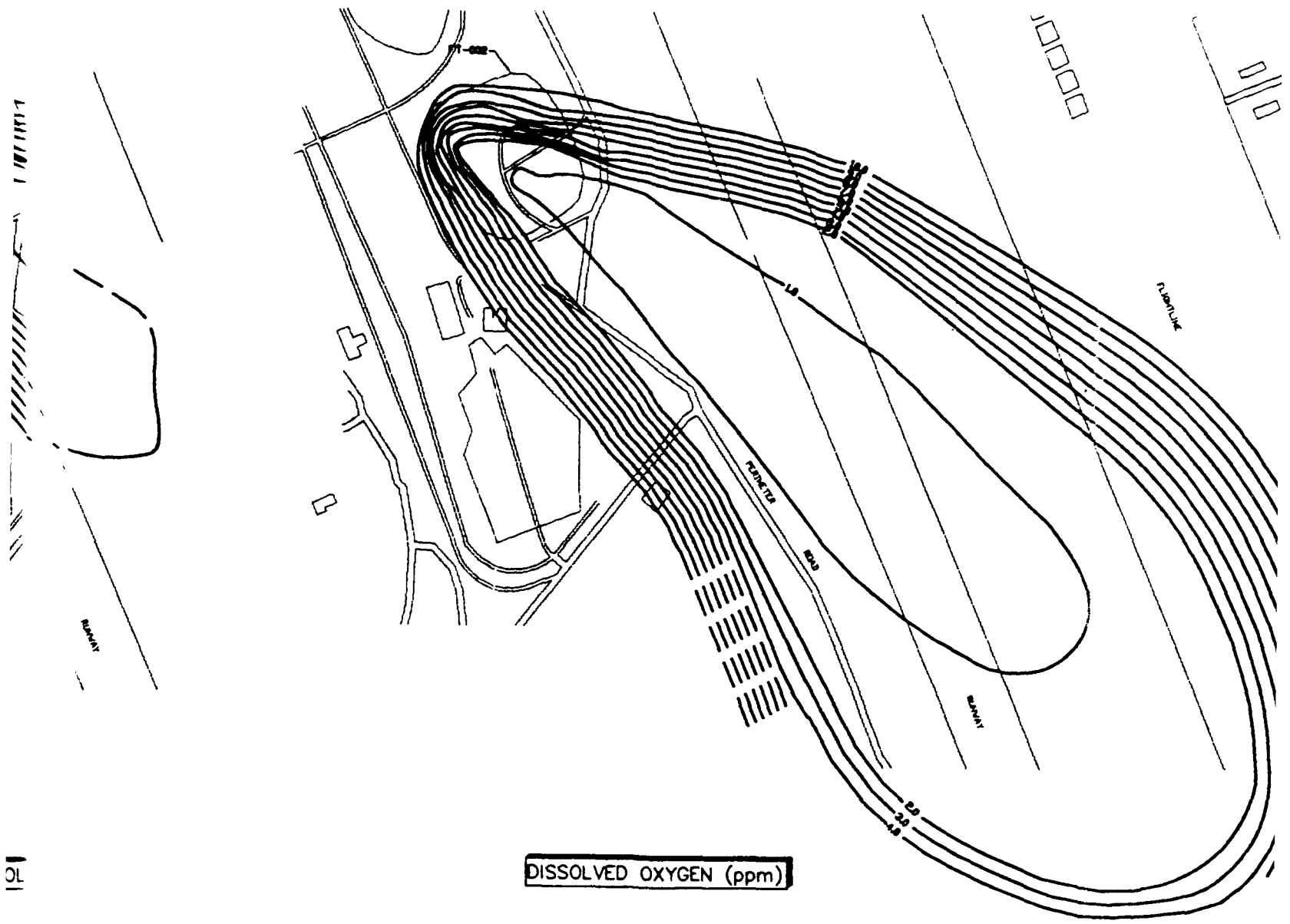


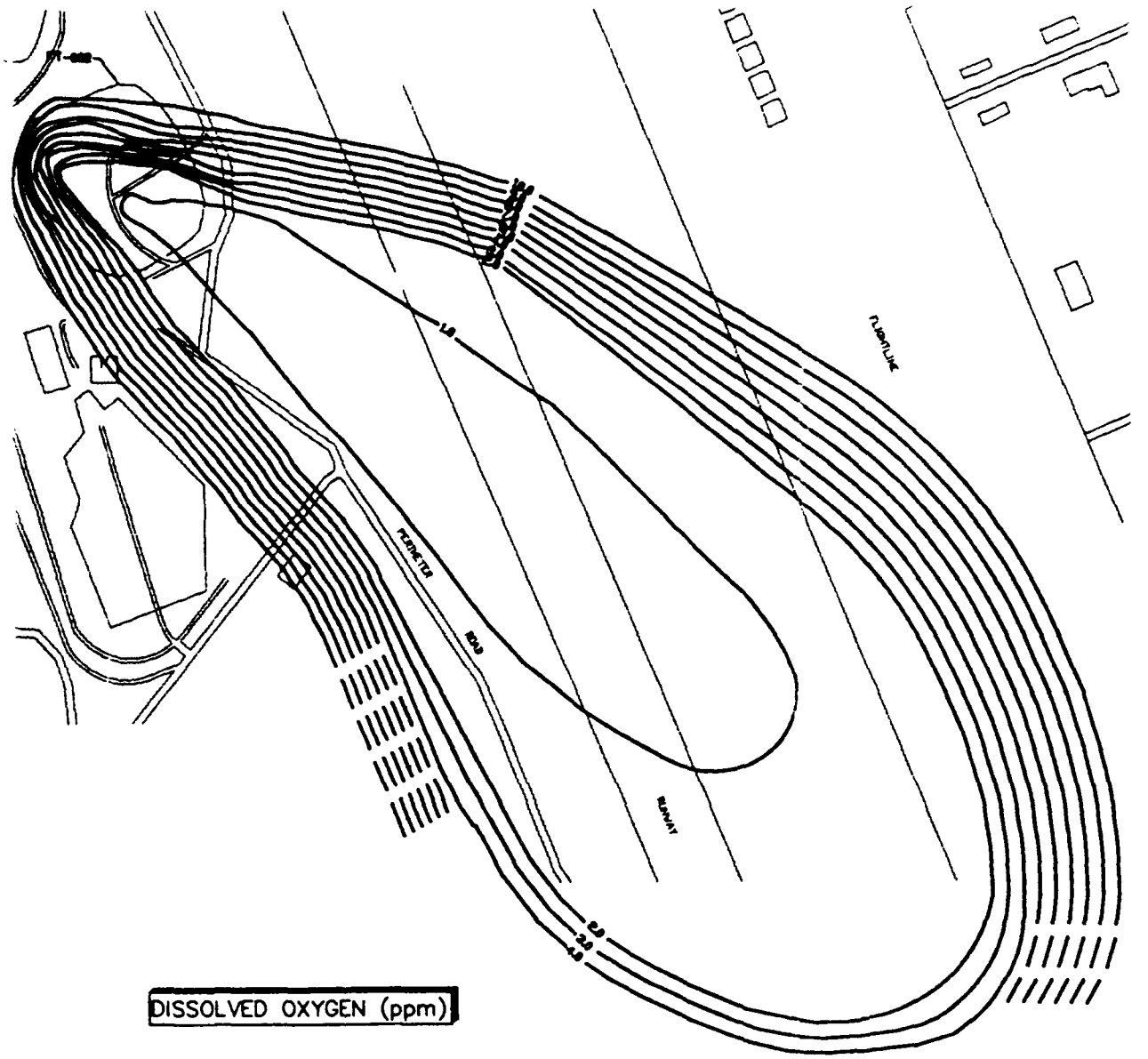
DISSOLVED OXYGEN (ppm)

0 175 325 650 1300
FEET

COMPA
AND

Fire
Intri
Platts

PAR
ENG



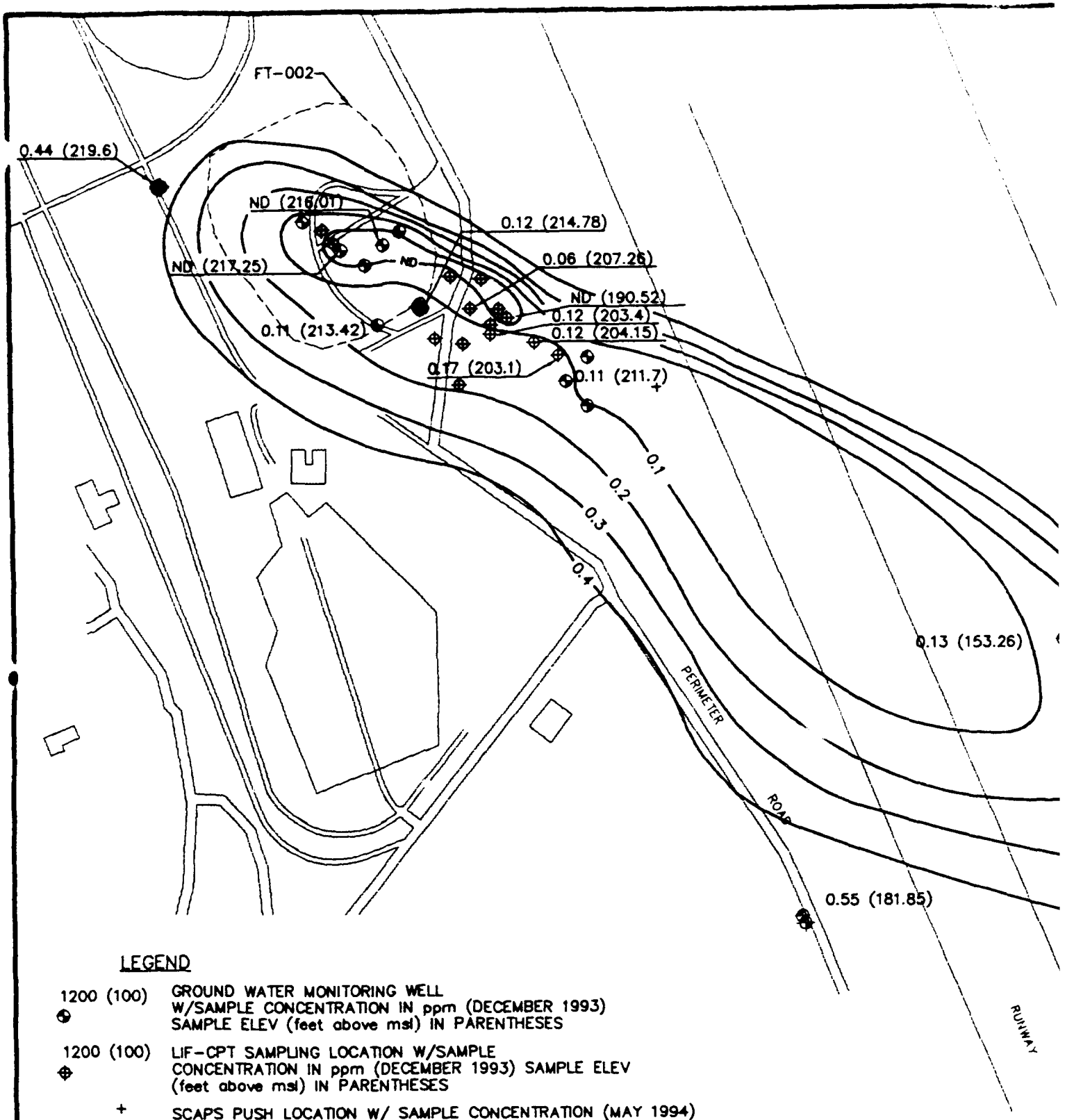
0 175 325 650 1300
FEET

FIGURE 5.3

COMPARISON OF TOTAL BTEX AND DISSOLVED OXYGEN

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado



LEGEND

1200 (100) ◉	GROUND WATER MONITORING WELL W/SAMPLE CONCENTRATION IN ppm (DECEMBER 1993) SAMPLE ELEV (feet above msl) IN PARENTHESES
1200 (100) ⊕	LIF-CPT SAMPLING LOCATION W/SAMPLE CONCENTRATION IN ppm (DECEMBER 1993) SAMPLE ELEV (feet above msl) IN PARENTHESES
+	SCAPS PUSH LOCATION W/ SAMPLE CONCENTRATION (MAY 1994) SAMPLE ELEV (feet above msl) IN PARENTHESES
— 2.0 —	LINE OF ESTIMATED EQUAL NITRATE/NITRITE CONCENTRATION (ppm)
	CONTOUR INTERVAL = 0.1 ppm

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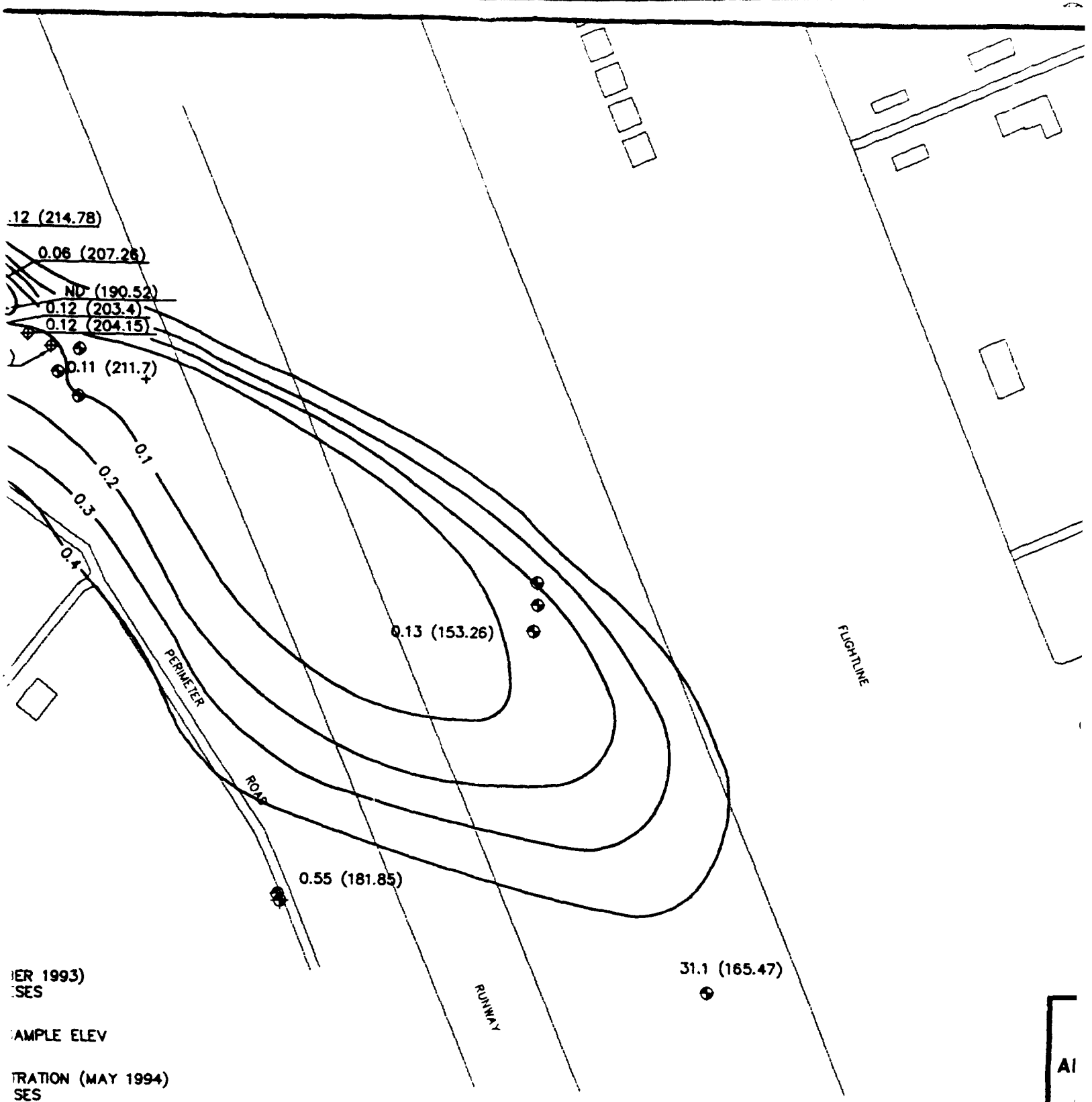


ER 1993)
SES

AMPLE ELEV

TRATION (MAY 1994)
SES

CONCENTRATION (ppm)

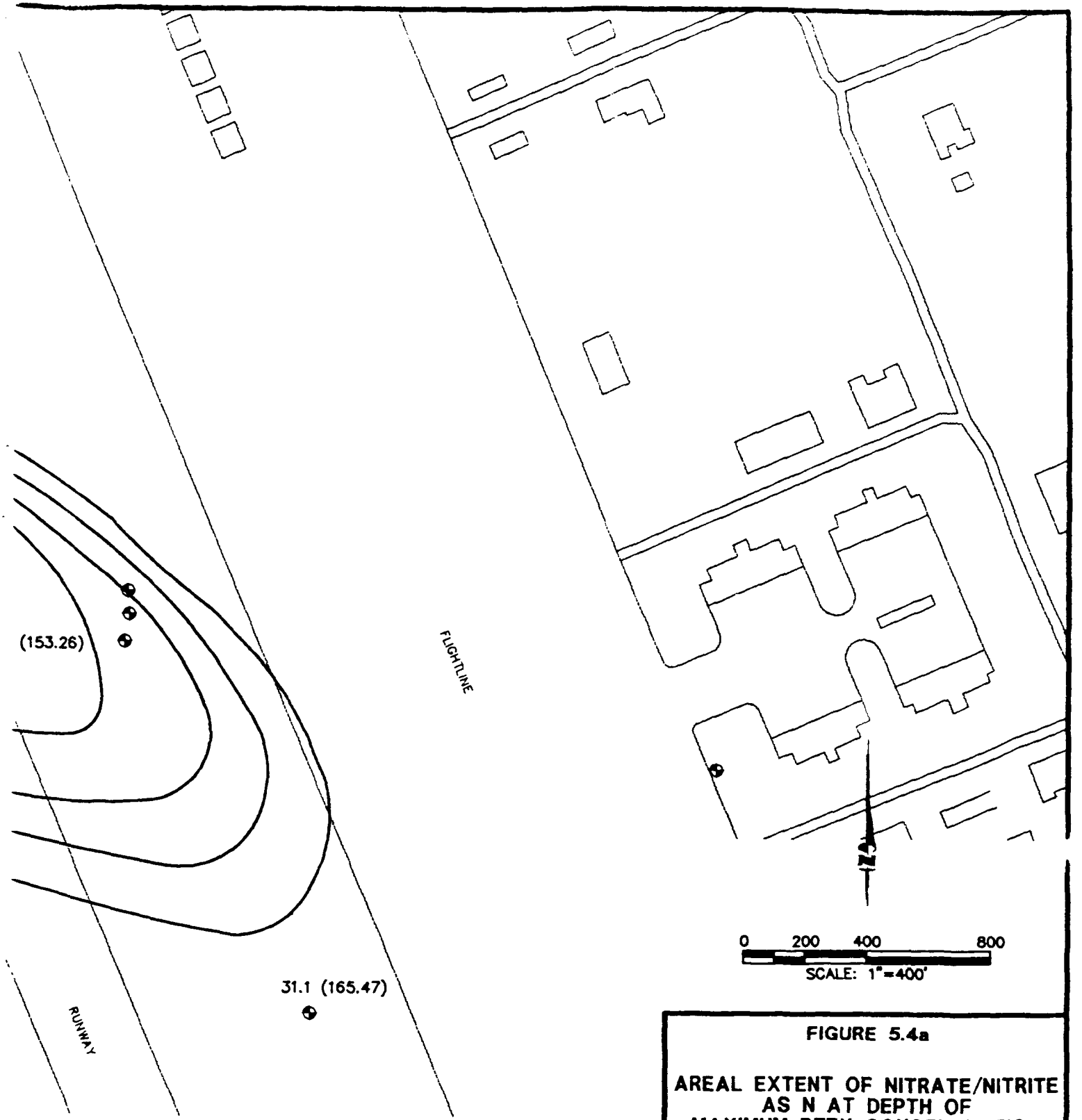
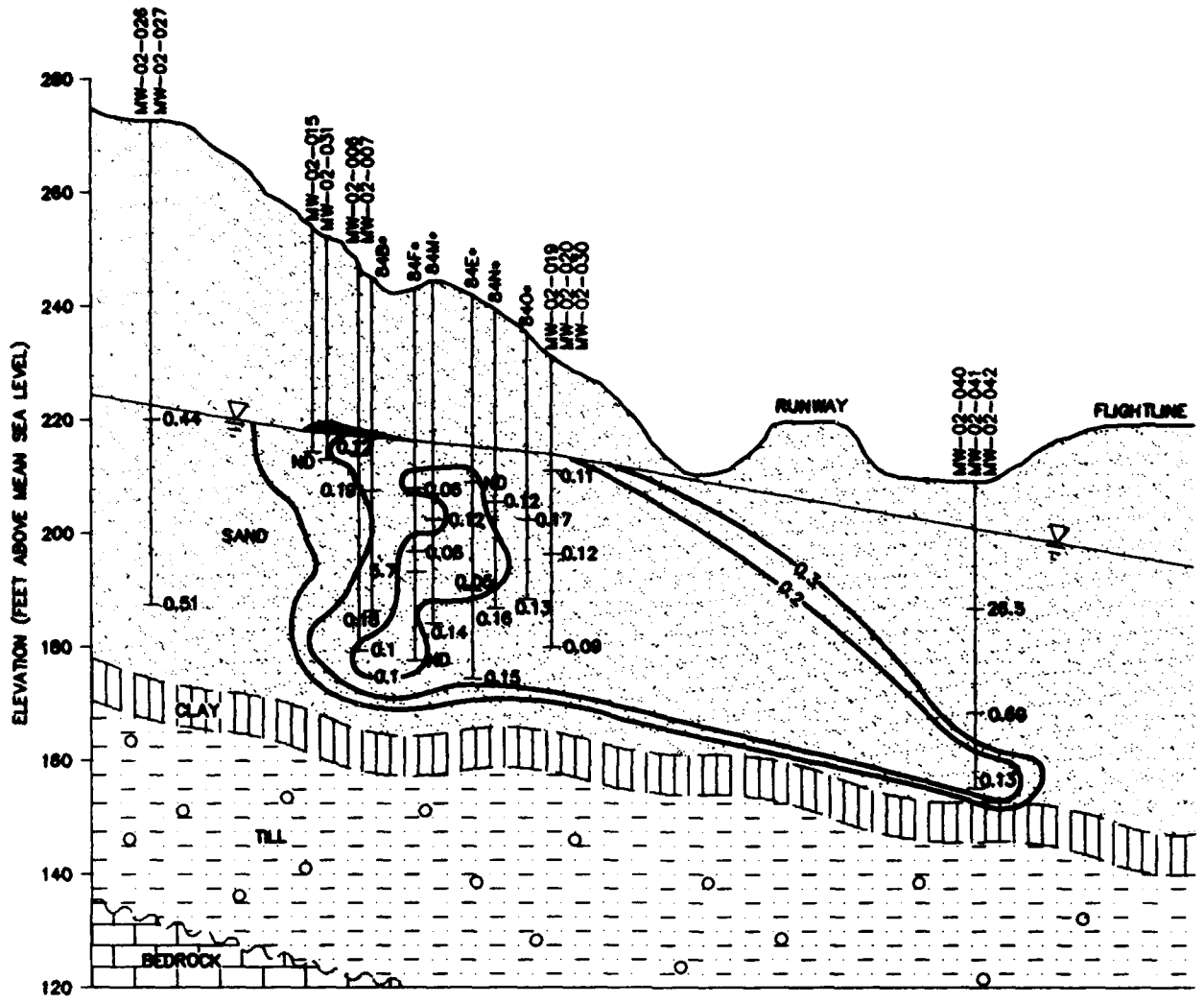


FIGURE 5.4a

AREAL EXTENT OF NITRATE/NITRITE AS N AT DEPTH OF MAXIMUM BTEX CONCENTRATION

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado



LEGEND

⊥	SAMPLE ELEVATION (ft above msl)
16.4	MEASURED CONCENTRATION OF NITRATE/NITRITE (ppm)
—20—	LINE OF ESTIMATED EQUAL CONCENTRATION OF NITRATE/NITRITE (ppm)
ND	NOT DETECTED
	ESTIMATED EXTENT OF LNAPL
▽	SURFACE OF GROUND WATER TABLE
	UNCONFORMITY
	LIGHT BROWN TO GRAY, WELL-SORTED, MEDIUM-TO FINE-GRAINED SAND
	DARK GRAY, MODERATELY PLASTIC CLAY. DARK MINERAL LAMINATIONS ARE PRESENT
	GRAY, POORLY-SORTED TILL. CLAY AND SILT-SIZE GRAINS TO GRAVEL. ANGULAR ROCK FRAGMENTS PRESENT
	CARBONATE BEDROCK

* WATER ELEVATION DATA FROM CPT POINTS ARE ESTIMATED VALUES

VERTICAL EXAGGERATION = 20X

HORIZ 0 300 600 1200

VERT 0 15 30 60

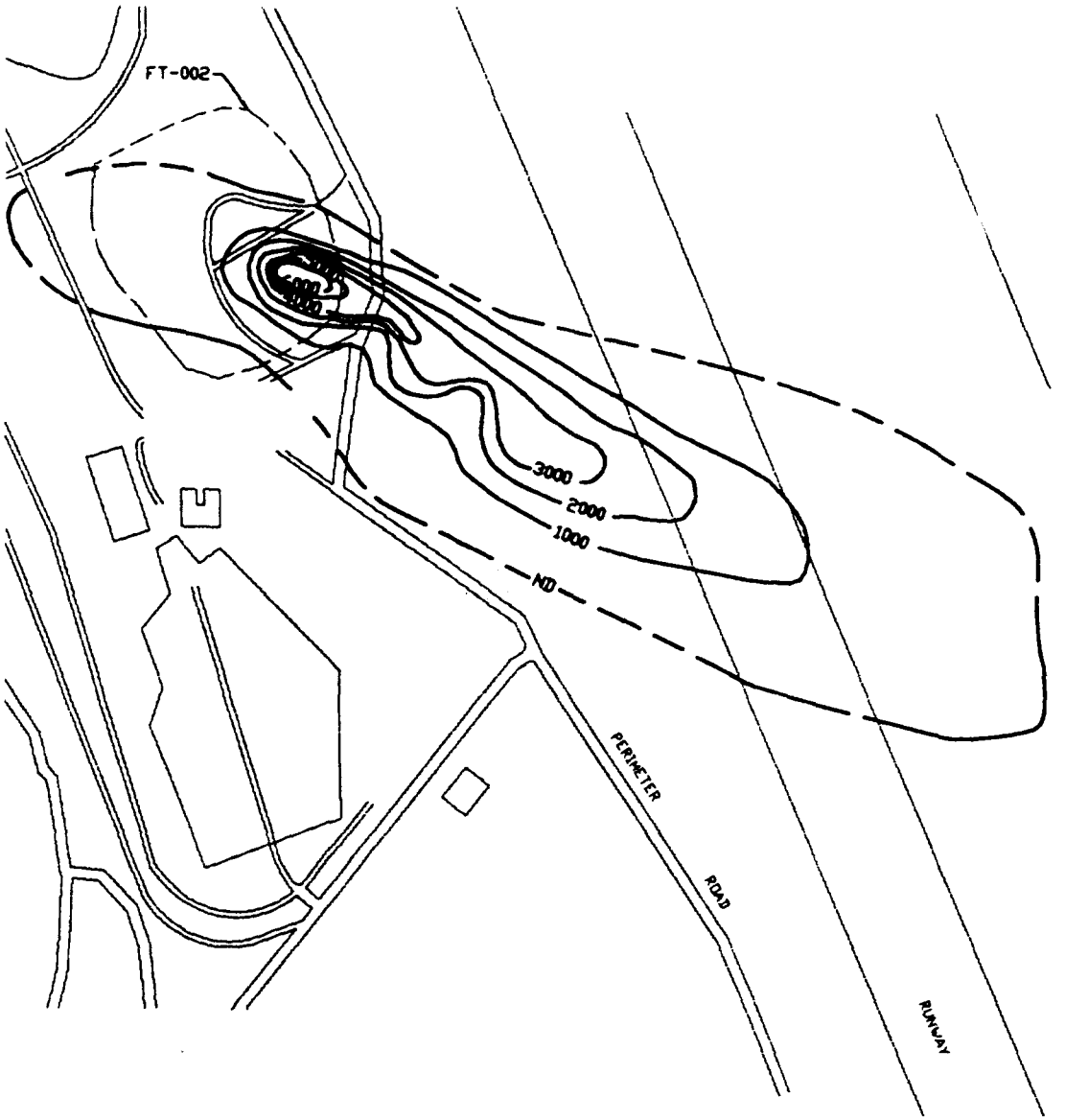
FIGURE 5.4b

VERTICAL EXTENT OF NITRATE/NITRITE as N ALONG PLUME CENTERLINE

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

N:\45004\DRAWINGS\94DN0238, 11/01/94 at 08:34



TOTAL BTEX (ppb)

NOTES

1. High concentrations of dissolved total BTEX correspond to low concentrations of nitrate relative to background concentrations.

2. The lack of nitrate in areas of high total BTEX suggest denitrification or nitrate reduction.

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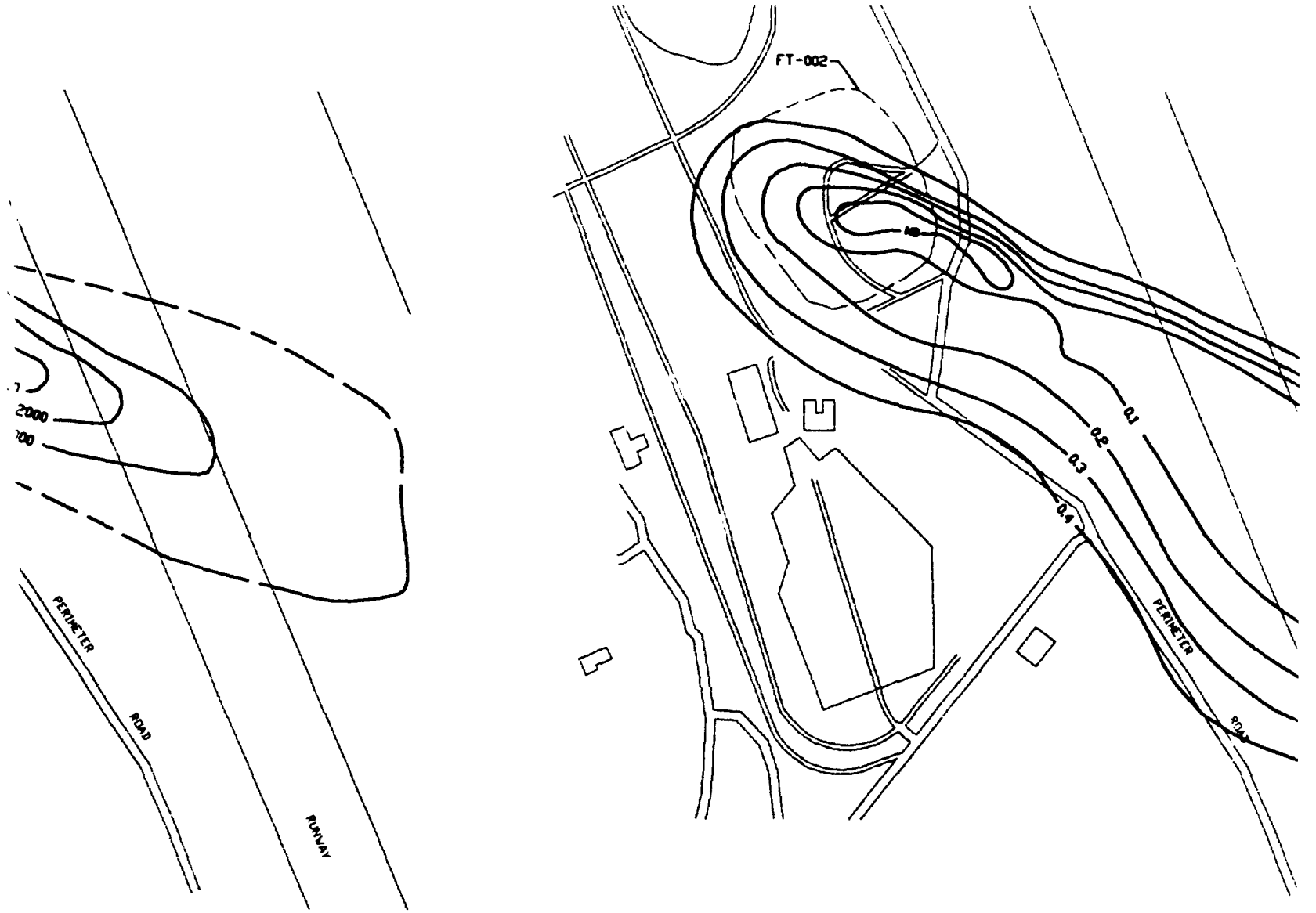

b)

NITRATE c

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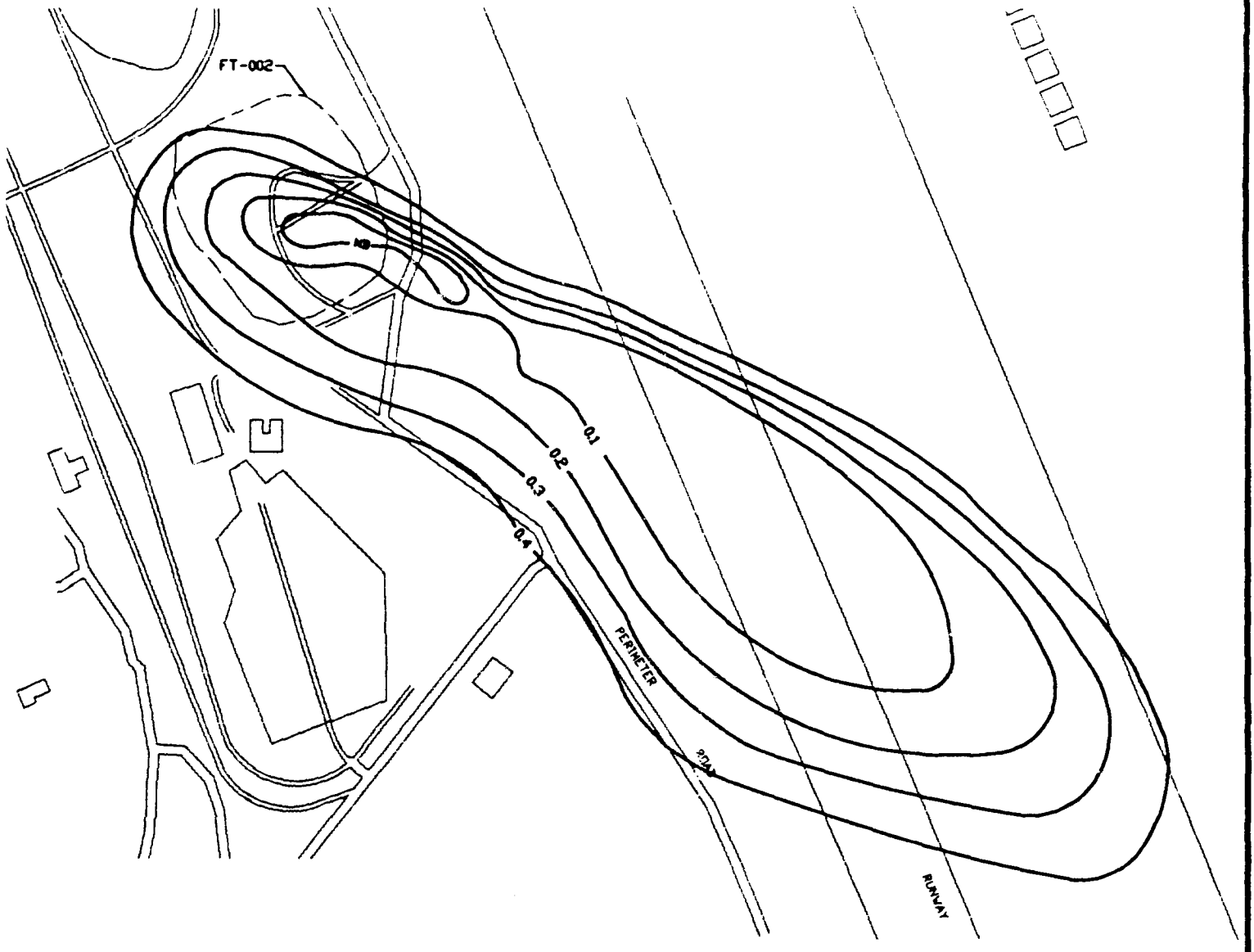
round

X suggest

0 125 250 500 1000
FEET



NITRATE as N (ppm)

0 125 250 500 1000
FEET

N

FIGURE 5.5

COMPARISON OF TOTAL BTEX AND NITRATE as N

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

TABLE 5.6
GROUND WATER QUALITY DATA FOR ADDITIONAL CHEMICAL PARAMETERS
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Sample Location	Sample Date	Sample Elevation (feet msl)[a]	Chloride (ppm)[b]	Ammonia as Nitrogen (ppm)	Total Phosphate (ppm)	Ethylene (ppm)	Total Alkalinity (ppm)	Conductivity (uhmos)	Total Organic Carbon (ppm)
84B	Dec. 1993	207.22	222	1.36	1.47	ND[c]	179	1236	11.3
84B	Dec. 1993	186.02	69.2	0.27	1.48	ND	135	516	6.2
84E	Dec. 1993	210.52	54.6	2.15	4.56	0.2198	268	695	15.5
84E	Dec. 1993	190.52	65	2.12	2.27	0.0055	290	784	36.7
84E (dup)	Dec. 1993	190.52	NR	NR	2.24	NR	NR	NR	36.5
84E	Dec. 1993	174.52	35.7	0.23	0.68	ND	35	416	7.6
84F	Dec. 1993	207.26	80	2.6	3.27	0.1287	285	772	21
84F (dup)	Dec. 1993	207.26	NR	NR	NR	0.1171	NR	NR	NR
84F	Dec. 1993	197.26	72	6.11	1.9	0.0012	140	794	22.5
84F	Dec. 1993	192.26	78.5	3.99	2.25	0.0009	224	725	17.7
84F	Dec. 1993	177.26	37.3	0.36	0.96	ND	136	410	3.6
84M	Dec. 1993	203.4	94.3	4.98	16.7	0.0284	290	884	36.6
84M	Dec. 1993	183.4	26.9	1.09	7.15	ND	161	370	3.1
84N	Dec. 1993	204.15	54.6	1.66	4.97	0.4738	288	725	22.5
84N (dup)	Dec. 1993	204.15	NR	NR	NR	NR	NR	NR	22.4
84N	Dec. 1993	184.15	68.8	1.64	3.3	0.0021	132	720	20
84O	Dec. 1993	203.1	28.3	1.51	3.33	0.0397	267	590	6.2
84O(dup)	Dec. 1993	203.1	NR	NR	NR	NR	230	640	NR
84O	Dec. 1993	188.1	55.2	2.83	1.48	0.0023	234	NR	14.3
84O (lab dup)	Dec. 1993	188.1	NR	NR	NR	NR	NR	NR	14.2
84-Field Blank	Dec. 1993	N/A[d]	NR	NR	NR	ND	NR	NR	0.1
MW-02-005	Dec. 1993	213.42	142	0.64	0.05	0.0005	232	NR	5.3
MW-02-005(dup)	Dec. 1993	213.42	NR	NR	NR	0.0004	NR	NR	NR
MW-02-006	Dec. 1993	214.78	193	1.69	0.05	ND	109	NR	4.8
MW-02-007	Dec. 1993	179.69	8.22	0.25	0.13	ND	113	NR	0.5
MW-02-014	Dec. 1993	216.01	63.5	2.1	0.06	0.0032	277	NR	37.4
MW-02-014 (lab dup)	Dec. 1993	216.01	NR	2.08	NR	0.0032	NR	NR	NR

TABLE 5.6 (Concluded)
GROUND WATER QUALITY DATA FOR ADDITIONAL CHEMICAL PARAMETERS
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Sample Location	Sample Date	Sample Elevation (feet msl)[a/]	Chloride (ppm)[b/]	Ammonia as Nitrogen (ppm)	Total Phosphate (ppm)	Ethylene (ppm)	Total Alkalinity (ppm)	Conductivity (uhmos)	Total Organic Carbon (ppm)
MW-02-015	Dec. 1993	217.25	26.6	0.59	0.08	ND	96	NR	5.5
MW-02-019	Dec. 1993	211.43	42.4	1.26	0.08	0.039	262	644	11.3
MW-02-020	Dec. 1993	195.16	25.1	3.04	BLQ[e/]	0.004	322	695	17.3
MW-02-020 (dup)	Dec. 1993	195.16	24.8	NR	NR	NR	NR	NR	NR
MW-02-021	Dec. 1993	181.85	9.14	0.59	2.2	ND	261	NR	4.6
MW-02-021 (lab dup)	Dec. 1993	181.85	NR	0.56	NR	NR	NR	NR	NR
MW-02-026	**Dec. 1993**	**219.6**	**103**	**BLQ**	**BLQ**	**ND**	**111**	**627**	**0.8**
MW-02-027	**Dec. 1993**	**186.72**	**84.7**	**0.17**	**BLQ**	**0.0006**	**1590**	**8670**	**3.4**
MW-02-027(dup)	Dec. 1993	186.72	82.6	NR	NR	NR	1517	NR	NR
MW-02-030	Dec. 1993	179.55	13.5	0.2	0.08	0.0002	110	288	0.9
MW-02-030 (dup)	Dec. 1993	179.55	NR	NR	NR	0.0002	NR	NR	NR
MW-02-040	Dec. 1993	184.02	2.14	BLQ	BLQ	ND	136	513	1.4
MW-02-041	Dec. 1993	169.05	11.2	BLQ	BLQ	0.0005	350	682	11.4
MW-02-042	Dec. 1993	153.26	11.3	0.117	0.06	0.0035	157	330	6
MW-02-043	Dec. 1993	165.47	0.93	BLQ	0.09	ND	180	NR	1
MW-02-044	Dec. 1993	166.24	BLQ	0.83	0.3	ND	110	1172	1.4
MW-02-044(dup)	Dec. 1993	166.24	NR	NR	NR	NR	NR	NR	1.3

a/ feet msl = feet above mean sea level
b/ ppm = parts per million
c/ ND = data not detected.
d/ NR = not reported
e/ BLQ = below practical limits of quantitation
f/ N/A = not applicable
Note: Background sampling locations placed in boldface

measured concentrations of total BTEX in the ground water with measured concentrations of nitrate/nitrite as N. There is a strong correlation between areas of high BTEX concentrations and areas depleted in nitrate/nitrite relative to measured background concentrations. The absence of nitrate/nitrite in contaminated ground water suggests that nitrate may be functioning as an electron acceptor.

The oxidation of the BTEX compounds by denitrification is thermodynamically more favorable than aerobic respiration (see Table 5.2). However, nitrate can only function as an electron acceptor in microbially facilitated BTEX degradation reactions if the ground water system has been depleted of oxygen (i.e., the ground water must be functionally anaerobic). Oxygen is toxic to the enzyme systems used for electron transfer and energy production of nitrate-reducing microorganisms (McCarty, 1972).

Data on ground water concentrations of NH_4^+ as N were also measured at all ground water sample locations in both December 1993 and May 1994. When coupled to analytical data for itrate/nitrite, these two compounds represent analytical data on both the oxidized and reduced chemical species of a potential relevant redox couple (i.e., NO_3^-- NH_4^+). Comparison of observed nitrate/nitrite concentrations to measured NH_4^+ concentrations shows an inverse relationship with respect to concentration. That is, more NH_4^+ was measured at sample locations with low concentrations of nitrate/nitrite relative to background concentrations. These data suggest nitrate may be acting as an electron acceptor via nitrate reduction rather than denitrification.

The analytical data on the chemical species involved in this nitrate redox couple suggest that the ground water system at Site FT-002 has advanced to a redox reaction that thermodynamically requires conditions more reduced than those required for denitrification reactions. Specifically, nitrate is used preferentially as an electron acceptor via denitrification, but can be used via nitrate reduction provided the redox conditions make such a redox couple thermodynamically possible.

Measured Eh (pe) levels at the site also suggest that the oxidizing potential of the ground water has been reduced sufficiently so that nitrate reduction can occur (see Figure 5.1). Additionally, Eh values calculated from the analytical concentrations of the oxidized and reduced forms of nitrate were in good agreement with theoretical Eh values for nitrate reduction (i.e., pe value of 5.79 based on analytical data compared to a theoretical pe value of 6.12). These data suggest that nitrate is likely acting as an electron acceptor via nitrate reduction at the site.

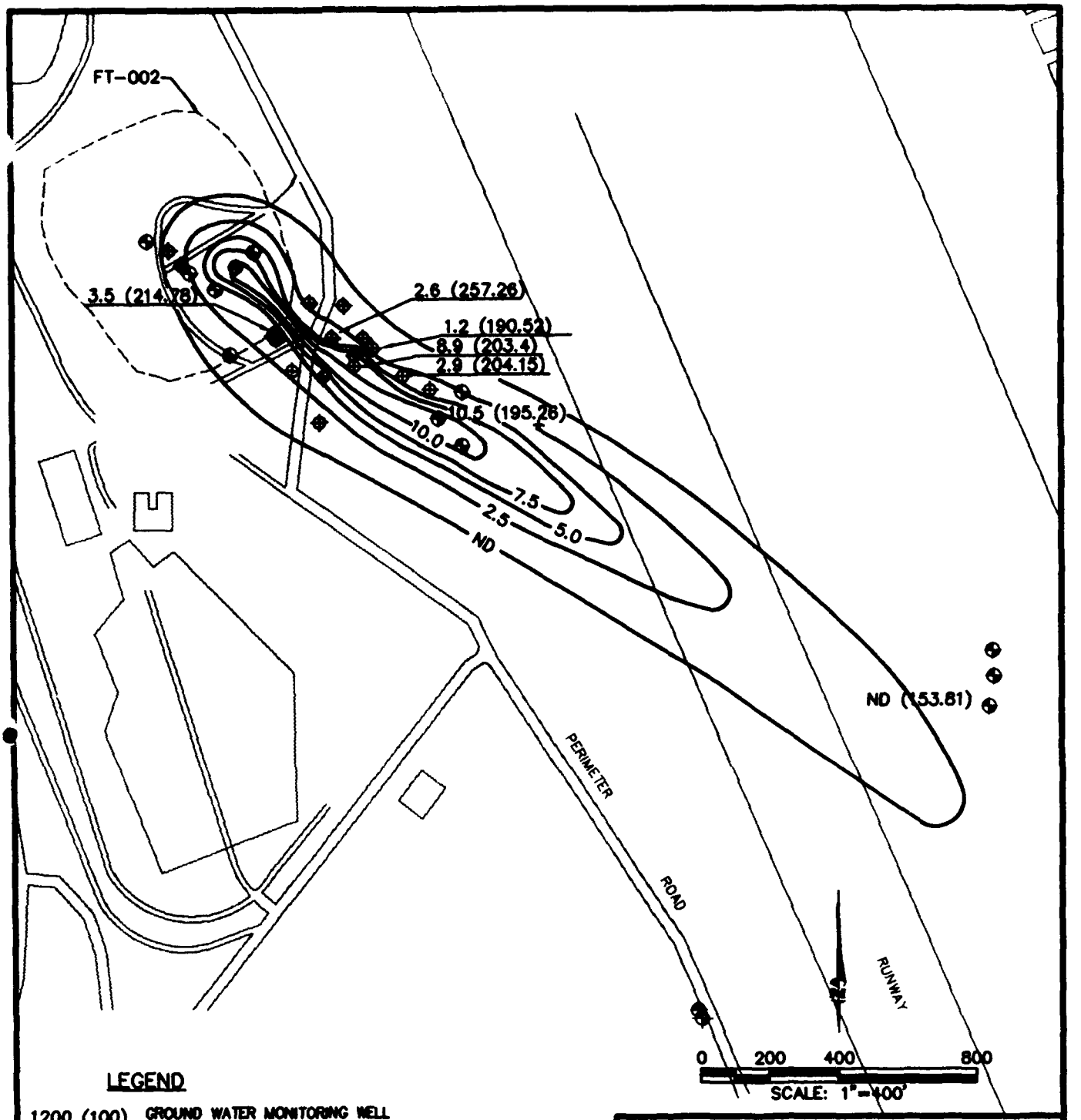
5.5.1.3 Ferrous Iron

Although relatively little is known about the anaerobic metabolic pathways involving the reduction of ferric iron, this exergonic process has been shown to be a major metabolic pathway for some microorganisms (Lovley and Phillips, 1988; Chapelle, 1993). High concentrations of ferrous iron are often found in anaerobic ground water systems. The concentrations of dissolved ferrous iron was once attributed to the spontaneous and reversible reduction of ferric oxyhydroxides, which are thermodynamically unstable in the presence of organic compounds such as BTEX. Yet recent evidence suggests that the reduction of ferric iron cannot proceed at all without microbial mediation (Lovley and Phillips, 1988; Lovley *et al.*, 1991; Chapelle, 1993). None of the common organic compounds found in low-temperature, neutral, reducing ground water could reduce ferric oxyhydroxides to ferrous iron under sterile laboratory conditions (Lovley *et al.*, 1991). This means that the reduction of ferric iron *requires* microbial mediation by microorganisms with the appropriate enzymatic capabilities.

Ferric iron may be present in large amounts within certain systems, thus providing a large reservoir of potential electron acceptors to facilitate BTEX degradation. The most easily reduced forms are amorphous ferric hydroxides, ferric oxyhydroxides, and ferric oxides (Norris *et al.*, 1994). Interestingly, studies with iron-reducing isolates show that these microorganisms must be in direct contact with the ferric iron to facilitate its reduction (Lovley *et al.*, 1991). The reduction of ferric iron results in the formation of ferrous iron.

To determine if ferric iron is being used as an electron acceptor at Site FT-002, ferrous iron concentrations were measured at ground water wells and CPT ground water sampling locations in December 1993. No data on ferrous iron concentrations were collected in May 1994. Table 5.5 presents analytical data for ferrous iron by sampling location. Figures 5.6a and 5.6b show the areal and vertical distribution of observed ferrous iron concentrations in ground water. Figure 5.7 compares measured concentrations of total BTEX in the ground water with measured concentrations of ferrous iron. There is a strong correlation between areas of high BTEX concentrations and areas of high ferrous iron relative to measured background concentrations.

Because the reduction of ferric iron cannot proceed without microbial intervention, the elevated concentrations of ferrous iron that were measured in the contaminated ground water at Site FT-002 are the strongest indicators of microbial activity. These geochemical data suggest that iron-reducing microorganisms are present in the ground water at the FT-002 site, and that these microorganisms are using ferric iron to energize BTEX metabolism. The correlation between high total BTEX concentrations and high ferrous iron concentrations suggests that the



LEGEND

1200 (100) ⊕	GROUND WATER MONITORING WELL W/SAMPLE CONCENTRATION IN ppm (DECEMBER 1993) SAMPLE ELEV (feet above msl) IN PARENTHESES
1200 (100) ◈	LIF–CPT SAMPLING LOCATION W/SAMPLE CONCENTRATION IN ppm (DECEMBER 1993) SAMPLE ELEV (feet above msl) IN PARENTHESES
+	SCAPS PUSH LOCATION W/ SAMPLE CONCENTRATION (MAY 1994) SAMPLE ELEV (feet above msl) IN PARENTHESES
2.0	LINE OF ESTIMATED EQUAL FERROUS IRON CONCENTRATION (ppm)
ND	NOT DETECTED
	CONTOUR INTERVAL = 2.5 ppm

FIGURE 5.6a

AREAL EXTENT OF FERROUS IRON AT DEPTH OF MAXIMUM BTEX CONCENTRATION

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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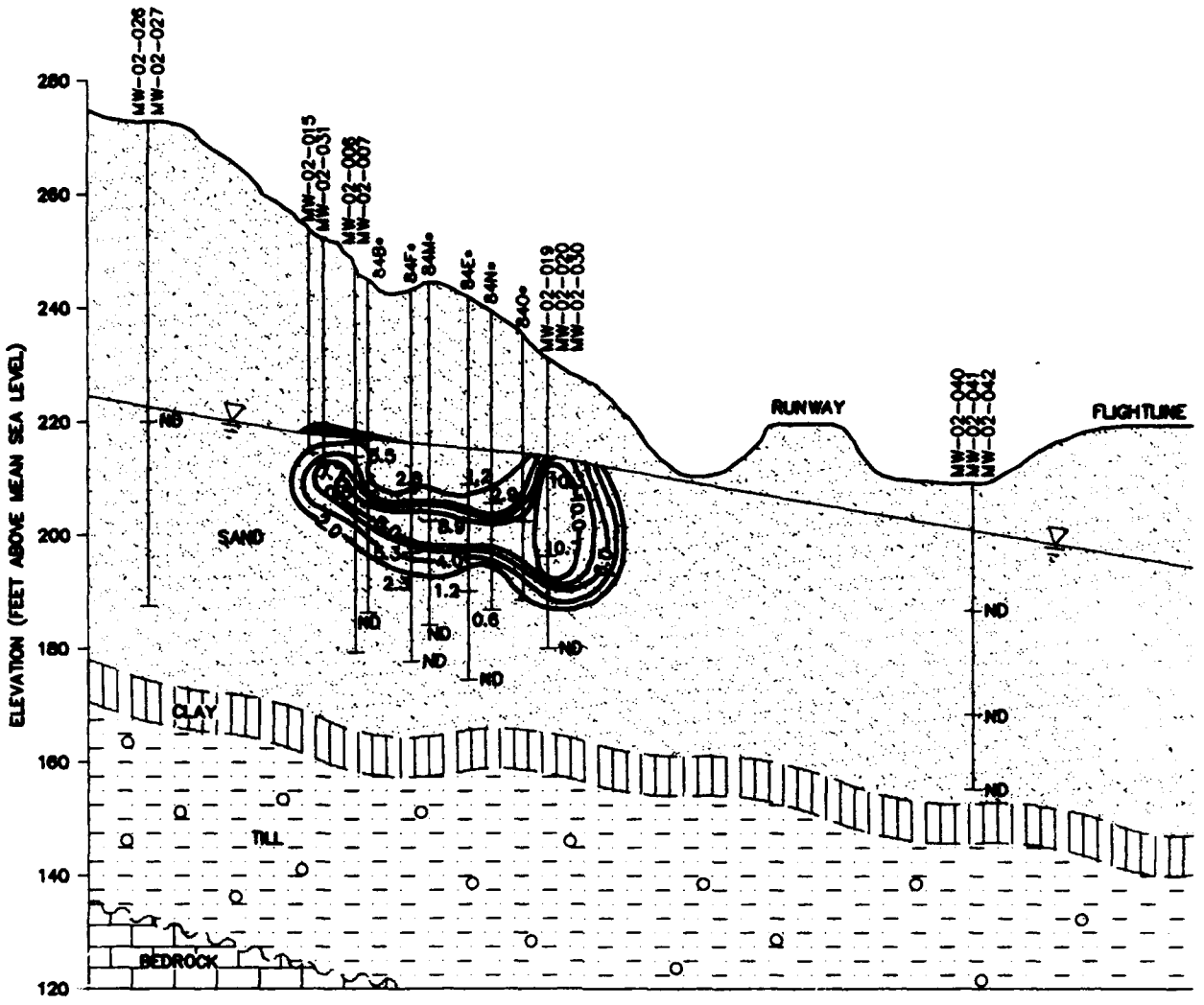

LEGEND

⊥	SAMPLE ELEVATION (ft above msl)
16.4	MEASURED CONCENTRATION OF Fe^{2+} (ppm)
—20—	LINE OF ESTIMATED EQUAL CONCENTRATION OF Fe^{2+} (ppm)
ND	NOT DETECTED
	ESTIMATED EXTENT OF LNAPL
▽	SURFACE OF GROUND WATER TABLE
	UNCONFORMITY
	LIGHT BROWN TO GRAY, WELL-SORTED, MEDIUM-TO FINE-GRAINED SAND
	DARK GRAY, MODERATELY PLASTIC CLAY. DARK MINERAL LAMINATIONS ARE PRESENT
	GRAY, POORLY-SORTED TILL. CLAY AND SILT-SIZE GRAINS TO GRAVEL. ANGULAR ROCK FRAGMENTS PRESENT
	CARBONATE BEDROCK

* WATER ELEVATION DATA FROM CPT POINTS ARE ESTIMATED VALUES

VERTICAL EXAGGERATION = 20X

HORIZ 0 300 600 1200

VERT 0 15 30 60

FIGURE 5.6b

VERTICAL EXTENT OF FERROUS IRON ALONG PLUME CENTERLINE

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

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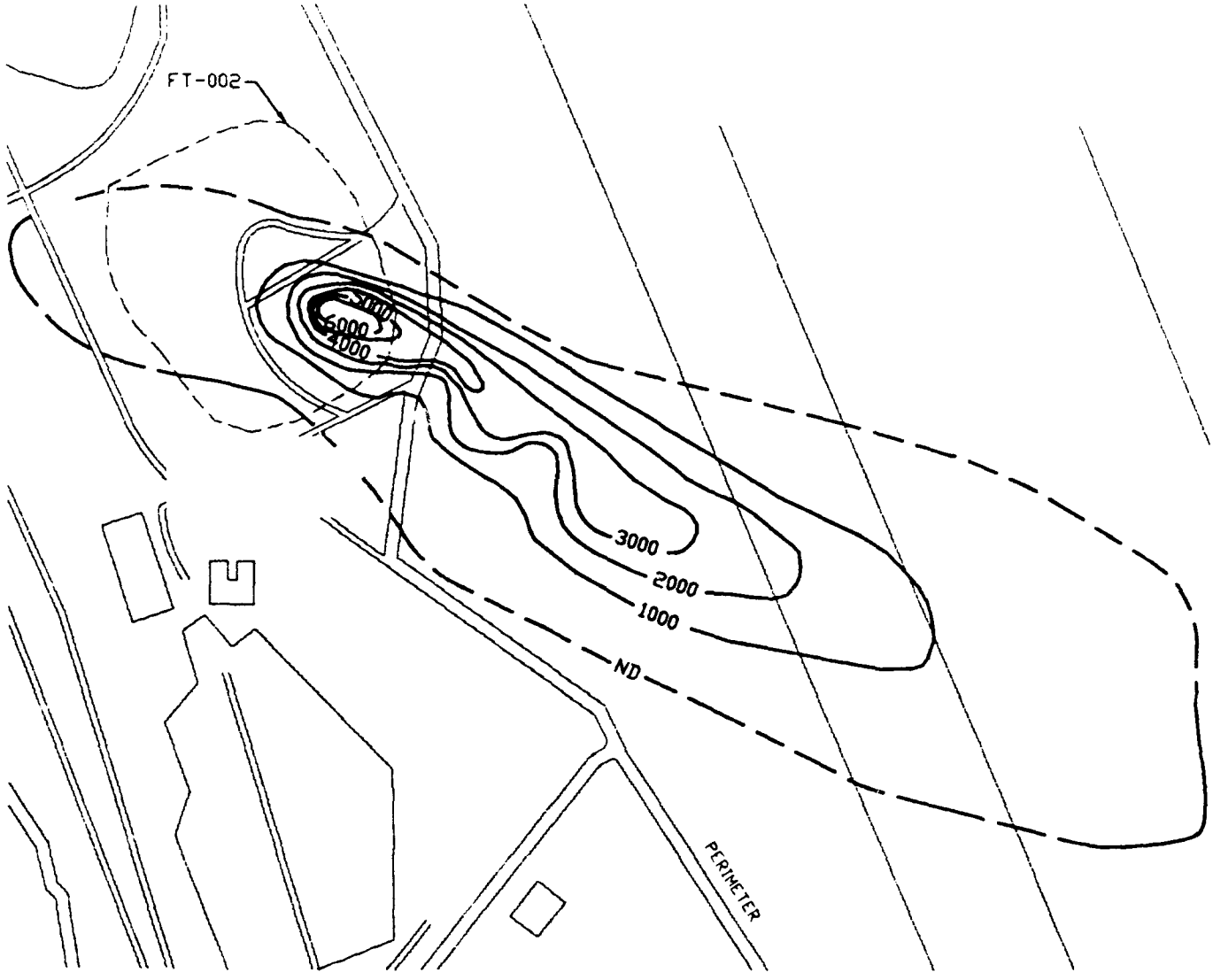

TOTAL BTEX (ppb)

NOTES

1. Areas of high dissolved total BTEX correspond well to elevated concentrations of Fe^{2+} relative to background levels.

2. The production of Fe^{2+} under reducing conditions is likely attributable to the reduction of ferric oxide (assumed to be the primary form of Fe^{3+}).

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FERROUS IRON (Fe^{2+})(ppm)

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0 100 200 400 800
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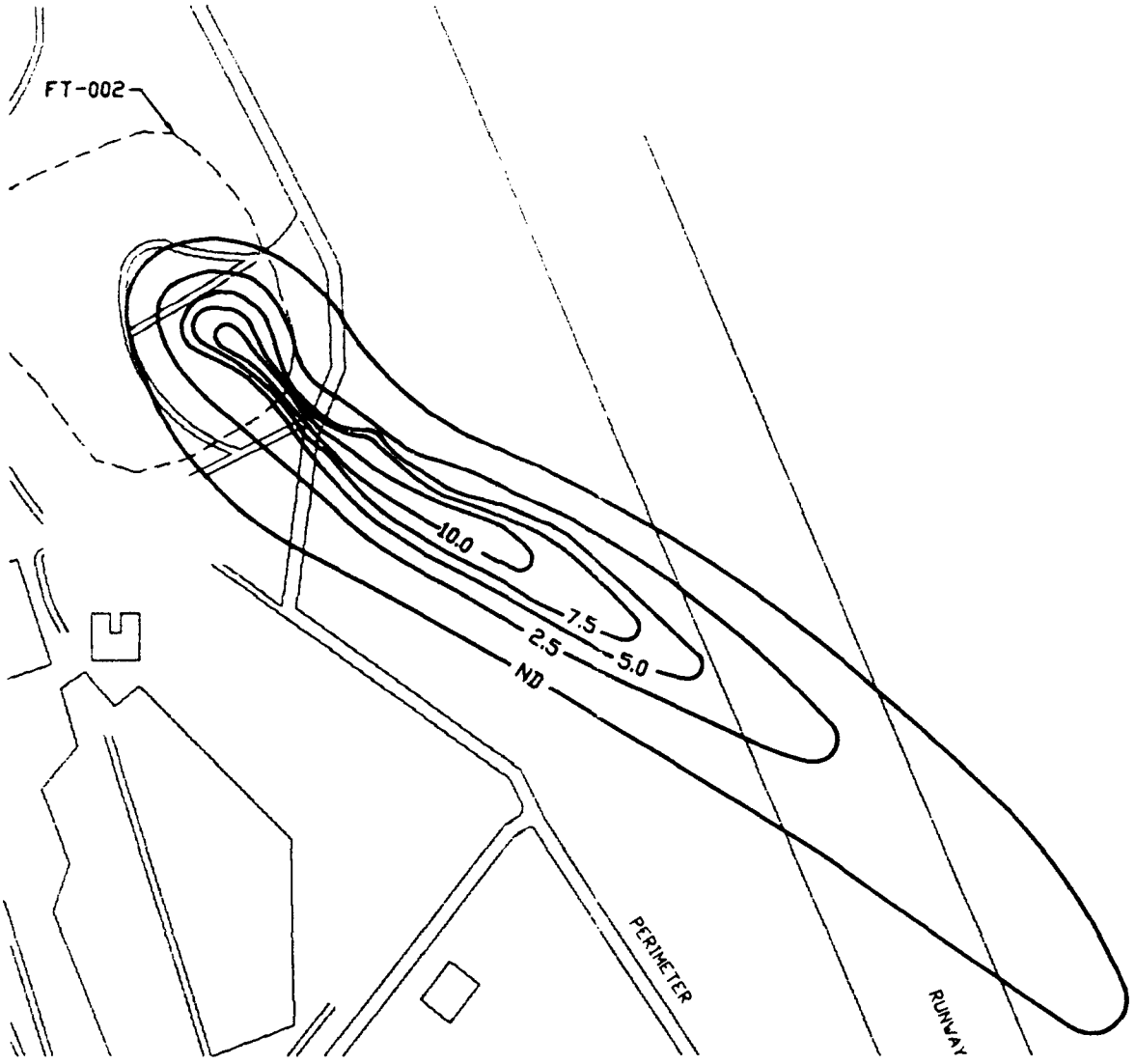


FERROUS IRON (Fe^{2+})(ppm)

0 100 200 400 800
FEET

N

FIGURE 5.7

COMPARISON OF TOTAL BTEX AND FERROUS IRON

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

iron-reducing microorganisms are probably using the ferric iron to oxidize the BTEX compounds. Measured Eh levels at the site also indicated that the ground water at Site FT-002 is sufficiently reducing for iron reduction to occur.

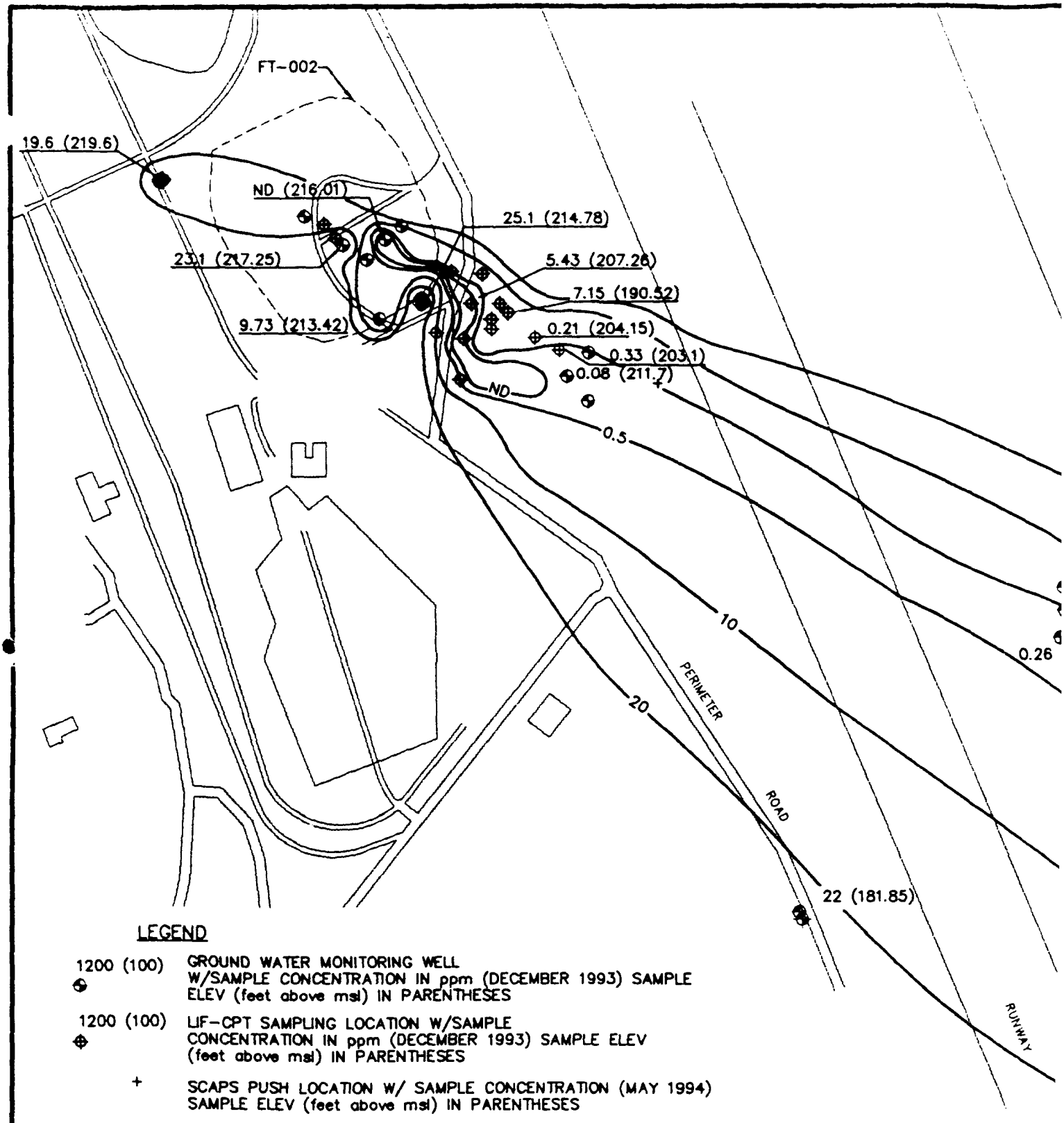
5.5.1.4 Sulfate

Sulfate may also be used as an electron acceptor during microbial degradation of fuel hydrocarbons under anaerobic conditions (Grbic-Galic, 1990). This redox reaction is commonly called sulfate reduction. Sulfate is reduced to sulfide during the oxidation of the BTEX compounds. The presence of decreased concentrations of sulfate and increased concentrations of sulfide relative to background concentrations indicates that sulfate may be participating in redox reactions at the site. To investigate the potential for sulfate reduction at Site FT-002, total sulfate concentrations were measured at ground water wells and CPT ground water sampling locations in December 1993 and at the Geoprobe® sample location and newly installed ground water monitoring points in May 1994. No measurements of sulfide concentrations were made at the site.

Table 5.5 summarizes the sulfate concentrations measured at Site FT-002 by sampling location. Figures 5.8a and 5.8b show the areal and vertical distribution of observed ferrous iron concentrations in ground water. Figure 5.9 compares measured concentrations of total BTEX in the ground water with measured concentrations of sulfate. There is a strong correlation between areas of high BTEX concentrations and areas with depleted sulfate concentrations relative to measured background concentrations. This depletion of sulfate within the BTEX plume suggests that this compound may be acting as an electron acceptor.

Generally, however, the extent and significance of BTEX biodegradation via sulfate reduction is not well understood (Norris *et al.*, 1994). Although oxidation of benzene by sulfate reduction is thermodynamically favorable (see Table 5.2), it is not as favorable as aerobic respiration, denitrification, nitrate reduction, or iron reduction. Additionally, sulfate-reducing microorganisms are typically sensitive to environmental conditions, including temperature, inorganic nutrients, and pH (Zehnder, 1978). An imbalance in suitable environmental conditions could severely limit the significance of BTEX degradation via sulfate reduction.

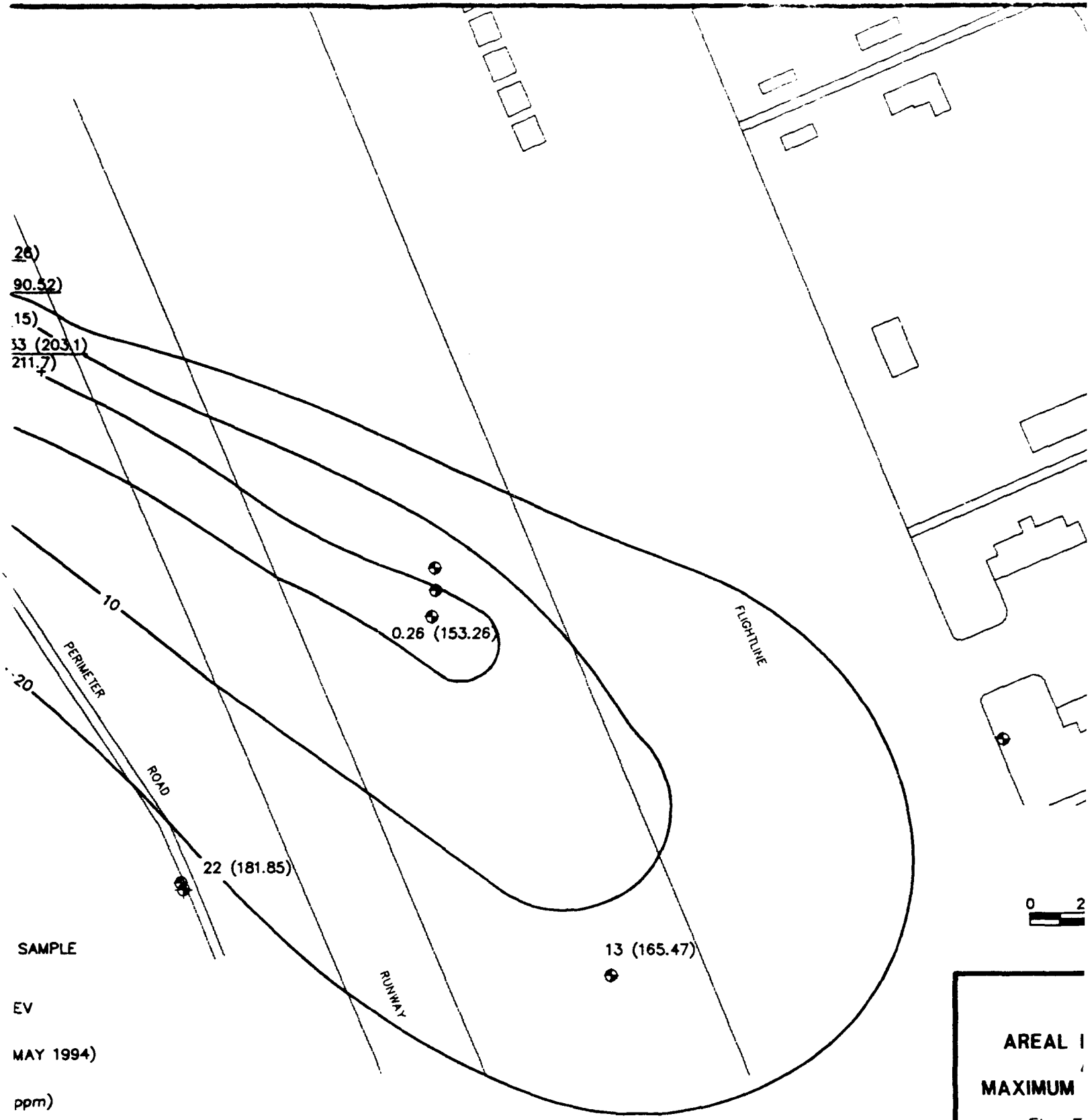
The measured Eh of the ground water at Site FT-002 contradicts the analytical data. Sulfate reduction can only be mediated in reducing conditions (low pe). Measured Eh levels at Site FT-002 are not sufficiently negative to suggest that sulfate reduction could occur at the site. This is characteristic of the problems associated with measuring oxidizing potential in the field. It is



LEGEND

1200 (100) ⊕	GROUND WATER MONITORING WELL W/SAMPLE CONCENTRATION IN ppm (DECEMBER 1993) SAMPLE ELEV (feet above msl) IN PARENTHESES
1200 (100) ⊕	LIF-CPT SAMPLING LOCATION W/SAMPLE CONCENTRATION IN ppm (DECEMBER 1993) SAMPLE ELEV (feet above msl) IN PARENTHESES
+	SCAPS PUSH LOCATION W/ SAMPLE CONCENTRATION (MAY 1994) SAMPLE ELEV (feet above msl) IN PARENTHESES
— 2.0 —	LINE OF ESTIMATED EQUAL SULFATE CONCENTRATION (ppm)
ND	NOT DETECTED

M:\45004\DRAWINGS\94DN0224, 10/07/94 at 14:00



SAMPLE

EV

MAY 1994)

ppm)

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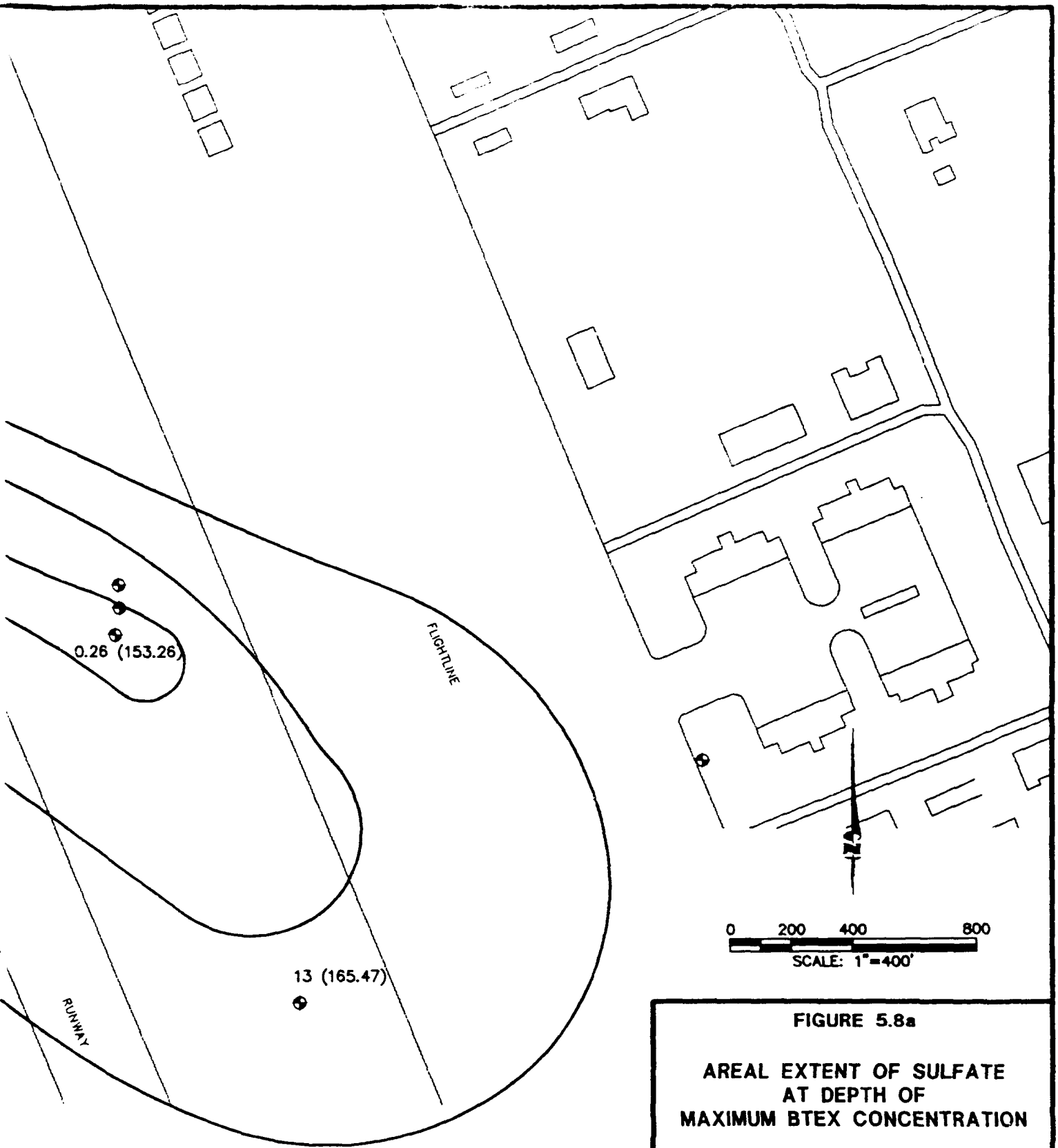
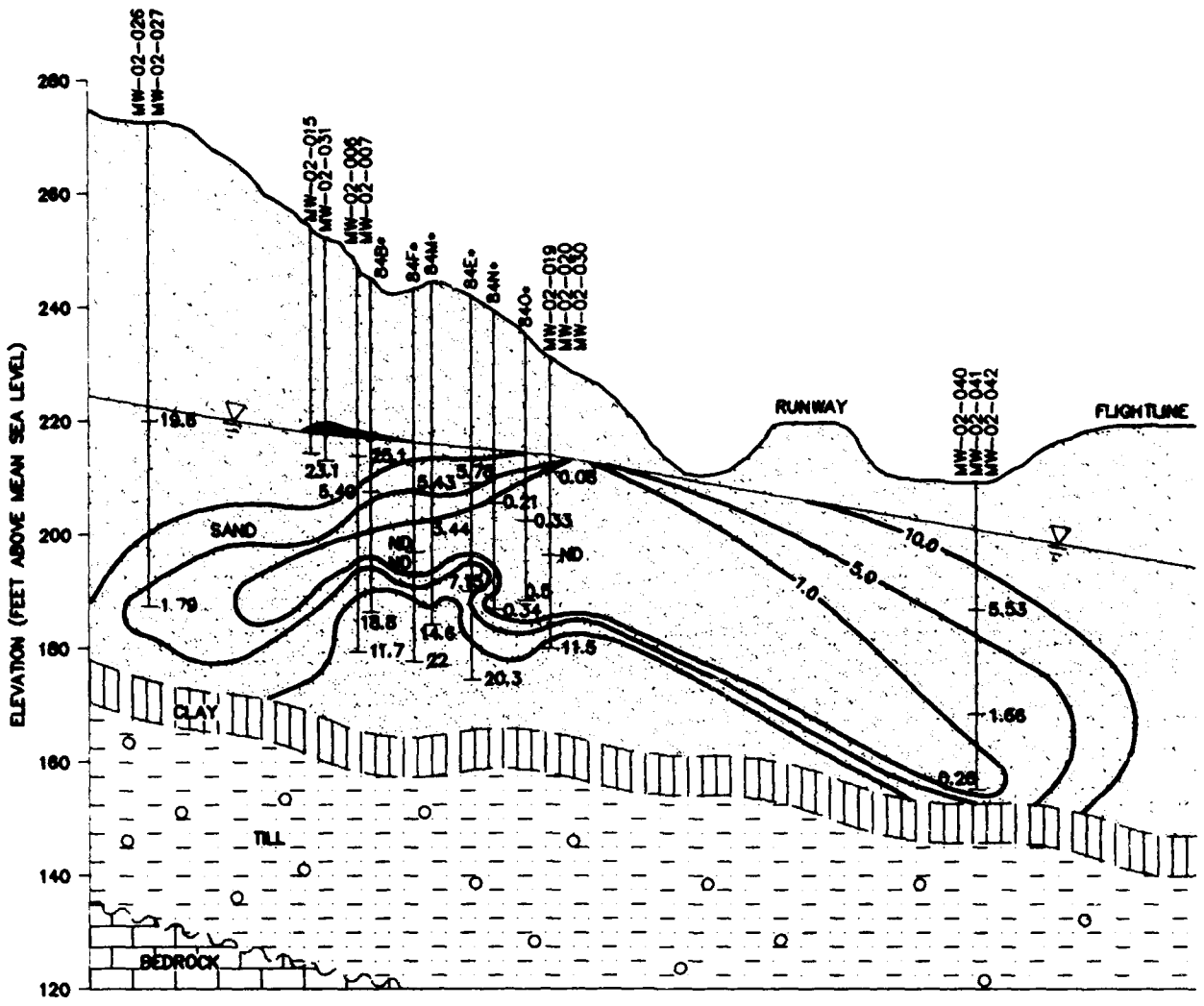


FIGURE 5.8a

AREAL EXTENT OF SULFATE AT DEPTH OF MAXIMUM BTEX CONCENTRATION

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado



LEGEND

⊥	SAMPLE ELEVATION (ft above msl)
16.4	MEASURED CONCENTRATION OF SULFATE (ppm)
—20—	LINE OF ESTIMATED EQUAL CONCENTRATION OF SULFATE (ppm)
ND	NOT DETECTED
	ESTIMATED EXTENT OF LNAPL
▽	SURFACE OF GROUND WATER TABLE
	UNCONFORMITY
	LIGHT BROWN TO GRAY, WELL-SORTED, MEDIUM-TO FINE-GRAINED SAND
	DARK GRAY, MODERATELY PLASTIC CLAY. DARK MINERAL LAMINATIONS ARE PRESENT
	GRAY, POORLY-SORTED TILL. CLAY AND SILT-SIZE GRAINS TO GRAVEL. ANGULAR ROCK FRAGMENTS PRESENT
	CARBONATE BEDROCK

* WATER ELEVATION DATA FROM CPT POINTS ARE ESTIMATED VALUES

VERTICAL EXAGGERATION = 20X

HORIZ 0 300 600 1200

VERT 0 15 30 60

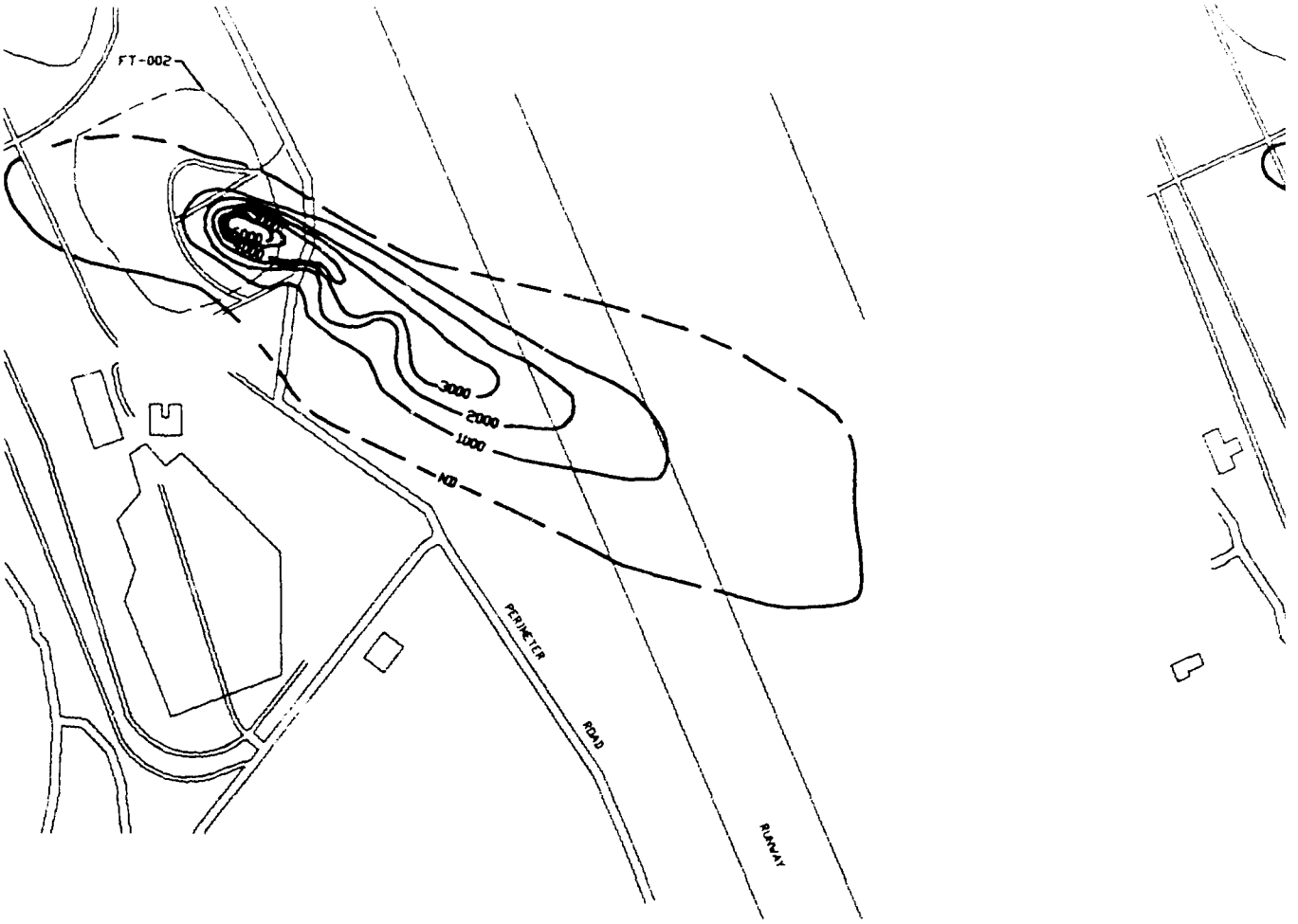
FIGURE 5.8b

VERTICAL EXTENT OF SULFATE ALONG PLUME CENTERLINE

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

N:\45004\DRAWINGS\94DN0239, 11/01/94 at 11:30



TOTAL BTEX (opb)

NOTES

1. Areas of high dissolved total BTEX concentration correlate well to areas depleted in sulfate relative to background levels.

2. Sulfate reduction, if mediated by biological enzymes, requires a highly reducing environment. If the aquifer (and ecological milieu) is not characterized by signficantly reducing conditions, reduction of sulfate is thermodynamically not possible.

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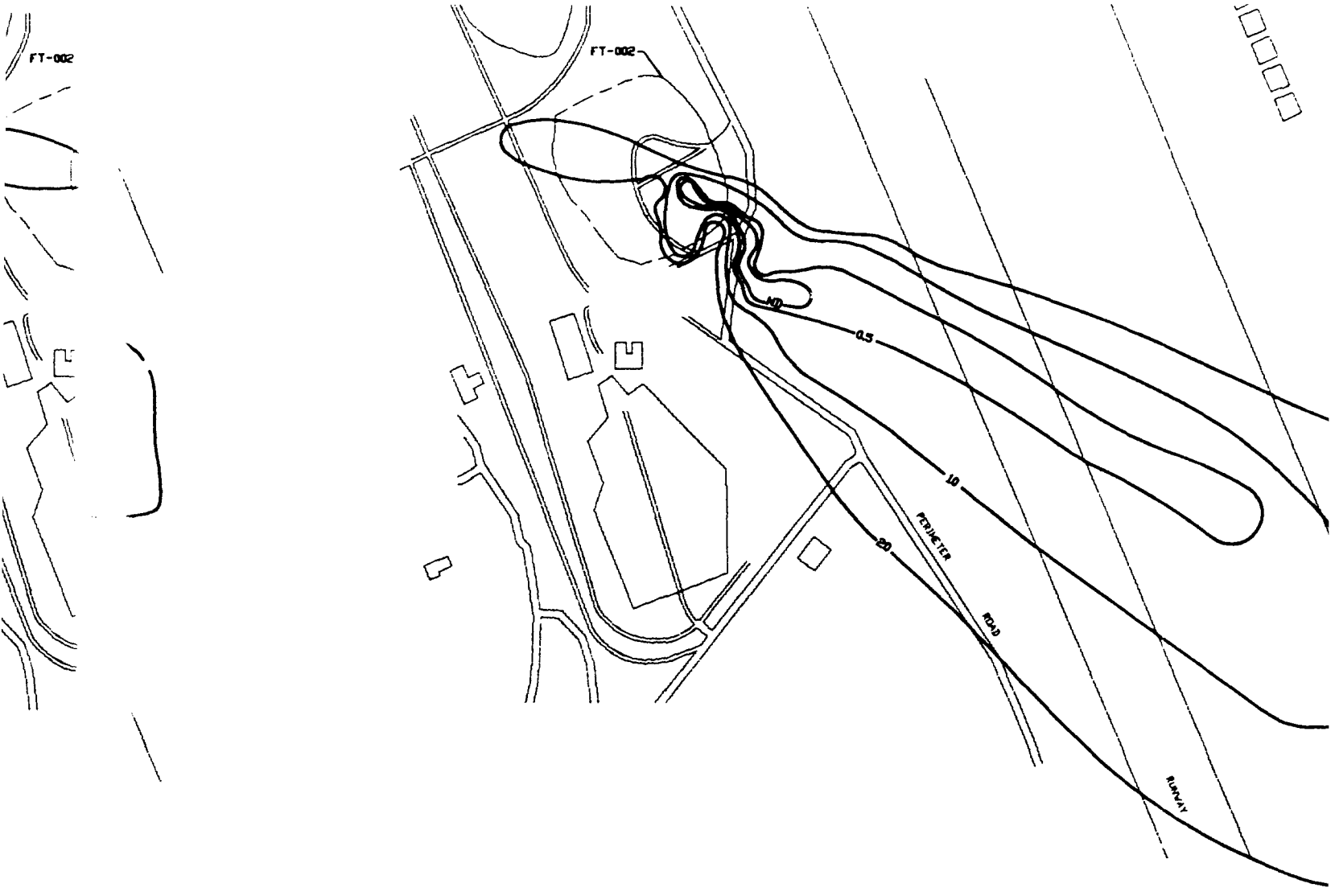

SULFATE (ppm)

0 150 300 600 1200

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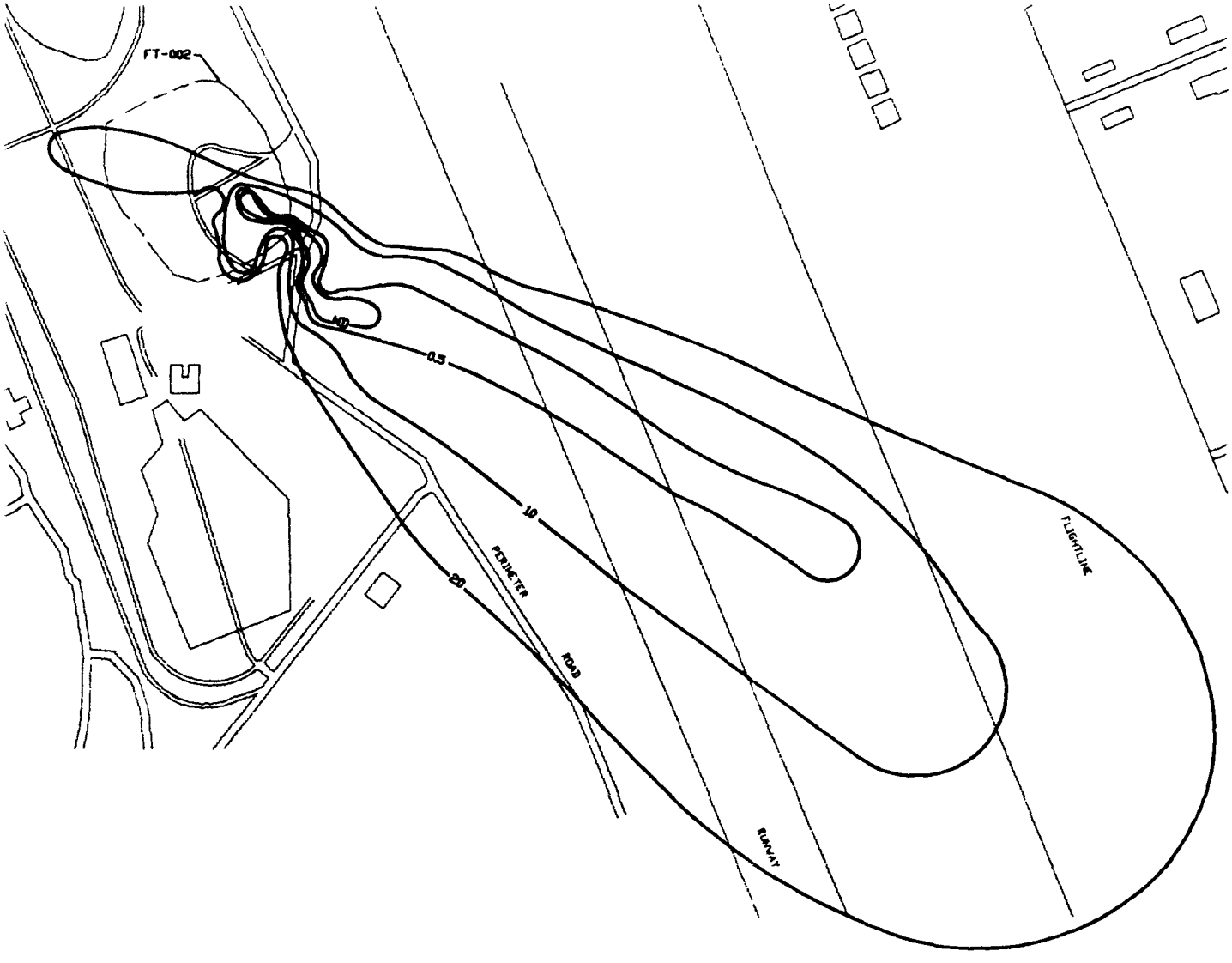


FIGURE 5.9

COMPARISON OF TOTAL BTEX AND SULFATE

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC
Denver, Colorado

quite likely that the platinum electrode probes are not sensitive to the sulfate/sulfide redox couple. Many authors have noted that measured Eh data cannot be solely used to reliably predict the electron acceptors that may be operating at a site (e.g., Stumm and Morgan, 1991; Godsey, 1994; Lovley *et al.*, 1994). However, integrating Eh measurements with analytical data on reduced and oxidized chemical species provides for reasonable interpretations regarding which electron acceptors are being used to biodegrade BTEX. This issue is revisited in Section 5.5.1.6.

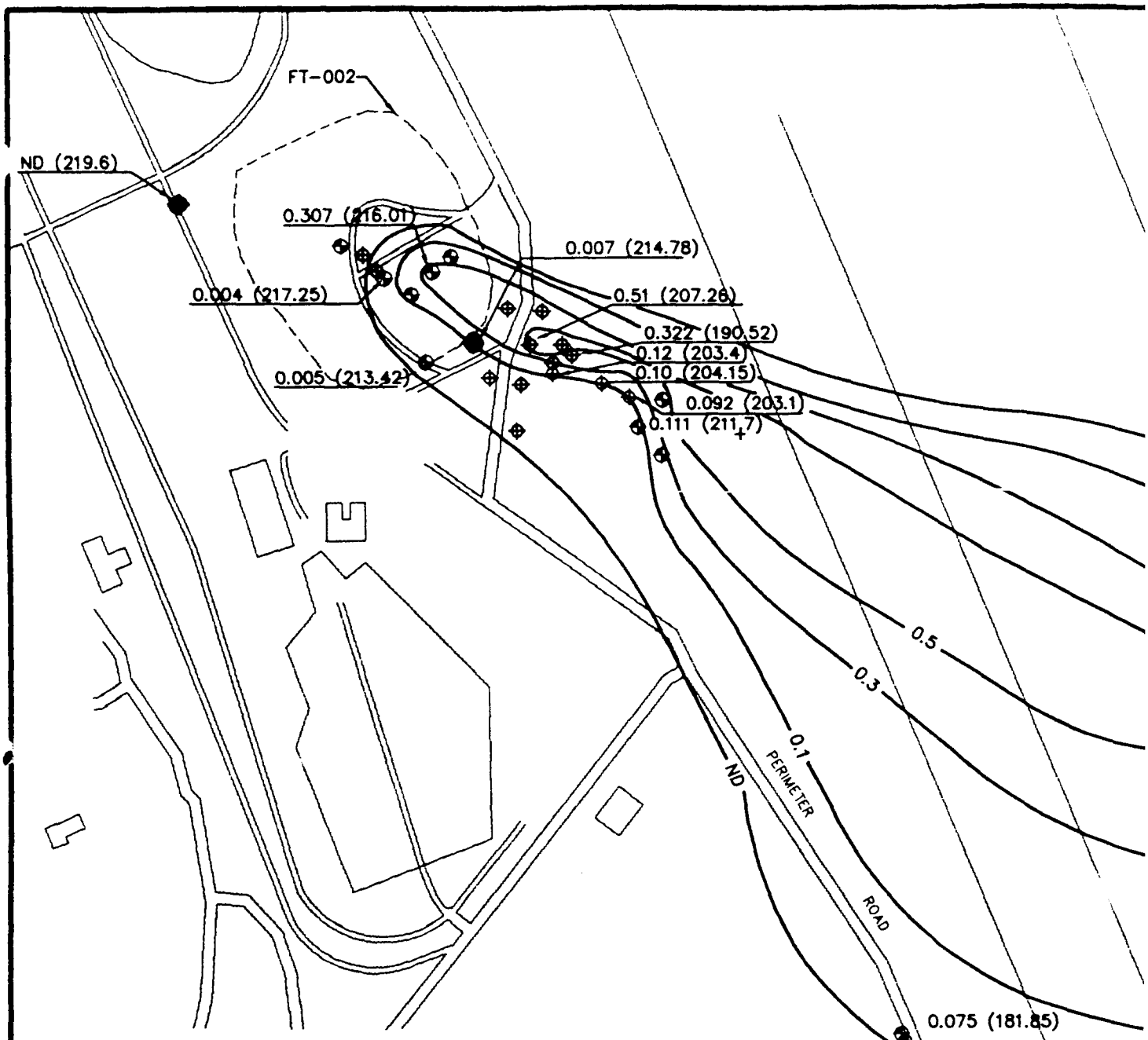
5.5.1.5 Methane

Based on the free energy yield and the oxidizing potential, the CO_2-CH_4 redox couple also could be used to oxidize BTEX compounds to carbon dioxide and water once the ground water is sufficiently reducing. To attain these reducing levels, other highly oxidizing chemical species such as oxygen, nitrate, and manganese must be reduced. This redox reaction is called methanogenesis or methane fermentation. Methane fermentation yields the least free energy to the system in comparison to other chemical species (see Figure 5.1). The presence of methane in ground water at concentrations elevated relative to background concentrations is a good indicator of methane fermentation because it is the only organic compound with the carbon cycle that is thermodynamically stable.

Carbon dioxide and methane concentrations were measured at ground water monitoring wells and CPT water sample locations in December 1993. No data on these compounds were collected in May 1994. Table 5.5 summarizes both carbon dioxide and methane concentrations by sample location. The maximum carbon dioxide concentration measured in the background well MW-02-026 was 102 ppm. Maximum background concentrations of methane were below 0.001 ppm. Carbon dioxide concentrations observed at Site FT-002 ranged from 80 ppm to 490 ppm. The maximum concentration of methane measured within the contaminated ground water plume at the site was 0.512 ppm. Figures 5.10a and 5.10b show the areal and vertical distribution of methane measured in ground water samples at Site FT-002. Figure 5.11 compares the total BTEX plume to the observed concentrations of methane. Elevated concentrations of methane correlate well with elevated concentrations of total BTEX, suggesting that methane may be produced by some process occurring within the contaminated microenvironment.

5.5.1.6 Correlation Between Observed Redox Processes and Measured Eh Levels

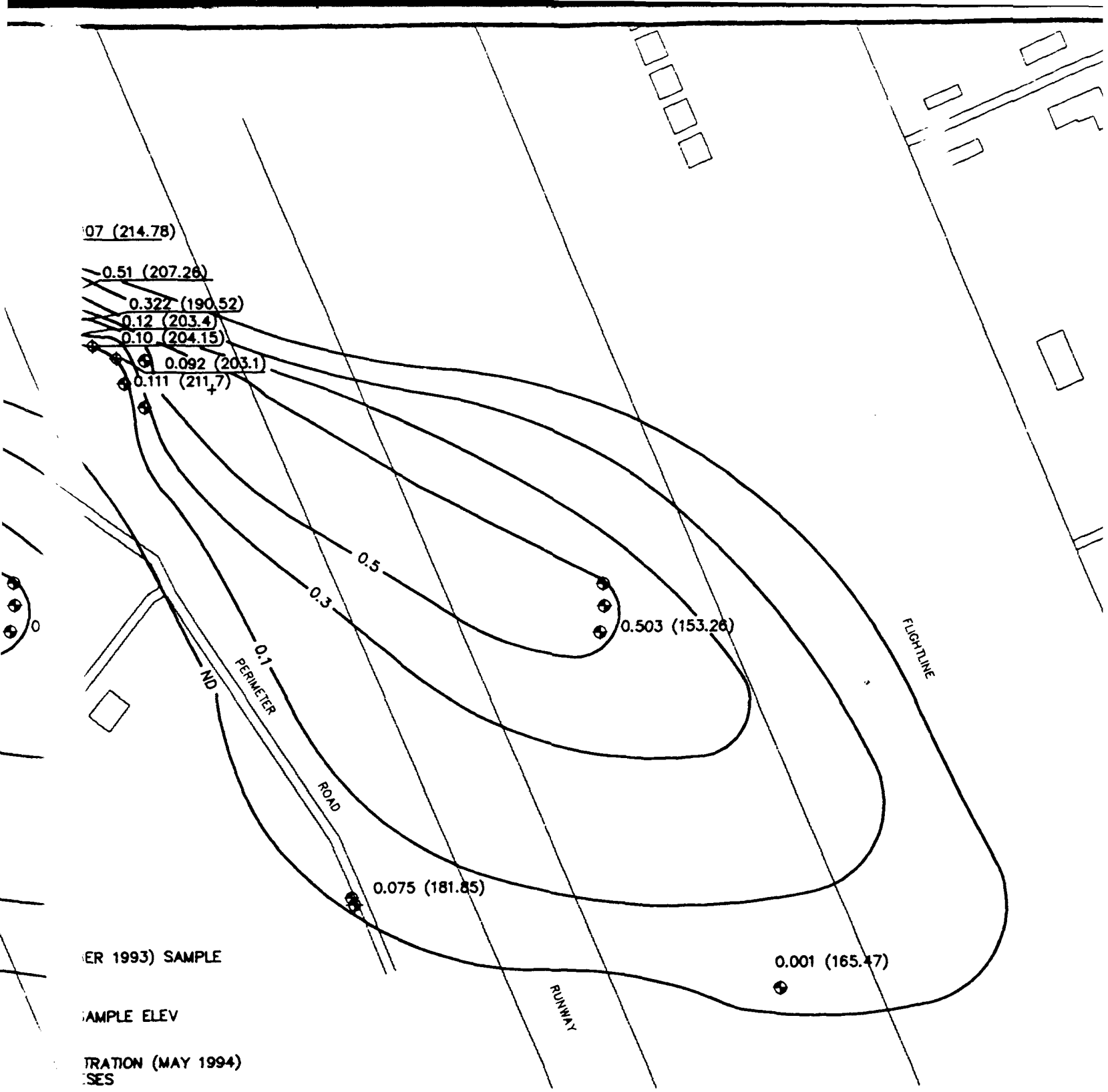
Eh measurements made in the field suggest that the ground water is not sufficiently reducing to allow methane fermentation to occur. Figures 5.12a and 5.12b show the areal and vertical pe



LEGEND

1200 (100) ◓	GROUND WATER MONITORING WELL W/SAMPLE CONCENTRATION IN ppm (DECEMBER 1993) SAMPLE ELEV (feet above msl) IN PARENTHESES
1200 (100) ⊕	LIF-CPT SAMPLING LOCATION W/SAMPLE CONCENTRATION IN ppm (DECEMBER 1993) SAMPLE ELEV (feet above msl) IN PARENTHESES
+	SCAPS PUSH LOCATION W/ SAMPLE CONCENTRATION (MAY 1994) SAMPLE ELEV (feet above msl) IN PARENTHESES
— 2.0 —	LINE OF ESTIMATD EQUAL METHANE CONCENTRATION (ppm)
	CONTOUR INTERVAL = 0.1ppm
ND	NOT DETECTED

M:\45004\DRAWINGS\94DN0225, 11/01/94 at 12:06



ER 1993) SAMPLE

AMPLE ELEV

TRATION (MAY 1994)
SES

TRATION (ppm)

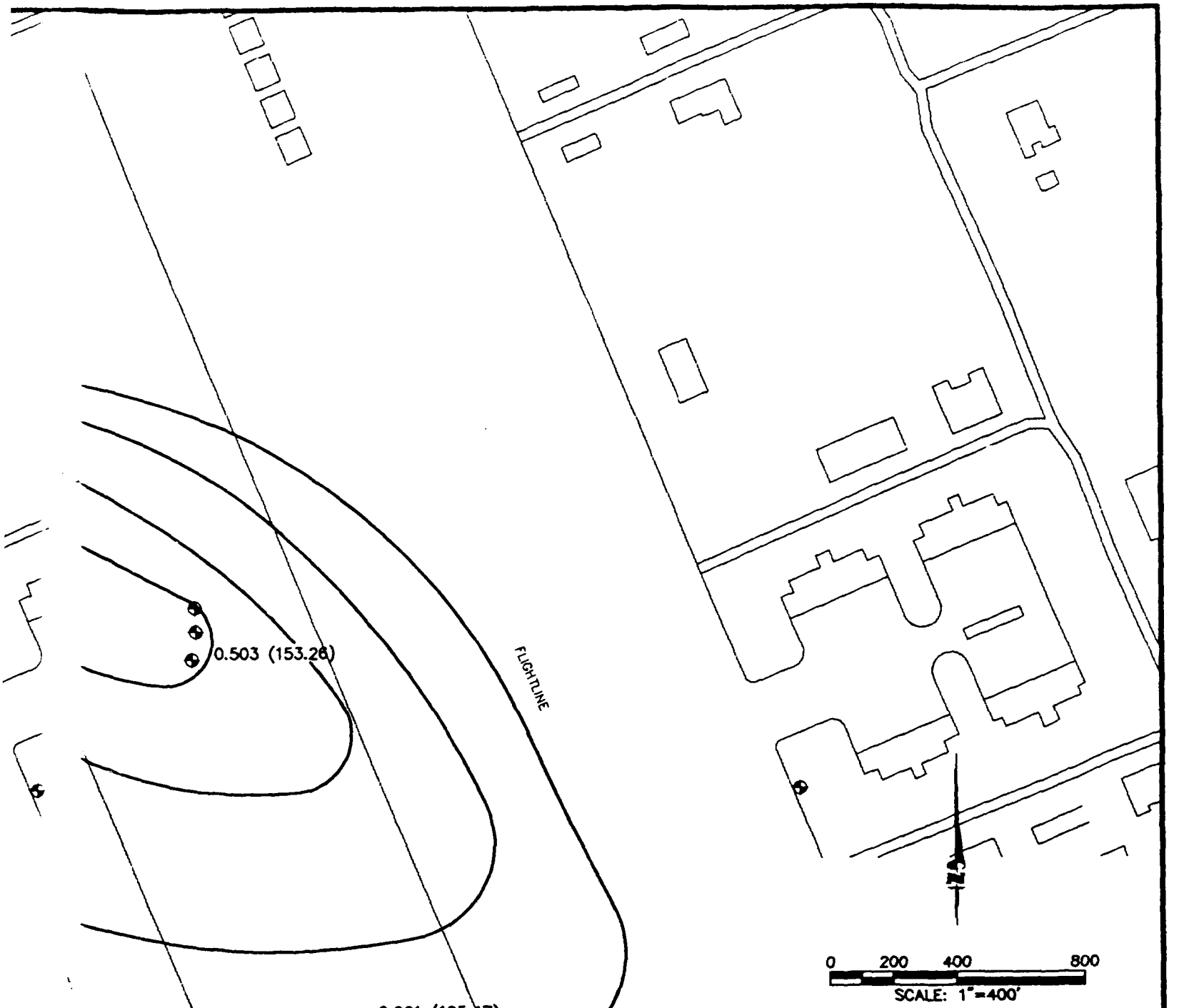


FIGURE 5.10a

AREAL EXTENT OF METHANE AT DEPTH OF MAXIMUM BTEX CONCENTRATION

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC.
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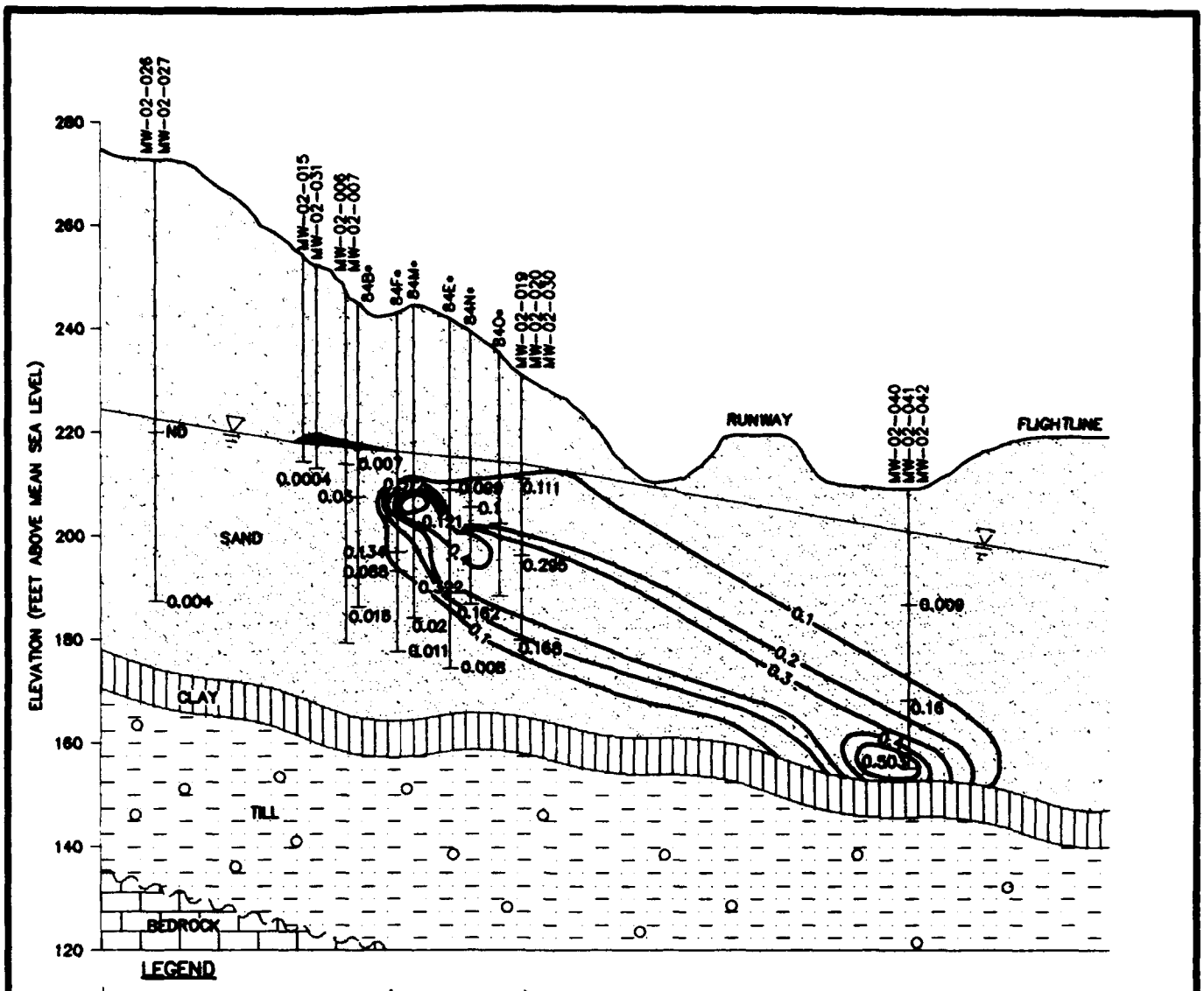

LEGEND

⊥	SAMPLE ELEVATION (ft above msl)
16.4	MEASURED CONCENTRATION OF METHANE (ppm)
20	LINE OF ESTIMATED EQUAL CONCENTRATION OF METHANE (ppm)
ND	NOT DETECTED
	ESTIMATED EXTENT OF LNAPL
	SURFACE OF GROUND WATER TABLE
	UNCONFORMITY
	LIGHT BROWN TO GRAY, WELL-SORTED, MEDIUM-TO FINE-GRAINED SAND
	DARK GRAY, MODERATELY PLASTIC CLAY. DARK MINERAL LAMINATIONS ARE PRESENT
	GRAY, POORLY-SORTED TILL. CLAY AND SILT-SIZE GRAINS TO GRAVEL. ANGULAR ROCK FRAGMENTS PRESENT
	CARBONATE BEDROCK

• WATER ELEVATION DATA FROM CPT POINTS ARE ESTIMATED VALUES

VERTICAL EXAGGERATION = 20X

HORIZ 0 300 600 1200
VERT 0 15 30 60

FIGURE 5.10b

VERTICAL EXTENT OF METHANE ALONG PLUME CENTERLINE

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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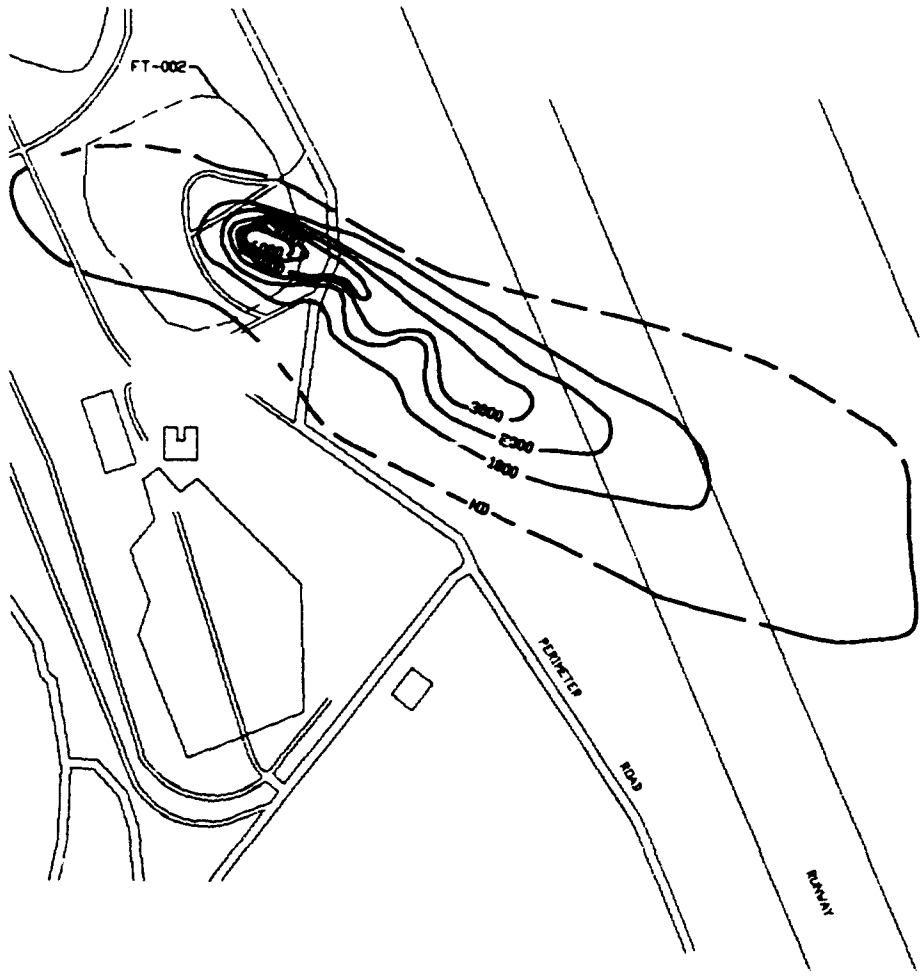
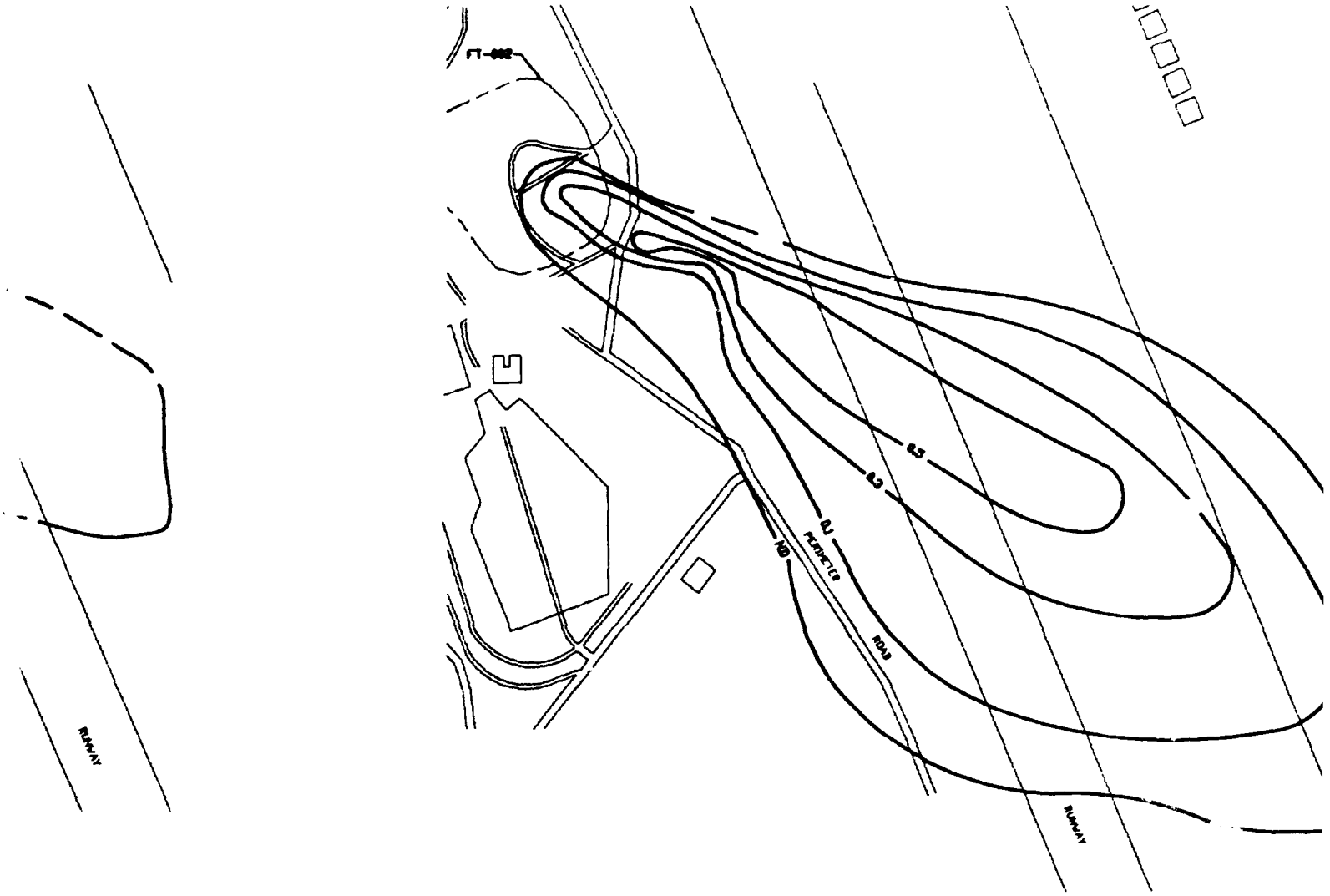


TOTAL BTEX (ppb)

NOTES

1. High concentrations of dissolved total BTEX correlate well with high concentrations of dissolved methane.

2. The presence of methane suggests fermentation of fuel hydrocarbons (methanogenesis).



METHANE (ppm)

0 150 300 600 1200

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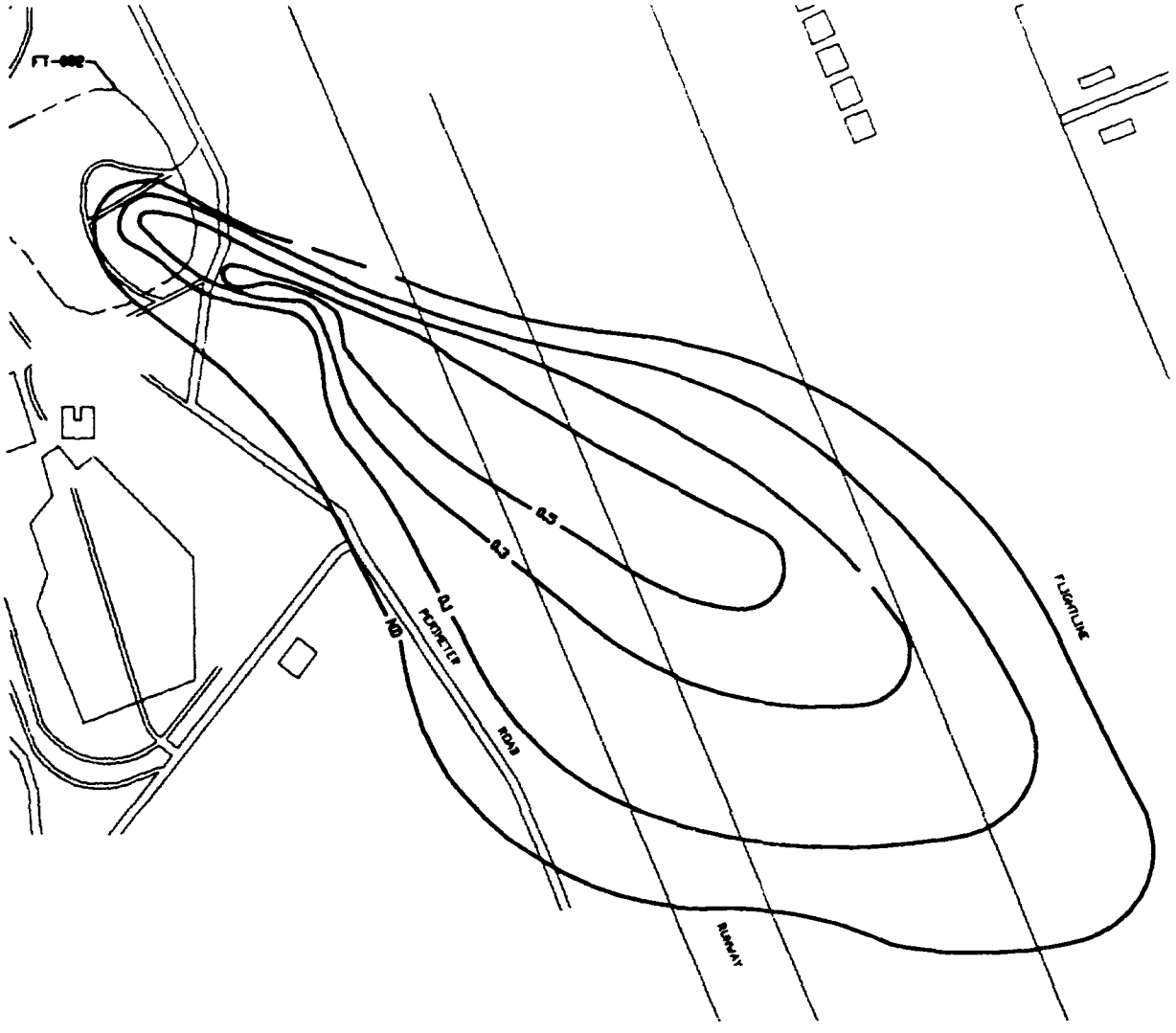
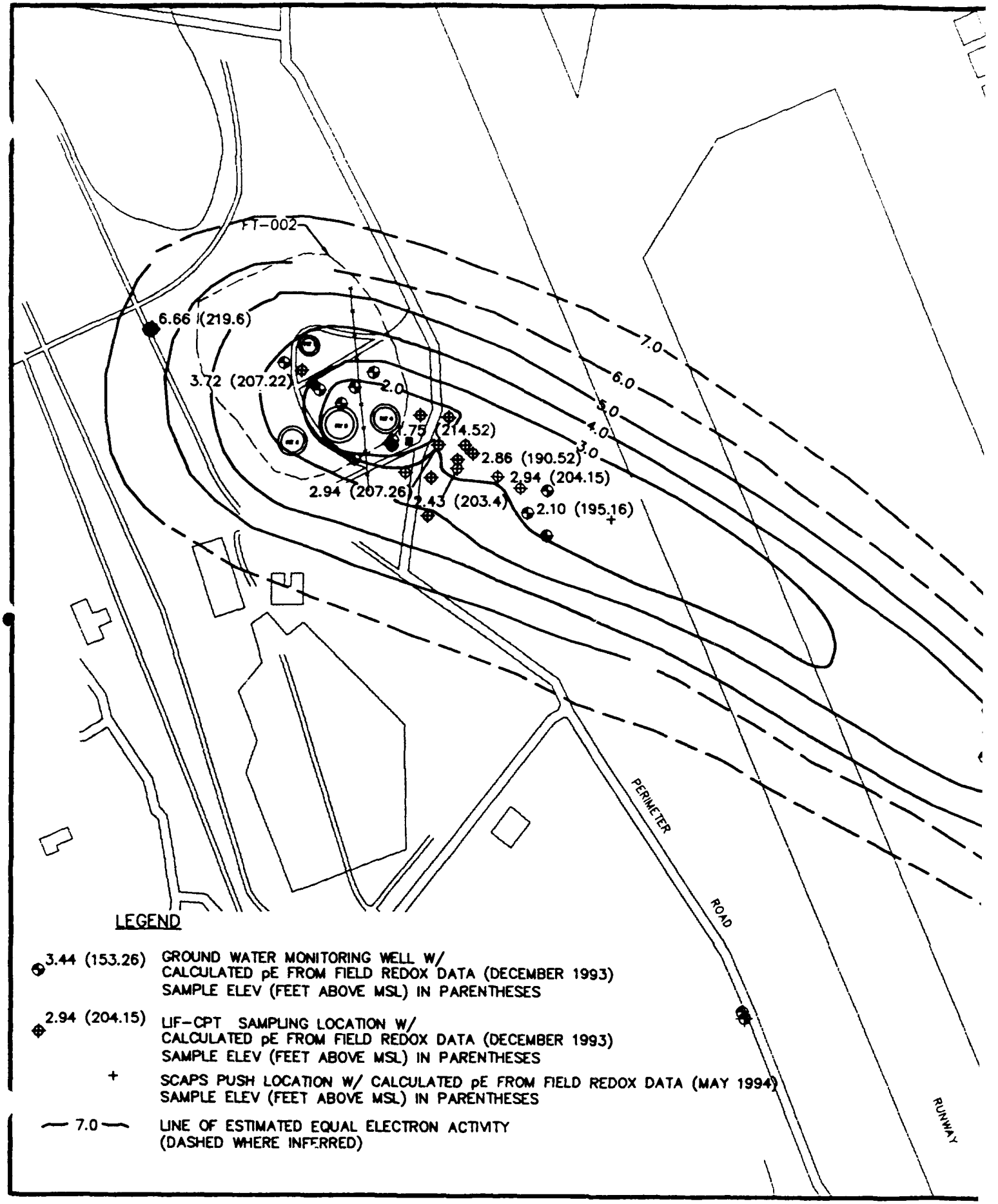


FIGURE 5.11

COMPARISON OF TOTAL BTEX AND METHANE

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado



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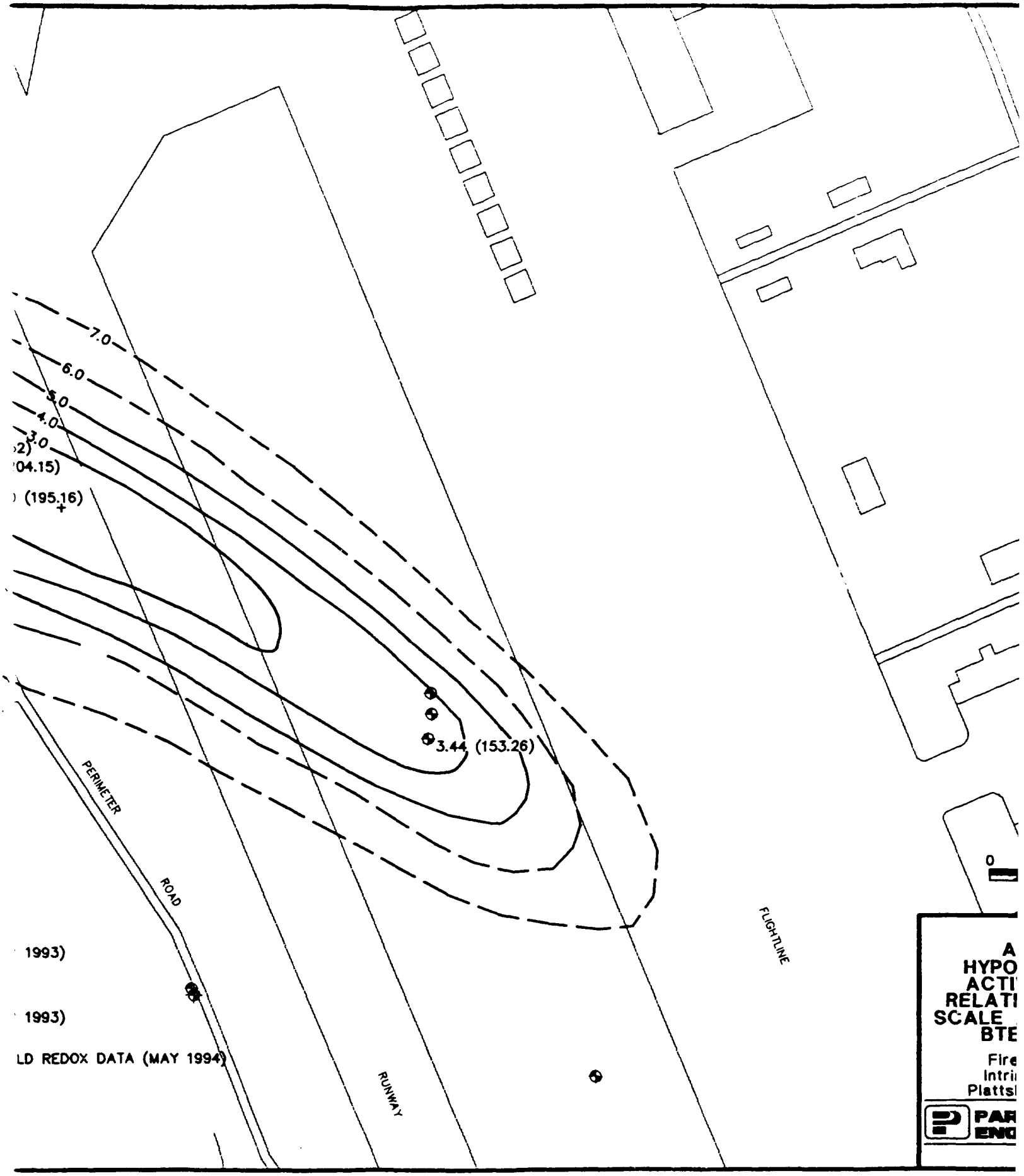
7.0
6.0
5.0
4.0
3.0
2)
04.15)
(195.16)
3.44 (153.26)
PERIMETER
ROAD
RUNWAY
FLIGHTLINE
0
1993)
1993)
LD REDOX DATA (MAY 1994)
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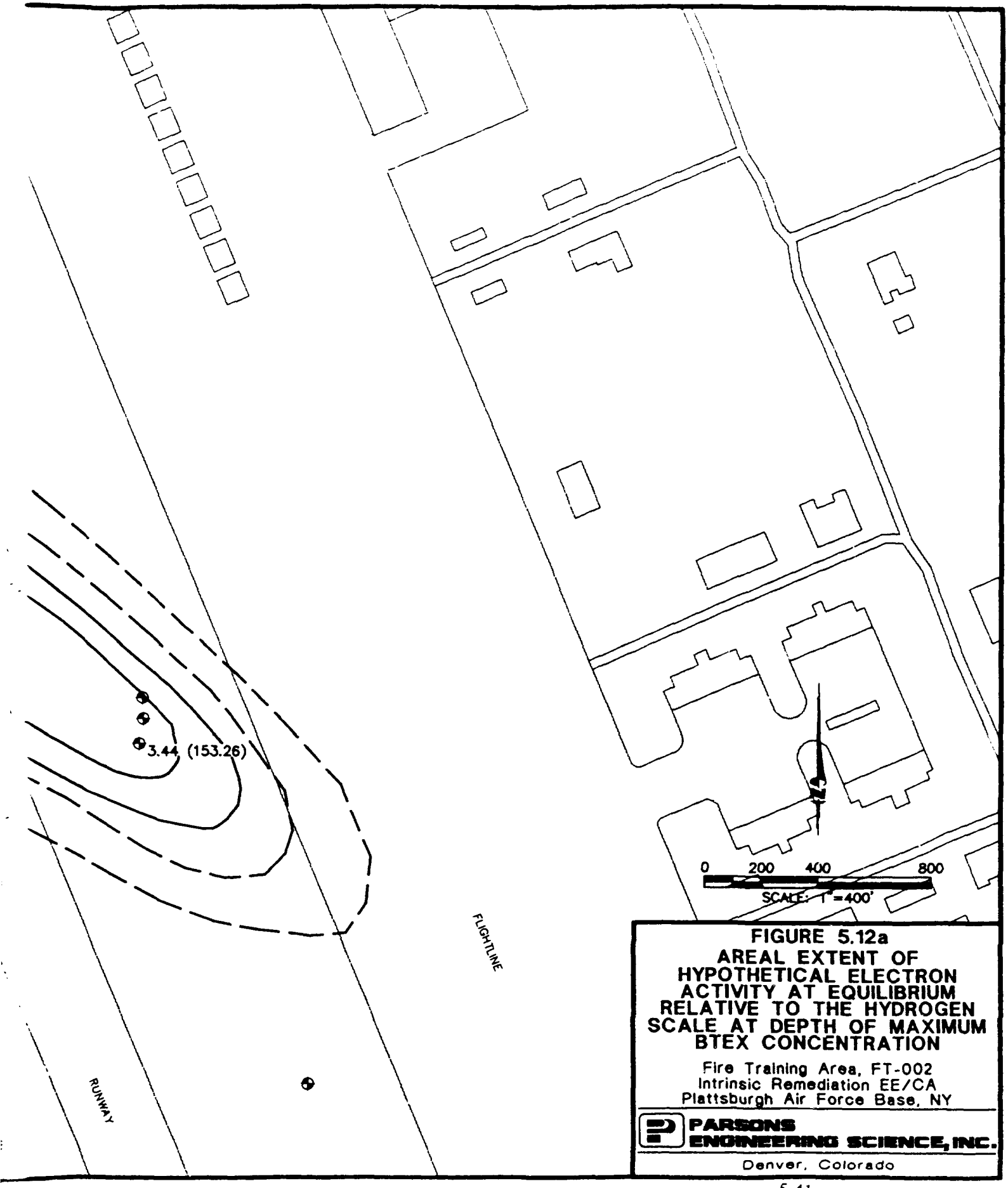
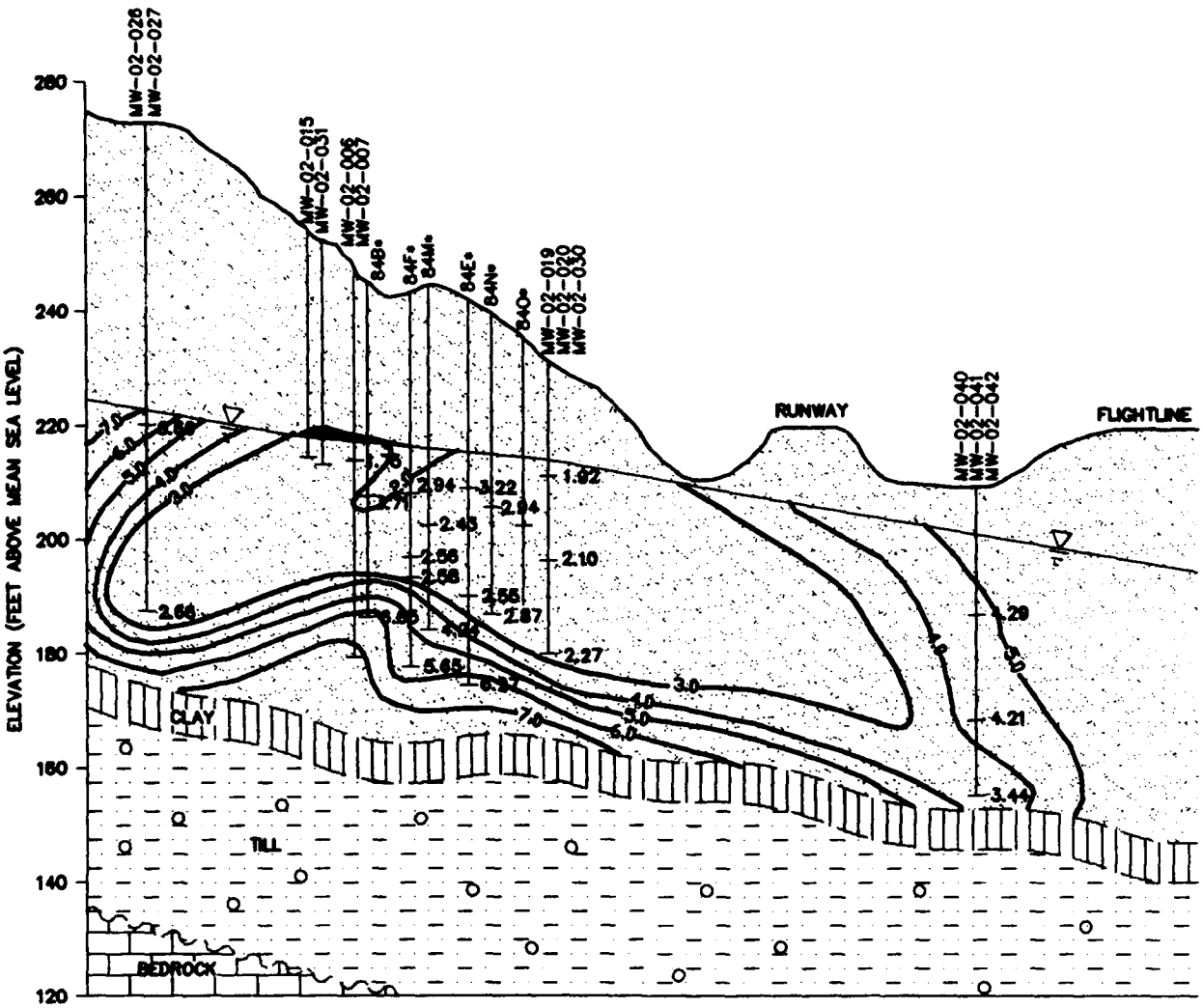


FIGURE 5.12a
AREAL EXTENT OF HYPOTHETICAL ELECTRON ACTIVITY AT EQUILIBRIUM RELATIVE TO THE HYDROGEN SCALE AT DEPTH OF MAXIMUM BTEX CONCENTRATION

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado



LEGEND

⊥	SAMPLE ELEVATION (ft above msl)
16.4	MEASURED CONCENTRATION OF pE
—20—	LINE OF ESTIMATED EQUAL pE
	ESTIMATED EXTENT OF LNAPL
▽	SURFACE OF GROUND WATER TABLE
	UNCONFORMITY
	LIGHT BROWN TO GRAY, WELL-SORTED, MEDIUM-TO FINE-GRAINED SAND
	DARK GRAY, MODERATELY PLASTIC CLAY. DARK MINERAL LAMINATIONS ARE PRESENT
	GRAY, POORLY-SORTED TILL. CLAY AND SILT-SIZE GRAINS TO GRAVEL. ANGULAR ROCK FRAGMENTS PRESENT
	CARBONATE BEDROCK

* WATER ELEVATION DATA FROM CPT POINTS ARE ESTIMATED VALUES

VERTICAL EXAGGERATION = 20X

HORIZ 0 300 600 1200

VERT 0 15 30 60

FIGURE 5.12b

VERTICAL EXTENT OF HYPOTHETICAL ELECTRON ACTIVITY AT EQUILIBRIUM RELATIVE TO THE HYDROGEN SCALE ALONG PLUME CENTERLINE

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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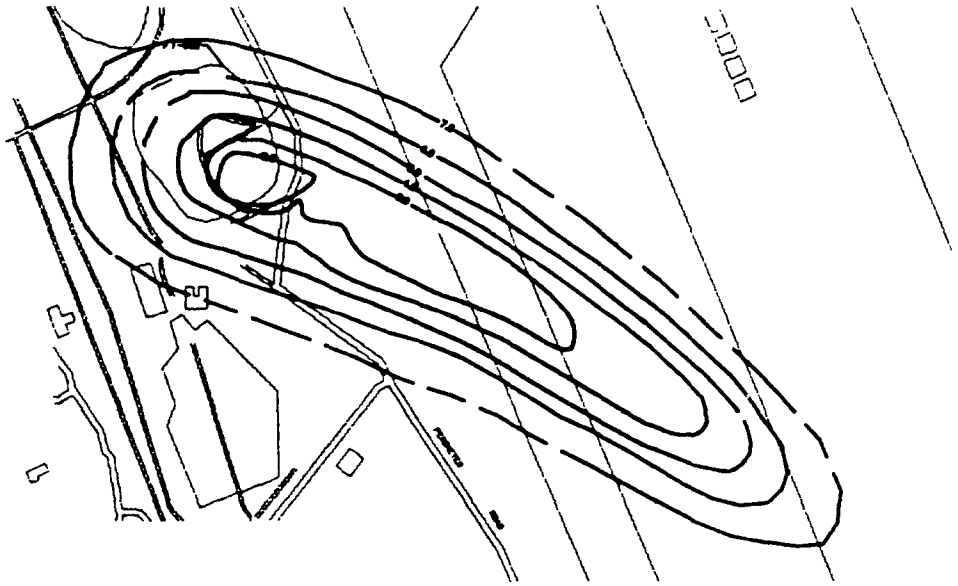
levels at Site FT-002 as calculated from field Eh measurements. Figure 5.13 compares measured Eh levels reported as pe with DO concentrations, nitrate concentrations, and ferrous iron concentrations. The measured Eh levels correlate roughly with the redox levels necessary for oxygen, nitrate, and iron reduction to proceed. Thus, the measured Eh levels may be used in these cases to deduce the types of redox reactions that are operating at the site. However, comparison of the measured Eh levels (reported as pe) to the theoretical pe required for sulfate reduction and methane fermentation suggest that these redox couples could not be used by the microorganisms to facilitate BTEX degradation. This, of course, contradicts field analytical data, which suggest that both sulfate reduction and methanogenesis are occurring. As discussed earlier, Eh measurements are only a partial indicator of which reactions are actually occurring at the site. This is the reason why analytical data on oxidized and reduced species are so important in determining if BTEX compounds may be biodegrading at a site.

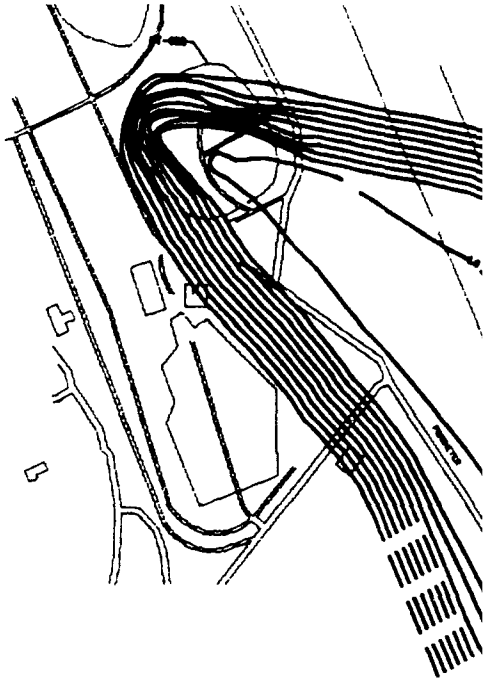
5.5.1.7 Cometabolism of Trichloroethene

Site FT-002 is also contaminated with chlorinated solvents, most notably TCE. Although the focus of this demonstration was the BTEX compounds, the fate and transport of the chlorinated solvents in the ground water will ultimately determine the type of remedial action warranted at the site. Chlorinated solvents can be transformed by biological processes (e.g., Bouwer *et al.*, 1981; Wilson and Wilson, 1985; Miller and Guengerich, 1982; Nelson *et al.*, 1986; Bouwer and Wright, 1988; Little *et al.*, 1988; Mayer *et al.*, 1988; Arciero *et al.*, 1989; Cline and Delfino, 1989; Freedman and Gosset, 1989; Folsom *et al.*, 1990; Harker and Kim, 1990; Alvarez-Cohen and McCarty, 1991a, 1991b; DeStefano *et al.*, 1991; Henry, 1991; McCarty *et al.*, 1991; Hartsman and deBont, 1992; McCarty and Semprini, 1994). Yet the transformation occurs differently than that used to degrade BTEX compounds. Microorganisms do not obtain free energy from the transformation of chlorinated solvents.

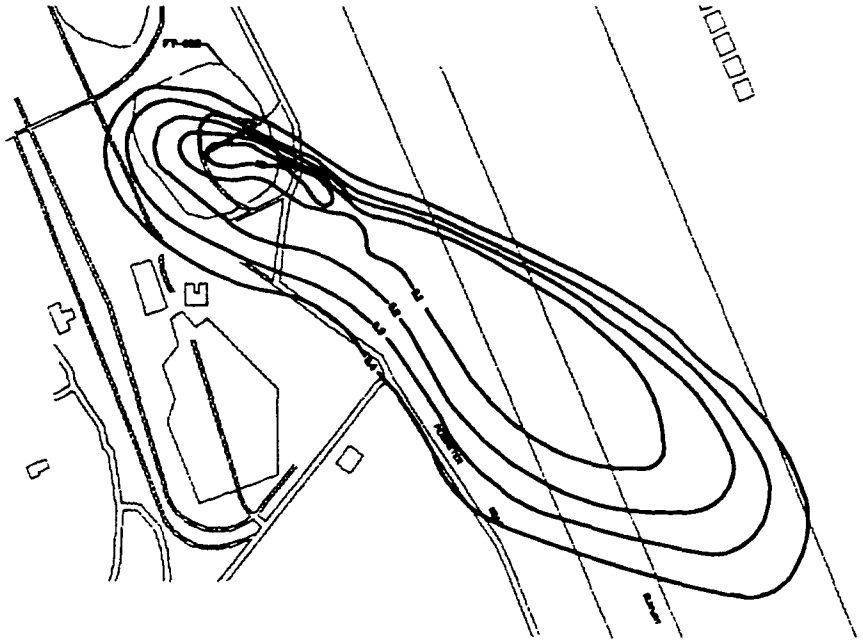
The degradation of these chemical compounds is brought about by cometabolism. The microorganisms present in the ground water produce enzymes or cofactors while facilitating the degradation of BTEX compounds. These enzymes and/or cofactors are then available in the aquifer to participate in the degradation of the chlorinated solvents. Thus, cometabolism of chlorinated solvents depends on the availability of a primary substrate, such as the BTEX compounds, which can satisfy the energy requirements of the microorganisms. In fact, this substrate must be of a chemical nature to stimulate the production of the enzymes and/or cofactors that can participate in the degradation of the chlorinated compounds.



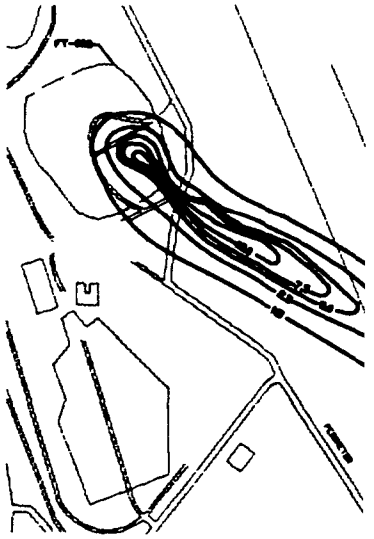
pE



DISSOLVED OXYGEN (



NITRATE as N (ppm)



FERROUS IRON (pp

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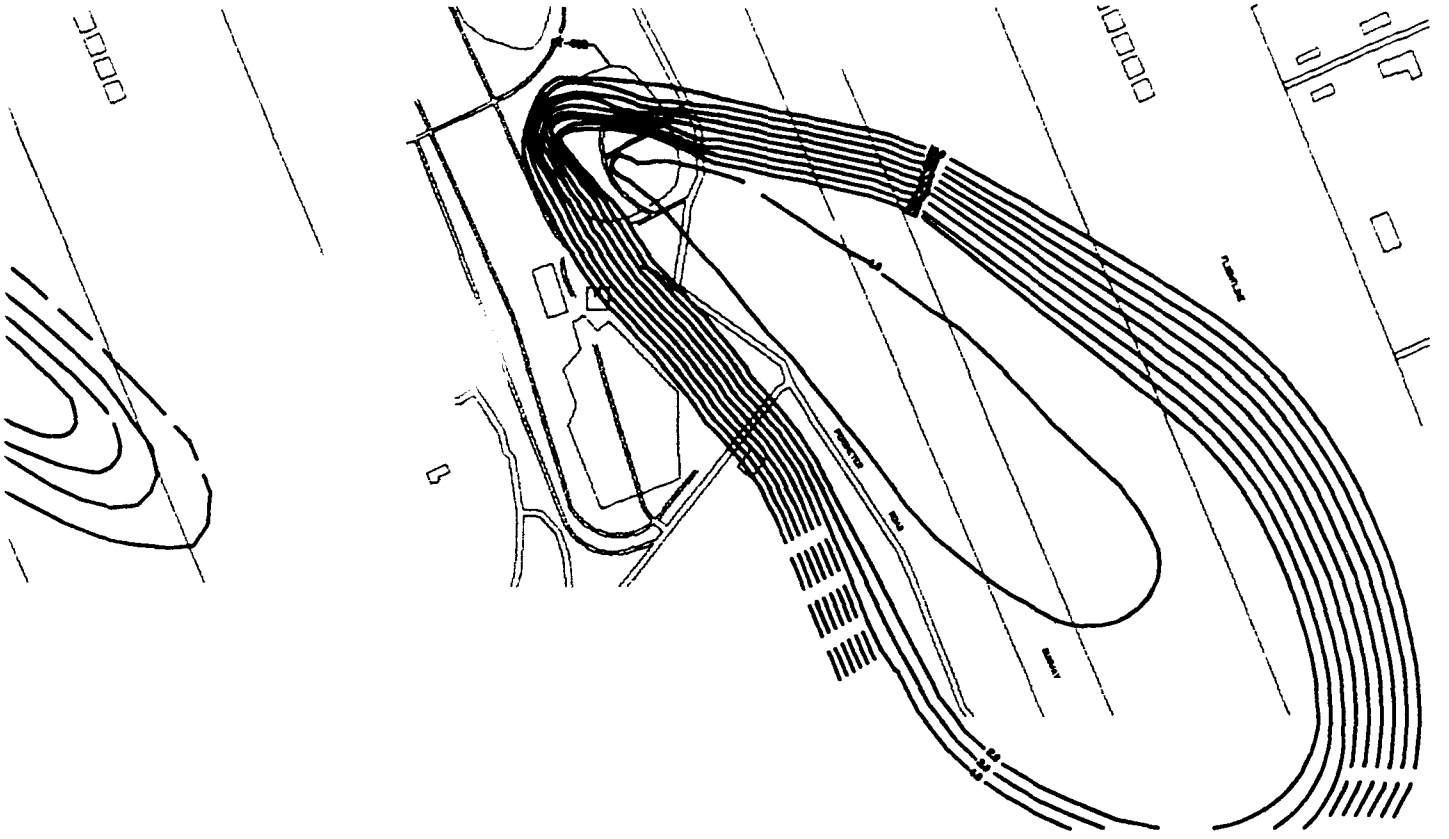

DISSOLVED OXYGEN (ppm)

NOTES

1. Generally the
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2. Comparison of
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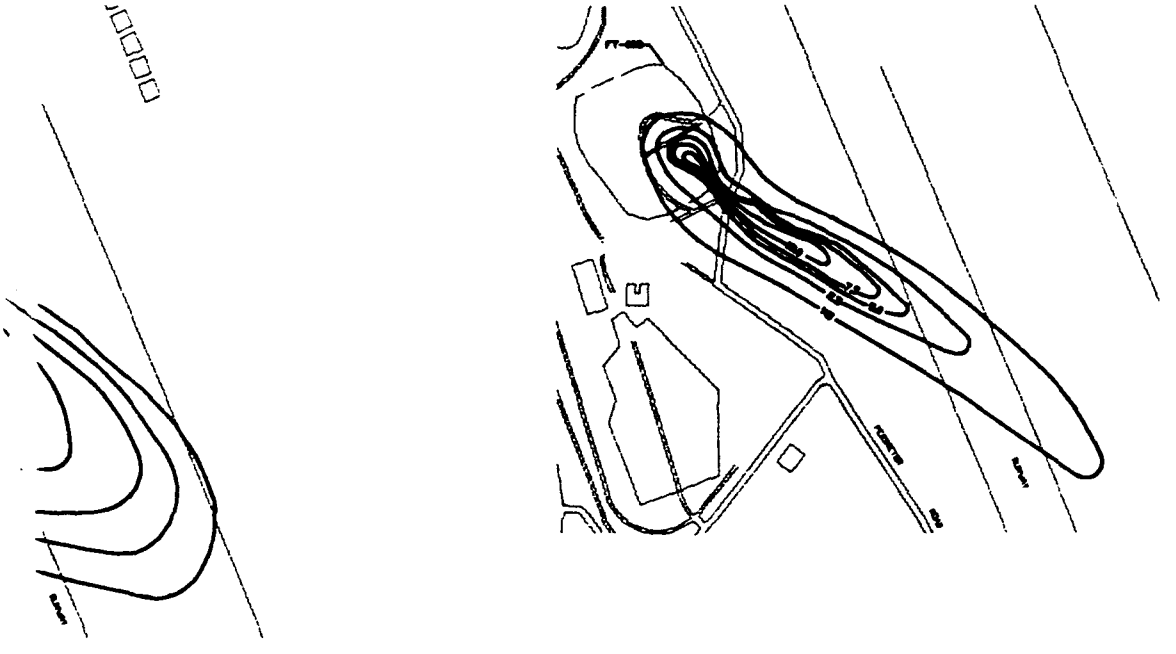
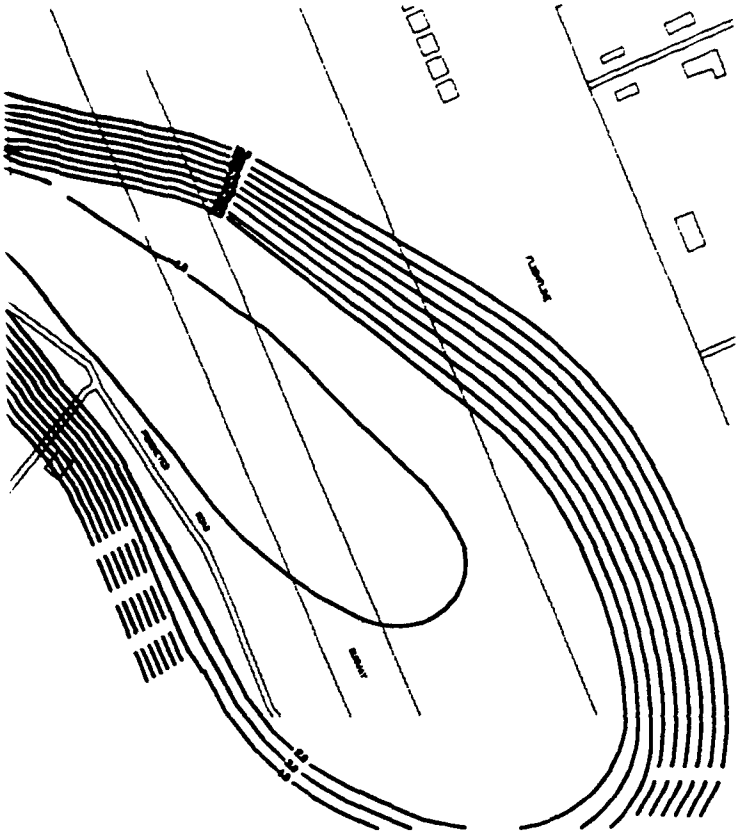
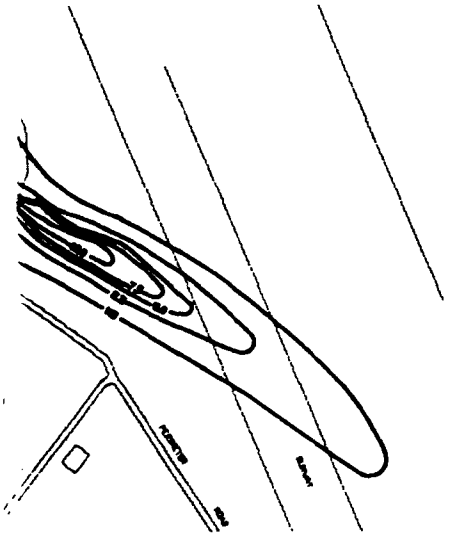
3. Measured pE
which electron a



FERROUS IRON (ppm)



DISSOLVED OXYGEN (ppm)



FERROUS IRON (ppm)

NOTES

1. Generally the oxidation of organic matter in closed systems has been observed to occur first by O_2 reduction, followed by denitrification, and then reduction of Fe^{3+} to Fe^{2+}.
2. Comparison of observed pE levels at the site suggest that this succession of redox reactions is thermodynamically possible.
3. Measured pE levels cannot be used alone to determine which electron acceptors are being used to degrade BTEX.

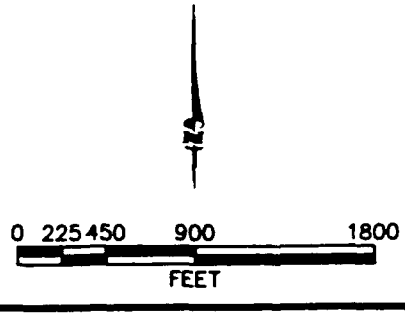


FIGURE 5.13

COMPARISON OF MICROBIALLY MEDIATED OXIDATION AND REDUCTION REACTIONS

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

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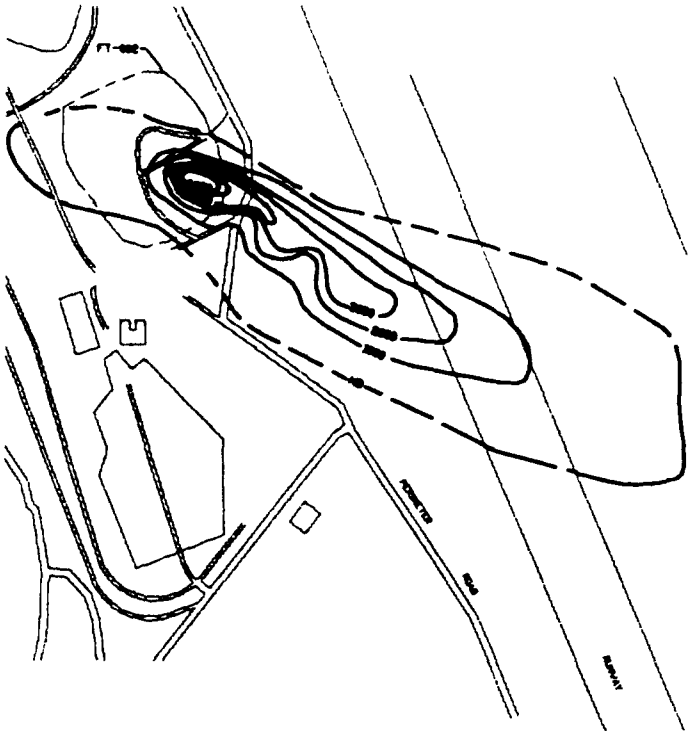
Chlorinated solvents are usually only partially transformed during cometabolic processes (McCarty and Semprini, 1994). The ultimate fate of the chlorinated solvents in the ground water will depend then on the effectiveness of other processes to completely mineralize these intermediate products. Cometabolism of TCE usually involves hydrogenolysis (the substitution of one hydrogen atom for a chlorine atom) or dihaloelimination (the substitution of two chlorine atoms with a double bond between the carbon atoms). Previous studies have shown that TCE can be anaerobically reduced to either cis- or trans-DCE, both of which can be further transformed to vinyl chloride (Miller and Guengerich, 1982; Wilson and Wilson, 1985; *Mayer et al.*, 1988; Nelson, *et al.*, 1988; Freedman *et al.*, 1989; Henson *et al.*, 1989; Tsien *et al.*, 1989; Henry, 1991; McCarty, 1994; Wilson *et al.*, 1994). Vinyl chloride may be subsequently reduced to ethylene or carbon dioxide.

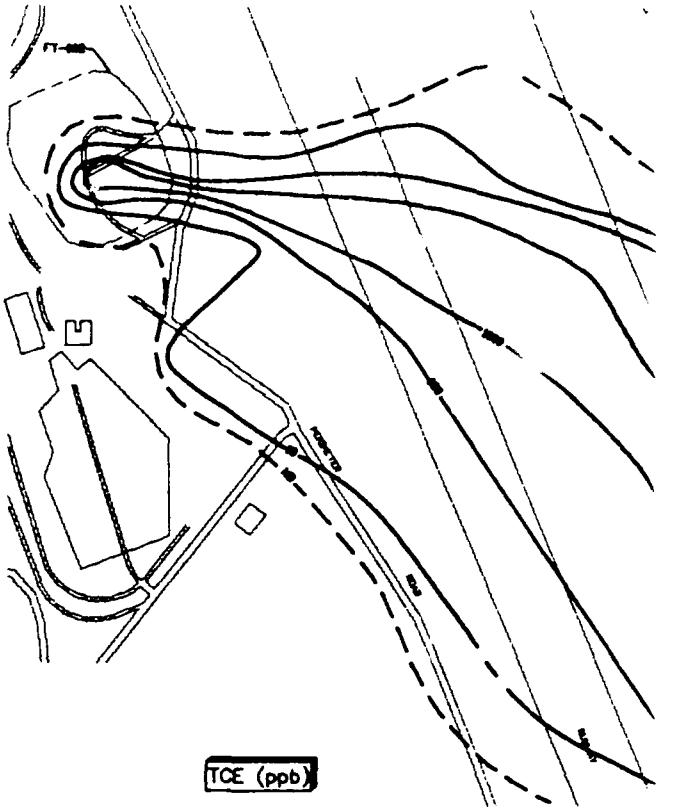
Reaction rates of cometabolism tend to be faster under reducing conditions associated with methane fermentation than under less reducing conditions associated with denitrification (Bouwer and Wright, 1988). There appears to be a correlation between rates of reaction and reducing conditions. The more reducing the conditions, the faster dechlorination occurs. This means that TCE degradation would likely be kinetically favorable in reducing environments where BTEX compounds are being degraded by denitrification, nitrate reduction, iron reduction, sulfate reduction, and methane fermentation. As described earlier, analytical data from the site suggest that all of these processes are occurring within areas of high BTEX concentrations at Site FT-002.

TCE, cis- and trans-DCE, vinyl chloride, ethylene, and chloride were measured at ground water monitoring wells and CPT water sampling locations in December 1993 and at the CPT sampling location and newly installed ground water monitoring points in May 1994. Table 4.7 in Section 4 presented analytical data for the chlorinated solvents by sample location. Table 5.6 summarizes analytical data on chloride and ethylene by sampling location.

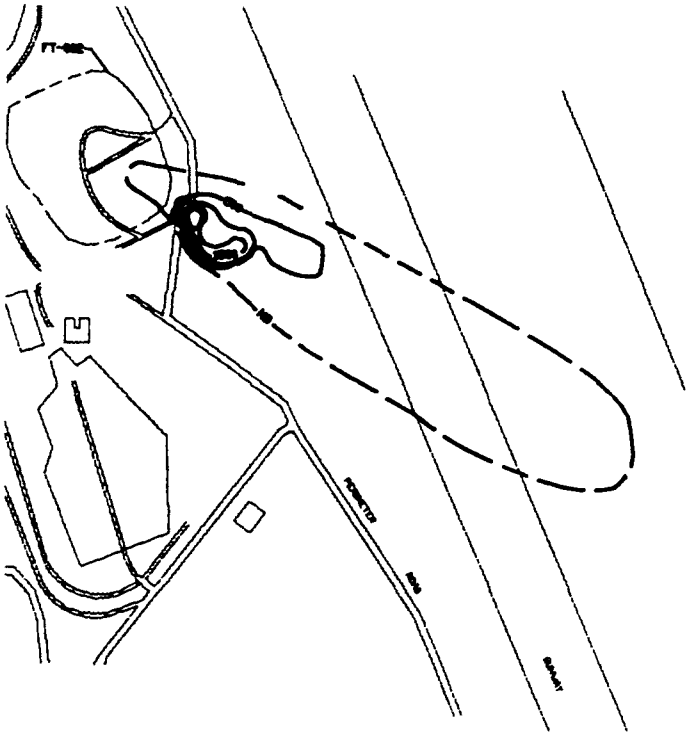
Figure 5.14 shows the apparent relationships between high BTEX concentrations and possible TCE degradation (vinyl chloride and chloride). The production of vinyl chloride and chloride correlate well with areas of high BTEX concentrations. Additionally, elevated vinyl chloride and chloride concentrations are limited to areas that appear to be anaerobic and highly reducing (see Figure 5.13 for comparison). Vinyl chloride in ground water is generally produced from the reductive dechlorination of TCE. Additionally, neither DCE nor vinyl chloride were identified in the free produce sample collected at the site (see Table 4.3). The absence of these compounds in the suspected source suggests that they are being produced within the ground water.



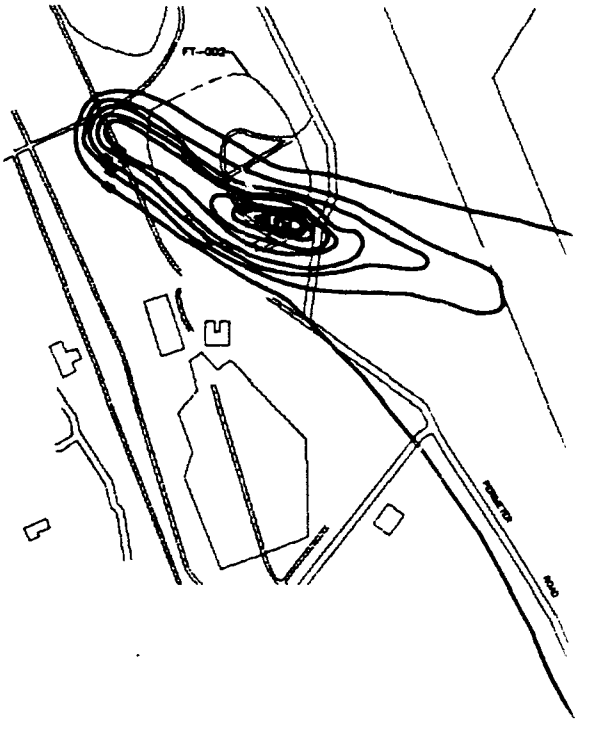
TOTAL BTEX (ppb)



TCE (ppb)



VINYL CHLORIDE (ppm)



CHLORIDE (ppm)

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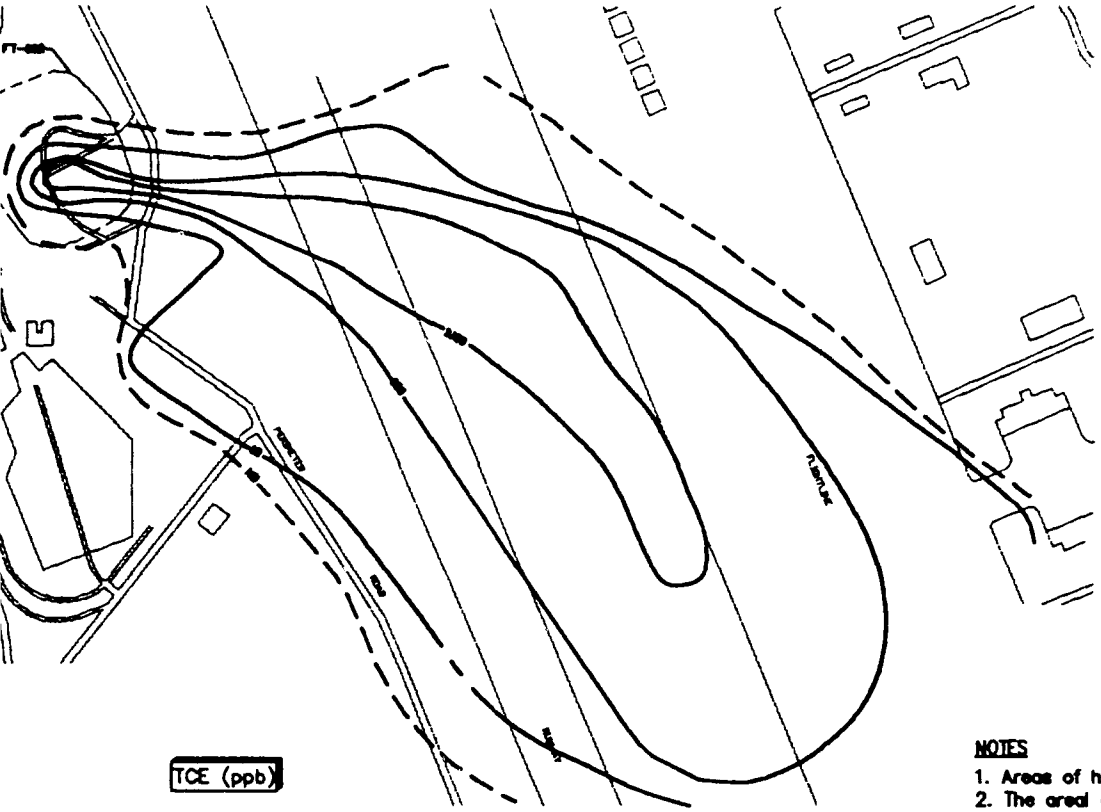

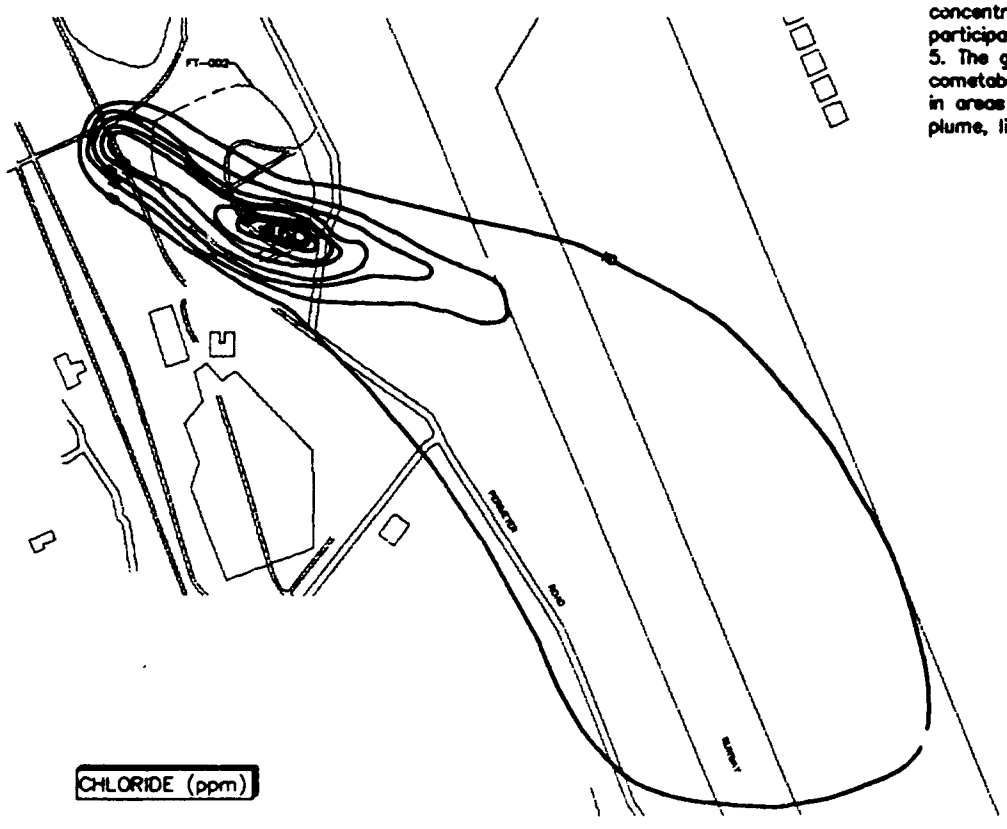

NOTES

1. Areas of high dissolved BTEX levels correlate well to high dissolve
2. The areal extent of the dissolved TCE plume is much greater tho plume even though the contaminants share the same source.
3. Elevated levels of vinyl chloride were observed in areas of both h concentrations of BTEX and TCE. Vinyl Chloride is a degradation pro
4. The production of DCE, vinyl chloride and chloride may be the re of TCE. Interestingly, elevated chloride and vinyl chloride levels corre concentrations. This relationship suggests BTEX may directly or indir participate in the dechlorination of TCE.
5. The greater areal extent of the TCE plume further supports the cometabolic degradation of TCE. Vinyl chloride and chloride are only in areas also contaminated with BTEX; once the TCE migrates beyon plume, little to no TCE degradation appears to be occurring.

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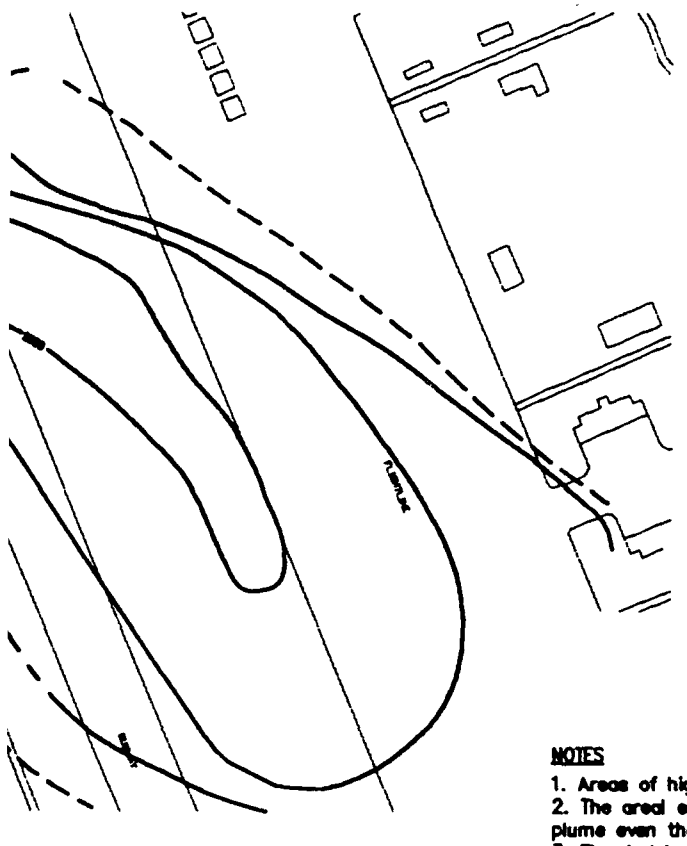

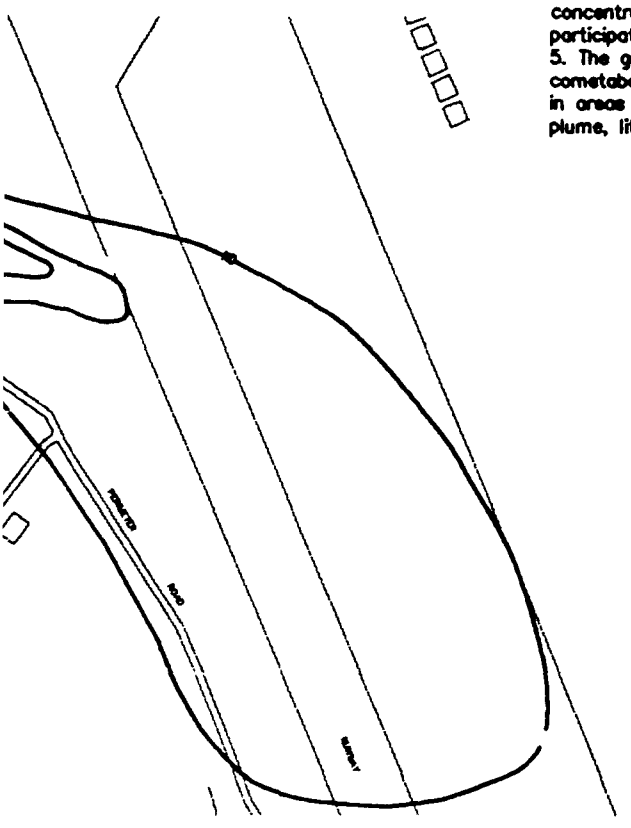

NOTES

1. Areas of high dissolved BTEX levels correlate well to high dissolved TCE levels.
2. The areal extent of the dissolved TCE plume is much greater than the dissolved BTEX plume even though the contaminants share the same source.
3. Elevated levels of vinyl chloride were observed in areas of both high concentrations of BTEX and TCE. Vinyl Chloride is a degradation product of TCE.
4. The production of DCE, vinyl chloride and chloride may be the result of dechlorination of TCE. Interestingly, elevated chloride and vinyl chloride levels correspond to elevated BTEX concentrations. This relationship suggests BTEX may directly or indirectly participate in the dechlorination of TCE.
5. The greater areal extent of the TCE plume further supports the hypothesis of cometabolic degradation of TCE. Vinyl chloride and chloride are only produced in areas also contaminated with BTEX; once the TCE migrates beyond the BTEX plume, little to no TCE degradation appears to be occurring.

0 200 400 800 1600

FEET

FIGURE 5.14

EVIDENCE SUGGESTING COMETABOLIC TCE DEGRADATION

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Anaerobic cometabolic degradation of TCE to the first intermediate product cis- or trans-DCE occurs as follows:

$$C_6H_6 + 4.5H_2O \rightarrow 2.25CO_2 + 3.75CH_4 + \text{microbially-produced cofactor} \rightarrow$$

$$\text{TCE} + \text{microbially-produced cofactor} \rightarrow \text{DCE} + Cl^-$$

This relationship shows how the reduction of BTEX via methane fermentation may bring about the dechlorination of TCE to DCE via cometabolic processes. Similar relationships can be developed for each of the intermediates or completely dehalogenated products (i.e., CO_2 and Cl^-). The TCE does not act as an oxidant in the same manner that other electron acceptors do during microbial respiration of BTEX compounds. Rather, the TCE is indirectly transformed by the hydrocarbon-degrading bacteria as they use the BTEX compounds to meet their energy requirements. Therefore, TCE does not enhance the degradation of BTEX, nor interfere with the use of electron acceptors such as ferric iron and carbon dioxide that may be involved in the oxidation of the BTEX compounds. It is possible, however, that the cometabolic degradation of TCE could inhibit the enzymatic capabilities of the hydrocarbon-degrading microorganisms because the degradation products of TCE are more toxic or may interfere with microbial electron transport systems. The cometabolism of TCE occurs through an epoxide, which is more toxic than its parent compound (McCarty and Semprini, 1994).

Aerobic degradation of TCE has also been documented (Wilson and Wilson, 1985; Little *et al.*, 1988; Fox *et al.*, 1990). TCE has been shown to be cometabolized under aerobic conditions by methanotrophic bacteria (i.e., microorganism that oxidize methane to meet their energy requirements) (Fogel *et al.*, 1986; Little *et al.*, 1988; Tsien *et al.*, 1989; Grbic-Galic, 1990; Lanarone and McCarty, 1990). More recent evidence suggests that TCE can also be mineralized by ethylene oxidizers, ammonia oxidizers, and vinyl chloride oxidizers (Arciero *et al.*, 1989; Henry, 1991; Vannelli *et al.*, 1990; Hartsman and deBonts, 1992).

Unfortunately, the chloride data for Site FT-002 cannot be used to quantitatively investigate whether TCE may also be biodegraded under aerobic conditions. Elevated concentrations of chloride in the background well (MW-02-026) made it difficult to determine if significant chloride production was occurring within and downgradient of the source area. Additionally, chloride is generally thought to be chemically conservative in ground water systems. Thus, chloride will migrate with the ground water. Any elevated concentrations of chloride downgradient of the BTEX plume may merely be the result of anaerobic dechlorination products that have migrated into areas where little or no dechlorination is occurring. As a result, it was

difficult to determine if TCE is being degraded in these downgradient areas. However, data suggest that little to no intermediate products such as DCE or vinyl chloride were being produced in areas downgradient from the BTEX plume.

Because TCE biodegradation occurs via cometabolic processes, it is unlikely that significant TCE is being biodegraded in areas downgradient of the source and dissolved BTEX plume. TCE biodegradation is brought about by specific enzymes or cofactors that are produced during metabolism of organic carbon sources. Areas depleted of this primary substrate will not stimulate the production of these chemically reactive agents. Consequently, it is unlikely that significant aerobic biodegradation of TCE is occurring at Site FT-002. However, the presence of TCE degradation products such as DCE and vinyl chloride suggest that TCE is being biodegraded under anaerobic conditions within the BTEX plume at Site FT-002.

5.5.2 Theoretical Assimilative Capacity Estimates

The preceding discussions have been devoted to determining if the BTEX compounds and chlorinated solvents were biodegrading at Site FT-002. Analytical data on reduced and oxidized chemical species indicate that indigenous microorganisms are facilitating the oxidation of thermodynamically possible redox reactions involving the BTEX compounds and other electron acceptors to generate free energy for cell maintenance and production. But just how much BTEX can be biodegraded? This question must be addressed before it is possible to assess the potential for intrinsic remediation at the site.

5.5.2.1 Relevant Stoichiometric Relationships

Mass balance relationships can be used to determine how much BTEX can be degraded by each of the redox reactions that the microorganisms might use to make free energy available for cell maintenance and production. The stoichiometric relationship between reductant (BTEX) and oxidant (electron acceptor) can be used to estimate the assimilative capacity of the ground water. Now that the redox reactions that are operating at Site FT-002 have been defined, it is possible to estimate how much BTEX can be assimilated or oxidized by available electron acceptors. This analysis will provide the basis for determining the potential for intrinsic remediation of ground water BTEX contamination at the site.

Table 5.2 lists the coupled redox reactions that may be used to biodegrade BTEX. As discussed earlier, BTEX appears to be biodegraded at Site FT-002 via oxygen reduction, nitrate

reduction, ferric iron reduction, sulfate reduction, and methane fermentation. Table 5.2 also presents the stoichiometric mass ratio of electron acceptors needed to oxidize each particular BTEX compound. For example, the mass ratio for aerobic respiration of benzene means that 3.07 grams of molecular oxygen are needed to completely oxidize 1 gram of benzene to carbon dioxide and water.

These stoichiometric mass ratios can be used to estimate the total assimilative capacity of the ground water at Site FT-002. This is accomplished by first determining the initial mass of each electron acceptor available in the ground water. Data on these chemical species were collected at sample locations upgradient of the site. These data are assumed to represent the "pristine" concentrations of these electron acceptors. As ground water migrates downgradient into the source area, electron acceptors are brought into contact with hydrocarbon-degrading microorganisms and BTEX contamination. These "pristine" concentrations are divided by the mass of electron acceptors required to mineralize each of the BTEX compounds to estimate the intrinsic capacity of the ground water to oxidize BTEX.

5.5.2.2 Total Assimilative Capacity

The background concentrations of each of the electron acceptors that appear to be operating at the site to degrade BTEX (as indicated by site analytical data) are listed in Table 5.7. This table also presents the total assimilative capacity of each electron acceptor for BTEX (using an average stoichiometric mass ratio). Based on this calculation, the ground water at Site FT-002 has the intrinsic capacity to oxidize a concentration of approximately 8.4 ppm of total BTEX using available oxygen, nitrate, ferric iron, sulfate, and carbon dioxide. The maximum concentration of total BTEX measured in the ground water at Site FT-002 was about 6 ppm. This comparison suggests that the intrinsic capacity of the ground water to oxidize BTEX is sufficient to remediate current levels of ground water contamination.

5.5.2.3 Apparent Distribution and Contribution of Redox Processes

As described earlier, the indigenous microorganisms can only utilize certain electron acceptors to oxidize the BTEX compounds if the environmental conditions make such a reaction thermodynamically feasible. The sequence of expected redox reactions occurring at the site are tied to the capabilities of the resident microorganisms, the amount of free energy the redox reaction will release to the microorganisms, and the availability of the electron acceptors to participate in these redox reactions. Figure 5.15 illustrates the apparent distribution of redox

TABLE 5.7
CALCULATION OF INTRINSIC ASSIMILATIVE CAPACITY
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Redox Process	Background Concentration of Electron Acceptor (ppm)	Mass of BTEX That Can Be Assimilated (ppm)
Oxygen Reduction	10	3.2
Nitrate Reduction	0.51	0.17
Ferric Iron Reduction	10.7*	0.49
Sulfate Reduction	19.6	4.1
Methane Fermentation	0.512*	0.4
	Total	8.36

*Concentration of reduced species at background level.
Assimilative capacity "back calculated" based on products.

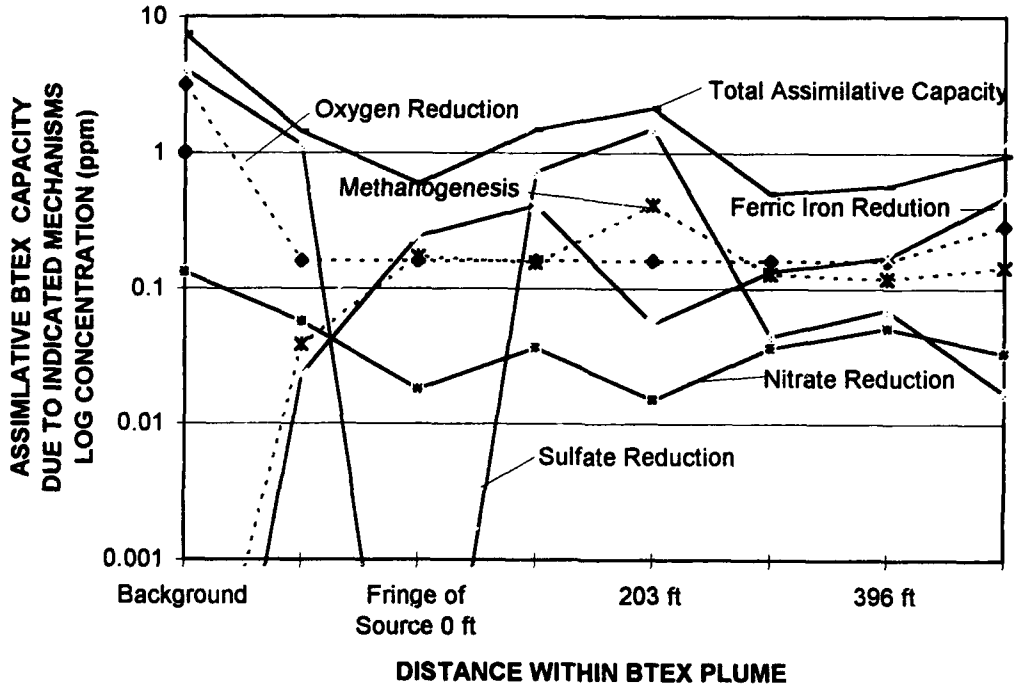

FIGURE 5.15

DISTRIBUTION OF GROUND WATER ASSIMILATIVE CAPACITY

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reactions at the FT-002 site relative to the BTEX plume. As this figure suggests, oxygen reduction occurs first. Once the oxygen has been depleted, nitrate reduction becomes the predominant redox reaction. The reduction of molecular oxygen and nitrate reduces the oxidizing capacity of the ground water to levels that are then sufficiently reducing for iron reduction, sulfate reduction, and methane fermentation to occur. This sequence of redox reactions appears to be occurring at the FT-002 site. However, it is important to keep in mind that defining the distribution of redox processes by location is complicated by mass transport mechanisms (Lovley *et al.*, 1994). It is difficult at best to define localized areas where specific redox processes are occurring in flowing ground water.

Figure 5.16 shows the relative contribution of each of the specific redox processes as a function of distance within the plume. These data suggest that oxygen reduction represents the greatest fraction of total assimilative capacity that is utilized at the site. Although sulfate is a larger potential reservoir of oxidizing capacity for BTEX, this redox process is not fully utilized (i.e., the oxidizing capacity of sulfate is not exhausted). Once within the source area of the BTEX contamination, ferric iron and carbon dioxide represent the majority of the oxidizing capacity of the ground water.

This type of comparison is instructive in that it indicates that not all of the available intrinsic assimilative capacity of the ground water is apparently being utilized. The calculated theoretical capacity of the ground water to oxidize BTEX represents an upper boundary. It can be used to estimate the total mass of BTEX that can be biodegraded at the site. Because the calculated theoretical assimilative capacity is greater than the maximum total BTEX concentration measured at the site, it implies that the ground water may have the capacity to oxidize higher concentrations of BTEX as they dissolve from the existing source into the ground water. Theoretically, the maximum concentration of BTEX that can partition from the source product into ground water was estimated to be almost an order of magnitude greater than the maximum BTEX concentration observed at the site in December 1993 (see Appendix E). Thus, it appears that the assimilative capacity at Site FT-002 may be sufficient to at least limit the concentration of BTEX in ground water to observed concentrations, which are an order of magnitude less than that predicted by chemical partitioning relationships.

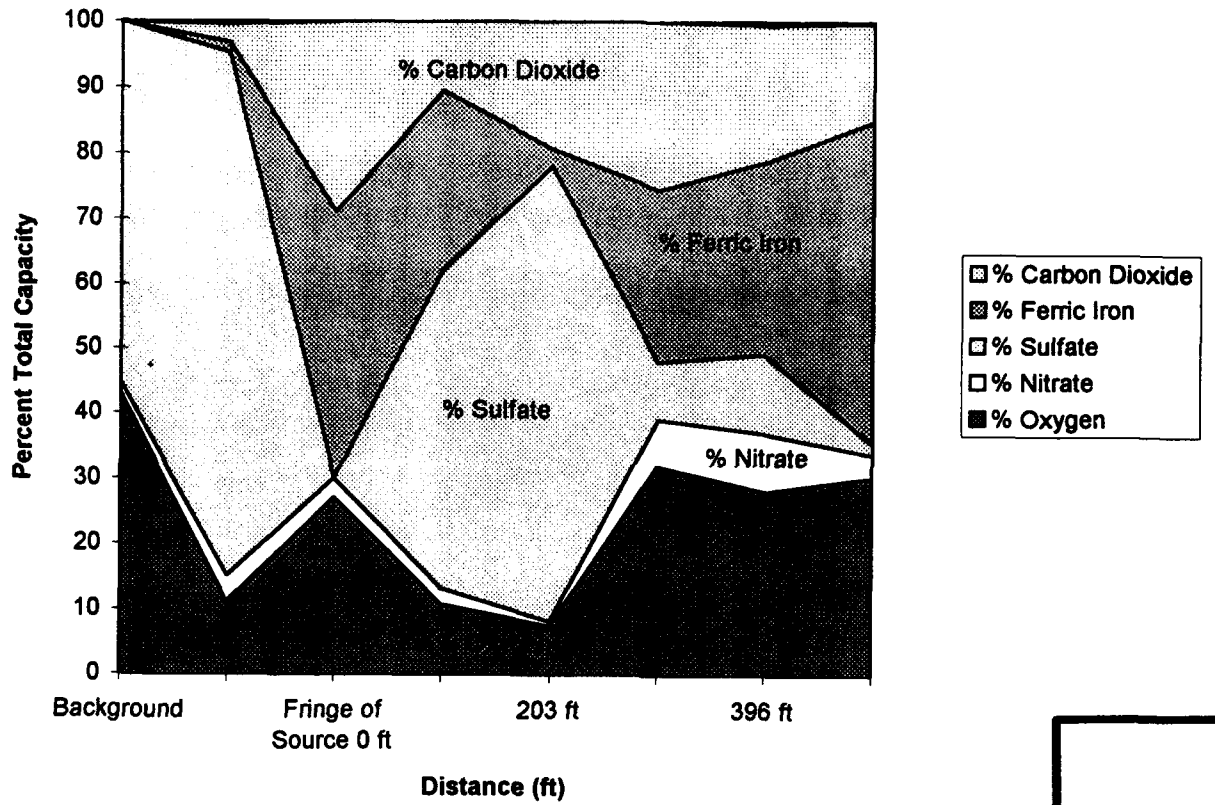

FIGURE 5.16

RELATIVE CONTRIBUTION OF REDOX PROCESSES

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5.5.3 Correlation Between Theoretical Assimilative Capacity and Observed Contaminant Mass Reduction

To investigate whether theoretical assimilative capacity estimates could be used to adequately describe the apparent reduction in BTEX mass due to destructive mechanisms, the change in assimilative capacity was compared to the mass reduction of BTEX as a function of distance within and downgradient of the BTEX source area. Figure 5.17 summarizes this comparison. As this figure shows, the reduction in the total assimilative capacity of the ground water roughly corresponds to the reduction in BTEX mass via destructive attenuation processes. Note that the BTEX concentrations included on this figure have been corrected for the effects of nondestructive mechanisms (i.e., dispersion, diffusion, and adsorption).

The potential for cometabolic degradation of chlorinated solvents also is suggested by theoretical assimilative capacity estimates. Although TCE degradation does not participate in the degradation of BTEX or exert a demand on the available electron acceptors, there is ng correlation between the extent of redox processes involving BTEX degradation ar E degradation. As the assimilative capacity of the ground water is reduced, the predominant redox processes become sulfate reduction and methane fermentation. The microorganisms that can facilitate these processes have been shown to produce the enzymes and/or cofactors necessary to degrade TCE (Miller and Guengerich, 1982; Wilson and Wilson, 1985; Mayer *et al.*, 1988; Nelson *et al.*, 1988; Freedman *et al.*, 1989; Henson *et al.*, 1989; Tsien *et al.*, 1989; Henry, 1991; McCarty, 1994; Wilson *et al.*, 1994).

Figure 5.18 shows that the production of TCE degradation products are inversely related to the reduction in the total assimilative capacity of the ground water. This means that as the ground water becomes more reducing, sulfate reduction and methane fermentation will become the predominant redox processes involved in BTEX biodegradation. The microorganisms that facilitate these reactions produce enzymes or cofactors that cause the dechlorination of TCE. This relationship is strong evidence that TCE is being cometabolized under anaerobic, reducing conditions at the FT-002 site. Downgradient of the BTEX plume core, the ground water is less anoxic and less reducing. Redox couples with relatively high oxidizing potentials are still present in the ground water and available to participate in the oxidation of BTEX. The types of microorganisms that will facilitate BTEX biodegradation in these downgradient areas are different than those that are utilizing electron acceptors with less oxidizing potential in the source area. These microorganisms may not produce the cofactor or enzyme necessary to dechlorinate TCE, DCE, and vinyl chloride. Thus, the type of cometabolic degradation of chlorinated solvents that occurs in the BTEX plume core would cease in these downgradient areas.

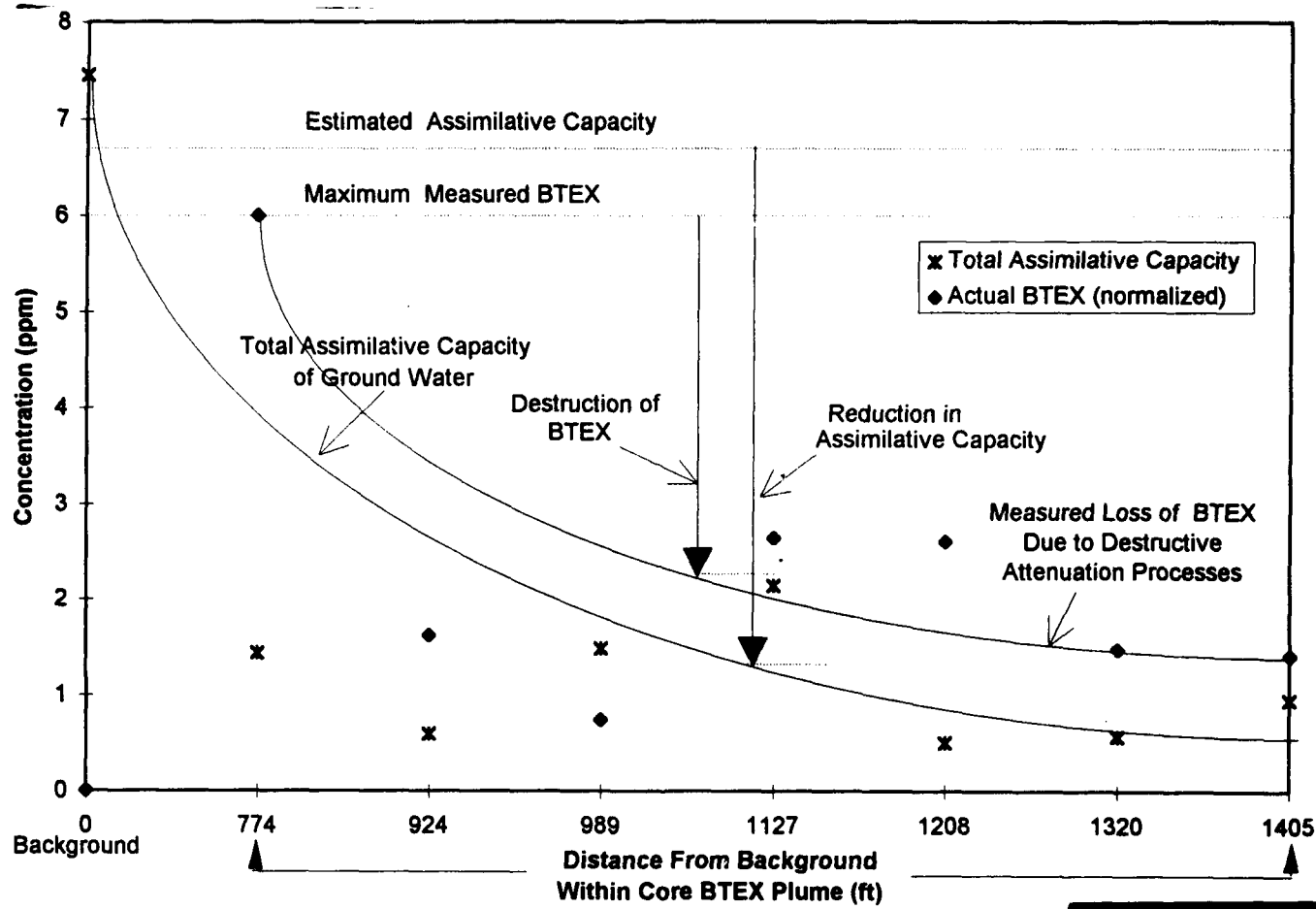

FIGURE 5.17

COMPARISON OF THEORETICAL ASSIMILATIVE CAPACITY TO OBSERVED BTEX MASS REDUCTION

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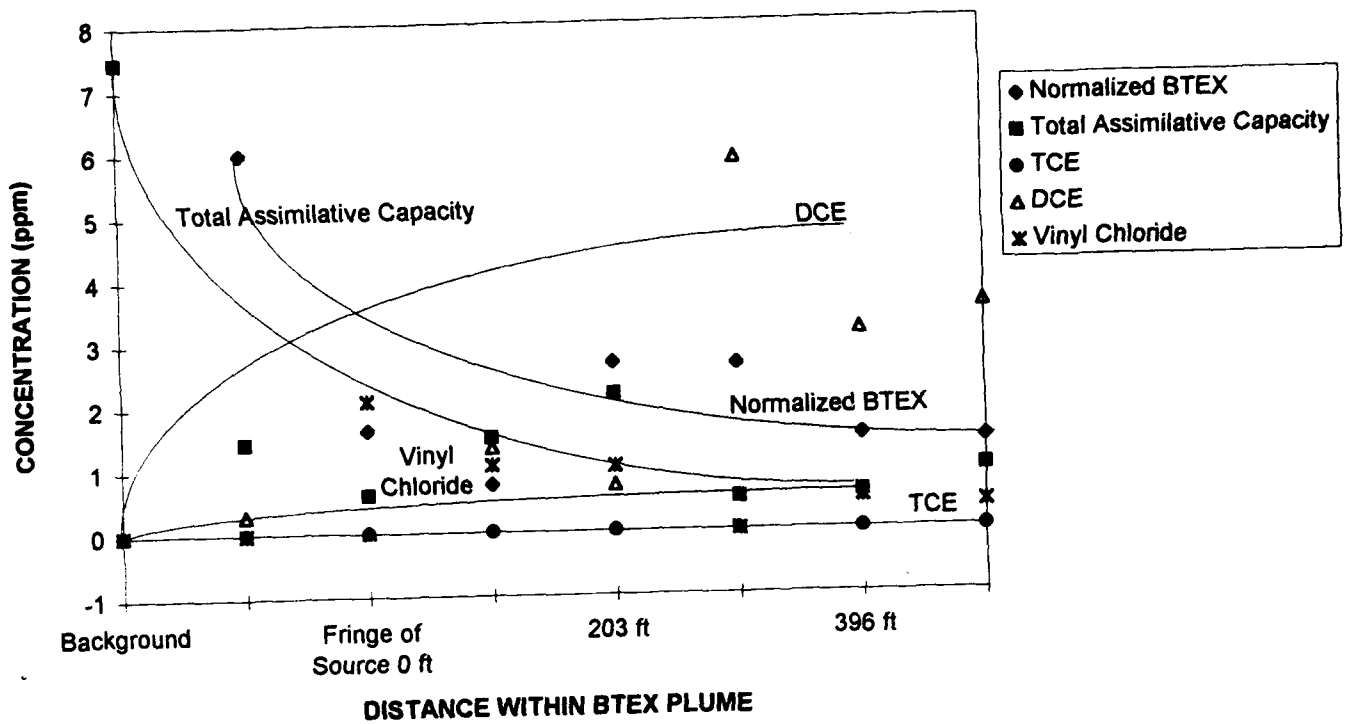

FIGURE 5.16

COMETABOLIC DEGRADATION OF TCE

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5.5.4 Equilibrium Limitations

Because the oxidation of BTEX is brought about by the reduction of some other chemical, it is conceivable that the degradation of BTEX could be halted once the redox processes reach equilibrium. That is, at some point, the degradation of BTEX would halt when it is no longer energy yielding (i.e., minimization of the Gibbs free energy). However, all of the ΔG_r values for the oxidation of the BTEX compounds are significantly negative (see Table 5.2). This is significant because it means that the BTEX compounds are thermodynamically unstable in ground water in the presence of these electron acceptors and microorganisms that can facilitate these redox processes. There will be no equilibrium level for the biodegradation of BTEX, and in the future no BTEX will remain if sufficient electron acceptors are available and the microorganisms are not prevented physically from facilitating these processes.

5.6 OTHER CONSIDERATIONS

Other data that should be considered when assessing the feasibility of intrinsic remediation are related to the ability of the ground water to maintain environmental conditions that are conducive to microbial activity. For example, total alkalinity is a measure of a ground water's ability to buffer changes in pH. This is important because microbial activity generates acids, which can ultimately interfere with the microorganisms' ability to oxidize BTEX. Tables 5.5 and 5.6 list alkalinity and pH data collected at the site. Both data sets suggest that site ground water can and has maintained a stable pH. The range of pH measured at Site FT-002 (i.e., 6.9 to 8.3) is optimal for BTEX-degrading microbes.

5.7 SUMMARY

This section has focused on explaining how and why intrinsic remediation occurs. Additionally, data have been presented that demonstrate that the BTEX compounds and chlorinated solvents at Site FT-002 are biodegrading. The main points of this section are summarized as follows:

- Microorganisms facilitate energy-consuming reactions such as BTEX oxidation by coupling them to energy-yielding reactions such as oxygen reduction;
- Microorganisms utilize electron acceptors in order of their thermodynamic energy yield and oxidizing potential;

- BTEX is biodegrading at Site FT-002 via oxygen reduction, nitrate reduction, ferric iron reduction, sulfate reduction, and methane fermentation;
- TCE is biodegrading at Site FT-002 under reduced conditions via anaerobic cometabolic mechanisms; and
- Theoretical assimilative capacity estimates for Site FT-002 and equilibrium considerations indicate that BTEX mass can be completely transformed in time.

Thus, the potential for intrinsic remediation of the shallow ground water exists at the site. The Bioplume II model was employed to test how effective these processes will be in reducing BTEX mass in the ground water over time. Modeling results are presented in Section 6.

SECTION 6

GROUND WATER FLOW AND CONTAMINANT TRANSPORT MODEL

6.1 GENERAL OVERVIEW AND MODEL DESCRIPTION

Parsons ES modeled the fate and transport of the dissolved-phase BTEX plume at the FT-002 site. The objectives of this modeling effort were to predict the future extent and concentration of the dissolved BTEX plume by modeling the combined effects of advection, dispersion, adsorption, and biodegradation; to assess whether any exposure pathways involving ground water could be completed; and to provide technical support for the natural attenuation remedial option at post-modeling regulatory negotiations. The model was developed using site-specific data and conservative assumptions about governing physical and chemical processes. Because of the conservative nature of model input parameters, the reduction in contaminant mass caused by destructive contaminant attenuation mechanisms is expected to exceed model predictions. The ground water fate and transport model can be used to support an exposure assessment at the site.

The Bioplume II model was used to estimate the potential for dissolved-phase BTEX migration and degradation by naturally occurring mechanisms operating at the FT-002 site. The Bioplume II model incorporates advection, dispersion, adsorption, and biodegradation to simulate contaminant plume migration and degradation. The model is based upon the USGS Method of Characteristics (MOC) two-dimensional (2-D) solute transport model of Konikow and Bredehoeft (1978). The model was modified by researchers at Rice University to include a biodegradation component that is activated by a superimposed DO plume. Based on the work of Borden and Bedient (1986), the model assumes a reaction between DO and BTEX that is instantaneous relative to the advective ground water velocity. Bioplume II solves the USGS 2-D solute transport equation twice, once for hydrocarbon concentrations in the aquifer and once for a DO plume. The two plumes are combined using superposition at every particle move to simulate the instantaneous, microbially-mediated reaction between BTEX compounds and oxygen.

Numerous laboratory and field studies suggest that anaerobic processes such as denitrification, iron reduction, sulfate reduction, and methanogenesis can also be important BTEX degradation mechanisms (Grbic'-Galic', 1990; Beller *et al.*, 1992; Edwards *et al.*, 1992; Edwards and Grbic'-Galic', 1992, Grbic'-Galic' and Vogel, 1987; Lovely *et al.*, 1989; Hutchins, 1991). There is evidence that anaerobic biodegradation processes are occurring at the FT-002 site (see Section 5). However, these processes were not accounted for during Bioplume II modeling due to the abundance of DO and the inability of the model to simulate the relative distribution and contribution of these redox processes and to be conservative. The following subsections discuss in more detail the model setup, input parameters and assumptions, model calibration, and simulation results.

6.2 CONCEPTUAL MODEL DESIGN AND ASSUMPTIONS

Prior to developing a ground water flow and contaminant transport model, it is important to determine if sufficient data are available to provide a reasonable estimate of aquifer conditions. In addition, it is important to ensure that any limiting assumptions can be justified. The most important assumption made when using the Bioplume II model is that oxygen-limited biodegradation is occurring at the site. The Bioplume II model assumes that the limiting factors for biodegradation are: 1) the presence of an indigenous hydrocarbon-degrading microbial population, and 2) sufficient background electron acceptor concentrations. Data and information presented in Section 5 suggest that oxygen, nitrate, ferric iron, sulfate, and carbon dioxide (methanogenesis) are being used as electron acceptors for aerobic and anaerobic biodegradation. To be conservative, only oxygen was used as an electron acceptor in the Bioplume II model presented herein. To model the biodegradation of BTEX compounds using DO as the only electron acceptor, the isopleth map for DO was superimposed on the model grid. Data from this map were then used for model input.

Based on the data presented in Section 3, the shallow saturated zone was conceptualized and modeled as a shallow unconfined aquifer comprised of sand (Figures 3.3 and 3.4). The use of a 2-D model was employed at the FT-002 site because the saturated interval is relatively homogenous. However, water level data indicate that the local flow system as defined by horizontal and vertical gradients could result in significant downward vertical migration of dissolved contamination (Figure 4.6b). To utilize the 2-D conceptual model for a 3-D environment, the zone of maximum BTEX concentration was assumed to be representative of the entire affected interval in the aquifer. Thus, the extent and

concentrations of the dissolved BTEX plume included in the Bioplume II model for this site were defined by the extent and concentration at the depth of maximum BTEX contamination. Assuming that the entire saturated zone of the aquifer was defined by these maximum BTEX concentrations is conservative. It was not possible to simulate the vertical distribution of dissolved BTEX compounds using a 2-D model. Existing evidence suggests that about 39,300 gallons of mobile LNAPL is present in the source area at the site (Table 4.3). Contaminated soils also are present at the site. Consequently, initial model simulations included a continuous source of dissolved BTEX contamination. This approach should appproximate the contaminant release mechanisms at the site. Both the mobile LNAPL and the contaminated soil could be significant sources of dissolved BTEX compounds. BTEX compounds partition from the LNAPL and thus dissolve into and migrate with ground water at the FT-002 site. Partitioning calculations included in Appendix E suggest that the mobile LNAPL, is the most significant source of BTEX.

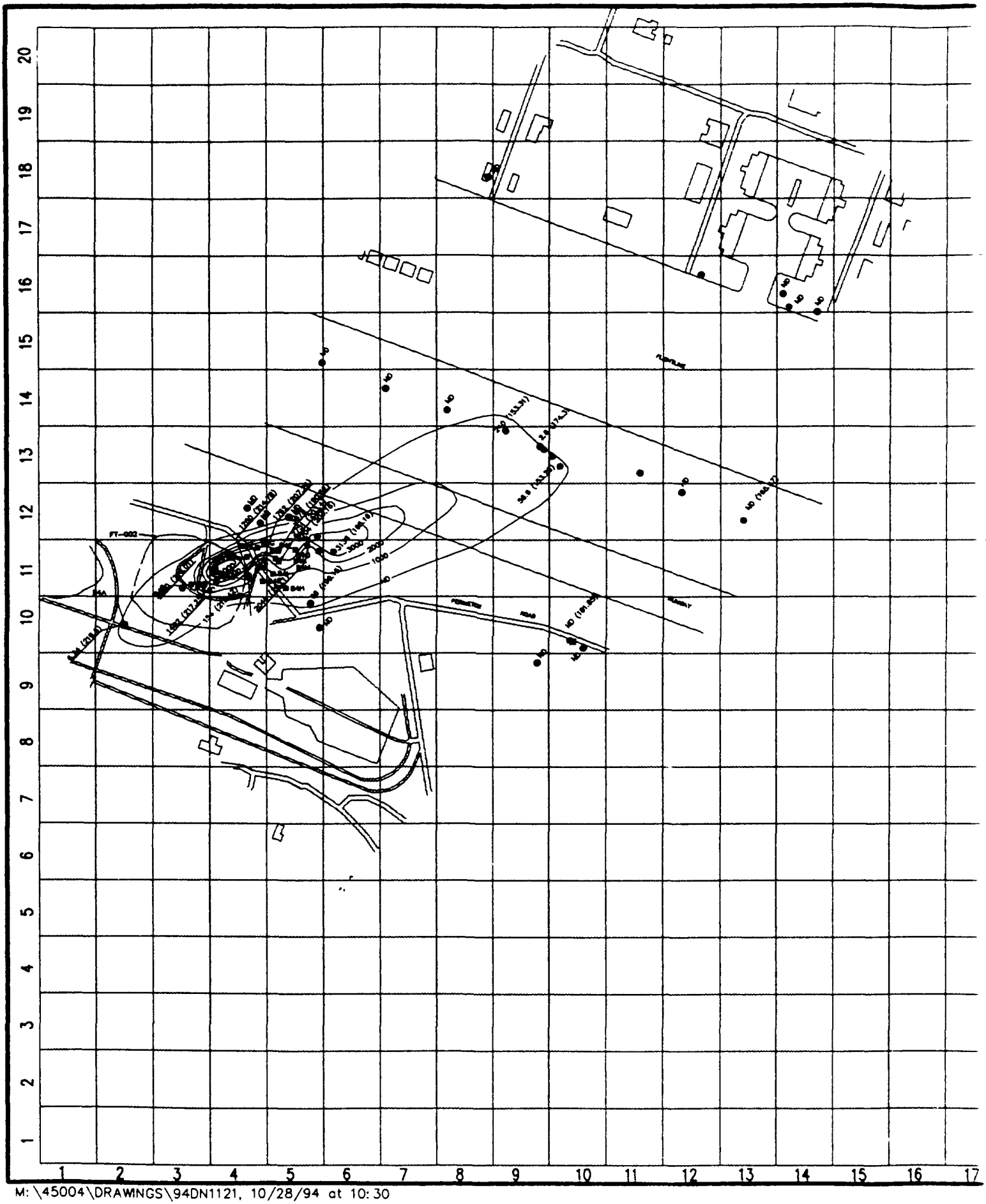
6.3 INITIAL MODEL SETUP

Where possible, the initial setup for this model was based on existing site data. Where site-specific data were not available (e.g., bulk density and effective porosity), reasonable assumptions for the types of materials comprising the shallow aquifer were made based on widely accepted literature values. The following sections describe the basic model setup. Those Bioplume II model parameters that were varied during model calibration are discussed in Section 6.4.

6.3.1 Grid Design and Boundary Conditions

The maximum grid size for the Bioplume II model is limited to 20 columns by 30 rows. The dimension of each column and row can range from 0.1 to 999.9 feet. A 20- by 20-cell grid was used to model the FT-002 site. Each grid cell was 400 feet long by 400 feet wide. The grid was oriented so that the grid was parallel to the overall direction of ground water flow. The model grid covers an area of 64 million square feet, or approximately 1,469 acres. The full extent of the model grid is indicated on Figure 6.1.

Model boundaries are mathematical statements that represent hydrogeologic boundaries, such as areas of specified head (e.g., surface water bodies or contour lines of



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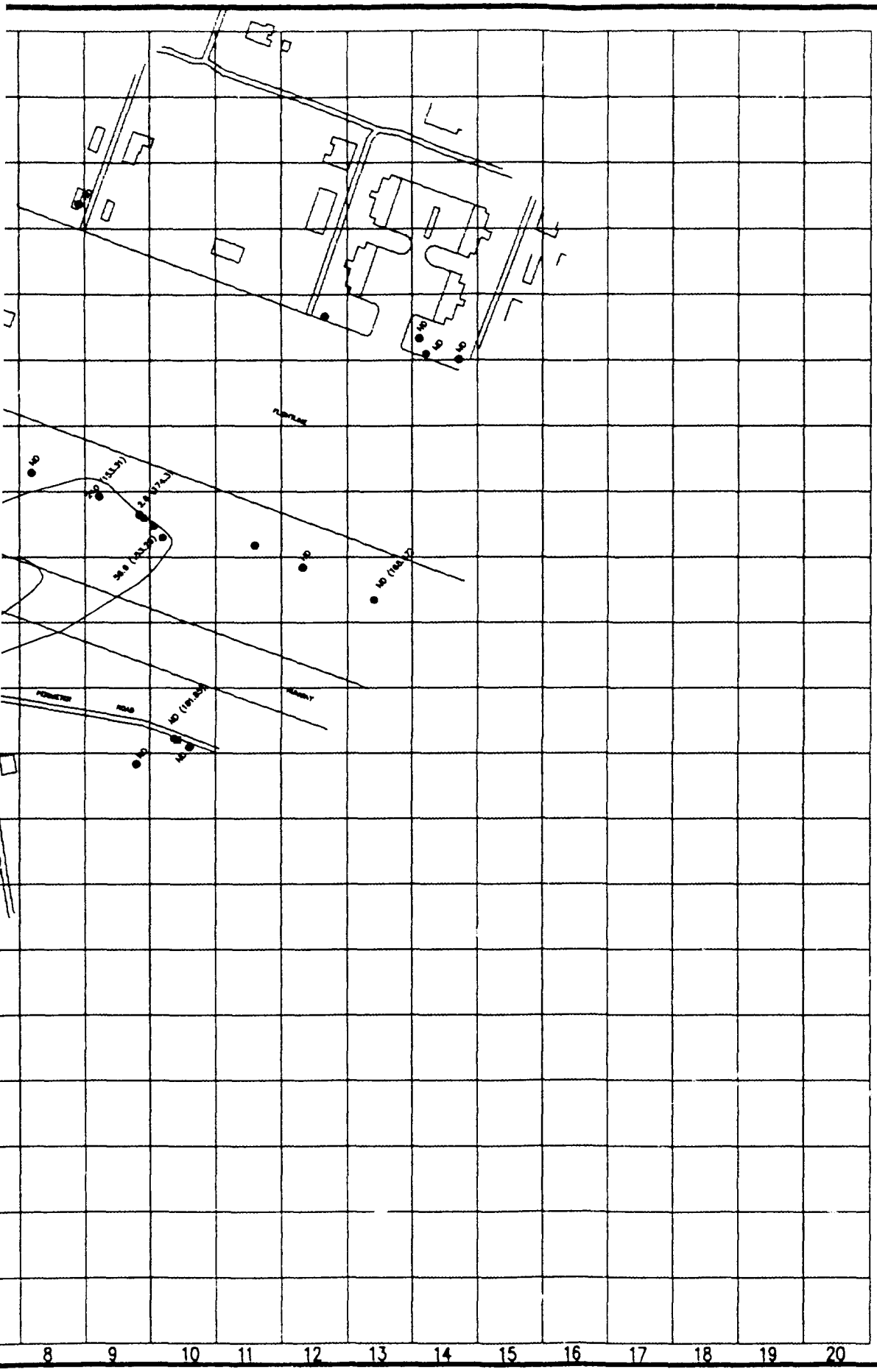
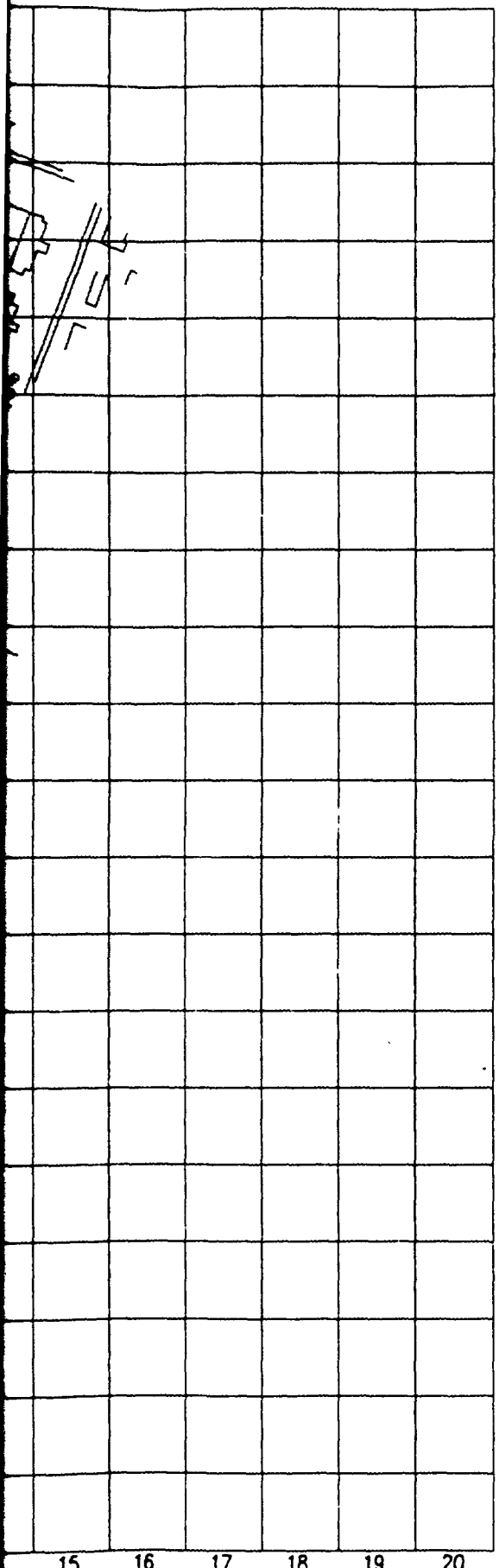


LEGEND

1200 (100) ◔	GROUND WATER MO W/TOTAL BTEX CON SAMPLE ELEV (feet
1200 (100) ⊕	LIF-CPT SAMPLING I CONCENTRATION IN (feet above msl) IN
—2.0—	LINE OF ESTIMATED
ND	NOT DETECTED
1000 ⊙	CONE PENETROMETE W/SAMPLE BTEX CO SAMPLE ELEV (FEET
	CONTOUR INTERVAL =

NOTES:

1. GRID CELL SIZE EQUA
2. ONLY SAMPLING LOCA DURING THIS CHARAC EFFORT ARE SHOWN



LEGEND

1200 (100) GROUND WATER MONITORING WELL W/TOTAL BTEX CONCENTRATION IN ppb (DECEMBER 1993) SAMPLE ELEV (feet above msl) IN PARENTHESES

1200 (100) LIF-CPT SAMPLING LOCATION W/TOTAL BTEX CONCENTRATION IN ppb (DECEMBER 1993) SAMPLE ELEV (feet above msl) IN PARENTHESES

—2.0— LINE OF ESTIMATED EQUAL TOTAL BTEX CONCENTRATION (ppb)

ND NOT DETECTED

1000 CONE PENETROMETER W/SAMPLE BTEX CONCENTRATION IN ppb (1991) SAMPLE ELEV (FEET ABOVE MSL) IN PARENTHESES

CONTOUR INTERVAL = 1000 ppb

NOTES:

1. GRID CELL SIZE EQUALS 400 FT. x 400 FT.
2. ONLY SAMPLING LOCATIONS USED DURING THIS CHARACTERIZATION EFFORT ARE SHOWN

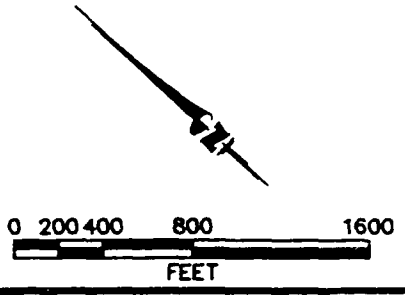


FIGURE 6.1

MODEL GRID

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constant hydraulic head) or specified flux. Hydrogeologic boundaries are represented by three mathematical statements that describe the hydraulic head at the model boundaries. These include:

- Specified-head boundaries (Dirichlet condition) for which the head is determined as a function of location and time only. Surface water bodies exhibit constant head conditions. Specified-head boundaries are expressed mathematically as:

$$Head = f(x,y,z,t)$$

where f is the function symbol, x,y,and z are position coordinates, and t is time.

- Specified-flow boundaries (Neumann conditions) for which the mathematical description of the flux across the boundary is given. The flux is defined as a volumetric flow rate per unit area (e.g., $ft^3/ft^2/day$). No-flow boundaries are a special type of specified flow boundary and are set by specifying the flux to be zero. Examples of no-flow boundaries include ground water divides and impermeable hydrostratigraphic units. Specified-flux boundaries are expressed mathematically as:

$$Flux = f(x,y,z,t)$$

- Head-dependent flow boundaries (Cauchy or mixed boundary conditions) where the flux across the boundary is calculated from a given boundary head value. This type of flow boundary is sometimes referred to as a mixed boundary condition because it is a combination of a specified-head boundary and a specified-flow boundary. Head-dependent flow boundaries are used to model leakage across semipermeable boundaries. Head-dependent flow boundaries are expressed mathematically as (Bear, 1979):

$$Flux = \frac{(H_0 - H)K'}{B'}$$

Where:
H = Head (feet) in the zone being modeled (generally the zone containing the contaminant plume),
H_0 = Head (feet) in external zone (separated from plume by semipermeable layer),
K' = Hydraulic conductivity (ft/day) of semipermeable layer, and
B' = Thickness (feet) of semipermeable layer.

Natural hydraulic boundaries are modeled using a combination of the three types of model boundary conditions listed above. When possible, hydrologic boundaries such as surface water bodies, ground water divides, contour lines, or hydrologic barriers should coincide with the perimeter of the model. In areas lacking obvious hydrologic boundaries, specified-head or specified-flux boundaries can be specified at the model perimeter if the boundaries are far enough removed from the contaminant plume that transport calculations are not affected. Bioplume II requires the entire model domain to be bounded by zero-flux cells (also known as no-flow cells), with other boundary conditions established within the subdomain specified by the no-flow cells.

Specified-head boundaries for the model were set on the northwestern and southeastern perimeter of the model grid to simulate the south-southeast ground water flow observed at the site. Both boundaries were set in the approximate location of the water table indicated by water level data. The head at the northwestern boundary was estimated to vary between 209 and 219 feet above msl. The head at the southeastern model boundary was assumed to vary between 155 and 167 feet above msl. The location of this contour was estimated from available water table elevation and flow gradient data (see Appendix B). These constant-head cells were placed far enough away from the BTEX plume to avoid potential boundary interferences.

The eastern and western model boundaries were configured as no-flow (specified flux) boundaries. In this case, the flux through these boundaries is assumed to be zero because flow is generally parallel to these boundaries. The base or lower boundary of the model is also assumed to be no-flow, and is defined by the upper surface of the confining glacial tills. The upper model boundary is defined by the simulated water table surface.

6.3.2 Ground Water Elevation and Gradient

The water table elevation map in Figure 3.5 was used to define the starting heads input into the Bioplume II model. Ground water flow in the vicinity of the FT-002 site is to the south-southeast with an average horizontal gradient of approximately 0.01 ft/ft between monitoring wells MW-02-006 and MW-02-043. The vertical ground water gradient was calculated to vary from 0.19 ft/ft upward to 0.15 ft/ft downward. Data quantifying seasonal variations in ground water flow direction and gradient at the site are presented in Table 3.1 and Appendix B. These data suggest that there are no significant seasonal variations in

ground water flow direction, and that seasonal horizontal gradients consistently vary around the average of approximately 0.01 ft/ft. As a result, it was assumed that the water levels measured in December 1993 were representative of steady-state conditions. As described in Section 6.4.1, the model was calibrated to the observed water table.

6.3.3 BTEX Concentrations

The total dissolved BTEX concentrations obtained from analytical results for each well location were used for model development. At well nests, the highest BTEX concentration observed at that location was used. Table 4.7 presents dissolved BTEX concentration data. Figures 4.6a and 4.6b show the December 1993 horizontal and vertical distribution of dissolved total BTEX compounds, respectively.

The extent and concentration of the BTEX plume in September 1991 was almost identical to the BTEX plume measured in December 1993. Little plume migration was observed during this time (see Section 5.3.1). The dissolved BTEX plume covers approximately 2.7 million square feet (63 acres). The shape and distribution of the total BTEX plume is the result of both advective-dispersive transport and biodegradation. As described in Section 6.4.2, the simulated BTEX plume was calibrated to match the observed BTEX plume.

6.3.4 Dissolved Oxygen

As discussed, the Bioplume II model assumes an instantaneous reaction between the BTEX plume and the DO plume. The data in Section 5.5.2 suggest that DO, nitrate, ferric iron, sulfate, and carbon dioxide (methanogenesis) are being used as electron acceptors during microbial respiration of BTEX compounds at the FT-002 site. To be conservative, the total BTEX plume at the site was modeled assuming that DO was the only electron acceptor being utilized at a rate that is instantaneous relative to the advective ground water velocity.

Ground water samples collected upgradient of the existing BTEX plume (i.e., at MW-02-026) suggest that background DO concentrations at the site are approximately 10 ppm. Therefore, background DO levels were assumed to be 10 ppm for Bioplume II model development. Table 5.4 presents DO data for the site. Figure 5.2a is a DO isopleth map at the depth of maximum BTEX concentration, and Figure 5.2b shows the vertical extent of DO at the FT-002 site. Oxygen input data are included in Appendix C.

The upgradient constant-head cells in the Bioplume II model require background DO concentrations to be input as constant concentrations to simulate incoming electron acceptors. The background DO concentration of 10 ppm was used for these cells.

6.4 MODEL CALIBRATION

Model calibration is an important component in the development of any numerical ground water model. Calibration of the ground water flow model demonstrates that the model is capable of matching hydraulic conditions observed at the site. Calibration of a contaminant transport model superimposed upon the calibrated flow model helps verify that contaminant loading and transport conditions are being appropriately simulated. The numerical ground water flow model presented herein was calibrated by altering transmissivity in a trial-and-error fashion until simulated heads approximated observed field values within a prescribed accuracy. After calibration of the ground water flow model, the numerical contaminant transport model was calibrated by altering hydraulic parameters and contaminant transport parameters in a trial-and-error fashion until the simulated BTEX plume approximated observed field values. Table 6.1 lists input parameters used for the modeling effort. Electronic copies of the model input and output are included in Appendix D.

6.4.1 Water Table Calibration

The shallow water table at the FT-002 site was assumed to be influenced only by continuous recharge and discharge at the constant-head cells established at the upgradient and downgradient model boundaries. To be conservative, recharge of the aquifer through rainfall (which would add water, thereby increasing dilution of the plume) was not included in the model. The rate of infiltration at the site has been estimated to be fairly low (ABB Environmental, Inc., and URS Consultants, Inc., 1993). Potential recharge by other sources was omitted because of a lack of reliable data. Only the initial water levels at the constant-head cells and the transmissivity values were varied to calibrate the water table surface. The model was calibrated under steady-state conditions.

Hydraulic conductivity is an important aquifer characteristic that determines the ability of the water-bearing strata to transmit ground water. Transmissivity is the product of the hydraulic conductivity and the thickness of the aquifer. An accurate estimate of hydraulic conductivity is important to help quantify advective ground water flow velocities and to

TABLE 6.1

BIOPLUME II MODEL INPUT PARAMETERS
FT-002 INTRINSIC REMEDIATION EE/CA
PLATTSBURGH AFB, NEW YORK

Parameter	Description	Model Runs		
		Calibrated Model Setup	PLATCAL	PLATPRD
NTIM	Maximum number of time steps in a pumping period	10	10	10
NPMP	Number of Pumping Periods	1	2	2
NX	Number of nodes in the X direction	20	20	20
NY	Number of nodes in the Y direction	20	20	20
NPMAX	Maximum number of Particles NPMAX=(NX-2)(NY-2)(NPTPND) + (Ns[a])(NPTPND) + 250	3600	3600	3600
NPNT	Time step interval for printing data	1	1	1
NITP	Number of iteration parameters	7	7	7
NUMOBS	Number of observation points	5	5	5
ITMAX	Maximum allowable number of iterations in ADIP [b]	200	200	200
NREC	Number of pumping or injection wells	2	2	2
NPTPND	Initial number of particles per node	9	9	9
NCODES	Number of node identification codes	1	1	1
NPNTMV	Particle movement interval (IMOV)	0	0	0
NPNTVL	Option for printing computed velocities	2	2	2
NPNTD	Option to print computed dispersion equation coefficients	2	0	0
NPDELC	Option to print computed changes in concentration	0	0	0
NPNCHV	Option to punch velocity data	0	0	0
NREACT	Option for biodegradation, retardation and decay	1	1	1
PINT	Pumping period (years)	38	38	38
TOL	Convergence criteria in ADIP	0.001	0.001	0.001
POROS	Effective porosity	0.3	0.3	0.3
BETA	Characteristic length (long. dispersivity; feet)	60	60	60
S	Storage Coefficient	0 (Steady-State)	0	0
TIMX	Time increment multiplier for transient flow	-	-	-
TINIT	Size of initial time step (seconds)	-	-	-
XDEL	Width of finite difference cell in the x direction (feet)	400	400	400
YDEL	Width of finite difference cell in the y direction (feet)	400	400	400
DLTRAT	Ratio of transverse to longitudinal dispersivity	0.25	0.25	0.25
CELDIS	Maximum cell distance per particle move	0.5	0.5	0.5
ANFCTR	Ratio of Tyy to Txx (1 = isotropic)	1.5	1.5	1.5
DK	Distribution coefficient	1.761	1.761	1.761
RHOB	Bulk density of the solid (grams/cubic centimeter)	1.6	1.6	1.6
THALF	Half-life of the solute	-	-	-
DEC1	Anaerobic decay coefficient (day^{-1})	0	0	0
DEC2	Reaeration coefficient (day^{-1})	0.001	0.001	0.001
F	Stoichiometric Ratio of Hydrocarbons to Oxygen	3.1	3.1	3.1

[a] Ns = Number of nodes that represent fluid sources (wells or constant head cells)
[b] ADIP = Alternating-direction implicit procedure (subroutine for solving ground water flow equation)

define the flushing potential of the aquifer and the quantity of electron-acceptor-charged ground water that is entering the site from upgradient locations. Based on the work of Rifai *et al.* (1988), the Bioplume II model is particularly sensitive to variations in hydraulic conductivity. Lower values of hydraulic conductivity result in a slower-moving plume that degrades at a slower rate because electron acceptors are not available for biodegradation. Higher values of hydraulic conductivity result in a faster-moving plume that degrades faster because more electron acceptors are available for biodegradation.

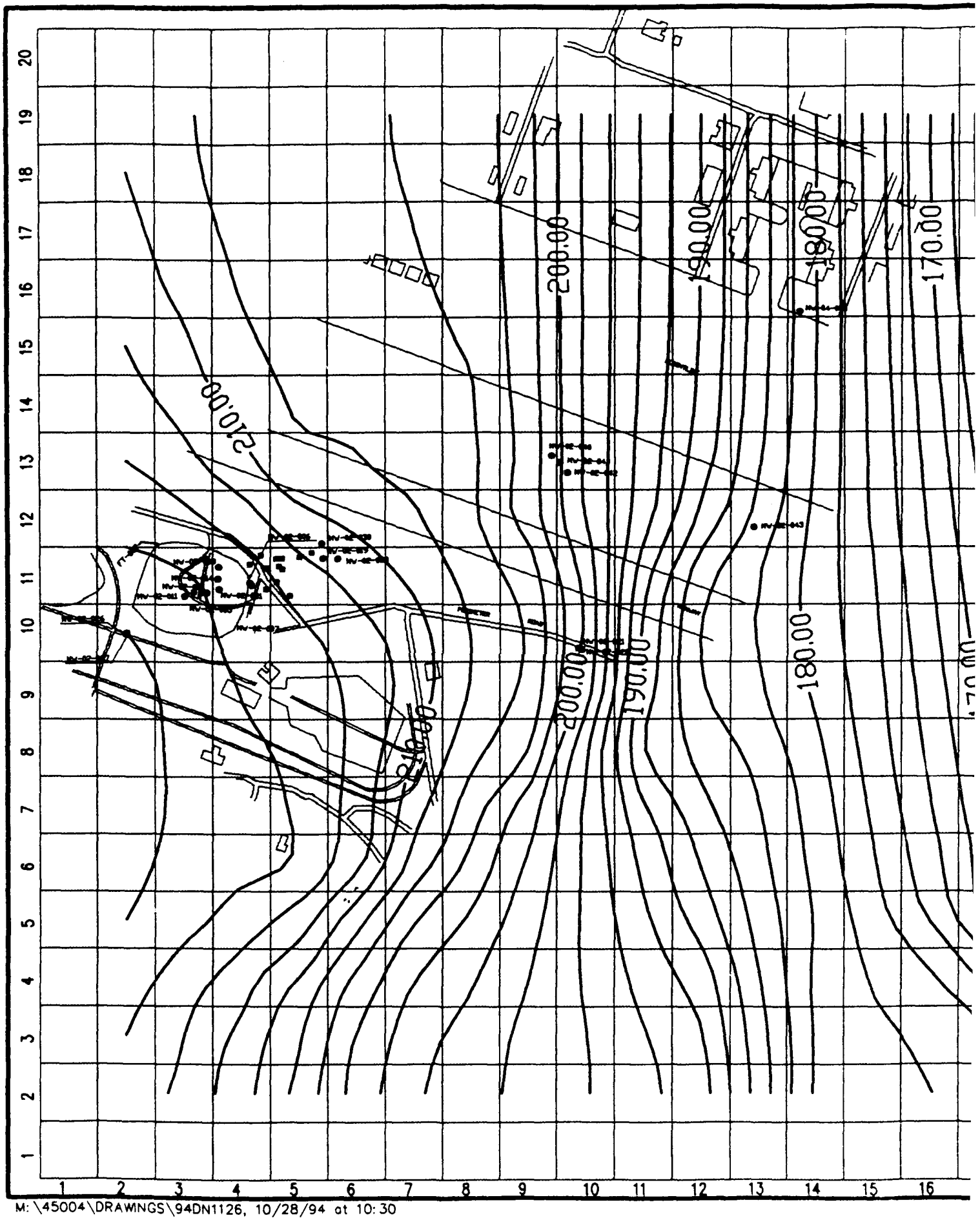
Saturated thickness data from previous reports, geologic logs, CPT surveys, seismic surveys, and water level measurements were used in conjunction with the average hydraulic conductivity (determined to be 11.6 feet/day (ABB Environmental, Inc., and URS Consultants, Inc., 1993) to estimate an initial uniform transmissivity for the entire model domain. To better match heads in the model to observed values, the transmissivities were progressively varied in blocks and rows until the simulated water levels for cells corresponded to the observed water levels at selected locations as closely as possible. Figure 6.2 shows the calibrated water table map. Calibrated model hydraulic conductivities ranged from 1.08 ft/day to 99.69 ft/day, which is within the range of K values determined during *in situ* testing (ABB Environmental Inc., and URS Consultants, Inc., 1993).

Water level elevation data from 13 ground water monitoring well locations were used to compare measured and simulated heads for calibration. The 13 selected locations were cells (4,3), (18,2), (11,4), (15,6), (11,8), (18,9), (4,10), (13,10), (18,12), (15,13), (7,15), (10,18), and (16,18).

The root mean squared (RMS) error is commonly used to express the average difference between simulated and measured heads. The RMS error is the average of the squared differences between measured and simulated heads, and can be expressed as:

$$\mathrm{RMS} = \left[\frac{1}{n} \sum_{i=1}^{n} (h_m - h_s)_i^2 \right]^{0.5}$$

Where: n = the number of points where heads are being compared,
h_m = measured head value, and
h_s = simulated head value.



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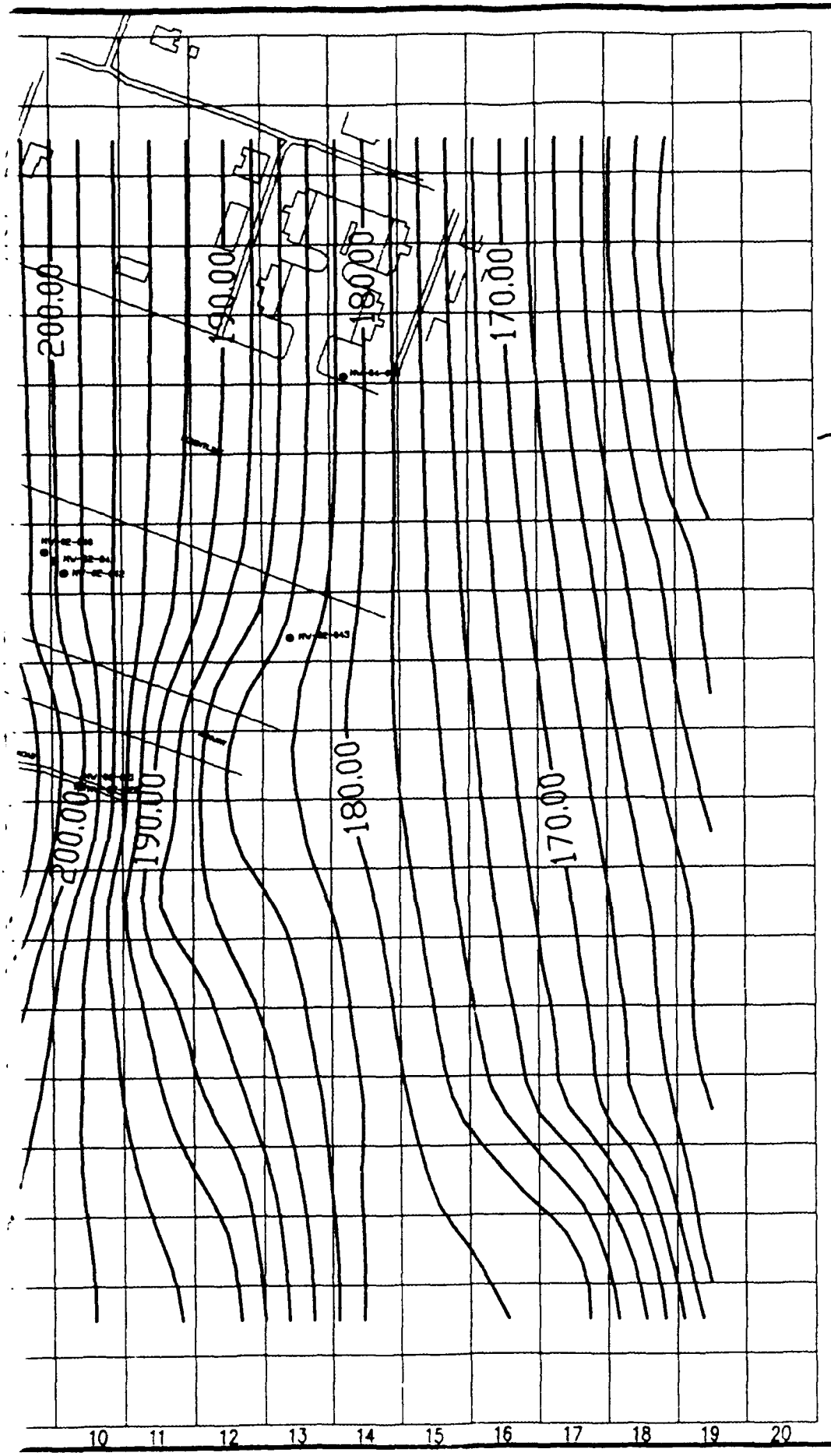

LEGEND

MW-02-20 GROUND WATER MONITORIN
(DECEMBER 1993)

84A LIF-CPT SAMPLING LOCATI(
(DECEMBER 1993)

—170.00— WATER TABLE ELEVATION (

NOTE:

GRID CELL SIZE EQUALS 400 F

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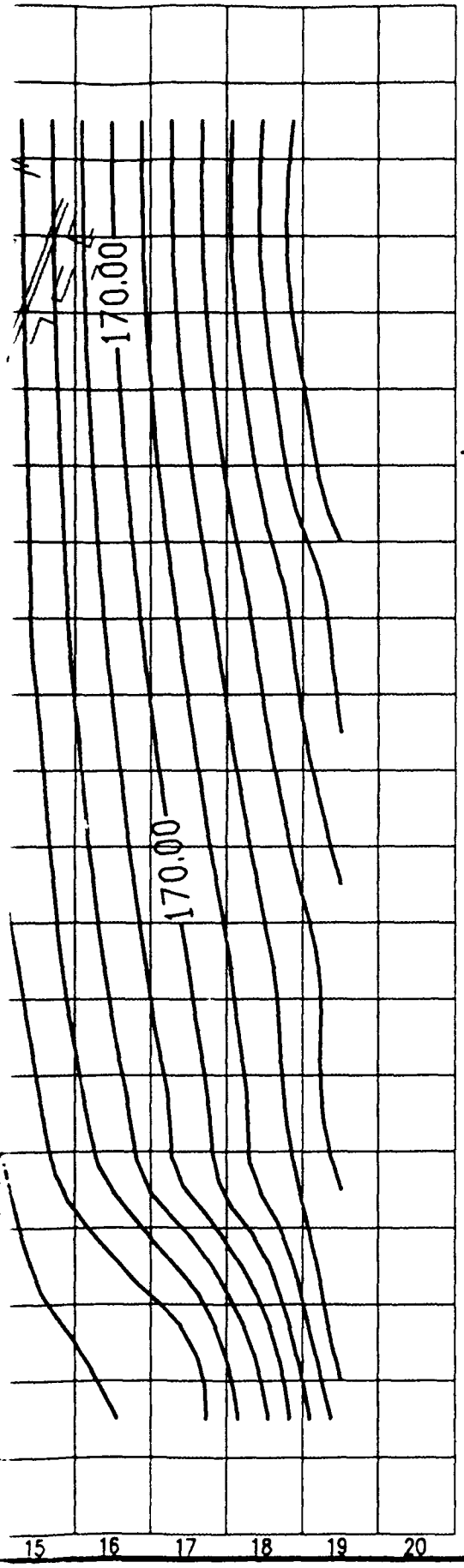


LEGEND

MW-02-20 ⊕ GROUND WATER MONITORING WELL (DECEMBER 1993)

84A ⊕ LIF-CPT SAMPLING LOCATION W/LABEL (DECEMBER 1993)

~170.00~ WATER TABLE ELEVATION (FEET ABOVE MSL)

NOTE:

GRID CELL SIZE EQUALS 400 FT. x 400 FT.

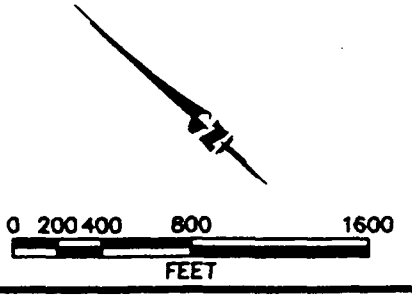


FIGURE 6.2

CALIBRATED WATER TABLE MAP

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

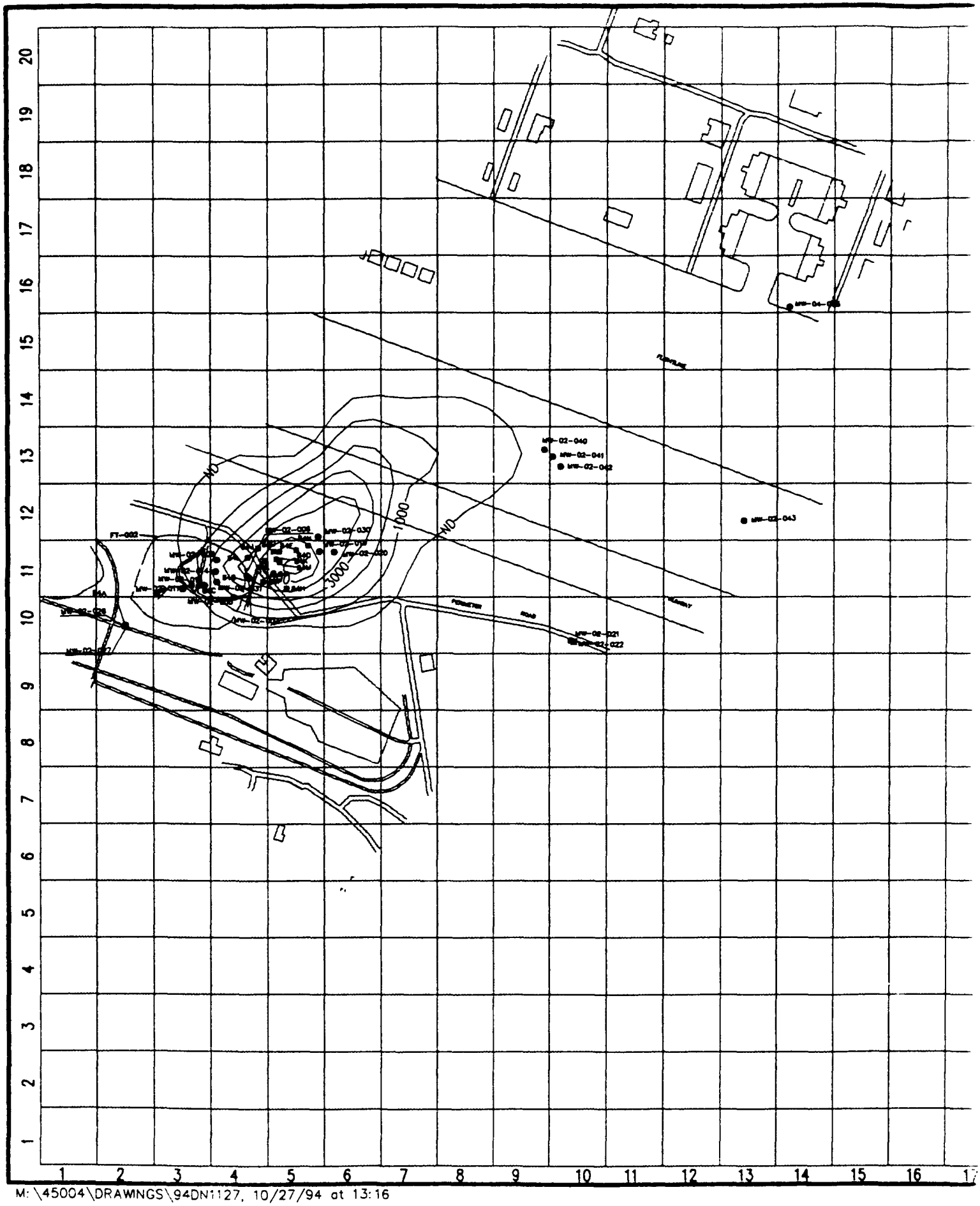
The RMS error between observed and calibrated values at the 13 comparison points was 2.14 feet, which corresponds to a calibration error of 3.3 percent (water levels dropped 65 feet over the length of the model grid). The RMS error calculations are summarized in Appendix C.

In solving the ground water flow equation, Bioplume II establishes the water table surface and calculates an overall hydraulic balance that accounts for the numerical difference between flux into and out of the system. The hydraulic mass balance for the calibrated model was excellent, with 99.9 percent of the water flux into and out of the system being numerically accounted for (i.e., a 0.1-percent error). According to Anderson and Woessner (1992), a mass balance error of around 1 percent is acceptable, while Konikow (1978) indicates an error of less than 0.1 percent is ideal.

6.4.2 BTEX Plume Calibration

Model input parameters affecting the distribution and concentration of the simulated BTEX plume were modified so that model predictions matched dissolved total BTEX concentrations observed in December 1993. To do this, model runs were made using the calibrated steady-state hydraulic parameters, with no initial BTEX concentration model distribution to simulate the site in its uncontaminated state. The plume calibration simulations were made over a model period of 38 years to represent the time period from the initial site contamination in 1955 to December 1993. In other words, the computed BTEX plume concentrations and configurations were simulated by providing for contaminant source, transport, and degradation for 38 years. The simulated plume was then compared to the BTEX plume measured in December 1993.

By varying the BTEX source, the reaeration coefficient, the coefficient of retardation, and dispersivity, the BTEX plume was calibrated reasonably well to the existing plume in terms of migration distance and BTEX concentrations in the plume area. The calibrated plume configuration is shown on Figure 6.3. Although not identical, the calibrated model plume compares favorably to the observed 1993 BTEX plume (Figure 4.6a). The simulated plume has concentrations slightly higher than those observed in December 1993, but the total area of the simulated BTEX plume is very similar to the plume observed in December 1993.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MW-02-041
MW-02-042
MW-02-043
MW-02-021
MW-02-022
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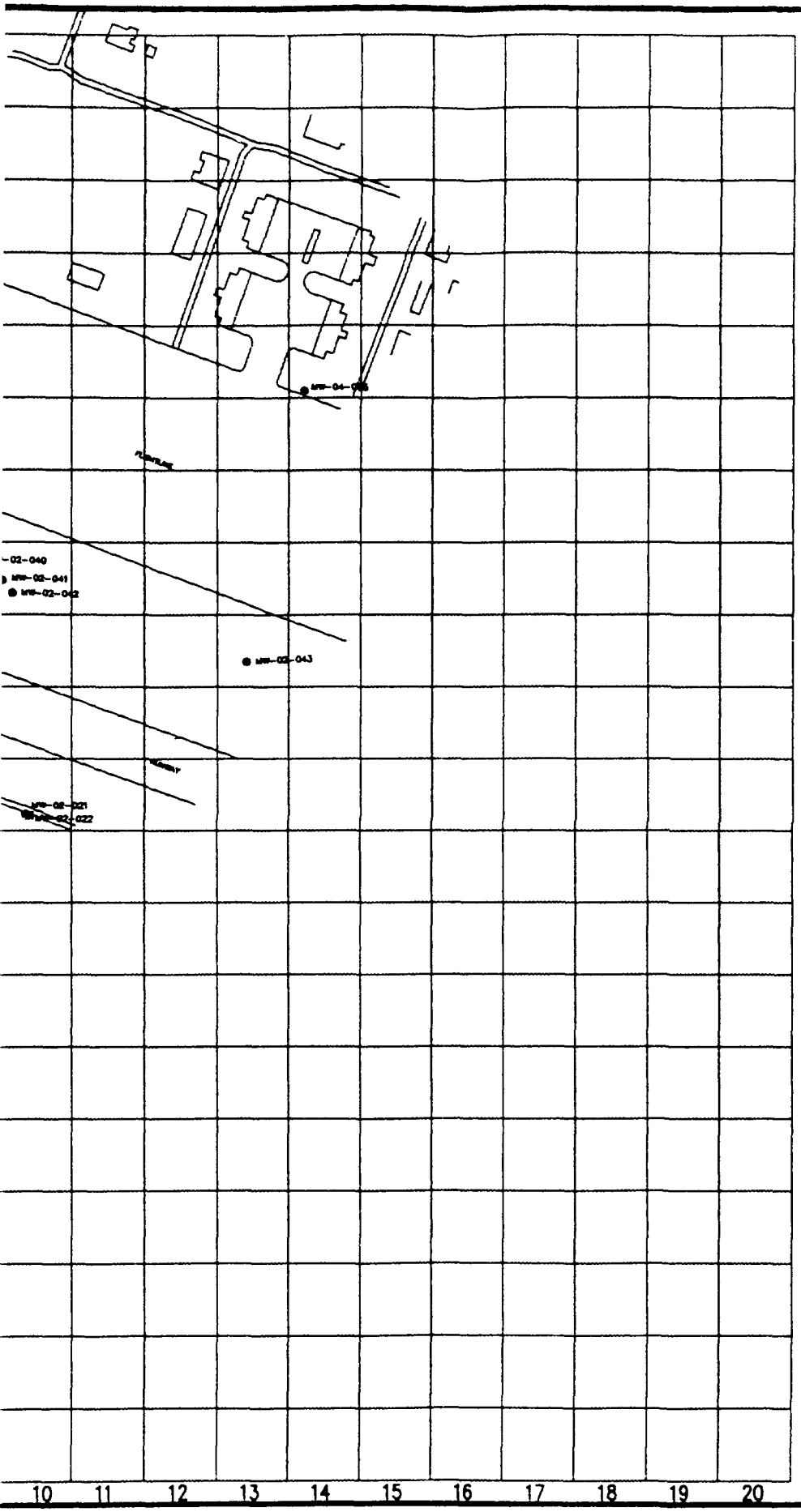

LEGEND

MW-02-006 GROUND WATER MONITORING WEL

84E LIF-CPT SAMPLING LOCATION

2.0 LINE OF ESTIMATED EQUAL TOTAL

ND NOT DETECTED

CONTOUR INTERVAL = 1000 ppb

NOTES:

1. GRID CELL SIZE EQUALS 400 FT. x
2. SIMULATION TIME = 38 YEARS (19

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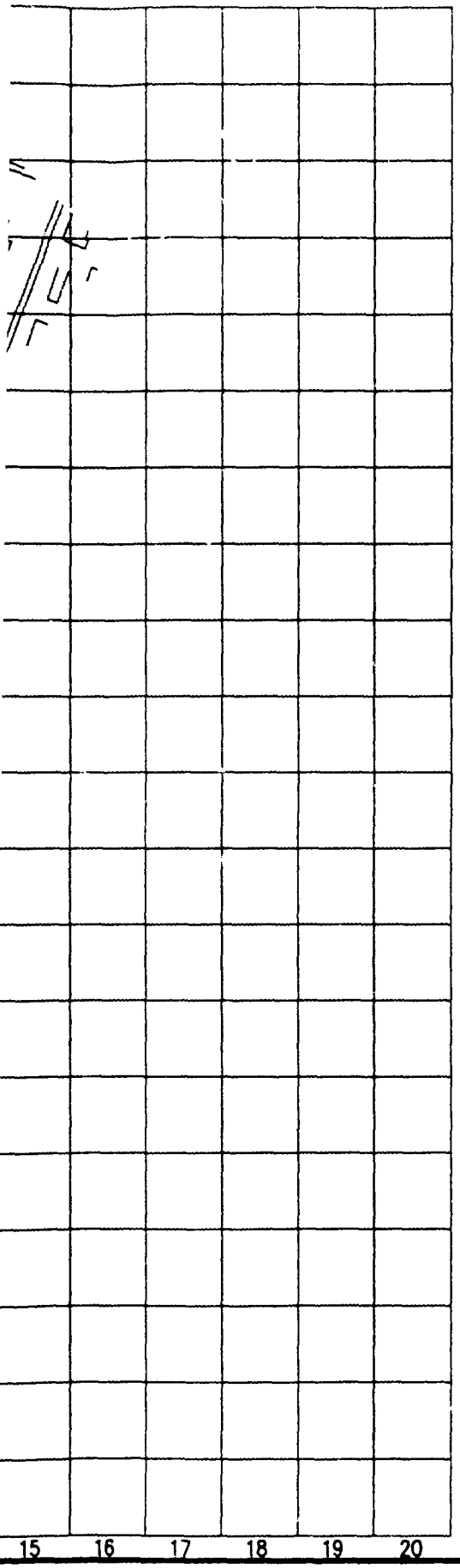


LEGEND

MW-02-006 GROUND WATER MONITORING WELL

84E LIF-CPT SAMPLING LOCATION

2.0 LINE OF ESTIMATED EQUAL TOTAL BTEX CONCENTRATION (ppb)

ND NOT DETECTED

CONTOUR INTERVAL = 1000 ppb

NOTES:

1. GRID CELL SIZE EQUALS 400 FT. x 400 FT.
2. SIMULATION TIME = 38 YEARS (1955 TO 1993)

0 200 400 800 1600

FEET

FIGURE 6.3

CALIBRATED BTEX PLUME

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

The maximum simulated total BTEX concentration was 6,800 ppb for the cell (11,4) in the vicinity of ground water well nest MW-02-006 and MW-02-007. The computed contaminant distribution represents a greater total mass of BTEX because the concentrations are higher than those observed, and because the model assumes that contamination extends throughout the total depth of the aquifer. In reality, the BTEX contamination is only present in a portion of the total aquifer thickness. By overestimating the BTEX mass in the ground water at the FT-002 site, the predictions made by this model should be conservative.

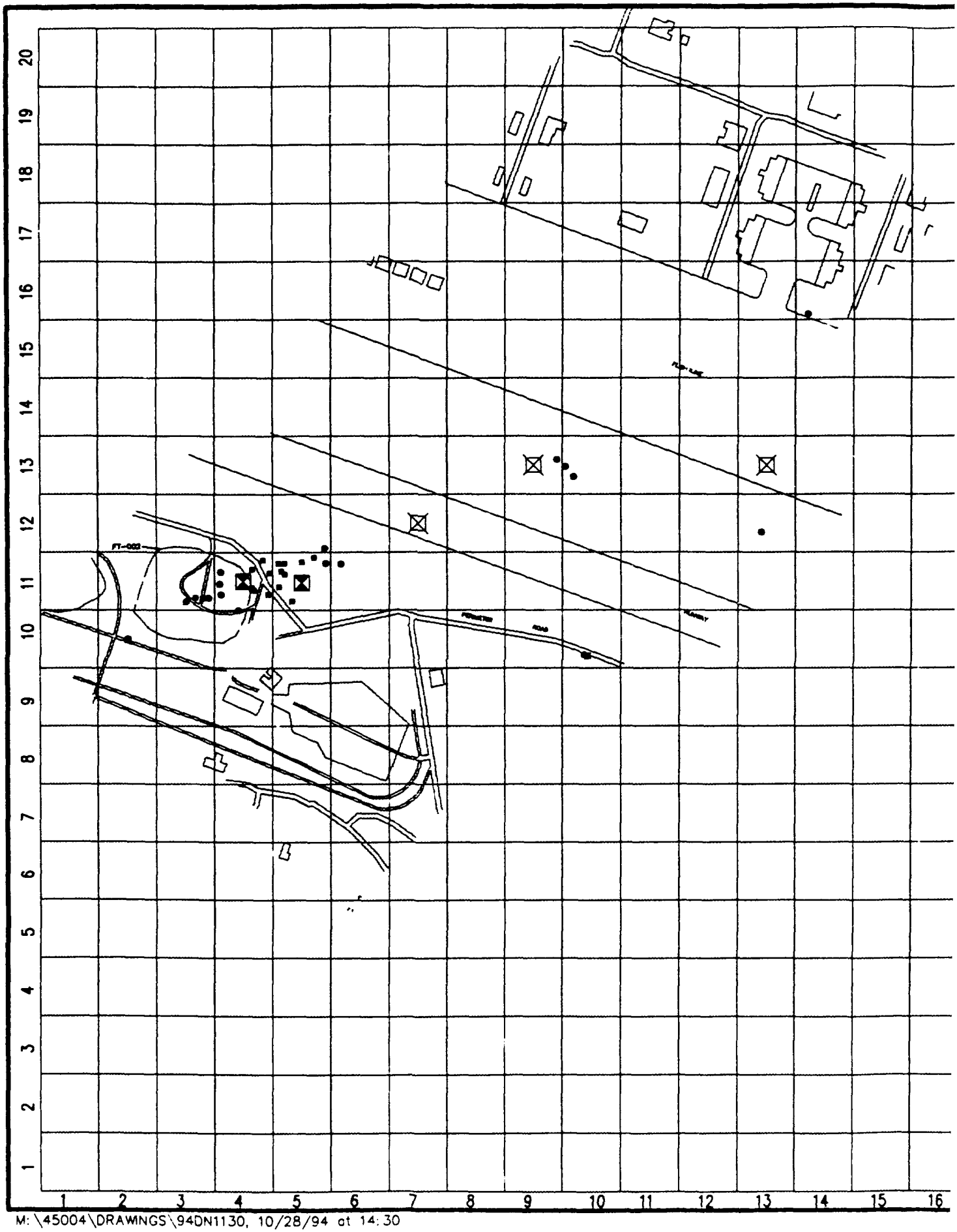
6.4.2.1 Discussion of Parameters Varied During BTEX Plume Calibration

As noted previously, the source and transport parameters varied during plume calibration were contaminant source concentration, dispersivity, the coefficient of retardation, and the reaeration coefficient. Those parameters were varied within reasonable ranges with intent of limiting plume migration to the observed extents. The original estimates for the parameters resulted in a calculated BTEX plume that extended almost twice as far as the observed plume. While these parameters were varied with this common intent, each had a slightly different impact on the size and shape of the simulated plume.

6.4.2.1.1 Contaminant Source Concentration

Contaminants were introduced into the aquifer using simulated injection wells located in source cells (11,4) and (11,5), as indicated on Figure 6.4. Contaminant concentrations in the injection wells were originally assumed to be 1,500 ppm. The concentration of these sources was increased to simulate the observed dissolved BTEX plume. A value of 4,500 ppm in both simulated injection wells was utilized in the calibrated model.

While the term "injection well" suggests contaminants are being introduced at a point, Bioplume II assumes that contamination introduced at a well instantly equilibrates throughout the entire cell in which the well is located. The injection rate for the cells was set at 5×10^{-4} ft^3/sec, a value low enough that the flow calibration and water balance were not affected. Relatively high BTEX concentrations were injected through the wells because of the low pumping rate. The total BTEX injection concentration for the model was set at 4,500 ppm in each of the two injection wells. After the mass is dispersed throughout the entire cell volume, this results in the total BTEX concentration in the source area of



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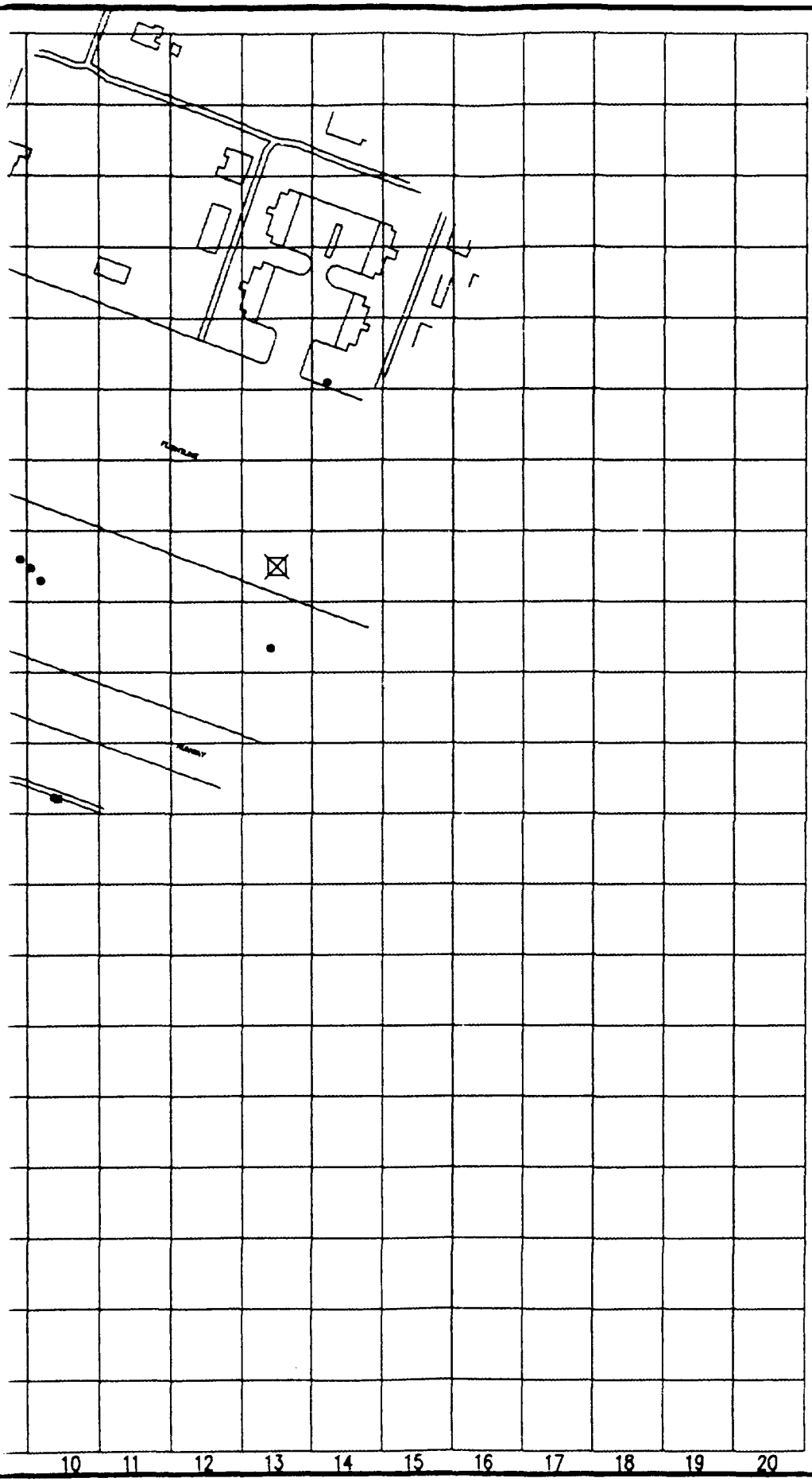

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- GROUND WATER MONITO
- LIF-CPT SAMPLING LOC
- LOCATION OF SIMULATEI
- LOCATION OF SIMULATEI BTEX INJECTION WELL

NOTE:

GRID CELL SIZE EQUALS 40(

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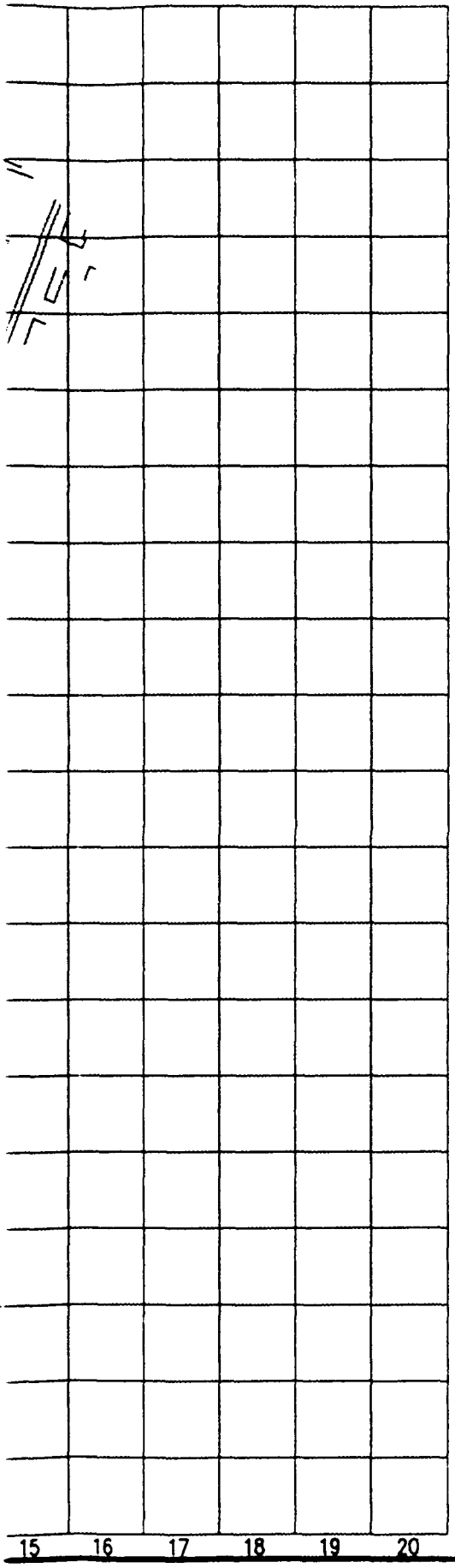

LEGEND

- GROUND WATER MONITORING WELL
- LIF-CPT SAMPLING LOCATION
- LOCATION OF SIMULATED OBSERVATION WELL
- LOCATION OF SIMULATED OBSERVATION AND BTEX INJECTION WELL

NOTE:

GRID CELL SIZE EQUALS 400 FT. x 400 FT.

0 200 400 800 1600

FEET

FIGURE 6.4

LOCATION OF SIMULATED INJECTION WELLS FOR MODEL CALIBRATION AND PREDICTION

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

approximately 6,500 ppb, which is similar to the maximum observed total BTEX concentration of about 6,000 ppb.

Although the loading rate indicated above results in a total of 5.5 kg of BTEX per day being introduced at each well, this loading rate does not cause the concentration in the source cells to exceed the maximum solubility of total BTEX, as calculated from equilibrium partitioning equations presented in Appendix E. In fact, the addition of 5.5 kg of total BTEX per day to the aquifer results in BTEX concentrations in these source cells that are less than those predicted using equilibrium relationships (see Appendix E). This is because the model assumes the mass of BTEX that enters each cell from the wells is instantly dispersed throughout a volume of water equivalent to the area of the cell times its saturated thickness. Because the aquifer is assumed to be 45 feet thick in the vicinity of the injection wells, the injected BTEX equilibrates with a very large volume of water. Thus, the contaminant source terms incorporated into this Bioplume II model are not unreasonable.

6.4.2.1.2 Dispersivity

Much controversy surrounds the concepts of dispersion and dispersivity. Longitudinal dispersivity values for soil similar to those found at the site range from 0.1 to 200 feet (Walton, 1988). Longitudinal dispersivity was originally estimated as 82 feet, using one-tenth (0.1) of the distance between the upgradient margin of the 6,000 ppb isopleth and the longitudinal centroid of the December 1993 plume (see Figure 4.6a). Dispersivity estimation calculations are included in Appendix C. Because transverse dispersivity values generally are estimated as one-tenth (0.1) of the longitudinal dispersivity values (Domenico and Schwartz, 1990), this value was used for the initial model input.

During plume calibration, longitudinal dispersivity was decreased to 60 feet from the original estimate of 82 feet. This was done to prevent the calibrated plume from extending too far downgradient. The dispersivity value also helped increase the lateral extent of the plume to better match the observed extents. Earlier contaminant transport models developed for this site assumed a longitudinal dispersivity of 45 feet (URS Consultants, Inc., 1993). Thus, the final longitudinal dispersivity value used in the calibrated model was within the expected range of values for the site.

6.4.2.1.3 Rearation Coefficient

The reaeration coefficient was originally estimated to be 0.001 day^{-1}. This value was varied during plume calibration, but the calibrated model used the original estimate. This prevented the plume from migrating too far in the calibration run, and at the same time prevented contaminant concentrations in the center portion of the plume from being excessively high.

6.4.2.1.4 Coefficient of Retardation

Retardation of the BTEX compounds relative to the advective velocity of the ground water occurs when BTEX compounds are adsorbed to the aquifer matrix. Based on literature values for TOC concentrations in the saturated zone as discussed in Section 4.3.3 and assuming a bulk density of 1.6 grams/cubic centimeter (Freeze and Cherry, 1979), and published values of the soil sorption coefficient (K_{oc}) for the BTEX compounds (as listed in Wiedemeier *et al.*, 1994), the coefficients of retardation for the BTEX compounds were calculated. The results of these calculations are summarized in Table 3 of Appendix E. Average coefficients of retardation were also computed for data from the FT-002 site at Plattsburgh AFB to provide an additional set of data for comparison. The coefficient of retardation originally calculated from these values was 10.39 (see Appendix E). This value represents the minimum retardation coefficient developed from available data. The lower the assumed coefficient of retardation, the farther the BTEX plume will migrate downgradient. The coefficient of retardation was varied during calibration. However, the final calibrated model used input parameters resulting in a coefficient of retardation of 10.39.

6.5 SENSITIVITY ANALYSIS

The purpose of the sensitivity analysis is to determine the effect on model output of varying model input parameters. Based on the work of Rifai *et al.* (1988), the Bioplume II model is most sensitive to changes in the coefficient of reaeration, the coefficient of anaerobic decay, and the hydraulic conductivity (transmissivity) of the media, and is less sensitive to changes in the retardation factor, porosity, and dispersivity. Because no coefficient of anearobic decay was included in this model, the sensitivity analysis was conducted by varying transmissivity, dispersivity, the coefficient of retardation, and the coefficient of reaeration.

To perform the sensitivity analyses, an individual run of the plume calibration model was made with the same input as the calibrated model, except that one of the aforementioned parameters was varied. The models were run for a 38-year period, just as the original was, so that the independent effect of each variable could be assessed. As a result, eight sensitivity runs of the calibrated model were made, with the following variations:

1) Transmissivity uniformly increased by a factor of 5;

2) Transmissivity uniformly decreased by a factor of 5;

3) Longitudinal dispersivity increased by a factor of 2;

4) Longitudinal dispersivity decreased by a factor of 2;

5) Coefficient of rearation increased by a factor of 3;

6) Coefficient of rearation decreased by a factor of 3;

7) Coefficient of retardation increased to 15; and

8) Coefficient of retardation decreased to 2.

The results of the sensitivity analyses are shown graphically in Figures 6.5, 6.6, 6.7, and 6.8. These figures show the simulated BTEX concentrations versus distance along the centerline of the plume. This manner of displaying data is useful because BTEX concentrations are highest along the centerline of the plume, the plume is relatively symmetrical, and the plume migrates in a direction parallel to the model grid. Furthermore, the figures allow easy visualization of the changes in BTEX concentration caused by varying model input parameters.

The effects of varying transmissivity are shown in Figure 6.5. Uniformly increasing the transmissivity by a factor of five increased contaminant mass loss such that the observed concentrations in the source cell area were completely eliminated almost instantaneously. Increasing transmissivity causes a greater flux of water into and out of the plume area, which brings a greater mass of DO (and other electron acceptors) into contact with the BTEX plume. Because more electron acceptors are available, biodegradation occurs more rapidly. Also, the faster ground water velocity produced by higher transmissivity values results in greater plume travel rates and distances. More BTEX is exposed to oxygenated water in areas affected by reaeration. In contrast, decreasing the transmissivity by a factor of five slowed overall plume migration, which shortened the plume and increased the maximum

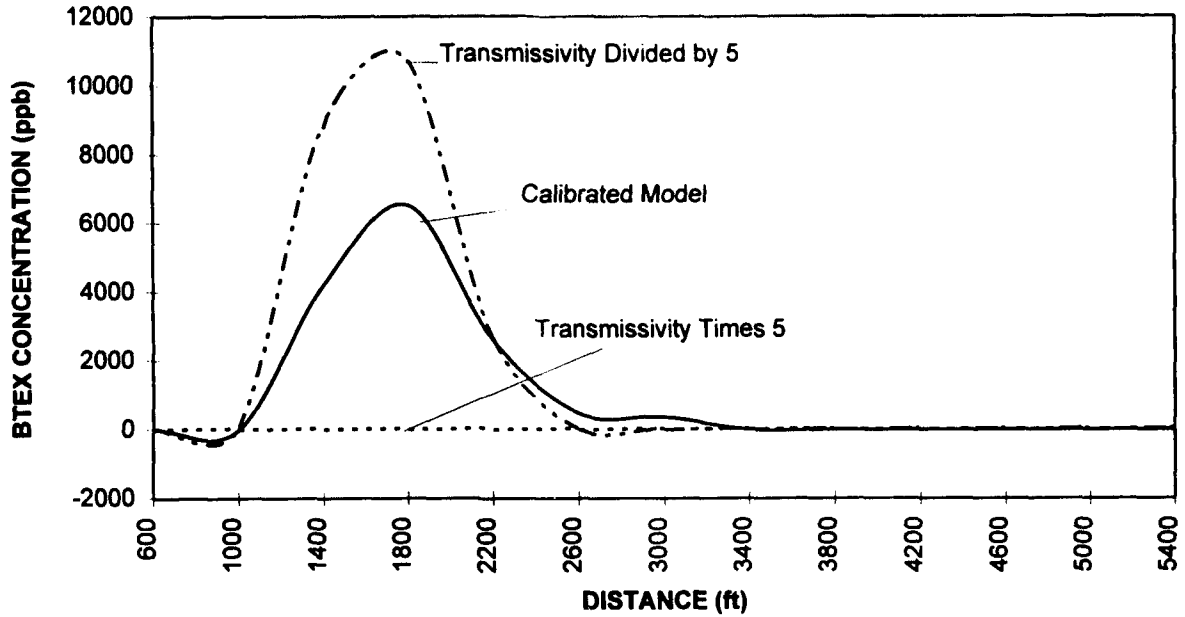

FIGURE 6.5

MODEL SENSITIVITY TO VARIATIONS IN TRANSMISSIVITY

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

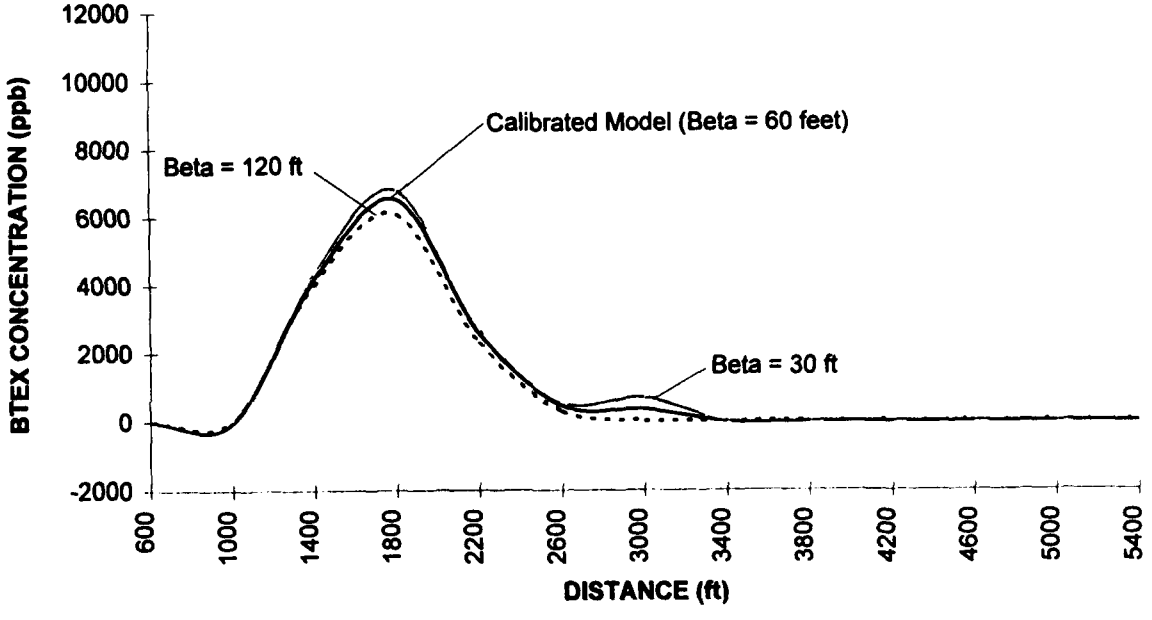

FIGURE 6.6

MODEL SENSITIVITY TO VARIATIONS IN LONGITUDINAL DISPERSIVITY

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

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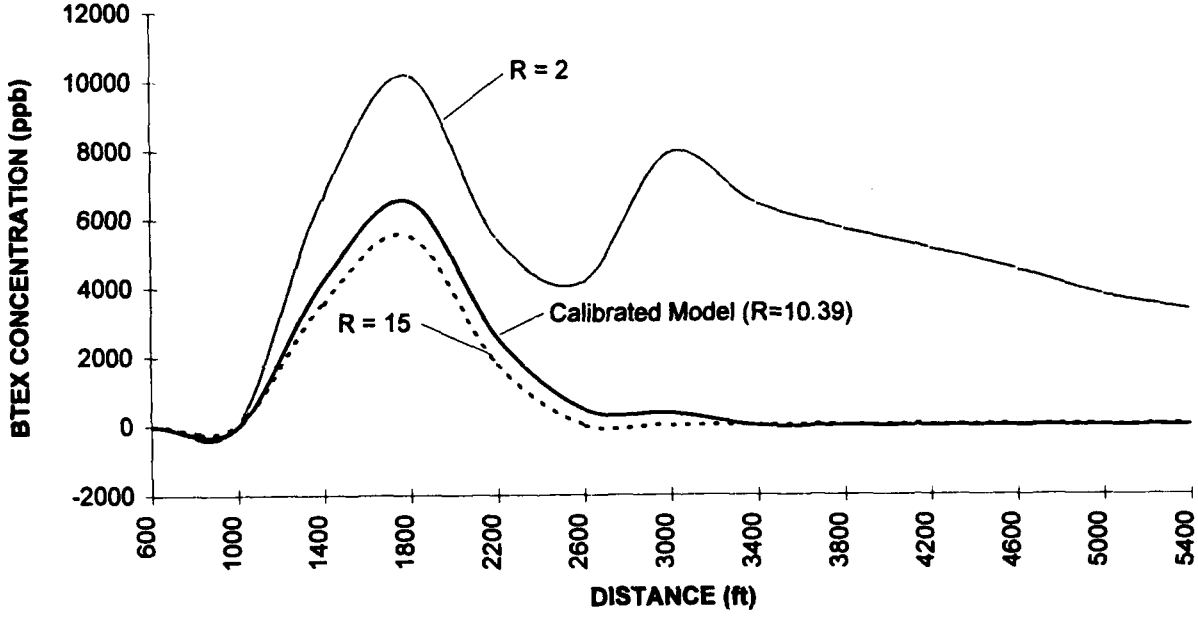

FIGURE 6.7

MODEL SENSITIVITY TO VARIATIONS IN SOLUTE RETARDATION

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC.
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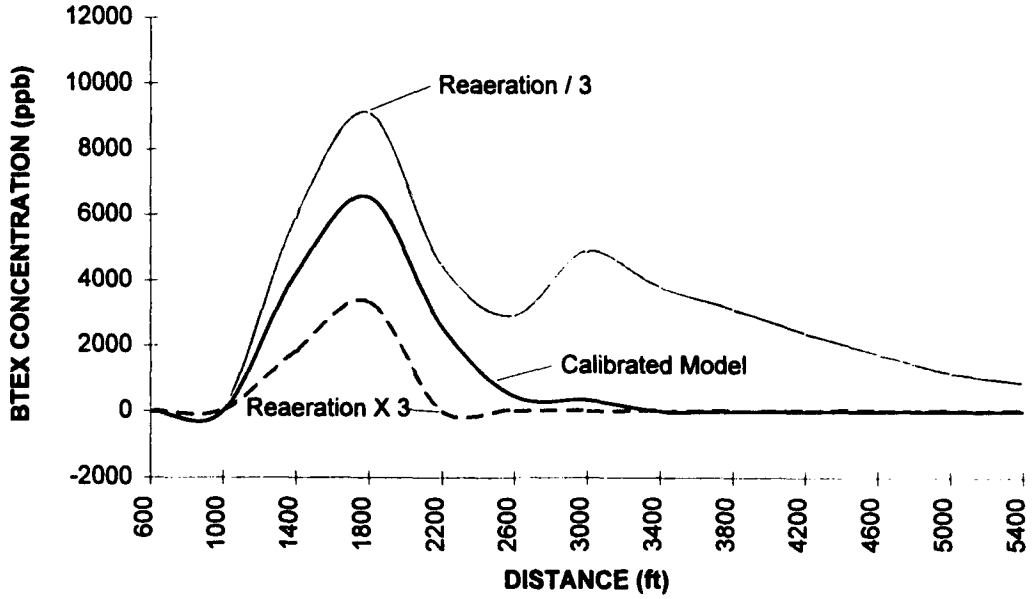

FIGURE 6.8

MODEL SENSITIVITY TO VARIATIONS IN REAERATION COEFFICIENT

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

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BTEX concentrations. Increased BTEX concentrations in the plume area are caused by a reduction in the plume travel rate and the amount of DO being brought into contact with the BTEX compounds from upgradient locations.

The effects of varying dispersivity are illustrated in Figure 6.6. Both longitudinal and transverse dispersivity were varied for this analysis, as the ratio of the two values was kept constant at 0.25. Increasing the dispersivity (beta) by a factor of two resulted in lower maximum BTEX concentrations, although the plume covered the same area. Decreasing dispersivity by a factor of two produced a plume with an extent similar to the calibrated plume, but with slightly higher concentrations.

The effects of varying the coefficient of retardation (R) are shown in Figure 6.7. Increasing R to 15 has a slight effect on the distribution of BTEX. The maximum BTEX concentration is approximately 1,000 ppb less than the calibrated plume. Further, increasing R produces a plume that is approximately 800 feet shorter than that observed in the calibrated model. On the other hand, decreasing R to 2 produces a plume that extends over 2,000 feet further downgradient than the original model plume. Decreasing R also increased the maximum dissolved concentration by nearly 4,000 ppb. In addition, the overall shape of the curve was altered, as more BTEX mass migrates downgradient. These results suggest that the R used in the Bioplume II model adequately simulates site conditions. The model is relatively insensitive to higher values of R, although lower values of R can affect the extent and concentration of the BTEX plume.

Figure 6.8 shows the effects of varying the reaeration coefficient. Increasing this parameter by a factor of three results in rapid degradation of dissolved BTEX. This dramatic reduction in contaminant mass is the result of the large increase in the oxygen available to participate in the degradation of BTEX. Conversely, decreasing the reaeration coefficient by a factor of three greatly decreases the rate of degradation, resulting in an increase of the computed maximum BTEX concentration to approximately 9,100 ppb. The increase in BTEX mass is accompanied by a large increase in plume length.

The results of the sensitivity analysis suggest that the calibrated model used for this report is reasonable. The calibrated model is most sensitive to transmissivity and the reaeration coefficient, although the coefficient of retardation is also an important parameter. Increasing the reaeration coefficient or the transmissivity greatly diminishes the predicted BTEX

concentrations. Lowering the values of the reaeration coefficient and the coefficient of retardation lengthens the plume beyond observed extents. While the model appears relatively insensitive to dispersivity, this parameter was adjusted to more closely match field data.

6.6 MODEL RESULTS

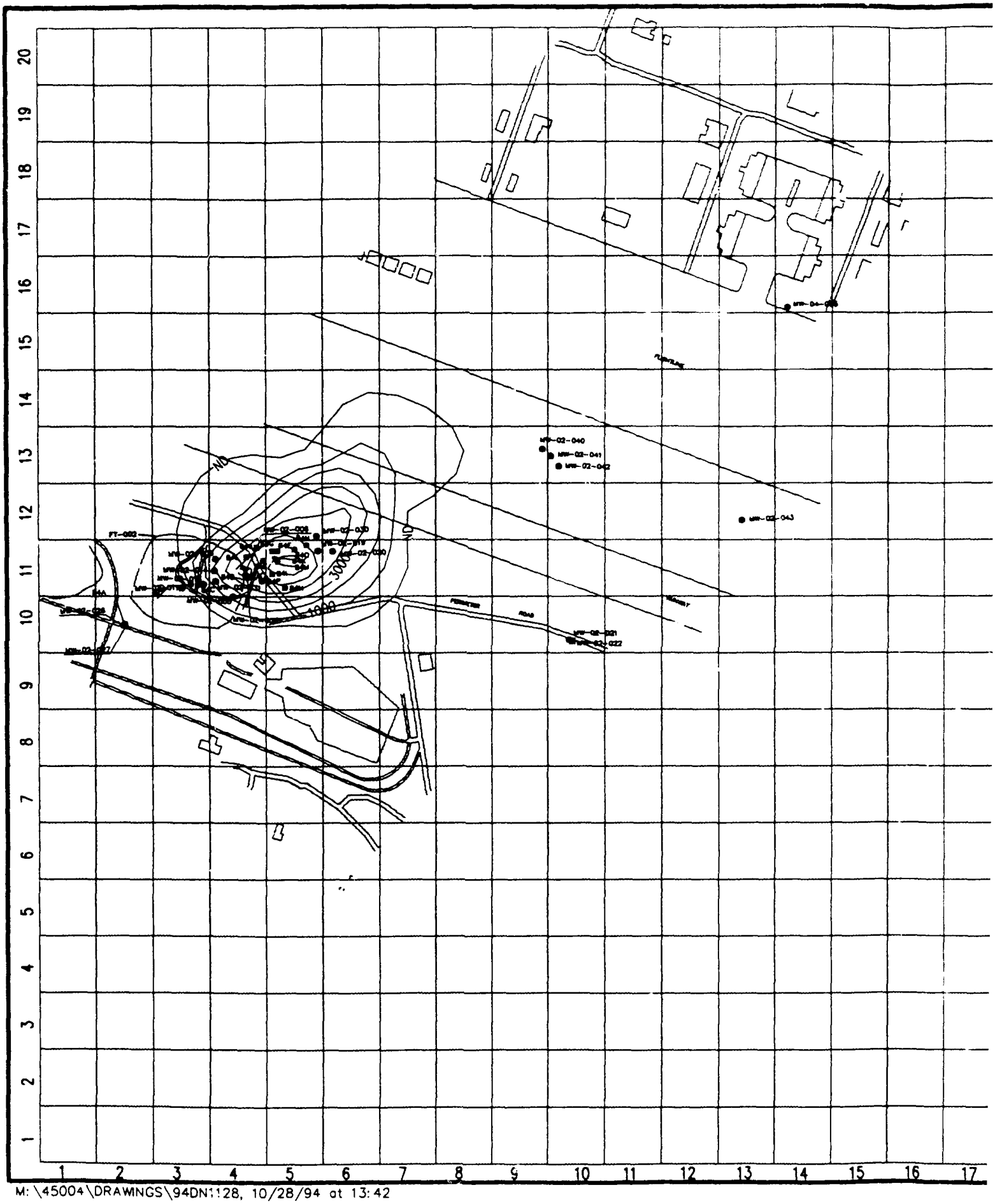
To predict the fate and transport of dissolved BTEX compounds at the FT-002 site, two Bioplume II simulations (PLATCAL and PLATPRD) were run under steady-state conditions. The first simulation assumed that conditions which produced the calibrated model continue. Specifically, the current source of dissolved BTEX would continue uninterrupted. The second simulation assumes that the source of BTEX is decreased by 20-percent from current levels. The objective of this second simulation is to investigate the effects of diminishing the contaminant source on the fate and transport of the dissolved BTEX compounds. A total 20-percent reduction in the source concentration was assumed to simulate the effects of either a product recovery network (i.e., LNAPL removal), or a naturally diminishing source of BTEX (i.e., less BTEX is available to partition into the ground water). This simulation was completed to determine the relative effectiveness of contaminant source remediation. Both models were run for 10 years beyond the calibration year (1993). Complete input and output files are included in Appendix D. Model results are described in the following sections.

6.6.1 Continuation of Calibrated Conditions (Model PLATCAL)

Model PLATCAL was used to simulate the migration and biodegradation of the BTEX plume assuming that the conditions that produced the calibrated model continue uninterrupted. This model includes a continuing source of dissolved BTEX compounds. The calibrated simulation was run to simulate the extent and concentration of the total BTEX plume in the year 2003. The total simulation time for this model was 48 years. Figure 6.9 shows the BTEX plume in the year 2003. Modeled BTEX concentrations increase slightly, to a maximum of 6,700 ppb. However, the plume has receded approximately 400 feet. This simulation suggests that the dissolved BTEX plume will decrease in size over the next 10 years, even in the absence of engineered or natural source removal activities.

6.6.2 Reduced BTEX Source (Model PLATPRD)

Model PLATPRD was used to assess the effects of reducing the current contaminant source by 20 percent. This reduced source continues uninterrupted for the duration of the



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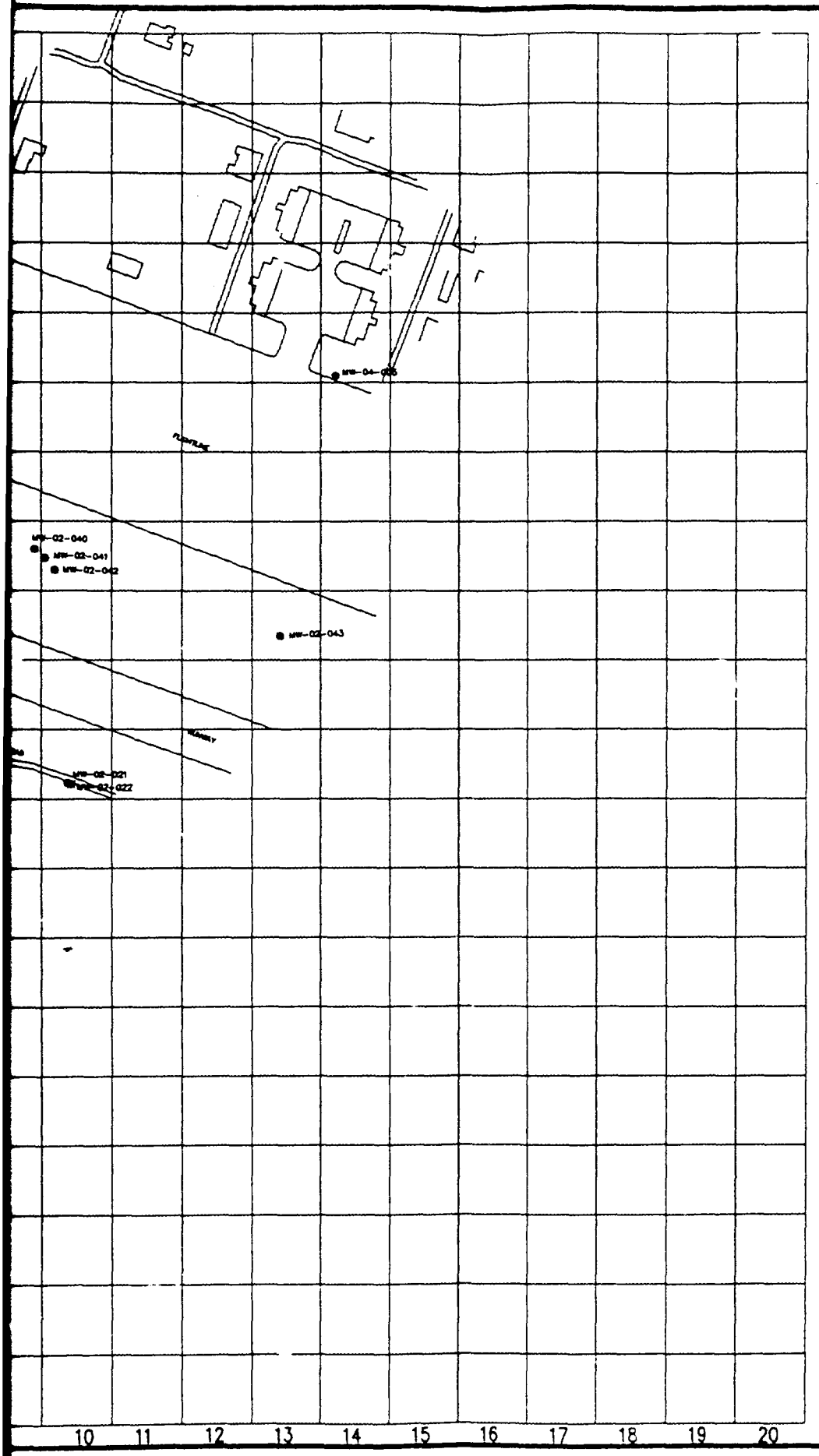


LEGEND

MW-02-006 GROUND WATER MONIT

84E LIF-CPT SAMPLE LOCA

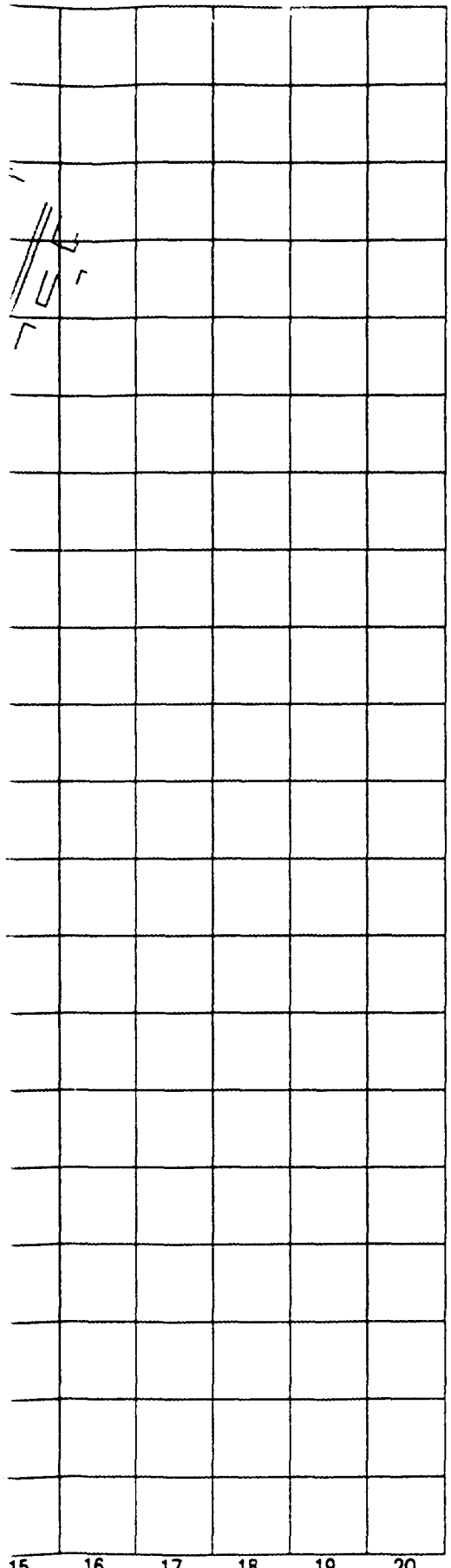
2.0 LINE OF ESTIMATED EQ
BTEX CONCENTRATION

ND NOT DETECTED

CONTOUR INTERVAL = 1

NOTES:

1. GRID CELL SIZE EQUALS 40
2. PLUME SIMULATED USING C
   NO REDUCTION IN SOURCE



LEGEND

MW-02-006 GROUND WATER MONITORING WELL

84E LIF-CPT SAMPLE LOCATION

2.0 LINE OF ESTIMATED EQUAL TOTAL BTEX CONCENTRATION (ppb)

ND NOT DETECTED

CONTOUR INTERVAL = 1000 ppb

NOTES:

1. GRID CELL SIZE EQUALS 400 FT. x 400 FT.
2. PLUME SIMULATED USING CONTINUING SOURCE; NO REDUCTION IN SOURCE CONCENTRATION FOR 10 YEARS.

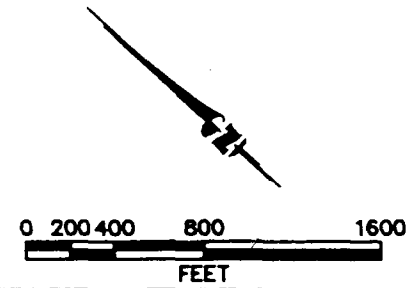


FIGURE 6.9

SIMULATED BTEX PLUME IN THE YEAR 2003

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

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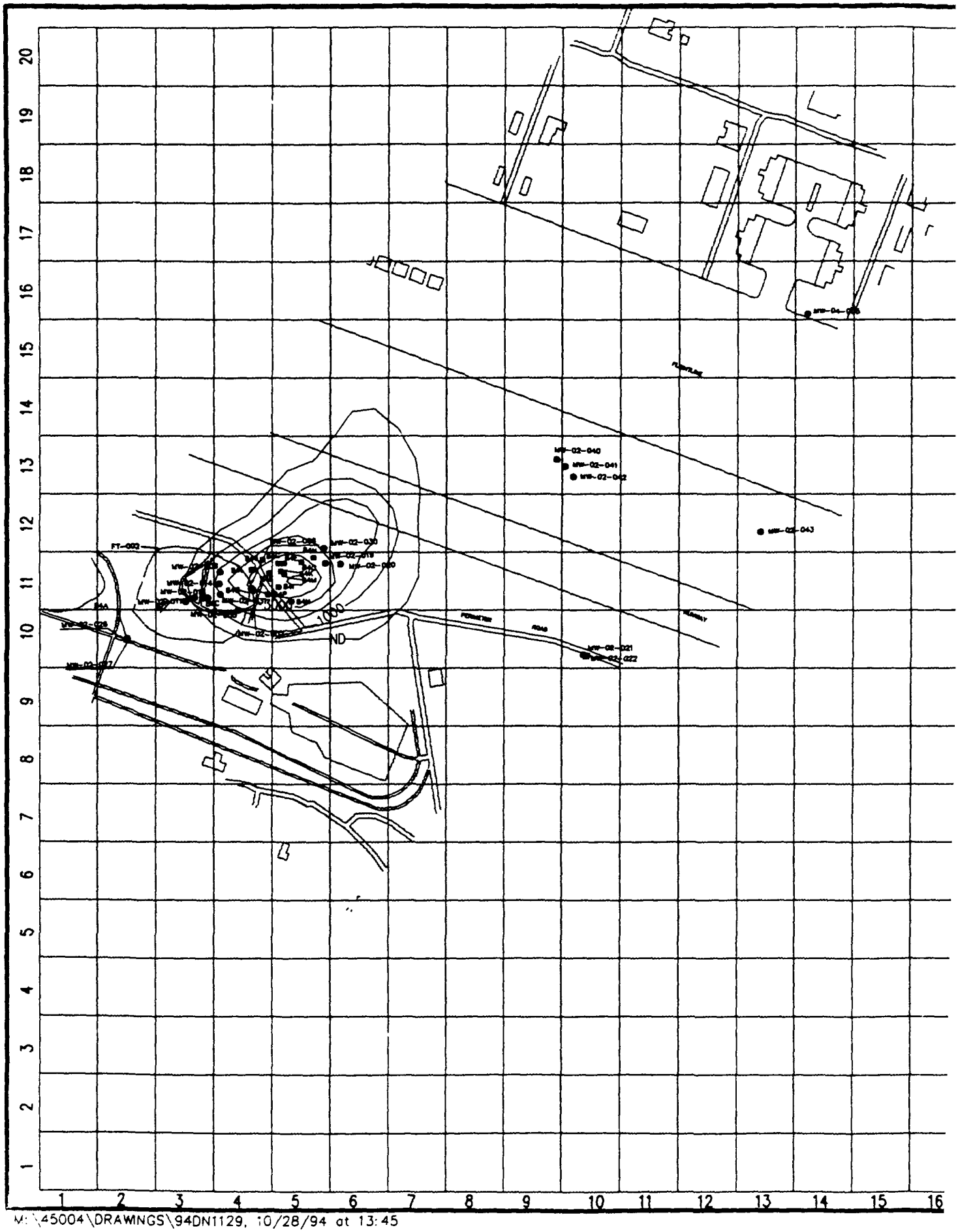
simulation. As with model PLATCAL, the simulation was set to run for 10 years beyond the original calibrated time (i.e., to the year 2003). Decreasing the BTEX source decreased the maximum concentration of BTEX to 5,300 ppb. Additionally, the BTEX receded nearly 800 feet (Figure 6.10). Thus, a 20-percent reduction in source contamination concentrations resulted in a 20-percent reduction in maximum contaminant concentration and a 33-percent reduction in the size of the plume by the year 2003. This simulation shows that attenuation of the BTEX plume can be enhanced by both engineered source removal activities, such as product extraction and bioventing, and natural reductions in the contaminant mass of the source. Thus, the existing mobile LNAPL recovery system and bioventing systems should expedite plume attenuation. The BTEX source will be naturally diminished as BTEX compounds partition from mobile LNAPL and contaminated soils and dissolve into ground water.

6.7 CONCLUSIONS AND DISCUSSION

The results of the two different Bioplume II model scenarios completed for the FT-002 site suggest that the dissolved BTEX plume front will diminish in size and concentration over the next 10 years, even in the absence of extensive source removal activities. Continuing the current source results in a 16-percent reduction in the size of the BTEX plume in the next 10 years. Reducing the source of BTEX compounds by total 20-percent causes a 33-percent reduction in the size of the BTEX plume. Both simulations suggest that the BTEX plume will be effectively attenuated in the ground water at FT-002 site.

PLATCAL results suggest that the downgradient migration of the BTEX plume will be halted and even reversed in the next 10 years even if the source area remains unremediated. The results of model PLATPRD show that source reduction can enhance the reduction in size and concentration of the BTEX plume. However, decreasing the contaminant source by 20-percent only enhanced plume reduction by 17 percent. More simply, source reduction had only a slight effect on the predicted fate and transport of the BTEX compounds. Comparison of site data from September 1991 to site data collected under this program in December 1993 indicated no measurable change in the size and concentration of the BTEX plume. These model simulations confirm these field data. The BTEX plume should not migrate appreciably downgradient in the next 10 years. The model predicts that about 91 percent of the source BTEX mass will be biodegraded.



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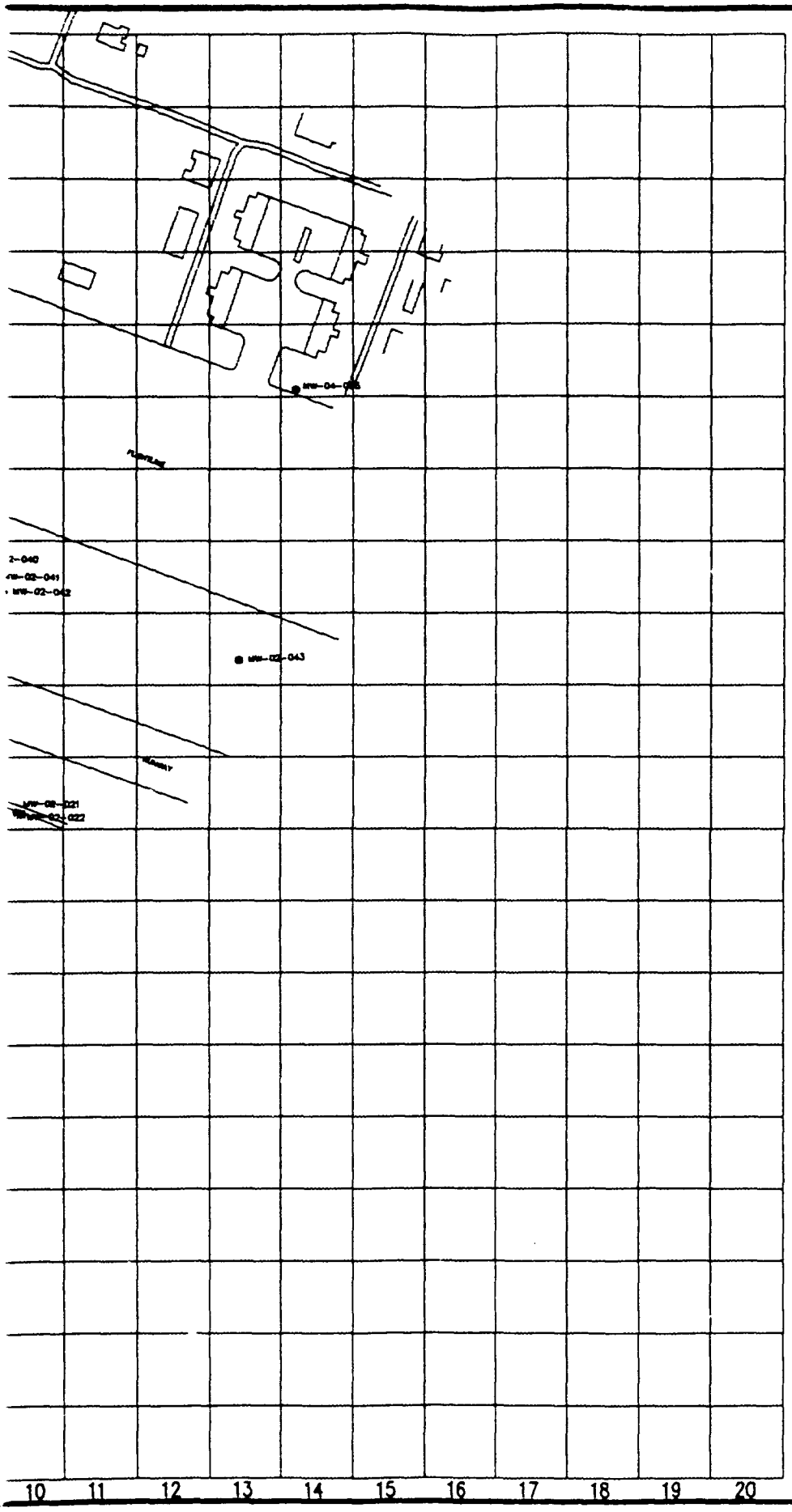

LEGEND

MW-02-006	GROUND WATER MONITORIN
84E	LIF-CPT SAMPLE LOCATION
2.0	LINE OF ESTIMATED EQUAL BTEX CONCENTRATION (ppb
ND	NOT DETECTED
	CONTOUR INTERVAL = 1000

NOTES:

1. GRID CELL SIZE EQUALS 400 F
2. PLUME SIMULATED USING CONTI DIMINISHED BY 20 PERCENT AF YEAR 1993. SIMULATION CONTIN WITH REDUCED BTEX LOADING.

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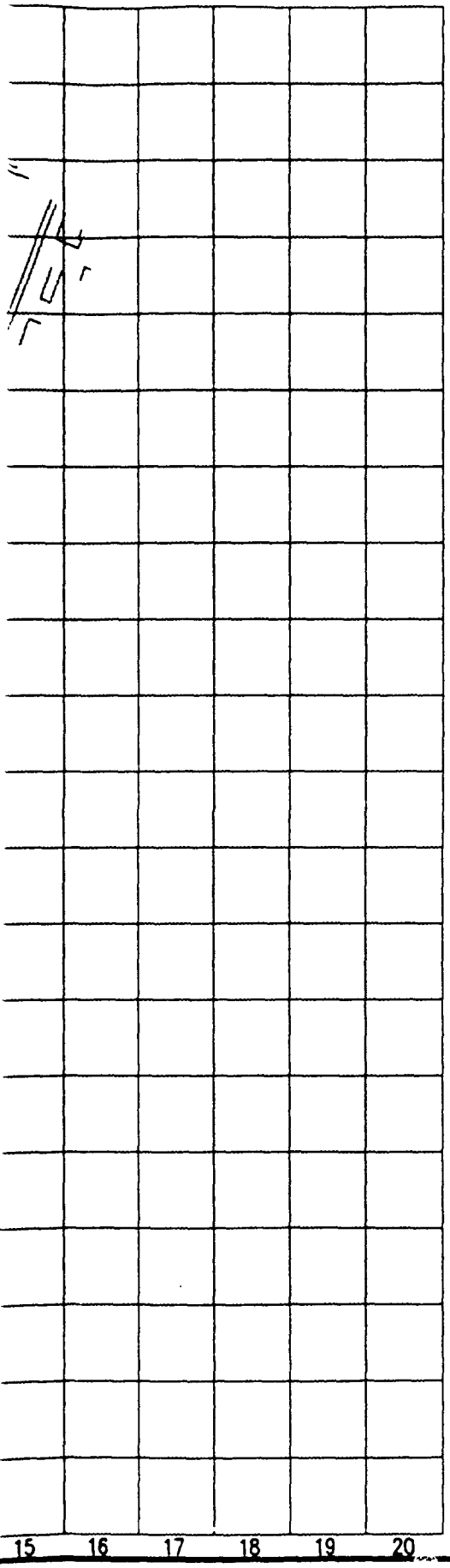

LEGEND

MW-02-006 — GROUND WATER MONITORING WELL

84E — LIF-CPT SAMPLE LOCATION

2.0 — LINE OF ESTIMATED EQUAL TOTAL BTEX CONCENTRATION (ppb)

ND — NOT DETECTED

CONTOUR INTERVAL = 1000 ppb

NOTES:

1. GRID CELL SIZE EQUALS 400 FT. x 400 FT.
2. PLUME SIMULATED USING CONTINUING SOURCE DIMINISHED BY 20 PERCENT AFTER THE YEAR 1993. SIMULATION CONTINUED FOR 10 YEARS WITH REDUCED BTEX LOADING.

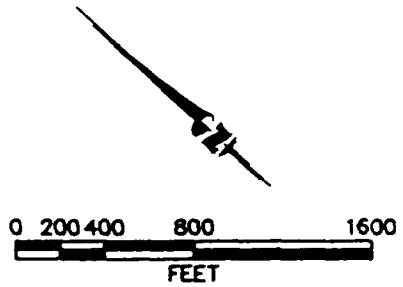

FIGURE 6.10

SIMULATED BTEX PLUME IN THE YEAR 2003 WITH SOURCE REDUCTION (T = 48 YEARS)

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

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The results of models PLATCAL and PLATPRD indicate that the BTEX mass can be slowly removed from the ground water by both nondestructive and destructive contaminant attenuation mechanisms. The BTEX plume should not migrate further downgradient in the next 10 years. Contaminant concentrations can also be expected to remain at or near the levels measured in December 1993. These model trends are consistent with analytical data on the size and concentration of the BTEX plume in September 1991 and December 1993.

The relatively slow removal of BTEX compounds predicted by the model simulations is largely a function of the high contaminant source concentrations. Sufficient BTEX mass is present within the system to hinder rapid biodegradation, even in the presence of elevated DO. Further, Bioplume II does not account for desorption of contaminants from the aquifer matrix. A review of the mass-balance computations for model PLATCAL and PLATPRD indicated that of the total mass of BTEX removed from the aquifer, approximately 50-percent is adsorbed. As a result, the concentrations of BTEX that could desorb after the dissolved BTEX diminishes could be a significant continuous source of BTEX contamination. Thus, saturated soils could act as a long-term BTEX source once other sources have been exhausted. These nondestructive attenuation mechanisms also will affect BTEX plume behavior over time.

These model simulations are conservative for three reasons:

1) The total mass of BTEX in the ground water has been overestimated by not considering the vertical distribution of contaminants;

2) No anaerobic degradation processes were included in the model, even though there is site evidence that these processes are involved in the mineralization of BTEX; and

3) The stoichiometry used to determine ratio between DO and total BTEX assumed that no microbial cell mass was produced during the reaction. As discussed in Section 5.5, this approach may be too conservative by a factor of three.

The Bioplume II model was employed at the FT-002 site to explore how the BTEX plume will behave over time. The Bioplume II model could not incorporate many of the physical and chemical processes that appear to be operating at the site. For example, the 2-D model could not capture the complexity of vertically distributed contaminants. Additionally, the

contribution and relative distribution of anaerobic redox processes cannot be modeled with Bioplume II. The model also uses simple stoichiometric relationships to define biodegradation potential. As discussed in Section 5.5.2.1, these relationships assume all electron acceptors in the ground water are available to participate in BTEX degradation. No adjustments based on thermodynamic principles is incorporated. Finally, the presence of TCE at this site will complicate BTEX degradation. Although BTEX is used as the primary substrate in cometabolism, the degradation of TCE could have a negative effect on the long-term ability of the aquifer to degrade BTEX. Some of the degradation products of TCE may limit the metabolic potential of resident microorganisms to mediate BTEX degradation (McCarty and Semprini, 1994).

SECTION 7

COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

This section presents the development and comparative analysis of four ground water remedial alternatives for Site FT-002. The intent of this evaluation is to determine if intrinsic remediation is an appropriate and cost-effective remedial technology to consider when developing final ground water remedial strategies for Site FT-002, especially when combined with other innovative and conventional remedial technologies

Section 7.1 presents the evaluation criteria used to evaluate ground water remedial alternatives. Section 7.2 discusses the development of remedial alternatives considered as part of this demonstration. Section 7.3 provides a brief description of each of these remedial alternatives. Section 7.4 provides a more detailed analysis of the remedial alternatives using the defined remedial alternative evaluation criteria. The results of this evaluation process are summarized in Section 7.5.

7.1 REMEDIAL ALTERNATIVE EVALUATION CRITERIA

The evaluation criteria used to identify the appropriate remedial alternative for shallow ground water contamination at Site FT-002 were adapted from those recommended by the USEPA (1988) for selecting remedies for Superfund sites (OSWER Directive 9355.3-01). These criteria included (1) long-term effectiveness and permanence, (2) technical and administrative implementability, and (3) relative cost. The following sections briefly describe the scope and purpose of each evaluation criterion. This report does not include a complete discussion of applicable or relevant and appropriate requirements (ARARs) for the site. Rather, this report focuses on the potential use of intrinsic remediation and source reduction technologies to reduce BTEX concentrations within the shallow ground water to levels that meet federal- and state-specified ground water quality standards. This report also briefly discusses if these remedial technologies would be an effective option for remediating chlorinated solvent contamination in ground water at the site.

7.1.1 Long-Term Effectiveness and Permanence

Each remedial technology or remedial alternative (which can be a combination of remedial technologies such as intrinsic remediation and institutional controls) was analyzed to determine how effectively it will minimize the expansion of the existing ground water plume so that promulgated ground water quality standards can be achieved at a proposed point of compliance (POC). The expected technical effectiveness based on case histories from other sites with similar conditions is also evaluated. The ability to minimize potential impacts to surrounding facilities and operations is considered. Also, the ability of each remedial alternative to protect both current and potential future receptors from potential risks associated with site-related contamination in shallow ground water is qualitatively assessed by conservatively estimating if a potential exposure pathway involving ground water could be completed, either now or in the future. This evaluation criterion also includes permanence and the ability to reduce contaminant mass, toxicity, and volume. Time to implementation and time until protection is achieved are described. Long-term reliability for providing continued protection, including an assessment of the potential for failure of the technology and the potential threats resulting from such a failure, is also evaluated.

7.1.2 Implementability

The technical implementation of each remedial technology or remedial alternative was evaluated in terms of technical feasibility and availability. Potential shortcomings and difficulties in construction, operations, and monitoring are presented and weighed against perceived benefits. Requirements for any post-implementation site controls such as long-term monitoring (LTM) and land use restrictions are described. Details on administrative feasibility in terms of the likelihood of public acceptance and the ability to obtain necessary approvals are discussed.

7.1.3 Cost

The total cost (present worth) of each remedial alternative was estimated for relative comparison. An estimate of capital costs, and operations and post-implementation costs for site monitoring and controls is included. An annual inflation factor of 5 percent was assumed in all present worth calculations.

7.2 FACTORS INFLUENCING ALTERNATIVES DEVELOPMENT

Several factors were considered during the identification and screening of remedial technologies for addressing shallow ground water contamination at Site FT-002. Factors considered included the objectives of the natural attenuation demonstration program; contaminant, ground water, and soil properties; present and future land use; and potential exposure pathways involving shallow ground water. The following section briefly describes each of these factors and how they were used to narrow the list of potentially applicable remedial technologies to the final remedial alternatives considered for Site FT-002.

7.2.1 Program Objectives

The intent of the intrinsic remediation demonstration program sponsored by AFCEE is to develop a systematic process for scientifically investigating and documenting naturally occurring subsurface attenuation processes that can be factored into overall site remediation plans. The objective of this program and the specific study at Site FT-002 is to provide solid evidence of intrinsic remediation of dissolved BTEX compounds so that this information can be used to develop an effective ground water remediation strategy. A secondary goal of this multi-site initiative is to provide a series of regional case studies that demonstrate that natural processes of contaminant degradation can often reduce contaminant concentrations in ground water to below acceptable cleanup standards before completion of potential exposure pathways.

Because the objective of this program is to study natural processes in the saturated zone rather than all contaminated media (i.e., soil, soil gas, etc.), technologies have been evaluated based primarily on their potential impact on shallow ground water and phreatic soils. However, technologies that can reduce vadose zone contamination and partitioning of contaminants into ground water have also been evaluated. Many of the source removal technologies evaluated in this section will also reduce soil and soil gas contamination, but it is important to emphasize that the remedial alternatives developed in this document are not intended to remediate all contaminated environmental media. Additional program objectives set forth by AFCEE include cost effectiveness and minimization of waste. Technologies that may meet these criteria include institutional controls, soil vapor extraction (SVE), bioventing, air sparging, ground water extraction and treatment, *in situ* permeable reaction walls, and intrinsic remediation. Soil excavation, slurry walls, sheet piling, carbon adsorption, *ex situ* biological or chemical treatment, and onsite/offsite disposal are not attractive remedial technology candidates for this site.

7.2.2 Contaminant Properties

The site-related contaminants considered as part of this demonstration at Site FT-002 are the BTEX compounds. Other known fuel-related compounds found in ground water at Site FT-002 are the chlorinated solvents TCE, DCE, and vinyl chloride. The source of all of these compounds is off-specification JP-4 fuel, which contained solvents and other chemicals, that was used in fire training exercises at Site FT-002. The physiochemical characteristics of JP-4, the individual BTEX compounds, and the chlorinated solvent compounds will greatly influence the effectiveness of various remedial technologies.

Petroleum hydrocarbon mixtures, such as JP-4, are comprised of over 300 compounds with different physiochemical characteristics. JP-4 is classified as an LNAPL with a liquid density of 0.75 gram per cubic centimeter (g/cc) at 20 °C (Smith *et al.*, 1981). Many compounds in JP-4 adsorb very well to soil and are concentrated in the capillary fringe because the mixture is less dense than water. JP-4 is slightly soluble in water, with a maximum solubility of approximately 300 ppm. JP-4 is also a primary substrate for biological metabolism. In fact, mineralization rates of hydrocarbons in mixtures, such as JP-4, may be faster than mineralization of the individual constituents as a result of cometabolic pathways (Jamison *et al.*, 1975; Perry, 1984).

The BTEX compounds are generally volatile, highly soluble in water, and adsorb less strongly to soil than other hydrocarbons in a petroleum mixture. These characteristics allow the BTEX compounds to leach more rapidly from contaminated soil into ground water, and to migrate as dissolved contamination (Lyman *et al.*, 1992). All of the BTEX compounds are highly amenable to *in situ* degradation by both biotic and abiotic mechanisms.

Benzene is very volatile, with a vapor pressure of 76 millimeters of mercury (mm Hg) at 20°C and a Henry's Law Constant of approximately 0.0054 atmosphere-cubic meters per mole (atm-m^3/mol) at 25°C (Hine and Mookerjee, 1975; Jury *et al.*, 1984). The solubility of pure benzene in water at 20°C has been reported to be 1,780 ppm (Verschueren, 1983). Benzene can be biodegraded to carbon dioxide, with catechol as a short-lived intermediate (Hopper, 1978; Ribbons and Eaton, 1992).

Toluene is also volatile, with a vapor pressure of 22 mm Hg at 20°C and a Henry's Law Constant of about 0.0067 atm-m^3/mol at 25°C (Pankow and Rosen, 1988; Hine and Mookerjee, 1975). Toluene adsorbs more readily to soil than benzene, but still is very mobile. The solubility of pure toluene in water at 20°C is approximately 515 ppm at 20°C (Verschueren, 1983). Toluene has been shown to degrade to pyruvate, acetaldehyde, and completely to carbon

dioxide via the intermediate catechol (Hopper, 1978; Wilson *et al.*, 1986; Ribbons and Eaton, 1992).

Ethylbenzene has a vapor pressure of 7 mm Hg at 20°C and a Henry's Law Constant of 0.0066 atm-m^3/mol (Pankow and Rosen, 1988; Valsaraj, 1988). Ethylbenzene adsorbs more strongly to soil than benzene but less strongly than toluene (Abdul *et al.*, 1987). Pure ethylbenzene is also less soluble than benzene and toluene in water at 152 ppm at 20°C (Verschueren, 1983; Miller *et al.*, 1985). Ethylbenzene can ultimately biodegrade to carbon dioxide via its intermediate 3-ethylcatechol (Hopper, 1978; Ribbons and Eaton, 1992).

The three isomers of xylene have vapor pressures ranging from 7 to 9 mm Hg at 20°C and Henry's Law Constants of between 0.005 and 0.007 atm-m^3/mol at 25°C (Mackay and Wolkoff, 1973; Hine and Mookerjee, 1975; Pankow and Rosen, 1988). Of all of the BTEX compounds, xylenes adsorb most strongly to soil, but still can leach from soil into the ground water (Abdul *et al.*, 1987). The solubility of pure xylenes in water range from 152 to 160 ppm at 20°C (Bohon and Claussen, 1951; Mackay and Shiu, 1981; Isnard and Lambert, 1988). Xylenes can biodegrade to carbon dioxide via pyruvate carbonyl intermediates (Hopper, 1978; Ribbons and Eaton, 1992).

The chlorinated solvents at Site FT-002 may be more recalcitrant to biodegradation than the BTEX compounds. The primary mechanisms of attenuation for chlorinated solvents once they reach the ground water are adsorption, biodegradation, and volatilization to the vadose zone. There are no known microorganisms that are capable of growth using halogenated aliphatic compounds (e.g., TCE, DCE, and vinyl chloride) as a primary carbon source Chapelle, 1993). The microorganisms that can degrade the chlorinated solvents in the soil and ground water use the BTEX compounds as the primary carbon substrate. Chlorinated compounds can be biodegraded via cometabolic processes (see Section 5).

TCE is very volatile, with a vapor pressure of 100 mm of Hg at 20 °C and a Henry's Law Constant of approximately 0.0099 atm-m^3/mol at 20 °C (Roberts and Dandliker, 1983). Although TCE adsorbs to soil, it is more mobile than all of the BTEX compounds except benzene. TCE is only slightly more adsorptive than benzene. The solubility of TCE in water is approximately 4,400 ppm at 20 °C. Microbial degradation of TCE by dehalogenation can result in the degradation products 1,1-dichloroethane (1,1-DCA), cis-1,2-DCE, trans-1,2-DCE, chloroethane, and vinyl chloride. Abiotic hydrolysis products include acetic acid and 1,1-DCE (Smith *et al.*, 1984).

DCE is also very volatile, with a vapor pressure of 591 mm of Hg at 25 °C (Verschueren 1983) and a Henry's Law Constant of 0.021 atm-m^3/mol (Schwille, 1988). DCE is significantly more mobile than both TCE and benzene (see Appendix E). The solubility of DCE in water is approximately 400 ppm at 20 °C. DCE can be biodegraded to vinyl chloride and/or carbon dioxide under methanogenic, anoxic ground water conditions.

Vinyl chloride is extremely volatile, with a vapor pressure of 2,580 mm of Hg at 20 °C (Lyman *et al.*, 1982) and a Henry's Law Constant of 0.056 atm-m^3/mol at 25°C (Hine *et al.*, 1975). Vinyl chloride does not adsorb as well as both TCE and DCE (Karickhoff *et al.*, 1979). It is more mobile than TCE, DCE, and benzene in ground water. The solubility of vinyl chloride in water is about 1,100 ppm at 25 °C (Verschueren, 1983).

Based on these physiochemical characteristics, intrinsic remediation, SVE, bioventing, air sparging, *in situ* permeable permeable wall, ground water extraction and treatment, and air stripping technologies all could be effective at collecting, destroying, and/or treating both BTEX and chlorinated solvent contaminants at Site FT-002.

7.2.3 Site-Specific Conditions

Two general categories of site-specific characteristics were considered when identifying remedial technologies for comparative evaluation as part of this demonstration. The first category was physical characteristics such as ground water depth, hydraulic conductivity, gradient, flow direction, and soil type, which influence the types of remedial technologies most appropriate for the site. The second category involved assumptions about future land use and potential exposure pathways. Each of these site-specific characteristics have influenced the selection of remedial alternatives included in the comparative evaluation.

7.2.3.1 Ground Water and Soil Characteristics

Site geology and hydrogeology will have a profound effect on the transport of contaminants and the effectiveness and scope of required remedial technologies at a given site. Hydraulic conductivity is perhaps the most important aquifer parameter governing ground water flow and contaminant transport in the subsurface. The velocity of the ground water and dissolved contamination is directly related to the hydraulic conductivity (K) of the saturated zone. Hydraulic conductivity values for the unconfined sand aquifer underlying Site FT-002 ranged from 0.059 to 90.7 ft/day (i.e., 2.1×10^{-5} to 3.2×10^{-2} cm/sec). The average K for Site FT-002 was determined by *in situ* testing to be 11.6 ft/day (i.e., 4.1×10^{-3} cm/sec). K values were

observed to decrease slightly with depth, probably due to a decrease in grain size and/or compaction of soils. The shallow ground water plume at Site FT-002 has migrated longitudinally downgradient and laterally away from the source area, thus increasing the extent of contamination (i.e., the plume has expanded).

The advective ground water velocity for the unconfined sand aquifer ranges from approximately 0.29 to 0.38 ft/day, which is characteristic of silty sand units interspersed with silt lenses. Under these conditions, the BTEX and chlorinated solvent plume should migrate downgradient relatively rapidly (see Table 5.3). The chlorinated solvents TCE, DCE, and vinyl chloride will migrate more readily than most of the BTEX compounds because of their lower adsorptive characteristics. Both DCE and vinyl chloride are more mobile than benzene; benzene is only slightly more mobile than TCE. Migration of the BTEX and the chlorinated solvents in ground water will enhance biodegradation processes and other remedial technologies. Ground water mass flow will provide indigenous microorganisms in the BTEX plume with a continual source of electron acceptors. Further, the dispersion of contaminants within the ground water will enhance biodegradation by distribution BTEX within areas enriched in available electron acceptors. Additionally, it may be less expensive and time-consuming to capture and treat the dissolved contaminant plume using a network of extraction wells in areas of high hydraulic conductivity. Contaminant recovery may also be maximized when contaminants are not significantly adsorbed to and retarded by phreatic soil. The effectiveness of air sparging may also be increased in highly conductive aquifers because of reduced entry pressures and increased radius of influence. Greater hydraulic conductivity also will increase the amount of contaminant mass traveling through the air sparging network.

Data collected as part of this demonstration and described in Sections 4 and 5 of this document indicate that Site FT-002 is characterized by adequate and available carbon/energy sources and electron acceptors to support biodegradation of the BTEX compounds and anaerobic cometabolism of the chlorinated solvents. Further, because fuel hydrocarbon-degrading microorganisms have been known to thrive under a wide range of temperature and pH conditions (Freeze and Cherry, 1979), the physical and chemical conditions of the ground water and phreatic soil at Site FT-002 are not likely to inhibit microorganism growth. Fuel hydrocarbon-degrading microorganisms are considered to be ubiquitous (see Section 5). Indigenous microorganisms have a distinct advantage over microorganisms injected into the subsurface to enhance biodegradation because indigenous microorganisms are well adapted to the physical and chemical conditions of the subsurface in which they reside (Goldstein *et al.*, 1985). Stimulating

natural biodegradation in phreatic soil and ground water by microbial inoculation was not considered a viable remedial technology for Site FT-002.

7.2.3.2 Potential Exposure Pathways Involving Shallow Ground Water

An exposure pathway analysis identifies the potential human and ecological receptors that could potentially come into contact with site-related contamination and the pathways through which these receptors might be exposed. To have a completed exposure pathway, there must be a source of contamination, a potential mechanism(s) of release, a pathway of transport to an exposure point, an exposure point, and a receptor. If any of these elements do not exist, the exposure pathway is considered incomplete, and receptors will not come into contact with site-related contamination. Evaluation of the potential long-term effectiveness of any remedial technology or remedial alternative as part of this demonstration includes determining if the approach will be sufficient and adequate to minimize plume expansion so that potential exposure pathways involving shallow ground water are incomplete.

Assumptions about current and future land uses at a site form the basis for identifying potential receptors, potential exposure pathways, reasonable exposure scenarios, and appropriate remediation goals. USEPA (1991) advises that the land use associated with the highest (most conservative) potential level of exposure and risk that can reasonably be expected to occur should be used to guide the identification of potential exposure pathways and to determine the level to which the site must be remediated.

The source areas at Site FT-002 include the four former fire training pits, a partially buried fuel storage tank, a network of underground fuel supply and drainage lines, and an intact oil/water separator. Hangars and other maintenance buildings, aircraft pads, taxiways, runway infields, and the flightline are located to the east and southeast of Site FT-002. The area south of the site is occupied by open fields and is bounded by the Salmon River. The nearest on-base housing unit is more than 6,000 feet southeast (downgradient) of Site FT-002. The nearest off-base residential area is the cluster of mobile homes located approximately 2,000 feet south (crossgradient) of the site. Various light industries are located about 800 feet to the west, and Interstate 87 is located about 1,600 feet west of the site. The ground water plume originating from Site FT-002 is migrating to the southeast. Site-related contamination in the shallow ground water extends about 4,800 feet downgradient from Site FT-002. Ground water BTEX contamination is less extensive than chlorinated solvent contamination, and is limited to an area about 2,800 feet downgradient from the suspected source area.

A human health baseline risk assessment has been completed for Site FT-002 (ABB Environmental, Inc. and URS Consultants, Inc., 1993). The site has been designated a controlled-access area. This means that only military personnel who work within the controlled area and civilians (i.e., contractors) that obtain prior security clearance can access Site FT-002. Access to the site by general base personnel and civilians is unlikely. Thus, the current land use within and downgradient of the FT-002 contaminant plume can be defined as military/industrial.

Under reasonable current land use assumptions, potential receptors are limited to base and contractor worker populations. It is unlikely that workers could be exposed to site-related contamination in phreatic soils or shallow ground water unless this material is removed during future construction excavations or remedial activities. Contact with shallow ground water is highly unlikely, even under construction scenarios, because the ground water table is located about 30 to 40 feet bgs.

The shallow ground water at Site FT-0[illegible] used to meet base or public water supply demands (ABB Environmental, Inc. and URS Consultants, Inc., 1993). The shallow ground water at Site FT-002 is also not likely to be used as a potable water source in the future, as base water requirements are fulfilled by the municipal water supply from the city of Plattsburgh. These potable water supplies are derived from the Westbrook, Patterson, and Mead reservoirs, which are located about 7.5 west of the base. Nearby housing areas that use private wells are located upgradient and crossgradient from Site FT-002.

Assumptions about hypothetical future land uses must also be made to ensure that the remedial technology or alternative considered for shallow ground water at the site is adequate and sufficient to provide long-term protection. Due to the proximity of the flightline and runway, no changes in land use are anticipated in the foreseeable future. The shallow ground water is not likely to be developed as a potable water source even if the site does not remain under military control (ABB Environmental, Inc. and URS Consultants, Inc., 1993). Two nearby housing areas rely on private wells to meet their water requirements. However, these housing areas are located 2,000 feet crossgradient and more than 5,000 feet upgradient from Site FT-002 (ABB Environmental, Inc. and URS Consultants, Inc., 1993). Even though the ground water underlying Site FT-002 has been classified as a potential potable water source, it is unlikely that these resources would be developed for unrestricted use. The base or local land use authority could also retain control of these resources to ensure long-term protection of human health and the environment. Therefore, the industrial land use assumption is the most appropriate exposure scenario considered for future potential receptors.

Ground water migrating from Site FT-002 is suspected to discharge into downgradient surface water bodies (see Section 3). No BTEX contamination has been measured in samples collected near or within these surface water bodies. Both analytical data and model results demonstrate that the BTEX plume is not likely to migrate sufficiently downgradient to affect these surface water resources. This exposure pathway is considered incomplete for the BTEX compounds. However, chlorinated solvents have been detected in several surface water samples (ABB Environmental, Inc. and URS Consultants, Inc., 1993). It is conceivable that potential human and ecological receptors could be exposed to chlorinated solvent ground water contamination when it discharges into receiving surface waters. These surface water bodies are located within the restricted-access area. This potential exposure pathway should be considered when developing appropriate remedial technologies for the chlorinated solvent compounds

In summary, the use of the intrinsic remediation technology at this site will require that the source area be maintained as industrial property and that restrictions on shallow ground water use be enforced at and downgradient from Site FT-002 until naturally occurring attenuation processes reduce contaminants to concentrations that are within acceptable levels. If source removal technologies such as SVE, bioventing, air sparging, or ground water extraction and treatment are implemented, they will have some impact on the short- and long-term land use options and will require some level of institutional control and worker protection during remediation. Because contaminated ground water currently discharges into onsite surface water, intrinsic remediation will not be an effective remedial technology alone for chlorinated solvent ground water contamination. Other innovative remedial technologies will be considered to supplement the effects of intrinsic remediation.

7.2.3.3 Potential Remediation Goals for Shallow Ground Water

Model results suggest that BTEX compounds are not likely to migrate further downgradient from the observed plume front. Both site data and model results suggest that the BTEX plume will gradually recede even in the absence of source reduction. Thus, the proposed POC for the BTEX compounds is an area located about 400 feet east and south of the current BTEX plume front. This would be a suitable location for monitoring and for demonstrating compliance with protective ground water quality standards, such as promulgated federal- and state-specified ground water maximum contaminant levels (MCLs). This area is located upgradient of the surface water bodies that may intercept contaminated ground water migrating from Site FT-002.

However, the proposed POC would have to be located further downgradient to monitor chlorinated solvent compounds. The current chlorinated solvent plume extends approximately

2,000 feet further downgradient than the existing BTEX plume. If the proposed POC was located within this larger plume, it is likely that federal MCLs for the individual chlorinated solvents would be exceeded. A more appropriate proposed POC for all site-related contaminants would be an area approximately 800 feet southeast of the leading front of the existing dissolved chlorinated solvent plume. This POC area contains the surface water bodies that may be receiving ground water discharge. However, it may also be difficult to delineate contamination from Site FT-002 at this downgradient location because the industrial area east of the flightline may be contaminated from other source areas. These considerations will have to be addressed when locating the POC wells for Site FT-002.

This remedial strategy assumes that compliance with promulgated, single-point remediation goals is not necessary if site-related contamination does not pose a threat to human health or the environment (i.e., the exposure pathway is incomplete). Thus, the magnitude of required remediation in areas that can and will be placed under institutional control is different from the remediation that is required in areas that may be available for unrestricted use. The primary remedial objective for shallow ground water within and downgradient from Site FT-002 is to limit plume expansion to prevent completion of an exposure pathway involving ground water. This means that viable remedial alternatives must be able to achieve concentrations that minimize plume migration and/or expansion.

There are several potential remediation goals for shallow ground water at Site FT-002. Table 7.1 identifies the three types of goals. The most stringent of these concentration goals are the New York State Department of Environmental Conservation (NYSDEC) ground water "GA" MCLs. Attainment of these goals assumes that the shallow ground water will be a potable source of water. Federal MCLs are the least stringent of the potential remediation goals for the shallow ground water. Federal MCLs should provide conservative remediation goals for Site FT-002 at the proposed POC if the ground water is not likely to be used as a potable water source. If the base or the local land use authority cannot maintain adequate institutional control on these downgradient resources, the New York drinking water MCLs or the New York ground water protection standards may be target concentrations at the proposed POC.

In summary, available data suggest that there is no complete potential exposure pathway involving BTEX-contaminated ground water under current conditions. Moreover, it is likely that potential exposure pathways involving BTEX-contaminated ground water will be incomplete under future land use assumptions, provided use of shallow ground water as a potable or industrial source of water is prohibited by institutional controls within the plume area.

Institutional controls will be a necessary component of any ground water remediation strategy for this site.

TABLE 7.1
POTENTIAL GROUND WATER REMEDIATION GOAL
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Compound	Federal MCLs [a] (ppb)	NYSDEC Ground Water Quality Protection Requirements [b] (ppb)	NY Drinking Water MCLs [c] (ppb)
Benzene	5	0.7	5
Toluene	1,000	5	5
Ethylbenzene	700	5	5
Total Xylenes	10,000	5	5
TCE	5	5	5
1,2-DCE (Total)	100 [d]	5	5
Vinyl Chloride	2	2	2

[a] Federal Maximum Contaminant Levels (EPA, 1992).
[b] NYSDEC Ground Water Classification, Quality Standards, and Ground Water Effluent Standards (6 NYCRR Chapter 701 and 703). Standards based on classification as "GA", suitable as a source of potable water.
[c] New York State Department of Health Drinking Water Supplies (10 NYCRR Chapter 5, subpart 5-1).
[d] As trans-DCE. Federal MCL for cis-DCE is 70 ppb.

7.2.4 Summary of Remedial Technology Screening

Several remedial technologies have been identified and screened for use in treating the contaminated ground water at Site FT-002. Table 7.2 identifies the initial remedial technologies considered as part of this demonstration and those retained for detailed comparative analysis. Screening was conducted systematically by considering the program objectives of the AFCEE intrinsic remediation demonstration, the physiochemical properties of the BTEX compounds and chlorinated solvents, and other site-specific characteristics such as hydrogeology, land use assumptions, potential exposure pathways, and appropriate remediation goals. All of these factors will influence the technical effectiveness, implementation, and relative cost of technologies that can be used to remediate shallow ground water underlying and migrating from the site. The remedial technologies retained for development of remedial alternatives and comparative analysis include institutional controls, intrinsic remediation, long-term monitoring, bioventing, air sparging, SVE, product recovery, and *in situ* permeable reactive barrier walls.

TABLE 7.2
INITIAL TECHNICAL IMPLEMENTABILITY SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS FOR GROUND WATER REMEDIATION
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

General Response Action	Technology Type	Process Option	Implementability	Retain
Long-Term Monitoring	Periodic Ground Water Monitoring	Confirmation Wells	Many existing wells are available to confirm the progress of remediation.	Yes
		Point-of-Compliance Wells	Sufficient distance exists between the plume and possible point-of-compliance to locate several wells.	Yes
Institutional Controls	Ground Water Use Control	Land Use Control/Regulate Well Permits	Plume area is currently within the base boundary and land-use and ground water use are currently under base jurisdiction.	Yes
		Seal/Abandon Existing Wells	No production wells are known to exist in the existing or predicted plume area.	No
		Point-of-Use Treatment	No ground water is extracted from the plume area for any use.	No
	Public Education	Meetings/ Newsletters	Base public relations and environmental management offices have many information avenues to workers and residents.	Yes
Containment of Plume	Hydraulic Controls	Passive Drain Collection	Requires significant disruption base operating area due to the depth contaminants have migrated within the saturated sand zone.	No
		Minimum Pumping/Gradient Control	A line or semicircle of vertical pumping wells could be located along the leading edge of plume to intercept and halt the advance of the plume.	Yes
	Physical Controls	Slurry Walls/Grout Curtains	Requires significant disruption of base operating area. Limited effectiveness. May be required for nonattenuated contamination.	Yes
		Sheet Piling	Requires significant disruption of base operating area. Limited effectiveness.	No
	Reactive/Semi-Permeable Barriers	Biologically/ Chemically Active Zones	Degradation of TCE, DCE, and vinyl chloride can be facilitated as contaminated ground water flows through iron-rich artificial "barrier" area.	Yes

TABLE 7.2 (Continued)
INITIAL TECHNICAL IMPLEMENTABILITY SCREENING OF
TECHNOLOGIES AND PROCESS OPTIONS FOR GROUND WATER REMEDIATION
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

General Response Action	Technology Type	Process Option	Implementability	Retain
In Situ Ground Water Treatment	Biological	Oxygen and/or Nutrient Enhanced Biodegradation (Biosparging)	Differs from biologically active zone in that oxygen and/or nutrients are injected upgradient of plume and allowed to migrate downgradient. In theory, this method can more rapidly reduce higher BTEX concentrations in and immediately downgradient of the source area.	Yes
	Chemical/Physical	Intrinsic Remediation	A combination of natural biological, chemical, and physical removal mechanisms which occur to varying degrees on every site. Ground water data from Site FT-002 indicates that this is a major, ongoing remediation process.	Yes
		Air Sparging (Volatilization)	Injection of air into contaminated aquifer creating a mass transfer of BTEX and chlorinated solvents into air bubbles and into vadose zone. Limited treatability results for site are positive for chlorinated solvents.	Yes
		Soil Vapor Extraction (SVE)	May need to be required to supplement air sparging to collect and treat contaminants transported through the vadose zone. May be difficult to implement due to shallow vadose zone.	Yes
Aboveground Ground Water Treatment	Ground Water Extraction	Vertical Pumping Wells	Entire ground water plume is pumped by installing numerous wells with submersible pumps. High cost and major disruption to area.	No
		Downgradient Horizontal Drains	See Passive Drain Collection.	No
	Biological	Bioreactors	High flow rates require excessive retention times and large reactors. BTEX is often volatilized in these systems.	No
	Chemical/Physical	Air Stripping	Cost-effective technology for removing varying concentrations of BTEX and chlorinated solvents at higher flow rates. Potential permitting for air emissions.	Yes
		Activated Carbon	Cost prohibitive for more concentrated BTEX. Creates a carbon disposal problem.	No
		UV/Ozone Reactors	High flow rates require excessive retention times and large, expensive reactors.	No

TABLE 7.2 (Continued)
INITIAL TECHNICAL IMPLEMENTABILITY SCREENING OF
TECHNOLOGIES AND PROCESS OPTIONS FOR GROUND WATER REMEDIATION
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

General Response Action	Technology Type	Process Option	Implementability	Retain
Ex Situ Treatment	Direct Discharge to Industrial Waste Water Treatment Plant (IWWTP)		Viable option when an IWWTP is available and capable of handling BTEX and hydraulic loading.	No
Treated Ground Water Disposal	Discharge to IWWTP or Sanitary Sewer	IWWTP	Viable option when access to sanitary sewer exists and hydraulic loading is acceptable.	No
		Sanitary Sewer	Viable option when access to sanitary sewer exists and hydraulic loading is acceptable.	No
	Treated Ground Water Reinjection	Vertical Injection Wells	Not recommended due to clogging and high maintenance.	No
		Injection Trenches	Require large trenches and can be subject to injection well permitting.	No
	Discharge to Surface Waters	Storm Drains	Viable option and currently used at site.	Yes
Source Removal/Soil *Remediation*	Free Product Recovery	Dual-Pump Systems	Best suited for sites with >1 foot free product where aboveground ground water treatment already exists	Yes
		Skimmer Pumps/Bailers/ Wicks	Best suited for sites with <1 foot free product where ground water pumping is undesirable.	No
		Total Fluids Pumping	Best suited for sites with thin saturated zones where excessive ground water will not be pumped.	No
		Bioslurping	Combined vapor extraction, bioventing, and free product recovery system has been operated at some sites with limited success.	No
	Excavation/ Treatment	Biological Landfarming	Excavation is not feasible at this site due to extent of contamination and proximity of flightline.	No

TABLE 7.2 (Concluded)
INITIAL TECHNICAL IMPLEMENTABILITY SCREENING OF
TECHNOLOGIES AND PROCESS OPTIONS FOR GROUND WATER REMEDIATION
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

General Response Action	Technology Type	Process Option	Implementability	Retain
	Excavation/ Treatment (cont'd)	Thermal Desorption	Excavation is not feasible at this site due to surface structures and site use.	No
	In Situ	Bioventing	Air injection to stimulate biodegradation of fuel residuals. Pilot system currently installed in source area with successful 1-year results.	Yes
		Soil Vapor Extraction	Vapor extraction has been successfully implemented at other sites. Requires expensive off-gas treatment.	Yes

7.3 BRIEF DESCRIPTION OF REMEDIAL ALTERNATIVES

This section describes how remedial technologies retained from the screening process were combined into four remedial alternatives for Site FT-002. Sufficient information on each remedial alternative is provided to facilitate a comparative analysis of effectiveness, implementability, and cost in Section 7.4.

7.3.1 Alternative 1 - Intrinsic Remediation, Institutional Controls, and Long-Term Ground Water Monitoring

Intrinsic remediation is achieved when naturally occurring attenuation mechanisms bring about a reduction in the total mass of a contaminant in the soil or dissolved in ground water. Intrinsic remediation results from the integration of several subsurface attenuation mechanisms that are classified as either destructive or nondestructive. Destructive attenuation mechanisms include biodegradation, abiotic oxidation, and hydrolysis. Nondestructive attenuation mechanisms include sorption, dilution (caused by mechanical dispersion, diffusion, and infiltration), and volatilization. In some cases, intrinsic remediation alone will be sufficient to reduce dissolved contaminant concentrations below proposed remediation concentration goals. Based on the existing evidence of intrinsic remediation described in Section 5, these processes are occurring at Site FT-002 and will continue to reduce both BTEX and chlorinated solvent contaminant mass.

Results of the PLATCAL Bioplume II modeling run (Section 6) suggest that the dissolved BTEX plume has reached its maximum horizontal extent and is receding. This model predicts that BTEX mass will continue to be slowly removed from the ground water by destructive attenuation mechanisms. After 10 years, the model predicts that the BTEX plume will recede about 400 feet from its current position. Model PLATCAL assumes biodegradation of BTEX occurs via oxygen reduction only. Analytical data presented in Section 5 suggest that other redox couples also are being utilized by microorganisms to oxidize BTEX at the site. Results of model PLATCAL suggest that even with a continuing source of contamination, the BTEX plume will not migrate significantly beyond its current position. However, BTEX contamination will persist in the ground water as long as the LNAPL source continues to release BTEX to the shallow ground water.

The model PLATCAL did not simulate the fate and transport of the chlorinated solvents in the shallow ground water underlying Site FT-002. Although analytical data suggest that TCE is being anaerobically biodegraded via cometabolic processes at the site, it is not likely that these

processes will be sufficient to significantly reduce the expansion of the chlorinated solvent plume. These processes have contributed to the reduction in chlorinated solvent mass at the site, but have not been sufficient to prevent these compounds from migrating beyond the BTEX compounds.

Implementation of Alternative 1 would require the use of institutional controls such as land use restrictions and LTM. Land use restrictions may include placing long-term restrictions on soil excavation within the source area and long-term restrictions on ground water well installations within and downgradient of the plume area. The intent of these restrictions would be to reduce potential receptor exposure to contaminants by legally restricting activities within areas affected by site-related contamination. Eliminating the source of BTEX contamination and chlorinated solvent contamination causes the plume to recede even further, although not disappear entirely.

At a minimum, ground water monitoring would be conducted twice annually as part of this remedial technology to evaluate the progress of natural attenuation processes. Based on the potential plume migration suggested by PLATCAL, it is unlikely that benzene concentrations exceeding the federal MCL/state drinking water MCL of 5 ppb would migrate beyond the existing plume front (this would be true even if it were assumed that model contaminant concentrations are all benzene rather than total BTEX). Results of PLATCAL suggest that the BTEX plume front is not advancing beyond its current position and may in fact be retreating from the December 1993 plume front.

Four nested POC wells could be placed downgradient of the modeled maximum extent of dissolved BTEX (e.g., slightly more than 400 feet downgradient of the source area). POC wells should be installed at multiple depths to ensure that the vertical distribution of contaminants is considered. In addition, four LTM wells within, upgradient, and immediately downgradient of the existing BTEX plume would be used to verify the effectiveness of intrinsic remediation. Three existing wells could be used as LTM wells. One additional nest of wells will have to be installed to supplement the existing well network. LTM wells are further described in Section 8.2.1. Detection of benzene in excess of 5 ppb at downgradient proposed POC wells may require additional evaluation and modeling to assess BTEX migration and to determine the probable extent of BTEX migration, or to determine if additional corrective action would be necessary. Changes in land use assumptions would also require reevaluation of remediation activities.

However, as noted earlier, the proposed POC wells may have to be located further downgradient to assess chlorinated solvent contamination. The four nested POC wells described

above would have to be located more than 2,000 feet downgradient of the existing dissolved BTEX plume to track the leading edge of the chlorinated solvent plume. The location of the four LTM wells would not change, as chlorinated solvents appear only to be cometabolized within the existing BTEX plume.

Public education on this alternative would be developed to inform base personnel and nearby civilians of the scientific principles underlying intrinsic remediation. This education could be accomplished through public meetings, presentations, press releases, and posting of signs where appropriate. Periodic site reviews could also be conducted every year using data collected from the long-term ground water monitoring program. The purpose of these periodic reviews would be to evaluate the extent of contamination, assess contaminant migration and attenuation through time, document the effectiveness of any ongoing source removal activities (i.e., continuing product recovery) and institutional controls at the site, and reevaluate the need for additional remedial actions at the site.

7.3.2 Alternative 2 - Source Removal via Continued/Expanded Product Recovery, Bioventing, Intrinsic Remediation, Institutional Controls, and Long-Term Ground Water Monitoring

This alternative is identical to Alternative 1, except that remedial activities would be expanded to include source removal. Both bioventing and existing/expanded product recovery technologies could be coupled at Site FT-002 to reduce soil contamination and LNAPL within the source area. Bioventing would be used to introduce oxygen into the unsaturated zone in the vicinity of the suspected source area to increase aerobic biodegradation of the BTEX compounds and to limit plume expansion resulting from leaching of hydrocarbons from the unsaturated zone. Bioventing would be accomplished at this site by injecting air throughout the contaminated soil profile to aerate unsaturated soils.

Bioventing wells and multiple-depth monitoring points have already been installed at each of the fire training pits as part of the Bioventing Initiative Test program (Section 1.3). Finalizing the bioventing system would involve manifolding each of the existing wells to fixed 2.5-horse power (HP) regenerative blower units. Each unit would be energized by a 230-volt, single-phase, 30-amp line power from a nearby power source. An injection rate of less than 50 scfm per well would likely be required to oxygenate the soils beneath each of the former fire training pits.

Source removal activities would also include continued operation of the existing product extraction and treatment system (Section 1.3). The product extraction system currently in place

at Site FT-002 could also be expanded to enhance source removal, if desired. Under this option, the existing product extraction and treatment system would be expanded by installing six additional extraction wells. Each extraction well would be advanced to a depth of about 45 feet within the Site FT-002 source area. Each well would be equipped with a 5-HP submersible pump to provide sufficient head to pump the extracted product/ground water to the existing treatment location. The expanded system would be operated at about 23 gallons per minute (gpm). Approximately 2,000 linear feet of additional manifold may be required to connect three series of two wells to the existing treatment system at the site. Effluent from the existing treatment system will be discharged to the storm sewer system, which eventually discharges to surface water.

The goal of continuing and/or expanding source removal operations at the site would be to expedite removal of dissolved BTEX and chlorinated solvents in the ground water. As described previously (Section 6), the Bioplume II model run PLATPRD suggested that a reduction in the source at the site could have an impact on how quickly the dissolved BTEX plume recedes from its current position. For example, the Bioplume II model run PLATPRD indicated that a 20-percent reduction in the total BTEX source would expedite removal of dissolved BTEX compounds in ground water within 10 years. A 20 percent reduction in the total mass of BTEX that can dissolved into the ground water underlying the source area caused the plume to decrease in size by 33 percent in 10 years. This simulation showed that attenuation of the BTEX plume could be enhanced by implementing source removal activities, such as bioventing or product recovery. The Bioplume II model did not account for chlorinated solvents, but it is likely that a reduction in the BTEX source will also reduce the levels of chlorinated solvents in the ground water. Removal of free product will also remove the significant mass of chlorinated solvents, which are dissolved in the free product.

This alternative also includes use of the intrinsic remediation technology as described in Alternative 1. Institutional controls and LTM would also be required. The proposed POC and LTM wells would be installed in the same locations indicated in the previous sections.

7.3.3 Alternative 3 - Source Removal via Continued/Expanded Product Recovery and Bioventing, Intrinsic Remediation Supplemented with Air Sparging, Institutional Controls, and Long-Term Ground Water Monitoring

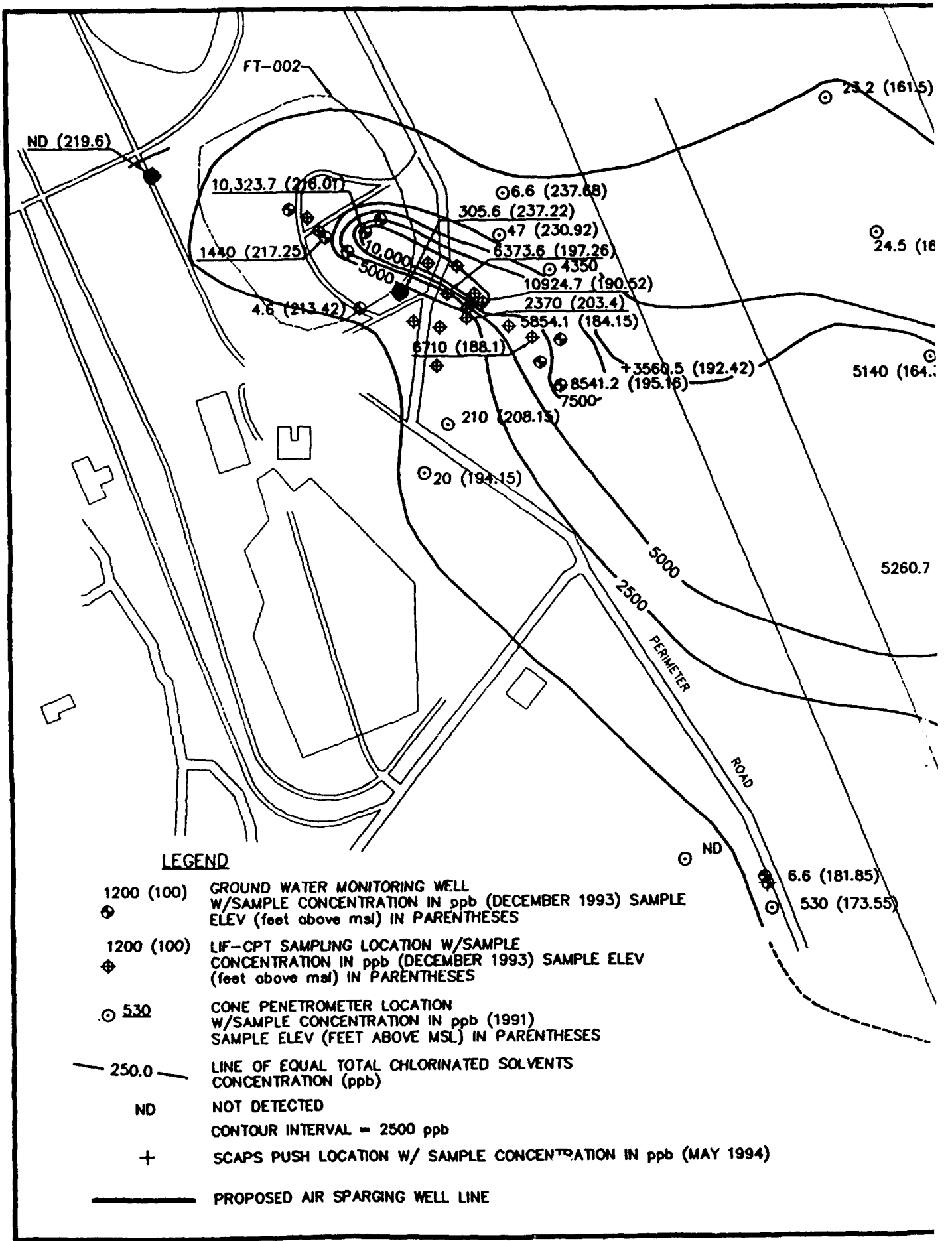
This alternative is identical to Alternative 2, except that air sparging would be integrated to facilitate the removal of chlorinated solvent compounds from the ground water. Air sparging is essentially an *in situ* air stripping process. Air is injected into the saturated zone beneath the

contaminated area, which causes VOCs to partition from the dissolved and adsorbed phases into the gas phase. These compounds are then transported into the unsaturated zone and collected via a vapor collection and treatment system. Air sparging can be used to supplement intrinsic remediation at Site FT-002 by treating the leading edge of the chlorinated solvent plume.

An air sparging pilot test was conducted at Site FT-002 in May 1994 to assess the feasibility of reducing concentrations of dissolved VOCs in ground water using air sparging. The results of this limited air sparging treatability test, which are described in Section 2.7, indicate that air sparging may be an effective method of reducing dissolved chlorinated concentrations. The dissolved constituents could be stripped from the ground water into the vadose zone, where they could then be recovered and treated using a SVE system with off-gas treatment, if required. However, Parsons ES recommends that a long-term (i.e., 90-day) pilot test be conducted to verify the radius of influence and uniformity of treatment. A three-well sparge line should be tested in the downgradient portion of the dissolved chlorinated solvent plume to confirm treatment effectiveness.

Assuming that the long-term pilot test confirmed the effectiveness of this remedial technology on dissolved chlorinated solvents at Site FT-002, air sparging wells would likely be installed and manifolded along a north-south line parallel to the flight line and a shorter east-west line near the leading edge of the chlorinated solvent plume just west of the flight line (Figure 7.1). Two separate lines of wells are required because the local direction of ground water flow changes from due east to southeast near the flightline. The lengths of the north-south and east-west lines are projected to be 1,700 feet and 700 feet, respectively, for an overall proposed length of 2,400 feet. The lateral extent of the chlorinated solvent plume at this point is about 1,500 feet (Figure 4.11a). Assuming that each sparging well has a radius of influence of 20 feet, a conservative well spacing of 35 feet has been selected, and a total of 70 air sparging wells will be required.

Chlorinated solvent compounds are distributed vertically within the unconfined sand unit down to the impermeable clay layer at this point (Figure 4.11b). To sparge the entire saturated alluvial thickness, sparging wells would be installed to a total depth of approximately 50 to 60 feet bgs, at the interface between the clay layer and the alluvium. Screened intervals of 1 to 3 feet would be used. The diameter for the ASWs will range from 1 to 2 inches. Shallow, horizontal manifold piping would be used to connect the ASWs to one or more oilless compressors, which would be used for air injection. Assuming a conservative flow rate of 3 scfm per well, a total flow rate of 210 scfm would be required. Several multiple-depth ground water monitoring points could also be installed along the air sparging line to monitor remedial progress.



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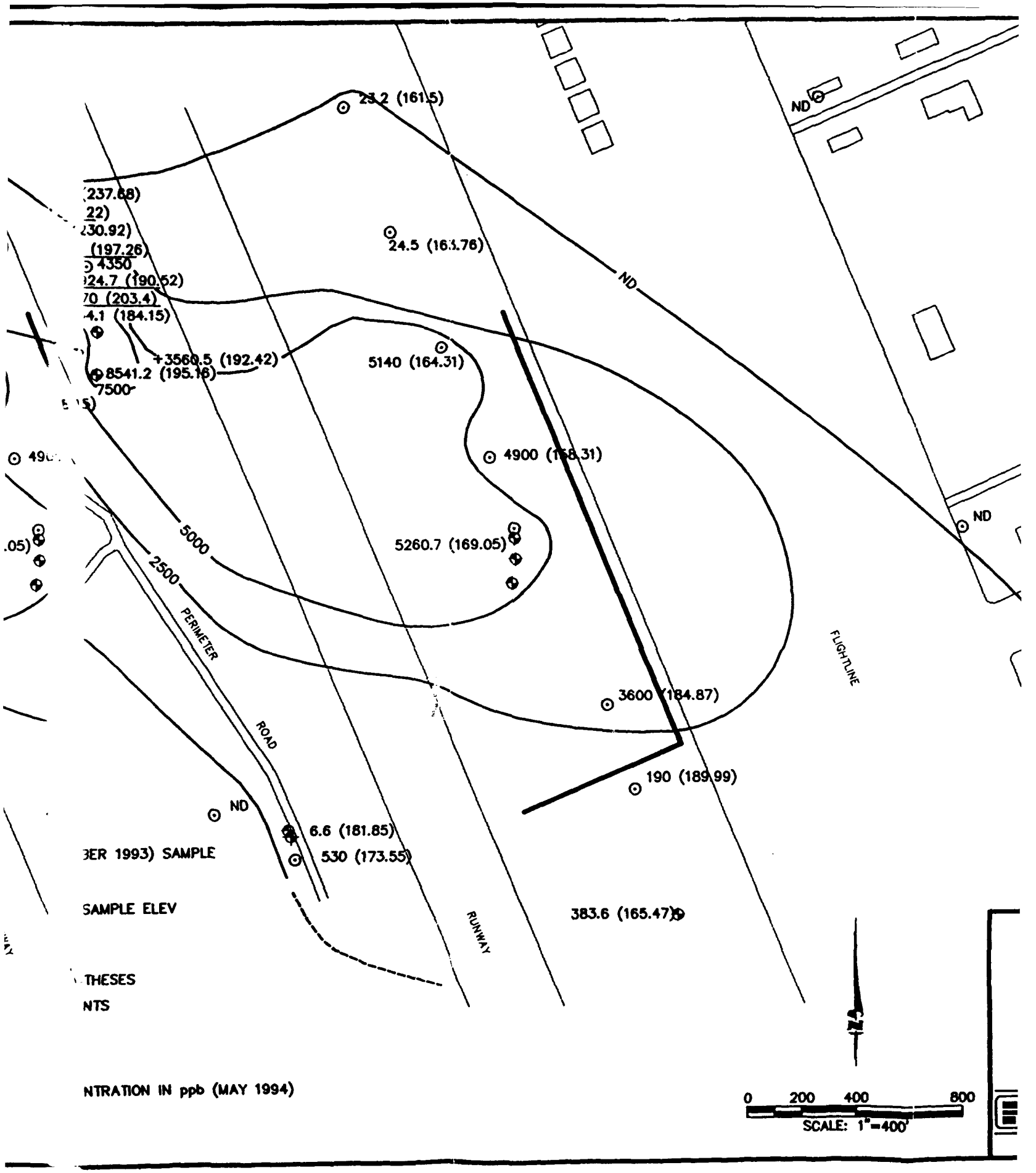
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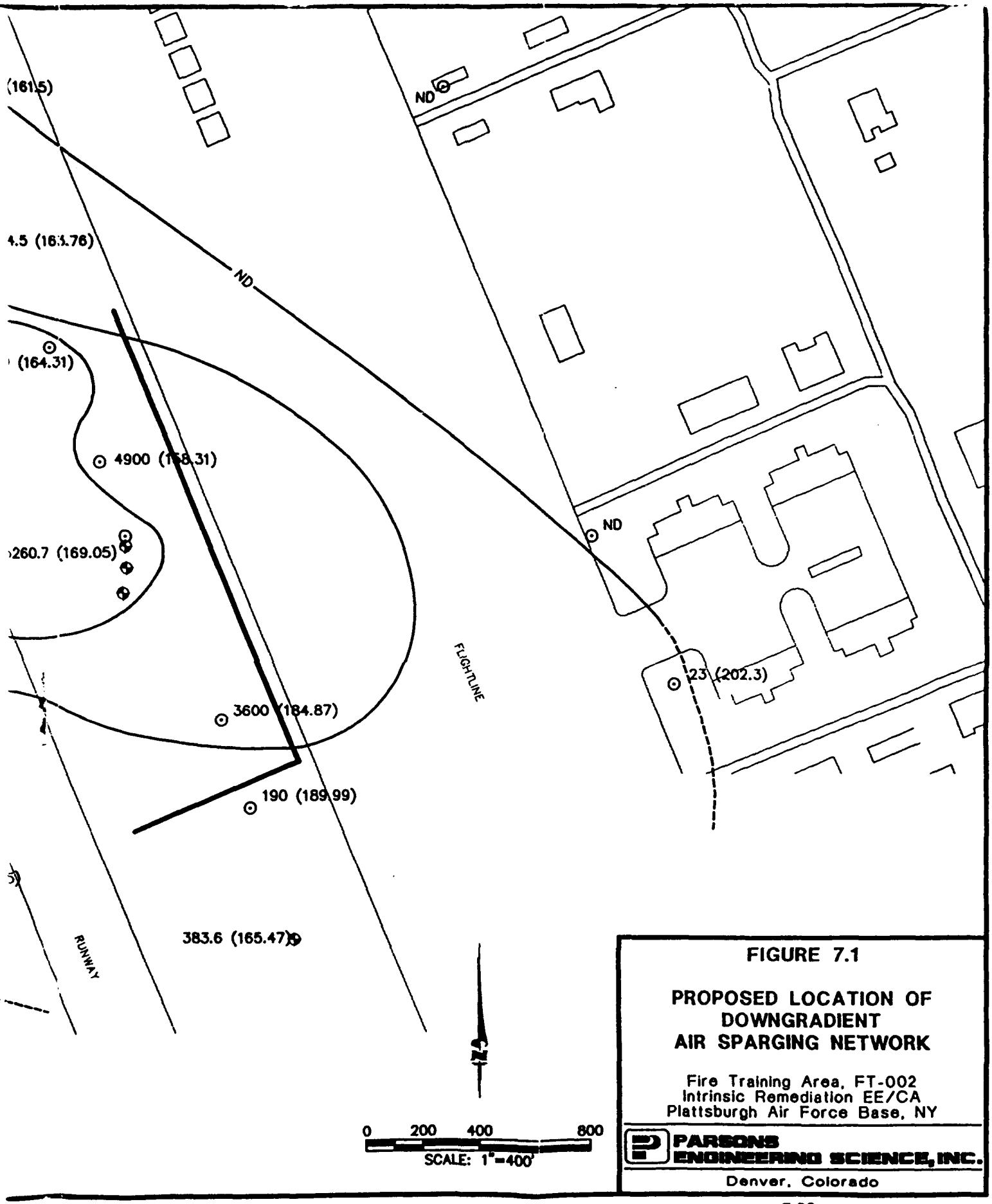

FIGURE 7.1

PROPOSED LOCATION OF DOWNGRADIENT AIR SPARGING NETWORK

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

If VOC removal rates are below applicable action levels, VOCs may be allowed to diffuse passively through the vadose zone into the atmosphere. A SVE system would not be required. If VOC removal rates exceed applicable action levels, a SVE system with off-gas treatment would be installed in the vadose zone above the line of sparging wells to capture and treat VOCs removed from the saturated zone. This system would likely consist of 4-inch diameter horizontal screened piping installed approximately 3 to 4 feet bgs, and connected to a central blower unit that extracts soil gas from the screened piping array. Activated carbon, catalytic oxidation, or some other form of off-gas treatment would be used to treat extracted soil gas before discharge to the atmosphere. VOC removal rates would be determined during the recommended long-term pilot test for air sparging at Site FT-002.

As with Alternative 2, this alternative assumes the source removal activities would be initiated and/or continued, and that institutional controls and LTM would be required. The locations of the POC and LTM wells would likely remain the same as described for Alternative 1.

7.3.4 Alternative 4 - Source Removal via Continued/Expanded Product Recovery and Bioventing, Intrinsic Remediation Supplemented with an *In Situ* Permeable Reaction Wall, Institutional Controls, and Long-Term Ground Water Monitoring

This alternative is similar to Alternative 3, except that the leading edge of the chlorinated solvent plume will be intercepted and treated with an *in situ* permeable reaction wall instead of air sparging. A permeable reaction wall consists of a porous medium containing an iron-based catalyst designed to completely dechlorinate chlorinated organic compounds as the compounds pass through the reaction wall. Although the specific mechanism of dechlorination is not well understood; available data suggest that the wall facilitates abiotic reductive dechlorination (Gillham and O'Hannesin, 1994). Pilot work completed at the Waterloo Centre for Groundwater Research in Ontario, Canada (O'Hannesin and Gillham, 1993) indicates that the concentrations of chlorinated organic compounds can be reduced by over 90 percent using this technology.

Use of such an *in situ* treatment system would supplement the effects of intrinsic remediation. The *in situ* permeable reaction wall has been proposed to replace air sparging to treat the leading edge of the chlorinated solvent plume. Treatment at this point would minimize further plume migration. This technology is not being considered to remediate the suspected source area. A reaction barrier system could be installed at Site FT-002 along the same north-south line and shorter east-west line near the west side of the flightline where the air sparge system would be installed (see Figure 7.1). Installation of this technology would consist of an alternating sections of impermeable material and reactive material constructed within a sheet pile or slurry wall.

Construction of this treatment system would require significant excavation between the runway and flightline at the site to install the wall matrix. The reactive barrier system would need to be at least 2,400 feet long to intercept the zone of maximum contamination and be installed approximately 50 feet bgs to capture all contaminated ground water flowing through this area.

This alternative would also include institutional controls and LTM. The proposed POC and LTM wells would be installed in the same locations indicated in the previous sections.

7.4 EVALUATION OF ALTERNATIVES

This section provides a comparative analysis of each of the remedial alternatives based on the effectiveness, implementability, and cost criteria. A summary of this evaluation is presented in Section 7.5.

7.4.1 Alternative 1 - Intrinsic Remediation, Institutional Controls, and Long-Term Monitoring

7.4.1.1 Effectiveness

Section 6 of this document presents the results of the Bioplume II modeling completed to assess the effectiveness of the intrinsic remediation alternative for BTEX contamination at Site FT-002. A quantitative evaluation of chlorinated solvent migration was beyond the scope of this study, and will have to be fully addressed in other subsequent studies. Two models (PLATCAL and PLATPRD) were developed to illustrate a range of potential future conditions at the site. PLATCAL simulated the fate and transport of BTEX in ground water in the next 10 years assuming that no source reduction occurred at the site. PLATPRD simulated the fate and transport of BTEX in ground water in the next 10 years assuming that the source was effectively reduced by 20 percent.

These model results suggest that natural attenuation mechanisms will significantly limit the migration of BTEX in the shallow ground water at Site FT-002. Based on these simulations, benzene concentrations should not exceed the most stringent potential remediation goals for the site at the proposed POC wells. It is important to note that the Bioplume II model is based upon several conservative assumptions. Ground water monitoring at the LTM and proposed POC wells will ensure the protectiveness of this alternative. While this alternative would not cease to be protective if the benzene plume was intercepted by the proposed POC wells, such an instance would indicate that site conditions should be reevaluated.

The effectiveness of this remedial alternative requires that excavations or drilling within the source area be conducted only by properly protected site workers. Reasonable land use assumptions for the plume area indicate that exposure is unlikely unless excavation or drilling activities bring saturated soil or contaminated ground water to the surface. Long-term land use restrictions will be required to ensure that shallow ground water will not be pumped or removed for potable use within, and approximately 400 feet in all directions from, the existing BTEX plume. Existing health and safety plans should be enforced to reduce risks from installing and monitoring additional POC wells.

Compliance with program goals is one component of the long-term effectiveness evaluation criterion. Alternative 1 will satisfy program objectives designed to promote intrinsic remediation as a component of site remediation and to scientifically document naturally occurring processes.

Alternative 1 is based on the effectiveness of enhanced naturally occurring processes that minimize contaminant migration and reduce contaminant mass over time, and the effectiveness of institutional controls. As described earlier, an investigation of the potential effectiveness of naturally occurring processes at the FT-002 site using field data and the Bioplume II model indicated that the BTEX plume has been attenuated (and is likely receding from its current position). The model sensitivity analysis completed for this site (Section 6) suggests that even under the most conservative (i.e., worst-case) conditions, the naturally occurring processes at Site FT-002 should reduce contaminant migration so that the maximum distance traveled by the plume is unlikely to be beyond the proposed POC wells.

Aside from the administrative concerns associated with enforcement of long-term land use restrictions and long-term ground water monitoring programs, this remedial alternative should provide reliable, continued protection. Model results suggest that the BTEX plume will continue to decrease in size over the next 10 years, although the plume will not be eliminated because the existing source will continue to contribute contaminant mass to the ground water at Site FT-002. Thus, this alternative includes 30 years of annual ground water monitoring to ensure that intrinsic remediation has effectively stabilized the migration of the BTEX plume.

7.4.1.2 Implementability

Alternative 1 is not technically difficult to implement. Installation of LTM and POC wells and annual ground water monitoring are standard procedures. Long-term management efforts will be required to ensure proper sampling procedures are followed. Periodic site reviews should be conducted to confirm the adequacy and completeness of LTM data and verify the

effectiveness of this remediation approach. There may also be administrative concerns associated with initial instating and long-term enforcement of ground water use restrictions. Future land use within the source area may be impacted by leaving contaminated soil and ground water in place. Regulators and the public will have to be informed of the benefits and limitations of the intrinsic remediation option. Educational programs are not difficult to implement, and the initial regulatory reaction to this alternative at other sites has generally been positive.

7.4.1.3 Cost

The cost of Alternative 1 is summarized in Table 7.3. Capital costs are limited to the construction of four nested POC wells and one new LTM well. Included in the $385,770 total present worth cost estimate for Alternative 1 are the costs of establishing and maintaining institutional controls and long-term ground water monitoring for a total of 30 years.

7.4.2 Alternative 2 - Source Removal via Continued/Expanded Product Recovery, Bioventing, Intrinsic Remediation, Institutional Controls, and Long-Term Ground Water Monitoring

7.4.2.1 Effectiveness

The effectiveness of the intrinsic remediation, institutional controls, and LTM components of this alternative have been described under Alternative 1. Bioventing is an established technology that effectively remediates fuel hydrocarbons in the unsaturated zone via the addition of oxygen to stimulate biodegradation by natural microorganisms that already are present at the site. Pilot tests at Site FT-002 have shown that this technology would gradually degrade residual hydrocarbons in the unsaturated soil matrix, thus removing a potential source of contaminants that could be leached to ground water. Initial bioventing tests conducted at Site FT-002 showed that air injection will be an effective method to stimulate aerobic biodegradation of the BTEX compounds (ES, 1993b).

Product recovery and treatment is also an established technology for eliminating source contamination and controlling plume migration. The existing product recovery system at the site has been effective at recovering LNAPL from the subsurface. Extraction operations would be limited to free product. No attempt would be made to capture and treat dissolved BTEX contamination using ground water wells. The Bioplume II model run PLATPRD suggests that reduction of the source would expedite the decrease in the size of the BTEX plume. The existing product treatment system has been effective at treating extracted LNAPL and ground water to levels that facilitate disposal. Expansion of this source removal technology will require

TABLE 7.3

COST ESTIMATE FOR ALTERNATIVE 1
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Capital Costs	Total Cost
Design and construction of four nested POC wells (two depths) and two LTM wells	$41,000
Land use restriction proceedings (unit cost)	$22,000
Operation, Maintenance, and Monitoring Costs (Annual)	**Annual Cost**
Conduct annual ground water sampling of ten LTM wells and eight proposed POC wells (30 years)	$10,000
Maintain institutional controls/public education (30 years)	$5,000
Project management (30 years)	$6,000
Present Worth of Alternative 1 [a/]	**$385,770**

[a/]Based on an annual inflation factor of 5 percent.

chemicals for the onsite treatment system, and result in the generation of waste and treated effluent that will require disposal. Activated carbon polishing before discharge to surface waters is included in the O&M costs for this alternative.

Unfortunately, neither bioventing nor product recovery will be effective at treating dissolved chlorinated solvent contamination downgradient of the source area. As discussed in Section 5, the chlorinated solvents appear to be dechlorinated under anaerobic, reducing conditions within the BTEX plume. Adding oxygen to the source area via bioventing will probably not stimulate the production of enzymes or cofactors that facilitate dechlorination of TCE, DCE, and vinyl chloride. Further, there is little evidence of significant chlorinated solvent degradation downgradient of the existing BTEX plume (i.e., under aerobic conditions). Product recovery activities will eventually decrease the source of both BTEX and chlorinated solvents, which are concentrated in the LNAPL. However, these source removal activities will not be effective at collecting and treating chlorinated solvent compounds that have already migrated downgradient or prevent existing dissolved contaminants from migrating further downgradient.

7.4.2.2 Implementability

Implementation of bioventing is relatively simple, as has been demonstrated under the pilot tests completed at Site FT-002. However, significant delays were encountered when the base attempted to obtain approval from the NYSDEC to conduct initial bioventing tests at the site. It is possible that the bioventing technology may not be well received by the local regulatory community because it has little impact on chlorinated solvent residuals in the soil.

Product extraction and treatment technologies have already been implemented at Site FT-002. Expanding these capabilities would require the installation of additional wells and associated piping. Installation and operation of product recovery wells are standard procedures. The existing treatment system should be able to meet increased treatment requirements. If the existing facility proves to be inadequate to meet increased influent requirements, the cost of this alternative will have to include expanding the treatment capabilities. Impacts to the existing effluent disposal system would also have to be evaluated once the scope of the optional, expanded extraction system is established.

7.4.2.3 Cost

The estimated capital and operating costs of Alternative 2 are shown in Table 7.4. The total present worth of Alternative 2 is about $2,886,740, assuming that all source removal activities,

TABLE 7.4

COST ESTIMATE FOR ALTERNATIVE 2
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Capital Costs	Total Cost
Design and construction of four nested POC wells (two depths) and two LTM wells	$41,000
Finalize design and construction of existing bioventing system in source area	$55,000
Design and construction of six additional product extraction wells in source area, including installation of submersible pump and manifolding to treatment system (optional)	$242,000
Land use restriction proceedings (unit cost)	$22,000
Operation, Maintenance, and Monitoring Cost (Annual)	**Annual Cost**
Conduct annual ground water sampling of ten LTM wells and eight proposed POC wells (30 years)	$10,000
Operation and maintenance of expanded extraction system (assuming 23 gpm) (5 years) (optional)	$30,000
Continued operation and maintenance of existing product recovery treatment system (assuming 23 gpm) (5 years)	$464,000 [a/]
Operate and maintain bioventing system (5 years)	$15,000
Maintain institutional controls/public education (30 years)	$5,000
Project management (30 years)	$6,000
Present Worth of Alternative 2 [b/]	**$2,886,740**

[a/] Based on previous cost estimates for product extraction, treatment, and discharge to surface water (URS Consultants, Inc., 1993)

[b/] Based on an annual inflation factor of 5 percent, and assuming all options are implemented.

including the expanded product extraction system, are implemented. The total capital cost of the bioventing system is projected to be $55,000, and the expanded product extraction system could be designed and installed for a projected total cost of $242,000. The total present worth of this alternative does not include upgrading the existing treatment facility to meet increased influent flow requirements. The cost of Alternative 2 is higher than the cost of Alternative 1 due to the added cost of source removal activities.

Long-term monitoring would be continued for the same length of time as Alternative 1 to verify that the BTEX plume and possibly the chlorinated solvent plume continue to degrade at the site and that any part of the dissolved plume does not reach the proposed POC wells. Annual long-term monitoring would continue for 30 years to ensure that intrinsic remediation is reducing BTEX concentrations throughout the plume.

7.4.3 Alternative 3 - Source Removal via Continued/Expanded Product Recovery and Bioventing, Intrinsic Remediation Supplemented with Air Sparging, Institutional Controls, and Long-Term Ground Water Monitoring

7.4.3.1 Effectiveness

Pilot test results indicate that air sparging may be an effective full-scale remedial technology for the removal of chlorinated solvents from ground water at Site FT-002 (see Section 2.7). A 90-day pilot test has been recommended to determine treatment effectiveness and to obtain system design parameters such as radius of influence. The full-scale air sparging system would be designed to remediate the dissolved chlorinated solvent plume at its leading edge, beyond the extent of the existing BTEX contamination (Figure 7.1). The air sparging system will strip chlorinated solvents from the saturated zone and transfer them upwards to the vadose zone. Without a SVE and off-gas treatment system, the VOCs will eventually be transported to the atmosphere. If these VOC emissions are shown to be below regulatory and risk-based action levels during the proposed extended pilot test for the site, a SVE and off-gas treatment system will not be required. VOC emissions exceeding these action levels will require the installation of a SVE system for the collection and treatment of VOCs in the vadose zone. SVE with off-gas treatment is a conventional *in situ* treatment technology with demonstrated effectiveness. Air sparging is still considered an emerging technology with limited full-scale treatment data available. Air sparging has been most effective in treating uniform, coarse-grained saturated soil contaminated with chlorinated VOCs, such as those that are found at Site FT-002.

Operation of the air sparging system will likely occur over at least a 30-year period. The air sparging system will have to be operated continuously to treat chlorinated solvents migrating from the Site FT-002 source area. The system would have to be operational until the chlorinated solvent source and plume had been treated to ensure that remediation goals can be achieved at the proposed POC. The optional SVE and off-gas treatment system may also require 30 years of operation if VOC concentrations transported through the vadose zone exceed applicable regulatory limits throughout the duration of the remediation activities.

As with Alternative 1, this alternative would require long-term land use restrictions and enforcement of health and safety plans to reduce potential risks associated with installing and operating the air sparging system and the optional SVE and off-gas treatment system and associated with installing and monitoring LTM and proposed POC wells. This alternative is designed to address both BTEX and chlorinated solvent compounds found at Site FT-002. Alternative 2 should provide reliable, continuous protection with little risk from temporary system failures. This alternative complies with the program goals because intrinsic remediation remains the predominant remedial technology for the site. However, this remedial alternative will result in the generation of additional drill cuttings and other wastes, including activated carbon, which may be required for off-gas treatment.

Model results suggest that benzene concentrations will exceed all potential ground water remediation goals within the source area for at least the next 10 years. Thus, this alternative also includes 30 years of annual ground water monitoring to ensure that intrinsic remediation has effectively attenuated the BTEX plume and possibly the chlorinated solvent plume. Annual monitoring would also be required to assess whether the air sparging system is effectively reducing concentrations of chlorinated solvents at the leading edge of the plume.

7.4.3.2 Implementability

Installing and operating an air sparging system and potentially a SVE and off-gas treatment system to limit the migration of the chlorinated solvent contamination will present additional implementability concerns. Installation of the air sparging wells and ground water monitoring points involves standard drilling practices. Air sparging manifolding and SVE screen installation will require limited shallow excavation and backfilling. The installation of electrical conduit for power supply to the SVE blower and air sparging compressor may also require excavation activities. These construction activities are routine, but they may cause temporary disruption to flight operations.

The material and equipment required for the system are readily available, and the technology used to construct the system is proven and reliable. O&M will be required for the blower, compressor, and off-gas treatment equipment. The blower used for the SVE equipment requires very little O&M; however, more intensive O&M may be required for the air sparging compressor and off-gas treatment system. The technical and administrative implementability concerns associated with the intrinsic remediation and long-term monitoring components of this remedial alternative are identical to those discussed in Alternative 1.

7.4.3.3 Cost

The estimated capital and operating costs of Alternative 3 are shown in Table 7.5. The total present worth of Alternative 3 is about $3,970,990 with no SVE and off-gas treatment system, assuming that 70 air sparging wells are required in a 2,400-foot line of wells. With the inclusion of the SVE and off-gas treatment system, the present worth of Alternative 3 is about $5,562,640. The total capital cost of the air sparging system is projected to be $700,000, and the SVE and off-gas treatment system could be designed and installed for a projected total cost of $900,000.

Long-term monitoring would be continued for the same length of time as other alternatives to verify that the BTEX plume and possibly the chlorinated solvent plume continue to degrade upgradient of the air sparging system and that any part of the dissolved plume does not reach the proposed POC wells. Annual long-term monitoring would continue for 30 years to ensure that intrinsic remediation is reducing BTEX concentrations throughout the plume.

7.4.4 Alternative 4 - Source Removal via Continued/Expanded Product Recovery and Bioventing, Intrinsic Remediation Supplemented with an In Situ Permeable Reaction Wall, Institutional Controls, and Long-Term Ground Water Monitoring

7.4.4.1 Effectiveness

The effectiveness of the intrinsic remediation, institutional controls, and LTM components under this alternative has been described under Alternative 1. Use of *in situ* permeable reaction walls for treatment of chlorinated organic compounds is an emerging technology that has not been proven repeatedly at the field scale. Pilot tests at various sites suggest that this technology may be feasible and effective in the short term, but more research is required to determine long-term effectiveness and operational and maintenance requirements. Impacts on the effectiveness of this alternative from seasonal climatic changes (e.g., subsurface soil and ground water temperatures) are unknown. Inclusion of this technology is speculative as treatment effectiveness cannot be fully defined at this time.

TABLE 7.5
COST ESTIMATE FOR ALTERNATIVE 3
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Capital Costs	Total Cost
Design and construction of four nested POC wells (two depths) and two LTM wells	$41,000
Finalize design and construction of existing bioventing system in source area	$55,000
Design and construction of six additional product extraction wells in source area, including installation of submersible pump and manifolding to treatment system (optional)	$242,000
Design and construction of air sparging system, including well installation, manifolding, and compressors (assuming 70 wells on 35-foot spacing)	$700,000
Design and construction of SVE and off-gas treatment system (optional)	($900,000)
Land use restriction proceedings (unit cost)	$22,000
Operation, Maintenance, and Monitoring Costs (Annual)	**Annual Cost**
Conduct annual ground water sampling of ten LTM wells and eight proposed POC wells (30 years)	$10,000
Operation and maintenance of expanded extraction system (assuming 23 gpm) (5 years) (optional)	$30,000
Continued operation and maintenance of existing product recovery treatment system (assuming 23 gpm) (5 years)	$464,000 [a/]
Operate and maintain bioventing system (5 years)	$15,000
Operate and maintain air sparging system (30 years)	$25,000
Operate and maintain SVE and off-gas treatment (30 years)(optional)	$45,000
Maintain institutional controls/public education (30 years)	$5,000
Project management (30 years)	$6,000
Present Worth of Alternative 3 [b/]	**$5,562,640**

[a/] Based on previous cost estimates for product extraction, treatment, and discharge to surface water (URS Consultants, Inc., 1993)

[b/] Based on an annual inflation factor of 5 percent, and assuming all options are implemented.

7.4.4.2 Implementability

Implementation of this remedial alternative may be difficult due to the areal extent of the chlorinated plume and the saturated thickness of the aquifer above the clay and bedrock aquitard. To implement this technology, peripheral barrier walls (i.e. slurry walls) may be required to "funnel" dissolved contaminants to a downgradient reaction wall to minimize the size of the reaction wall. The cost of this peripheral barrier wall is not considered as part of this alternative. The reaction wall would consist of alternating permeable and impermeable sections. Installation of this *in situ* treatment system at the leading edge of the dissolved chlorinated solvent plume would require considerable excavation and waste materials handling. Alternatively, the reaction wall could be installed immediately downgradient from the plume core, which would contribute to source removal, but the dissolved ground water contaminants would remain untreated.

7.4.4.3 Cost

The cost of Alternative 4 is summarized in Table 7.6. Capital costs are estimated for a impermeable and reaction wall approximately 2,400 feet long by 50 feet deep and for four new nested POC wells and two new LTM wells. The total present worth of this remedial alternative, $38,455,240, is significantly higher than other remedial alternatives considered for the site in this assessment. Installation of the *in situ* permeable reaction wall at the leading edge of the dissolved chlorinated solvent plume adds $34,800,000 to the total cost. This alternative is presented to compare against the merits and disadvantages of air sparging. Both Alternatives 3 and 4 are designed to address both BTEX and chlorinated solvent compounds in ground water migrating from Site FT-002.

7.5 RECOMMENDED REMEDIAL APPROACH

Four alternatives for remediating shallow ground water at Site FT-002 were evaluated. Each of the alternatives evaluated incorporated intrinsic remediation, because available data and the Bioplume II modeling effort suggest that this remedial technology will be effective at minimizing the migration of BTEX contamination in ground water. The previously described alternatives differ based on inclusion of different source removal technologies or other technologies to treat dissolved chlorinated organic compounds that are migrating beyond the current BTEX plume. Table 7.7 summarizes the results of the evaluation based upon effectiveness, implementability, and total cost. Based on this evaluation, Parsons ES recommends Alternative 3 as achieving the best combination of risk reduction and cost

TABLE 7.6
COST ESTIMATE FOR ALTERNATIVE 4
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Capital Costs	Total Cost
Design and construction of four nested POC wells (two depths) and two LTM wells	$41,000
Finalize design and construction of existing bioventing system in source area	$55,000
Design and construction of six additional product extraction wells in source area, including installation of submersible pump and manifolding to treatment system (optional)	$242,000
Design and construction of downgradient *in situ* permeable reaction barrier wall (1,200.000 sq. feet)	$34,800,000
Land use restriction proceedings (unit cost)	$22,000
Operation, Maintenance, and Monitoring Costs (Annual)	**Annual Cost**
Conduct annual ground water sampling of ten LTM wells and eight proposed POC wells (30 years)	$10,000
Operation and maintenance of expanded extraction system (assuming 23 gpm) (5 years) (optional)	$30,000
Continued operation and maintenance of existing product recovery treatment system (assuming 23 gpm) (5 years)	$464,000 [a/]
Operate and maintain bioventing system (5 years)	$15,000
Maintain and repair *in situ* permeable reaction barrier wall (30 years)	$50,000
Maintain institutional controls/public education (30 years)	$5,000
Project management (30 years)	$6,000
Present Worth of Alternative 4 [b/]	**$38,455,240**

[a/] Based on previous cost estimates for extraction, treatment, and discharge to surface water (URS Consultants, Inc., 1993)

[b/] Based on an annual inflation factor of 5 percent, and assuming all options are implemented.

TABLE 7.7

SUMMARY OF REMEDIAL ALTERNATIVES EVALUATION
GROUND WATER REMEDIATION
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Remedial Alternative	Effectiveness	Implementability	Present Worth Cost Estimate
Alternative 1			$385,770
- Intrinsic Remediation - Long-Term Monitoring - Institutional Controls	Contaminant mass, volume, and toxicity will gradually be reduced over next ten years by intrinsic remediation alone. Ground water MCLs for BTEX not likely to be exceeded at proposed POC. Chlorinated solvents not effectively attenuated downgradient of the BTEX plume.	Readily implementable. Long-term management, ground water use controls and monitoring required for at least 10 years. Minimal exposure of site workers if excavation is carefully controlled in source area. If MCLs are exceeded at POC, additional remedial work may be required.	
Alternative 2			$2,[illegible]+0
- Intrinsic Remediation - Long-Term Monitoring - Institutional Controls - Continued/Expanded Source Removal via Bioventing and Product Extraction and Treatment	Similar to Alternative 1, with the addition of source removal activity via bioventing and product extraction, treatment, and disposal. *Continued or enhanced* source removal may expedite reduction in contaminant mass in the source area. Contaminant mass, volume, and toxicity will be gradually reduced downgradient of the source area, and more quickly than in Alternative 1. Will not be effective at treating dissolved chlorinated solvent plume downgradient of the existing BTEX plume.	Readily implementable. Bioventing and product recovery systems estimated to operate for 5 years. Existing product recovery activities would be expanded. Existing treatment system operational at site. *Long-term management, ground water* controls and monitoring required for at least 10 years. [illegible]CLs are exceeded at POC, additional rem[illegible]k may be required.	

TABLE 7.7 (Concluded)

SUMMARY OF REMEDIAL ALTERNATIVES EVALUATION
GROUND WATER REMEDIATION
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Remedial Alternative	Effectiveness	Implementability	Present Worth Cost Estimate
Alternative 3			$5,562,640
- Intrinsic Remediation - Long-Term Monitoring - Institutional Controls - Continued/Expanded Source Removal via Bioventing and Product Extraction and Treatment - Air Sparging with optional SVE	Similar to Alternative 2, with the addition of an air sparging network located at the leading edge of the dissolved chlorinated solvent plume. Treatment of the dissolved chlorinated solvent plume will prevent additional contaminant mass from migrating downgradient. May assure that ground water MCLs for chlorinated solvents can be met at the proposed POC.	Readily implementable. Bioventing system estimated to operate for 5 years. Existing product recovery activities would be expanded. Existing treatment system operational at site. Sparging system estimated to operate for 5 years. Optional SVE system may be required to treat contaminants transported to the vadose zone. Shallow vadose zone may complicate design and construction. Off-gas treatment will increase waste disposal costs. Long-term management, ground water controls, and monitoring required for at least 10 years. If MCLs are exceeded at POC, additional remedial work may be required.	
Alternative 4			$38,455,240
- Intrinsic Remediation - Long-Term Monitoring - Institutional Controls - Continued/Expanded Product Recovery via Bioventing and Product Extraction and Treatment - *In situ* Permeable Reaction Wall	Similar to Alternative 2, except leading edge of chlorinated solvent plume will be intercepted and treated by chemical reaction with *in situ* system. Inclusion of this technology is speculative. May ensure that MCLs for chlorinated solvents can be met at proposed POC.	Requires significant construction due to vertical distribution of contamination. Technology is still unproven at field scale. Long-term management, ground water controls, and monitoring required for at least 10 years. If MCLs are exceeded at POC, additional remedial work may be required.	

effectiveness (due to the presence of dissolved chlorinated solvents that are migrating downgradient and impacting surface water quality).

Alternative 3 makes maximum use of intrinsic remediation to reduce concentrations of BTEX and chlorinated solvents. However, this alternative provides for additional protection by facilitating the treatment of dissolved chlorinated organics by air sparging and possibly SVE with off-gas treatment at the leading edge of the existing chlorinated solvent plume. Although not modeled at Site FT-002 under this program, initial tests at this site suggest that air sparging may be effective at reducing chlorinated solvent concentrations within the ground water.

Parsons ES recommends that a 90-day sparging pilot test be conducted in the downgradient plume area to investigate the long-term removal of chlorinated solvents from the ground water. Air sparging would be necessary as long as the mass of chlorinated organics in the ground water was sufficient to exceed defined remediation goals at the proposed POC wells. The continued reduction of the LNAPL in the source area by the existing extraction system should eventually expedite remediation of the ground water. As the LNAPL source is depleted, less contaminant mass will be contributed to the ground water that will require treatment at the air sparging network. Waste will be generated during the excavation and installation of air sparging wells, proposed POC wells, and the additional LTM wells. However, this waste will be relatively small in volume, particularly when compared to the volume of waste that could be generated under Alternative 4. This waste could be managed in accordance with the investigation-derived waste disposal plan for the base.

This alternative should be acceptable to the public and regulatory community because it incorporates different remedial techniques to address all types of contaminants at the site. Although intrinsic remediation, LTM, and institutional controls would be sufficient for the BTEX compounds, these technologies would not address the chlorinated solvent ground water contamination. Available data suggest that these compounds could migrate to a potential receptor exposure point at concentrations that exceed potential ground water remediation goals unless additional action is taken. This alternative will ensure that potential remediation goals for each of the site-related contaminants can be met at the proposed POC.

SECTION 8

LONG-TERM MONITORING PLAN

8.1 OVERVIEW

In keeping with the requirements of the recommended remedial alternative for Site FT-002 (i.e., continued source reduction using bioventing and product recovery, intrinsic remediation and institutional controls with LTM, and air sparging the leading edge of the chlorinated solvent plume), a long-term ground water monitoring plan must be developed. The purpose of this component of the recommended remedial alternative for Site FT-002 is to assess site conditions over time, confirm the effectiveness of ongoing source removal activities, air sparging, and naturally occurring processes at reducing contaminant mass and minimizing contaminant migration, and evaluate the need for additional remediation.

To demonstrate attainment with potential ground water remediation goals for the site and to verify the predictions of the Bioplume II model developed for Site FT-002, the LTM plan consists of identifying the location of two separate ground water monitoring networks and developing a ground water sampling and analysis strategy. The strategy described in this section is designed to monitor plume migration over time and to verify that intrinsic remediation is occurring at rates sufficient to minimize plume migration so that no exposure pathway involving ground water is completed. In the event that data collected under this LTM program indicate that the recommended remedial activities are insufficient to meet remedial objectives, contingency controls would be necessary.

This demonstration focused on the fate and transport of the BTEX compounds. However, the presence of the chlorinated solvent compounds in the ground water must be considered when developing a remedial strategy for the site. The recommended remedial alternative for this site includes continued source reduction via product recovery and bioventing, intrinsic remediation of both BTEX and chlorinated solvents, institutional controls, LTM, and air sparging the leading edge of the chlorinated solvent plume to ensure that no contaminant exceeds selected remediation goals at the proposed POC. Thus, the LTM plan included in this section covers the

BTEX compounds, TCE, DCE, and vinyl chloride. Any other compounds that should be monitored at the site can be incorporated into this basic proposal.

8.2 MONITORING NETWORKS

Two separate sets of wells will be installed at Site FT-002 as part of the recommended remedial alternative. The first set will consist of four LTM wells located upgradient, within, and downgradient of the existing BTEX plume to verify the results of the Bioplume II model and to ensure that naturally occurring attenuation processes are sufficient to minimize plume expansion. This network of wells will consist of existing and one newly-installed nest of wells screened at multiple depths within the shallow aquifer to provide short-term confirmation and verification of the quantitative ground water modeling results. The second set of ground water monitoring well nests will be located along a northeast-southwest line approximately 4,000 feet downgradient from the source area. These wells would be located 800 feet downgradient of the suspected edge of the chlorinated solvent plume. The purpose of these proposed POC or sentry wells is to verify that no concentrations of BTEX compounds exceeding at least federal MCLs migrate beyond the area under institutional control. These wells are also located sufficiently downgradient to act as sentry wells or proposed POC wells for the chlorinated compounds that may be migrating from Site FT-002 as well.

The proposed POC or sentry well network will consist of four nested pairs of ground water monitoring wells. Two wells in each well nest should be sufficient to assess the vertical distribution of contaminants in the saturated zone at the proposed POC. Available site data on the vertical distribution of the both the BTEX compounds and the chlorinated solvents (Section 4) indicate that contamination appears to preferentially migrate into deeper portions of the aquifer downgradient of the source area. Thus, the proposed POC or sentry wells should consist of a shallow and deep well. The shallow well will be screened across the first 10 feet of the shallow aquifer, and the deep well will be screened near the bottom of the shallow aquifer ending at the top of the confining clay layer. Both the LTM and proposed POC wells will be sampled and analyzed for the parameters listed in Tables 8.1 and 8.2, respectively.

8.2.1 Long-Term Monitoring Wells

One set of nested LTM wells will be located upgradient of the existing BTEX plume to monitor background conditions. The existing well pair MW-02-026/MW-02-027 should be adequate to characterize background conditions. The next pair of nested LTM wells should be located within the BTEX plume that is affected by the source area. Ideally, the area should be

TABLE 8.1

LONG-TERM MONITORING ANALYTICAL PROTOCOL
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Analyte	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Ferrous Iron (Fe^{2+})	Colorimetric A3500-Fe D	Field only	Elevated ferrous iron concentrations may be indicative of the anaerobic biodegradation process of iron reduction	Annually	Collect 100 mL of water in a glass container; acidify with hydrochloric acid per method	Field
Ferrous Iron (Fe^{2+})	Colorimetric HACH 25140-25	Alternate method; field only	Elevated ferrous iron concentrations may be indicative of the anaerobic biodegradation process of iron reduction	Annually	Collect 100 mL of water in a glass container	Field
Temperature	E170.1	Field only	Metabolism rates for microorganisms depend on temperature	Annually	N/A	Field
Dissolved Oxygen	Dissolved oxygen meter	Refer to Method A4500 for a comparable laboratory procedure	The oxygen concentration is a data input to the Bioplume II model; concentrations less than 1 mg/L generally indicate an anaerobic pathway	Annually	Collect 300 mL of water in biochemical oxygen demand bottles; analyze immediately; alternately, measure dissolved oxygen in situ	Field
pH	E150.1/SW9040, direct reading meter	Protocols/Handbook methods	Aerobic and anaerobic processes are pH-sensitive	Annually	Collect 100–250 mL of water in a glass or plastic container; analyze immediately	Field
Conductivity	E120.1/SW9050, direct reading meter	Protocols/Handbook methods	General water quality parameter used as a marker to verify that site samples are obtained from the same ground water system	Annually	Collect 100–250 mL of water in a glass or plastic container	Field
Nitrate (NO_3^{-1})	IC method E300 or method SW9056; colorimetric, method E353.1	Method E300 is a Handbook method; method SW9056 is an equivalent procedure	Used to support microbial respiration if oxygen is depleted	Annually	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C; analyze within 48 hours	Fixed-base

TABLE 8.1 (CONTINUED)
LONG-TERM MONITORING ANALYTICAL PROTOCOL
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Analyte	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Nitrite (NO_2^{-1})	IC method E300 or method SW9056; colorimetric, method E353.1	Method E300 is a Handbook method; method SW9056 is an equivalent procedure	Product of nitrate reduction which may occur during BTEX biodegradation	Annually	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C; analyze within 48 hours	Fixed-base
Ammonia (NH_4^+)	E350.1	Method E350.1 is a Handbook method	Product of nitrate reduction which may occur during BTEX biodegradation	Annually	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C: analyze within 48 hours	Fixed-base
Sulfate (SO_4^{2-})	IC method E300 or method SW9056 or HACH SulfaVer 4 method	Method E300 is a Handbook method; method SW9056 is an equivalent procedure. HACH method is photometric	Used to support microbial respiration in anaerobic, reducing conditions	Annually	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C	Fixed-base or field (for HACH method)
Sulfide (S^{2-})	Hach HS-WR method (2238-01)	Method E300 is a Handbook method; method SW9056 is an equivalent procedure. HACH method is photometric	Production of sulfide may be indicative of sulfate reduction during BTEX biodegradation	Annually	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C	Field
Redox potential	A2580 B	Measurements are made with electrodes; results are displayed on a meter; samples should be protected from exposure to atmospheric oxygen	The redox potential of ground water influences and is influenced by biologically mediated reactions; the redox potential of ground water may range from more than 200 mV to less than -400 mV	Annually	Collect 100–250 mL of water in a glass container, filling container from bottom; analyze immediately	Field

TABLE 8.1 (CONTINUED)
LONG-TERM MONITORING ANALYTICAL PROTOCOL
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Analyte	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Methane	RSKSOP-147 modified to analyze water samples for methane by headspace sampling with dual thermal conductivity and flame ionization detection.	Method published and used by the US Environmental Protection Agency Robert S. Kerr Laboratory	The presence of methane suggests BTEX degradation via an anaerobic pathway utilizing carbon dioxide (carbonate) as the electron acceptor (methanogenesis)	Annually	Collect water samples in 40 mL volatile organic analysis (VOA) vials with butyl gray/Teflon-lined caps (zero headspace); cool to 4°C	Fixed-base
Aromatic hydrocarbons (BTEX)	Purge and trap GC method SW8020	Handbook method; analysis may be extended to higher molecular weight alkylbenzenes	BTEX is the primary target analyte for monitoring natural attenuation; BTEX concentrations must also be measured for regulatory compliance	Annually	Collect water samples in a 40 mL VOA vial with zero headspace; cool to 4°C; add hydrochloric acid to pH ≤2	Fixed-base
TCE	Method 8240, GC/MS of volatile organics packed column technique	SW846	TCE is possible target analyte for this site	Annually	Collect water samples in a 40 mL VOA vial with zero headspace; cool to 4°C; add hydrochloric acid to pH ≤2	Fixed-base
DCE (cis- and trans-)	Method 8240, GC/MS of volatile organics packed column technique	SW846	DCE is a degradation product of TCE. Presence may be indicative of cometabolism	Annually	Collect water samples in a 40 mL VOA vial with zero headspace; cool to 4°C; add hydrochloric acid to pH ≤2	Fixed-base
Vinyl Chloride	Method 8240, GC/MS of volatile organics packed column technique (may require Method 8010 due to PQL [b/])	SW846	Vinyl chloride is a degradation product of TCE. Presence may be indicative of cometabolism	Annually	Collect water samples in a 40 mL VOA vial with zero headspace; cool to 4°C; add hydrochloric acid to pH ≤2	Fixed-base

TABLE 8.1 (CONCLUDED)

LONG-TERM MONITORING ANALYTICAL PROTOCOL
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Analyte	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Ethylene	RSKSOP-147	Method published and used by the US Environmental Protection Agency Robert S. Kerr Laboratory	Ethylene is a degradation product of chlorinated solvents. Presence may be indicative of cometabolism	Annually	Collect water samples in a 40 mL VOA vial with zero headspace; cool to 4°C; add hydrochloric acid to pH ≤2	Fixed-base

a/ Protocol methods are presented by Wiedemeier *et al.* (1994).
b/ PQL=Practical quantitation limit.

TABLE 8.2

POINT-OF-COMPLIANCE MONITORING ANALYTICAL PROTOCOL
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Analyte	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Temperature	E170.1	Field only	Well development	Annually	N/A	Field
Dissolved Oxygen	Dissolved oxygen meter	Refer to method A4500 for a comparable laboratory procedure	The oxygen concentration is a data input to the Bioplume model; concentrations less than 1 mg/L generally indicate an anaerobic pathway	Annually	Collect 300 mL of water in biochemical oxygen demand bottles; analyze immediately; alternately, measure dissolved oxygen in situ	Field
pH	E150.1/SW9040, direct reading meter	Protocols/Handbook methods[a/]	Aerobic and anaerobic processes are pH-sensitive	Annually	Collect 100–250 mL of water in a glass or plastic container; analyze immediately	Field
Conductivity	E120.1/SW9050, direct reading meter	Protocols/Handbook methods	General water quality parameter used as a marker to verify that site samples are obtained from the same ground water system	Annually	Collect 100–250 mL of water in a glass or plastic container	Field
Redox potential	A2580 B	Measurements are made with electrodes; results are displayed on a meter; samples should be protected from exposure to atmospheric oxygen	The redox potential of ground water influences and is influenced by biologically mediated reactions; the redox potential of ground water may range from more than 200 mV to less than -400 mV	Annually	Collect 100–250 mL of water in a glass container, filling container from bottom; analyze immediately	Field
Aromatic hydrocarbons (BTEX)	Purge and trap GC method SW8020	Handbook method; analysis may be extended to higher molecular weight alkylbenzenes	BTEX is the primary target analyte for monitoring natural attenuation; BTEX concentrations must also be measured for regulatory compliance	Annually	Collect water samples in a 40 mL VOA vial with zero headspace; cool to 4°C; add hydrochloric acid to pH ≤2	Fixed-base

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TABLE 8.2 (CONCLUDED)

POINT-OF-COMPLIANCE MONITORING ANALYTICAL PROTOCOL
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Analyte	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
TCE	Method 8240, GC/MS of volatile organics packed column technique	SW846	TCE is possible target analyte for this site	Annually	Collect water samples in a 40 mL VOA vial with zero headspace; cool to 4°C; add hydrochloric acid to pH ≤2	Fixed-base
DCE (cis- and trans-)	Method 8240, GC/MS of volatile organics packed column technique	SW846	DCE is a degradation product of TCE. Presence may be indicative of cometabolism	Annually	Collect water samples in a 40 mL VOA vial with zero headspace; cool to 4°C; add hydrochloric acid to pH ≤2	Fixed-base
Vinyl Chloride	Method 8240, GC/MS of volatile organics packed column technique (may require Method 8010 due to PQL [b/])	SW846	Vinyl chloride is a degradation product of TCE. Presence may be indicative of cometabolism	Annually	Collect water samples in a 40 mL VOA vial with zero headspace; cool to 4°C; add hydrochloric acid to pH ≤2	Fixed-base
Ethylene	RSKSOP-147	Method published and used by the US Environmental Protection Agency Robert S. Kerr Laboratory	Ethylene is a degradation product of chlorinated solvents. Presence may be indicative of cometabolism	Annually	Collect water samples in a 40 mL VOA vial with zero headspace; cool to 4°C; add hydrochloric acid to pH ≤2	Fixed-base

a/ Protocol methods are presented by Wiedemeier *et al.* (1994).
b/ PQL=Practical quantitation limit.

anoxic. Existing well pair MW-02-006/MW-02-007 and MW-02-014 are located within the center of the existing BTEX plume. Both MW-02-006 and MW-02-007 had high concentrations of total BTEX and chlorinated solvents in December 1993. Free product was found in both of these wells. MW-02-007 is screened at a much deeper interval than these other two wells, and can therefore be used to assess the vertical distribution of contaminants in the source area. The next series of nested LTM wells should be located within the dissolved BTEX plume. Existing MW-02-019/MW-02-020/MW-02-030 are located downgradient of the suspected source area but well within the dissolved BTEX plume. These nested wells are screened are various depths, which should provide valuable data about the vertical distribution of contaminants as a function of time (see Appendix B for details).

The last nested LTM wells should be located downgradient of the existing BTEX plume to monitor the progress of the plume in the short-term. Although existing wells MW-02-040/MW-02-041/MW-02-042 are located downgradient from the existing BTEX plume, these wells are located more than 700 feet beyond the existing BTEX plume. Earlier site characterization data and model simulations indicate that the BTEX plume is being effectively attenuated and may actually be receding. These existing nested wells are located too far downgradient to provide short-term feedback on the progress of the BTEX plume. Therefore, one additional nested well set should be installed between existing wells MW-02-019/MW-02-020/MW-02-030 and existing wells MW-02-040/MW-02-041/MW-02-042 to provide short-term confirmation of model results.

The most appropriate location of these wells would be on the east side of the runway in the topographic low. Siting the wells at this location would serve a dual purpose. First, the wells would be used to determine if the BTEX plume is migrating beyond its existing boundaries. Second, the wells could be used to determine if BTEX-contaminated water could reach surface water bodies that may receive ground water discharge. Because ground water from Site FT-002 may be affecting surface water downgradient of the site, it would be prudent to monitor potential source locations. Although ground water is not known to be intercepted in this area and routed to surface water on base, these wells would provide valuable data about the potential completion of exposure pathways involving ground water.

This new nested well series should consist of at least two wells screened over different zones. The variable depth of the BTEX plume caused by strong vertical gradients present at Site FT-002 necessitate the use of multiple monitoring depths to track the vertical distribution of contaminants. Failure to monitor the vertical distribution of contaminants at this site could complicate short- and long-term compliance efforts.

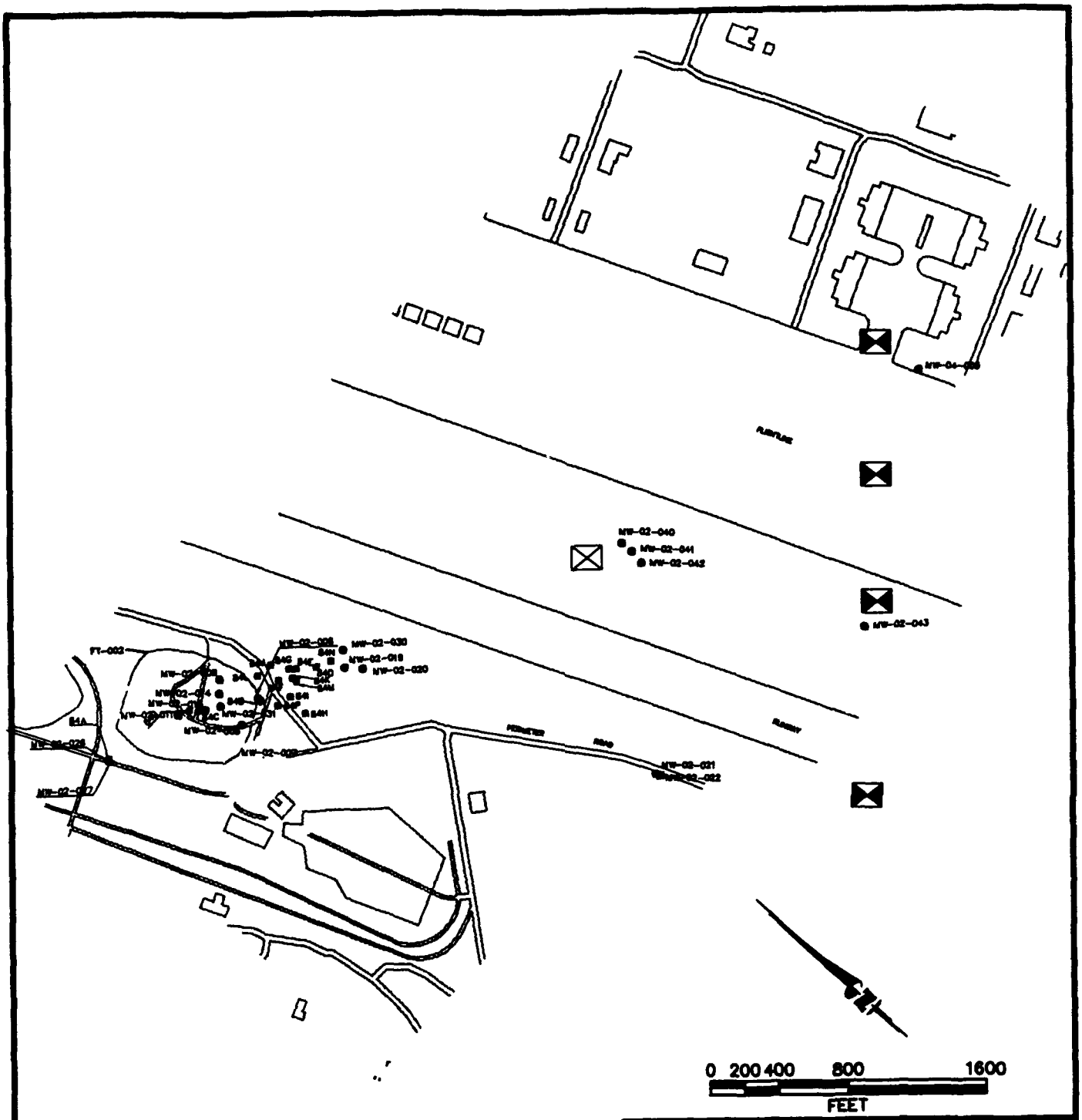
The new nested LTM well located between the flightline and runway should be constructed with 10-foot screens at each screened interval. The shallow screened well should be constructed with approximately 8 feet of the screen below the water table. The base of the deep screened well should be placed in the confining clay layer. Figure 8.1 identifies the proposed locations of the new well and the existing wells to be used for LTM. This network will supplement the proposed POC wells to provide early confirmation of model predictions and to allow additional response time if necessary. All LTM wells will be sampled and analyzed for the parameters listed in Table 8.1 to verify the effectiveness of the intrinsic remediation remedial alternative.

8.2.2 Proposed POC or Sentry Wells

The purpose of the sentry wells is to verify that no contaminated ground water exceeding appropriate ground water MCLs migrates beyond the area that is to be placed under land use controls. Although the Bioplume II model results suggest that the dissolved BTEX plume will not migrate significantly further downgradient than its present position, these sentry wells are the technical mechanisms used to demonstrate that contaminated ground water from Site FT-002 does not migrate into areas that are not under land use restrictions at concentrations that exceed potential ground water remediation goals (Table 7.1). These sentry wells also can be used to monitor the progress of the chlorinated solvent plume, and demonstrate compliance with these additional chemical-specific ground water remediation goals. Sentry wells should be installed and monitored for the parameters listed in Table 8.2 to assure that the selected remedy is providing the anticipated level of risk reduction and remediation at the site.

Four monitoring well nests will be utilized to monitor the zone downgradient of the BTEX and chlorinated solvents plume. POC or sentry well nests will be placed over 2,000 feet downgradient of the leading edge of the dissolved BTEX plume and approximately 800 feet downgradient of the leading edge of the chlorinated solvent plume. All well nests should consist of a shallow and a deep well. All wells should be constructed with 10-foot screens at each screened interval. The shallow screened well should be constructed with approximately 8 feet of the screen below the water table. The base of the deep screened well should be placed in the confining clay layer. The location of each of these wells are identified in Figure 8.1.

A sentry well nest should be located approximately 1,200 feet downgradient (southeast) of monitoring well nest MW-02-021 and MW-02-022, approximately 2,000 feet to the southeast of the centerline of the leading edge of the dissolved BTEX plume. The next sentry well nest



LEGEND

MW-02-006 ⊕ GROUND WATER MONITORING WELL

84E ⊕ LIF-CPT SAMPLE LOCATION

☒ LONG-TERM MONITORING WELL

⧓ PROPOSED POINT-OF-COMPLIANCE WELL

FIGURE 8.1

PROPOSED LOCATIONS OF LTM AND POC WELLS

Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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should be located near existing ground water monitoring well MW-02-043. The third sentry well nest should be located within the flightline to monitor the progress of the dissolved chlorinated solvent plume. The last sentry well nest should be located adjacent to existing ground water monitoring well MW-04-005 to the east of the flightline. These wells are then located on a northeast-southwest line approximately 800 feet beyond the leading edge of the dissolved chlorinated solvent plume.

8.3 GROUND WATER SAMPLING

To ensure that sufficient contaminant removal is occurring at Site FT-002 to comply with ground water remediation goals at the proposed POC, the LTM plan includes a comprehensive sampling and analysis plan. Both LTM and sentry wells will be sampled and analyzed annually to verify that naturally occurring processes are effectively reducing contaminant mass and mobility. Reductions in toxicity will be implied by mass reduction. The sampling and analysis plan will also be aimed at assuring intrinsic remediation can achieve site-specific remediation concentration goals for BTEX compounds and possibly the chlorinated solvents.

8.3.1 Analytical Protocol

All LTM and sentry wells in the LTM program will be sampled and analyzed to determine compliance with chemical-specific remediation goals and to verify the effectiveness of the recommended remedial alternative, which includes intrinsic remediation. Water level measurements will be made during each sampling event. Ground water samples will be analyzed for the parameters listed in Tables 8.1 and 8.2. A site-specific ground water sampling and analysis plan should be prepared prior to initiating the LTM program.

8.3.2 Sampling Frequency

Each of the LTM and sentry sampling points will be sampled once each year for at least thirty years. If the data collected at any time during the monitoring period indicate the need for additional remedial activities at the site, sampling frequency should be adjusted accordingly.

SECTION 9

CONCLUSIONS AND RECOMMENDATIONS

This report presents the results of an EE/CA performed by Parsons ES to evaluate the use of intrinsic remediation (natural attenuation) for remediation of fuel-hydrocarbon-contaminated ground water at Site FT-002, Plattsburgh AFB, New York. Ground water contaminant and geochemical data strongly suggest that BTEX is biodegrading at the site via aerobic respiration, nitrate reduction, ferric iron reduction, sulfate reduction, and methane fermentation. These data also suggest that dissolved chlorinated organic compounds are biodegrading via anaerobic cometabolic processes that occur predominantly within the BTEX plume. The finite-difference ground water model Bioplume II was used in conjunction with site-specific geologic, hydrologic, and analytical data to simulate the migration and biodegradation of fuel hydrocarbon compounds dissolved in ground water

To collect the data necessary for the intrinsic remediation demonstration, Parsons ES and RSKERL collected soil and ground water samples from the site in December 1993 and May 1994. Physical and chemical data collected under this program were supplemented with data collected during previous site characterization events. Site-specific geologic, hydrologic, and laboratory analytical data were then used in the Bioplume II numerical ground water model to simulate the effects of advection, hydrodynamic dispersion, adsorption, and biodegradation on the fate and transport of the dissolved BTEX plume. Extensive site-specific data were used for model calibration and implementation. Model parameters that could not be obtained from existing site data were estimated using widely-accepted literature values for soils similar to those found at the site. Conservative aquifer parameters were used to construct the Bioplume II model for this study, and therefore, the model results presented herein represent a worst-case scenario.

Two model simulations were examined during this study. The first simulation (PLATCAL) assumed that the conditions which produced the calibrated model would persist for at least the next 10 years (i.e., the full duration of the simulation). This is the most conservative scenario, because the beneficial effects of product recovery and other

source removal activities are not included. This model suggested that the BTEX plume would not migrate any further downgradient and would actually decrease in size in the next 10 years. The second model developed during this study (PLATPRD) accounted for the beneficial impacts of source removal actions by reducing the source by a total of 20 percent. This approach is analogous to assuminng that 20 percent of the mass of source that can contribute to ground water contamination is removed. The simulation results from this model also suggest that the migration of the BTEX plume will be halted and even reversed in the next 10 years. Additionally, the reduction in the source of BTEX caused a 17 percent greater reduction in the size of the dissolved BTEX plume at the end of the simulation in comparison to PLATCAL. Neither of the models suggested that the dissolved BTEX plume would retreat quickly.

Actual dissolved BTEX degradation rates observed during LTM at the site will probably be less than predicted by model PLATPRD and greater than predicted by model PLATCAL. This means that the dissolved BTEX plume will not migrate any further downgradient and should retreat at least 400 feet back toward the source area in the next 10 years. The two major uncertainties in the model simulations is the lack of data regarding contaminant mass loading into the aquifer and the inability to simulate biodegradation via anaerobic processes within the source area. However, both models predict that naturally occurring attenuation processes operating at the site should be effective in preventing the migration of dissolved BTEX compounds, even in the absence of significant source removal activities.

Quantitative fate and transport analyses for the dissolved chlorinated organics were not completed under this study. Available site data imply that dissolved chlorinated organic compounds will not be effectively attenuated once these compounds migrate beyond the existing BTEX plume.

The results of this study suggest that a combination of continued source reduction using bioventing and product recovery, intrinsic remediation, institutional controls, and LTM is the most cost-effective remedial alternative for dissolved BTEX contamination at and migrating from Site FT-002. Naturally occurring attenuation mechanisms should be sufficient to prevent further migration of the dissolved BTEX plume so that federal- and state-specified ground water protection standards can be achieved before any exposure pathway involving ground water can be completed. Expanded source removal activities would expedite ground water remediation. However, this study also indicates that these

technologies alone would not be sufficient to remediate dissolved chlorinated organic contamination at and migrating from Site FT-002. Preliminary treatability data suggest that air sparging may be an effective method for reducing the mass of chlorinated organic compounds in the shallow ground water at the site. Parsons ES recommends that an extended pilot test be completed on this technology before full-scale implementation is considered.

Thus, Parsons ES recommends intrinsic remediation supplemented with continued and/or expanded product recovery and bioventing, institutional controls, and LTM to remediate dissolved BTEX contamination. An additional remedial technology, such as air sparging, will be required to prevent dissolved chlorinated organics from migrating further downgradient and completing an exposure pathway at concentrations that exceed federal- and state-specified ground water protection goals.

To verify the results of the Bioplume II modeling effort and to ensure that natural attenuation is occurring at rates sufficient to protect potential downgradient receptors, ground water from ten LTM wells and 8 proposed POC wells should be sampled annually and analyzed for the parameters listed in Tables 8.1 and 8.2. Figure 8.1 shows the suggested locations for the LTM and proposed POC wells for Site FT-002. Parsons ES recommends that these wells be sampled annually for at least 30 years. If this sampling program suggests at any time that the recommended remedial approach will not be sufficient, the remediation strategy will be re-evaluated to determine if additional contingency controls may be required.

SECTION 10

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APPENDIX A

CPT PROFILES AND SOIL BORING LOGS

CONE PENETROMETER LOGS

SCAPS (1994)

Job name : Plattsburg AFB
Description : Survey points and monitoring well locations
Field surveyor : D. Veldhouse, R Hunter
Computer operator : J. Campbell
Date printed : 06/06/94
Reference : MW02-008

SCAPS Push Locations

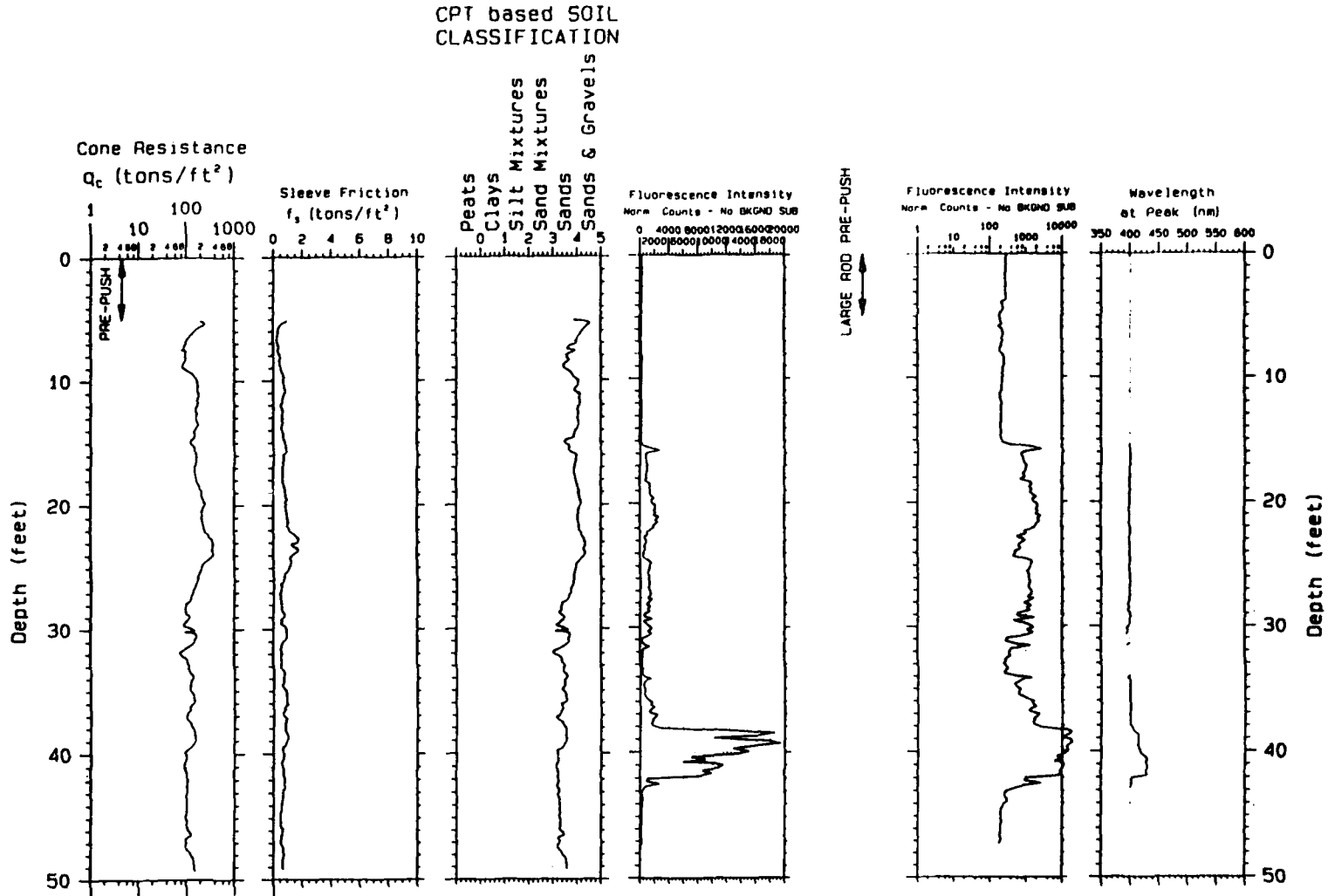
Push		Northing	Easting	Elev	
02PTR1SF		1700634.138	722229.625	257.476	
04PTR1SF		1700529.908	722368.380	257.400	
06PTR1SF		1700640.588	722235.556	257.765	
08PTR1SF		1700642.435	722310.058	257.170	
10PTR1SF		1700617.551	722258.873	257.370	
12PTR1NF		1700809.787	722114.042	255.018	
14PTR2SF		1700739.539	722309.984	259.226	
16PTR2SF		1700596.392	722433.458	259.337	
18PTR2SF		1700595.857	722436.938	259.258	
20PTR2SS	See table for depths	1700594.827	722464.361	259.239	
22PTR2SF		1700583.674	722538.857	260.898	
24PTR2SF		1700505.221	722433.759	257.116	
26PTR3SF		1700607.733	722385.231	258.578	
28PTR3SF		1700688.024	722464.401	260.952	
30PTR3SF		1700719.861	722407.319	260.533	
32PTR3NF		1700795.054	722181.163	257.215	
34PTR3NF		1700755.279	722145.846	256.565	
36PTR3NS	See table for depths	1700815.195	722117.349	255.137	
38PTR2NF		1700619.295	722203.811	257.129	
40PTR2NF		1700671.610	722109.454	255.885	
42PTR3NF		1700776.002	722219.276	257.614	
44PTR2NF		1700640.103	722091.795	254.985	
46PTR2NF		1700855.916	722061.919	253.848	
48PTR4NF		1700520.932	722089.696	252.769	
50PTR4NF		1700731.566	721998.076	251.232	
52PTR4NF		1700637.784	721990.070	252.733	
54PTR5NF		1700268.340	721790.686	243.622	
56PTR6NF		1700138.629	722083.238	245.254	
58PTR5NF		1700571.228	721910.198	247.062	
60PTR5NF		1700640.513	721905.828	247.429	
62PTR6NF		1700544.050	721984.142	250.943	
64PTR2NF		1700647.030	722154.258	256.515	
66,67,68PTR1SS		1700592.925	722258.062	257.231	See table for depths
70,71,72PTR3SS		1700718.929	722405.188	260.566	See table for depths
74,75,76PTR2NS		1700697.707	722061.566	254.420	See table for depths
SURVEY SETUP(MW02-008)		1700606.740	722211.738	257.400	

Job name : Plattsburg AFB
Description : Survey points and monitoring well locations
Field surveyor : D. Veldhouse, R Hunter
Computer operator : J. Campbell
Date printed : 06/06/94
Reference : MW02-008

Existing Feature Location

Push	Northing	Easting	Elev
MW02-029	1700716.508	722177.887	256.999
MW02014	1700469.575	722060.995	250.065
MW02017	1700680.893	721932.941	248.110
MW02024	1700842.735	722095.102	253.724
MW02033	1700589.500	722257.658	257.100
MW106	1700256.228	722014.816	245.078
84BLIF	1700365.083	722006.597	246.638
84FLIF	1700268.726	722002.115	245.016
84GLIF	1700120.765	721819.138	242.616
84HLIF	1700097.086	721925.864	243.516
84ILIF	1700157.788	721774.558	241.356
84JLIF	1699977.955	721986.256	241.528
84KLIF	1700193.246	721858.442	243.053
PIT 1	1700676.125	722257.287	257.625
PIT 2	1700554.807	722180.821	255.460
PIT	1700339.873	722181.070	248.228
PIT 4	1700315.747	722086.048	247.254
Recovery Well 1	1700615.952	722206.876	258.700
Recovery Well 2	1700646.441	722169.226	256.450
Recovery Well 3	1700709.322	722123.001	253.550
Recovery Well 4	1700698.487	722198.508	259.440
SURVEY SETUP(MW02-008)	1700606.740	722211.738	257.400

Soil sample depth in Feet (Below ground level)										
20PTR2SS	36PTR3NS	66PTR1SS	67PTR1SS	68PTR1SS	70PTR3SS	71PTR3SS	72PTR3SS	74PTR2NS	75PTR2NS	76PTR2NS
42.3	35.5	11.0	20.0	39.5	10.0	21.0	43.0	13.0	33.8	38.0



CPT: 02PTR1SF

Project: Plattsburg AFB <NEW>

STATE COORDINATES:

EASTING (ft.)	NORTHING (ft.)	ELEVATION (ft.)
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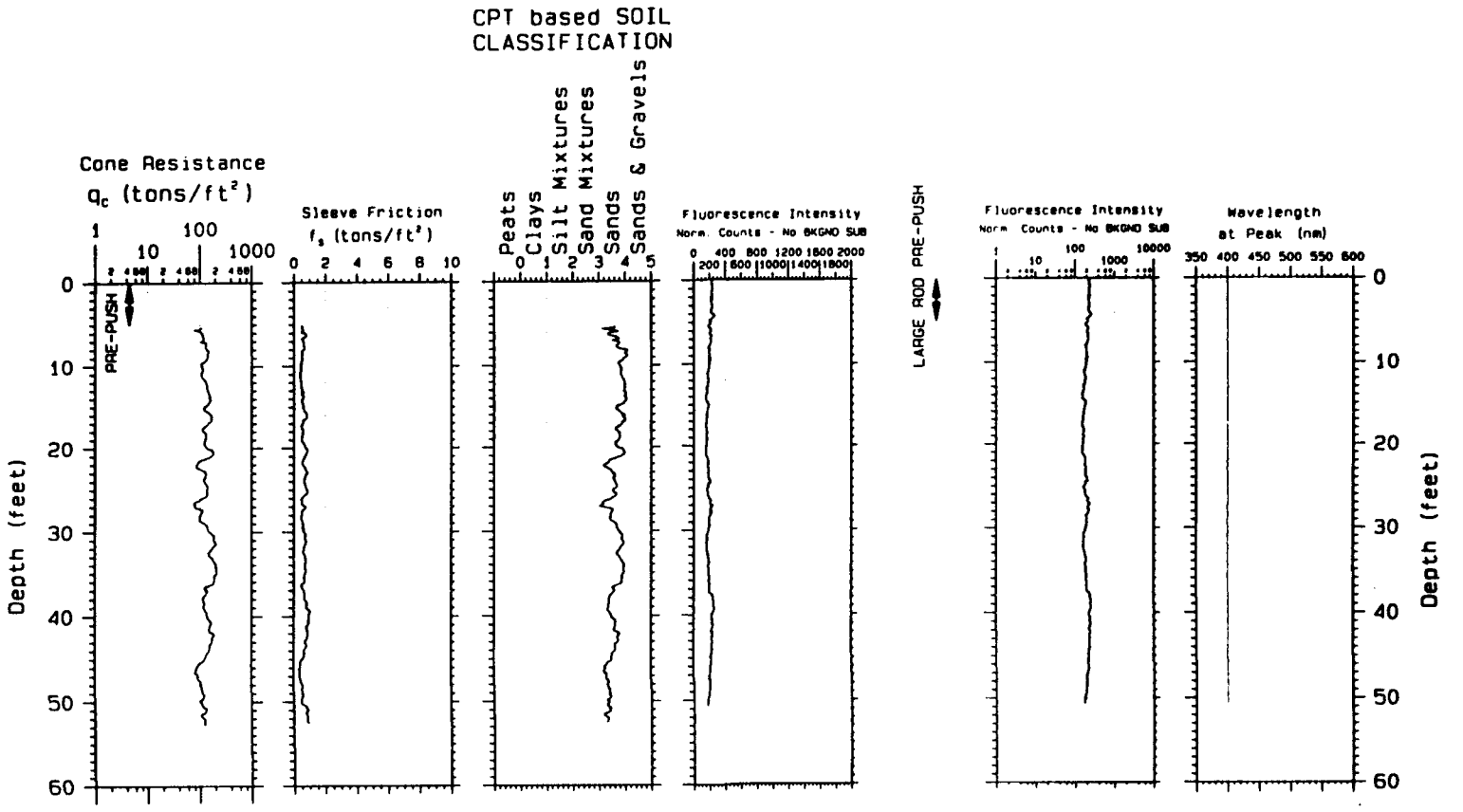
Probe date 05-16-1994



CPT: 04PTR1SF

Project: Plattsburg AFB

STATE COORDINATES:

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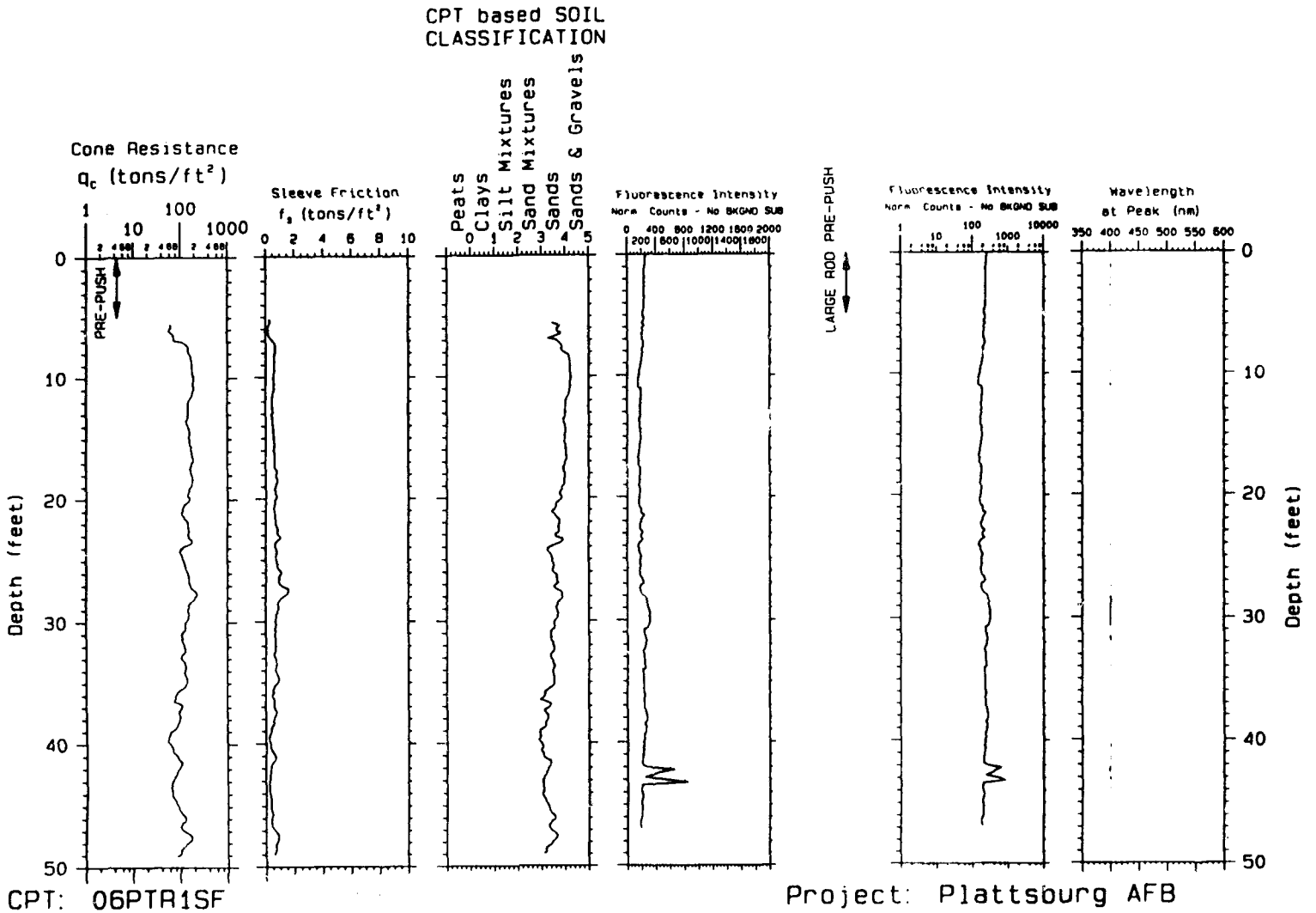
Probe date 05-16-1994



CPT: 06PTR1SF

Project: Plattsburg AFB

STATE COORDINATES:

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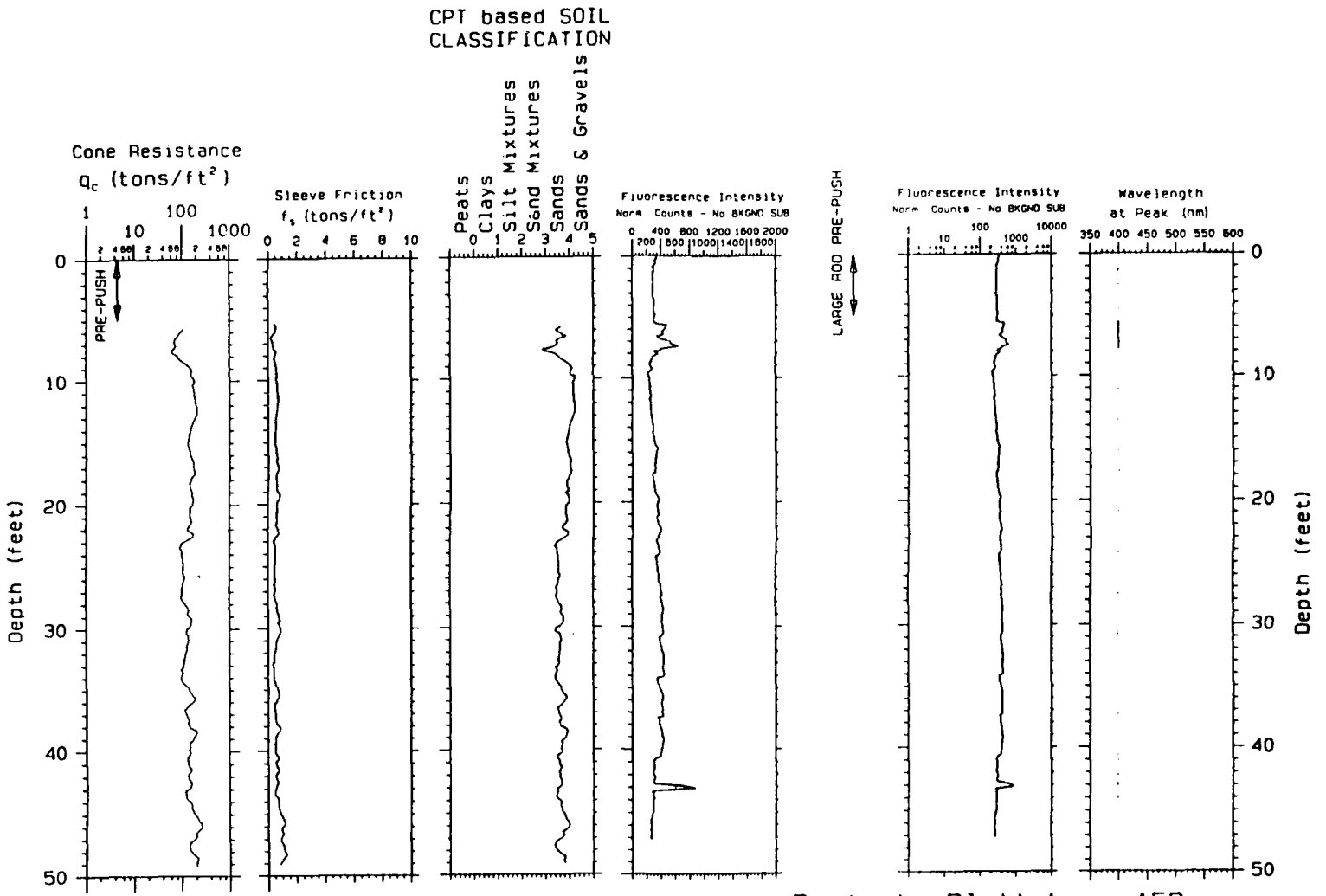
Probe date 05-16-1994



CPT: 08PTR1SF

Project: Plattsburg AFB

STATE COORDINATES:

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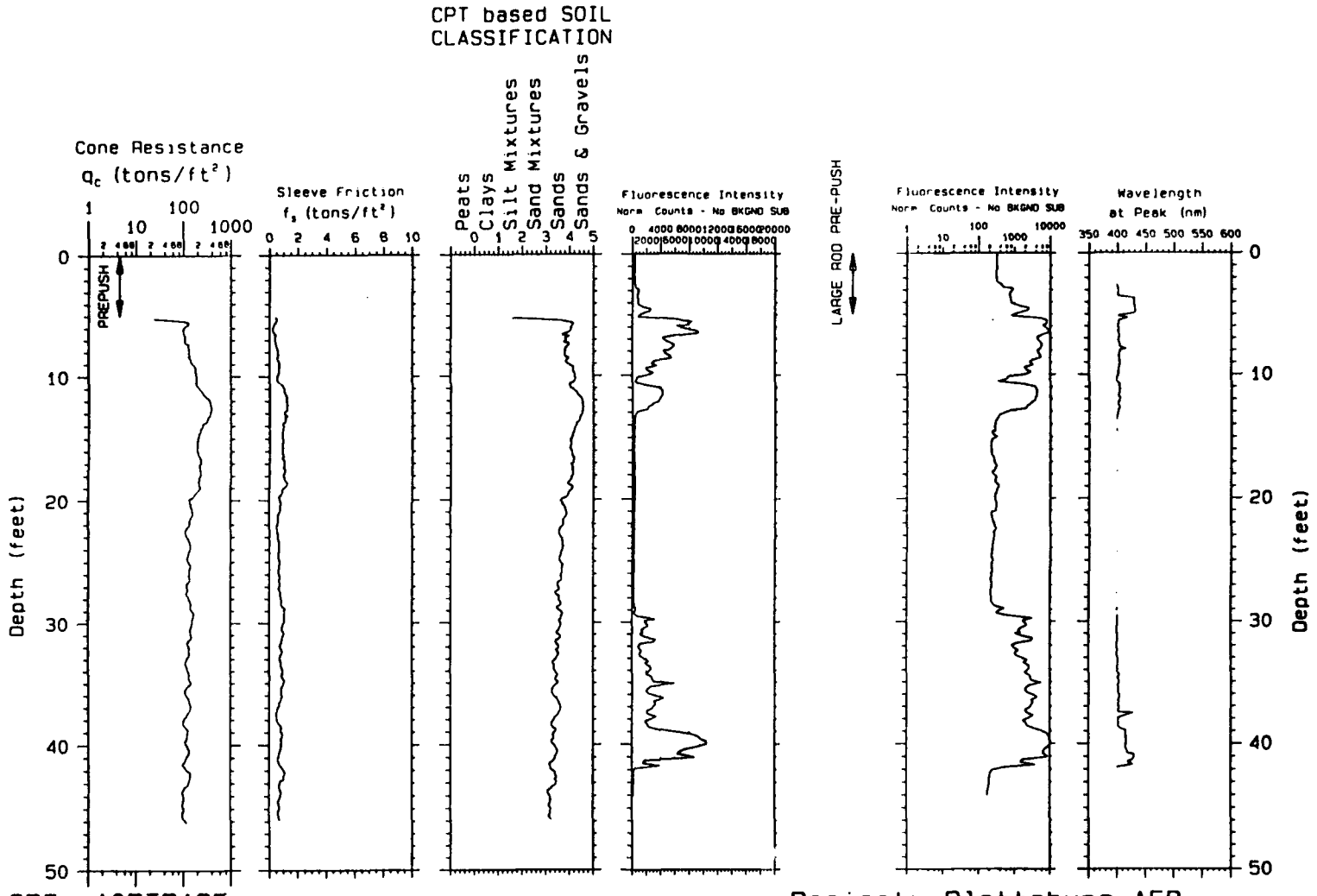
Probe date 05-16-1994



CPT: 10PTR1SF

Project: Plattsburg AFB

STATE COORDINATES:

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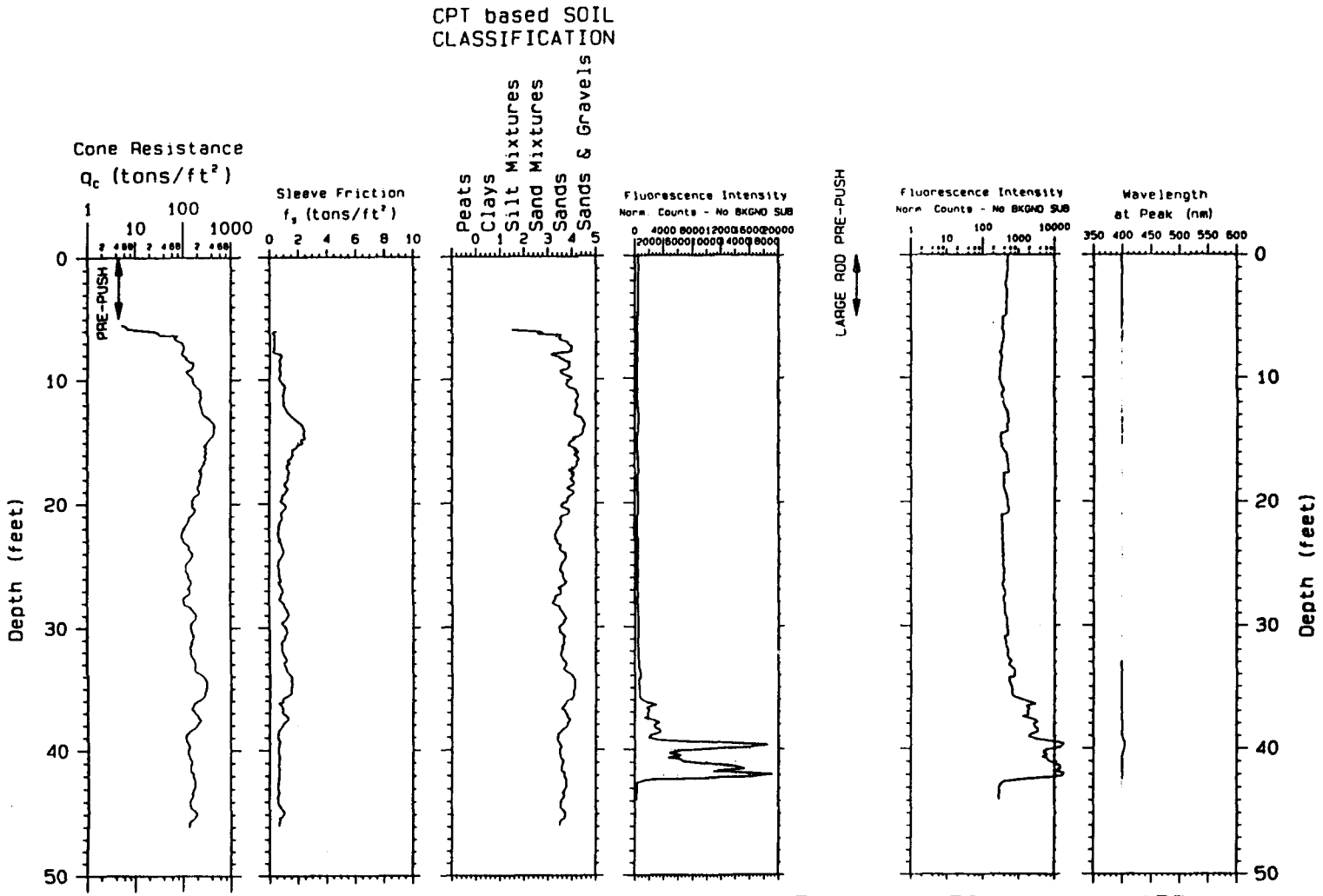
Probe date 05-16-1994



CPT: 12PTR1NF

Project: Plattsburg AFB

STATE COORDINATES:

EASTING (ft.)	NORTHING (ft.)	ELEVATION (ft.)
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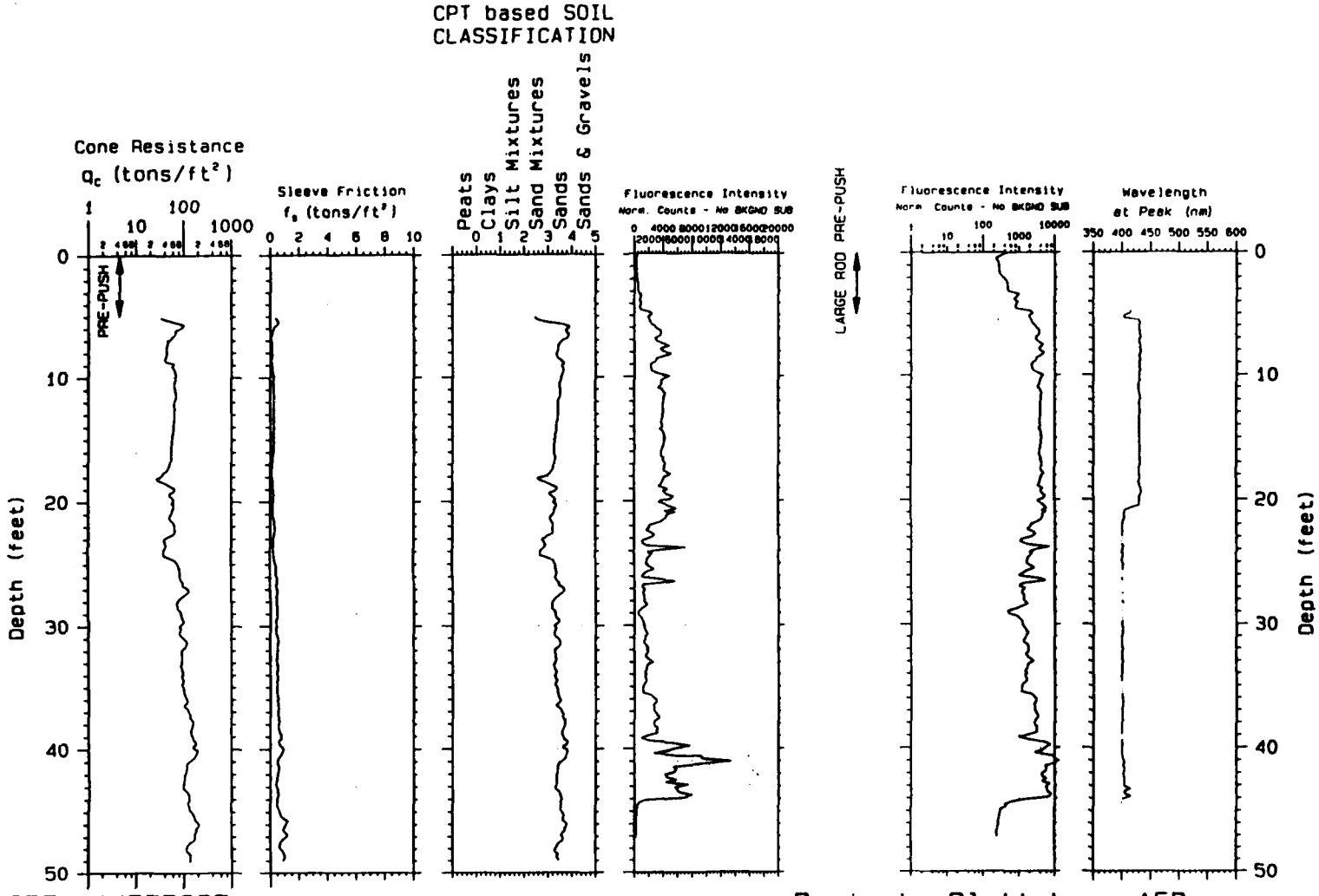
Probe date 05-16-1994



CPT: 14PTR2SF

Project: Plattsburg AFB

STATE COORDINATES:

EASTING (ft.)	NORTHING (ft.)	ELEVATION (ft.)
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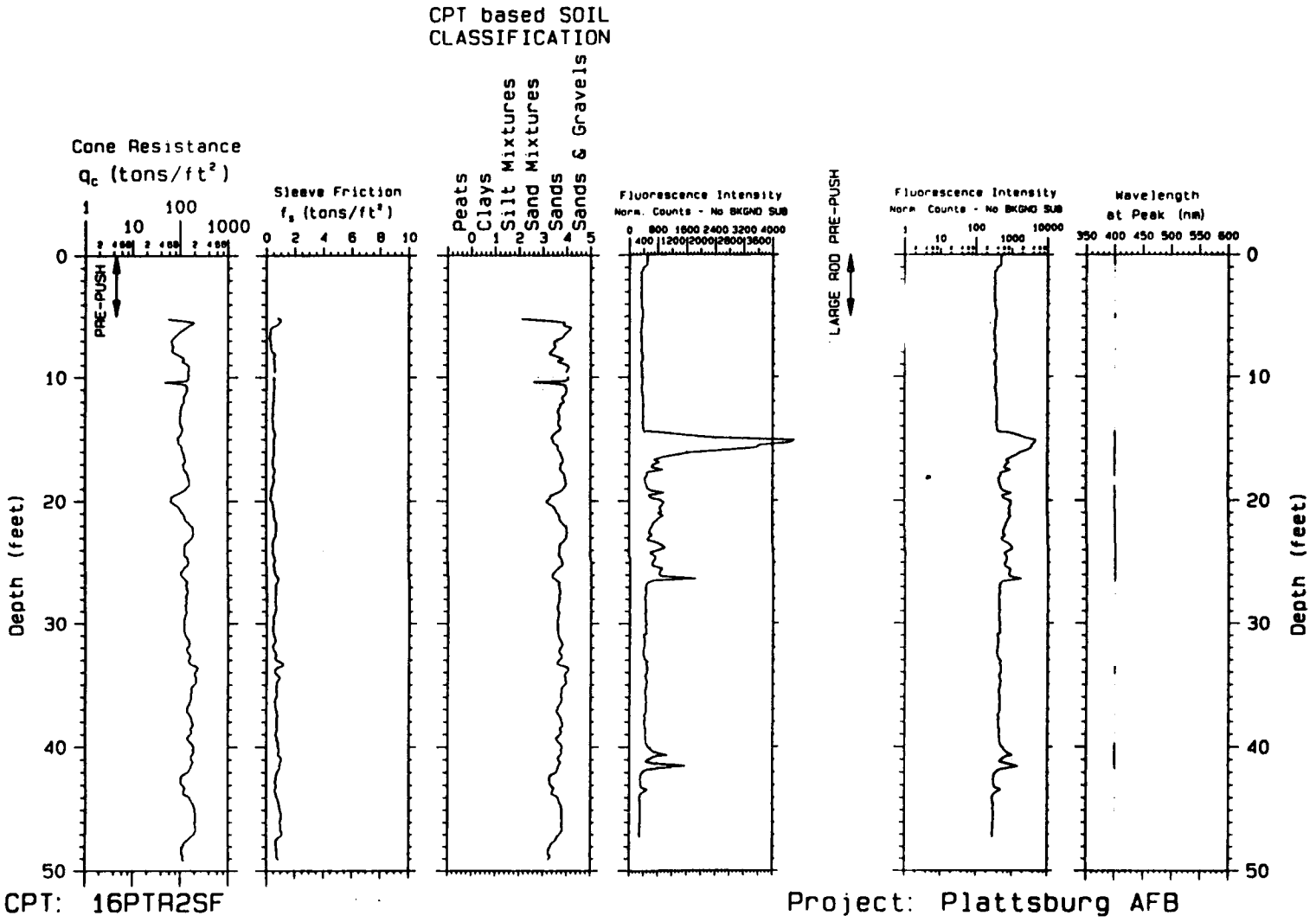
Probe date 05-16-1994



CPT: 16PTR2SF

Project: Plattsburg AFB

STATE COORDINATES:

EASTING (ft.)	NORTHING (ft.)	ELEVATION (ft.)
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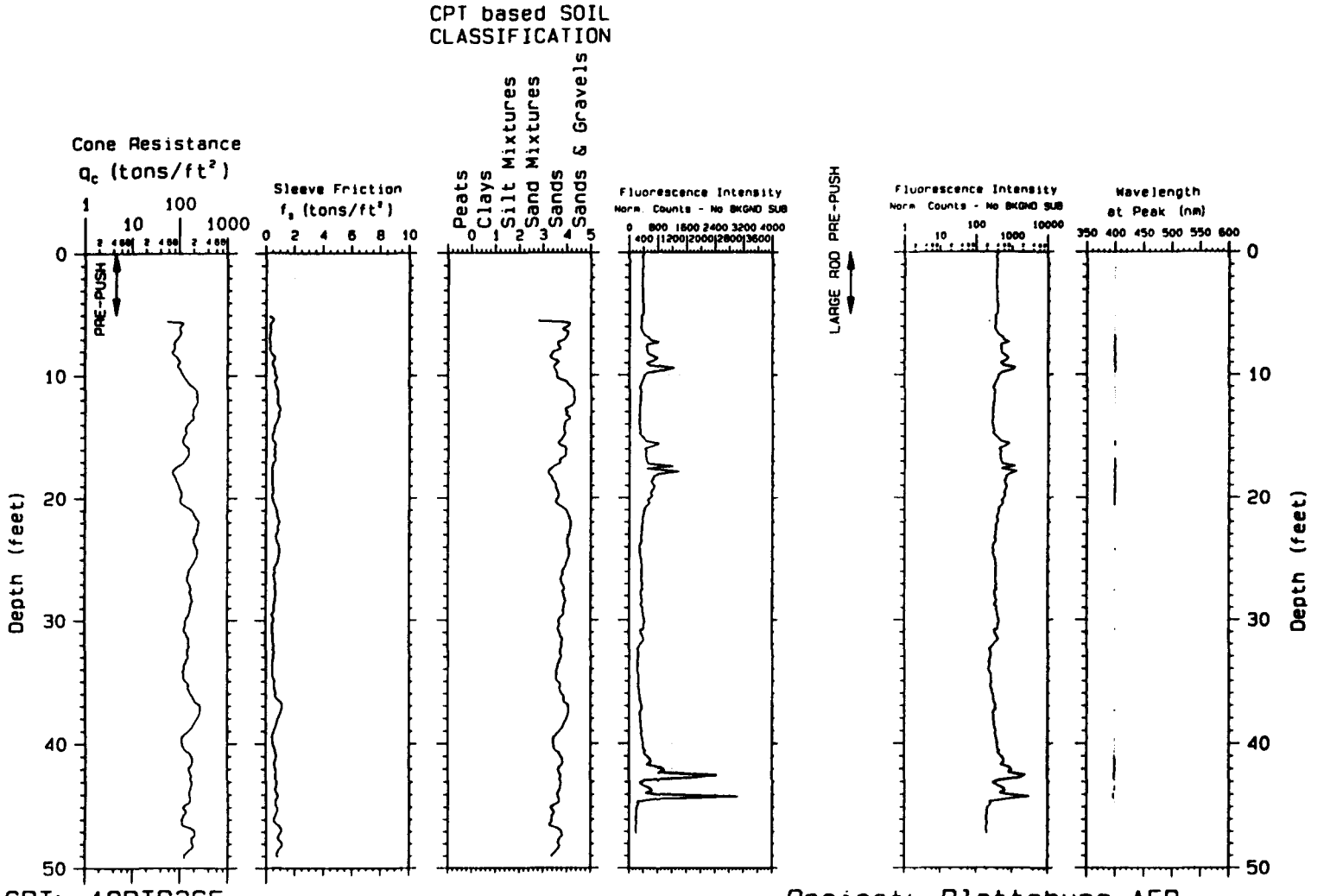
Probe date 05-17-1994



CPT: 18PTR2SF

Project: Plattsburg AFB

STATE COORDINATES:

EASTING (ft.)	NORTHING (ft.)	ELEVATION (ft.)
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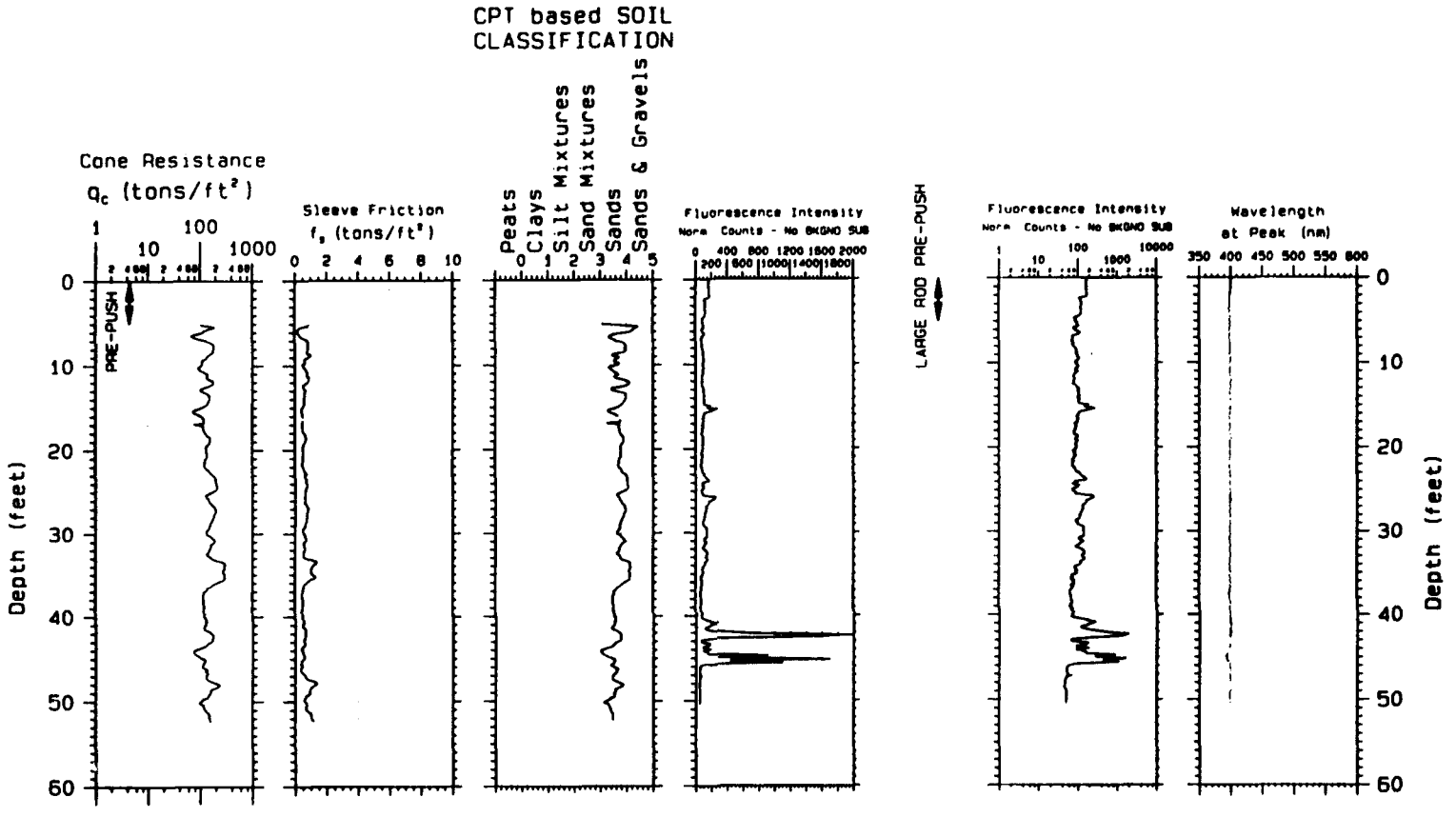
Probe date 05-17-1994



CPT: 22PTR2SF

Project: Plattsburg AFB

STATE COORDINATES:

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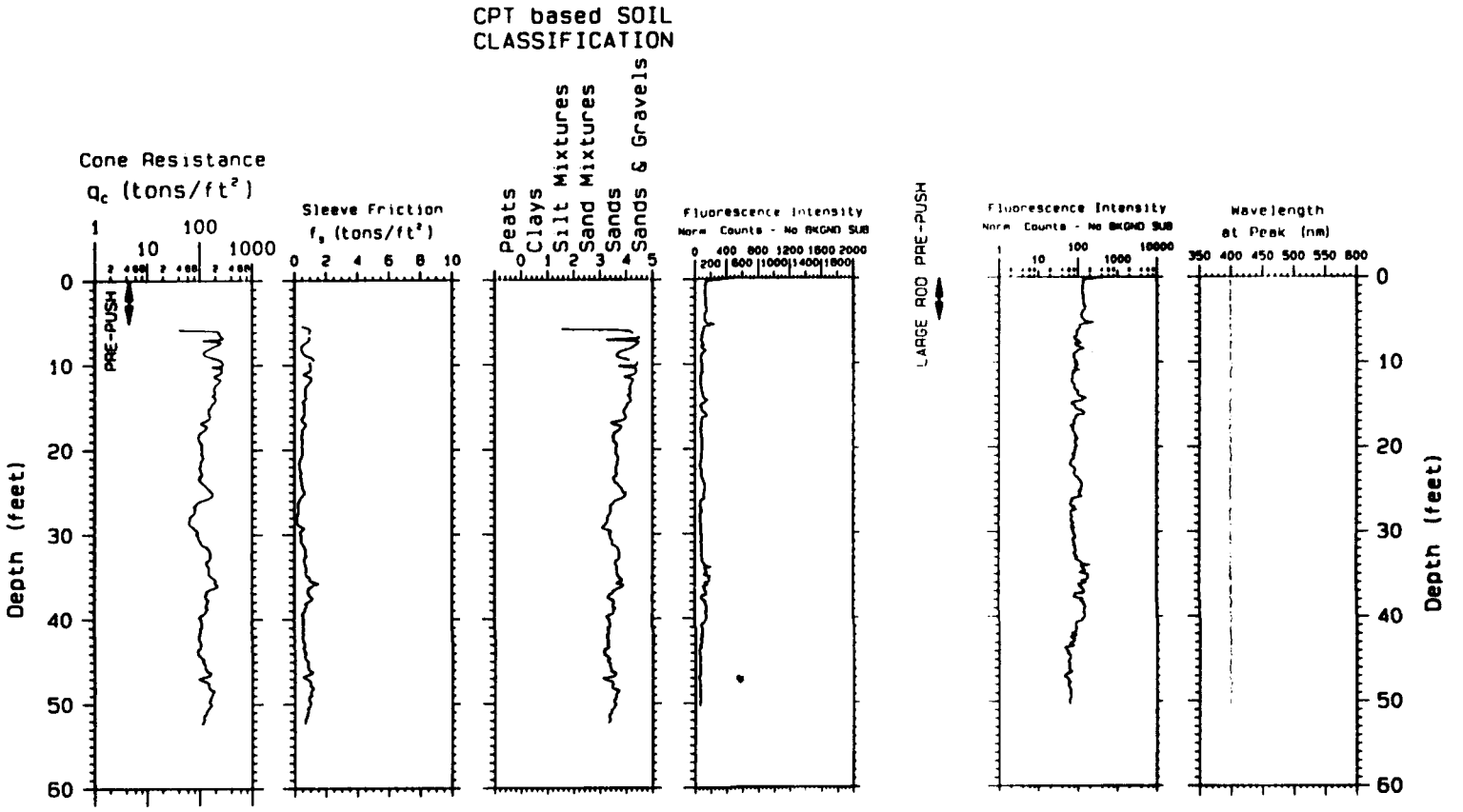
Probe date 05-17-1994



CPT: 24PTR2SF

Project: Plattsburg AFB

STATE COORDINATES:

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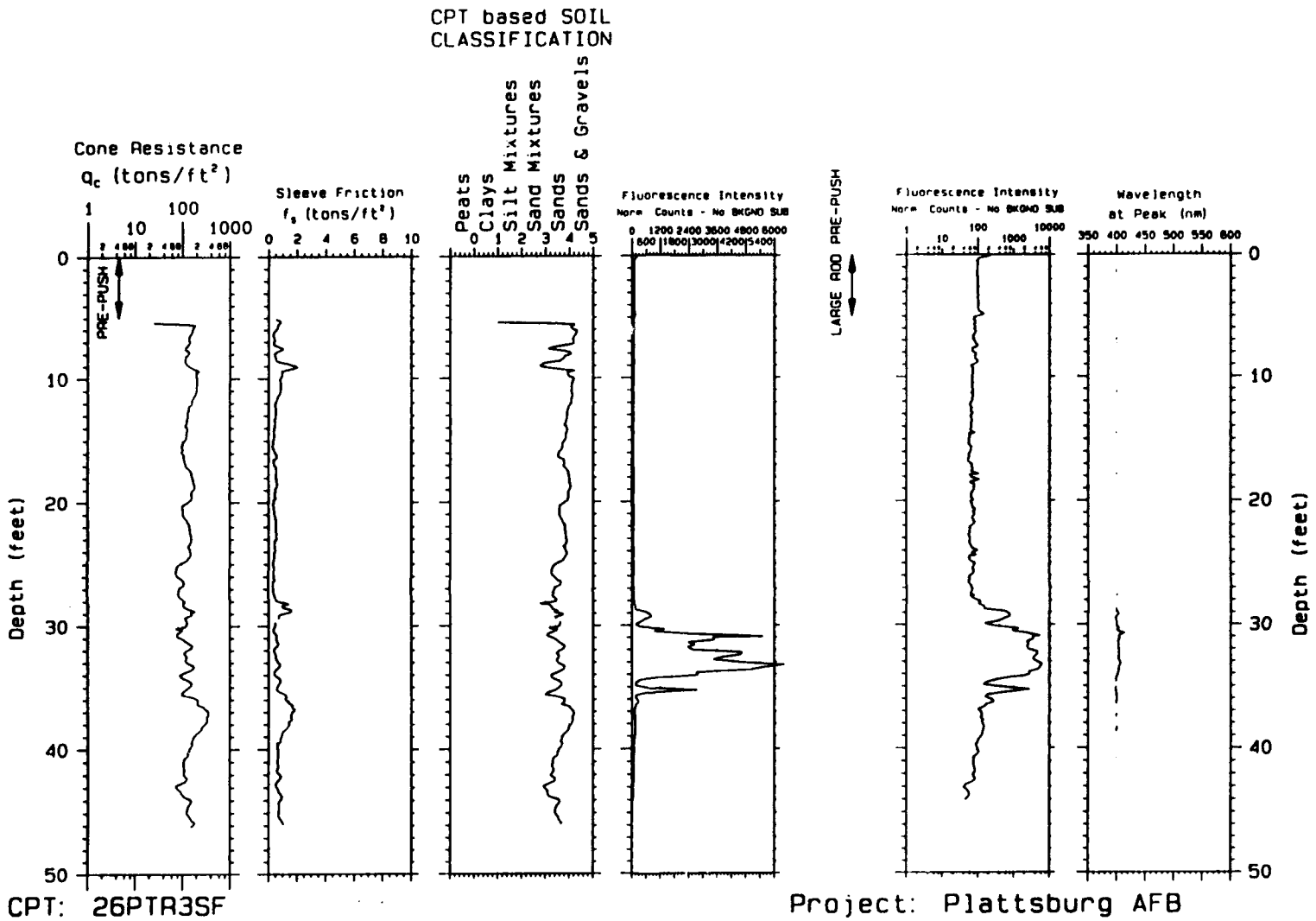
Probe date 05-17-1994



CPT: 26PTR3SF

Project: Plattsburg AFB

STATE COORDINATES:

EASTING (ft.)	NORTHING (ft.)	ELEVATION (ft.)
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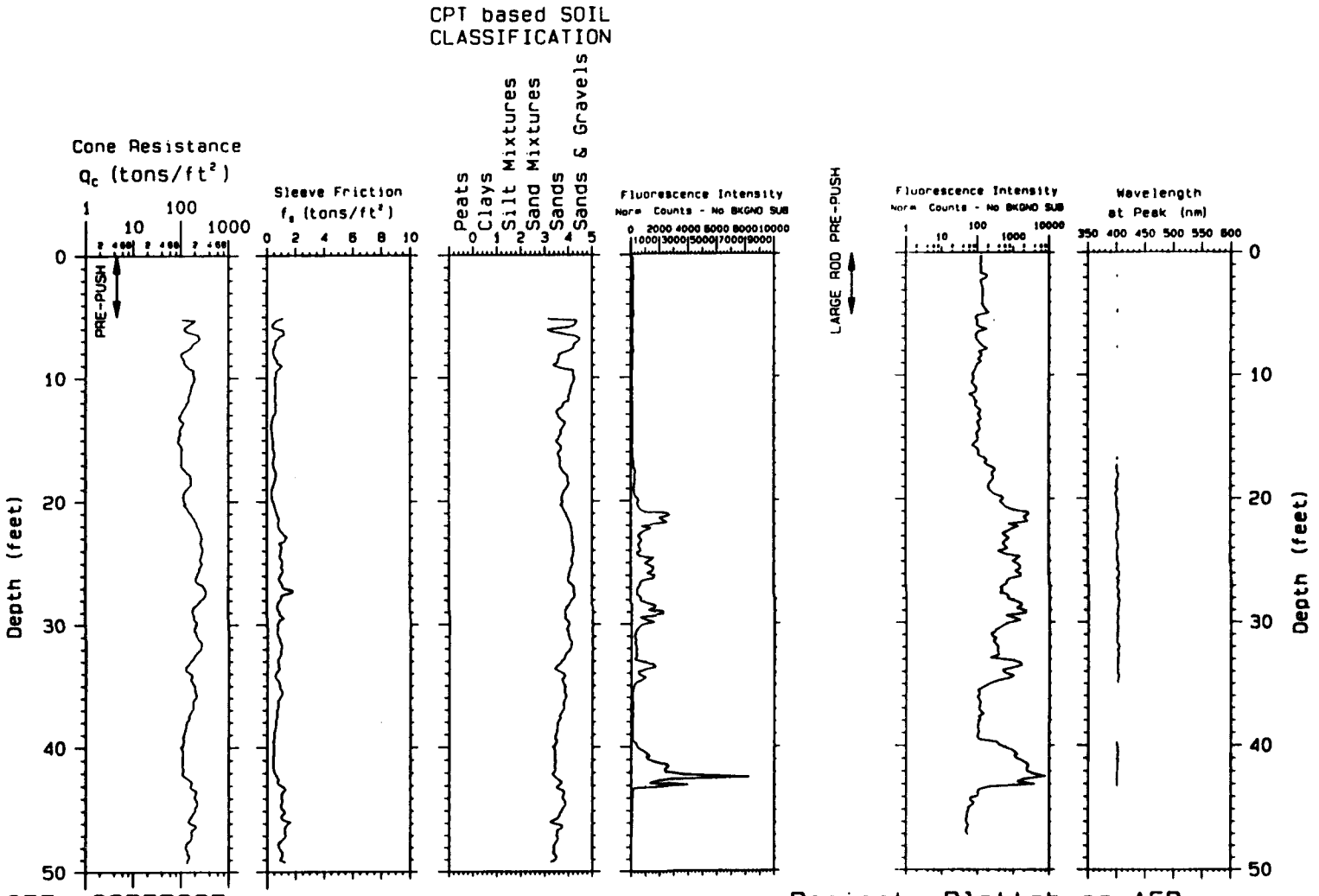
Probe date 05-17-1994



CPT: 28PTR3SF

Project: Plattsburg AFB

STATE COORDINATES:

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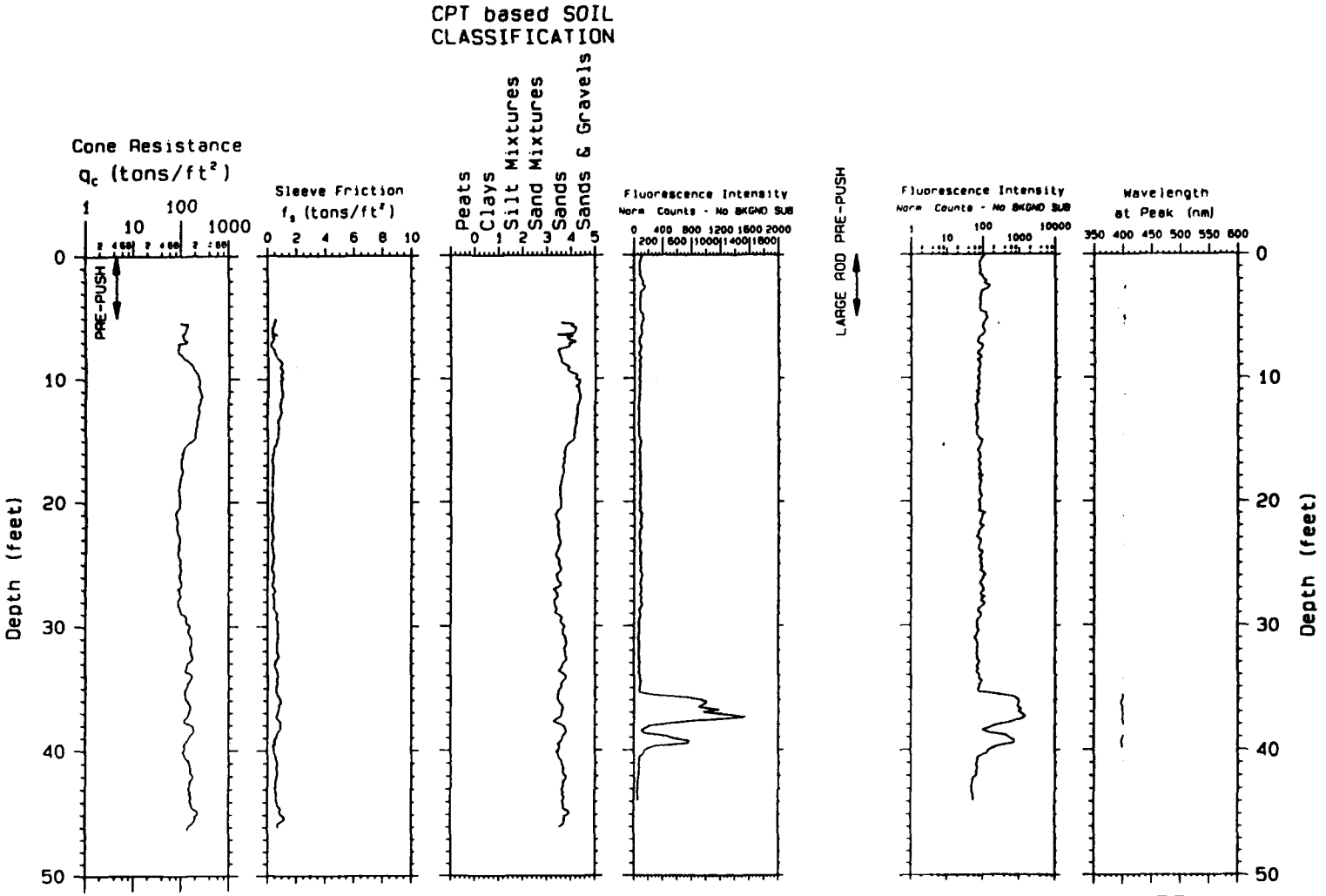
Probe date 05-18-1994



CPT: 30PTR3SF

Project: Plattsburg AFB

STATE COORDINATES:

EASTING (ft.)	NORTHING (ft.)	ELEVATION (ft.)
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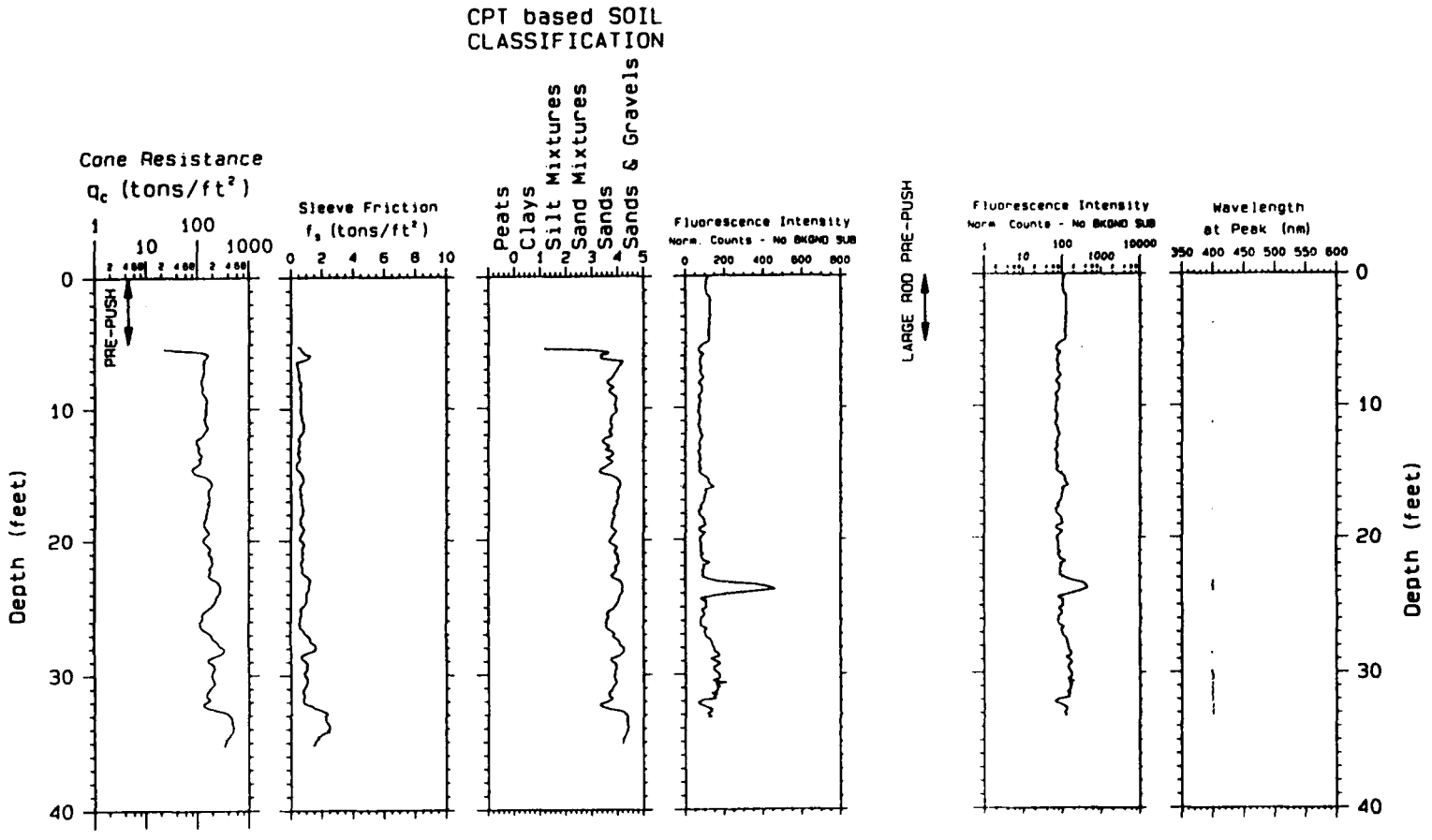
Probe date 05-18-1994



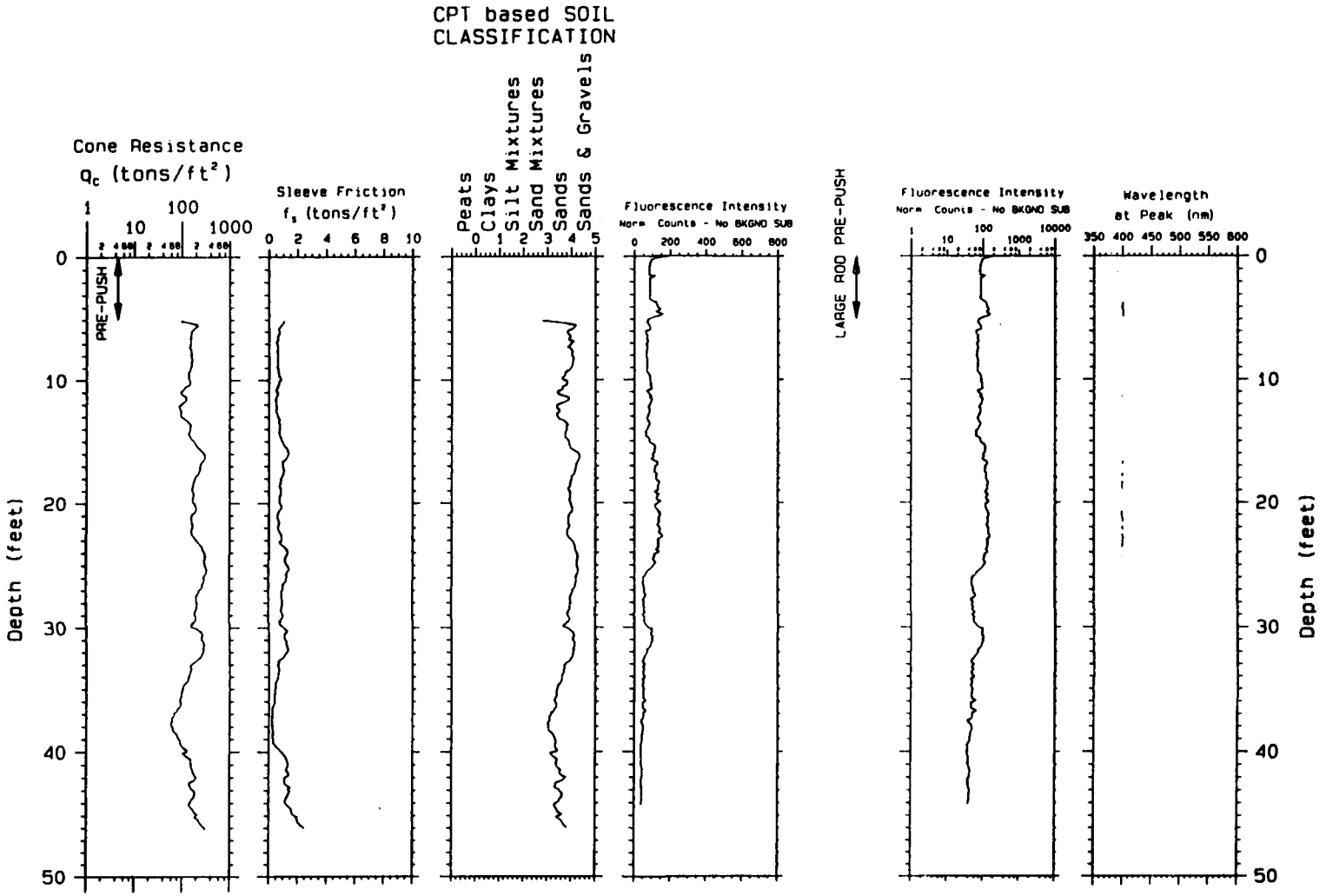
CPT: 32PTR3NF

Project: Plattsburg AFB

STATE COORDINATES:

EASTING (ft.)	NORTHING (ft.)	ELEVATION (ft.)
-1	-1	0

Probe date 05-18-1994



CPT: 34PTR3NF

Project: Plattsburg AFB

STATE COORDINATES:

EASTING (ft.)	NORTHING (ft.)	ELEVATION (ft.)
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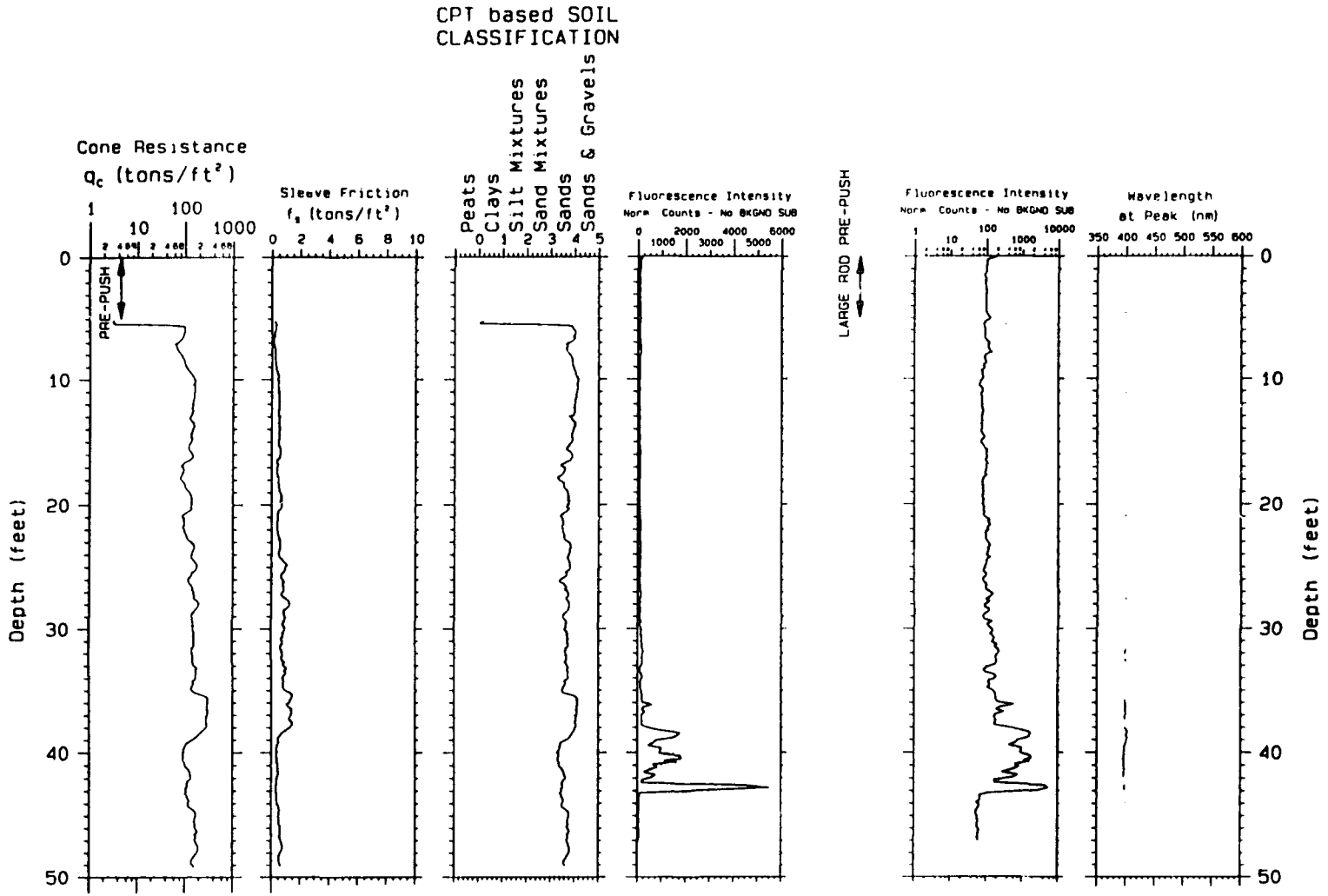
Probe date 05-18-1994



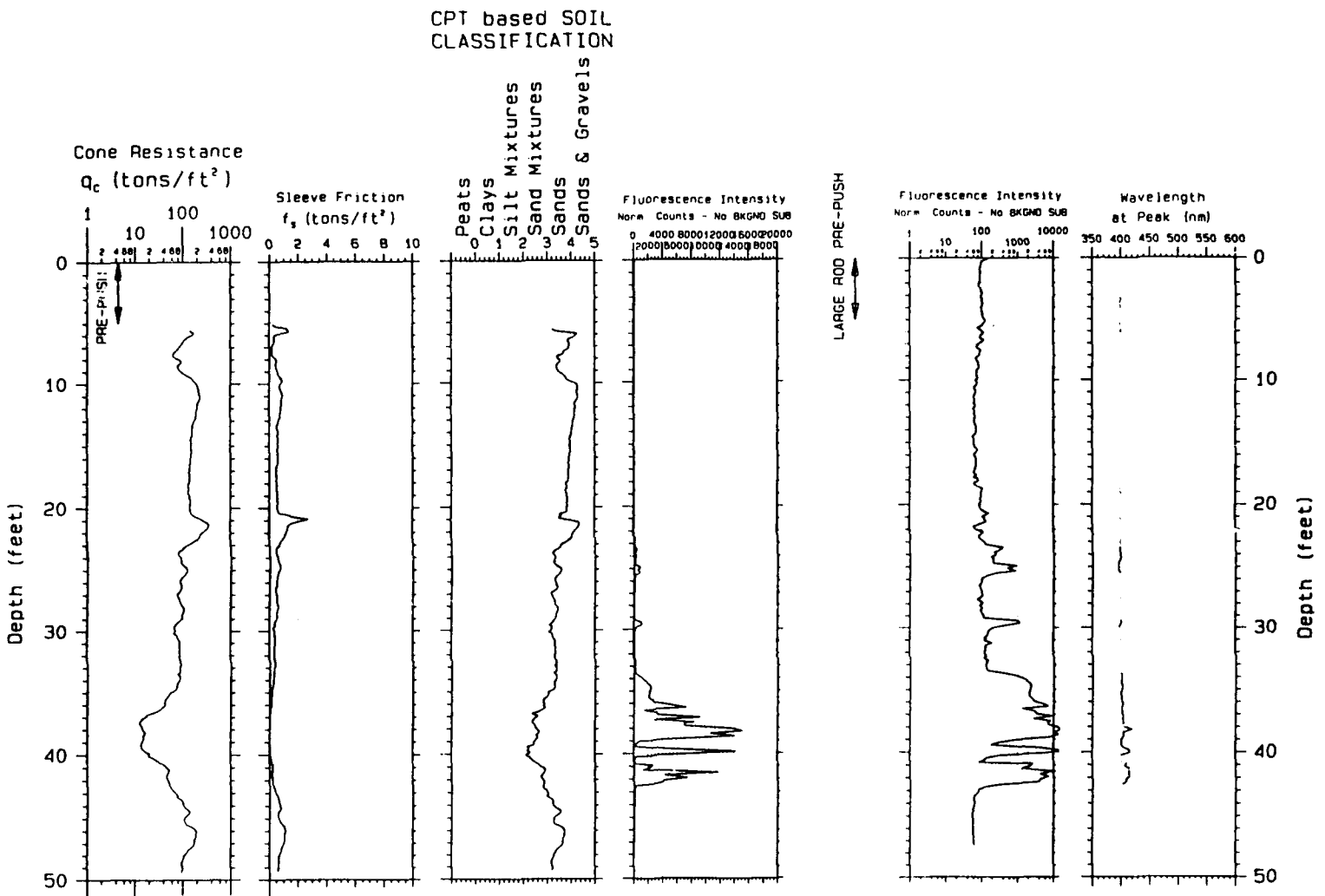
CPT: 38PTR2NF

Project: Plattsburg AFB

STATE COORDINATES:

EASTING (ft.)	NORTHING (ft.)	ELEVATION (ft.)
-1	-1	0

Probe date 05-18-1994



CPT: 40PTR2NF

Project: Plattsburg AFB

STATE COORDINATES:

EASTING (ft.)	NORTHING (ft.)	ELEVATION (ft.)
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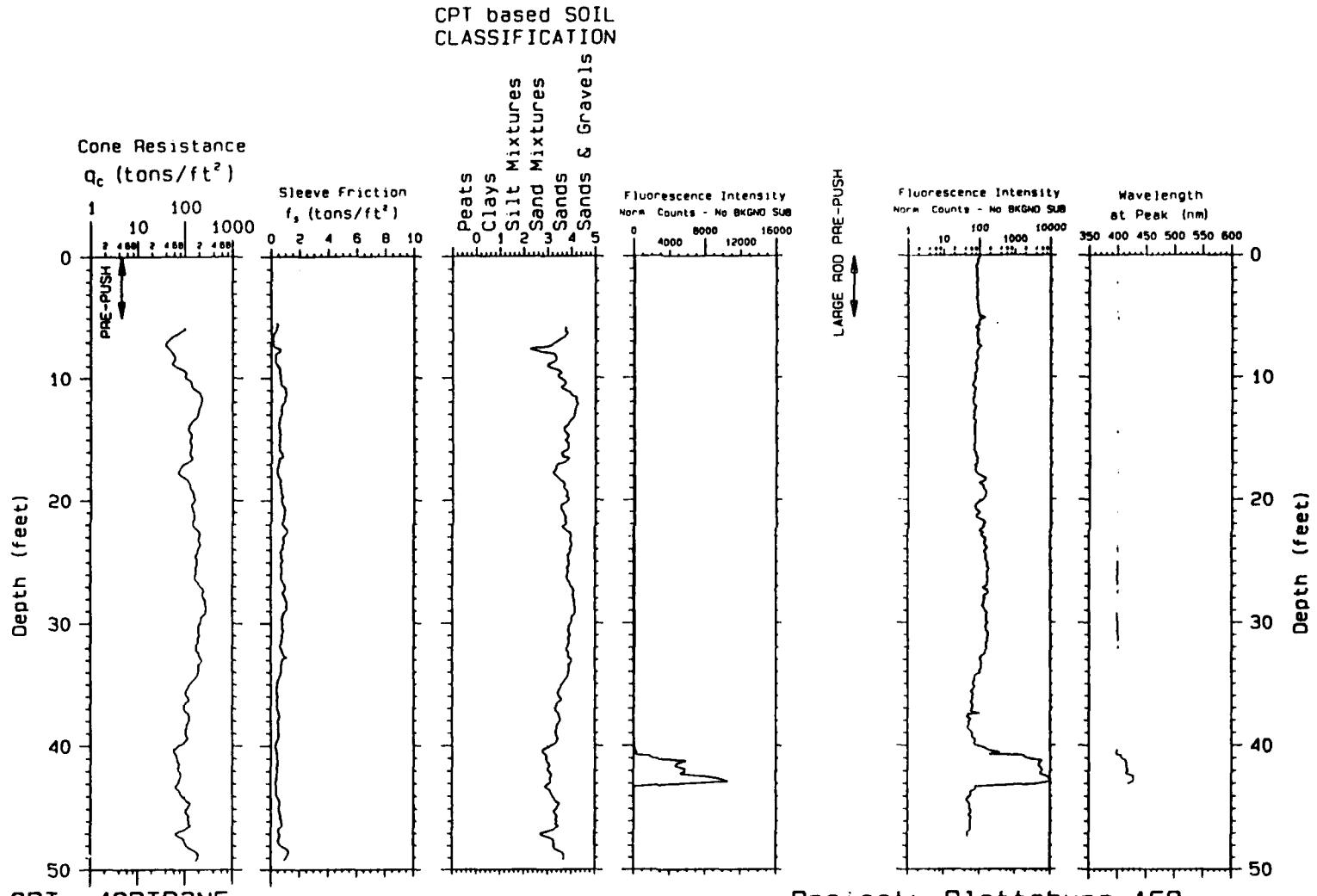
Probe date 05-18-1994



CPT: 42PTR3NF

Project: Plattsburg AFB

STATE COORDINATES:

EASTING (ft.)	NORTHING (ft.)	ELEVATION (ft.)
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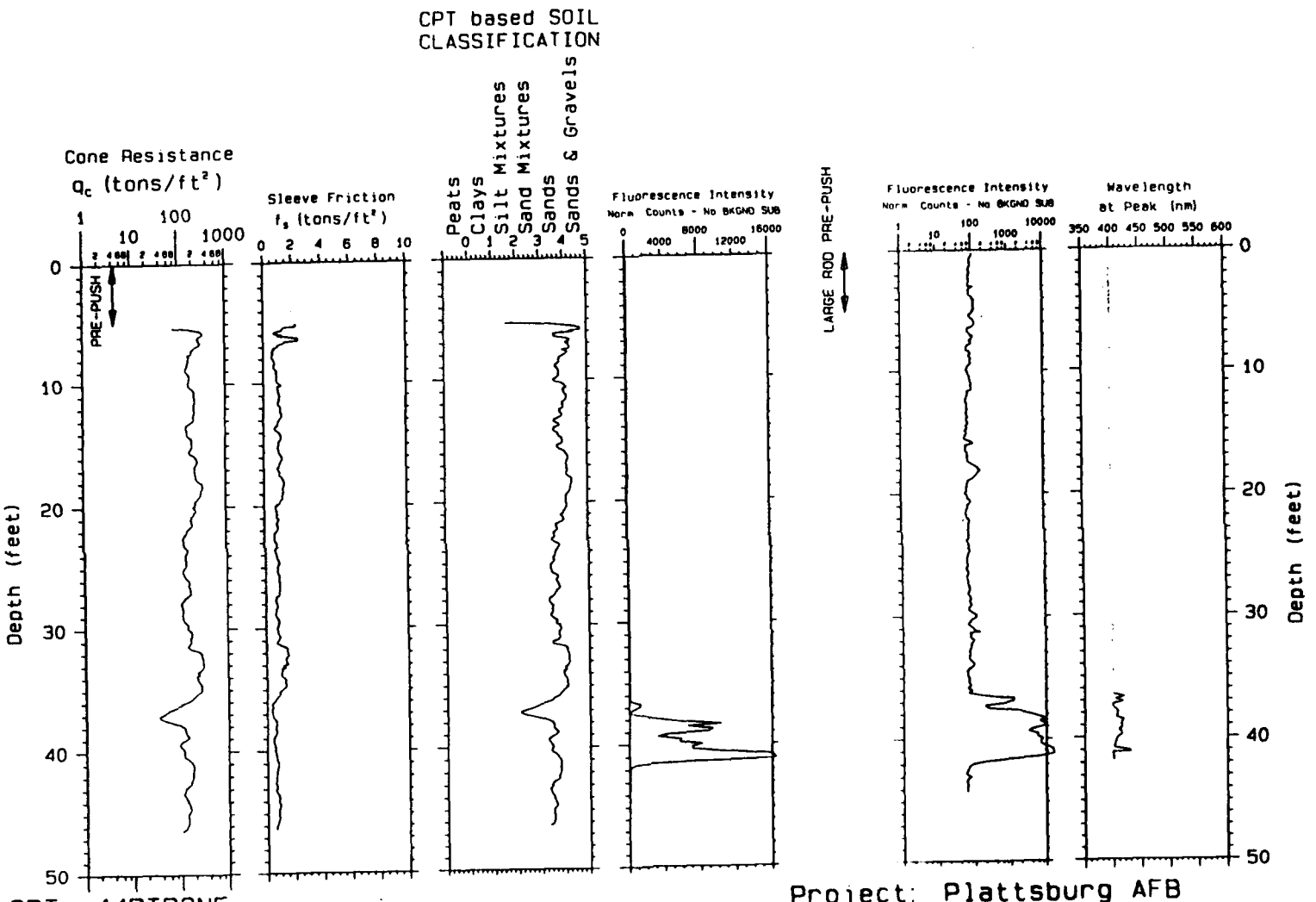
Probe date 05-18-1994



CPT: 44PTR2NF

STATE COORDINATES:

EASTING (ft.)	NORTHING (ft.)	ELEVATION (ft.)
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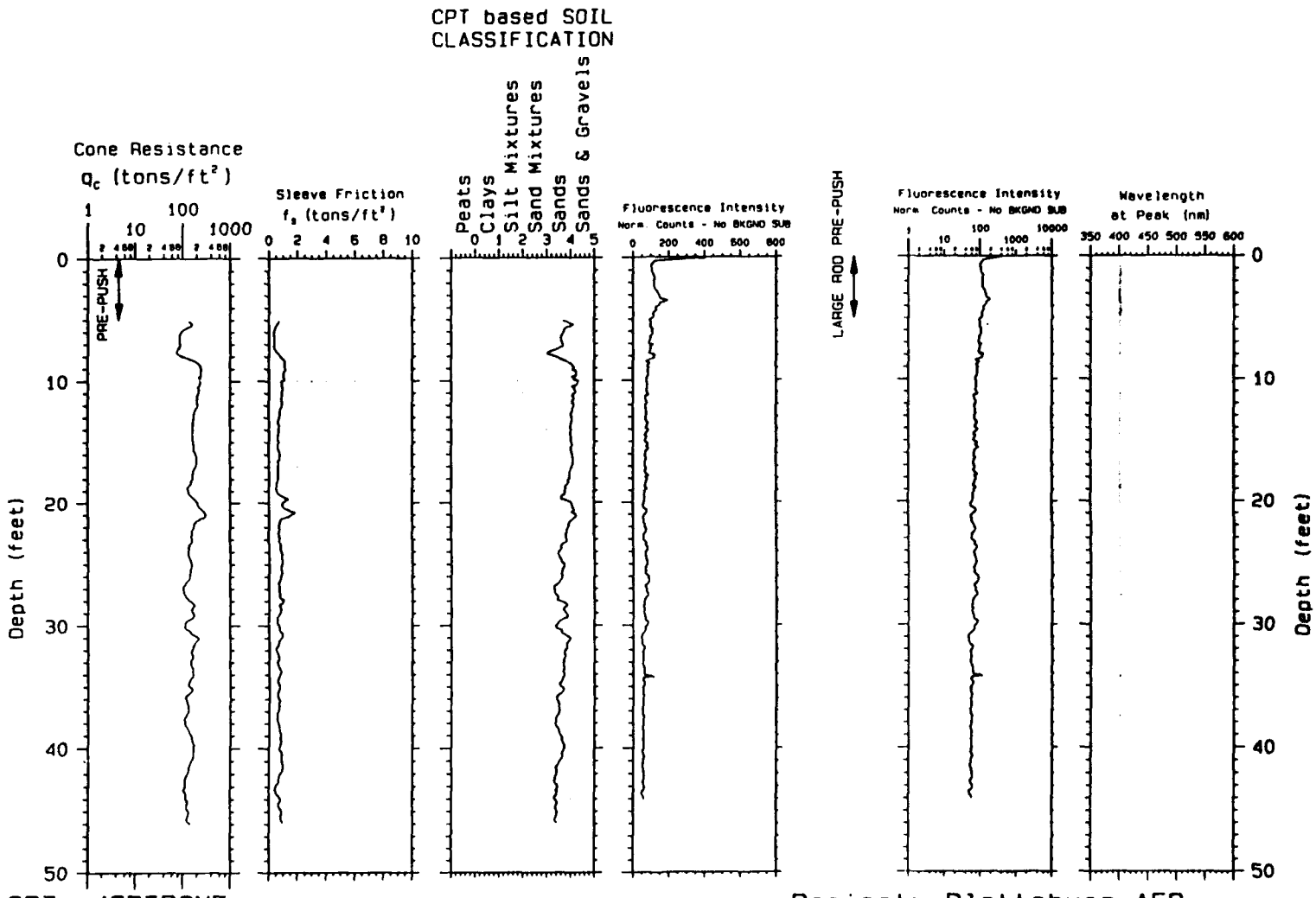
Project: Plattsburg AFB

Probe date 05-18-1994



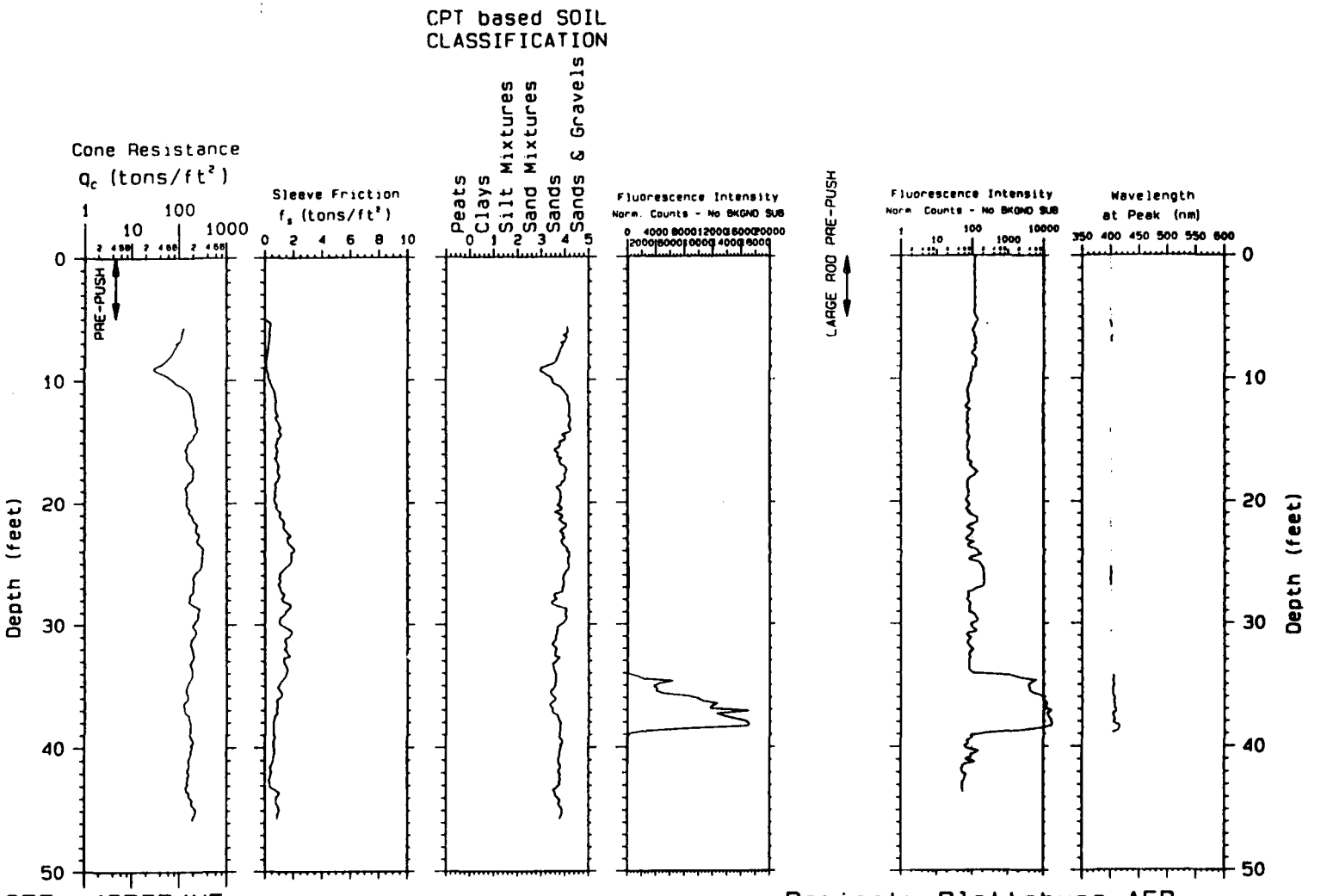
CPT: 46PTR2NF

Project: Plattsburg AFB

STATE COORDINATES:

EASTING (ft.)	NORTHING (ft.)	ELEVATION (ft.)
-1	-1	0

Probe date 05-19-1994



CPT: 48PTR4NF

Project: Plattsburg AFB

STATE COORDINATES:

EASTING (ft.)	NORTHING (ft.)	ELEVATION (ft.)
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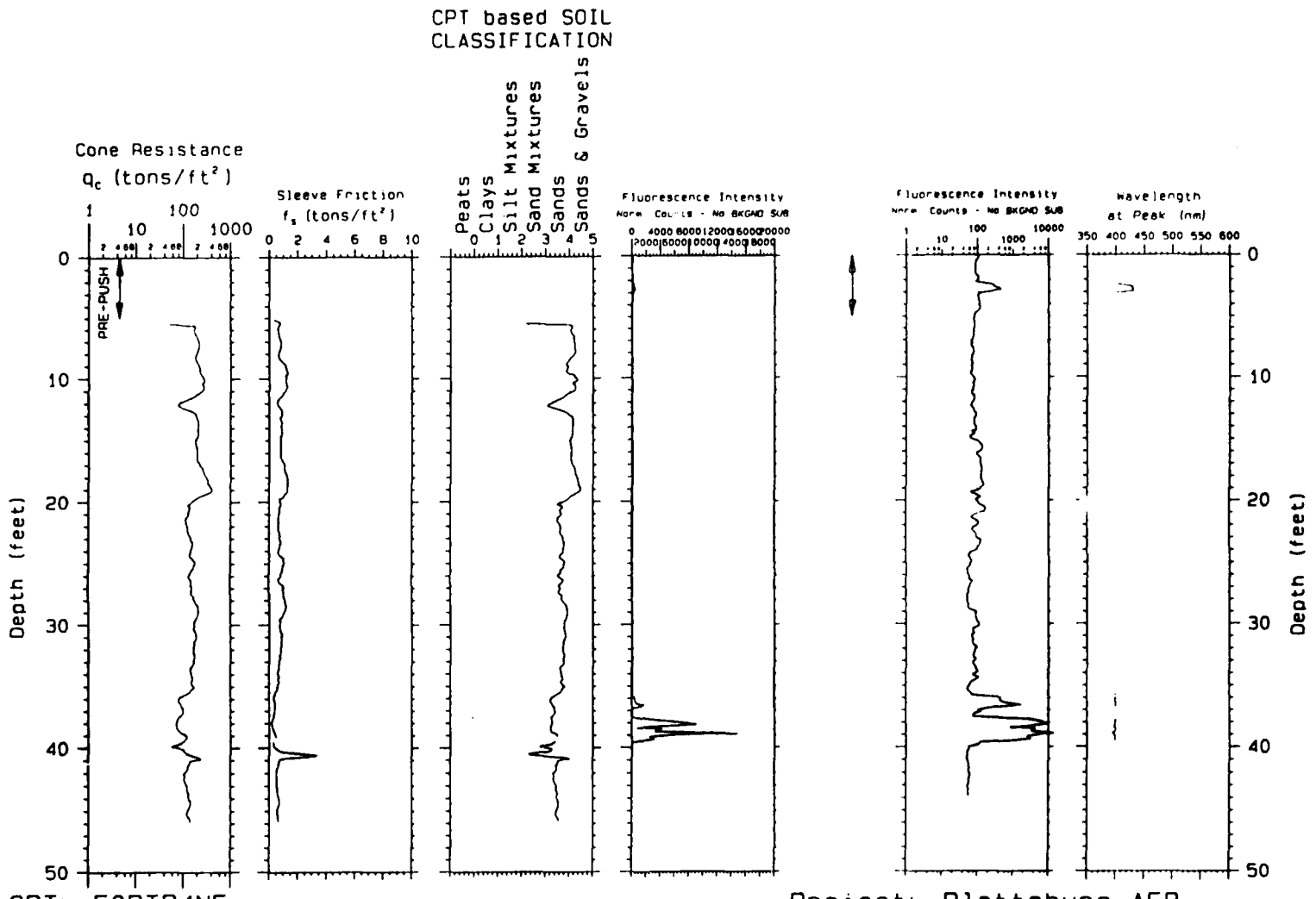
Probe date 05-19-1994



CPT: 50PTR4NF

Project: Plattsburg AFB

STATE COORDINATES:

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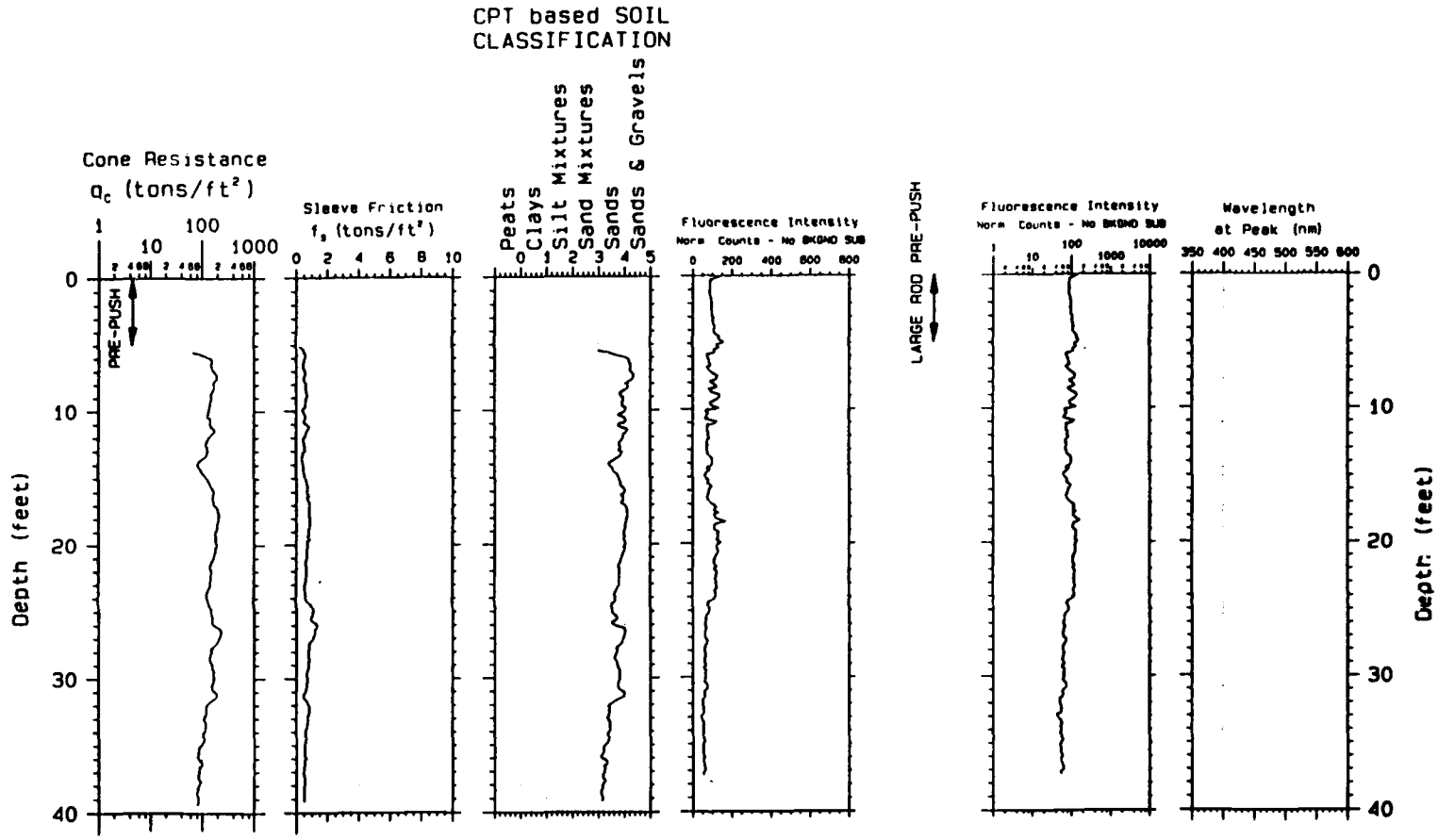
Probe date 05-19-1994



CPT: 52PTR4NF

Project: Plattsburg AFB

STATE COORDINATES:

EASTING (ft.)	NORTHING (ft.)	ELEVATION (ft.)
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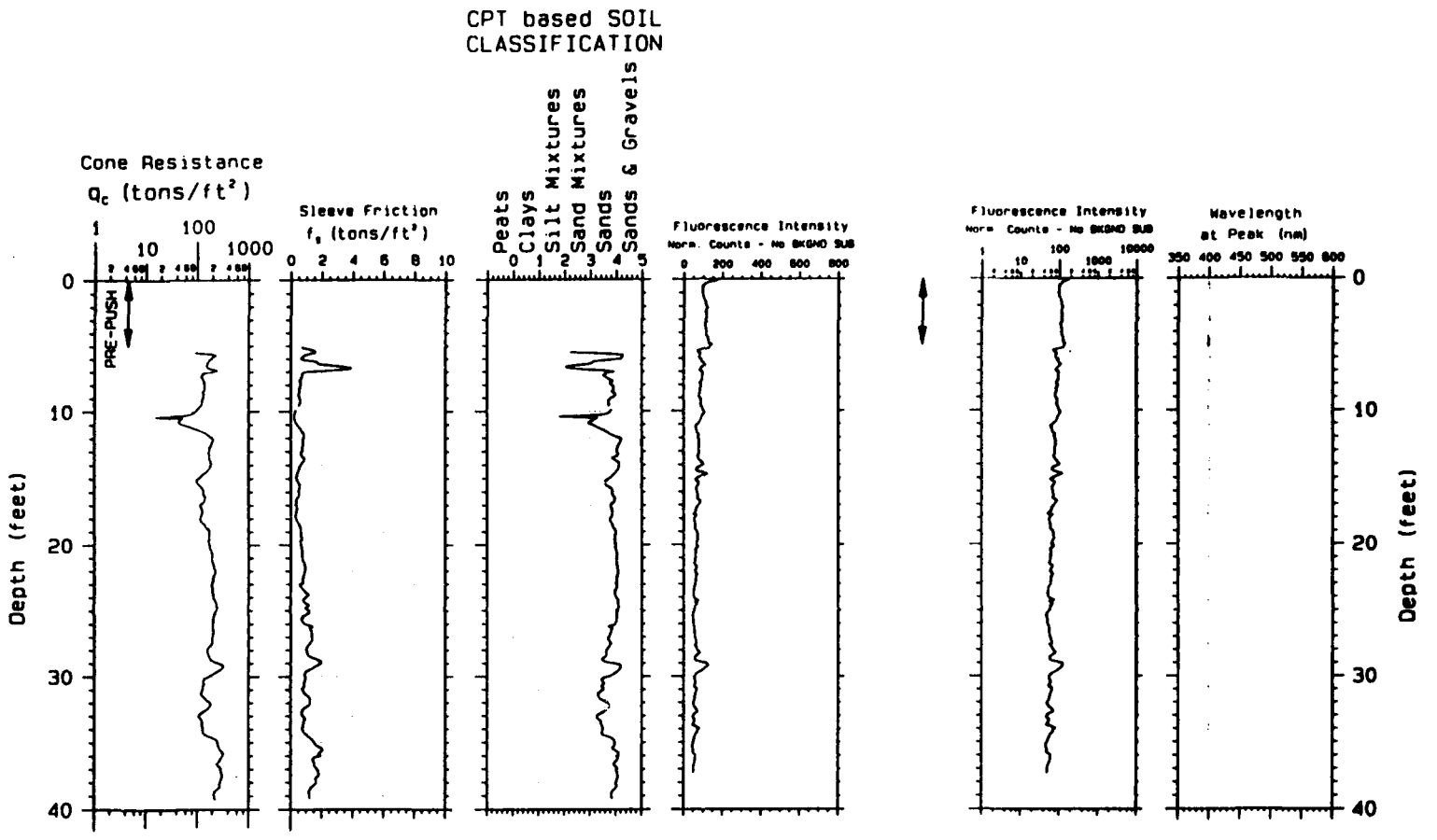
Probe date 05-19-1994



CPT: 54PTR5NF

Project: Plattsburg AFB

STATE COORDINATES:

EASTING (ft.)	NORTHING (ft.)	ELEVATION (ft.)
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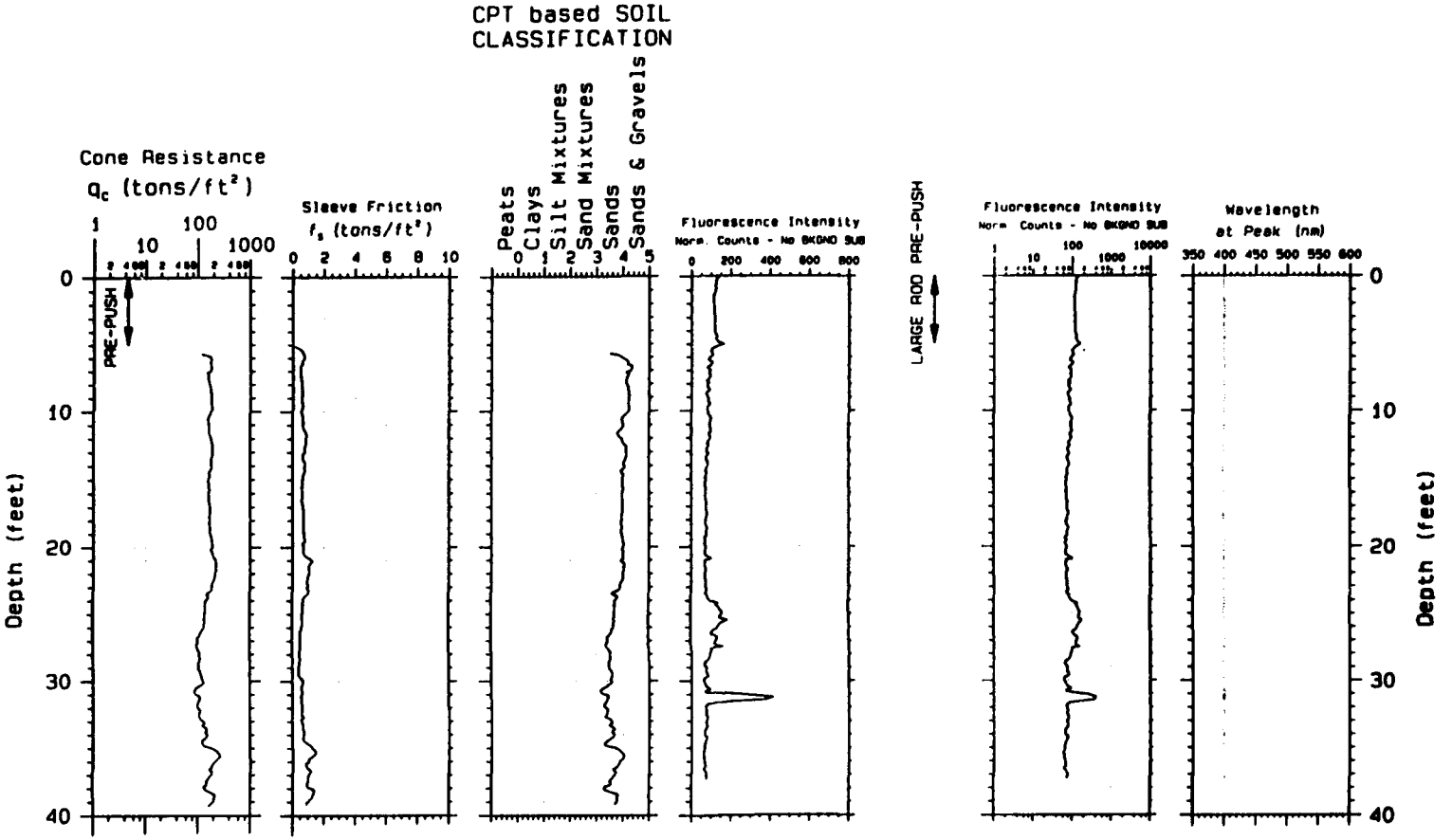
Probe date 05-19-1994



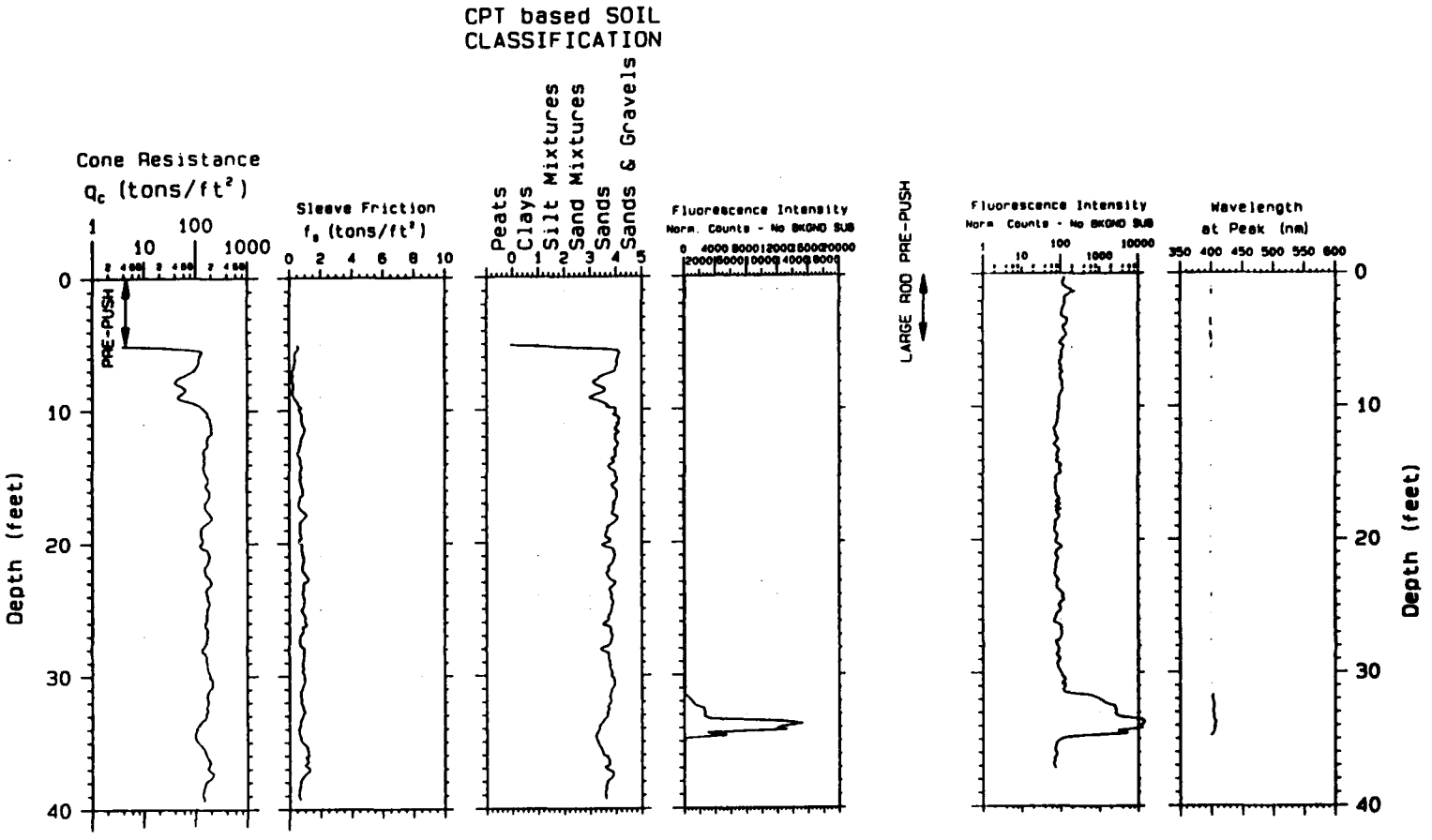
CPT: 56PTR6NF

Project: Plattsburg AFB

STATE COORDINATES:

EASTING (ft.)	NORTHING (ft.)	ELEVATION (ft.)
-1	-1	0

Probe date 05-19-1994



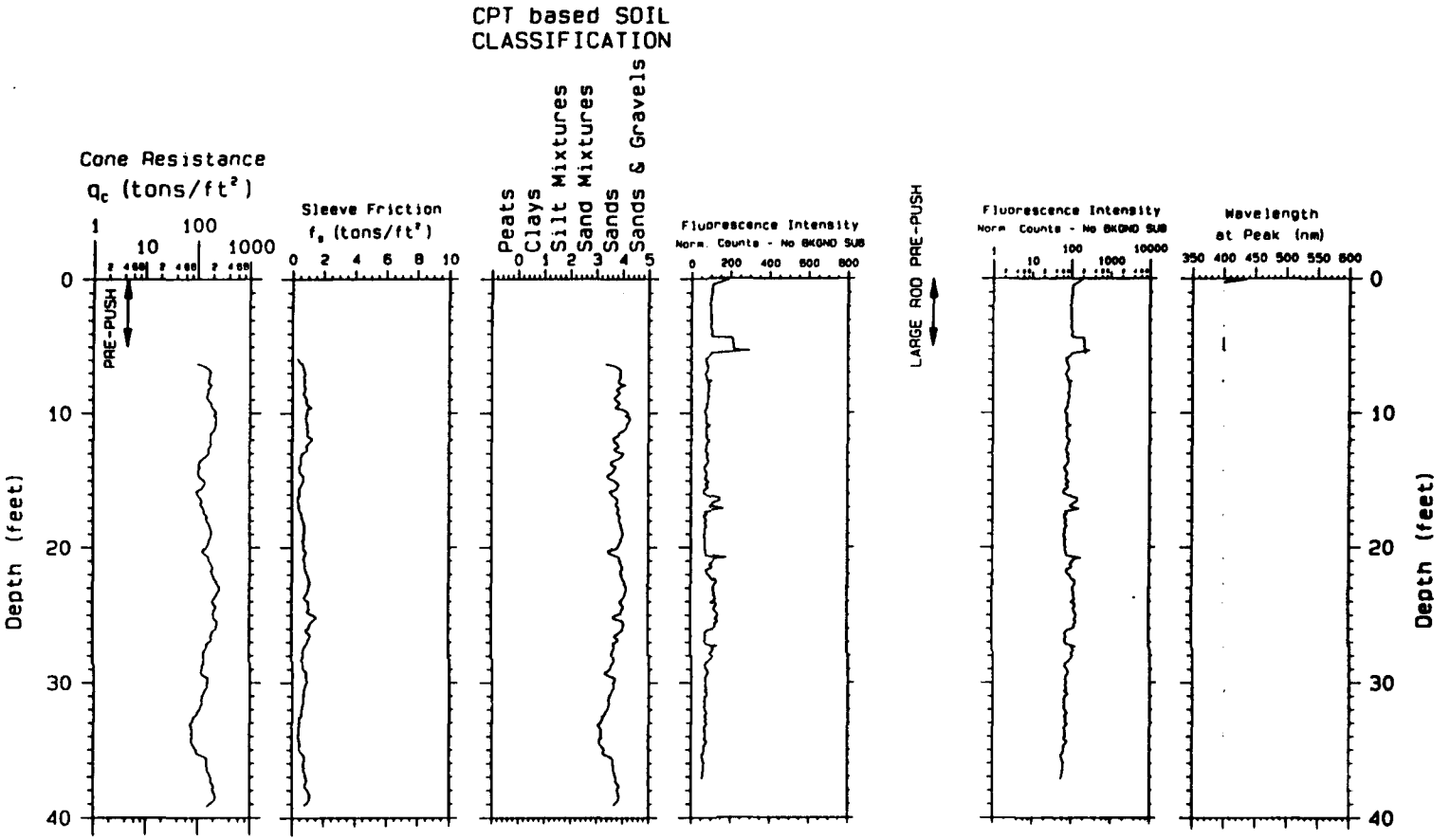
CPT: 58PTR5NF

Project: Plattsburg AFB

STATE COORDINATES:

EASTING (ft.)	NORTHING (ft.)	ELEVATION (ft.)
-1	-1	0

Probe date 05-19-1994



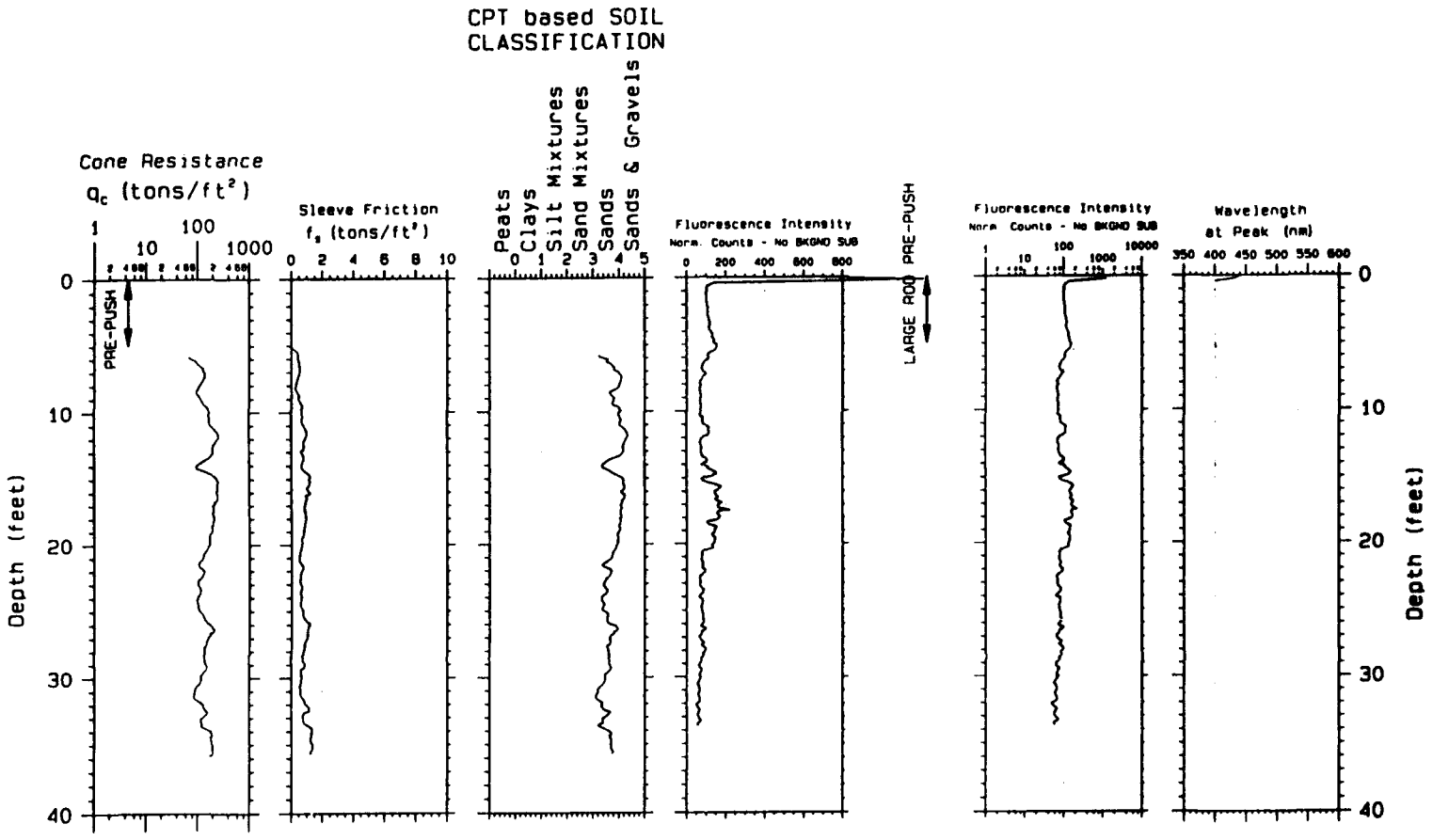
CPT: 60PTR5NF

Project: Plattsburg AFB

STATE COORDINATES:

EASTING (ft.)	NORTHING (ft.)	ELEVATION (ft.)
-1	-1	0

Probe date 05-19-1994



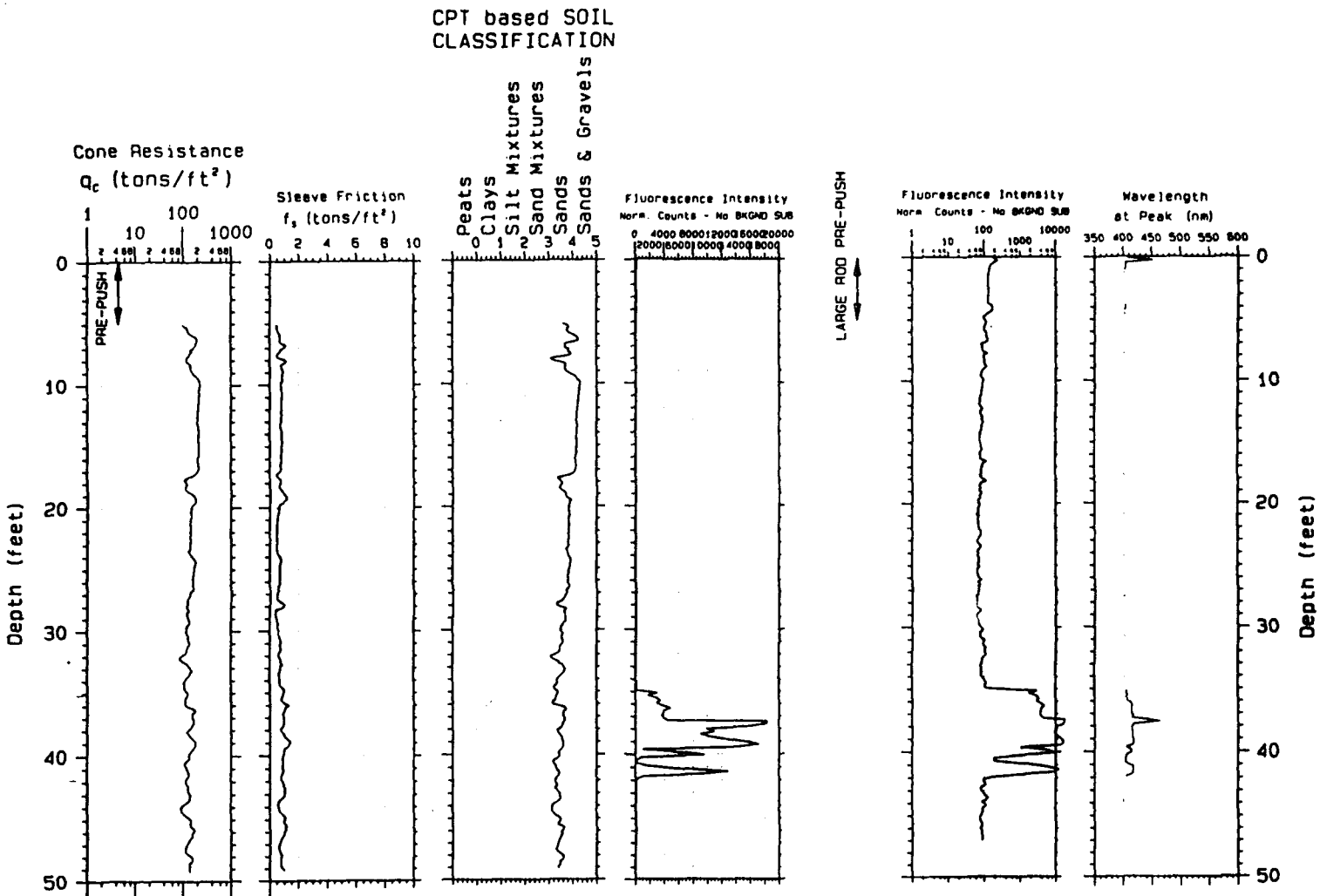
CPT: 62PTR6NF

Project: Plattsburg AFB

STATE COORDINATES:

EASTING (ft.)	NORTHING (ft.)	ELEVATION (ft.)
-1	-1	0

Probe date 05-19-1994



CPT: 64PTR2NF

Project: Plattsburg AFB

STATE COORDINATES:

EASTING (ft.)	NORTHING (ft.)	ELEVATION (ft.)
-1	-1	0

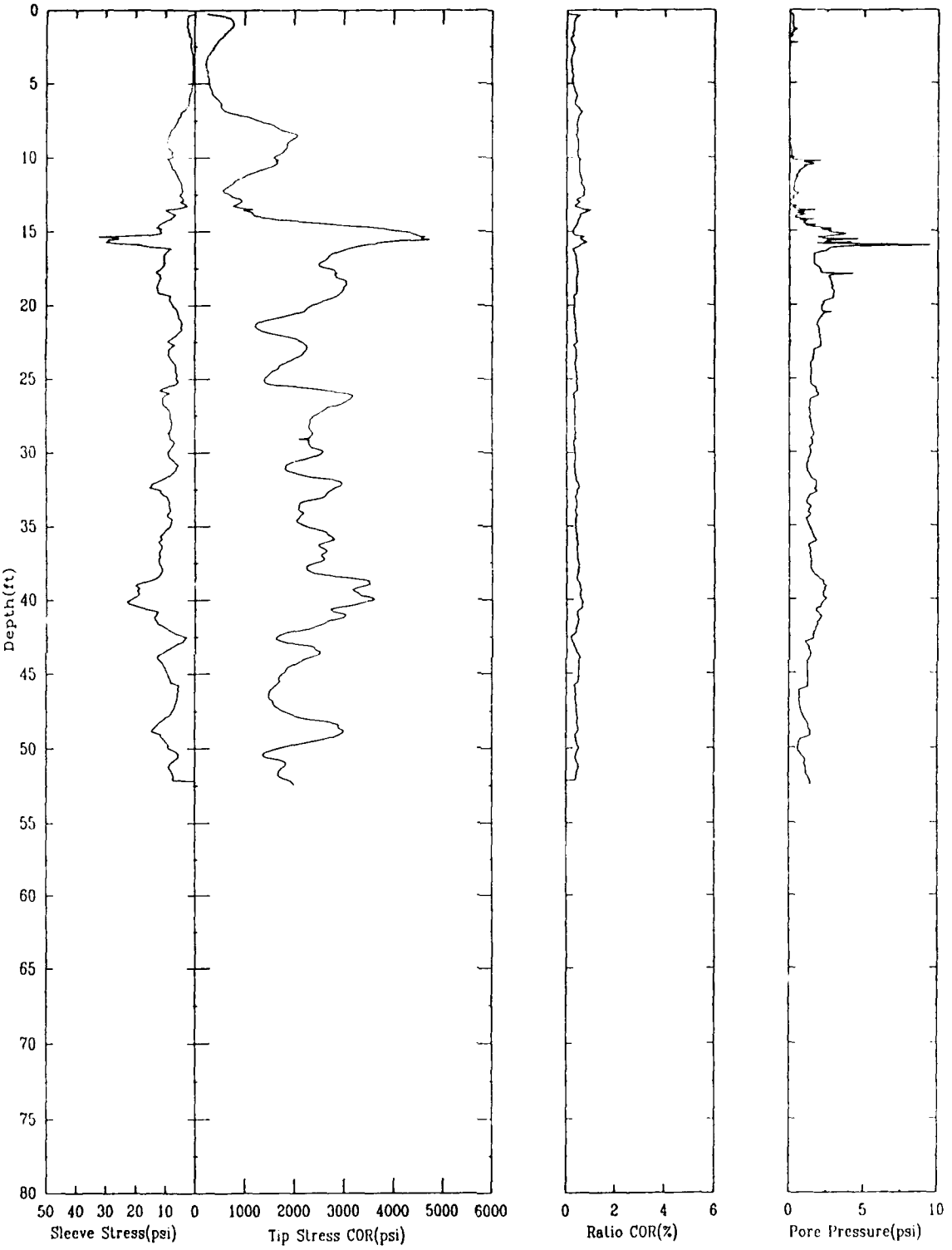
Probe date 05-20-1994

CONE PENETROMETER LOGS

(1993)

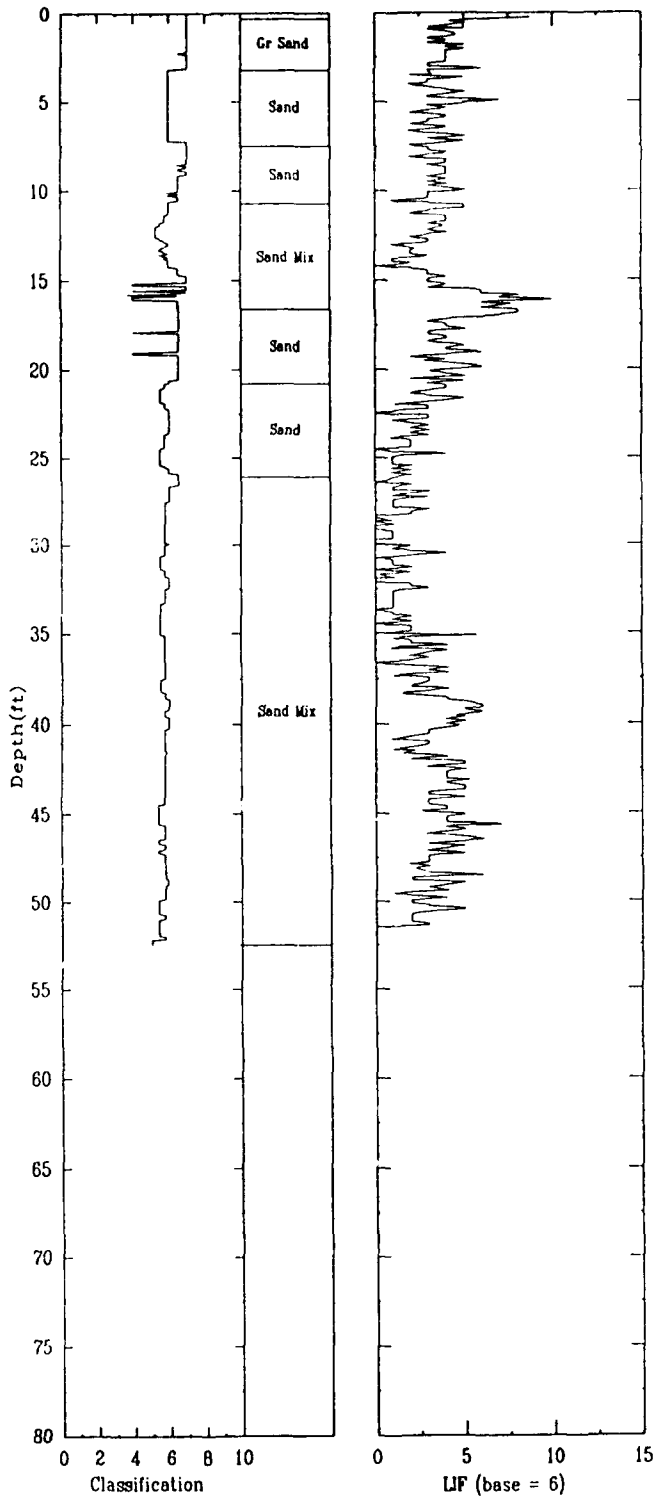
84A-LIF APPLIED RESEARCH ASSOCIATES, INC. 11/30/93

MW-02-026 AND 027 CLEAN ,BACKGROUND SITE



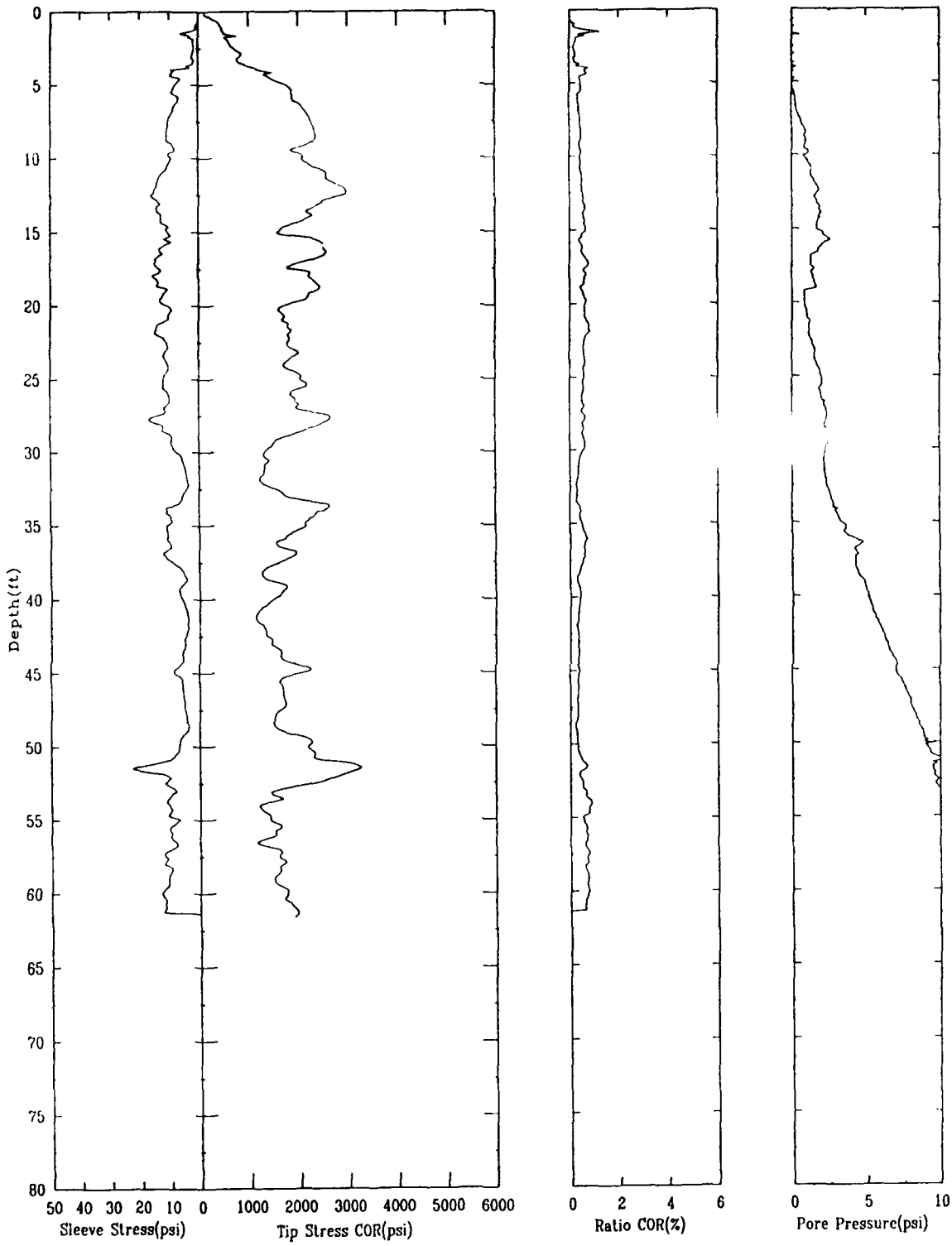
84A-LIF APPLIED RESEARCH ASSOCIATES, INC. 11/30/93

MW-02-026 AND 027 CLEAN ,BACKGROUND SITE



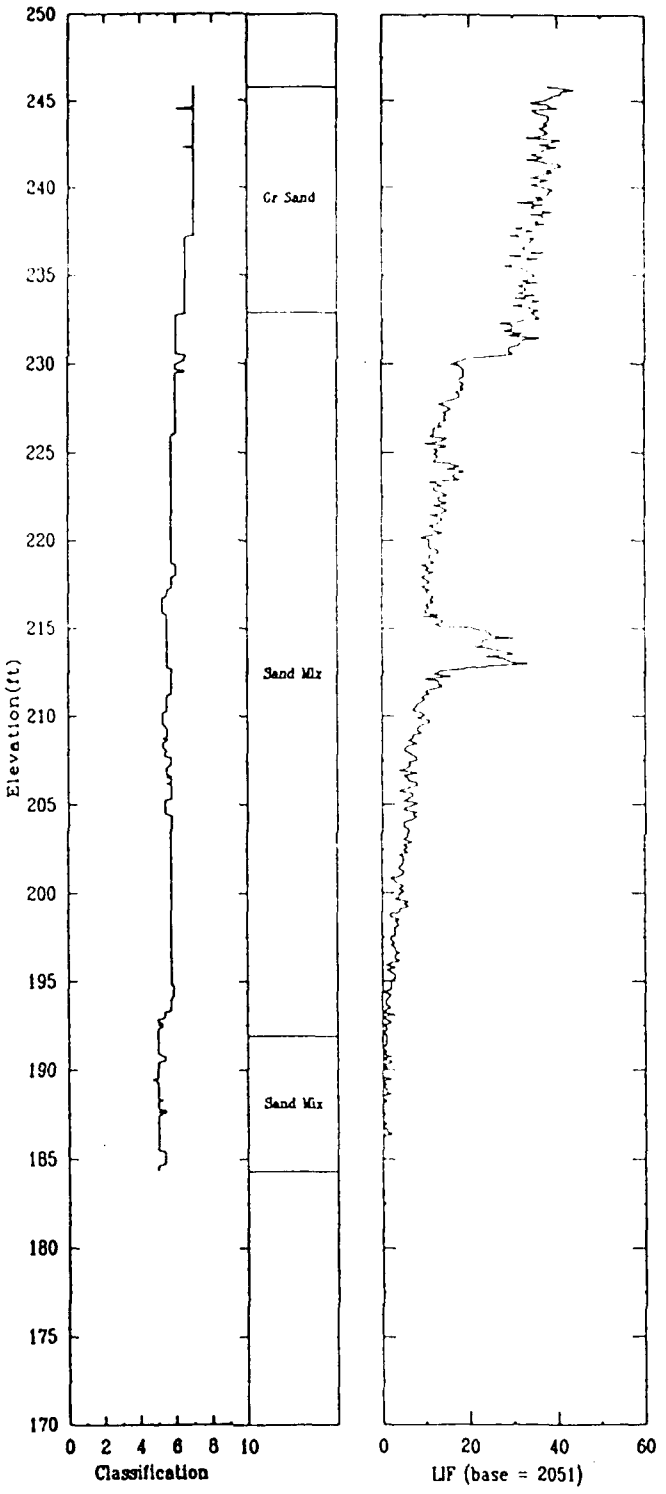
84B-LIF APPLIED RESEARCH ASSOCIATES, INC. 12/03/93

MW-02-006 AND 007



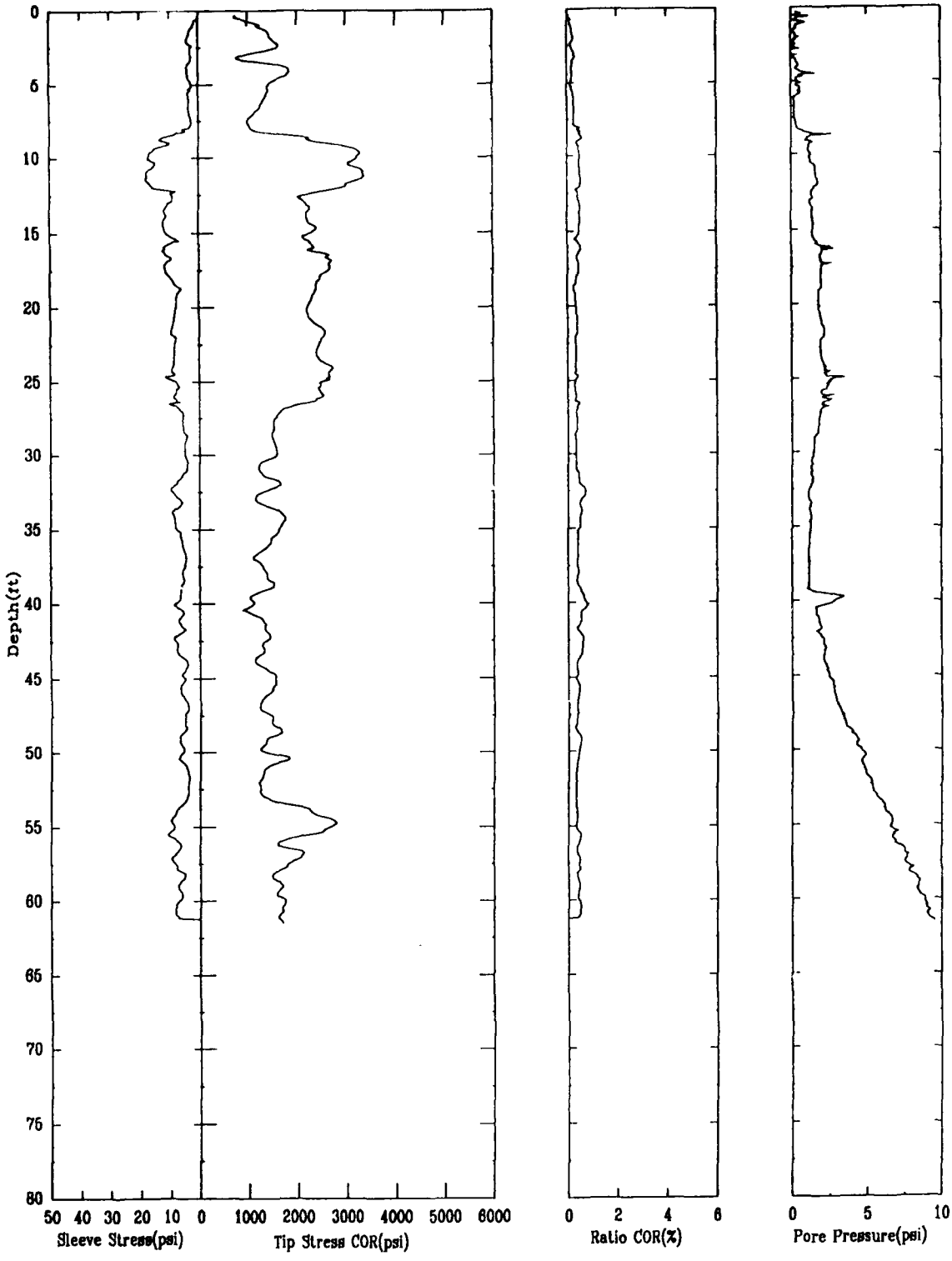
84B-LIF APPLIED RESEARCH ASSOCIATES, INC. 12/03/93

North 1700360 East 722267 Elevation 246



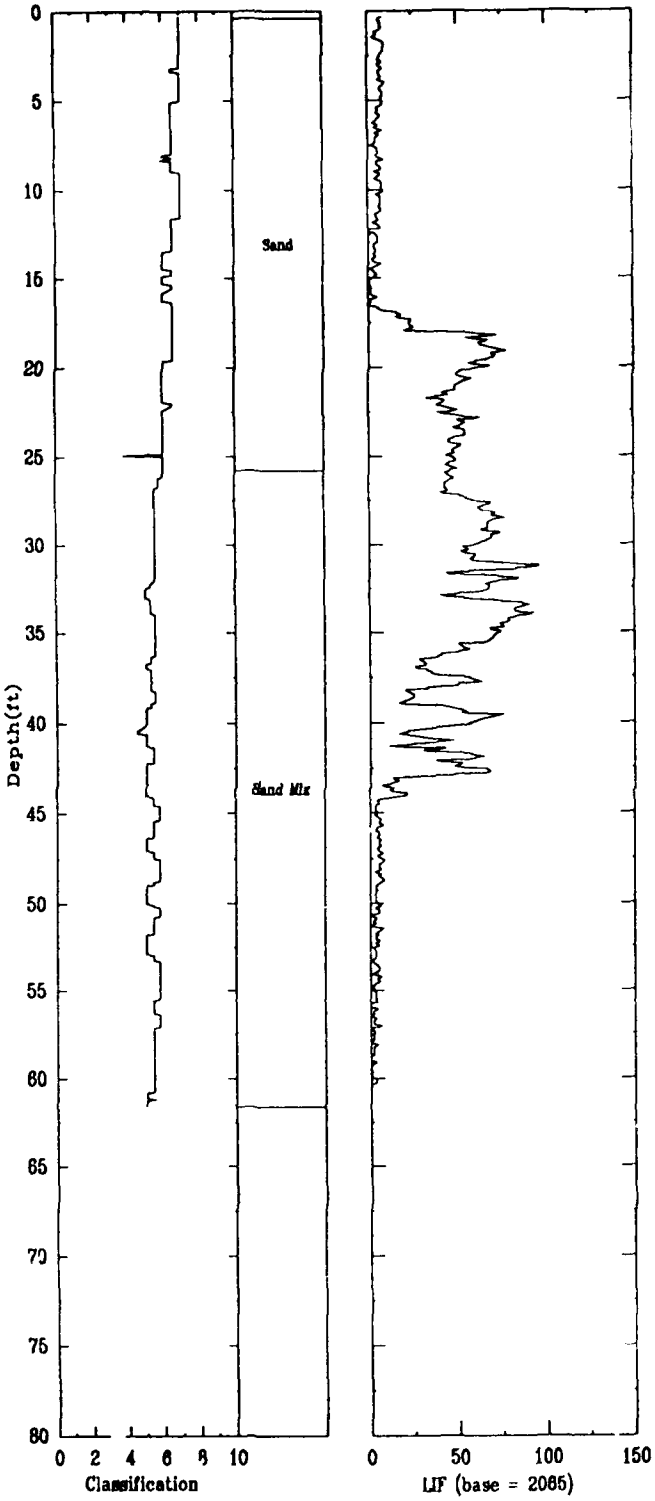
84D-LIF APPLIED RESEARCH ASSOCIATES, INC. 12/04/93

ADJACENT TO MW-02-008



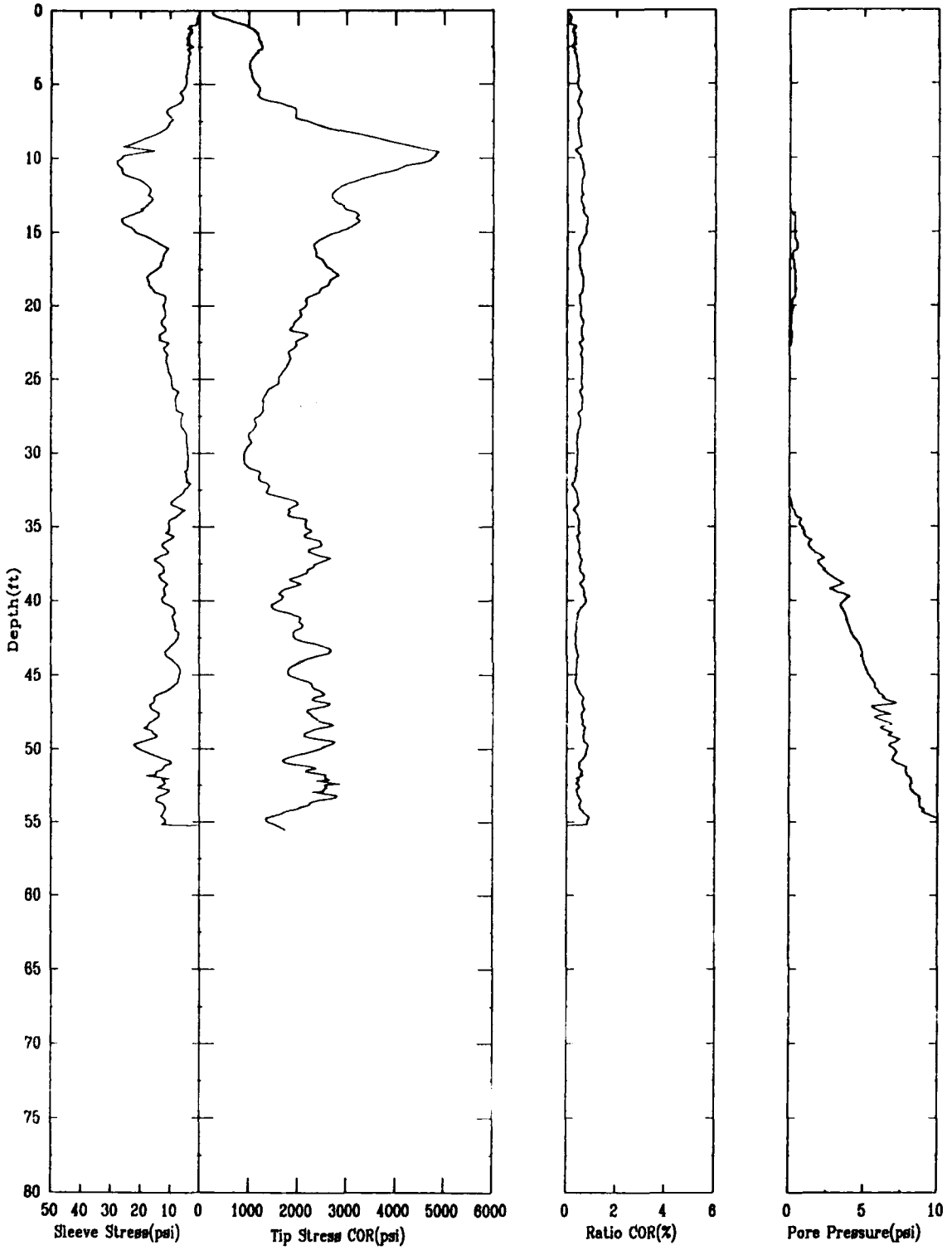
84D-LIF APPLIED RESEARCH ASSOCIATES, INC. 12/04/93

ADJACENT TO MW-02-008



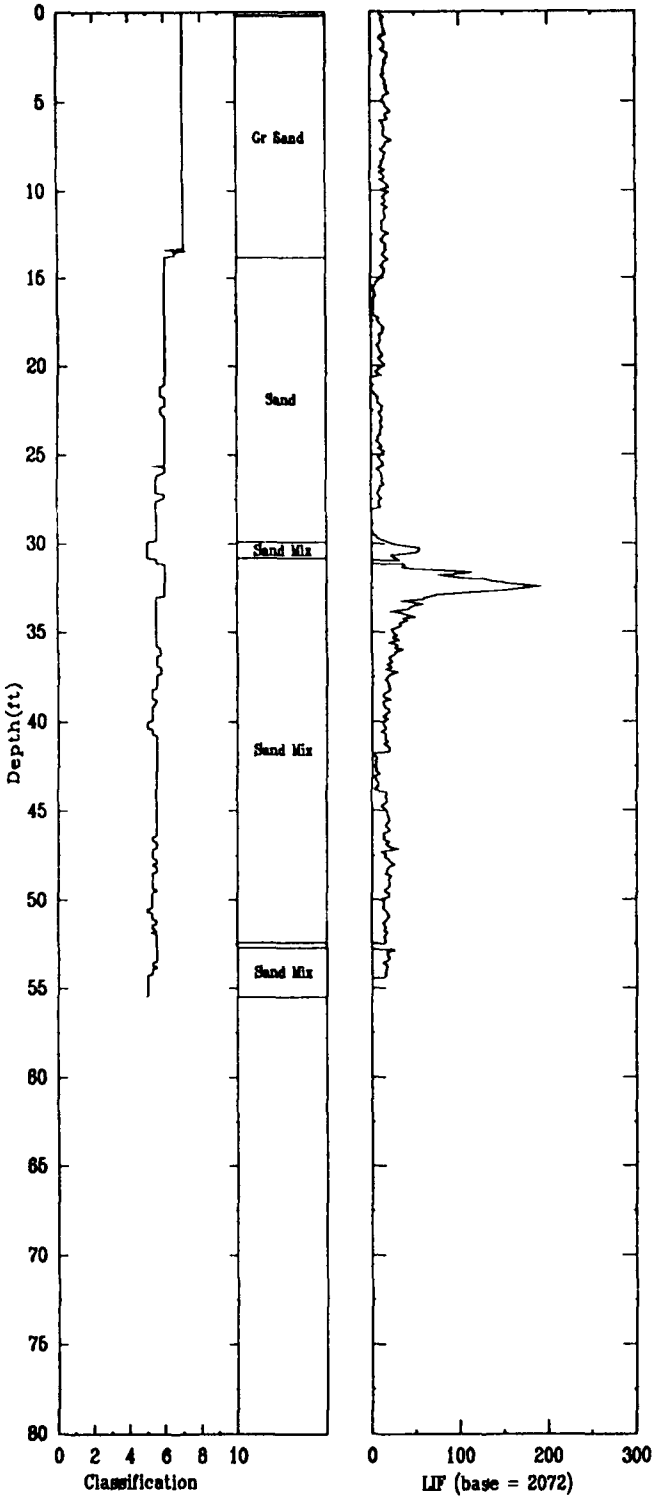
84F-LIF APPLIED RESEARCH ASSOCIATES, INC. 12/03/93

MIDWAY 84B LIF 2 AND 84E P,R,G



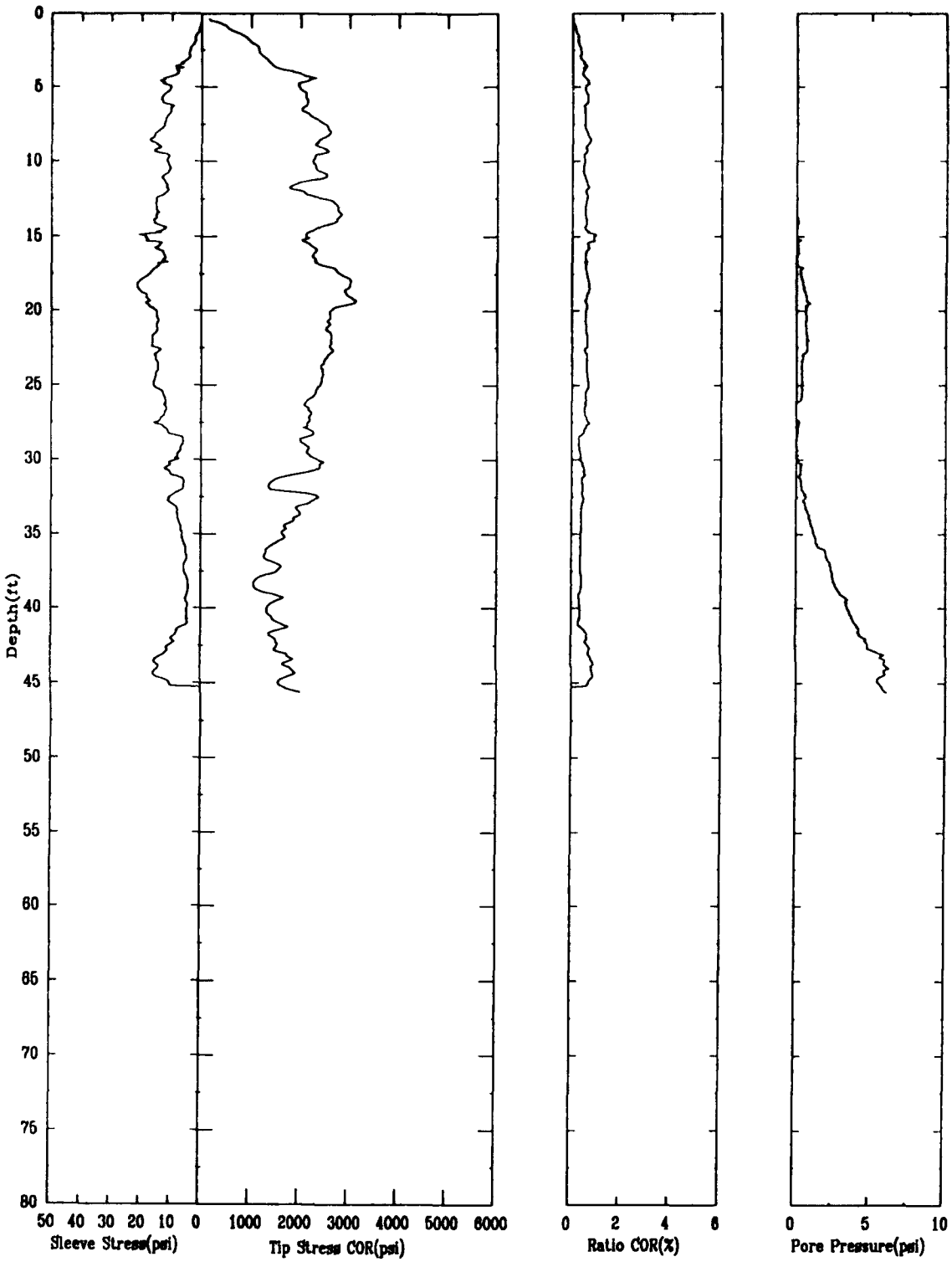
84F-LIF APPLIED RESEARCH ASSOCIATES, INC. 12/03/93

MIDWAY 84B LIF 2 AND 84E P,R,G



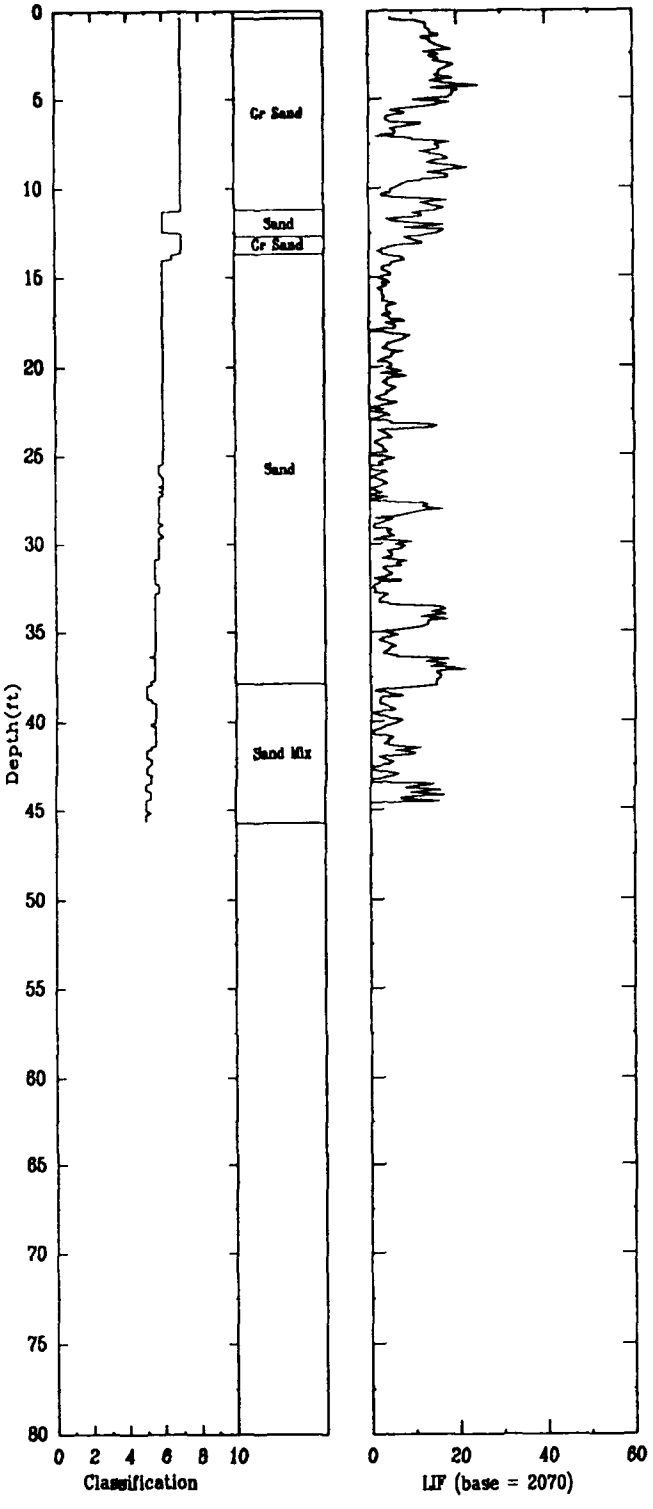
84G-LIF APPLIED RESEARCH ASSOCIATES, INC. 12/03/93

NEAR E



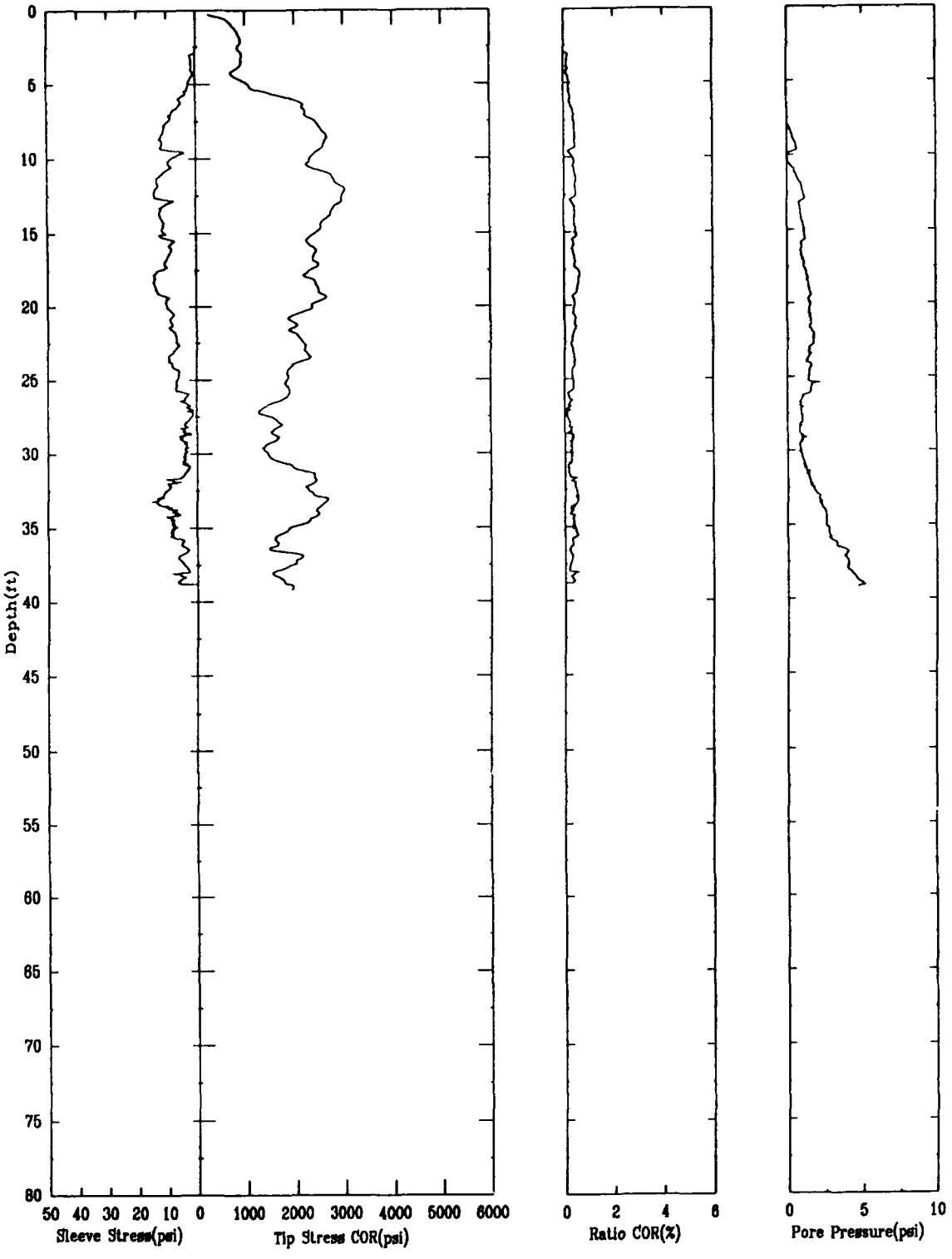
84G-LIF APPLIED RESEARCH ASSOCIATES, INC. 12/03/93

NEAR E



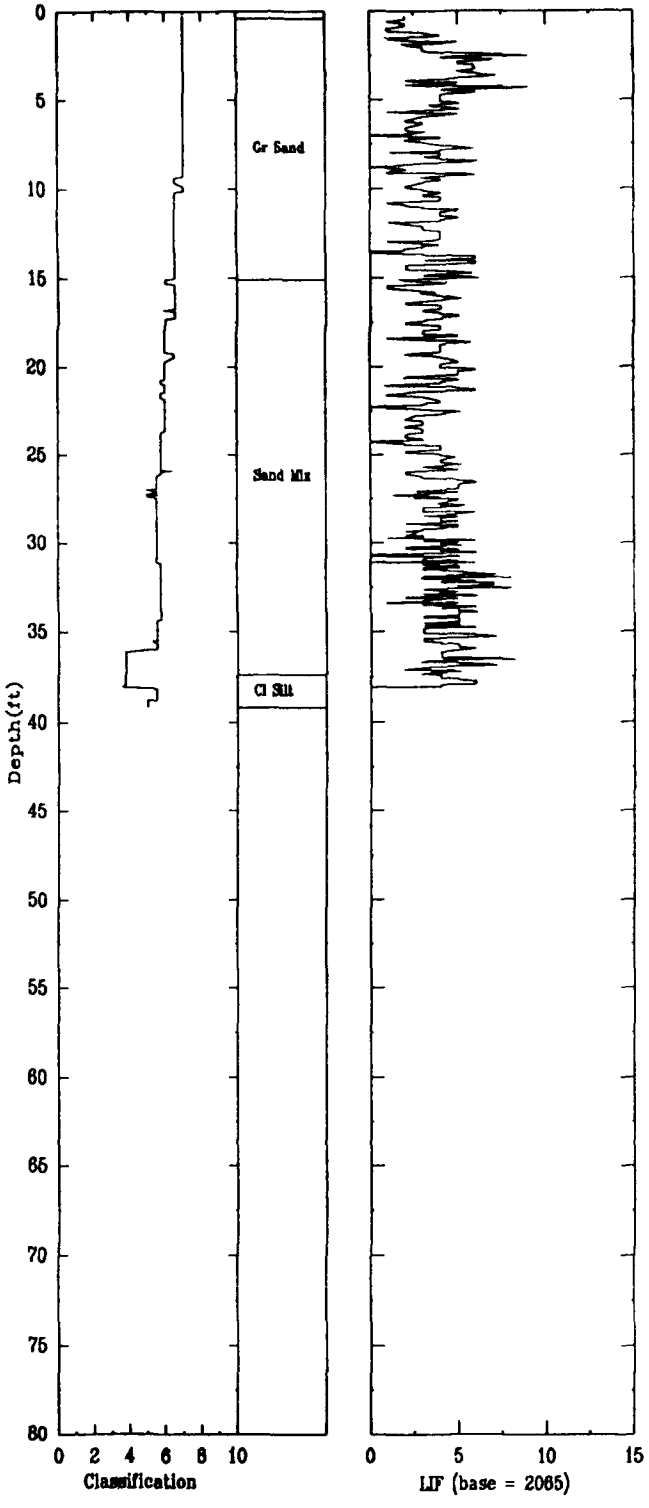
84H-LIF APPLIED RESEARCH ASSOCIATES, INC. 12/04/93

ADJACENT SOIL PILES ON SLAB,SE CORNER TOE



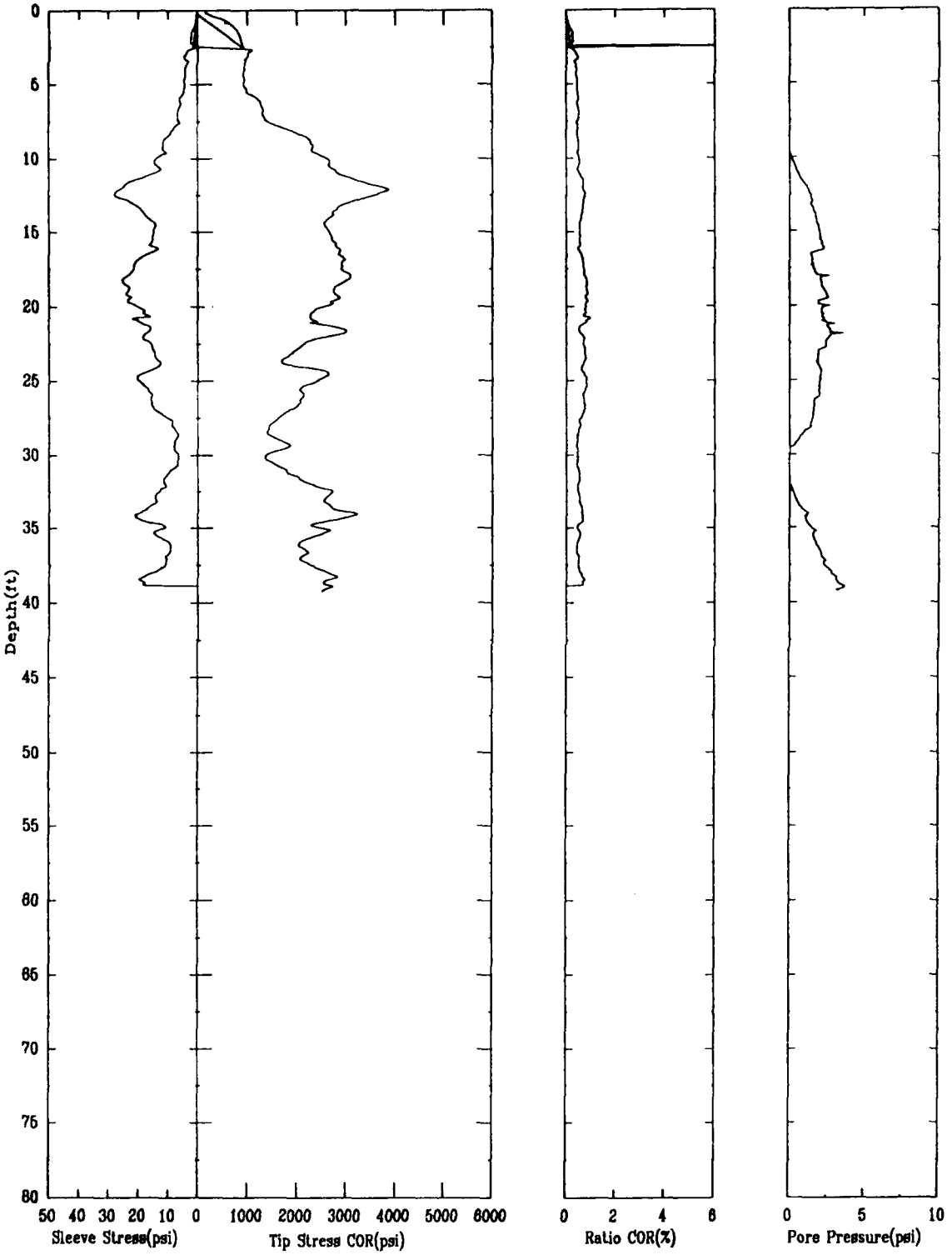
84H-LIF APPLIED RESEARCH ASSOCIATES, INC. 12/04/93

ADJACENT SOIL PILES ON SLAB,SE CORNER TOE



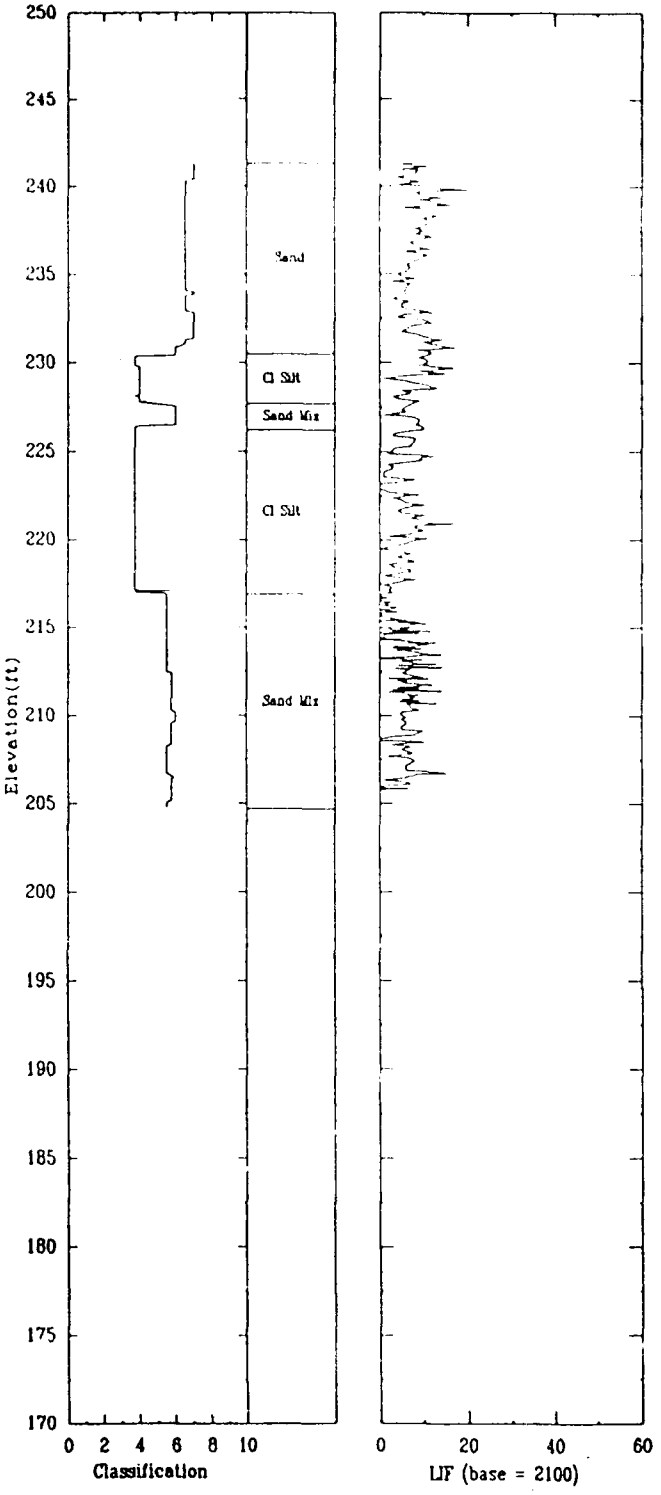
841-LIF APPLIED RESEARCH ASSOCIATES, INC. 12/04/93

MIDWAY 84F AND 84H ON NE -SW TRANSECT



841-LIF APPLIED RESEARCH ASSOCIATES, INC. 12/04/93

North 1700240 East 722411 Elevation 244

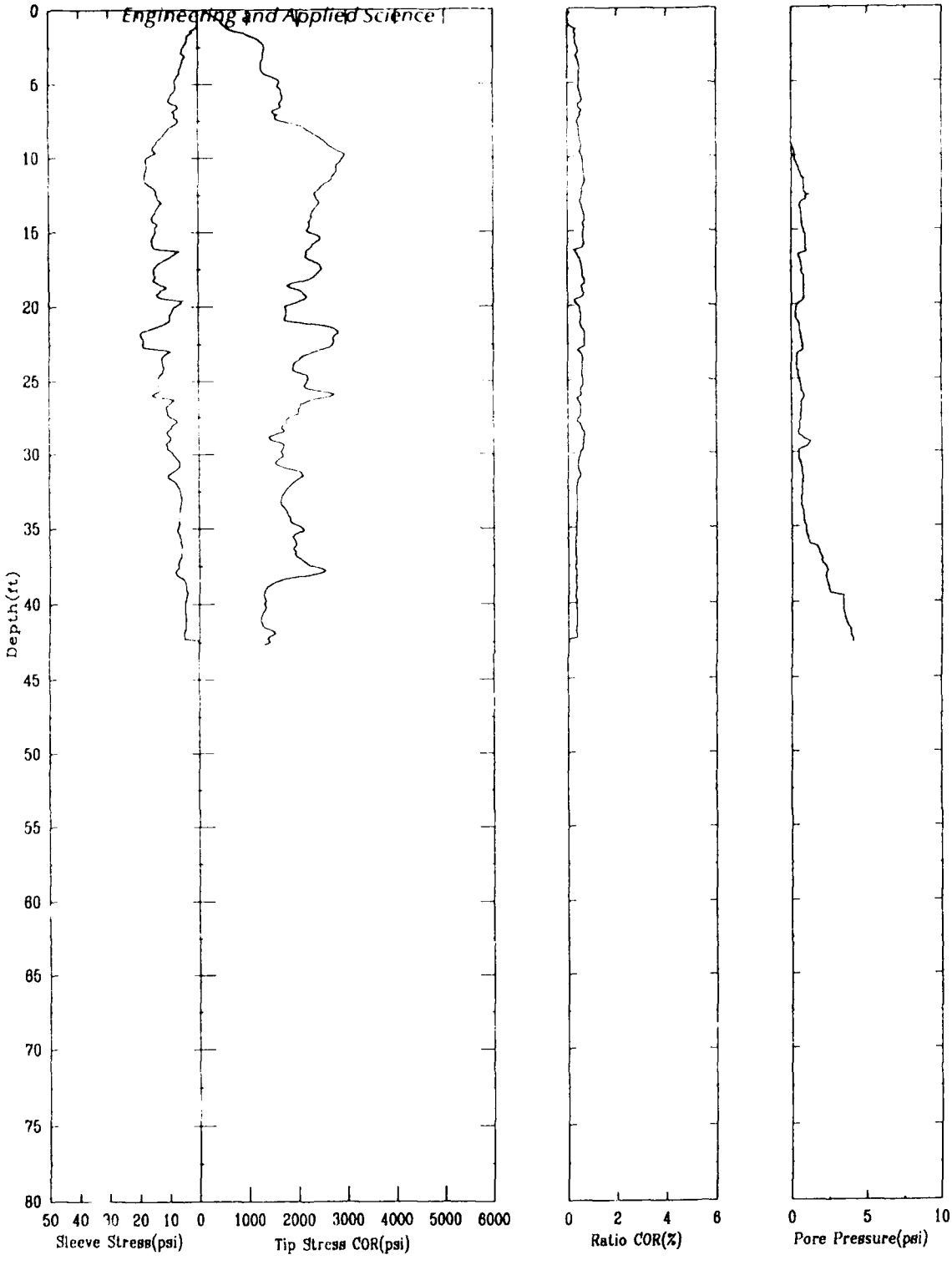


APPLIED RESEARCH ASSOCIATES, INC.

Engineering and Applied Science

APPLIED RESEARCH ASSOCIATES, INC. 12/04/93

SURVEY 84F AND 84H ON NE - SW TRANSECT

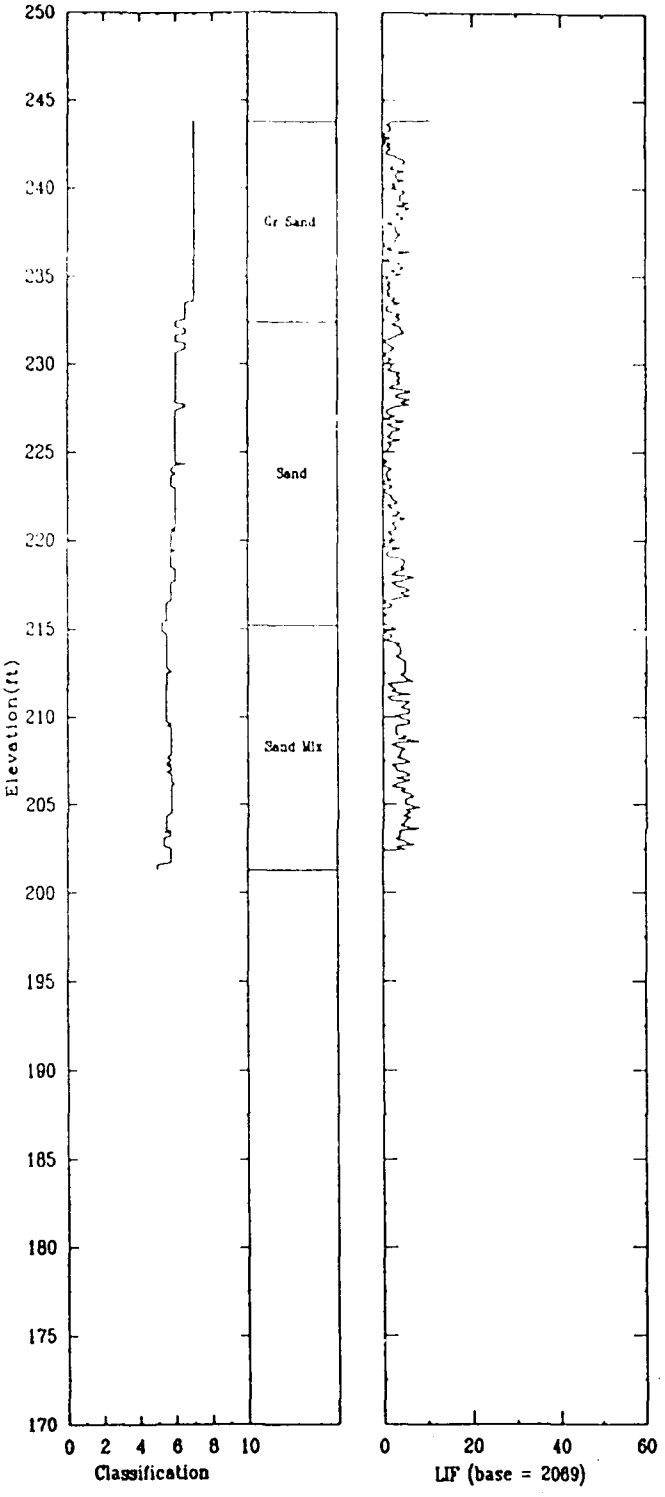


WATERMAN ROAD RR1 ■ SOUTH ROYALTON, VT 05068

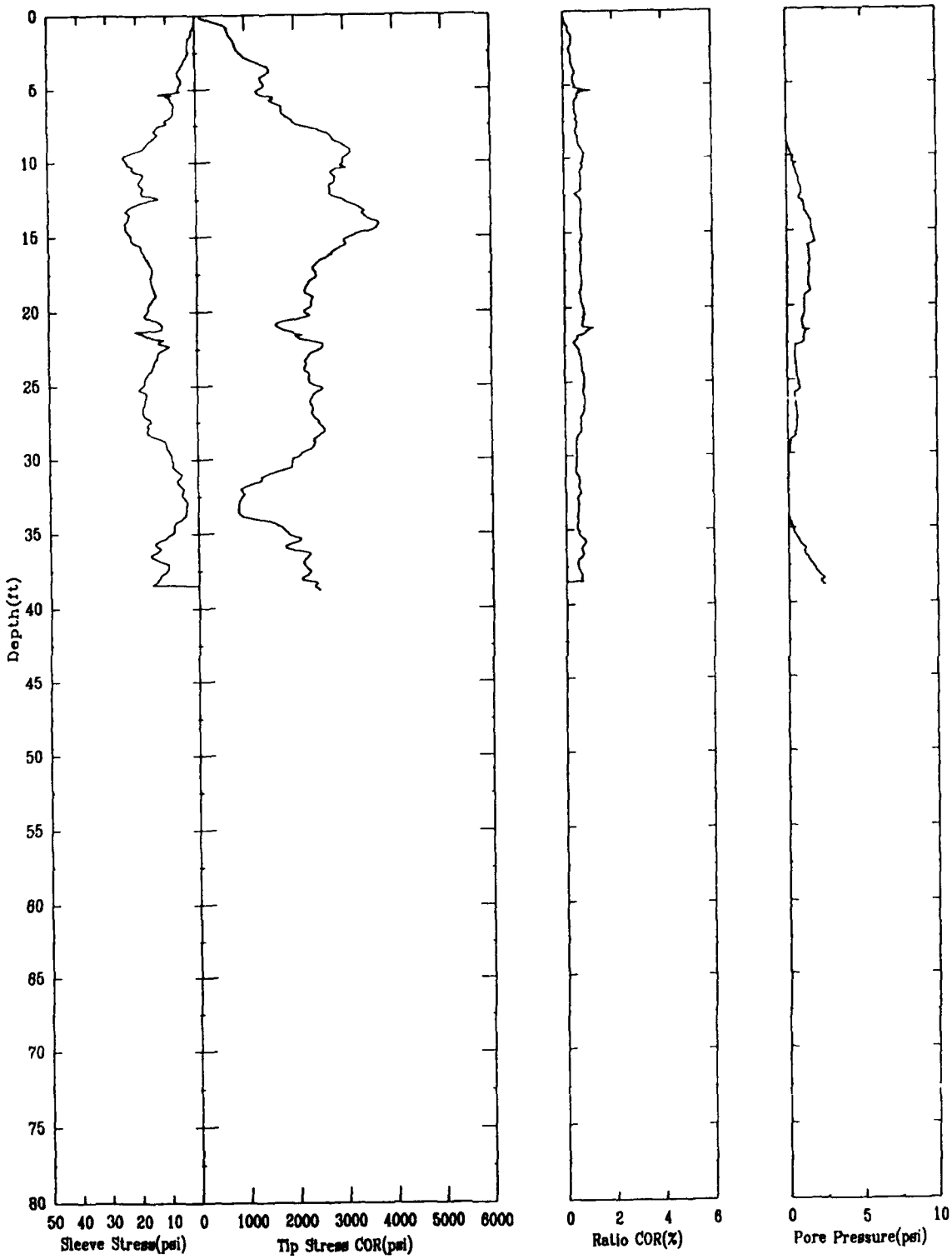
(802) 763-8348 ■ FAX (802) 763-8783

84J-LIF APPLIED RESEARCH ASSOCIATES, INC. 12/04/93

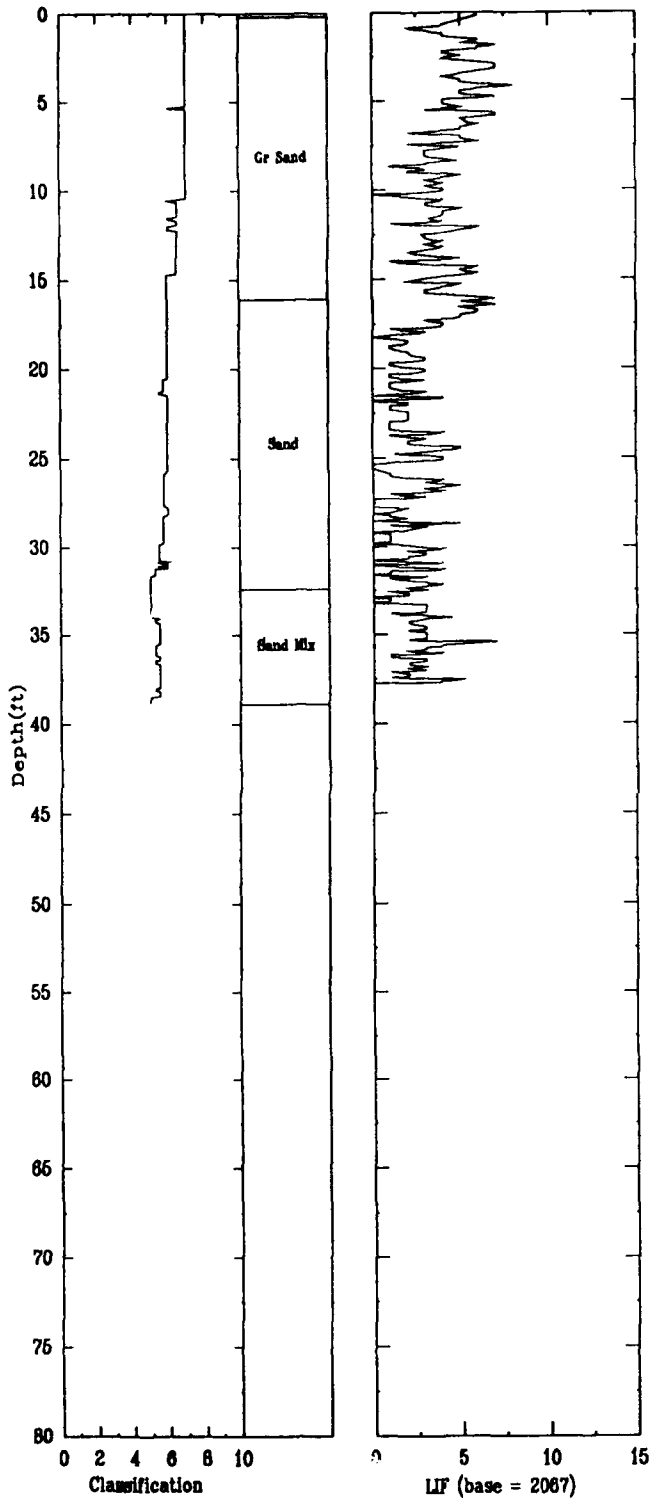
North 1700450 East 722471 Elevation 244



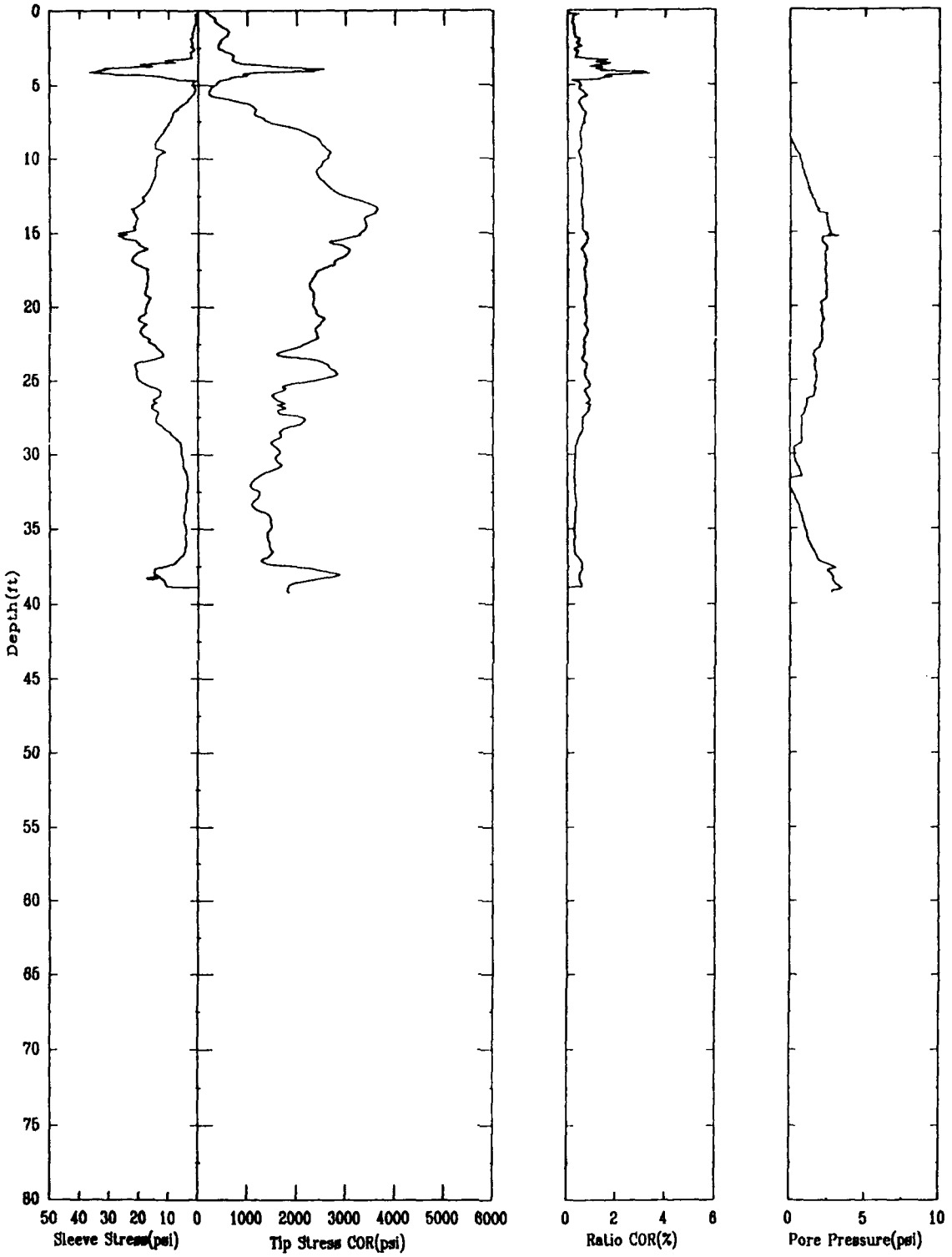
84K-LIF


Depth(ft)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
50 40 30 20 10 0
Sleeve Stress(psi)
0 1000 2000 3000 4000 5000 6000
Tip Stress COR(psi)
0 2 4 6
Ratio COR(%)
0 5 10
Pore Pressure(psi)

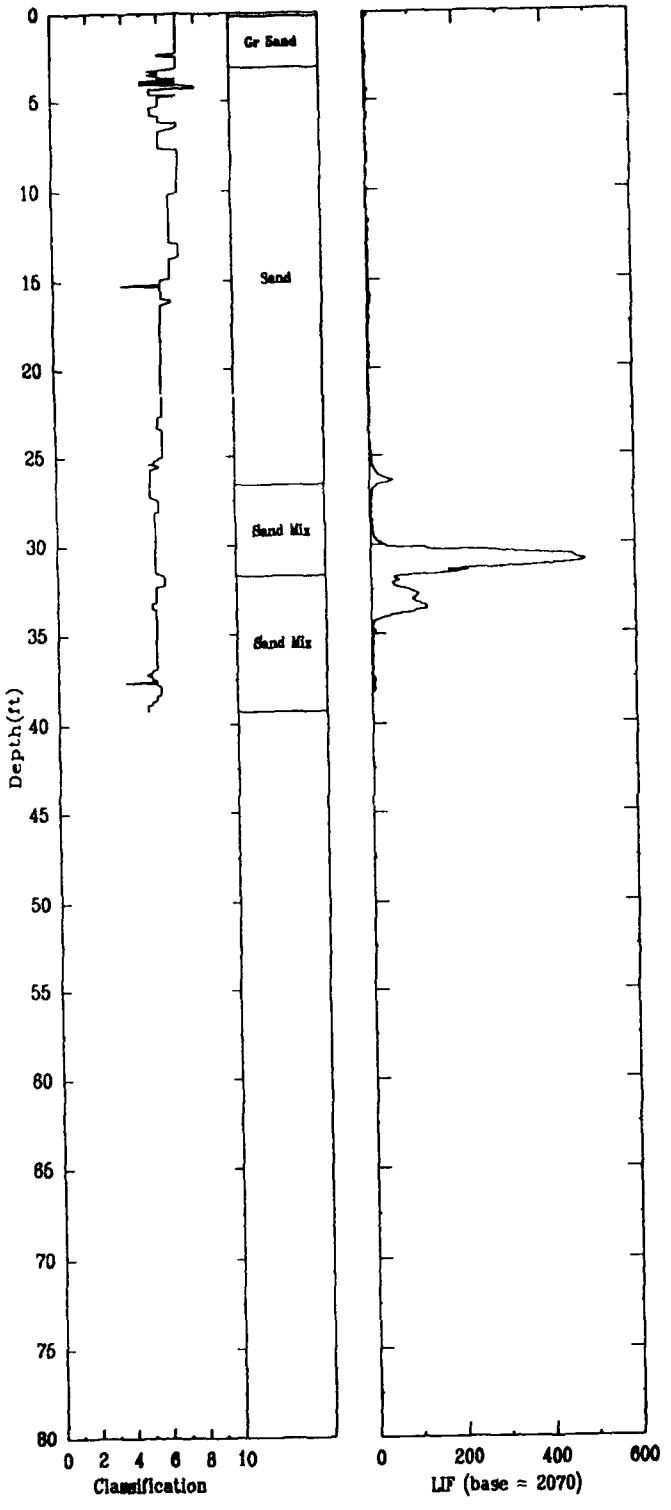
84K-LIF


Gr Sand
Sand
Sand Mix
Depth(ft)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
0 2 4 6 8 10
Classification
0 5 10 15
LIF (base = 2067)

84L-LIF


Depth(ft)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
50 40 30 20 10 0
Sleeve Stress(psi)
0 1000 2000 3000 4000 5000 6000
Tip Stress COR(psi)
0 2 4 6
Ratio COR(%)
0 5 10
Pore Pressure(psi)

84L-LIF


Gr Sand
Sand
Sand Mix
Sand Mix
Depth(ft)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
0 2 4 6 8 10
Classification
0 200 400 600
LIF (base = 2070)

CONE PENETROMETER LOGS

SOIL DESCRIPTIONS

(1993)

CONE PENETROMETER LOG

BORING NO.:	84A-LIF	CONTRACTOR:	ARA, INC.	DATE SPUD:	11/30/93
CLIENT:	AFCEE	RIG TYPE:	CPT-LIF	DATE CMPL.:	11/30/93
JOB NO.:	722450.04	DRLG METHOD:	CPT	ELEVATION:	G = 271
LOCATION:	PLATTSBURG AFB	BORING DIA.:	1.75"	TEMP:	30 deg. F
GEOLOGIST:	NS/LB	DRLG FLUID:	NONE	WEATHER:	PARTLY CLOUDY
COMENTS:	FIRE TRAINING AREA FT-002				

Elev (ft)	Depth (ft)	Pro-file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
268'	1		SG	Gravelly SAND			NOT MEASURED	NOT MEASURED				
	5		SP	Well sorted SAND								
260'	10		SM	Silty SAND								
254'	15		SP	Well sorted SAND								
	20											
245'	25		SM	Silty SAND								
	30											
	35											

bgs – Below Ground Surface
GS – Ground Surface
TOC – Top of Casing
NS – Not Sampled
SAA – Same As Above

SAMPLE TYPE
D – DRIVE
C – CORE
G – GRAB

D Core recovery
Core lost

▼ Water level drilled 53'

CONE PENETROMETER LOG

BORING NO.:	84A-LIF	CONTRACTOR:	ARA, INC.	DATE SPUD:	11/30/93
CLIENT:	AFCEE	RIG TYPE:	CPT-LIF	DATE CMPL.:	11/30/93
JOB NO.:	722450.04	DRLG METHOD:	CPT	ELEVATION:	GS = 271
LOCATION:	PLATTSBURG AFB	BORING DIA.:	1.75"	TEMP:	30 deg. F
GEOLOGIST:	NS/LB	DRLG FLUID:	NONE	WEATHER:	PARTLY CLOUDY
COMENTS:	FIRE TRAINING AREA FT-002				

Elev (ft)	Depth (ft)	Pro-file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	36		SM	Silty SAND					0			
268'												
	40								0			
							NOT MEASURED	NOT MEASURED				
	45								0			
									0			
	50											
254'									1.2			
				TD @ 53 feet Water Table @ 53'								
	55											
	60											
245'												
	65											
	70											

bgs – Below Ground Surface
GS – Ground Surface
TOC – Top of Casing
NS – Not Sampled
SAA – Same As Above

SAMPLE TYPE
D – DRIVE
C – CORE
G – GRAB

D Core recovery
Core lost

Water level drilled 53'

CONE PENETROMETER LOG

BORING NO.:	84B-LIF	CONTRACTOR:	ARA, INC.	DATE SPUD:	12/03/93
CLIENT:	AFCEE	RIG TYPE:	CPT-LIF	DATE CMPL.:	12/03/93
JOB NO.:	722450.04	DRLG METHOD:	CPT	ELEVATION:	G = 246
LOCATION:	PLATTSBURG AFB	BORING DIA.:	1.75"	TEMP:	30 deg. F
GEOLOGIST:	NS/LB	DRLG FLUID:	NONE	WEATHER:	PARTLY CLOUDY
COMENTS:	FIRE TRAINING AREA FT-002				

Elev (ft)	Depth (ft)	Pro-file	USCS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	1		SG	Gravel, SAND			NOT MEASURED	NOT MEASURED				
	5											
	10											
213'			SM	Silty SAND								
	15											
	20											
	25											
218'				Water Table @ 28'								
	30			CONTAMINANT present @ 31 ft bgs								
215'												
213'												
	35											

bgs – Below Ground Surface
GS – Ground Surface
TOC – Top of Casing
NS – Not Sampled
SAA – Same As Above

SAMPLE TYPE
D – DRIVE
C – CORE
G – GRAB

D Core recovery
Core lost

Water level drilled 28'

CONE PENETROMETER LOG

BORING NO.:	84B-LIF	CONTRACTOR:	ARA, INC.	DATE SPUD:	12/03/93
CLIENT:	AFCEE	RIG TYPE:	CPT-LIF	DATE CMPL.:	12/03/93
JOB NO.:	722450.04	DRLG METHOD:	CPT	ELEVATION:	GS = 246
LOCATION:	PLATTSBURG AFB	BORING DIA.:	1.75"	TEMP:	30 deg. F
GEOLOGIST:	NS/LB	DRLG FLUID:	NONE	WEATHER:	PARTLY CLOUDY
COMENTS:	FIRE TRAINING AREA FT-002				

Elev (ft)	Depth (ft)	Pro-file	US CS	Geologic Description	Sample Nc.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	36			Silty SAND								
			SM						0			
	40								0			
							N	N				
							O	O	0			
				Clean sand @ 43 ft bgs			T	T				
	45								0			
							M	M				
							E	E				
	50						A	A	1.2			
							S	S				
							U	U				
	55						R	R				
							E	E				
							D	D				
	60											
185'				TD @ 61 feet								
	65											
	70											

bgs – Below Ground Surface
GS – Ground Surface
TOC – Top of Casing
NS – Not Sampled
SAA – Same As Above

SAMPLE TYPE
D – DRIVE
C – CORE
G – GRAB

D Core recovery
Core lost

Water level drilled 28'

CONE PENETROMETER LOG

BORING NO.:	84D-LIF	CONTRACTOR:	ARA, INC.	DATE SPUD:	12/04/93
CLIENT:	AFCEE	RIG TYPE:	CPT-LIF	DATE CMPL.:	12/04/93
JOB NO.:	722450.04	DRLG METHOD:	CPT	ELEVATION:	G = 258
LOCATION:	PLATTSBURG AFB	BORING DIA.:	1.75"	TEMP:	30 deg. F
GEOLOGIST:	NS/LB	DRLG FLUID:	NONE	WEATHER:	PARTLY CLOUDY
COMENTS:	FIRE TRAINING AREA FT-002				

Elev (ft)	Depth (ft)	Pro-file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	1			Well sorted SAND								
	5		SP				NOT MEASURED	NOT MEASURED	0			
	10								3			
	15								2			
241'				CONTAMINANT present @ 17' bgs								
	20											
	25											
232'				Silty SAND								
	30		SM									
	35											

bgs – Below Ground Surface
GS – Ground Surface
TOC – Top of Casing
NS – Not Sampled
SAA – Same As Above

SAMPLE TYPE
D – DRIVE
C – CORE
G – GRAB

D Core recovery
Core lost

▼ Water level drilled 39'

CONE PENETROMETER LOG

BORING NO.:	84D-LIF	CONTRACTOR:	ARA, INC.	DATE SPUD:	12/04/93
CLIENT:	AFCEE	RIG TYPE:	CPT-LIF	DATE CMPL.:	12/04/93
JOB NO.:	722450.04	DRLG METHOD:	CPT	ELEVATION:	GS = 258
LOCATION:	PLATTSBURG AFB	BORING DIA.:	1.75"	TEMP:	30 deg. F
GEOLOGIST:	NS/LB	DRLG FLUID:	NONE	WEATHER:	PARTLY CLOUDY
COMENTS:	FIRE TRAINING AREA FT-002				

Elev (ft)	Depth (ft)	Pro-file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	36			Silty SAND								
			SM									
				▼ Water Table @ 39'								
	40						NOT MEASURED	NOT MEASURED				
213'	45			Clean soil @ 45' bgs					5			
	50											
	55											
	60											
196'				TD @ 62 feet								
	65											
	70											

bgs – Below Ground Surface
GS – Ground Surface
TOC – Top of Casing
NS – Not Sampled
SAA – Same As Above

SAMPLE TYPE
D – DRIVE
C – CORE
G – GRAB

D Core recovery
Core lost

▼ Water level drilled 39'

CONE PENETROMETER LOG

BORING NO.:	84F-LIF	CONTRACTOR:	ARA, INC.	DATE SPUD:	12/03/93
CLIENT:	AFCEE	RIG TYPE:	CPT-LIF	DATE CMPL.:	12/03/93
JOB NO.:	722450.04	DRLG METHOD:	CPT	ELEVATION:	G = 244
LOCATION:	PLATTSBURG AFB	BORING DIA.:	1.75"	TEMP:	30 deg. F
GEOLOGIST:	NS/LB	DRLG FLUID:	NONE	WEATHER:	PARTLY CLOUDY
COMENTS:	FIRE TRAINING AREA FT-002				

Elev (ft)	Depth (ft)	Pro-file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	1			Gravelly SAND								
	5		SG				NOT MEASURED	NOT MEASURED				
	10											
230'												
	15			Well sorted SAND								
	20		SP									
	25								2			
									1			
									3			
215'									1			
	30			CONTAMINANT present @29' bgs					44			
212'			SM	Silty SAND					208			
				Water Table @ 32'					408			
210'									236			
	35			Clean soil @ 34' bgs								

bgs – Below Ground Surface
GS – Ground Surface
TOC – Top of Casing
NS – Not Sampled
SAA – Same As Above

SAMPLE TYPE
D – DRIVE
C – CORE
G – GRAB

D Core recovery

Core lost

Water level drilled 32'

CONE PENETROMETER LOG

BORING NO.:	84F-LIF	CONTRACTOR:	ARA, INC.	DATE SPUD:	12/03/93
CLIENT:	AFCEE	RIG TYPE:	CPT-LIF	DATE CMPL.:	12/03/93
JOB NO.:	722450.04	DRLG METHOD:	CPT	ELEVATION:	GS = 244
LOCATION:	PLATTSBURG AFB	BORING DIA.:	1.75"	TEMP:	30 deg. F
GEOLOGIST:	NS/LB	DRLG FLUID:	NONE	WEATHER:	PARTLY CLOUDY
COMENTS:	FIRE TRAINING AREA FT-002				

Elev (ft)	Depth (ft)	Pro-file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	36			Silty SAND								
	40		SM				NOT MEASURED	NOT MEASURED				
	45											
	50											
188'	55			TD @ 56 feet								
	60											
	65											
	70											

bgs – Below Ground Surface
GS – Ground Surface
TOC – Top of Casing
NS – Not Sampled
SAA – Same As Above

SAMPLE TYPE
D – DRIVE
C – CORE
G – GRAB

D Core recovery
Core lost

▼ Water level drilled 32'

CONE PENETROMETER LOG

BORING NO.:	84G-LIF	CONTRACTOR:	ARA, INC.	DATE SPUD:	12/03/93
CLIENT:	AFCEE	RIG TYPE:	CPT-LIF	DATE CMPL.:	12/03/93
JOB NO.:	722450.04	DRLG METHOD:	CPT	ELEVATION:	G = 242
LOCATION:	PLATTSBURG AFB	BORING DIA.:	1.75"	TEMP:	30 deg. F
GEOLOGIST:	NS/LB	DRLG FLUID:	NONE	WEATHER:	PARTLY CLOUDY
COMENTS:	FIRE TRAINING AREA FT-002				

Elev (ft)	Depth (ft)	Pro-file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	1		SG	Gravelly SAND			NOT MEASURED	NOT MEASURED				
	5											
	10											
231'			SP	Well sorted SAND								
230'			SG	Gravelly SAND								
229'			SP	Well sorted SAND								
	15											
	20											
	25											
	30											
209'				Water Table @ 33'								
	35											

bgs – Below Ground Surface
GS – Ground Surface
TOC – Top of Casing
NS – Not Sampled
SAA – Same As Above

SAMPLE TYPE
D – DRIVE
C – CORE
G – GRAB

D Core recovery
Core lost

▼ Water level drilled 33'

CONE PENETROMETER LOG

BORING NO.:	84G-LIF	CONTRACTOR:	ARA, INC.	DATE SPUD:	12/03/93
CLIENT:	AFCEE	RIG TYPE:	CPT-LIF	DATE CMPL.:	12/03/93
JOB NO.:	722450.04	DRLG METHOD:	CPT	ELEVATION:	GS = 242
LOCATION:	PLATTSBURG AFB	BORING DIA.:	1.75"	TEMP:	30 deg. F
GEOLOGIST:	NS/LB	DRLG FLUID:	NONE	WEATHER:	PARTLY CLOUDY
COMENTS:	FIRE TRAINING AREA FT-002				

Elev (ft)	Depth (ft)	Pro-file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	36		SP	Well sorted SAND								
			SM	Silty SAND								
	40						NOT	NOT				
	45											
				TD @ 46 feet			MEASURED	MEASURED				
254'	50											
	55											
245'	60											
	65											
	70											

bgs - Below Ground Surface
GS - Ground Surface
TOC - Top of Casing
NS - Not Sampled
SAA - Same As Above

SAMPLE TYPE
D - DRIVE
C - CORE
G - GRAB

D Core recovery
Core lost

▼ Water level drilled 33'

CONE PENETROMETER LOG

BORING NO.:	84H-LIF	CONTRACTOR:	ARA, INC.	DATE SPUD:	12/04/93
CLIENT:	AFCEE	RIG TYPE:	CPT-LIF	DATE CMPL.:	12/04/93
JOB NO.:	722450.04	DRLG METHOD:	CPT	ELEVATION:	GS = 242
LOCATION:	PLATTSBURG AFB	BORING DIA.:	1.75"	TEMP:	30 deg. F
GEOLOGIST:	LB	DRLG FLUID:	NONE	WEATHER:	PARTLY CLOUDY
COMENTS:	TRAINING AREA FT-002				

Elev (ft)	Depth (ft)	Profile	USCS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	1			Gravelly SAND								
	5		SG				NOT MEASURED	NOT MEASURED				
	10											
227'	15			Well sorted SAND								
	20		SP									
	25											
214'				Water Table @ 28'								
	30											
207'	35											

bgs - Below Ground Surface
GS - Ground Surface
TOC - Top of Casing
NS - Not Sampled
SAA - Same As Above

SAMPLE TYPE
D - DRIVE
C - CORE
G - GRAB

D Core recovery
Core lost

▼ Water level drilled 28'

CONE PENETROMETER LOG

BORING NO.:	84H-LIF	CONTRACTOR:	ARA, INC.	DATE SPUD:	12/04/93
CLIENT:	AFCEE	RIG TYPE:	CPT-LIF	DATE CMPL.:	12/04/93
JOB NO.:	722450.04	DRLG METHOD:	CPT	ELEVATION:	GS = 242
LOCATION:	PLATTSBURG AFB	BORING DIA.:	1.75"	TEMP:	30 deg. F
GEOLOGIST:	NS/LB	DRLG FLUID:	NONE	WEATHER:	PARTLY CLOUDY
COMENTS:	FIRE TRAINING AREA FT-002				

Elev (ft)	Depth (ft)	Pro-file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	36		SP	Well sorted SAND								
203'												
	40			TD ● 39 feet bgs			NOT MEASURED	NOT MEASURED				
	45											
	50											
	55											
	60											
	65											
	70											

bgs – Below Ground Surface
GS – Ground Surface
TOC – Top of Casing
NS – Not Sampled
SAA – Same As Above

SAMPLE TYPE
D – DRIVE
C – CORE
G – GRAB

D Core recovery
Core lost

▼ Water level drilled 28'

CONE PENETROMETER LOG

BORING NO.:	841-LIF	CONTRACTOR:	ARA, INC.	DATE SPUD:	12/04/93
CLIENT:	AFCEE	RIG TYPE:	CPT-LIF	DATE CMPL.:	12/04/93
JOB NO.:	722450.04	DRLG METHOD:	CPT	ELEVATION:	G = 244
LOCATION:	PLATTSBURG AFB	BORING DIA.:	1.75"	TEMP:	30 deg. F
GEOLOGIST:	NS/LB	DRLG FLUID:	NONE	WEATHER:	PARTLY CLOUDY
COMENTS:	FIRE TRAINING AREA FT-002				

Elev (ft)	Depth (ft)	Profile	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	1			Well sorted SAND			NOT MEASURED	NOT MEASURED				
	5											
	10		SP									
	15											
	20											
221'				Silty SAND								
	25											
215'			SM									
	30			Water Table @ 29'								
	35											

bgs – Below Ground Surface
GS – Ground Surface
TOC – Top of Casing
NS – Not Sampled
SAA – Same As Above

SAMPLE TYPE
D – DRIVE
C – CORE
G – GRAB

D Core recovery
Core lost

▼ Water level drilled 29'

CONE PENETROMETER LOG

BORING NO.:	841-LIF	CONTRACTOR:	ARA, INC.	DATE SPUD:	12/04/93
CLIENT:	AFCEE	RIG TYPE:	CPT-LIF	DATE CMPL.:	12/04/93
JOB NO.:	722450.04	DRLG METHOD:	CPT	ELEVATION:	GS = 244
LOCATION:	PLATTSBURG AFB	BORING DIA.:	1.75"	TEMP:	30 deg. F
GEOLOGIST:	NS/LB	DRLG FLUID:	NONE	WEATHER:	PARTLY CLOUDY
COMENTS:	FIRE TRAINING AREA FT-002				

Elev (ft)	Depth (ft)	Pro-file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	36		SM	Silty SAND								
229'	40			TD @ 40 feet			NOT MEASURED	NOT MEASURED				
	45											
254'	50											
	55											
245'	60											
	65											
	70											

bgs – Below Ground Surface
GS – Ground Surface
TOC – Top of Casing
NS – Not Sampled
SAA – Same As Above

SAMPLE TYPE
D – DRIVE
C – CORE
G – GRAB

D Core recovery
Core lost

▼ Water level drilled 29'

CONE PENETROMETER LOG

BORING NO.:	84J-LIF	CONTRACTOR:	ARA, INC.	DATE SPUD:	12/04/93
CLIENT:	AFCEE	RIG TYPE:	CPT-LIF	DATE CMPL.:	12/04/93
JOB NO.:	722450.04	DRLG METHOD:	CPT	ELEVATION:	GS = 244
LOCATION:	PLATTSBURG AFB	BORING DIA.:	1.75"	TEMP:	30 deg. F
GEOLOGIST:	NS/LB	DRLG FLUID:	NONE	WEATHER:	PARTLY CLOUDY
COMENTS:	FIRE TRAINING AREA FT-002				

Elev ('t)	Depth (ft)	Pro-file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	1			Gravelly SAND								
	5		SG				NOT MEASURED	NOT MEASURED				
233'	10											
	15			Well sorted SAND								
	20		SP									
	25											
215'	30											
212'			SM	▼ Water Table @ 32'								
	35											

bgs – Below Ground Surface
GS – Ground Surface
TOC – Top of Casing
NS – Not Sampled
SAA – Same As Above

SAMPLE TYPE
D – DRIVE
C – CORE
G – GRAB

D Core recovery
Core lost

▼ Water level drilled 32'

CONE PENETROMETER LOG

BORING NO.:	84J-LIF	CONTRACTOR:	ARA, INC.	DATE SPUD:	12/04/93
CLIENT:	AFCEE	RIG TYPE:	CPT-LIF	DATE CMPL.:	12/04/93
JOB NO.:	722450.04	DRLG METHOD:	CPT	ELEVATION:	GS = 244
LOCATION:	PLATTSBURG AFB	BORING DIA.:	1.75"	TEMP:	30 deg. F
GEOLOGIST:	NS/LB	DRLG FLUID:	NONE	WEATHER:	PARTLY CLOUDY
COMENTS:	FIRE TRAINING AREA FT-002				

Elev (ft)	Depth (ft)	Pro-file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	36			Mixed SAND								
			SM									
	40											
201'							N	N				
							O	O				
				TD @ 43 feet bgs			T	T				
	45											
							M	M				
							E	E				
	50						A	A				
							S	S				
							U	U				
	55						R	R				
							E	E				
							D	D				
	60											
	65											
	70											

bgs – Below Ground Surface
GS – Ground Surface
TOC – Top of Casing
NS – Not Sampled
SAA – Same As Above

SAMPLE TYPE
D – DRIVE
C – CORE
G – GRAB

D Core recovery
Core lost

▼ Water level drilled 32'

CONE PENETROMETER LOG

BORING NO.:	84K-LIF	CONTRACTOR:	ARA, INC.	DATE SPUD:	12/04/93
CLIENT:	AFCEE	RIG TYPE:	CPT-LIF	DATE CMPL.:	12/04/93
JOB NO.:	722450.04	DRLG METHOD:	CPT	ELEVATION:	GS = 244
LOCATION:	PLATTSBURG AFB	BORING DIA.:	1.75"	TEMP:	30 deg. F
GEOLOGIST:	NS/LB	DRLG FLUID:	NONE	WEATHER:	PARTLY CLOUDY
COMENTS:	FIRE TRAINING AREA FT-002				

Elev (ft)	Depth (ft)	Pro-file	USCS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	1			Gravelly SAND								
			SG									
	5						NOT MEASURED	NOT MEASURED				
	10											
	15											
227'				Well sorted SAND								
	20		SP									
	25											
	30											
312'				Silty SAND								
313'			SM	Water Table @ 33'								
	35											

bgs – Below Ground Surface
GS – Ground Surface
TOC – Top of Casing
NS – Not Sampled
SAA – Same As Above

SAMPLE TYPE
D – DRIVE
C – CORE
G – GRAB

D Core recovery
Core lost

▼ Water level drilled 33'

CONE PENETROMETER LOG

BORING NO.:	84K-LIF	CONTRACTOR:	ARA, INC.	DATE SPUD:	12/04/93
CLIENT:	AFCEE	RIG TYPE:	CPT-LIF	DATE CMPL.:	12/04/93
JOB NO.:	722450.04	DRLG METHOD:	CPT	ELEVATION:	GS = 244
LOCATION:	PLATTSBURG AFB	BORING DIA.:	1.75"	TEMP:	30 deg. F
GEOLOGIST:	NS/LB	DRLG FLUID:	NONE	WEATHER:	PARTLY CLOUDY
COMENTS:	FIRE TRAINING AREA FT-002				

Elev (ft)	Depth (ft)	Pro-file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
206'	36		SM	Silty SAND			NOT MEASURED	NOT MEASURED				
				TD @ 38 feet bgs								
	40											
	45											
	50											
	55											
	60											
	65											
	70											

bgs - Below Ground Surface
GS - Ground Surface
TOC - Top of Casing
NS - Not Sampled
SAA - Same As Above

SAMPLE TYPE
D - DRIVE
C - CORE
G - GRAB

D Core recovery
Core lost

▼ Water level drilled 33'

CONE PENETROMETER LOG

BORING NO.:	84L-LIF	CONTRACTOR:	ARA, INC.	DATE SPUD:	12/04/93
CLIENT:	AFCEE	RIG TYPE:	CPT-LIF	DATE CMPL.:	12/04/93
JOB NO.:	722450.04	DRLG METHOD:	CPT	ELEVATION:	GS = 246
LOCATION:	PLATTSBURG AFB	BORING DIA.:	1.75"	TEMP:	30 deg. F
GEOLOGIST:	NS/LB	DRLG FLUID:	NONE	WEATHER:	PARTLY CLOUDY
COMENTS:	FIRE TRAINING AREA FT-002				

Elev (ft)	Depth (ft)	Pro-file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	1		SG	Gravelly SAND								
	5		SW	Well sorted SAND			NOT MEASURED	NOT MEASURED				
	10											
	15											
	20											
	25											
219'				Silty SAND								
216'	30		SM	CONTAMINANT present at 30' bgs								
214'				Water Table @ 32'								
212'				Clean soil @ 34' bgs								
	35											

bgs - Below Ground Surface
GS - Ground Surface
TOC - Top of Casing
NS - Not Sampled
SAA - Same As Above

SAMPLE TYPE

D - DRIVE
C - CORE
G - GRAB

D Core recovery

Core lost

▼ Water level drilled 32'

CONE PENETROMETER LOG

BORING NO.:	84L-LIF	CONTRACTOR:	ARA, INC.	DATE SPUD:	12/04/93
CLIENT:	AFCEE	RIG TYPE:	CPT-LIF	DATE CMPL.:	12/04/93
JOB NO.:	722450.04	DRLG METHOD:	CPT	ELEVATION:	GS = 246
LOCATION:	PLATTSBURG AFB	BORING DIA.:	1.75"	TEMP.	30 deg. F
GEOLOGIST:	NS/LB	DRLG FLUID:	NONE	WEATHER:	PARTLY CLOUDY
COMENTS:	FIRE TRAINING AREA FT-002				

Elev (ft)	Depth (ft)	Pro-file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	36		SM	Silty SAND								
207'												
	40			TD @ 39 feet bgs			NOT MEASURED	NOT MEASURED				
	45											
	50											
	55											
	60											
	65											
	70											

bgs – Below Ground Surface
GS – Ground Surface
TOC – Top of Casing
NS – Not Sampled
SAA – Same As Above

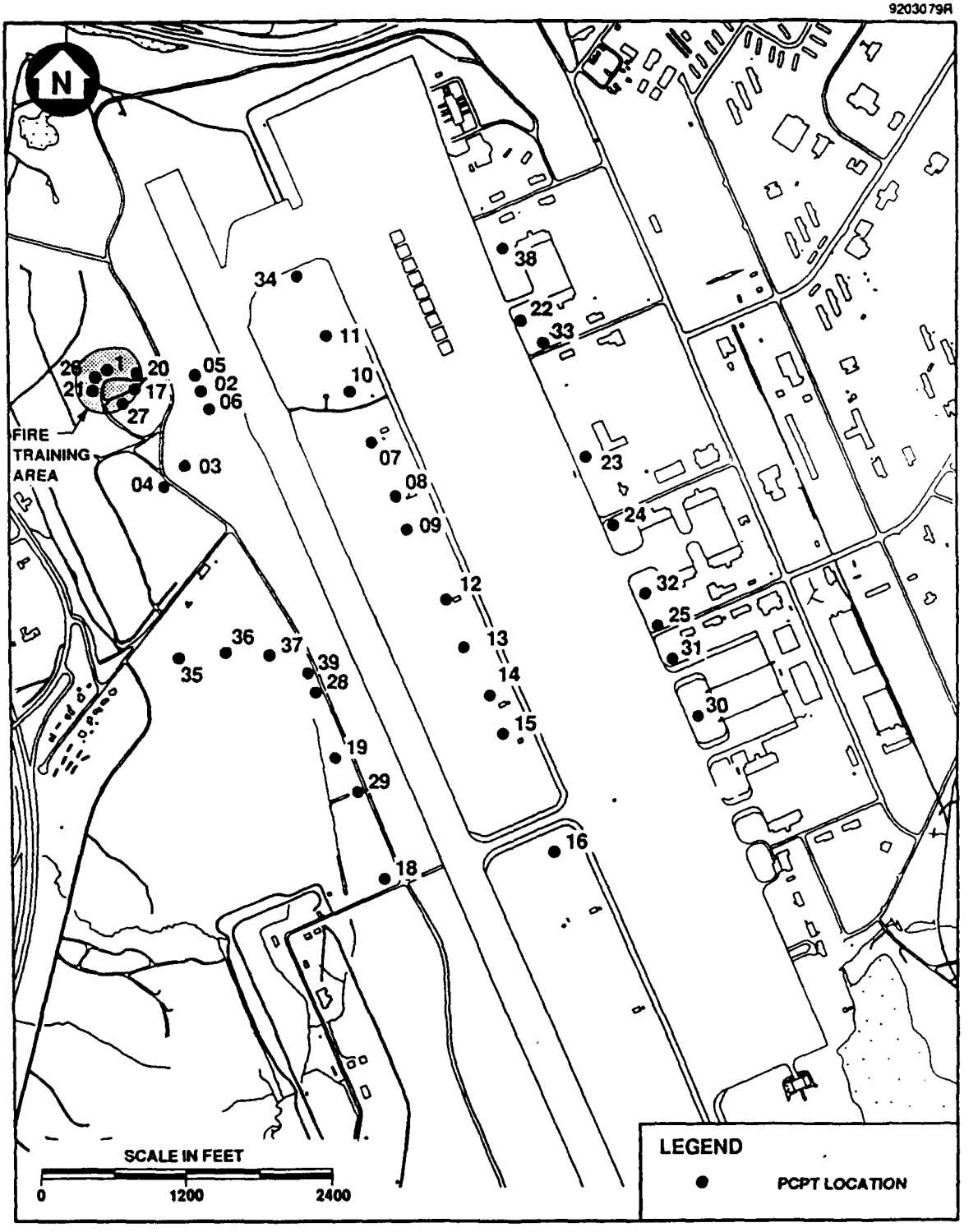
SAMPLE TYPE
D – DRIVE
C – CORE
G – GRAB

D Core recovery
Core lost

▼ Water level drilled 32'

CONE PENETROMETER LOGS

(1991)



PCPT BORING LOCATIONS

CP-02-002 Applied Research Associates, Inc. 06/10/91
ABB Environmental, Plattsburgh Air Force Base

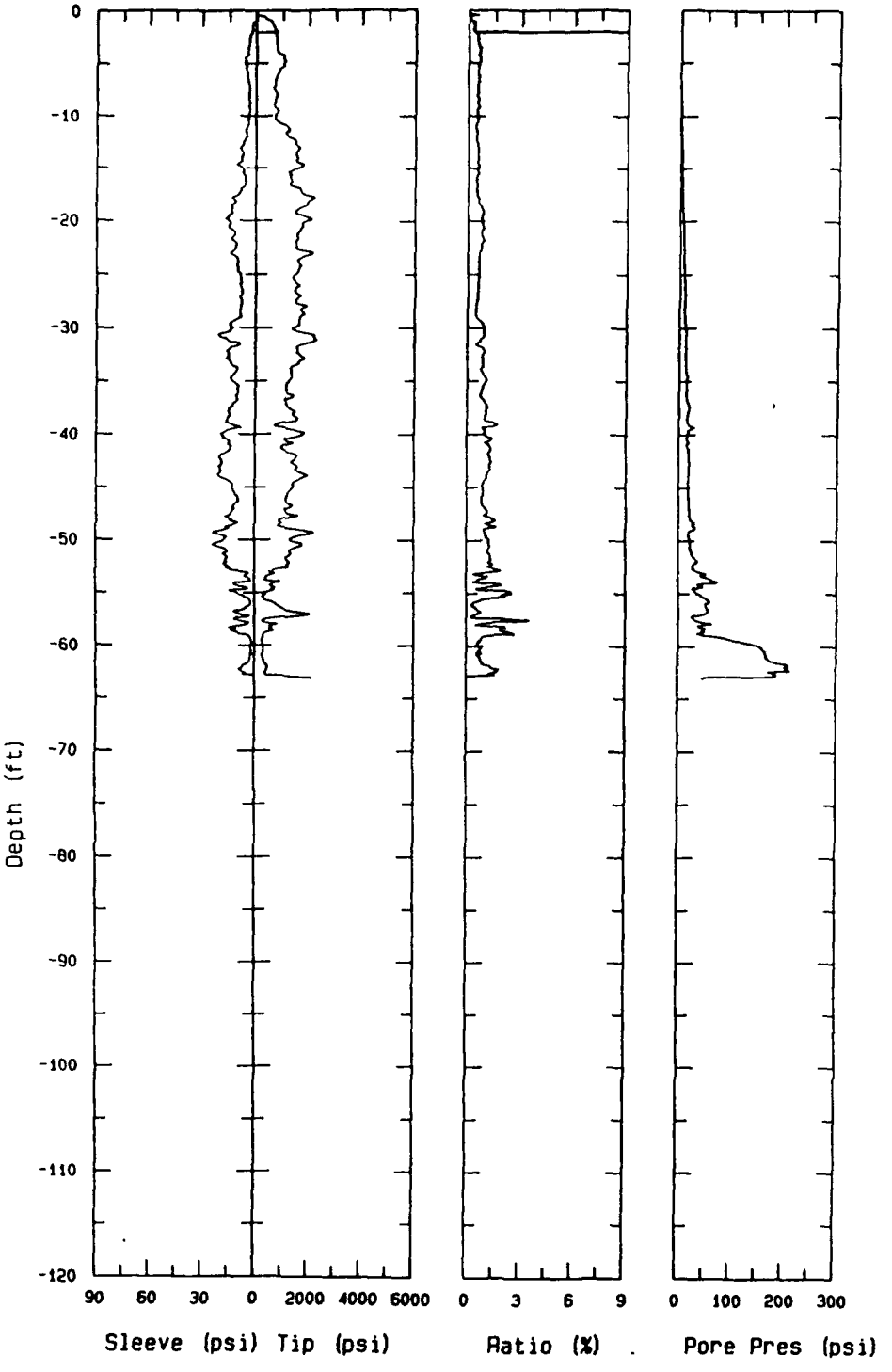


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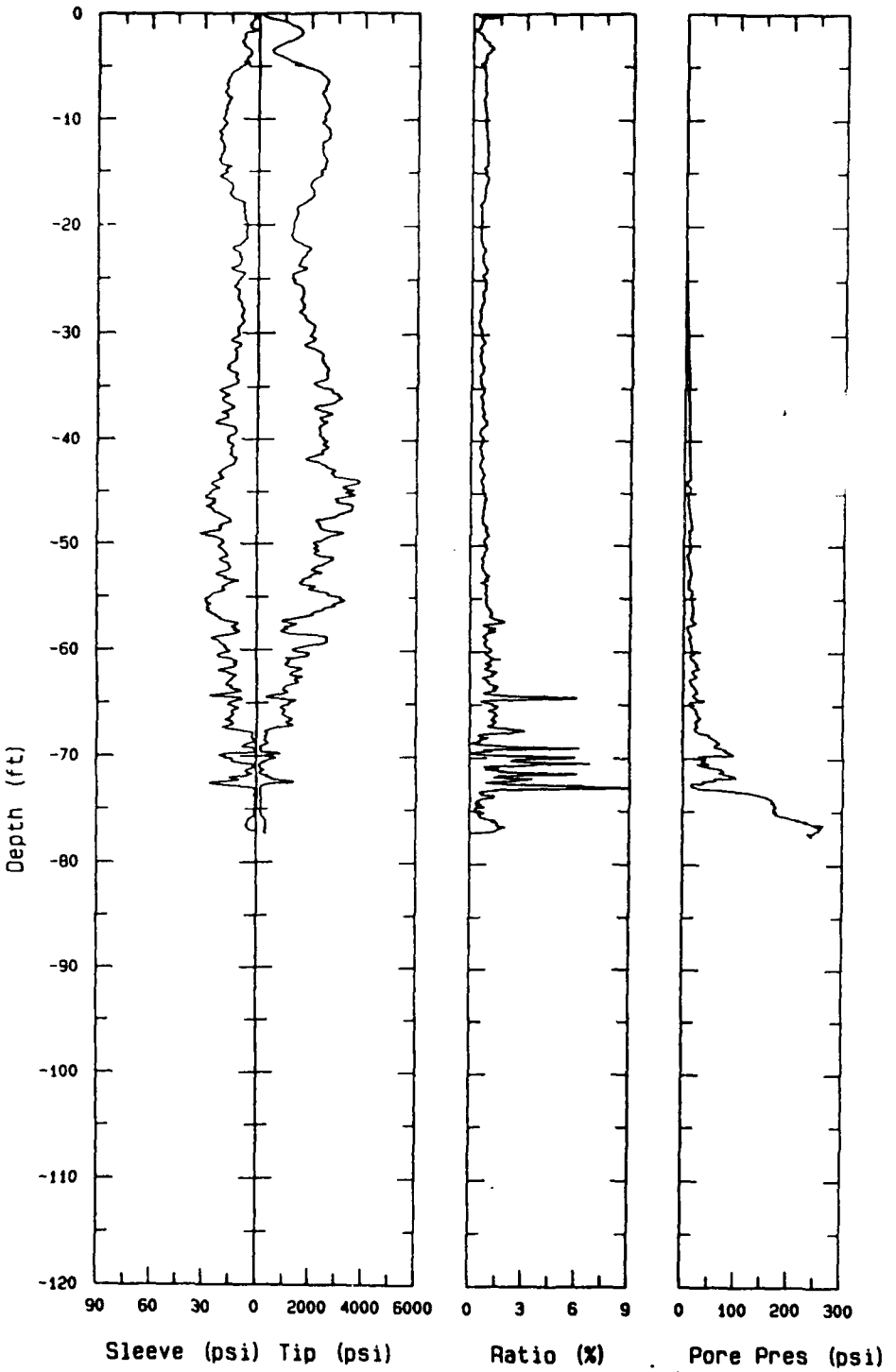
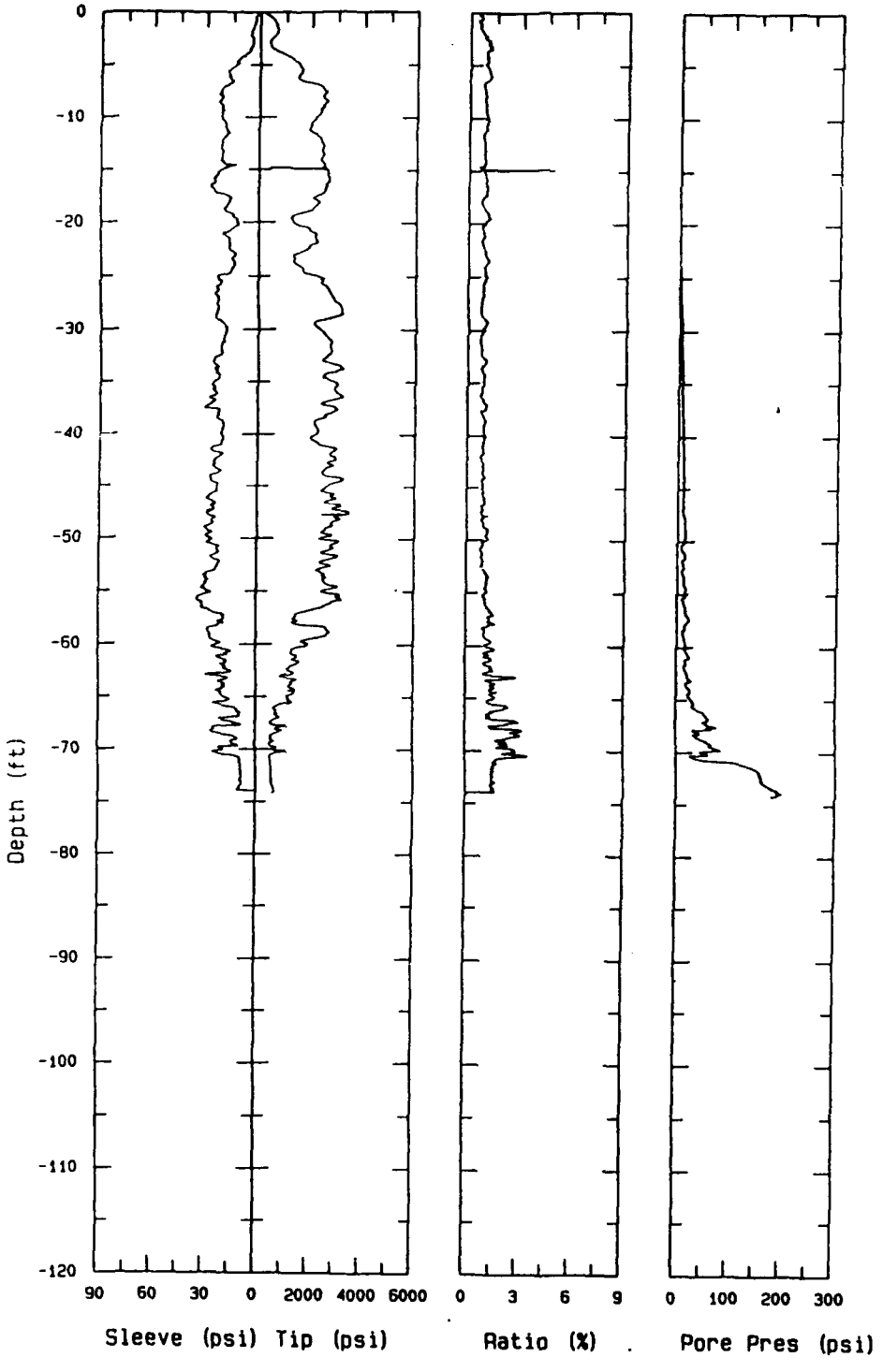
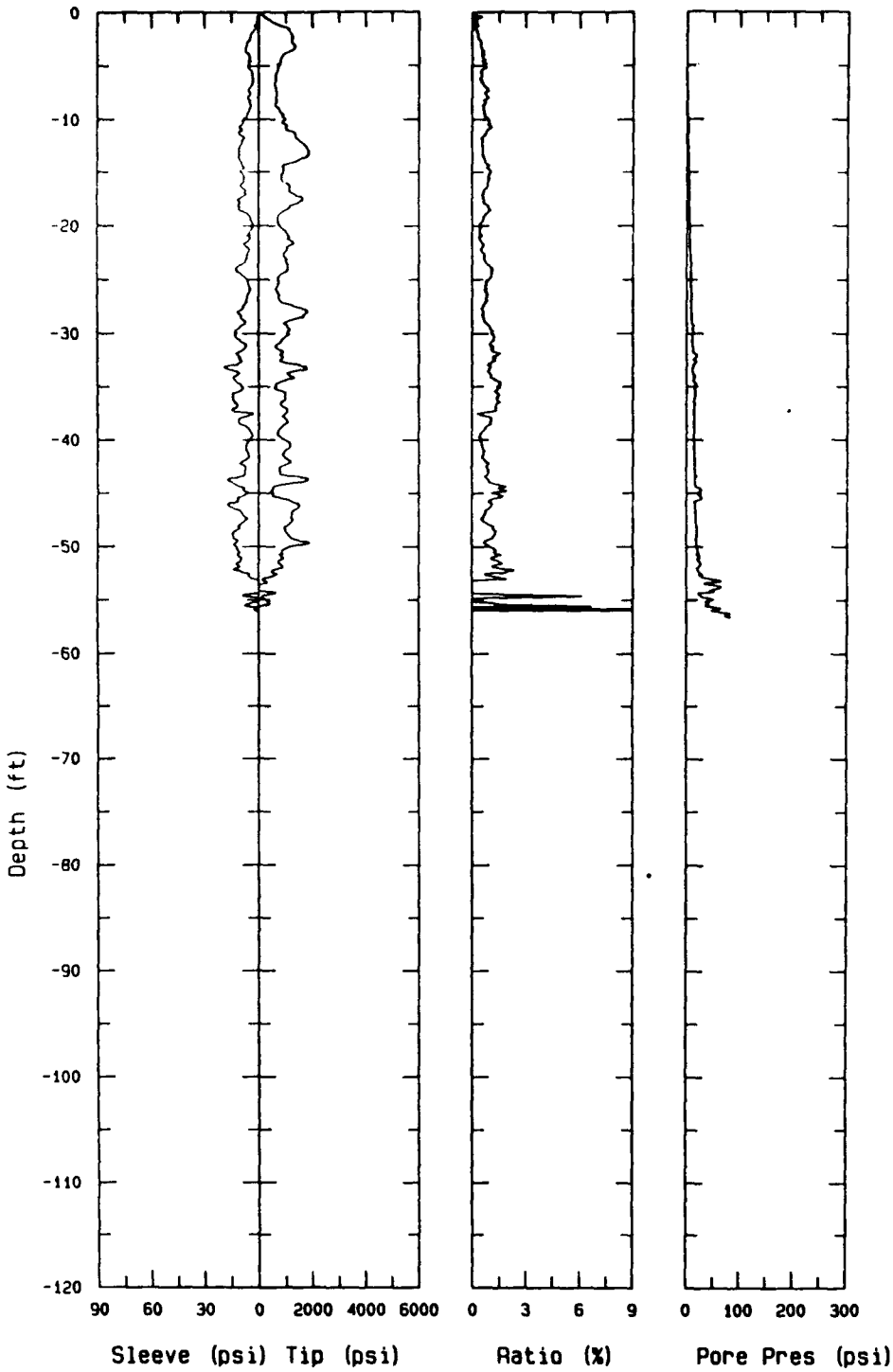
ABB Environmental, Plattsburgh Air Force Base



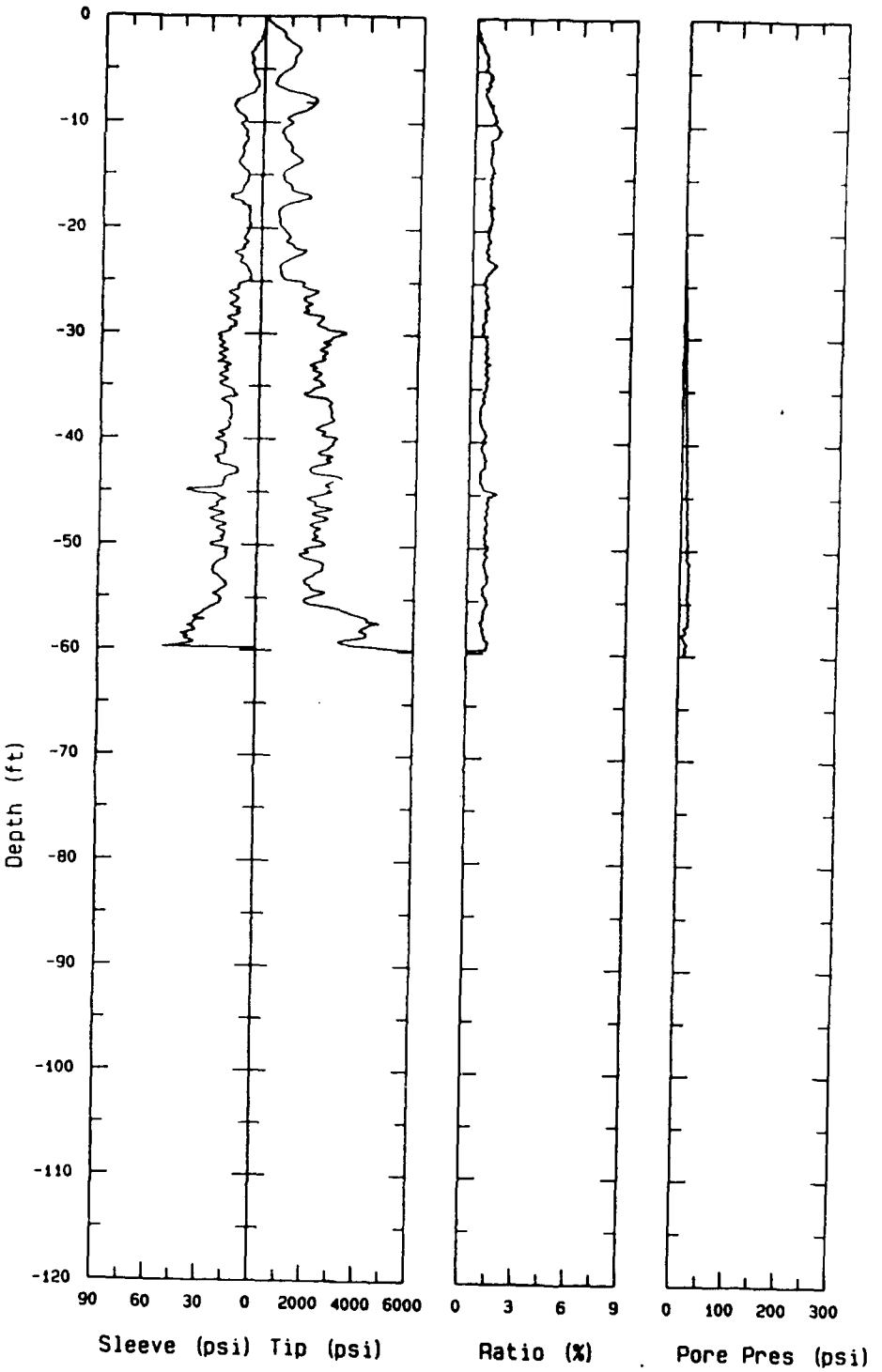
CP-02-004 Applied Research Associates, Inc. 06/10/91
ABB Environmental, Plattsburgh Air Force Base



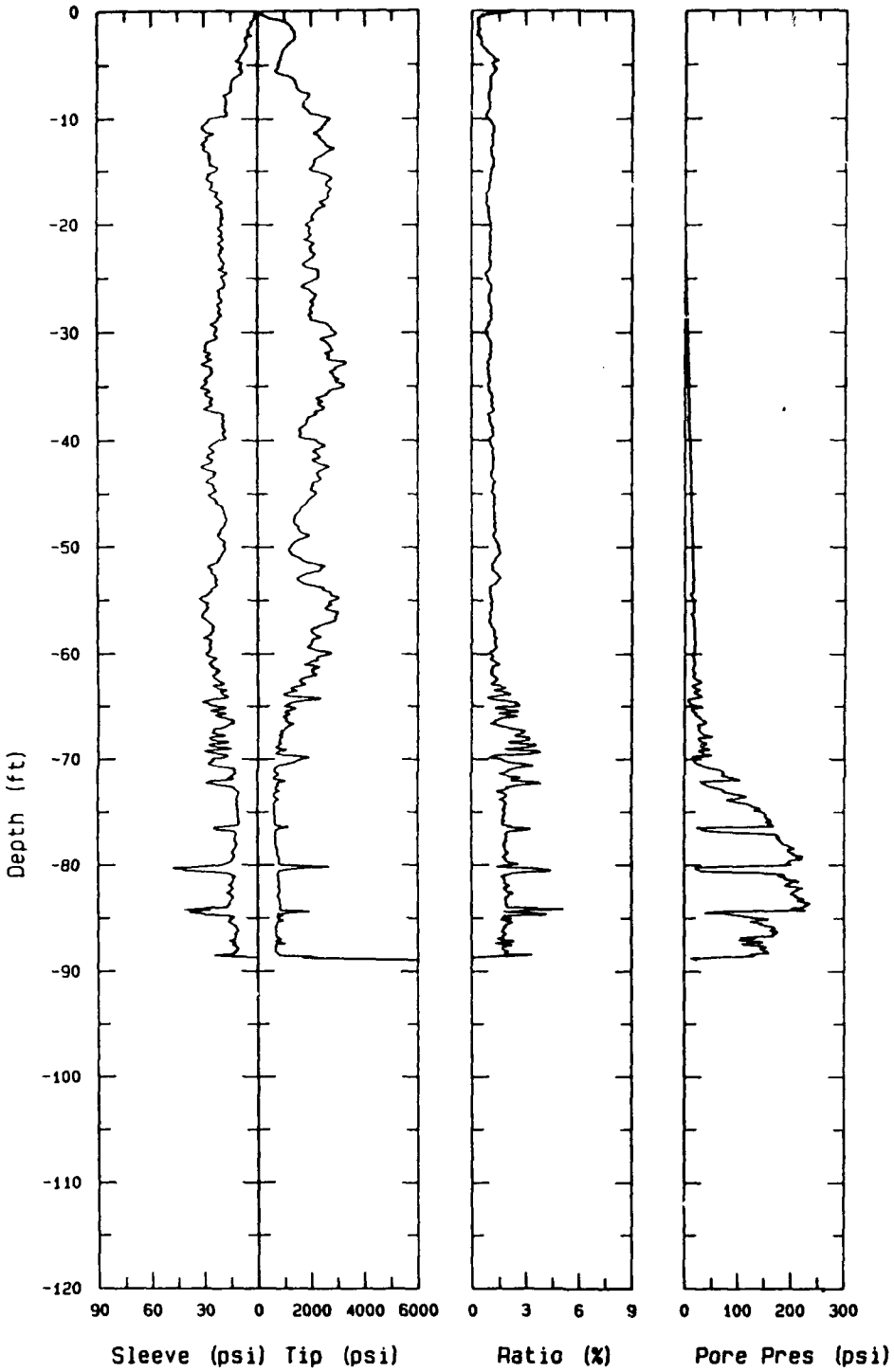
CP-02-005 Applied Research Associates, Inc. 06/12/91
ABB Environmental, Plattsburgh Air Force Base



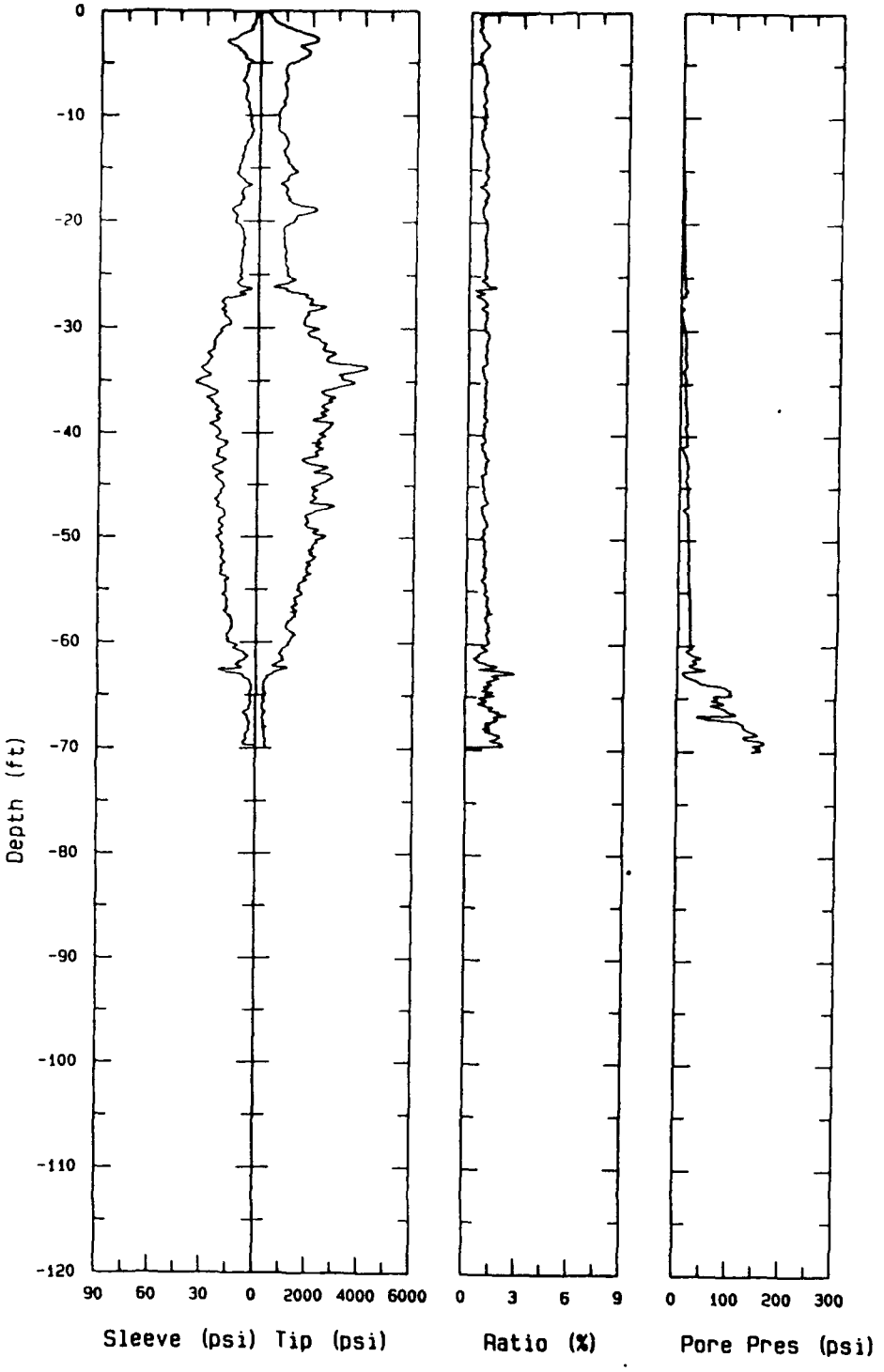
CP-02-007 Applied Research Associates, Inc. 06/14/91
ABB Environmental, Plattsburgh Air Force Base



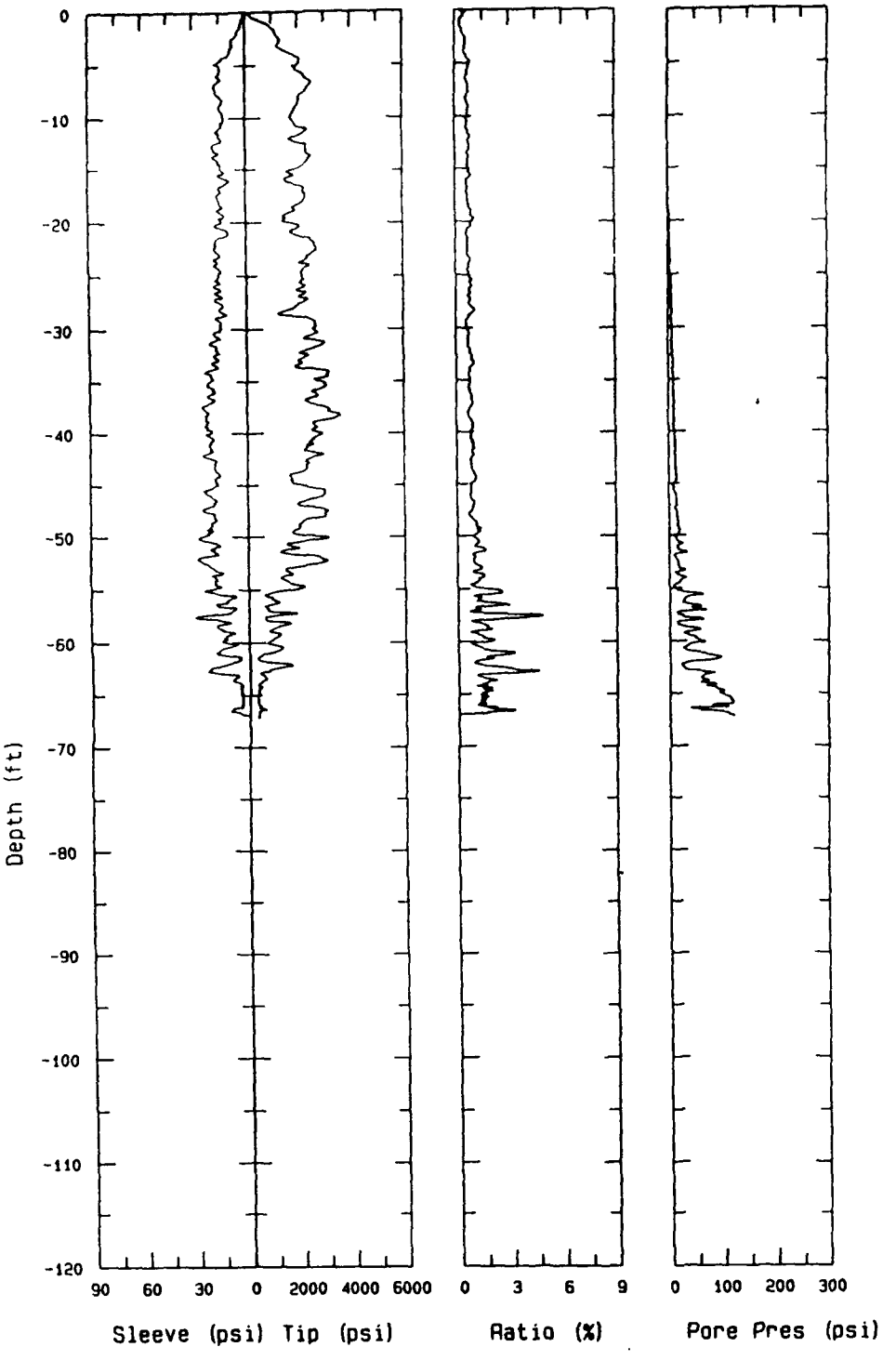
CP-02-008 Applied Research Associates, Inc. 06/14/91
ABB Environmental, Plattsburgh Air Force Base



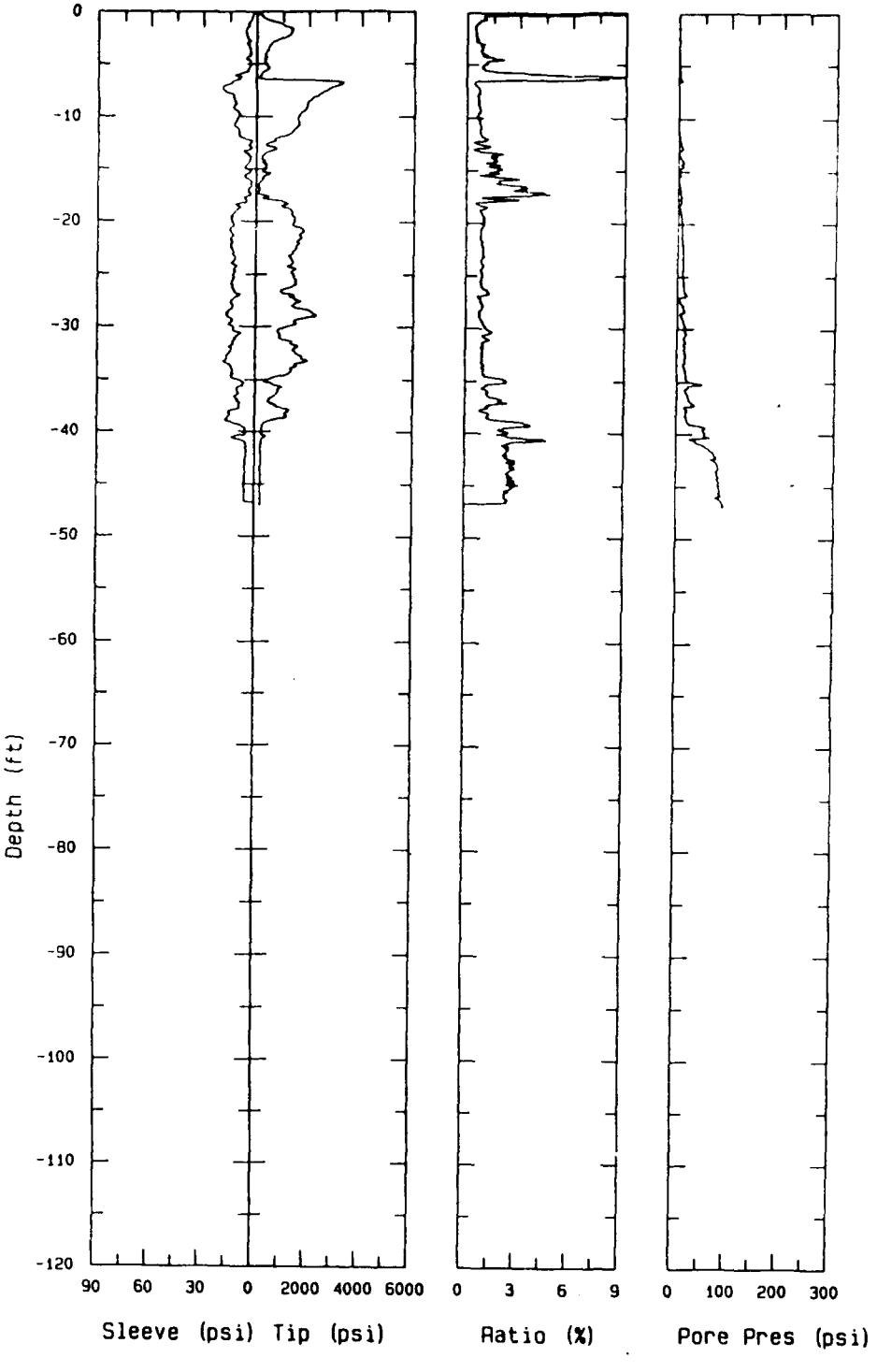
CP-02-009 Applied Research Associates, Inc. 06/14/91
ABB Environmental, Plattsburgh Air Force Base



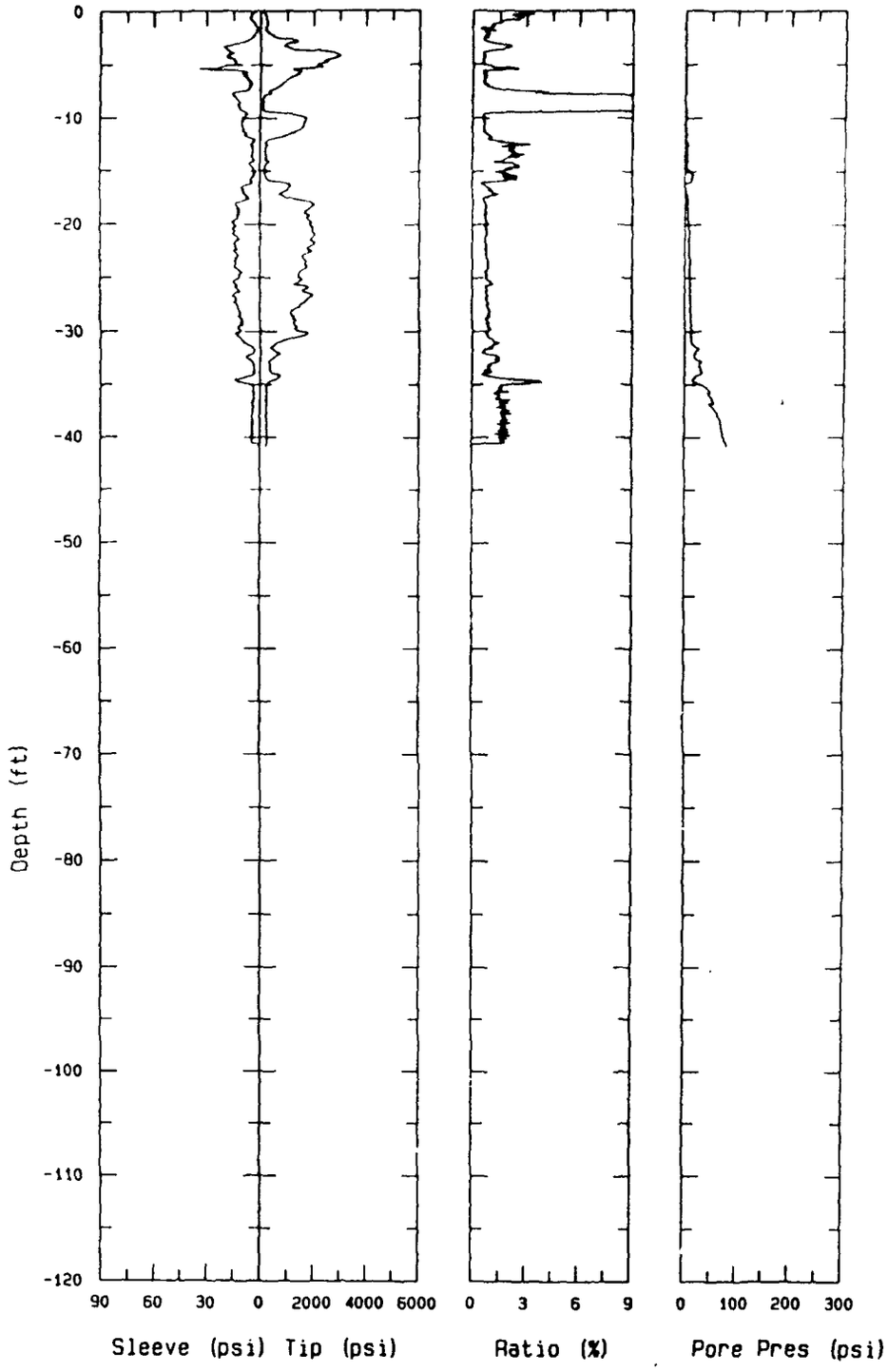
CP-02-010 Applied Research Associates, Inc. 06/17/91
ABB Environmental, Plattsburgh Air Force Base



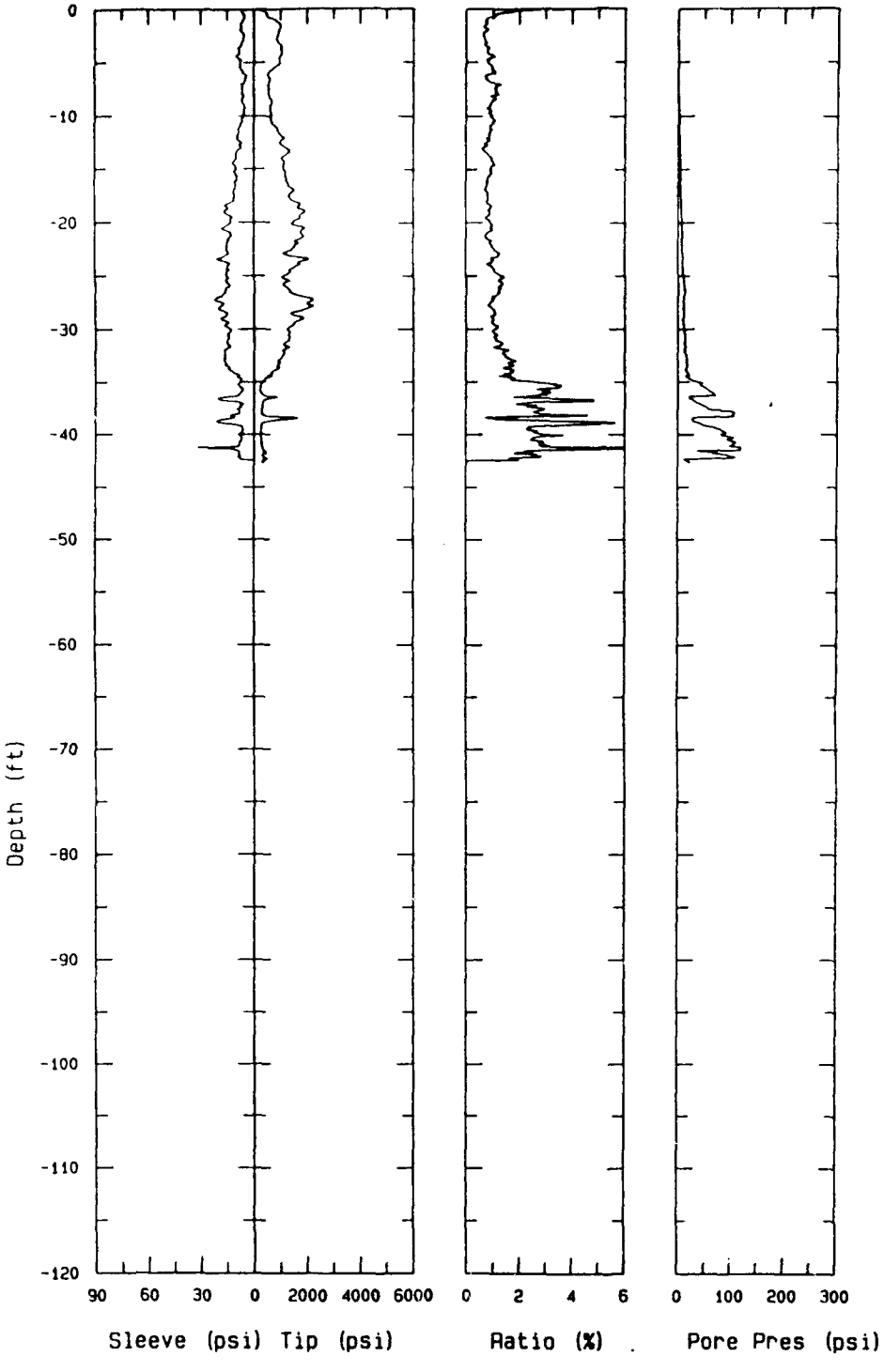
CP-02-012 Applied Research Associates, Inc. 06/17/91
A88 Environmental, Plattsburgh Air Force Base



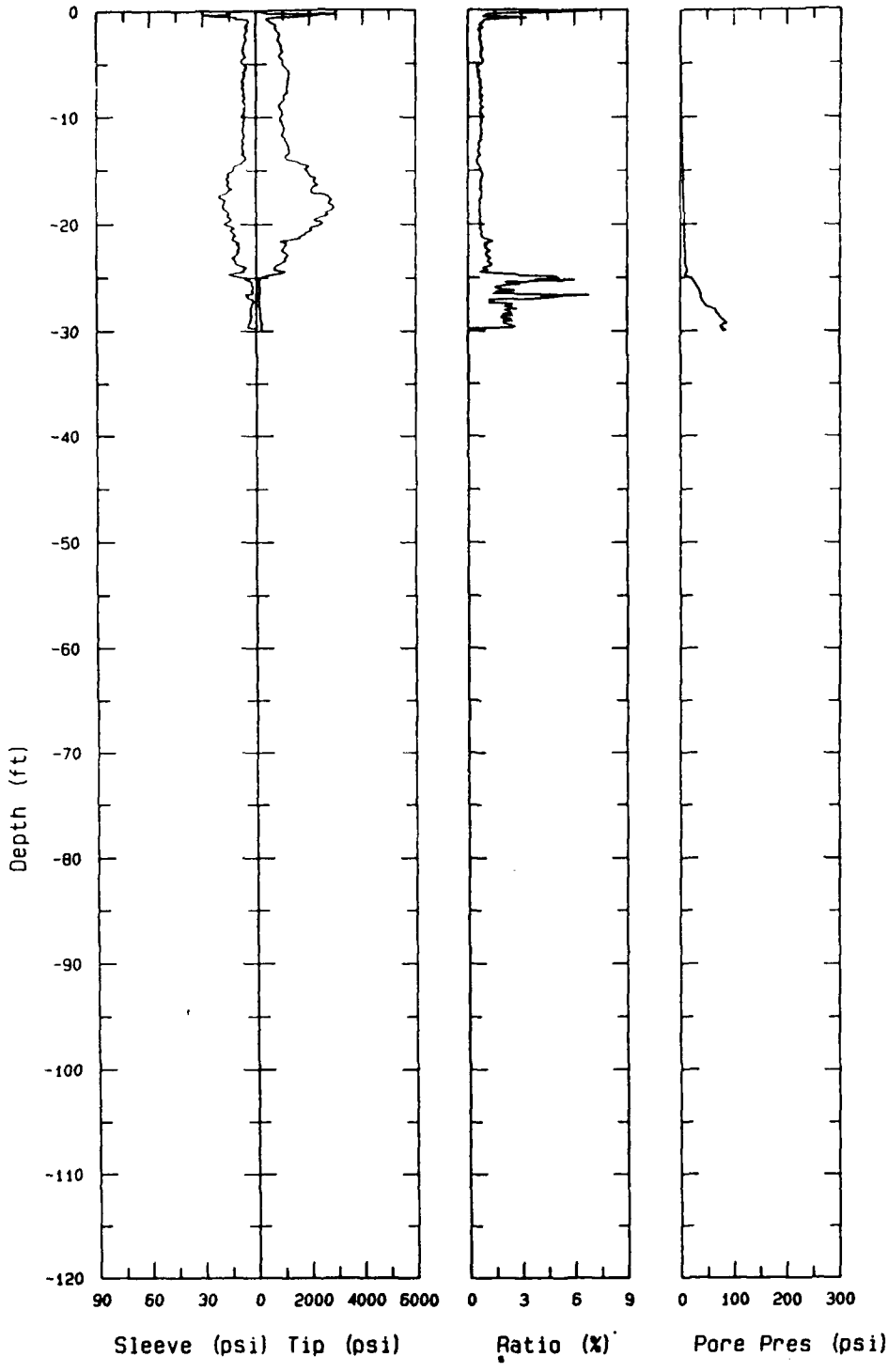
CP-02-013 Applied Research Associates, Inc. 06/17/91
ABB Environmental, Plattsburgh Air Force Base



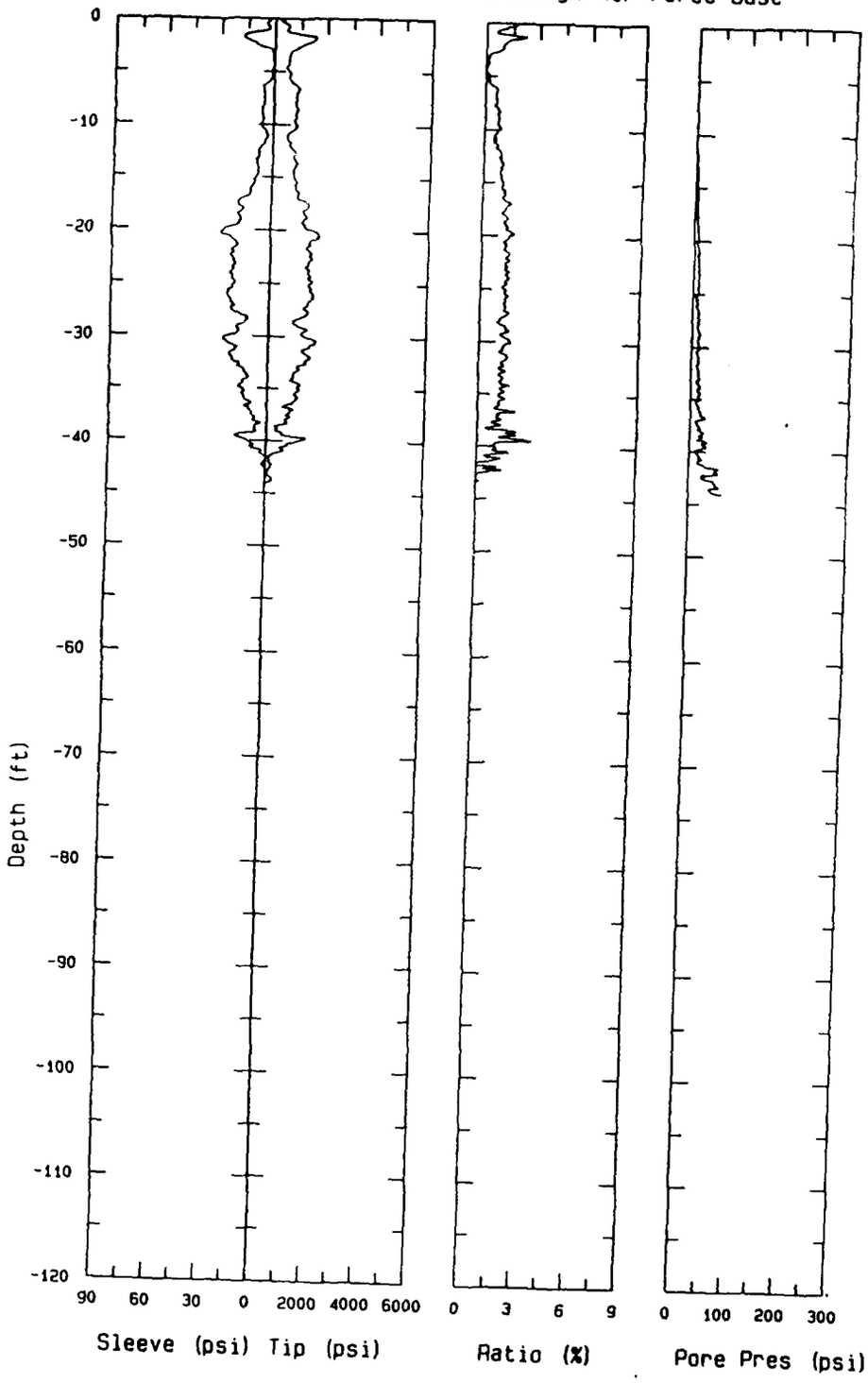
CP-02-024 Applied Research Associates, Inc. 06/25/91
ABB Environmental, Plattsburgh Air Force Base



CP-02-025 Applied Research Associates, Inc. 06/25/91
ABB Environmental, Plattsburgh Air Force Base



CP-02-037 Applied Research Associates, Inc. 06/27/91
ABB Environmental, Plattsburgh Air Force Base



APPENDIX B

AVAILABLE SOIL AND GROUND WATER DATA

DIVIDER.DOC

SOIL DATA

DECEMBER 1993

DIVIDER.DOC

MANTECH

Ref: 94-DK1/vg

January 19, 1993

Mr. Fred M. Pfeffer
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

Don Campbell

THRU: S.A. Vandegrift SAV

Dear Fred:

This report contains the results of my GC/MSD analysis of your Plattsburg AFB core extracts for the quantitation of 15 compounds, namely, benzene, toluene, ethylbenzene (EB), p-Xylene, m-Xylene, o-Xylene, 1,3,5-trimethylbenzene (1,3,5-TMB), 1,2,4-trimethylbenzene (1,2,4-TMB), 1,2,3-trimethylbenzene (1,2,3-TMB), 1,3-dichlorobenzene (1,3-DCB), 1,4-dichlorobenzene (1,4-DCB), 1,2-dichlorobenzene (1,2-DCB), naphthalene, 2-methylnaphthalene and 1-methylnaphthalene as per Service Request #SF-0-28, modification #3. t-Dichloroethene (t-DCE) was not quantified due its presence as impurity in the methylene chloride extraction solvent.

The analytical method was a modification of RSKSOP-124. Cool (38 C) on-column injection (0.1 µl) was used with electronic pressure control (EPC) set for a constant flow of 0.9 ml/min. A 30M X 0.25 mm Restek Stabilwax (Crossbonded Carbowax-PEG, 0.5 µm film) capillary GC column with 1 foot long X 0.53 mm ID uncoated capillary precolumn was used. Quantitation was based on calibration curves of a single target ion for each compound with the addition of up to two qualifier ions recorded to verify chromatographic separation or purity. The ions chosen were those listed in EPA method 524.2 Revision 3.0 except for the methylnaphthalenes (target=142, Q1=141, Q2=115) which are not listed in any EPA method. The lower limit of quantitation was 0.1 µg/ml (BLQ < 0.1) except for the naphthalenes where BLQ was <0.5 µg/ml due to carryover between injections. Dilution of some sample extracts was necessary to keep concentrations within the upper level of the calibration curve. A complete report detailing the acquisition method and calibration has been recorded. The samples were analyzed for SIM quantitation of target compounds on January 4-5, 1994.

Also included in this report are the following example chromatograms:

i. a scan mode comparison of JP-4 (diluted 1:10) and the Plattsburg AFB extract 63-84D 39.5-40' showing the presence of non-petroleum compounds in high concentration which elute late in the chromatogram. The non-petroleum compound of highest apparent concentration (retention time=29.34 min.) has been positively identified by authentic compound as the 'plasticizer Bis[2-ethylhexyl] adipate.
ii. another scan mode chromatogram of Plattsburg AFB extract 63-84D 39.5-40' with improved peak separation obtained using a 130m hybrid column. The Bis[2-ethylhexyl] adipate is shown at retention time 122.43 min.
iii. SIM mode chromatogram showing the target compounds for quantitation seen in a check standard mixture analysis.
iv. the SIM chromatogram for Plattsburg AFB extract 63-84D 39.5-40' target compound quantitation.

If I can be of further assistance, please feel free to contact me.

Sincerely,

David A. Kovacs

xc: R.L. Cosby
J.L. Seeley jlo
G. Smith
J. Wilson
D. Kampbell

S.R. SF-0-28 Mod.#3 Plattsburg AFB Core Analysis by GC/MSD Units = mg/kg

Sample	Benzene	TCE	Toluene	EB	p-Xylene	m-Xylene	o-Xylene	1,3,5-TMB	1,2,4TMB	1,2,3TMB	1,3-DCB
50 µg/ml	4.79E+01	4.51E+01	4.67E+01	4.65E+01	4.71E+01	4.70E+01	4.70E+01	4.77E+01	4.74E+01	4.75E+01	4.67E+01
Method Blank #1	ND	ND	ND	BLQ	ND	ND	ND	BLQ	BLQ	BLQ	BLQ
1-84F 30-31'	ND	ND	BLQ	BLQ	BLQ	BLQ	BLQ	2.80E-01	1.87E-01	8.41E-02	9.43E-02
10-84B 31-32.5'	BLQ	BLQ	1.73E+00	5.01E+00	6.91E+00	1.82E+01	7.91E+00	6.26E+00	1.63E+01	6.37E+00	BLQ
23-84D 16-16.5'	7.38E-02	ND	2.58E+00	2.65E+00	3.76E+00	8.98E+00	5.22E+00	4.61E+00	1.13E+01	4.83E+00	BLQ
24-84D 15.5-16'	2.62E-01	BLQ	5.35E+00	3.89E+00	6.01E+00	1.36E+01	8.81E+00	1.03E+01	1.55E+01	1.13E+01	5.50E-02
25-84D 15-15.5'	ND	ND	5.85E-02	BLQ	BLQ	3.69E-02	BLQ	BLQ	BLQ	3.47E-02	ND
27-84D 16.5-17'(A)	3.51E-01	BLQ	9.31E+00	7.98E+00	1.10E+01	2.66E+01	1.48E+01	1.17E+01	2.83E+01	1.20E+01	5.26E-02
28-84D 16.5-17'(B)	4.35E-02	BLQ	1.36E+00	1.23E+00	1.71E+00	4.08E+00	2.31E+00	1.92E+00	4.77E+00	1.97E+00	BLQ
29-84D 17-17.5'	2.63E-01	BLQ	8.41E+00	7.60E+00	1.05E+01	2.61E+01	1.43E+01	1.11E+01	2.82E+01	1.16E+01	4.74E-02
30-84D 17.5-18'	1.62E-01	ND	6.53E+00	6.90E+00	9.77E+00	2.44E+01	1.34E+01	1.11E+01	2.92E+01	1.21E+01	4.85E-02
5 µg/ml	4.72E+00	5.21E+00	5.07E+00	4.91E+00	4.90E+00	5.09E+00	4.86E+00	5.04E+00	4.94E+00	4.97E+00	5.11E+00
0.5 µg/ml	4.98E-01	5.40E-01	5.30E-01	5.04E-01	5.03E-01	5.07E-01	4.97E-01	6.11E-01	4.78E-01	4.96E-01	5.48E-01
31-84D 18-18.5'	3.88E-01	BLQ	1.10E+01	9.49E+00	1.32E+01	3.29E+01	1.76E+01	1.30E+01	3.33E+01	1.36E+01	5.33E-02
32-84D 18.5-19'	2.10E-01	BLQ	6.52E+00	5.91E+00	8.29E+00	2.09E+01	1.12E+01	8.39E+00	2.28E+01	9.09E+00	3.59E-02
33-84D 19-19.5'	1.63E-01	BLQ	6.39E+00	6.12E+00	8.58E+00	2.18E+01	1.15E+01	8.39E+00	2.26E+01	9.05E+00	3.64E-02
34-84D 19.5-20'	1.31E-01	BLQ	4.78E+00	4.50E+00	6.37E+00	1.61E+01	8.52E+00	6.32E+00	1.75E+01	6.92E+00	2.87E-02
35-84D 20-20.5'	1.77E-01	BLQ	5.93E+00	5.00E+00	6.93E+00	1.77E+01	9.26E+00	6.31E+00	1.77E+01	6.94E+00	BLQ
36-84D 20.5-21'	3.55E-02	ND	1.89E+00	2.03E+00	2.88E+00	7.37E+00	4.04E+00	3.02E+00	8.84E+00	3.44E+00	BLQ
37-84D 14-14.5'	ND	ND	BLQ	BLQ	BLQ	BLQ	BLQ	3.37E-02	BLQ	ND	BLQ
48-84D 21-21.5'	1.31E-01	BLQ	3.99E+00	3.49E+00	4.90E+00	1.24E+01	6.59E+00	4.70E+00	1.36E+01	5.37E+00	BLQ
49-84D 21.5-22'	2.75E-01	BLQ	8.55E+00	7.31E+00	1.02E+01	2.60E+01	1.39E+01	9.70E+00	2.73E+01	1.11E+01	4.33E-02
50-84D 22-22.5'	1.58E-01	BLQ	6.11E+00	5.55E+00	7.76E+00	1.97E+01	1.05E+01	7.61E+00	2.18E+01	8.75E+00	BLQ
50 µg/ml	5.25E+01	5.16E+01	5.36E+01	5.32E+01	5.36E+01	5.35E+01	5.37E+01	5.33E+01	5.32E+01	5.30E+01	5.33E+01
20 µg/ml QC Mix 1	2.01E+01	2.22E+01	2.03E+01	2.07E+01	N/A	N/A	N/A	N/A	N/A	N/A	2.07E+01
100 µg/ml QC Mix 2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	9.85E+01
methylene chloride	ND	ND	ND	ND	ND	ND	ND	BLQ	ND	ND	BLQ
Method Blank #2	ND	ND	ND	ND	ND	ND	ND	BLQ	ND	ND	BLQ
0.5 µg/ml	5.69E-01	5.36E-01	5.32E-01	5.08E-01	5.03E-01	4.99E-01	4.97E-01	5.44E-01	4.72E-01	5.06E-01	5.18E-01
51-84D 22.5-23'	2.40E-01	BLQ	8.14E+00	6.98E+00	9.80E+00	2.47E+01	1.32E+01	9.28E+00	2.60E+01	1.05E+01	4.09E-02
52-84D 23-23.5'	3.10E-01	BLQ	7.90E+00	5.95E+00	8.19E+00	2.06E+01	1.10E+01	7.26E+00	2.04E+01	8.33E+00	3.27E-02
53-84D 23.5-24'	BLQ	ND	1.31E-01	1.25E-01	1.79E-01	4.57E-01	2.71E-01	2.50E-01	7.59E-01	3.11E-01	BLQ
54-84D 35-35.5'	BLQ	BLQ	1.32E-01	3.69E-02	5.09E-02	1.31E-01	6.33E-02	3.17E-02	9.41E-02	3.69E-02	ND
55-84D 35.5-36'	BLQ	ND	1.45E-01	2.75E-02	4.08E-02	9.51E-02	4.69E-02	BLQ	3.47E-02	BLQ	BLQ
56-84D 36-36.5'	8.12E-01	5.06E+00	1.35E+01	6.55E+00	8.25E+00	2.24E+01	9.87E+00	6.80E+00	1.92E+01	7.62E+00	7.81E-02
57-84D 36.5-37'	1.47E+00	1.74E+01	2.58E+01	1.25E+01	1.66E+01	4.58E+01	1.90E+01	1.39E+01	3.54E+01	1.48E+01	1.21E-01
58-84D 37-37.5'	4.90E+00	5.72E+01	8.42E+01	3.14E+01	3.83E+01	9.40E+01	3.94E+01	3.05E+01	6.26E+01	2.93E+01	2.95E-01
59-84D 37.5-38'	9.63E+00	1.69E+02	1.09E+02	5.14E+01	6.81E+01	1.61E+02	6.24E+01	4.45E+01	8.25E+01	3.82E+01	9.23E-01
20 µg/ml QC Mix 1	1.96E+01	2.10E+01	1.91E+01	1.95E+01	N/A	N/A	N/A	N/A	N/A	N/A	1.99E+01
5 µg/ml	5.28E+00	4.89E+00	4.91E+00	4.59E+00	4.66E+00	4.91E+00	4.73E+00	4.64E+00	5.18E+00	4.91E+00	5.20E+00
60-84D 38-38.5'	6.01E+00	2.10E+02	8.01E+01	4.05E+01	4.77E+01	1.39E+02	4.97E+01	2.69E+01	7.62E+01	2.86E+01	8.76E-01
61-84D 38.5-39'	2.05E+01	8.15E+02	2.36E+02	1.28E+02	1.35E+02	3.90E+02	1.37E+02	7.14E+01	1.93E+02	7.35E+01	2.76E+00
62-84D 39-39.5'	3.29E+01	9.31E+02	4.12E+02	2.39E+02	2.44E+02	6.97E+02	2.45E+02	1.27E+02	3.28E+02	1.27E+02	5.25E+00
63-84D 39.5-40'	4.80E+01	1.28E+03	5.47E+02	3.13E+02	3.20E+02	8.99E+02	3.18E+02	1.65E+02	4.25E+02	1.64E+02	6.92E+00
64-84D 40-40.5'	4.26E+01	1.13E+03	4.70E+02	2.60E+02	2.65E+02	7.51E+02	2.62E+02	1.34E+02	3.43E+02	1.33E+02	5.82E+00
65-84D 40.5-41'	2.74E+01	8.76E+02	3.03E+02	1.68E+02	1.71E+02	4.99E+02	1.73E+02	8.95E+01	2.39E+02	8.99E+01	3.97E+00
66-84D 41-41.5'	7.38E+00	3.14E+02	7.72E+01	4.48E+01	4.57E+01	1.34E+02	4.60E+01	2.46E+01	6.71E+01	2.64E+01	1.36E+00
67-84D 44-44.3'	ND	ND	BLQ	4.00E-02	3.56E-02	9.78E-02	4.38E-02	BLQ	BLQ	BLQ	ND
methylene chloride	ND	ND	ND	ND	ND	ND	ND	BLQ	ND	ND	ND
83-84F 28-28.5'	ND	BLQ	ND	BLQ	ND	ND	ND	BLQ	ND	ND	ND
84-84F 30-30.5'	1.19E-01	ND	9.17E-01	1.52E+00	1.83E+00	4.69E+00	2.06E+00	1.90E+00	5.28E+00	2.37E+00	ND
85-84F 30.5-31'	1.22E-01	ND	2.89E+00	2.07E+00	2.51E+00	6.77E+00	3.23E+00	2.31E+00	6.91E+00	2.29E+00	ND
86-84F 31-31.5'	3.15E-01	ND	9.20E+00	7.38E+00	8.70E+00	2.40E+01	1.16E+01	8.21E+00	1.94E+01	7.16E+00	ND
20 µg/ml QC Mix 1	2.07E+01	2.21E+01	1.98E+01	1.97E+01	N/A	N/A	N/A	N/A	N/A	N/A	1.99E+01
100 µg/ml	9.72E+01	9.35E+01	1.00E+02	1.00E+02	1.00E+02	1.00E+02	1.00E+02	1.00E+02	9.56E+01	9.42E+01	9.47E+01

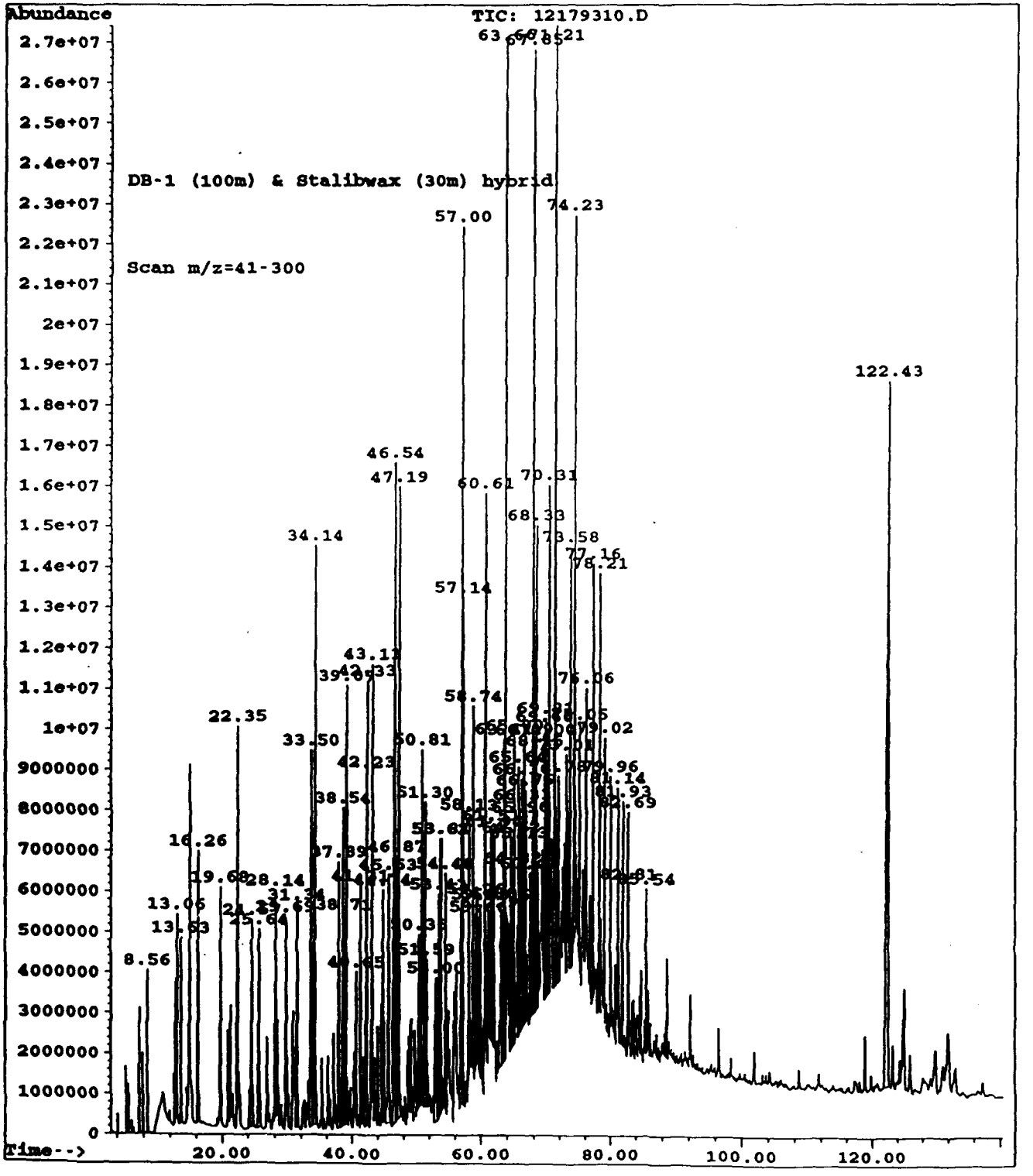
Analyst: D.A. Kovacs BLQ = 0.1 µg/ml except naphthalenes = 0.5 µg/ml

S.R. SF-0-28 Mod.#3 Plattsburg AFB Core Analysis by GC/MSD Units = mg/kg

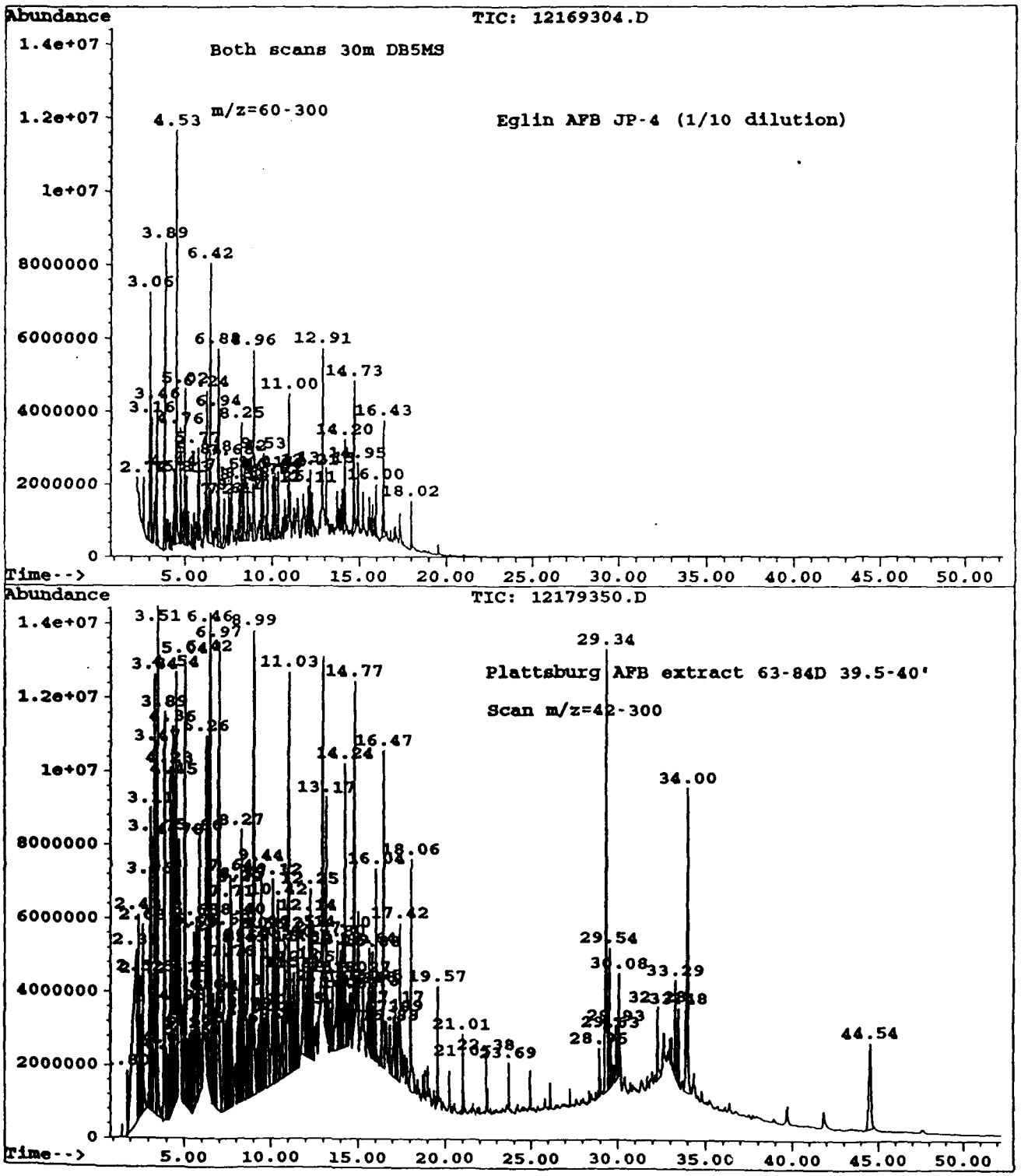
Sample	1,4-DCB	1,2-DCB	Naphthalene	2-methylnaphthalene	1-methylnaphthalene
50 µg/ml	4.49E+01	4.68E+01	4.77E+01	4.83E+01	4.83E+01
Method Blank #1	BLQ	BLQ	BLQ	BLQ	BLQ
1-84F 30-31'	BLQ	BLQ	BLQ	BLQ	BLQ
10-84B 31-32.5'	3.98E-02	BLQ	2.79E+00	4.03E+00	2.69E+00
23-84D 16-16.5'	6.72E-02	1.42E-01	1.24E+00	1.38E+00	1.33E+00
24-84D 16.5-16'	1.27E-01	ND	1.71E+00	3.93E+00	4.02E+00
25-84D 16-16.5'	ND	ND	BLQ	BLQ	BLQ
27-84D 16.5-17' (A)	1.23E-01	N/A	6.33E+00	8.30E+00	6.33E+00
28-84D 16.5-17' (B)	3.21E-02	6.09E-02	6.82E-01	6.11E-01	4.34E-01
29-84D 17-17.5'	1.13E-01	4.51E-01	8.03E+00	9.56E+00	6.92E+00
30-84D 17.5-18'	1.16E-01	4.97E-01	8.97E+00	1.07E+01	7.75E+00
5 µg/ml	4.73E+00	5.29E+00	5.43E+00	4.99E+00	4.86E+00
0.5 µg/ml	5.13E-01	5.19E-01	6.61E-01	5.00E-01	5.00E-01
31-84D 18-18.5'	1.27E-01	5.67E-01	9.49E+00	1.11E+01	7.99E+00
32-84D 18.5-19'	8.71E-02	3.60E-01	6.58E+00	7.94E+00	5.63E+00
33-84D 19-19.5'	8.58E-02	4.13E-01	6.59E+00	7.89E+00	5.59E+00
34-84D 19.5-20'	6.73E-02	3.04E-01	5.20E+00	6.48E+00	4.59E+00
35-84D 20-20.5'	6.65E-02	3.08E-01	4.95E+00	5.99E+00	4.23E+00
36-84D 20.5-21'	3.61E-02	1.46E-01	2.58E+00	3.14E+00	2.16E+00
37-84D 14-14.5'	BLQ	BLQ	BLQ	BLQ	BLQ
48-84D 21-21.5'	5.11E-02	2.41E-01	3.95E+00	4.98E+00	3.54E+00
49-84D 21.5-22'	1.03E-01	4.96E-01	8.13E+00	1.01E+01	7.27E+00
50-84D 22-22.5'	8.00E-02	3.80E-01	6.45E+00	8.17E+00	5.77E+00
50 µg/ml	5.29E+01	5.37E+01	5.16E+01	5.21E+01	5.21E+01
20 µg/ml QC Mix 1	2.33E+01	2.00E+01	N/A	N/A	N/A
100 µg/ml QC Mix 2	N/A	N/A	N/A	N/A	1.07E+02
methylene chloride	BLQ	ND	BLQ	BLQ	BLQ
Method Blank #2	BLQ	ND	BLQ	BLQ	BLQ
0.5 µg/ml	4.62E-01	5.26E-01	4.15E-01	4.42E-01	4.71E-01
51-84D 22.5-23'	9.65E-02	4.51E-01	7.54E+00	9.74E+00	6.99E+00
52-84D 23-23.5'	7.77E-02	4.07E-01	5.82E+00	7.43E+00	5.28E+00
53-84D 23.5-24'	BLQ	BLQ	2.75E-01	BLQ	BLQ
54-84D 35-35.5'	ND	BLQ	BLQ	BLQ	BLQ
55-84D 35.5-36'	ND	BLQ	BLQ	BLQ	BLQ
56-84D 36-36.5'	3.07E-01	1.48E+00	5.15E+00	6.81E+00	4.79E+00
57-84D 36.5-37'	3.67E-01	2.34E+00	9.73E+00	1.17E+01	8.36E+00
58-84D 37-37.5'	8.79E-01	5.09E+00	1.86E+01	2.23E+01	1.64E+01
59-84D 37.5-38'	2.68E+00	1.17E+01	2.39E+01	3.03E+01	2.22E+01
20 µg/ml QC Mix 1	2.26E+01	1.93E+01	N/A	N/A	N/A
5 µg/ml	4.83E+00	5.19E+00	4.83E+00	4.75E+00	4.06E+00
60-84D 38-38.5'	2.57E+00	1.17E+01	1.55E+01	2.01E+01	1.25E+01
61-84D 38.5-39'	8.01E+00	3.61E+01	3.97E+01	5.29E+01	3.53E+01
62-84D 39-39.5'	1.49E+01	6.66E+01	6.74E+01	9.03E+01	6.15E+01
63-84D 39.5-40'	1.98E+01	8.82E+01	8.83E+01	1.16E+02	7.87E+01
64-84D 40-40.5'	1.67E+01	7.34E+01	6.98E+01	9.27E+01	6.26E+01
65-84D 40.5-41'	1.14E+01	5.14E+01	4.79E+01	6.23E+01	4.01E+01
66-84D 41-41.5'	3.91E+00	1.83E+01	1.37E+01	1.84E+01	1.19E+01
67-84D 44-44.3'	ND	ND	BLQ	BLQ	BLQ
methylene chloride	ND	ND	BLQ	BLQ	BLQ
83-84F 28-28.5'	ND	ND	BLQ	BLQ	BLQ
84-84F 30-30.5'	ND	ND	6.15E-01	1.45E+00	8.21E-01
85-84F 30.5-31'	ND	ND	9.21E-01	1.80E+00	9.58E-01
86-84F 31-31.5'	ND	ND	2.45E+00	6.24E+00	3.88E+00
20 µg/ml QC Mix 1	2.28E+01	1.88E+01	N/A	N/A	N/A
100 µg/ml	9.97E+01	9.34E+01	9.03E+01	9.59E+01	1.00E+02

Analyst: D.A. Kovacs BLQ = 0.1 µg/ml except naphthalenes = 0.5 µg/ml

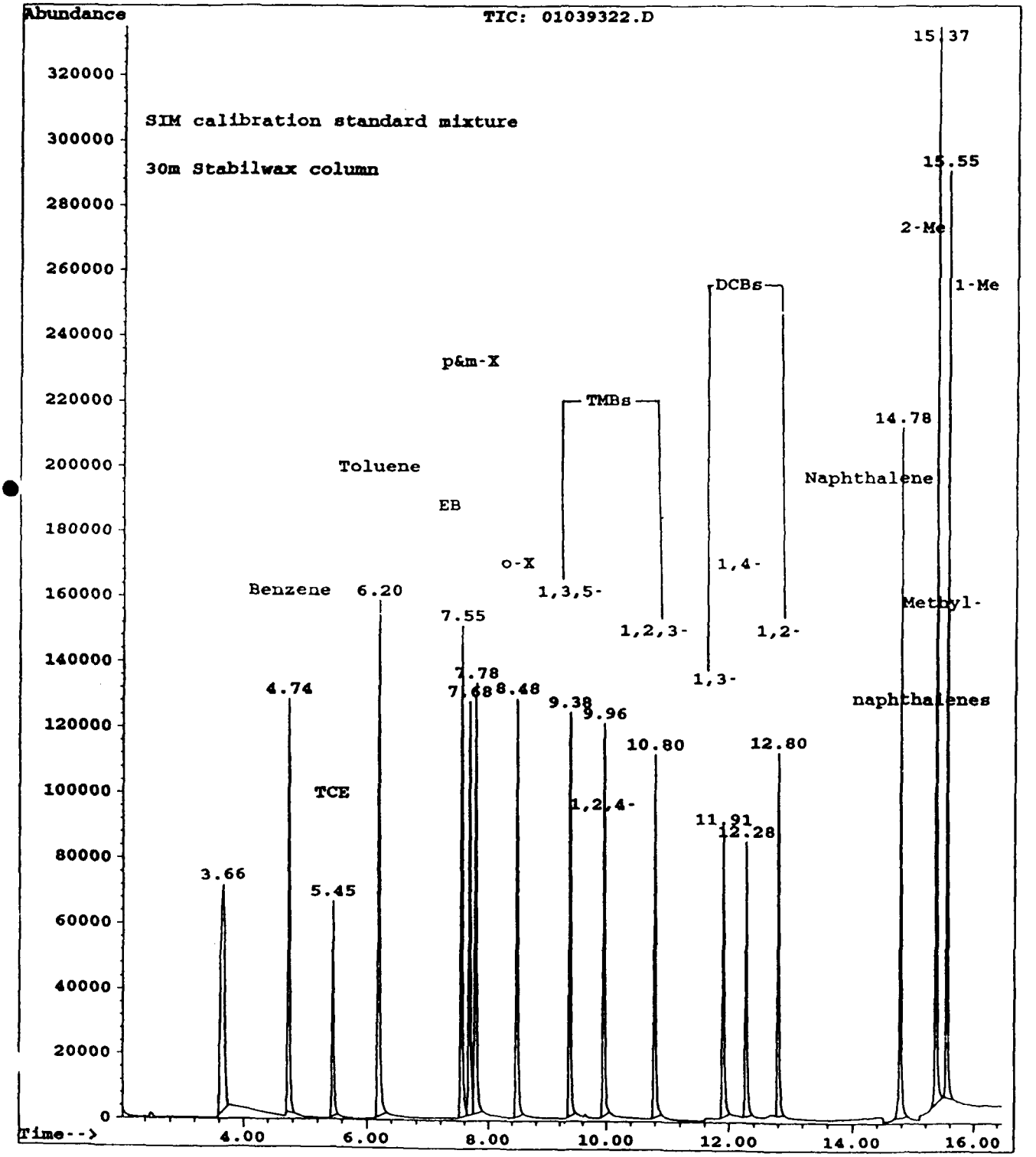
File : C:\HPCHEM\1\DATA\12179310.D
Operator : DAK
Acquired : 18 Dec 93 3:11 pm using AcqMethod SF28-130.M
Instrument : GC/MS
Sample Name: 84D 39.5-40' NO DILUTION
Misc Info : Plattsburg AFB extr. 12/16/93 16.36g
Vial Number: 8



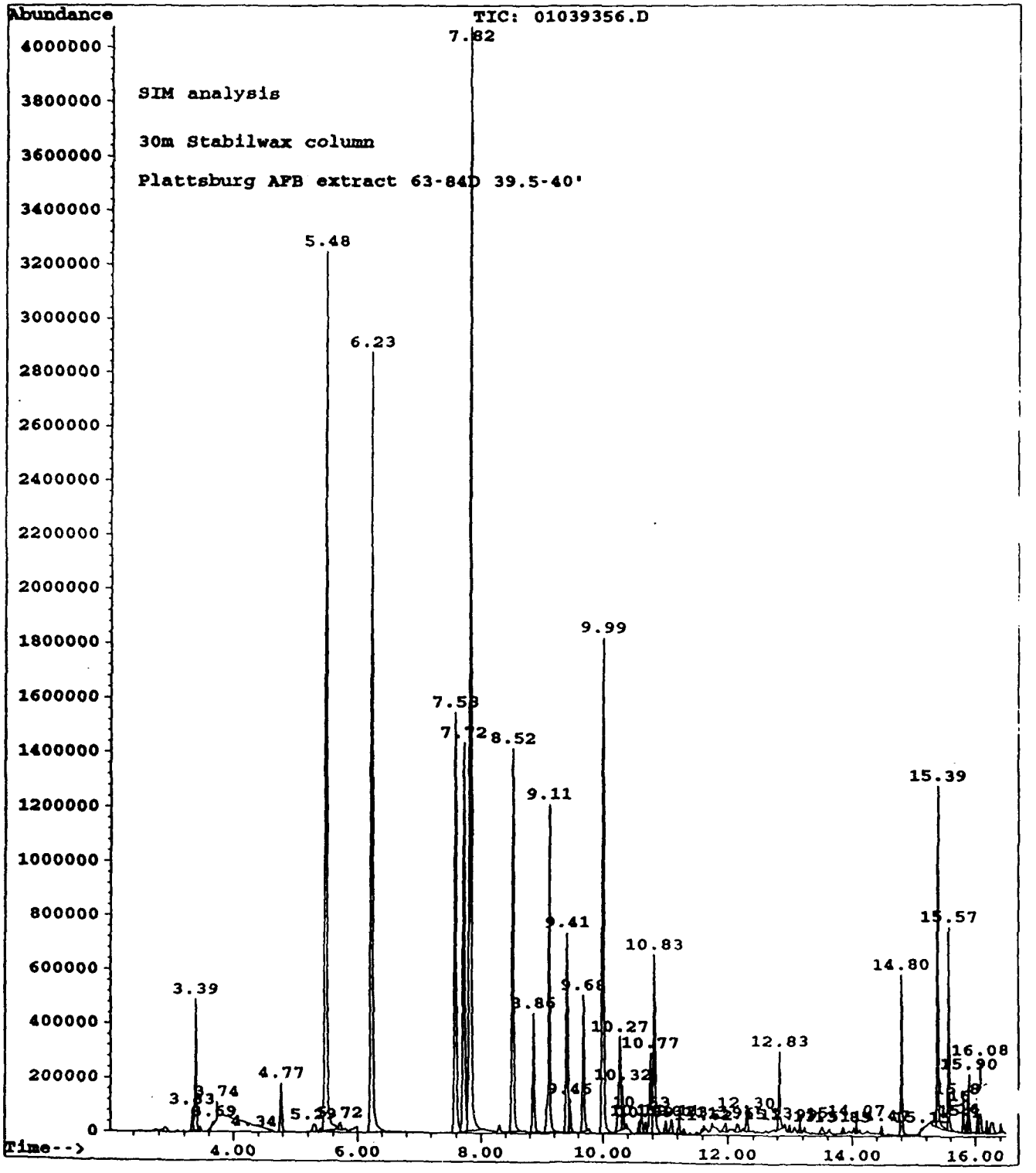
File : C:\HPCHEM\1\DATA\12179350.D
Operator : DAK
Acquired : 17 Dec 93 12:45 pm using AcqMethod SF28SCN2.M
Instrument : GC/MS
Sample Name: 84D 39.5-40' NO DIL. 0.1µl inj.
Misc Info : Plattsburg AFB extr. 12/16/93 16.36g
Vial Number: 8



File : C:\HPCHEM\1\DATA\01039322.D
Operator : DAVID ALLEN KOVACS
Acquired : 4 Jan 94 1:24 pm using AcqMethod 28SIMPT1.M
Instrument : GC/MS
Sample Name: 5 ppm
Misc Info :
Vial Number: 21



File : C:\HPCHEM\1\DATA\01039356.D
Operator : DAVID ALLEN KOVACS
Acquired : 5 Jan 94 3:06 pm using AcqMethod 28SIMPT1.M
Instrument : GC/MS
Sample Name: 63-84D 1/20
Misc Info :
Vial Number: 20



Pfeffer
corrections
4/18/94

PLATTSBU.FD2

PLATTSBURGH AFB, NEW YORK					
Sample Code	Date	Sample Location (ft)Below Ground Surface	TPH mg/kg Dry Basis	OVM	Sample Locations (ft) Above MSL
5	12/07/93	84F 27.5-28	<25	nr	216.5 - 216.
4	"	84F 28-28.5	<25	nr	216. - 215.5
3	"	84F 28.5-29	<25	nr	215.5 - 215.
2	"	84F 29-29.5	<25	nr	215. - 214.5
8	"	84F 30-30.5	80	nr	214. - 213.5
7	"	84F 30.5-31	<25	nr	213.5 - 213.
6	"	84F 31-31.5	<25	nr	213. - 212.5
78	12/10/93	84F 25.5-26	<25	2	218.5 - 218.
79	"	84F 26-26.5	<25	1	218. - 217.5
80	"	84F 26.5-27	<25	3	217.5 - 217.
81	"	84F 27-27.5	<25	1	217. - 216.5
82	"	84F 27.5-28	<25	1	216.5 - 216.
83	"	84F 28-28.5	<25	1	216. - 215.5
75	"	84F 28.5-29	<25	1	215.5 - 215.
76	"	84F 29-29.5	64	6	215. - 214.5
77	"	84F 29.5-30	106	44	214.5 - 214.
84	"	84F 30-30.5	762	208	214. - 213.5
85	"	84F 30.5-31	812	408	213.5 - 213.
86	"	84F 31-31.5	2,050	236	213. - 212.5

PLATTSBURGH AFB, NEW YORK					
Sample Code	Date	Sample Location (ft)Below Ground Surface	TPH mg/kg Dry Basis	OVM	Sample Locations (ft) Above MSL
9	1207/93	84L 31.5-32.5	34	nr	214.5 - 213.5
10	12/08/93	84B 31-32.5	1,890	nr	215. - 213.5
11	"	84B 31.5-33	nr	nr	214.5 - 213.
12	12/08/93	84D 3-3.5	<25	nr	255. - 254.5
13	"	84D 3.5-4	<25	nr	254.5 - 254.
14	"	84D 4-4.5	<25	nr	254. - 253.5
15	"	84D 4.5-5	<25	nr	253.5 - 253.
16	"	84D 5-5.5	<25	nr	253. - 252.5
17	"	84D 5.5-6	<25	nr	252.5 - 252.
18	"	84D 6-6.5	176	nr	252. - 251.5
19	"	84D 7-7.5	<25	nr	251. - 250.5
20	"	84D 7.5-8	<25	0	250.5 - 250.
21	"	84D 8-8.5	<25	3	250. - 249.5
22	"	84D 8.5-9	<25	2	249.5 - 249.
47	"	84D 9-9.5	<25	1	249. - 248.5
46	"	84D 9.5-10	<25	nr	248.5 - 248.
45	"	84D 10-10.5	<25	nr	248. - 247.5
44	"	84D 10.5-11	<25	2	247.5 - 247.

PLATTSBURGH AFB, NEW YORK					
Sample Code	Date	Sample Location (ft)Below Ground Surface	TPH mg/kg Dry Basis	OVM	Sample Locations (ft) Above MSL
43	12/08/93	84D 11-11.5	<25	3	247. - 246.5
42	"	84D 11.5-12	<25	1	246.5 - 246.
41	"	84D 12-12.5	<25	3	246. - 245.5
40	"	84D 12.5-13	<25	2	245.5 - 245.
39	"	84D 13-13.5	<25	1	245. - 244.5
38	"	84D 13.5-14	<25	1	244.5 - 244.
37	"	84D 14-14.5	<25	0	244. - 243.5
26	"	84D 14.5-15	<25	1	243.5 - 243.
25	"	84D 15-15.5	94	45	243. - 242.5
24	"	84D 15.5-16	4,120	297	242.5 - 242.
23	"	84D 16-16.5	2,080	655	242. - 241.5
27	"	84D 16.5-17	5,180	584	241.5 - 241.
28	"	"	389	nr	241.5 - 241.
29	"	84D 17-17.5	5,400	663	241. - 240.5
30	"	84D 17.5-18	4,480	591	240.5 - 240.
31	"	84D 18-18.5	4,230	709	240. - 239.5
32	"	84D 18.5-19	3,450	616	239.5 - 239.
33	"	84D 19-19.5	3,030	610	239. - 238.5
34	"	84D 19.5-20	2,880	673	238.5 - 238.
35	"	84D 20-20.5	2,360	481	238. - 237.5

PLATTSBURGH AFB, NEW YORK					
Sample Code	Date	Sample Location (ft)Below Ground Surface	TPH mg/kg Dry Basis	OVM	Sample Location (ft) Above MSL
36	12/08/93	84D 20.5-21	1,150	631	237.5 - 237.
48	"	84D 21-21.5	1,790	558	237. - 236.5
49	"	84D 21.5-22	2,340	488	236.5 - 236.
50	"	84D 22-22.5	2,220	584	236. - 235.5
51	"	84D 22.5-23	3,240	562	235.5 - 235.
52	"	84D 23-23.5	3,710	713	235. - 234.5
53	"	84D 23.5-24	194	501	234.5 - 234.
54	12/09/93	84D 35-35.5	112	42	222. - 222.5
55	"	84D 35.5-36	99	38	222.5 - 222.
56	"	84D 36-36.5	3,380	219	222. - 221.5
57	"	84D 36.5-37	4,780	471	221.5 - 221.
58	"	84D 37-37.5	7,570	408	221. - 220.5
59	"	84D 37.5-38	10,100	490	220.5 - 220.
60	"	84D 38-38.5	18,800	521	220. - 219.5
61	"	84D 38.5-39	39,400	414	219.5 - 219.
62	"	84D 39-39.5	75,300	454	219. - 218.5
63	"	84D 39.5-40	125,000	340	218.5 - 218.
64	"	84D 40-40.5	120,000	490	218. - 217.5
65	"	84D 40.5-41	78,700	348	217.5 - 217.
66	"	84D 41-41.5	19,400	521	217. - 216.5

PLATTSBURGH AFB, NEW YORK					
Sample Code	Date	Sample Location (ft)Below Ground Surface	TPH mg/kg Dry Basis	OVM	Sample Locations (ft) Above MSL
67	12/09/93	84D 44-44.3	<25	5	214. - 213.7
68	12/09/93	84P 26-26.5	<25	1	219. - 218.5
69	"	84P 26.5-27	<25	1	218.5 - 218.
70	"	84P 27-27.5	<25	1	218. - 217.5
71	"	84P 27.5-28	39	1	217.5 - 217.
72	"	84P 28-28.5	<25	33	217. - 216.5
73	"	84P 28.5-29	<25	14	216.5 - 216.
74	"	84P 29-29.5	35	11	216. - 215.5

SR#SF-0-28 / Kampbell / Plattsburgh AFB, NY all conc. are ug/g

Sample I.D.	Dilution Factor	JP-4	Fuel Carbon (JP-4 x 0.85)
10 84B 31-32.5'	1	1550.00	1320.00
37 84D 14-14.5'	1	2.09	1.78
25 84D 15-15.5'	1	19.40	16.50
24 84D 15.5-16'	1	4370.00	3710.00
23 84D 16-16.5'	1	1330.00	1130.00
27 84D 16.5-17' (A)	1	3140.00	2670.00
28 84D 16.5-17' (B)	1	571.00	485.00
29 84D 17-17.5'	1	2880.00	2450.00
30 84D 17.5-18'	1	3000.00	2550.00
31 84D 18-18.5'	1	3290.00	2800.00
32 84D 18.5-19'	1	2340.00	1990.00
33 84D 19-19.5'	1	2200.00	1870.00
34 84D 19.5-20'	1	1810.00	1540.00
35 84D 20-20.5'	1	1740.00	1480.00
36 84D 20.5-21'	1	795.00	676.00
48 84D 21-21.5'	1	1310.00	1110.00
49 84D 21.5-22'	1	2410.00	2050.00
50 84D 22-22.5'	1	1940.00	1650.00
51 84D 22.5-23'	1	2240.00	1900.00
52 84D 23-23.5'	1	1860.00	1580.00
53 84D 23.5-24'	1	79.60	67.70
54 84D 35-35.5'	1	19.10	16.20
55 84D 35.5-36'	1	10.90	9.27
56 84D 36-36.5'	1	1750.00	1490.00
57 84D 36.5-37'	1	3440.00	2920.00
58 84D 37-37.5'	1	7840.00	6660.00
59 84D 37.5-38'	1	12600.00	10700.00
60 84D 38-38.5'	1	8000.00	6800.00
61 84D 38.5-39'	10	22500.00	19100.00
62 84D 39-39.5'	10	39000.00	33200.00
63 84D 39.5-40'	10	52700.00	48600.00
64 84D 40-40.5'	10	44300.00	37700.00
65 84D 40.5-41'	10	28800.00	24500.00
66 84D 41-41.5'	10	7900.00	6720.00
67 84D 44-44.3'	1	2.73	2.32
83 84F 28-28.5'	1	nd	
84 84F 30-30.5'	1	591.00	502.00
85 84F 30.5-31'	1	618.00	525.00
86 84F 31-31.5'	1	1770.00	1500.00
1 84F 30-31'	1	139.00	118.00

NOTE: all reported values are corrected for dilution factors where applicable

SR#SF-0 / Kampbell / QC Table all conc. are ng/ul

Sample I.D.	Date Analyzed	JP-4
blank MeCl2	27DEC93	1.01
Method blk #1		1.08
Method blk #2		1.43
500 ng/ul jp4		544.00
1000 ng/ul jp4		993.00
5000 ng/ul jp4		4900.00
10000 ng/ul jp4		9240.00
50000 ng/ul jp4		48800.00
blank MeCl2	08JAN94	1.08
5000 ng/ul jp4		5320.00
10000 ng/ul jp4		10500.00
50000 ng/ul jp4		50600.00

MeCl2 = methylene chloride solvent blank
jp4 = JP-4 fuel standard

GROUND WATER DATA

DECEMBER 1993

DIVIDER.DOC

MANTECH

Ref: 94-DK2/vg

January 24, 1994

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SAV

Dear Don:

This report contains the results of my GC/MSD analysis of your Plattsburg AFB "floating product" sample "MW02-015" (Service Request #SF-0-40) which was analyzed for identification and semiquantitation of organic compounds. The information in this report is divided into three main areas:

i. a complete chromatogram of the sample (Scan m/z=44-450) and a serial expansion of this chromatogram with the identity of some peaks noted.

ii. a report of peak identities obtained by a ChemStation mass spectral library search of the sample. Note that each integrated peak is given a peak number, a retention time and an area%.

iii. a listing of concentration estimates for each integrated peak. To obtain peak identity information, cross-reference the peak # in the quantitation list with the peak # on the mass spectral library search. Also included, is a Figure showing the mathematically defined standard curve used to generate the peak concentration estimates. I have reported previous work where similar calibration curves were generated using paraffins, isoparaffins, cycloalkanes, olefins, aromatics and PNAs (>100 compounds per curve). This previous work also showed that a reasonably similar curve could be generated by simply using a mixture of paraffins and PNAs (including naphthalene). I have used this abbreviated form to provide the semiquantitative information in this report.

Analysis was based on a 1:25 dilution of the sample. A detailed ChemStation method report for this analysis has been recorded. Chromatographic separation was performed using 30m X 0.25mm Restek "Stabilwax" capillary column in series with a 100m X 0.25mm J&W DB-1 "Petrocol" capillary column (total length = 130m). The injection volume was 0.1µl injected on-column. I routinely use this method for analysis petroleum compounds (such as JP-4) in methylene chloride soil core extracts.

ManTech Environmental Technology, Inc.

P.O. Box 12313, 2 Triangle Drive, Research Triangle Park, North Carolina 27709 919-549-0611 FAX 919-549-4665

Incidently, only trace amounts of benzene and t-DCE were observed. These levels were below the integration threshold set for peak detection and so are not reported in the mass spectral library search report. Also, other diotic esters possibly of C9 and C10 were also tentatively identified in significant concentration eluting after the adipate (C6,rt=122 min.) but are not shown on the chromatogram included in this report.

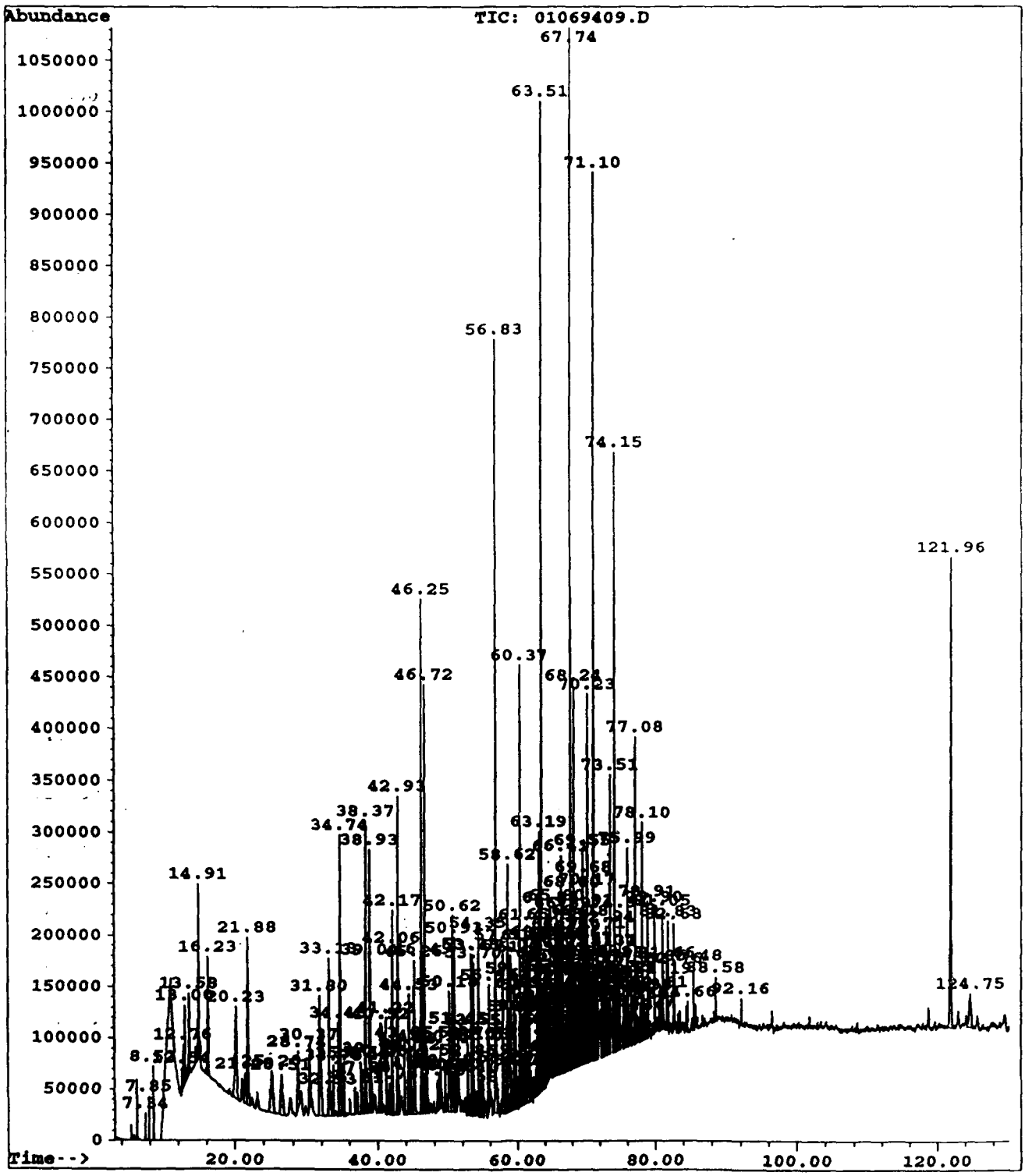
If you need additional information, please feel free to contact me.

Sincerely,

David A. Kovacs

xc: R.L. Cosby
J.L. Seeley
G. Smith
J. Wilson

File : C:\HPCHEM\1\DATA\01069409.D
Operator :
Acquired : 7 Jan 94 12:25 pm using AcqMethod SF40-130.M
Instrument : GC/MS
Sample Name: MW02-15 PRODUCT
Misc Info : Plattsburg D. Kampbell 12/16/93
Vial Number: 8



SR# SF-0-40 Dr. Kampbell Plattsburg AFB Sample MW02-015 Product GC/MSD Semiquantitative

Peak#	Retention Time	mg/ml
1	7.343	1.52E+00
2	7.855	2.48E+00
3 (Hexane)	8.519	4.09E+00
4	12.539	2.54E+00
5	12.758	3.50E+00
6	13.003	7.07E+00
7	13.581	8.07E+00
8	14.909	1.68E+01
9 (Heptane)	16.226	1.17E+01
10	20.232	1.74E+01
11	21.487	4.21E+00
12 (TCE)	21.876	1.64E+01
13	25.198	8.34E+00
14	26.513	6.72E+00
15	28.738	6.11E+00
16	30.374	5.41E+00
17	31.803	1.46E+01
18	32.926	9.99E-01
19 (Toluene)	33.128	8.97E+00
20	33.779	1.85E+00
21	34.431	3.11E+00
22 (Octane)	34.738	1.46E+01
23	35.273	1.79E+00
24	36.807	1.27E+00
25	37.644	1.56E+00
26	37.862	1.16E+00
27	38.368	1.07E+01
28	38.928	7.23E+00
29	39.039	4.18E+00
30	39.175	1.90E+00
31	40.26	1.65E+00
32	40.518	2.48E+00
33	41.216	2.87E+00
34	41.728	8.49E-01
35	42.057	4.61E+00
36	42.168	5.39E+00
37	42.78	1.75E+00

Peak#	Retention Time	mg/ml
38	42.926	8.55E+00
39	43.853	2.17E+00
40	44.356	2.21E+00
41	44.53	3.50E+00
42	44.637	9.61E-01
43	44.817	1.56E+00
44 (Ethylbenzene)	45.258	5.44E+00
45 (Nonane)	46.252	1.53E+01
46 (p-Xylene)	46.494	4.92E+00
47 (m-Xylene)	46.719	1.37E+01
48	47.025	2.48E+00
49	48.451	9.50E-01
50	48.688	9.91E-01
51	48.937	2.09E+00
52	49.572	1.17E+00
53	50.178	4.54E+00
54	50.624	5.26E+00
55	50.802	7.16E-01
56 (o-Xylene)	50.926	4.57E+00
57	51.281	1.04E+00
58	51.448	1.09E+00
59	52.761	1.97E+00
60	52.856	1.07E+00
61	53.281	3.18E+00
62	53.468	3.33E+00
63	53.549	1.30E+00
64	53.701	3.03E+00
65	54.347	3.25E+00
66	54.76	1.79E+00
67	55.055	7.48E-01
68	55.657	1.23E+00
69	55.72	1.06E+00
70	55.904	2.57E+00
71 (Decane)	56.827	1.76E+01
72 (1,3,5-trimethylbenzene)	57.907	4.11E+00
73	58.152	3.89E-01
74	58.392	6.77E-01

Peak#	Retention Time	mg/ml
75	58.623	3.77E+00
76	59.045	3.24E+00
77	59.541	3.03E+00
78	59.747	2.49E+00
79	59.914	7.90E-01
80 (1,2,4-trimethylbenzene)	60.375	6.96E+00
81	60.654	1.48E+00
82	60.79	6.10E-01
83	60.979	1.53E+00
84	61.186	1.75E+00
85	61.411	2.23E+00
86	61.66	1.99E+00
87	61.835	2.18E+00
88	62.034	6.24E-01
89	62.658	3.85E-01
90	62.839	1.07E+00
91	62.941	1.48E+00
92 (1,2,3-trimethylbenzene)	63.193	3.56E+00
93	63.338	2.00E+00
94 (undecane , C11)	63.511	1.20E+01
95	63.687	1.19E+00
96	63.777	1.39E+00
97	64.027	1.35E+00
98	64.203	3.72E-01
99	64.385	1.06E+00
100	64.443	9.99E-01
101	64.568	6.53E-01
102	64.669	1.46E+00
103	64.909	2.43E+00
104	65.218	4.49E-01
105	65.292	1.00E+00
106	65.489	1.18E+00
107	65.55	1.57E+00
108	65.644	1.37E+00
109	65.762	1.06E+00
110	65.803	1.99E+00
111	66.047	1.11E+00

Peak#	Retention Time	mg/ml
112	66.091	1.56E+00
113	66.255	1.55E+00
114	66.414	2.06E+00
115	66.526	1.55E+00
116	66.689	1.51E+00
117	66.91	1.15E+00
118	67.214	8.27E-01
119	67.268	6.32E-01
120	67.373	1.36E+00
121	67.582	1.60E+00
122	67.643	4.90E-01
123 (C12)	67.736	1.11E+01
124	67.901	7.88E-01
125	68.005	2.30E+00
126	68.094	1.86E+00
127	68.242	5.28E+00
128	68.443	1.28E+00
129	68.54	1.16E+00
130	68.782	8.09E-01
131	68.872	6.59E-01
132	68.956	7.56E-01
133	69.038	6.10E-01
134	69.087	7.49E-01
135	69.18	2.65E+00
136	69.549	3.32E+00
137	69.676	2.20E+00
138	69.771	1.38E+00
139	69.909	3.53E+00
140	70.168	1.44E+00
141	70.231	5.07E+00
142	70.48	1.39E+00
143	70.524	6.42E-01
144	70.631	1.69E+00
145	70.936	5.22E-01
146	70.98	7.55E-01
147 (C13)	71.103	9.32E+00
148	71.195	1.01E+00

Peak#	Retention Time	mg/ml
149	71.39	1.29E+00
150	71.473	8.28E-01
151	71.619	1.62E+00
152	71.71	1.83E+00
153	72.354	2.13E+00
154	72.671	1.23E+00
155	72.773	9.58E-01
156	72.94	2.09E+00
157	73.072	1.17E+00
158	73.168	6.78E-01
159	73.312	1.12E+00
160	73.509	2.70E+00
161	73.939	8.32E-01
162	74.051	4.80E-01
163 (C14)	74.148	5.49E+00
164	74.275	1.28E+00
165	74.429	1.22E+00
166	74.62	1.11E+00
167 (Naphthalene)	74.942	1.37E+00
168	75.416	7.24E-01
169	75.553	9.46E-01
170	75.868	4.50E-01
171	75.989	2.45E+00
172	76.176	5.57E-01
173	76.591	1.05E+00
174 (C15)	77.08	2.98E+00
175	77.338	3.23E-01
176	77.856	5.36E-01
177 (2-methylnaphthalene)	78.103	1.99E+00
178	78.38	7.40E-01
179	78.769	2.86E-01
180 (1-methylnaphthalene)	78.911	1.40E+00
181	79.896	1.20E+00
182	80.611	3.66E-01
183	81.046	1.11E+00
184	81.188	5.82E-01
185	81.661	5.72E-01

Peak#	Retention Time	mg/ml
186	81.834	1.37E+00
187	82.63	1.04E+00
188	82.759	6.43E-01
189	84.657	2.65E-01
190	85.476	5.78E-01
191	88.581	3.94E-01
192	92.158	3.87E-01
193	121.961	1.02E+01
194	124.748	1.37E+00

MANTECH

Ref: 93-LP35/vg

December 21, 1993

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SAV

Dear Don:

Below are TOC results for a set of nine aqueous samples from Plattsburg AFB submitted December 9, 1993 as part of Service Request #SF-0-28. The analyses were done December 10, 1993 using RSKSOP-102.

Blanks, duplicates, and a known AQC sample were analyzed along with your samples for quality control.

Sincerely,

Lynda Pennington

Lynda Pennington

xc: R.L. Cosby
J.L. Seeley
J. Wilson jlw

Sample	mg/L TOC
84 E WS3	7.6
84 M WS1	36.6
84 M WS2	3.1
84 N WS1	22.5
84 N WS1 Dup	22.4
84 N WS2	20.0
84 O WS1	16.2
84 O WS2	14.3
84 O WS2 Dup	14.2
MW-02-005	5.3
MW-02-044	1.4
MW-02-044 Dup	1.3
WP030 II	13.7
	14.0
WP030 II T.V.	14.0

ManTech Environmental Technology, Inc.

P.O. Box 12313, 2 Triangle Drive, Research Triangle Park, North Carolina 27709 919-549-0611 FAX 919-549-4665

PLATTSBURGH AF3, NEW YORK

Field Data Plattsburgh AFB, NY						
Sample	Date	pH	Redox	Cond	Total Alk	Ferrous Iron
84-CPT-B1	12/3/93	-	-24	1236	179	.5
84-CPT-B2	12/3/93	-	+150	516	135	<.05
84-F-WS1	12/5/93	7.1	-70	772	285	2.6
84-F-WS2	12/5/93	7.4	-92	794	140	5.3
84-F-WS3	12/5/93	7.3	-85	725	224	2.3
840F-WS4	12/5/93	7.8	+90	410	136	<.05
84-E-WS1	12/6/93	7.4	-50	695	268	1.2
84-E-WS2	12/6/93	7.5	-75	784	290	1.2
84-E-WS3	12/6/93	7.8	+127	416	35	<.05
MW-26	12/6/93	7.8	+150	627	-	<.05
MW-27	12/6/93	12.1	-90	8670	-	-
MW-19	12/6/93	7.4	-130	644	-	10.3
MW-20	12/6/93	7.3	-120	695		10.7
MW-30	12/6/93	7.7	-110	288	-	<.05
MW-40	12/6/93	8.2	+10	513	-	<.05
MW-41	12/6/93	7.9	+5	682	-	<.05
MW-42	12/6/93	7.9	-40	330	-	<.05
84-M-WS1	12/6/93	7.2	-100	884	290	8.9
84-M-WS2	12/6/93	8.4	7	370	161	<.05
84-N-WS1	12/6/93	7.1	-70	725	288	2.9
84-N-WS2	12/7/93	7.6	-74	720	132	.8
MW-02-031	12/7/93		-122		-	7.7
MW-02-006	12/7/93		-140		-	3.5

Field Data Plattsburgh AFB, NY						
Sample	Date	pH	Redox	Cond	Total Alk	Ferrous Iron
MW-02-005	12/7/93	7.4	-106	933	261	4.9
MW-02-44	12/8/93	6.9	-180	1172	110	<.05
84-0-WS1	12/8/93	7.2	-100	590	267	3.7
84-0-WS1	12/8/93	7.0	-90	640	230	4.6

MANTECH ENVIRONMENTAL TECHNOLOGY

Ref: 93-MW51/vg
93-TH52/vg
93-PR59/vg

December 16, 1993

Dr. Don Kampbell/Dr. John Wilson
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SAV

Dear Don/John:

Attached are the results of 31 microcosm samples submitted to ManTech Environmental as part of Service Request #SF-0-28. The samples were received on December 6, 9, and 12, 1993 and analyzed immediately. The methods used for analysis were EPA methods 353.1, 350.1, 360.1, 150.1 for NO^-_2 + NO^-_3, NH_3, T-P, and T-Alk, Cl^- and SO^-_4 were analyzed using Water's capillary electrophoresis method N-601. Blanks, spikes, duplicates, and known AQC samples were analyzed along with the samples for quality assurance.

If you have any questions concerning these results, please feel free to contact us.

Sincerely,

Mark White

Tim Hensley

Priscilla Rhynes

xc: R.L. Cosby
J.L. Seeley jle

ManTech Environmental Technology, Inc.
P.O. Box 12313, 2 Triangle Drive, Research Triangle Park, North Carolina 27709 919-549-0611 FAX 919-549-4665

Sample	mg/l $NO_2^- + NO_3^-$ (N)	mg/l NH_3 (N)	mg/l T-P	mg/l T-Alk	mg/l Cl^-	mg/l SO_4^{-2}
84-CPT-B1	.19	1.36	1.47	189	222	5.49
84-CPT-B2	.19	.27	1.48	162	69.2	18.8
84-CPT-B2 Dup	.18	.27				
84E-WS-1	<.05	2.15	4.56	794	54.6	5.78
84E-WS-2	.05	2.12	2.27	559	65.0	7.15
84E-WS-2 Dup			2.24		64.7	7.17
84E-WS-3	.15	.23	.68	129	35.7	20.3
84F-Water 1	.06	2.60	3.27	418	80.0	5.43
84F-WS-2	.06	6.11	1.90	457	72.0	<.5
84F-WS-2 Dup	.06	6.13				
84F-WS-3	<.05	3.99	2.25	368	78.5	<.5
84F-WS-4	<.05	.36	.96	209	37.3	22.0
84F-WS-4 Dup				203		
84M-WS-1	.12	4.98	16.7	278	94.3	3.44
84M-WS-2	.14	1.09	7.15	126	26.9	14.6
84N-WS-1	.12	1.66	4.97	292	54.6	.21
84N-WS-2	.16	1.64	3.30	244	68.8	.34
84N-WS-2 Dup					70.0	.33
84O-WS-1	.17	1.51	3.33	268	28.3	.33
84O-WS-1 Dup	.17	1.52				
84O-WS-2	.13	2.83	1.48	234	55.2	.50
MW-02-005	.10	.64	.05	232	142	9.73
MW-02-006	.12	1.69	.05	109	193	25.1
MW-02-007	.10	.25	.13	113	8.22	11.7
MW-02-014	<.05	2.10	.06	277	63.5	<.5
MW-02-014 Dup	<.05	2.08				
MW-02-015	<.05	.59	.08	96.0	26.6	23.1
MW-02-019	.11	1.26	.08	262	42.4	.08
MW-02-019 Dup			.08			
MW-02-020	.12	3.04	<.05	322	25.1	<.5
MW-02-020 Dup					24.8	<.5
MW-02-021	.55	.59	2.20	261	9.14	22.0
MW-02-021 Dup	.53	.56				
MW-02-026	.44	<.05	<.05	111	103	19.6
MW-02-026 Dup				113		
MW-02-027	.51	.17	<.05	1590	84.7	1.79
MW-02-027 Dup				1517	82.6	1.88
MW-02-030	.09	.20	.08	110	13.5	11.5
MW-02-040	26.5	<.05	<.05	136	2.14	5.53
MW-02-041	.69	<.05	<.05	350	11.2	1.66
MW-02-042	.13	.17	.06	157	11.3	.26
MW-02-043	31.1	<.05	.09	180	.93	13.0
MW-02-044	94.9	.83	.30	195	<.05	9.00
MW-02-044 Dup	96.6		.23	197		
AQC	7.16	9.74	3.00	----	177	40.8
	7.15	9.74				
	7.15					
True Value	7.10	9.80	3.20	----	178	42.0
Spike Recovery	101%	98%	100%	----	96%	97%
	99%	101%			94%	99%

SF-0-28 DATA

GW; already - db

ANALYZED 12/8-15/93

SAMPLE	CARBON DIOXIDE	METHANE	ETHYLENE
LAB BLANK	ND	0.0004	ND
84CPT-B1	176	0.030	ND
84CPT-B2	121	0.016	ND
MW-02-006	117	0.007	ND
MW-02-007	80	0.204	ND
MW-02-019	278	0.111	0.039
MW-02-019 LAB DUP	260	0.103	0.042
MW-02-020	381	0.295	0.004
MW-02-021	290	0.075	ND
MW-02-026	102	ND	ND
MW-02-027	ND	0.004	0.0006
MW-02-030	102	0.168	0.0002
MW-02-030 FIELD DUP	101	0.160	0.0002
LAB BLANK	ND	ND	ND
MW-02-040	119	0.009	ND
MW-02-041	334	0.160	0.0005
MW-02-042	164	0.503	0.0035
MW-02-043	225	0.001	ND
MW-02-014	319	0.307	0.0032
MW-02-014 LAB DUP	293	0.293	0.0032
MW-02-015	107	0.0004	ND
84-FIELD BLANK	0.902	0.0002	ND
84E WS-1	490	0.099	0.2198
84E WS-2	426	0.322	0.0055
84F WATER 1	550	0.512	0.1287
84F WATER 1 FIELD DUP	549	0.501	0.1171
LAB BLANK	ND	0.0003	ND
84F WS-2	356	0.134	0.0012
84F WS-3	323	0.088	0.0009
84F WS-4	138	0.011	ND
84E WS-3	124	0.008	ND
84M WS-1	899	0.121	0.0284
84M WS-2	369	0.020	ND
84N WS-1	484	0.100	0.4738
84N WS-2	374	0.162	0.0021
84O WS-1	618	0.092	0.0397
84O WS-2	303	0.123	0.0023
LAB BLANK	ND	ND	ND
MW-02-005	250	0.005	0.0005
MW-02-005 LAB DUP	229	0.004	0.0004
MW-02-044	294	0.001	ND
100 PPM CO2	113.8	ND	ND
1000 PPM CO2	998.3	ND	ND

SF-0-28 DATA

ANALYZED 12/8-15/93

SAMPLE	CARBON DIOXIDE	METHANE	ETHYLENE
1 % CO2	1.0	ND	ND
5 % CO2	5.0	ND	ND
10 % CO2	10.4	ND	ND
15 % CO2	14.6	ND	ND
10 PPM CH4	ND	11.21	ND
100 PPM CH4	ND	98.09	ND
1000 PPM CH4	ND	1000.25	ND
1 % CH4	ND	0.94	ND
10 PPM C2H4	ND	ND	10.15
100 PPM C2H4	ND	ND	95.08
1000 PPM C2H4	ND	ND	1020.10
1 % C2H4	ND	ND	1.00
LIMITS OF QUANTITATION			
LOWER	0.169	0.0009	0.0026
UPPER	1521	0.945	2.64

UNITS FOR SAMPLES ARE mg/L.

UNITS FOR THE STANDARDS CORRESPOND TO THE UNITS IN THE SAMPLE COLUMN.

PLATTSBURG AFB SAMPLES

Sample	mg/L TOC
84 CPt-B1	11.3
84 CPt-B2	6.2
MW-02-006	4.8
MW-02-007	0.5
MW-02-019	11.3
MW-02-020	17.3
MW-02-021	4.6
MW-02-026	0.8
MW-02-026 Dup	0.8
MW-02-027	3.4
MW-02-030	0.9
MW-02-040	1.4
MW-02-041	11.4
MW-02-042	6.0
MW-02-043	1.0
MW-02-014	37.4
MW-02-015	5.5
84 Field Blank	0.1
84E WS-1	15.5
84E WS-2	36.7
84E WS-2 Dup	36.5
84F Water 1	21.0
84F WS-2	22.5
84F WS-3	17.7
84F WS-4	3.6
WP030	13.9
	13.9
	13.8
	13.7
WP030 T.V.	14.0

Printed 16-Dec-93 SR:SF-0-28 OI-P&T/GC-PID:FID Plattsburg AFB Aqueous Samples for Dr. Kampbell Units=ng/mL Analyst:L.Secre

SAMPLE NAME	BENZENE	TOLUENE	ETHYLBENZENE	p-XYLENE	m-XYLENE	o-XYLENE	1,3,5-TMB	1,2,4-TMB	1,2,3-TMB	FUEL CARBON
QC, OBSERVED, PPB	4.62E+01	4.73E+01	4.83E+01	4.90E+01	4.84E+01	4.86E+01	4.90E+01	5.07E+01	4.76E+01	N/A
QC, TRUE VALUE, PPB	5.00E+01	5.00E+01	5.00E+01	5.00E+01	5.00E+01	5.00E+01	5.00E+01	5.00E+01	5.00E+01	N/A
100 PPB	9.95E+01	9.94E+01	9.92E+01	9.92E+01	9.92E+01	9.93E+01	1.00E+02	9.91E+01	9.91E+01	N/A
84 CPT-B-1	7.10E+01	5.29E+01	1.62E+01	8.53E+00	2.47E+01	1.49E+01	BLQ	2.24E+00	2.46E+00	2.98E+02
82 CPT-B2	ND	BLQ	BLQ	ND	BLQ	BLQ	ND	ND	ND	BLQ
MW-02-006B	7.32E+00	1.01E+02	1.44E+02	2.00E+02	5.15E+02	2.83E+02	1.80E+02	5.88E+02	3.08E+02	3.82E+03
MW-02-006B Field Dup.	7.98E+00	2.63E+02	1.39E+02	1.47E+02	3.67E+02	1.87E+02	4.35E+01	1.22E+02	6.83E+01	1.88E+03
MW-02-007	ND	ND	ND	ND	ND	ND	ND	ND	BLQ	BLQ
MW-02-019	3.21E+02	3.27E+02	4.33E+02	3.52E+02	7.03E+02	2.63E+02	6.59E+01	1.79E+02	9.32E+01	4.41E+03
MW-02-020	2.85E+02	1.46E+02	5.63E+02	5.34E+02	1.19E+03	4.19E+02	1.18E+02	3.22E+02	1.57E+02	7.56E+03
MW-02-21	ND	ND	ND	ND	BLQ	ND	ND	ND	ND	BLQ
MW-02-26	ND	BLQ	BLQ	BLQ	3.89E+00	2.55E+00	1.19E+00	1.98E+00	1.66E+00	2.57E+01
MW-02-27	ND	BLQ	ND	ND	9.97E-01	BLQ	BLQ	BLQ	BLQ	BLQ
MW-02-30	1.85E+01	1.06E+00	1.99E+01	3.00E+00	4.72E+00	1.48E+00	ND	1.10E+00	BLQ	1.45E+02
MW-02-30 Field Dup.	1.98E+01	1.05E+00	2.16E+01	2.37E+00	3.04E+00	9.69E-01	BLQ	BLQ	BLQ	1.58E+02
500 PPB	4.94E+02	5.00E+02	4.96E+02	4.95E+02	4.98E+02	4.99E+02	4.93E+02	4.95E+02	4.96E+02	N/A
GC LAB BLANK	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A
84 FIELD BLANK	2.42E+00	BLQ	ND	ND	ND	ND	ND	ND	ND	4.77E+00
MW-02-40	1.93E+00	ND	ND	ND	ND	ND	ND	ND	ND	9.20E+01
MW-02-015	3.02E+01	3.03E+02	1.61E+02	1.83E+02	5.12E+02	2.13E+02	9.30E+01	2.55E+02	1.45E+02	2.80E+03
MW-02-41	4.07E+01	BLQ	ND	BLQ	ND	9.14E-01	ND	ND	ND	1.85E+03
MW-02-042	5.69E+01	ND	ND	ND	ND	ND	ND	ND	ND	4.69E+02
84 E-WS-3	6.65E+00	BLQ	7.28E+00	ND	BLQ	BLQ	ND	ND	ND	7.43E+01
MW-02-43	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW-02-43 Field Dup.	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
84 M-WS-1	1.83E+02	2.77E+02	4.49E+02	4.80E+02	1.01E+03	3.52E+02	8.86E+01	2.42E+02	1.30E+02	4.30E+03
MW-02-014	3.42E+02	1.55E+03	8.08E+02	7.95E+02	1.79E+03	7.15E+02	1.11E+02	3.52E+02	1.89E+02	9.94E+03
10 PPB	9.72E+00	1.00E+01	9.99E+00	9.88E+00	1.03E+01	9.94E+00	1.01E+01	9.98E+00	9.74E+00	N/A
84 M-WS-2	1.63E+01	1.03E+00	1.57E+01	6.25E+00	BLQ	BLQ	ND	BLQ	ND	1.24E+02
84 N-WS-1	4.16E+02	1.09E+03	4.88E+02	4.29E+02	9.02E+02	3.79E+02	7.08E+01	1.98E+02	9.98E+01	4.62E+03
84 N-WS-2	2.87E+02	2.41E+02	3.18E+02	2.78E+02	6.07E+02	2.23E+02	3.78E+01	1.02E+02	5.68E+01	4.20E+03
84 O-WS-1	2.98E+02	3.09E+02	3.29E+02	2.94E+02	5.74E+02	2.44E+02	5.89E+01	1.49E+02	7.19E+01	3.37E+03
84 O-WS-2	2.42E+02	7.87E+01	2.73E+02	2.33E+02	5.12E+02	1.93E+02	3.26E+01	8.99E+01	5.00E+01	3.28E+03
MW-02-005	1.27E+00	ND	1.07E+02	3.71E+01	7.69E+00	1.27E+00	2.57E+00	5.48E+00	7.65E+00	8.44E+02
MW-02-044	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
84 F-WS-3	8.34E+01	1.07E+02	1.66E+02	1.38E+02	2.28E+02	7.82E+01	1.73E+01	6.56E+01	3.32E+01	1.93E+03
84 E-WS-01	2.64E+02	5.25E+02	3.54E+02	3.03E+02	6.71E+02	2.68E+02	5.40E+01	1.49E+02	8.08E+01	3.06E+03
84 F-WS-4	1.59E+00	BLQ	1.13E+01	BLQ	BLQ	BLQ	ND	ND	ND	5.31E+01
QC, OBSERVED, PPB	4.98E+01	5.12E+01	5.18E+01	5.23E+01	5.19E+01	5.24E+01	5.13E+01	5.37E+01	5.06E+01	N/A
QC, TRUE VALUE, PPB	5.00E+01	5.00E+01	5.00E+01	5.00E+01	5.00E+01	5.00E+01	5.00E+01	5.00E+01	5.00E+01	N/A
84 E-WS-2	4.48E+02	9.44E+02	6.06E+02	5.53E+02	9.79E+02	4.48E+02	7.86E+01	2.27E+02	1.20E+02	7.56E+03
84 F-WATER 1	1.78E+02	4.43E+02	2.63E	2.55E+02	3.74E+02	2.49E+02	5.74E+01	1.59E+02	8.07E+01	2.57E+03
84 F-WS-2	1.61E+02	3.83E+02	2.50E+02	2.19E+02	4.61E+02	1.64E+02	2.97E+01	9.71E+01	4.96E+01	3.36E+03
GC LAB BLANK, PPB	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A
100 PPB	9.75E+01	9.78E+01	9.71E+01	9.66E+01	9.71E+01	9.68E+01	9.53E+01	9.52E+01	9.50E+01	N/A

ND = None Detected; BLQ = Below Limit of Quantitation, 1 ppb; N/A = Not Analyzed

MANTECH TECHNOLOGY

Ref: 93-BB21

December 14, 1993

Dr. Don Kampbell/John Wilson
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift GAV

Dear Don/John:

As requested in Service Request # SF-0-28, headspace GC/MS analysis of 33 water samples for vinyl chloride, trans-dichloroethene (t-DCE), cis-dichloroethene (c-DCE) and trichloroethene (TCE) was completed. The samples were received on December 6, 7 and 9, 1993 and analyzed on December 6-13, 1993. RSKSOP-148 (Determination of Volatile Organic Compounds in Water by Automated Headspace Gas Chromatography/Mass Spectrometry (Saturn II Ion Trap Detector) was used for this analysis.

An internal standard calibration method was established for the 4 compounds. The standard curves for vinyl chloride, t-DCE and TCE ranged from 1.0 to 2000 ppb. The standard curve for c-DCE ranged from 1.0 to 10000 ppb. The lower quantitation limits were 0.5 ppb. The internal standard was fluorobenzene at a concentration of 100 ppb in the headspace vial.

Samples analyzed without dilution were prepared by adding 10 ml of sample to a headspace vial containing 2 g of sodium chloride (NaCl). 8 µl of 125 µg/ml fluorobenzene was added to this 10 ml liquid volume before the vial was capped. Diluted samples were prepared by adding 5 ml of sample to a headspace vial containing 5 ml of organic free water and 2 g of NaCl. The fluorobenzene internal standard was then added and the vial capped.

A dilution corrected quantitation report for the samples, field duplicates, lab duplicates, lab blanks, and QC standards is presented in Tables 1&2.

ManTech Environmental Technology, Inc.

P.O. Box 12313, 2 Triangle Drive, Research Triangle Park, North Carolina 27709 919-549-0611 FAX 919-549-4665

If you should have any questions, please feel free to contact me.

Sincerely,

Bradley D. Black

Bradley D. Black

xc: R.L. Cosby
G.B. Smith
D.D. Fine
J.L. Seeley

Table 1. Dillution Corrected Quantitation Report for SR# SF-0-28.

Concentration = ppb

Compound	84CPt-B1	84CPt-B2	84E-WS-01	84E-WS-01 Lab Dup	84E-WS-2	84E-WS-2 Field Dup 1/2 Dil	84E-WS-3	84-Field Blank
VINYL CHLORIDE	---	---	1020	1010	25.7	22.4	---	---
TRANS-DICHLOROETHENE	---	---	1.2	1.1	1.3	1.3	---	---
CIS-DICHLOROETHENE	300	3.1	752	710	***	10900	160	---
TRICHLOROETHENE	5.6	---	0.5	0.5	0.7	1.0	20.6	---

	84F-Water-1	84F-Water-1 Field Dup 1/2 Dil	84F-WS-2	84F-WS-3	84F-WS-4	84M-WS-1	84M-WS-1 Lab Dup	84M-WS-2
VINYL CHLORIDE	2080	1610	3.6	5.7	---	1050	995	---
TRANS-DICHLOROETHENE	---	---	---	---	---	---	---	---
CIS-DICHLOROETHENE	9.1	8.3	6370	4310	69.0	1320	1250	240
TRICHLOROETHENE	---	---	---	0.6	12.8	---	---	9.1

	84N-WS-1	84N-WS-1 Field Dup	84N-WS-2	84O-WS-1	84O-WS-2	84O-WS-2 Lab Dup	MW-02-005	MW-02-006B
VINYL CHLORIDE	1710	1550	3.1	486	---	---	---	---
TRANS-DICHLOROETHENE	---	---	1.0	---	---	---	---	---
CIS-DICHLOROETHENE	208	209	5850	3140	6710	6650	4.0	28.7
TRICHLOROETHENE	---	---	---	2.8	---	---	0.6	0.6

	MW-02-007	MW-02-007 Field Dup	MW-02-014	MW-02-014 Field Dup	MW-02-015	MW-02-019	MW-02-020	MW-02-021
VINYL CHLORIDE	---	---	4.5	3.7	---	384	9.8	---
TRANS-DICHLOROETHENE	---	---	---	---	---	---	---	---
CIS-DICHLOROETHENE	---	---	9050	9760	110	3540	8530	2.0
TRICHLOROETHENE	---	---	1030	560	1330	1.9	1.4	4.6

Dup = Duplicate Dil = Dilution --- = Below Quantitation Limit (0.5 ppb) *** = Above Quantitation Limit (10000 ppb)

Table 2. Dillution Corrected Quantitation Report for SR# SF-0-28.

Concentration = ppb

	MW-02-021 Lab Dup	MW-02-026	MW-02-027	MW-02-030	MW-02-040	MW-02-041	MW-02-042	MW-02-042 Lab Dup
VINYL CHLORIDE	---	---	---	---	0.8	---	2.2	2.3
TRANS-DICHLOROETHENE	---	---	---	0.7	---	---	1.1	1.0
CIS-DICHLOROETHENE	2.1	---	---	185	339	5230	1570	1570
TRICHLOROETHENE	4.5	---	---	79.7	3.1	30.7	98.5	91.0

	MW-02-043	MW-02-044	QC1206A 50 ppb	QC1206B 500 ppb	QC1207A 50 ppb	QC1207D 500 ppb	QC1208A 500 ppb	QC1208B 500 ppb
VINYL CHLORIDE	---	---	48.2	491	49.3	507	490	494
TRANS-DICHLOROETHENE	---	---	52.8	542	54.6	529	524	532
CIS-DICHLOROETHENE	10.6	2.9	51.5	531	53.1	521	531	534
TRICHLOROETHENE	373	135	49.2	511	48.6	527	536	526

	QC1208C 50 ppb	QC1209B 500 ppb	QC1209C 50 ppb	QC1209D 500 ppb	QC1209E 50 ppb	QC1210A 500 ppb	QC1210B 50 ppb	QC1210C 500 ppb
VINYL CHLORIDE	51.2	497	52.4	529	50.8	524	51.2	524
TRANS-DICHLOROETHENE	50.9	500	49.6	533	51.2	523	52.9	534
CIS-DICHLOROETHENE	50.8	500	52.0	519	51.5	509	51.9	505
TRICHLOROETHENE	50.4	506	51.3	512	50.6	512	50.7	525

	QC1210D 50 ppb	QC1213a 50 ppb	QC1213b 500 ppb	BK1207A	BK1207B	BK1208A	BK1209D	BK1210C
VINYL CHLORIDE	53.6	54.6	505	---	---	---	---	---
TRANS-DICHLOROETHENE	53.2	51.5	527	---	---	---	---	---
CIS-DICHLOROETHENE	48.9	49.8	516	---	---	---	---	---
TRICHLOROETHENE	51.0	50.6	530	---	---	---	---	---

Dup = Duplicate QC = Quality Control Sta. d BK = Blank --- = Below Quantitation Limit (0.5 ppb)

compound	MW-02-015	84F-1	84E-1	84M-1	84N-1	84O-1	MW-02-019	MW-02-040
	-------(ug/liter)---							
Trichloroethylene	1330	<0.5	0.5	<0.5	<0.5	2.8	1.9	3.1
trans-Dichloroethylene	<0.5	<0.5	1.2	<0.5	<0.5	<0.5	<0.5	<0.5
cis-Dichloroethylene	110	9.1	752	1320	208	3140	3530	339
Vinyl Chloride	<0.5	2080	1020	1050	1710	486	384	0.08
Ethylene	<3	129	220	28	474	40	39	<3
	----(mg/liter)----							
Oxygen	1.0						0.9	1.5
Nitrate	<0.05	0.06	<0.05	0.12	0.12	0.17	0.11	26.5
Sulfate	23.1	5.43	5.78	3.44	0.21	0.33	0.08	5.53
Iron II		2.6	1.2	8.9	2.9	3.7	10.3	<0.05
Methane	0.0004	0.13	0.22	0.028	0.47	0.40	0.039	0.009
Total Organic C	5.5	21.0	15.5	36.6	22.5	16.2	11.3	1.4
pH	7.9	7.1	7.4	7.2	7.1	7.2	7.4	8.2
Alkalinity	96	418	794	278	292	268	262	136

compound	MW-02-015	84F-2	84F-3	84E-2	84N-2	84O-2	MW-02-020	MW-02-041
	-------(ug/liter)---							
Trichloroethylene	1330	<0.5	0.6	1.0	<0.5	<0.5	1.4	30.7
trans-Dichloroethylene	<0.5	<0.5	<0.5	1.3	1.0	<0.5	<0.5	<0.5
cis-Dichloroethylene	110	6370	4310	10900	5850	6710	8530	5230
Vinyl Chloride	<0.5	3.6	5.7	22.4	3.1	<0.5	9.8	<0.5
Ethylene	<3	1.2	0.9	5.5	2.1	2.3	4.0	0.5
	-----(mg/liter)---							
Oxygen	1.0							
Nitrate	<0.05	0.06	<0.05	0.05	0.16	0.13	0.12	0.69
Sulfate	23.1	<0.5	<0.5	7.15	0.34	0.50	<0.5	1.66
Iron II		5.3	2.3	1.2	0.8	4.6	10.7	<0.05
Methane	0.0004	0.0012	0.0009	0.0055	0.0021	0.0023	0.0040	0.0005
Total Organic C	5.5	22.5	17.7	36.7	20.0	14.3	17.3	11.4
pH	7.9	7.4	7.3	7.8	7.6	7.0	7.3	7.9
Alkalinity	96	457	368	559	244	234	322	350

compound	MW-02-026	MW-02-015	84F-1	84E-1	84M-1	84N-1	84O-1	MW-02-019	MW-02-040
		-------(ug/liter)---							
TCE	<0.5	1330	<0.5	0.5	<0.5	<0.5	2.8	1.9	3.1
t-DCE	<0.5	<0.5	<0.5	1.2	<0.5	<0.5	.5	<0.5	<0.5
c-DCE	<0.5	110	9.1	752	1320	208	40	3530	339
VC	<0.5	<0.5	2080	1020	1050	1710	86	384	0.08
Ethylene	<3	<3	129	220	28	474	40	39	<3
		----(mg/liter)----							
Oxygen	10.0	1.0						0.9	1.5
Nitrate	0.44	<0.05	0.06	<0.05	0.12	0.12	0.17	0.11	26.5
Sulfate	19.6	23.1	5.43	5.78	3.44	0.21	0.33	0.08	5.53
Iron II	0.05		2.6	1.2	8.9	2.9	3.7	10.3	<0.05
Methane	<0.001	0.0004	0.13	0.22	0.028	0.47	0.40	0.039	0.009
TOC	0.8	5.5	21.0	15.5	36.6	22.5	16.2	11.3	1.4
pH	7.8	7.9	7.1	7.4	7.2	7.1	7.2	7.4	8.2
Chloride	103	26.6	80.0	54.6	94.3	54.6	28.3	42.4	2.14
Redox	150							10.0	8.0
Temp	7.2	9.3	-70	-50	-100	-70		-130	8
Alkalin	111	96	418	794	278	292	268	262	136

(9)

compound	MW-02-026	MW-02-015	84F-1	84E-1	84M-1	84N-1	84O-1	MW-02-019	MW-02-040
		-------(ug/liter)---							
Benzene	<1.0	30.2	178	264	183	416	296	321	1.9
Toluene	<1.0	303	443	525	277	1090	309	327	<1.0
E-benz	<1.0	161	263	354	449	488	329	433	<1.0
p-Xylene	<1.0	183	255	303	480	429	294	352	<1.0
m-Xylene	3.9	512	374	671	1010	902	574	703	<1.0
0-Xylene	2.6	213	249	268	352	379	244	263	<1.0
123-TMB	1.7	145	80.7	80.8	130	10.0	7.2	9.3	<1.0
		----(mg/liter)----							
Oxygen	10.0	1.0						0.9	1.5
Nitrate	0.44	<0.05	0.06	<0.05	0.12	0.12	0.17	0.11	26.5
Sulfate	19.6	23.1	5.43	5.78	3.44	0.21	0.33	0.08	5.53
Iron II	0.05		2.6	1.2	8.9	2.9	3.7	10.3	<0.05
Methane	<0.001	0.0004	0.13	0.22	0.028	0.47	0.40	0.039	0.009
TOC	0.8	5.5	21.0	15.5	36.6	22.5	16.2	11.3	1.4
pH	7.8	7.9	7.1	7.4	7.2	7.1	7.2	7.4	8.2
Chloride	103	26.6	80.0	54.6	94.3	54.6	28.3	42.4	2.14
Redox	150							10.0	8.0
Temp	7.2	9.3	-70	-50	-100	-70		-130	8
Alkalin	111	96	418	794	278	292	268	262	136

(10)

compound	MW-02-015	MW-02-006B	MW-02-007	84F-4	84E-3	84M-2	MW-02-030	MW-02-042
	-------(ug/liter)---							
Trichloroethylene	1330	0.6	<0.5	12.8	20.6	9.1	79.7	98.5
trans-Dichloroethylene	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.7	1.1
cis-Dichloroethylene	110	28.7	<0.5	69.0	160	240	185	1570
Vinyl Chloride	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	2.2
Ethylene	<3	<3	<3	<3	<3	<3	0.2	3.5

(11)

compound	MW-02-015	84F-2	84F-3	84E-2	84N-2	84O-2	MW-02-020	MW-02-041
	-------(micro-moles/liter)----							
Trichloroethylene	10.1	<0.004	0.005	0.008	<0.004	<0.004	0.011	0.23
trans-Dichloroethylene	<0.005	<0.005	<0.005	0.013	0.01	<0.005	<0.005	<0.005
cis-Dichloroethylene	1.13	65.7	44.4	112.4	60.3	69.2	87.9	53.9
Vinyl Chloride	<0.008	0.06	0.09	0.36	0.049	<0.008	0.16	<0.008
Ethylene	<0.1	0.04	0.03	0.20	0.075	0.08	0.14	0.018
Total Ethylenes	11.2	65.8	44.5	113.0	60.4	69.3	88.2	54.1

(12)

compound	MW-02-015	84F-2	84F-3	84E-2	84N-2	84O-2	MW-02-020	MW-02-041
	-------(ug/liter)---							
Trichloroethylene	1130	<0.5	0.6	1.0	<0.5	<0.5	1.4	30.7
trans-Dichloroethylene	<0.5	<0.5	<0.5	1.3	1.0	<0.5	<0.5	<0.5
cis-Dichloroethylene	110	6370	4310	10900	5850	6710	8530	5230
Vinyl Chloride	<0.5	3.6	5.7	22.4	3.1	<0.5	9.8	<0.5
Ethylene	<3	1.2	0.9	5.5	2.1	2.3	4.0	0.5
	-----(mg/liter)---							
Oxygen	1.0							
Nitrate	<0.05	0.06	<0.05	0.05	0.16	0.13	0.12	0.69
Sulfate	23.1	<0.5	<0.5	7.15	0.34	0.50	<0.5	1.66
Iron II		5.3	2.3	1.2	0.8	4.6	10.7	<0.05
Methane	0.0004	0.0012	0.0009	0.0055	0.0021	0.0023	0.0040	0.0005
Total Organic C	5.5	22.5	17.7	36.7	20.0	14.3	17.3	11.4
pH	7.9	7.4	7.3	7.8	7.6	7.0	7.3	7.9
Alkalinity	96	457	368	559	244	234	322	350

(13)

compound	MW-02-26	MW-02-015	84F-2	84F-3	84E-2	84N-2	84O-2	MW-02-020	MW-02-041
		-------(ug/liter)---							
Benzene	<1.0	30.2	161	83.4	448	287	242	285	4.1
Toluene	<1.0	303	383	107	944	241	78.7	146	<1.0
E-benz	<1.0	161	250	166	606	318	273	563	<1.0
p-Xylene	<1.0	183	219	138	553	276	233	534	<1.0
m-Xylene	3.9	512	461	228	979	607	512	1190	<1.0
0-Xylene	2.6	213	164	78.2	448	223	193	419	0.9
123-TMB	1.7	145	49.6	33.2	120	56.8	71.9	157	<1.0
		-----(mg/liter)---							
Oxygen	10.0	1.0						1.3	3.0
Nitrate	0.44	<0.05	0.06	<0.05	0.05	0.16	0.13	0.12	0.69
Sulfate	19.6	23.1	<0.5	<0.5	7.15	0.34	0.50	<0.5	1.66
Iron II	0.05		5.3	2.3	1.2	0.8	4.6	10.7	<0.05
Methane	<0.001	0.0004	0.0012	0.0009	0.0055	0.0021	0.0023	0.0040	0.0005
TOC	0.8	5.5	22.5	17.7	36.7	20.0	14.3	17.3	11.4
pH	7.8	7.9	7.4	7.3	7.8	7.6	7.0	7.3	7.9
Chloride	103	26.6	72.0	78.5	65.0	68.8	55.2	25.1	11.2
Redox	150		-92	-85	-75	-74		-130	5
Temp	7.2	9.3						10.0	8.4
Alkalin	111	96	457	368	559	244	234	322	350

(14)

compound	MW-02-015	84F-1	84E-1	84M-1	84N-1	84O-1	MW-02-019	MW-02-040
	----(micro-moles/liter)-----							
Trichloroethylene	10.1	<0.004	0.004	<0.004	<0.004	0.02	0.014	0.023
trans-Dichloroethylene	<0.005	<0.005	0.012	<0.005	<0.005	<0.005	<0.005	<0.005
cis-Dichloroethylene	1.13	0.15	7.7	13.6	2.1	32.3	56.5	3.59
Vinyl Chloride	<0.018	33.3	16.3	16.8	27.4	7.8	6.1	<0.001
Ethylene	<0.1	4.6	7.8	1.0	16.9	1.4	1.4	<0.1
Total Ethylenes	11.2	38.0	31.8	31.4	46.4	41.4	64.0	3.6

SOIL DATA

MAY 1994

DIVIDER.DOC

SF-0-64 Drs. Kampbell/Wilson GC/MS Plattsburg AFB Cores Units = mg/kg

SAMPLE	Benzene	Toluene	EB	p-Xylene	m-Xylene
36PTR3NS	ND	BLQ	BLQ	BLQ	1.17E-02
66PTR1SS	3.23E-02	5.48E-01	1.52E+00	7.38E+00	1.69E+01
67PTR1SS	ND	BLQ	BLQ	BLQ	BLQ
68PTR1SS	4.75E+00	8.47E+01	1.20E+02	1.14E+02	4.33E+02
70PTR33S	ND	BLQ	BLQ	BLQ	BLQ
71PTR3SS	BLQ	2.64E+00	7.06E+00	1.17E+01	3.44E+01
72PTR3SS	8.47E-03	1.15E+01	1.13E+01	1.65E+01	4.37E+01
74PTR2NS	ND	BLQ	BLQ	BLQ	BLQ
75PTR2NS	ND	BLQ	BLQ	BLQ	BLQ
76PTR2NS	BLQ	5.23E+00	1.11E+01	1.12E+01	2.60E+01
84AB-13	BLQ	BLQ	BLQ	BLQ	BLQ
84BA-1	BLQ	BLQ	BLQ	BLQ	BLQ
84BA-2	ND	BLQ	BLQ	BLQ	BLQ
84BA-3	ND	BLQ	BLQ	BLQ	BLQ
84BA-4	ND	BLQ	BLQ	BLQ	BLQ
84BA-5	ND	BLQ	BLQ	BLQ	BLQ
84BA-6	BLQ	BLQ	BLQ	BLQ	BLQ
84BA-7	BLQ	BLQ	BLQ	BLQ	BLQ
84BA-8	BLQ	BLQ	BLQ	BLQ	BLQ
84BA-9	BLQ	BLQ	BLQ	BLQ	BLQ
84BA-10	ND	BLQ	BLQ	BLQ	BLQ
84BA-11	BLQ	BLQ	BLQ	BLQ	BLQ
84BA-12	ND	BLQ	BLQ	BLQ	BLQ
84BA-14	BLQ	BLQ	BLQ	BLQ	BLQ
84BA-15	ND	BLQ	BLQ	BLQ	BLQ
84BA-16	ND	BLQ	BLQ	BLQ	BLQ
84BA-17	ND	BLQ	BLQ	BLQ	BLQ
84BA-18	ND	BLQ	BLQ	BLQ	BLQ
84BA-19	ND	BLQ	BLQ	BLQ	BLQ
84BA-20	BLQ	BLQ	BLQ	BLQ	BLQ
84CA-1	1.62E-02	6.43E+01	7.02E+01	6.27E+01	2.28E+02
84S-1	ND	BLQ	BLQ	BLQ	BLQ
84S-2	BLQ	8.26E-03	1.15E-02	1.87E-02	5.14E-02
84S-3	BLQ	BLQ	BLQ	BLQ	8.64E-03
84S-4	BLQ	BLQ	BLQ	BLQ	BLQ
84S-5	2.56E-02	1.93E-01	1.00E-01	1.70E-01	4.58E-01
84S-8	2.84E+00	5.37E+01	4.00E+01	4.17E+01	1.24E+02
84S-10	1.16E+00	2.66E+01	1.95E+01	2.17E+01	6.56E+01
84S-12	1.32E+00	2.57E+01	1.88E+01	2.05E+01	6.20E+01
84S-14	4.75E-02	2.10E+00	2.10E+00	2.37E+00	7.43E+00
84S-16	9.95E+00	1.08E+02	7.90E+01	6.71E+01	3.57E+02
84S-18(1)	4.25E+00	5.93E+01	4.16E+01	4.27E+01	2.04E+02
84S-18(2)	2.26E+00	2.98E+01	2.84E+01	2.81E+01	8.54E+01
84S-20(1)	2.04E+00	2.16E+01	1.54E+01	1.48E+01	4.45E+01
84S-20(2)	3.47E+00	3.73E+01	2.63E+01	2.50E+01	7.33E+01
84S-22	4.81E-01	1.29E+00	3.49E-01	3.27E-01	1.06E+00

Analyst: David A. Kovacs BLQ = <0.02 µg/ml Printed: 7/12/94

SF-0-64 Drs. Kampbell / Wilson GC/MS Plattsburg AFB Cores Units = mg/kg

SAMPLE	o-Xylene	1,3,5-TMB	1,2,4-TMB	1,2,3-TMB	TCE
36PTR3NS	BLQ	BLQ	8.49E-03	BLQ	1.30E-01
66PTR1SS	9.23E+00	7.10E+00	1.59E+01	7.28E+00	9.79E-03
67PTR1SS	BLQ	BLQ	BLQ	BLQ	BLQ
68PTR1SS	9.00E+01	4.82E+01	1.06E+02	4.00E+01	7.05E-01
70PTR33S	BLQ	BLQ	BLQ	BLQ	BLQ
71PTR3SS	1.82E+01	1.75E+01	3.39E+01	1.31E+01	BLQ
72PTR3SS	1.53E+01	1.16E+01	2.49E+01	8.12E+00	3.34E-02
74PTR2NS	BLQ	ND	BLQ	ND	1.98E-02
75PTR2NS	BLQ	BLQ	BLQ	BLQ	7.66E-02
76PTR2NS	8.04E+00	7.88E+00	1.88E+01	7.97E+00	3.32E+01
84AB-13	BLQ	BLQ	BLQ	BLQ	BLQ
84BA-1	BLQ	BLQ	BLQ	BLQ	BLQ
84BA-2	BLQ	BLQ	BLQ	BLQ	BLQ
84BA-3	BLQ	BLQ	BLQ	BLQ	BLQ
84BA-4	BLQ	BLQ	BLQ	BLQ	BLQ
84BA-5	BLQ	BLQ	BLQ	BLQ	BLQ
84BA-6	BLQ	BLQ	BLQ	BLQ	BLQ
84BA-7	BLQ	BLQ	BLQ	BLQ	BLQ
84BA-8	BLQ	BLQ	BLQ	BLQ	BLQ
84BA-9	BLQ	BLQ	BLQ	BLQ	BLQ
84BA-10	BLQ	ND	BLQ	ND	BLQ
84BA-11	BLQ	BLQ	BLQ	ND	BLQ
84BA-12	BLQ	BLQ	ND	BLQ	BLQ
84BA-14	BLQ	BLQ	BLQ	ND	BLQ
84BA-15	BLQ	BLQ	ND	ND	BLQ
84BA-16	BLQ	ND	ND	ND	BLQ
84BA-17	BLQ	ND	BLQ	ND	BLQ
84BA-18	BLQ	ND	ND	ND	BLQ
84BA-19	BLQ	BLQ	BLQ	BLQ	BLQ
84BA-20	BLQ	BLQ	BLQ	ND	BLQ
84CA-1	4.61E+01	2.26E+01	4.23E+01	1.95E+01	1.44E+02
84S-1	BLQ	BLQ	BLQ	BLQ	BLQ
84S-2	2.26E-02	2.71E-02	6.71E-02	2.36E-02	BLQ
84S-3	BLQ	BLQ	8.33E-03	BLQ	7.56E-03
84S-4	BLQ	BLQ	BLQ	BLQ	BLQ
84S-5	2.58E-01	2.45E-01	7.96E-01	2.85E-01	7.78E-03
84S-8	3.75E+01	2.53E+01	5.37E+01	2.44E+01	1.91E+01
84S-10	2.04E+01	1.42E+01	3.10E+01	1.34E+01	8.03E+00
84S-12	1.97E+01	1.36E+01	3.09E+01	1.27E+01	7.78E+00
84S-14	2.67E+00	2.07E+00	5.39E+00	2.02E+00	4.08E-01
84S-16	7.31E+01	3.98E+01	1.02E+02	4.24E+01	8.38E+01
84S-18(1)	4.08E+01	2.28E+01	5.88E+01	2.60E-01	2.91E+01
84S-18(2)	2.46E+01	1.67E+01	3.55E+01	1.57E+01	2.07E+01
84S-20(1)	1.40E+01	7.72E+00	1.67E+01	6.62E+00	1.54E+01
84S-20(2)	2.32E+01	1.22E+01	2.68E+01	1.04E+01	3.02E+01
84S-22	3.78E-01	1.08E-01	2.43E-01	1.16E-01	1.25E+00

-- Analyst: David A. Kovacs BLQ = <0.02 µg/ml Printed: 7/12/94

SF-0-64 Drs. Kampbell / Wilson GC/MS Plattsburg AFB Cores Units = mg/kg

SAMPLE	Benzene	Toluene	EB	p-Xylene	m-Xylene
84S-24	7.05E+00	6.74E+01	5.30E+01	5.33E+01	2.29E+02
84S-26(1)	3.10E-02	1.71E+00	2.45E-01	2.29E-01	7.25E-01
84S-26(2)	4.31E-02	2.05E+00	4.16E-01	3.85E-01	1.19E+00
84S-28	4.73E+00	1.26E+02	7.53E+01	7.12E+01	2.27E+02
84SW	BLQ	BLQ	7.87E-03	7.43E-03	1.39E-02
B8133384	BLQ	BLQ	7.38E+00	8.90E+00	2.45E+01
Quality Control Summary					
MeCl2	ND	BLQ	ND	ND	BLQ
Method Blank(1)	ND	BLQ	BLQ	BLQ	BLQ
Method Blank (2)	BLQ	BLQ	BLQ	BLQ	BLQ
0.1 µg/ml	1.01E-01	1.02E-01	9.97E-02	1.01E-01	9.94E-02
0.1 µg/ml	1.00E-01	9.99E-02	1.01E-01	1.00E-01	1.00E-01
0.1 µg/ml	9.20E-02	9.57E-02	9.56E-02	9.06E-02	9.16E-02
1 µg/ml	1.02E+00	1.02E+00	1.02E+00	1.02E+00	1.02E+00
1 µg/ml	1.01E+00	1.05E+00	1.00E+00	9.79E-01	9.94E-01
1 µg/ml	9.71E-01	9.66E-01	9.94E-01	1.01E+00	1.02E+00
1 µg/ml	1.02E+00	1.04E+00	1.03E+00	1.01E+00	1.01E+00
10 µg/ml	1.09E+01	1.06E+01	1.05E+01	1.02E+01	1.03E+01
10 µg/ml	1.08E+01	1.06E+01	1.03E+01	1.01E+01	1.02E+01
10 µg/ml	1.12E+01	1.10E+01	1.05E+01	1.01E+01	1.04E+01
10 µg/ml QC	9.12E+00	9.80E+00	9.53E+00	9.76E+00	9.99E+00
10 µg/ml QC	1.04E+01	1.02E+01	9.58E+00	9.82E+00	9.75E+00
10 µg/ml QC	1.02E+01	1.01E+01	9.64E+00	9.70E+00	9.65E+00
100 µg/ml	9.44E+01	9.83E+01	9.80E+01	9.78E+01	9.60E+01
100 µg/ml	1.04E+02	1.03E+02	1.02E+02	1.02E+02	9.97E+01
100 µg/ml	1.05E+02	1.02E+02	1.00E+02	1.01E+02	1.01E+02
100 µg/ml	9.98E+01	9.99E+01	9.99E+01	1.00E+02	9.99E+01

Analyst: David A. Kovacs BLQ = <0.02 µg/ml Printed: 7/12/94

SF-0-64 Drs. Kampbell/Wilson GC/MS Plattsburg AFB Cores Units = mg/kg

SAMPLE	o-Xylene	1,3,5-TMB	1,2,4-TMB	1,2,3-TMB	TCE
84S-24	4.66E+01	2.80E+01	6.60E+01	2.58E+01	6.04E+01
84S-26 (1)	2.65E-01	4.98E-02	1.41E-01	6.39E-02	1.17E-01
84S-26 (2)	4.58E-01	1.18E-01	2.88E-01	1.24E-01	2.51E-01
84S-28	7.38E+01	3.81E+01	9.09E+01	3.28E+01	7.01E+01
84SW	5.86E-03	BLQ	5.42E-03	BLQ	BLQ
B8133384	4.04E-02	8.47E+00	1.99E+01	7.74E+00	BLQ
Quality Control Summary					
MeCl2	ND	ND	BLQ	ND	ND
Method Blank (1)	BLQ	BLQ	BLQ	ND	BLQ
Method Blank (2)	BLQ	ND	BLQ	ND	BLQ
0.1 µg/ml	9.99E-02	1.04E-01	1.06E-01	1.03E-01	9.77E-02
0.1 µg/ml	1.00E-01	1.00E-01	1.00E-01	1.00E-01	9.89E-02
0.1 µg/ml	9.65E-02	1.00E-01	9.89E-02	1.04E-01	1.05E-01
1 µg/ml	1.02E+00	1.03E+00	1.05E+00	1.03E+00	1.02E+00
1 µg/ml	1.05E+00	9.79E-01	1.05E+00	1.03E+00	1.03E+00
1 µg/ml	9.71E-01	9.47E-01	9.48E-01	9.37E-01	1.01E+00
1 µg/ml	1.06E+00	1.07E+00	1.08E+00	1.08E+00	1.08E+00
10 µg/ml	1.06E+01	1.04E+01	1.05E+01	1.06E+01	1.03E+01
10 µg/ml	1.07E+01	1.08E+01	1.07E+01	1.07E+01	1.04E+01
10 µg/ml	1.14E+01	1.22E+01	1.21E+01	1.21E+01	1.08E+01
10,5 (TCE) QC	9.41E+00	9.71E+00	9.58E+00	9.61E+00	4.61E+00
10 µg/ml QC	1.01E+01	1.08E+01	1.07E+01	1.05E+01	N/A
10,5 (TCE) QC	1.03E+01	1.08E+01	1.06E+01	1.04E+01	4.95E+00
100 µg/ml	9.83E+01	9.57E+01	9.66E+01	9.61E+01	N/A
100 µg/ml	1.03E+02	1.02E+02	1.03E+02	1.02E+02	1.11E+02
100 µg/ml	1.00E+02	1.01E+02	1.00E+02	1.01E+02	1.06E+02
100 µg/ml	9.98E+01	9.97E+01	9.97E+01	9.97E+01	1.10E+02

Analyst: David A. Kovacs BLQ = <0.02 µg/ml Printed: 7/12/94

[illegible] on TPH

Plattsburgh AFB May 20, 1994

sample	sample wt	tare	tare+wet	tare+dry	absorb	f
70PTR3SS	10.1	30.44	42.45	41.8	0.05	1
71PTR3SS	9.7	50.55	68.25	67.24	0.91	1
72PTR3SS	10.6	29.31	40.02	38.58	0.77	3
84BA-5	9.2	50.83	69.21	67.61	0.01	1
84BA-20	10.6	29.46	42.6	40.78	0.01	1
66PTR1SS	10.3	31.15	41.81	41.35	0.73	3
68PTR1SS	9.6	26.17	38.25	36.19	0.66	9
84S-1	9.6	31.15	47.83	46.88	0.08	1
84S-8	10	51.56	69.07	67.18	0.83	3
84S-10	9.7	50.16	67.2	66.65	0.37	3
84S-12	10.1	51.32	71.34	70.97	0.46	3
84S-14	9.8	50.83	69.06	68.79	0.01	1
84S-16	10	55.48	74.4	72.06	1.4	3
84S-18	10.5	29.88	50.7	48.35	0.57	9
84S-20	10.5	51.6	70.06	66.62	0.87	1
84S-24	9.6	29.14	44.02	41.86	0.46	9
84S-28	9.6	31.48	50.41	47.1	0.9	1

SAMPLE	DRY WT	MG/ML	MG/KG
70PTR3SS	9.55	0.10	151
71PTR3SS	9.15	2.06	~~3383~~ 3,380
72PTR3SS	9.17	1.64	~~8025~~ 8,020
84BA-5	8.40	0.04	~~76~~ <70
84BA-20	9.13	0.04	~~70~~ <70
66PTR1SS	9.86	1.52	~~6948~~ 6,950
68PTR1SS	7.96	1.33	~~22547~~ 22,500
84S-1	9.05	0.14	229
84S-8	8.92	1.81	9150
84S-10	9.39	0.65	~~3094~~ 3,090
84S-12	9.91	0.84	~~3807~~ 3,810
84S-14	9.65	0.04	~~66~~ <70
84S-16	8.76	3.88	~~19936~~ 19,900
84S-18	9.31	1.10	~~15920~~ 15,900
84S-20	8.54	1.94	3400
84S-24	8.21	0.84	~~13798~~ 13,800
84S-28	7.92	2.03	~~3846~~ 3,850

Report following as <70 mg/kg:
67PTR1SS
74PTR2NS
75PTR2NS
84S-2,3,4,5,14,22,26
84BA- 1 through 20

SEP-26-1994 16:36 USEPA RSKERL-ADA SSB/SPB 405 436 8703 P.04

SR#SF-0-64 / Wilson / Plattsburgh AFB — all conc. are ug/g

Sample I.D.	Dilution Factor	JP-4	Fuel Carbon (JP-4 x 0.85)
36PTR3NS	1	1.60	1.36
66PTR1SS	1	3440.00	2920.00
67PTR1SS	1	0.95	0.81
68PRT1SS	1	14500.00	123600.00
70PTR3SS	1	5.84	4.96
71PTR3SS	1	3430.00	2920.00
72PTR3SS	1	3900.00	3320.00
74PTR2NS	1	0.65	0.55
75PTR2NS	1	0.75	0.63
76PTR2NS	1	2120.00	1800.00
84S-1	1	12.70	10.80
84S-2	1	17.50	14.90
84S-3	1	0.76	0.65
84S-4	1	0.78	0.66
84S-5	1	76.80	65.30
84S-8	1	9750.00	8290.00
84S-10	1	4690.00	3990.00
84S-12	1	4390.00	3730.00
84S-14	1	611.00	519.00
84S-16	10	20600.00	17500.00
84S-18 (1)	1	8780.00	7460.00
84S-18 (2)	1	7960.00	6770.00
84S-20 (1)	1	2410.00	2050.00
84S-20 (2)	1	4090.00	3480.00
84S-22	1	32.20	27.40
84S-24	10	15400.00	13100.00
84S-26 (1)	1	16.40	13.90
84S-26 (2)	1	39.00	33.20
84S-28	1	9990.00	8490.00

NOTE: all reported values are corrected for dilution factors where applicable
nd = none detected

OJECT

Continued From Page

Drilled to 36.5', cored to 39.0', recovered 1.8'

84S-15	38.6'	39.0'	Grey sand, wet
84S-16	38.2'	38.6'	Grey sand, wet
84S-17	37.8'	38.2'	Grey sand, wet
84S-18	37.4'	37.8'	Grey sand - moist
84S-19	37.2'	37.4'	Grey sand, dry

Drilled to 39.0', cored 41.5', recovered 1.8'

84S-20	39.7'	41.5'	Grey wet sand
84S-21			
84S-22			
84S-23			
84S-24			

84S-20	41.5'	41.1'	Grey, wet
84S-21	41.1'	40.7'	medium to
84S-22	40.7'	40.3'	fine sand.
84S-23	40.3'	39.9'	
84S-24	39.9'	39.7'	

DRILLED TO 41.5', CORED TO 43.5' RECOVERED 1.7

84S-25	43.5'	43.1'
84S-26	43.1'	42.7'
84S-27	42.7'	42.3'
84S-28	42.3'	41.9'
84S-29	41.9'	41.8'

Continued on Page

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JECT _____ Continued From Page _____

84 BA - Water Table at 33.6' below grd

Drilled 10.0' - cored 2.5', recovered 2.6'

84 BA-1	12.1	12.5	oxidized coarse sand
84 BA-2	11.7	12.1	SAME
84 BA-3	11.3	11.7	fine silty sand
84 BA-4	10.9	11.3	oxidized medium
84 BA-5	10.5	10.9	
84 BA-6	10.1	10.5	
discard 0.3			

Drilled to 31.5', cored to 34.0', recovered 2.5'

84 BA-7	33.6	34.0	
84 BA-8	33.2	33.6	
84 BA-9	32.8	33.2	
84 BA-10	32.4	32.8	
84 BA-11	32.0	32.4	
84 BA-12	31.6	32.0	
84 BA-13	31.5	31.6	(NO SUB-SAMPLE -

Drilled to 34.0', cored to 36.5', recovered 2.5

84 BA-14	36.1	36.5	
84 BA-15	35.7	36.1	
84 BA-16	35.3	35.7	
84 BA-17	34.9	35.3	
84 BA-18	34.5	34.9	
84 BA-19	34.1	34.5	
84 BA-20	34.0	34.1	(NO SUB-SAMPLE - TOP

Continued on Page _____

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Continued From Page

West A (74) PTR 2NS

84 CA. (75) Near PTR 44

Drilled to 37.0', cored 2.5', recovered 1.5'

Probably slipped out of core barrel. No way bottom sample is high, indicating contact with ground water

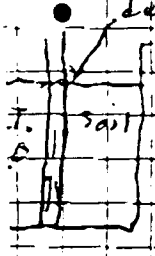
84 CA-1	35.0 – 37.5	35.1 – 38.5
84 CA-2	37.5 – 37.6	37.7 – 38.1
84 CA-3	37.6 – 37.7	37.3 – 37.7
84 CA-4		37.0 – 37.3

Samples are wet, oily and smell like [redacted] & ND. Only 84 CA-1 extracted

2/9/94

Yield test - core material from sponge sheet

Used peristaltic pump - max rate with foam header



Depth	test period	volume water yield	
0.25 ft.	60 sec	155 ml	0.34 ml/cm sec
0.25		155 ml	
0.50		220 ml	= 1.0×10^{-2} cm/sec
0.50		225 ml	
0.75		230 ml	2.5 cm/sec
0.75	↓	250 ml	
1.00	30 sec	200 ml	
1.00	↓	220 ml	

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GROUND WATER DATA

MAY 1994

DIVIDER.DOC

Printed 27-May-94 SF-0-64 DP-P&T/GC-FID Analyses for Dr. Kampbell Units=ng/mL Analyst:L.Secrest

SAMPLE NAME	VINYL CHLORIDE	t-DCE	c-DCE	TCE
QC, OBSERVED, PPB	1.87E+01	4.92E+01	4.83E+01	4.90E+01
QC, TRUE VALUE, PPB	2.00E+01	5.00E+01	5.00E+01	5.00E+01
~~100 PPB~~	1.05E+02	1.05E+02	1.04E+02	1.04E+02
84MW-43	1.65E+00	2.49E+00	1.14E+01	3.03E+02
84MW-43 Field Duplicate	2.14E+00	3.32E+00	1.39E+01	3.21E+02
84Q-2	1.18E+00	1.08E+00	1.56E+02	2.79E+00
84Q-2 Field Duplicate	BLQ	1.79E+00	1.55E+02	3.07E+00
84Q-3	4.88E+02	2.56E+01	6.01E+02	6.94E+00
84Q-3 Lab Spike, Percent Recovery	93	>100	98	>100
84Q-4	1.61E+02	2.28E+02	3.15E+03	2.15E+01
84Q-5	3.23E+01	3.38E+01	9.08E+02	1.29E+02
84Q-6	2.85E+01	1.19E+01	1.12E+03	1.04E+02
84Q-6 Lab Spike, Percent Recovery	98	>100	>100	>100
84SP1-14 (5/15)	2.33E+02	3.49E+01	8.40E+02	4.44E+00
84SP1-14' Field Duplicate	2.32E+02	3.74E+01	8.37E+02	5.12E+00
84SP1-14' 5/17	2.17E+02	3.76E+01	8.34E+02	4.58E+00
84SP1A-14' 5/21	2.30E+02	3.31E+01	8.47E+02	5.29E+00
250/500 PPB	2.44E+02	4.87E+02	4.93E+02	4.85E+02
84SP1-24' 5/15	1.67E+02	2.28E+02	1.87E+03	2.31E+01
84SP1-24' 5/17	1.94E+02	2.81E+02	* 1.67E+03	2.18E+01
84SP1A-24' 5/21	1.46E+02	1.77E+02	* 1.67E+03	1.58E+01
84SP2-14' 5/15	2.99E+01	1.37E+02	7.31E+02	1.62E+02
84SP2-14' 5/17	1.59E+01	8.95E+01	4.33E+02	1.31E+02
84SP2A-14' 5/21	4.44E+00	2.09E+01	1.93E+02	4.95E+01
84SP3-14' 5/15	5.37E+02	5.25E+01	5.78E+02	1.04E+01
84SP3-14' 5/17	5.05E+02	4.70E+01	5.29E+02	6.66E+00
84SP3A-14' 5/21	4.84E+02	2.73E+01	4.65E+02	8.38E+00
84SP4-14' 5/15	4.59E+02	6.71E+01	8.48E+02	9.87E+00
84SP4-14' Lab Spike, Percent Recovery	82	64	93	<50
84SP4-14' 5/17	4.68E+02	6.06E+01	7.51E+02	1.78E+01
450/900 PPB	4.34E+02	8.59E+02	8.70E+02	8.59E+02
84SP4A-14' 5/21	4.73E+02	6.70E+01	8.17E+02	9.62E+00
84SP4-24' 5/15	1.95E+02	2.33E+02	3.46E+03	1.48E+01
84SP4-24' 5/17	1.90E+02	2.29E+02	* 1.59E+03	1.86E+01
84SP4A-24' 5/21	1.76E+02	1.70E+02	* 1.59E+03	1.40E+01
84SP5-14' 5/15	7.17E+02	5.58E+01	3.24E+02	4.73E+00
84SP5-14' 5/17	* 6.34E+02	5.92E+01	2.20E+02	5.99E+00
84SP5A-14' 5/21	* 6.11E+02	5.47E+01	1.45E+02	4.99E+00
QC, OBSERVED, PPB	9.56E+01	2.61E+02	2.54E+02	2.59E+02
QC, TRUE VALUE, PPB	1.00E+02	2.50E+02	2.50E+02	2.50E+02

* Compound concentration calculated by MAXIMA outside the calibration range

BLQ = Below Limit of Quantitation, 1 ppb

OJECT Plattsburgh AFB 5/14/94 NOTEBOOK NO.

Continued From Page_

mple	Depth	Yield	D.O.	p.H.	Temp	Redox	Sulfide
4G-1	2.27' below top marked on Equipment tube (BTOT)						
TG-2	7' top of screen 2.5' Lower screen 7 = 2.7' BTOT	335 ml/min 0.25 ft drawdown 250 ml/45 sec	1.5	8.5	7.6	-35	0.0 0.85 mg/L
TG-3	16' top of screen 3.52' ft to Water table	335 ml/min. 0.5 ft draw down 10 min	0.1	7.5	10.7	-53	0.26 mg/L 0.0
2-4	25' top of screen 3.42' ft to Water Table	0.5 ft draw down 330 ml in 45 Sec.	0.2 (DO)	7.5	—	-65	0.0 0.46 mg/L
2-5	34' top of screen 3.18' ft to water table	0.5 ft draw down 160 ml in 1.0 min	0.2 to 0.6	8.3	—	-57	1.0 0.175 mg/L
2-6	43' top of screen 3.07' ft to water table	0.5 ft draw down 300 ml in 1.0 min	0.2	8.2		-25	0.0 0.375 mg/L

5/14/94	D.O.	pH	ORP	Temp	∇ TOC
MW-43	0.3	8.0	+119	7.0	3.4'

Smells of VFA's

Continued on Page

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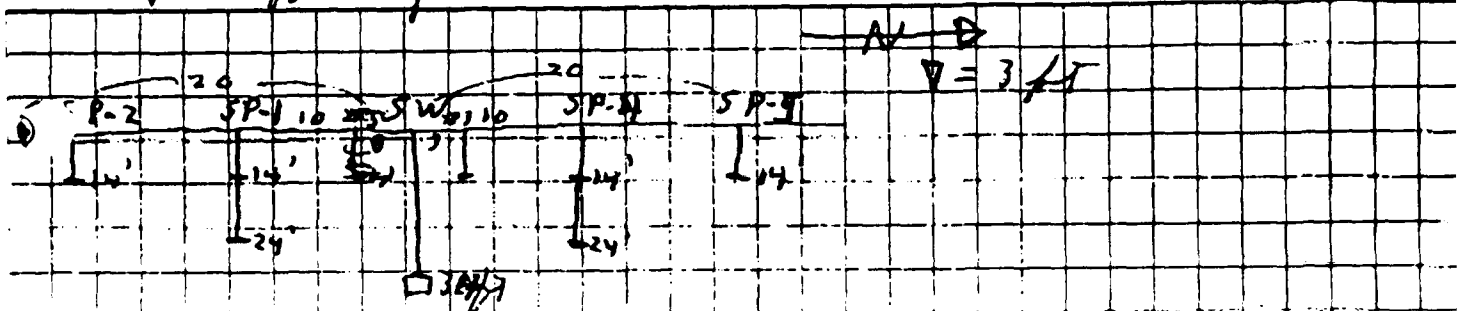
OJECT Sparge Effectiveness Test Start 5/15/94

Continued From Page



Sample	Time	pH	mg/l D.O.	C° Temp	TCE	c-DCE	t-DCE	VC
						mg/l		
SP-1-14'	0940-5/15	8.1	0.4	9.6				
SP 1-24'	0944-5/15	7.9	0.2	9.5				
SP 2-14'	0945 5/15	7.7	0.4	9.3				
SP 3-14'	1054 5/15	7.8	0.1	9.0				
SP4-14'	1057 5/15	7.9	0.2	8.2				
SP4-24'	1102 5/15	7.7	0.4	9.3				
SP5-17'	1130 5/15	8.0	0.2	9.5				

Turned air flow on at 1530

Pressure psig	Flow SCFHr
12	0
12	Break out
13	5
14	36
15	65
16	83
15.3	80

Operated at 80 SCFHr

Continued on Page

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NOTEBOOK NO.

SUBJECT Continued Sponge efficiency Test 5/16/94 Continued From Page

[redacted] set sponge rate at 3 cfm
air compressor turned on at 1200
caught on fire at 1300 - short closing
rental air compressor turned on at 1738
air flow = 3 cfm, pressure = 19 psi
5/16/94 1752 air flow 3 cfm, press 18
5/17/94 0208 " 3 cfm, press 18
5/16/94
5/17/94 - 0600
air flow = 3 cfm, pressure = 17.6 psi
5/17/94 - 1000

5/17/94 - 1400
3 cfm, 17.6 psi.

5/18/94 - 0215
compressor shut off when DK arrived at site
refueled and started engine, then engine shut off at 0215 checked by JW
turned compressor to rental agency in morning
5/19/94 - 1030 started a higher capacity compressor 3 cfm, 18 psi.

5/21/94 1030 - shut down

Pittsburgh AFB - Security Police
565 - 7191

Continued on Page

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Signed Date Signed Date

JECT V. Catalytic ATU Soil gas

Continued From Page...

Geoprobe screen point 1/4 inch Tubing

Return	Depth	O_2 %	ITV	CO_2	CH_4	Halogen Sniffer	ICE
S4R	7 ft	10.1	1200	7.2	4.8	C	
to over	75+	10.0	1900	6.9	5.5		
	16+6	15.5	360	5.1	0.8		
					0.2		
	25 ft	14.2	2000	4.1	2.7	+3	
Trip →	34 ft	20.8		4.1	4.1	+1	Acetone Typical
	Do this on Trip						
S4R	7 ft	2.0	1400	9.3	4.4	C	
~~2PLTOP~~							
DTRISE	16 ft	3.6	1400	10.5	6.8	C	
	25 ft	2.5	1800	10.4	6.2	+4	
	34 ft	0.9	4600	10.9	45.7	+7	
5/18/94							
S4S	7 ft	15.8	100	3.4	<.1	C	
2DTR2MP	16 ft	12.5	150	5.3	<.1	C	
	25 ft	1.9	2000	10.4	4.1	0	
	34 ft	0.0	6000	11.3	66.3	+3	
S4T	7 ft	18.8	320	1.1	<.1	C	
DTRIVE	16 ft	17.3	180	1.8	<.1	C	
	25 ft	13.7	260	3.3	<.1	C	
	34 ft	11.4	290	4.0	<.1	C	
Trip →	34 ft	0	1000	10.4	0.6	+3	5/20/94

Continued from page 11

Continued on Page

Read and Understood By

Signed Date Signed Date

OJECT [redacted] 5/17/94

Continued From Page

Purge after

Sample	Time	D.O.	Temp
SP1-14'	1340 - 5/17	0.3	9.4
SP1-24	1340 - 5/17	0.3	10.3
SP2-14'	1350 - 5/17	0.4	10.2
SP3-14'	1406 - 5/17	0.2	10.4
SP4-14'	1468 - 5/17	0.4	9.0
SP5-14'	1417 - 5/17	0.1	9.3
SP4-24'	1415 - 5/17	0.6	9.6
7/7/94		PSI = 17.3	
SP1-14'	1620	0.8	8.6
SP1-24'	1640	0.8	9.5
SP2-14'		0.6	8.9
SP3-14'		1.4	8.9
SP4-14'		0.8	8.7
SP4-24'		1.2	8.8
SP5-14'		0.5	8.4
7/8/94	1150	PSI = 15.2	
SP1-14'		0.5	9.7
SP1-24'		0.3	10.3
SP2-14'	1220	0.3	10.5
SP3-14'		0.6	10.6
SP4-14'		0.5	9.8
SP4-24'		0.6	9.9
SP5-14'		0.6	9.6
5/21/94	1130 - 1215		
SP1-14'		0.5	10.5
SP1-24'		0.4	11.4
SP2-14'		0.7	11.5
SP3-14'		2.0	11.6
SP4-14'		0.6	10.0
SP4-24'		0.6	10.7
SP5-14'		0.6	10.7

Continued on Page

Read and Understood By

Signed Date Signed Date

Notebook No. ____

PROJECT Soil Gas Measurements 5/18/94

Continued From Page ____

Location	Depth	O_2 %	TLV ppm	CO_2 %	CH_4 %	Halogen Sniffer
84W	7 ft	2.5	4700	8.7	22.1	+5
14PTR25E	16 ft	0	+4000	11.0	24.2	+6
	25 ft	0	Not Detected	11.3	15.7	+7
	34 ft	0	ND	11.4	63.6	+5
84W	7 ft	15.3	340	3.4	<0.1	0
08PTR5E	16 ft	13.5	410	4.2	<.1	0
	25 ft	8.6	580	6.4	<0.1	0
	34 ft	9.2	2500	7.7	8.7	0
84W	7 ft	19.0	310	0.2	<.1	0
06PTLTO1E	16 ft	18.1	360	1.7	<.1	0
	25 ft	11.0	420	5.2	<.1	0
	34 ft	0.1	3500	9.7	11.1	0
	5/19/94					
84X	7 ft	14.2	370	4.4	<.1	0
16PTR28	16 ft	1.8	1200	10.5	.3	0
	25 ft	1.7	410	.0	25.5	0
	34 ft	1.0	4600	12.5	43.2	0
84Y						
30PTR35E	7 ft	13.0	490	4.9	<.1	0
	16 ft	4.6	360	7.3	<0.1	0
	25 ft	4.9	320	8.6	<0.1	0
	34 ft	0	850	11.2	<0.1	0

Continued on page 12

Continued on Page

Read and Understood By

Signed Date

PROJECT [redacted] 5/19/94

Continued From Page

Location	Depth	O_2 %	TLV ppm	CO_2 %	CH_4 %	Halogen Sensor
84 3	7 ft	17.7	270	1.3	<0.1	0
48 PTR 4 N/F	16 ft	16.5	300	2.1	<0.1	0
	25 ft	2.1	750	8.7	<0.1	0
	31 ft	0	3000	10.2	28.7	+3
84 AA	7 ft	18.0	240	1.0	<0.1	0
44 PTR 3 N/F	16 ft	14.5	285	2.7	<0.1	0
	25 ft	7.3	320	6.3	<0.1	INCREASE TO FULL SCALE - AND LIGHT CAME ON THEN OFF
	31 ft	4.6	330	7.8	<0.1	+3

Continued on Page

Read and Understood By

Signed Date Signed Date

SOIL GAS DATA

MAY 1994

DIVIDER.DOC

location	depth	oxygen	hydrocarbons	carbon dioxide	methane	halogen sniffer
	feet	%	ppm as hexane	%	%	relative
84R	7	2.0	1400	9.3	4.4	0
10PTR	16	3.6	1400	11.5	6.8	0
	25	2.5	1800	10.4	6.2	+4
	34	0.9	4600	10.9	46.7	+7
84S	7	15.8	100	3.4	<0.1	0
40PTR	16	12.5	150	5.3	<0.1	0
	25	1.8	2000	10.4	4.1	0
	34	0.0	6000	11.3	66.3	+3
84T	7	18.8	320	1.1	<0.1	0
12PTR	16	17.3	180	1.8	<0.1	0
	25	13.7	260	3.3	<0.1	0
	34	0.0	1000	10.4	0.6	+3

location	depth	oxygen	hydrocarbons	carbon dioxide	methane	halogen sniffer
	feet	%	ppm as hexane	%	%	relative
84U	7	2.5	4700	8.7	22.1	+5
14ptr	16	0	+4000	11.0	24.2	+6
	25	0	can not determine	11.3	38.7	+7
	34	0		11.4	63.0	+5
84V	7	15.3	340	3.4	<0.1	0
08PTR	16	13.5	410	4.2	<0.1	0
	25	8.6	580	6.4	<0.1	0
	34	4.2	2500	7.7	8.7	0
84W	7	19.0	310	0.2	<0.1	0
06PTR	16	18.1	360	1.7	<0.1	0
	25	11.0	420	5.2	<0.1	0
	34	0.1	1800	9.7	11.1	0

location	depth	oxygen	hydrocarbons	carbon dioxide	methane	halogen sniffer
	feet	%	ppm as hexane	%	%	relative
84X	7	14.2	370	4.4	<0.1	0
16PTR	16	1.8	1200	10.5	0.3	0
	25	1.7	4100	10.1	28.8	0
	34	1.0	4600	10.5	43.8	0
84Y	7	13.0	490	4.9	<0.1	0
30PTR	16	8.6	360	7.3	<0.1	0
	25	4.9	320	8.6	<0.1	0
	34	0	850	?	<0.1	0
84Z	7	17.7	270	1.3	<0.1	0
48PTR	16	16.5	300	2.1	<0.1	0
	25	2.1	750	8.7	<0.1	0
	34	0	3000	10.2	28.7	+3
84AA	7	18.0	290	1.0	<0.1	0
44PTR	16	14.5	285	2.7	<01.	0
	25	7.3	320	6.3	<0.1	0 / +1
	34	4.6	330	7.8	<0.1	+3

GROUND WATER ELEVATION DATA

Appendix B
Ground Water Elevation/Free Product Data
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Sample Location	Easting	Northing	Datum Elevation (ft msl)	Water Table (Dec. 1993) (feet btoc)	Ground water Elevation (Dec. 1993) (ft msl)	LNAPL Thickness (Dec. 1993) (feet)	Water Table (Oct. 1991) (feet btoc)	Groundwater Elevation (Oct. 1991) (ft msl)	Water Table (Jan. 1989) (feet btoc)	Groundwater Elevation (Jan. 1989) (ft msl)	Water Table (Aug. 1988) (feet btoc)	Ground water Elevation (Aug. 1988) (ft msl)	Water Table (Dec. 1987) (feet btoc)	Ground water Elevation (Dec. 1987) (ft msl)
MW-02-005	722393.85	1700306.02	250.92				32.52	218.4	35.12	215.8	34.72	216.2	34.62	216.3
MW-02-006	722521.64	1700372.17				0.11		217.6		215.4		214.2		215.9
MW-02-007	722521.41	1700354.16	248.69	32.4	216.29		30.59	218.1	33.09	215.6	34.59	214.1	32.49	216.2
MW-02-014	722146.23	1700554.89	254.01			1.54								
MW-02-015	722023.54	1700547.37	256.25	40.03	216.22	0.57								
MW-02-019	722797.86	1700166.45	227.93	14.85	213.08		12.93	215	14.93	213				
MW-02-020	722807.69	1700165.37	230.16	13.15	217.01		12.26	217.9	17.06	213.1				
MW-02-021	723492.61	1698394.41	193.85	3.99	189.86		6.25	187.6						
MW-02-026	721429.01	1700757.23	274.06	56.4	217.66		51.36	222.7	55.16	218.9				
MW-02-027	721430.77	1700751.15	274.22	53.05	221.17		51.22	223	55.12	219.1				
MW-02-030	722808.70	1700172.70	229.55	14.6	214.95		11.55	218	16.25	213.3				
MW-02-031	722098.87	1700498.83	250.81	33.88	216.93		30.41	220.4	34.41	216.4				
MW-02-040	724351.63	1699361.02	209.02	9.4	199.62		8.92	200.1	18.12	190.9				
MW-02-041	724363.83	1699363.58	209.05	8.33	200.72		7.05	202	-8.25	217.3				
MW-02-042	724368.43	1699352.83	208.76	7.9	200.86		7.26	201.5						
MW-02-043	724953.42	1698070.12	185.47	3.45	182.02		3.07	182.4						
MW-02-044	725474.64	1697178.35	190.21	7.62	182.59		7.11	183.1						
84B	722267.00	1700360.00	241.52	25.5	216.02	2								
84E	722437.00	1700360.00	241.52	28	213.52									
84F	722437.00	1700360.00	244.26	28.5	215.76	2.14								
84M	722502.00	1700270.00	243.40	29	214.4									
84O	722723.00	1700310.00	234.10	21.6	212.5									

IN SITU TESTING RESULTS

RESULTS OF UNCONFINED AQUIFER HYDRAULIC CONDUCTIVITY ANALYSES

FT-002 GROUNDWATER REMEDIAL INVESTIGATION REPORT
PLATTSBURGH AFB

MONITORING WELL	TEST NUMBER	HYDRAULIC CONDUCTIVITY (CM/S)	AVERAGE (AVG)	STANDARD DEVIATION (STD)	STD/AVG (%)
MW-02-004	1	4.3e-03	4.0e-03	3.5e-04	8.9
	2	3.6e-03			
MW-02-019	1	3.8e-02	3.8e-02	2.1e-10	0.0
	2	3.8e-02			
MW-02-020	1	3.9e-03	3.9e-03	0.0	0.0
	2	3.9e-03			
MW-02-021	1	1.3e-04	1.4e-04	7.5e-06	5.5
	2	1.5e-04			
MW-02-022	1	1.4e-04	1.4e-04	5.0e-07	0.4
	2	1.4e-04			
MW-02-030	1	1.0e-03	1.1e-03	3.5e-05	3.3
	2	1.1e-03			
MW-02-033	1	7.0e-05	7.1e-05	2.5e-06	3.5
	2	6.8e-05			
	3	7.4e-05			
MW-02-035	1	1.9e-04	2.0e-04	1.8e-05	8.6
	2	2.2e-04			
MW-02-036	1	9.0e-03	8.8e-03	2.5e-04	2.9
	2	8.5e-03			
MW-02-037	1	3.0e-03	2.8e-03	2.5e-04	9.1
	2	2.5e-03			
MW-02-038	1	5.7e-04	5.6e-04	1.0e-05	1.8
	2	5.5e-04			
MW-02-039	1	3.7e-03	4.0e-03	2.5e-04	6.3
	2	4.2e-03			
MW-02-040	1	3.4e-03	3.5e-03	5.0e-05	1.4
	2	3.5e-03			
MW-02-041	1	2.6e-03	2.7e-03	5.0e-05	1.9
	2	2.7e-03			
MW-02-042	1	6.0e-04	6.0e-04	2.1e-12	0.0
	2	6.0e-04			
MW-02-043	1	3.8e-04	3.8e-04	2.6e-12	0.0
	2	3.8e-04			

(Continued)

RESULTS OF UNCONFINED AQUIFER HYDRAULIC CONDUCTIVITY ANALYSES

FT-002 GROUNDWATER REMEDIAL INVESTIGATION REPORT
PLATTSBURGH AFB

MONITORING WELL	TEST NUMBER	HYDRAULIC CONDUCTIVITY (CM/S)	AVERAGE (AVG)	STANDARD DEVIATION (STD)	STD/AVG (%)
MW-02-044	1	1.1e-03	1.2e-03	5.0e-05	4.3
	2	1.2e-03			
MW-02-045	1	4.8e-04	4.9e-04	1.0e-05	2.0
	2	5.0e-04			
MW-02-046	1	6.8e-03	6.2e-03	1.3e-03	21.3
	2	7.5e-03			
	3	4.4e-03			
MW-02-047	1	6.5e-03	6.3e-03	2.5e-04	4.0
	2	6.0e-03			
MW-02-048	1	6.7e-03	6.1e-03	6.0e-04	9.8
	2	5.5e-03			
MW-02-049	1	4.0e-04	4.3e-04	2.5e-05	5.9
	2	4.5e-04			
MW-04-001	1	1.3e-04	1.3e-04	0.0	0.0
	2	1.3e-04			
MW-11-009	1	2.0e-03	2.4e-03	4.0e-04	16.7
	2	2.8e-03			
MW-13-002	1	6.9e-04	6.9e-04	0.0	0.0
	2	6.9e-04			
MW-16-001	1	1.2e-02	1.2e-02	0.0	0.0
	2	1.2e-02			
Average for all tests --->		4.1e-03			

EMPIRICAL METHOD RELATING GRAIN SIZE TO HYDRAULIC CONDUCTIVITY

MONITORING WELL	d 10	K (cm/s)
MW-02-034	0.05	2.5e-03
MW-02-034	0.18	3.2e-02

where : d 10 is the size which ten percent of the sample is finer than.
K is the square of the d 10 value

SLUG TEST RAW DATA

MW-02-004 (TEST 1)
W02004R1.HMT
SE1000C
Environmental Logger
11/20 12:04

Unit# 00000 Test 0

INPUT 1: Level (F) TOC

Reference 0.000
Linearity 0.000
Scale factor 20.000
Offset 0.000
Delay mSEC 50.000

Step 0 11/20 09:49:10

Elapsed Time minutes	INPUT 1 feet
0.0000	-0.012
0.0033	0.258
0.0066	3.597
0.0100	5.370
0.0133	5.219
0.0166	2.738
0.0200	1.868
0.0233	1.868
0.0266	1.741
0.0300	1.691
0.0333	1.621
0.0500	1.306
0.0666	1.085
0.0833	0.889
0.1000	0.744
0.1166	0.618
0.1333	0.517
0.1500	0.435
0.1666	0.366
0.1833	0.309
0.2000	0.265
0.2166	0.227
0.2333	0.195
0.2500	0.170
0.2666	0.145
0.2833	0.126
0.3000	0.113
0.3166	0.094
0.3333	0.082
0.4166	0.044
0.5000	0.018
0.5833	0.012
0.6666	0.006
0.7500	0.000
0.8333	0.000
0.9166	0.000
1.0000	-0.006
1.0833	0.000
1.1666	0.000
1.2500	-0.006
1.3333	-0.006
1.4166	-0.006
1.5000	-0.006
1.5833	-0.006
1.6666	-0.006
1.7500	-0.006
1.8333	0.000
1.9166	-0.006
2.0000	-0.006
2.5000	0.000
3.0000	0.000
3.5000	-0.006
4.0000	0.000
4.5000	0.000
5.0000	0.000
5.5000	0.000
6.0000	-0.006
6.5000	0.000
7.0000	0.000
7.5000	0.000
8.0000	0.000
8.5000	0.000
9.0000	0.000
9.5000	-0.006
10.0000	-0.006
11.0000	-0.006
12.0000	0.006
13.0000	0.000
14.0000	0.006
15.0000	0.012
16.0000	0.012
17.0000	0.012
18.0000	0.006
19.0000	0.000

END

MW-02-004 (TEST 2)
W02004R2.HMT
SE1000C
Environmental Logger
11/20 12:10

Unit# 00000 Test 1

INPUT 1: Level (F) TOC

Reference 0.000
Linearity 0.000
Scale factor 20.000
Offset 0.000
Delay mSEC 50.000

Step 0 11/20 10:12:25

Elapsed Time minutes	INPUT 1 feet
0.0000	7.604
0.0033	9.996
0.0066	12.735
0.0100	12.325
0.0133	10.053
0.0166	9.769
0.0200	9.630
0.0233	9.453
0.0266	9.365
0.0300	9.296
0.0333	9.226
0.0500	8.923
0.0666	8.677
0.0833	8.488
0.1000	8.343
0.1166	8.223
0.1333	8.128
0.1500	8.046
0.1666	7.983
0.1833	7.933
0.2000	7.888
0.2166	7.850
0.2333	7.819
0.2500	7.787
0.2666	7.768
0.2833	7.749
0.3000	7.731
0.3166	7.712
0.3333	7.705
0.4166	7.661
0.5000	7.642
0.5833	7.630
0.6666	7.623
0.7500	7.617
0.8333	7.617
0.9166	7.617
1.0000	7.617
1.0833	7.617
1.1666	7.617
1.2500	7.611
1.3333	7.611
1.4166	7.611
1.5000	7.611
1.5833	7.611
1.6666	7.611
1.7500	7.611
1.8333	7.604
1.9166	7.611
2.0000	7.611

END

MW-02-019 (TEST 1)
W02019R1.HMT
SE1000C
Environmental Logger
11/20 15:41

Unit# 00000 Test 2

INPUT 1: Level (F) TOC

Reference 0.000
Linearity 0.000
Scale factor 20.000
Offset 0.000
Delay mSEC 50.000

Step 0 11/20 15:15:38

Elapsed Time minutes	INPUT 1 feet
0.0000	0.530
0.0033	2.088
0.0066	2.309
0.0100	2.082
0.0133	1.880
0.0166	1.369
0.0200	0.896
0.0233	0.612
0.0266	0.448
0.0300	0.340
0.0333	0.271
0.0500	0.132
0.0666	0.094
0.0833	0.075
0.1000	0.069
0.1166	0.056
0.1333	0.050
0.1500	0.044
0.1666	0.037
0.1833	0.031
0.2000	0.031
0.2166	0.031
0.2333	0.025
0.2500	0.018
0.2666	0.018
0.2833	0.018
0.3000	0.018
0.3166	0.018
0.3333	0.012
0.4166	0.012
0.5000	0.006
0.5833	0.006
0.6666	0.006
0.7500	0.006
0.8333	0.006
0.9166	0.006
1.0000	0.006
1.0833	0.000
1.1666	0.006
1.2500	0.000
1.3333	0.000
1.4166	0.006
1.5000	0.006
1.5833	0.006
1.6666	0.006
1.7500	0.006
1.8333	0.006
1.9166	0.006
2.0000	0.006
2.5000	0.006
3.0000	0.006
3.5000	0.000
4.0000	0.000
4.5000	0.006
5.0000	0.006
5.5000	0.000
6.0000	0.000
6.5000	0.000
7.0000	0.000
7.5000	0.000
8.0000	0.000
8.5000	0.000
9.0000	0.000
9.5000	0.000
10.0000	0.000
11.0000	0.000
12.0000	0.006
13.0000	0.000

END

MW-02-019 (TEST 2)
W02019R2.HMT
SE1000C
Environmental Logger
11/20 15:43

Unit# 00000 Test 3

INPUT 1: Level (F) TOC

Reference 0.000
Linearity 0.000
Scale factor 20.000
Offset 0.000
Delay mSEC 50.000

Step 0 11/20 15:34:30

Elapsed Time minutes	INPUT 1 feet
0.0000	0.504
0.0033	1.886
0.0066	2.454
0.0100	2.170
0.0133	1.672
0.0166	1.375
0.0200	0.997
0.0233	0.700
0.0266	0.504
0.0300	0.385
0.0333	0.296
0.0500	0.145
0.0666	0.107
0.0833	0.082
0.1000	0.069
0.1166	0.063
0.1333	0.050
0.1500	0.050
0.1666	0.044
0.1833	0.031
0.2000	0.031
0.2166	0.031
0.2333	0.025
0.2500	0.025
0.2666	0.018
0.2833	0.018
0.3000	0.018
0.3166	0.018
0.3333	0.012
0.4166	0.012
0.5000	0.006
0.5833	0.006
0.6666	0.006
0.7500	0.000
0.8333	0.006
0.9166	0.006
1.0000	0.000
1.0833	0.000
1.1666	0.000
1.2500	0.000
1.3333	0.000
1.4166	0.000
1.5000	0.000
1.5833	0.000
1.6666	0.000
1.7500	0.000
1.8333	0.000
1.9166	0.000
2.0000	0.000

END

MW-02-020 (TEST 1)
W02020R1.HMT
SE1000C
Environmental Logger
11/20 16:22

Unit# 00000 Test 0

INPUT 1: Level (F) TOC

Reference 0.000
Linearity 0.000
Scale factor 20.000
Offset 0.000
Delay mSEC 50.000

Step 0 11/20 16:01:45

Elapsed Time minutes	INPUT 1 feet
0.0000	0.574
0.0033	3.887
0.0066	3.073
0.0100	4.323
0.0133	3.464
0.0166	2.284
0.0200	1.887
0.0233	1.729
0.0266	1.640
0.0300	1.609
0.0333	1.552
0.0500	1.255
0.0666	1.022
0.0833	0.833
0.1000	0.688
0.1166	0.568
0.1333	0.479
0.1500	0.403
0.1666	0.347
0.1833	0.296
0.2000	0.258
0.2166	0.227
0.2333	0.202
0.2500	0.176
0.2666	0.157
0.2833	0.145
0.3000	0.132
0.3166	0.119
0.3333	0.113
0.4166	0.082
0.5000	0.069
0.5833	0.063
0.6666	0.063
0.7500	0.056
0.8333	0.056
0.9166	0.056
1.0000	0.056
1.0833	0.056
1.1666	0.056
1.2500	0.056
1.3333	0.056
1.4166	0.056
1.5000	0.056
1.5833	0.056
1.6666	0.050
1.7500	0.050
1.8333	0.050
1.9166	0.056
2.0000	0.050
2.5000	0.050
3.0000	0.056
3.5000	0.050
4.0000	0.050
4.5000	0.050
5.0000	0.056
5.5000	0.050
6.0000	0.050
6.5000	0.050
7.0000	0.050
7.5000	0.050
8.0000	0.050
8.5000	0.050
9.0000	0.050
9.5000	0.050
10.0000	0.050
11.0000	0.050

END

MW-02-020 (TEST 2)
W020208.2.HMT
SE1000C
Environmental Logger
11/20 16:23

Unit# 00000 Test 1

INPUT 1: Level (F) TOC

Reference 0.000
Linearity 0.000
Scale factor 20.000
Offset 0.000
Delay mSEC 50.000

Step 0 11/20 16:17:15

Elapsed Time minutes	INPUT 1 feet
0.0000	0.246
0.0033	2.215
0.0066	2.473
0.0100	3.843
0.0133	3.546
0.0166	2.606
0.0200	1.943
0.0233	1.811
0.0266	1.659
0.0300	1.628
0.0333	1.584
0.0500	1.268
0.0666	1.041
0.0833	0.852
0.1000	0.700
0.1166	0.580
0.1333	0.486
0.1500	0.416
0.1666	0.347
0.1833	0.303
0.2000	0.265
0.2166	0.233
0.2333	0.202
0.2500	0.183
0.2666	0.164
0.2833	0.151
0.3000	0.132
0.3166	0.126
0.3333	0.119
0.4166	0.088
0.5000	0.075
0.5833	0.063
0.6666	0.063
0.7500	0.056
0.8333	0.056
0.9166	0.056
1.0000	0.056
1.0833	0.056
1.1666	0.056
1.2500	0.056
1.3333	0.056
1.4166	0.056
1.5000	0.056
1.5833	0.050
1.6666	0.050
1.7500	0.050
1.8333	0.050
1.9166	0.050
2.0000	0.050

END

MW-02-021 (TEST 1)
W02021F1.HMT
SE1000C
Environmental Logger
11/19 18:17

Unit# 00000 Test 5

INPUT 1: Level (F) TOC

Reference 0.000
Linearity 0.000
Scale factor 20.000
Offset 0.000
Delay mSEC 50.000

Step 0 11/19 17:28:47

Elapsed Time minutes	INPUT 1 feet
0.0000	-0.012
0.0033	-0.006
0.0066	-1.300
0.0100	-3.054
0.0133	-3.628
0.0166	-3.957
0.0200	-4.083
0.0233	-2.877
0.0266	-1.754
0.0300	-1.104
0.0333	-0.492
0.0500	-1.849
0.0666	-1.514
0.0833	-1.533
0.1000	-1.552
0.1166	-1.533
0.1333	-1.521
0.1500	-1.508
0.1666	-1.508
0.1833	-1.476
0.2000	-1.464
0.2166	-1.451
0.2333	-1.438
0.2500	-1.426
0.2666	-1.413
0.2833	-1.401
0.3000	-1.388
0.3166	-1.375
0.3333	-1.369
0.4166	-1.306
0.5000	-1.249
0.5833	-1.199
0.6666	-1.148
0.7500	-1.104
0.8333	-1.060
0.9166	-1.022
1.0000	-0.978
1.0833	-0.940
1.1666	-0.908
1.2500	-0.870
1.3333	-0.839
1.4166	-0.807
1.5000	-0.776
1.5833	-0.744
1.6666	-0.725
1.7500	-0.694
1.8333	-0.669
1.9166	-0.650
2.0000	-0.624
2.5000	-0.498
3.0000	-0.403
3.5000	-0.328
4.0000	-0.265
4.5000	-0.214
5.0000	-0.170
5.5000	-0.138
6.0000	-0.107
6.5000	-0.088
7.0000	-0.069
7.5000	-0.050
8.0000	-0.037
8.5000	-0.025
9.0000	-0.018
9.5000	-0.006
10.0000	-0.006
11.0000	0.006

END

MW-02-021 (TEST 2)
W02021R1.HMT
SE1000C
Environmental Logger
11/19 18:15

Unit# 00000 Test 4

INPUT 1: Level (F) TOC

Reference 0.000
Linearity 0.000
Scale factor 20.000
Offset 0.000
Delay mSEC 50.000

Step 0 11/19 17:06:50

Elapsed Time minutes	INPUT 1 feet
0.0000	-2.656
0.0033	4.525
0.0066	4.682
0.0100	-1.710
0.0133	-2.259
0.0166	-1.230
0.0200	-0.687
0.0233	-1.047
0.0266	-1.237
0.0300	-1.142
0.0333	-1.104
0.0500	-1.161
0.0666	-1.180
0.0833	-1.205
0.1000	-1.218
0.1166	-1.237
0.1333	-1.249
0.1500	-1.262
0.1666	-1.274
0.1833	-1.287
0.2000	-1.300
0.2166	-1.306
0.2333	-1.319
0.2500	-1.331
0.2666	-1.337
0.2833	-1.350
0.3000	-1.363
0.3166	-1.369
0.3333	-1.382
0.4166	-1.426
0.5000	-1.470
0.5833	-1.514
0.6666	-1.552
0.7500	-1.590
0.8333	-1.621
0.9166	-1.653
1.0000	-1.685
1.0833	-1.716
1.1666	-1.748
1.2500	-1.773
1.3333	-1.798
1.4166	-1.823
1.5000	-1.849
1.5833	-1.868
1.6666	-1.893
1.7500	-1.912
1.8333	-1.937
1.9166	-1.956
2.0000	-1.975
2.5000	-2.076
3.0000	-2.158
3.5000	-2.227
4.0000	-2.278
4.5000	-2.322
5.0000	-2.354
5.5000	-2.385
6.0000	-2.410
6.5000	-2.429
7.0000	-2.448
7.5000	-2.461
8.0000	-2.467
8.5000	-2.480
9.0000	-2.486
9.5000	-2.492
10.0000	-2.499
11.0000	-2.505
12.0000	-2.511
13.0000	-2.511
14.0000	-2.518
15.0000	-2.505

END

MW-02-021 (TEST 3)
W02021R2.HMT
SE1000C
Environmental Logger
11/19 18:18

Unit# 00000 Test 6

INPUT 1: Level (F) TOC

Reference 0.000
Linearity 0.000
Scale factor 20.000
Offset 0.000
Delay mSEC 50.000

Step 0 11/19 17:42:21

Elapsed Time minutes	INPUT 1 feet
0.0000	0.000
0.0033	0.063
0.0066	3.647
0.0100	6.816
0.0133	3.212
0.0166	1.123
0.0200	1.558
0.0233	2.038
0.0266	1.906
0.0300	1.760
0.0333	1.792
0.0500	1.729
0.0666	1.697
0.0833	1.666
0.1000	1.647
0.1166	1.622
0.1333	1.603
0.1500	1.590
0.1666	1.577
0.1833	1.558
0.2000	1.546
0.2166	1.527
0.2333	1.508
0.2500	1.495
0.2666	1.489
0.2833	1.470
0.3000	1.464
0.3166	1.451
0.3333	1.439
0.4166	1.375
0.5000	1.331
0.5833	1.274
0.6666	1.230
0.7500	1.186
0.8333	1.142
0.9166	1.104
1.0000	1.066
1.0833	1.028
1.1666	0.990
1.2500	0.959
1.3333	0.927
1.4166	0.896
1.5000	0.864
1.5833	0.833
1.6666	0.801
1.7500	0.776
1.8333	0.751
1.9166	0.725
2.0000	0.700
2.5000	0.574
3.0000	0.473
3.5000	0.385
4.0000	0.321
4.5000	0.271
5.0000	0.220
5.5000	0.183
6.0000	0.151
6.5000	0.132
7.0000	0.107
7.5000	0.088
8.0000	0.082
8.5000	0.069
9.0000	0.056
9.5000	0.050
10.0000	0.044
11.0000	0.031
12.0000	0.025

END

MW-02-022 (TEST 1)
W02022R1.HMT
SE1000C
Environmental Logger
11/22 10:22

Unit# 00000 Test 2

INPUT 1: Level (F) TOC

Reference 0.000
Linearity 0.000
Scale factor 20.000
Offset 0.000
Delay mSEC 50.000

Step 0 11/22 10:04:28

Elapsed Time minutes	INPUT 1 feet
0.0000	-0.006
0.0033	2.013
0.0066	7.061
0.0100	10.059
0.0133	1.375
0.0166	0.517
0.0200	2.840
0.0233	4.177
0.0266	2.259
0.0300	1.722
0.0333	2.789
0.0500	2.303
0.0666	2.417
0.0833	2.372
0.1000	2.347
0.1166	2.322
0.1333	2.297
0.1500	2.278
0.1666	2.259
0.1833	2.240
0.2000	2.221
0.2166	2.202
0.2333	2.189
0.2500	2.170
0.2666	2.152
0.2833	2.139
0.3000	2.120
0.3166	2.101
0.3333	2.082
0.4166	2.013
0.5000	1.937
0.5833	1.868
0.6666	1.798
0.7500	1.735
0.8333	1.672
0.9166	1.615
1.0000	1.558
1.0833	1.502
1.1666	1.451
1.2500	1.401
1.3333	1.356
1.4166	1.306
1.5000	1.262
1.5833	1.217
1.6666	1.180
1.7500	1.135
1.8333	1.098
1.9166	1.060
2.0000	1.022
2.5000	0.826
3.0000	0.675
3.5000	0.555
4.0000	0.448
4.5000	0.372
5.0000	0.302
5.5000	0.252
6.0000	0.208
6.5000	0.170
7.0000	0.145
7.5000	0.119
8.0000	0.100
8.5000	0.082
9.0000	0.075
9.5000	0.063
10.0000	0.056
11.0000	0.037
12.0000	0.031
13.0000	0.031

END

MW-02-022 (TEST 2)
W020228R2.HMT
SE1000C
Environmental Logger
11/22 11:13

Unit# 00000 Test 3

INPUT 1: Level (F) TOC

Reference 0.000
Linearity 0.000
Scale factor 20.000
Offset 0.000
Delay mSEC 50.000

Step 0 11/22 10:32:06

Elapsed Time minutes	INPUT 1 feet
0.0000	0.000
0.0033	3.679
0.0066	10.974
0.0100	3.862
0.0133	0.302
0.0166	1.110
0.0200	3.729
0.0233	3.780
0.0266	1.653
0.0300	1.931
0.0333	3.041
0.0500	2.278
0.0666	2.404
0.0833	2.372
0.1000	2.341
0.1166	2.322
0.1333	2.303
0.1500	2.284
0.1666	2.265
0.1833	2.246
0.2000	2.227
0.2166	2.215
0.2333	2.196
0.2500	2.177
0.2666	2.164
0.2833	2.145
0.3000	2.133
0.3166	2.114
0.3333	2.101
0.4166	2.025
0.5000	1.956
0.5833	1.887
0.6666	1.823
0.7500	1.760
0.8333	1.691
0.9166	1.634
1.0000	1.584
1.0833	1.527
1.1666	1.476
1.2500	1.426
1.3333	1.382
1.4166	1.331
1.5000	1.287
1.5833	1.249
1.6666	1.205
1.7500	1.161
1.8333	1.123
1.9166	1.085
2.0000	1.053
2.5000	0.858
3.0000	0.700
3.5000	0.580
4.0000	0.479
4.5000	0.397
5.0000	0.334
5.5000	0.277
6.0000	0.233
6.5000	0.201
7.0000	0.170
7.5000	0.145
8.0000	0.126
8.5000	0.107
9.0000	0.094
9.5000	0.088
10.0000	0.075
11.0000	0.063

END

MW-02-030 (TEST 1)
W02030F1.HMT
SE1000C
Environmental Logger
11/20 15:01

Unit# 00000 Test 0

INPUT 1: Level (F) TOC

Reference 0.000
Linearity 0.000
Scale factor 20.000
Offset 0.000
Delay mSEC 50.000

Step 0 11/20 14:32:07

Elapsed Time minutes	INPUT 1 feet
0.0000	5.156
0.0033	5.143
0.0066	0.473
0.0100	3.856
0.0133	3.414
0.0166	2.048
0.0200	2.234
0.0233	1.249
0.0266	1.754
0.0300	1.173
0.0333	1.274
0.0500	3.774
0.0666	3.452
0.0833	3.635
0.1000	3.679
0.1166	3.837
0.1333	3.994
0.1500	3.912
0.1666	3.969
0.1833	4.039
0.2000	4.095
0.2166	4.152
0.2333	4.203
0.2500	4.329
0.2666	4.297
0.2833	4.272
0.3000	4.323
0.3166	4.430
0.3333	4.455
0.4166	4.619
0.5000	4.733
0.5833	4.827
0.6666	4.891
0.7500	4.947
0.8333	4.985
0.9166	5.023
1.0000	5.048
1.0833	5.067
1.1666	5.086
1.2500	5.099
1.3333	5.105
1.4166	5.111
1.5000	5.124
1.5833	5.124
1.6666	5.130
1.7500	5.137
1.8333	5.137
1.9166	5.143
2.0000	5.143
2.5000	5.149
3.0000	5.149
3.5000	5.156
4.0000	5.156
4.5000	5.149
5.0000	5.156
5.5000	5.156
6.0000	5.156
6.5000	5.156
7.0000	5.156
7.5000	5.156
8.0000	5.156
8.5000	5.156
9.0000	5.156
9.5000	5.156
10.0000	5.156
11.0000	5.156
12.0000	5.149
13.0000	5.149
14.0000	5.149

END

MW-02-030 (TEST 2)
W02030R1.HMT
SE1000C
Environmental Logger
11/20 15:02

Unit# 00000 Test 1

INPUT 1: Level (F) TOC

Reference 0.000
Linearity 0.000
Scale factor 20.000
Offset 0.000
Delay mSEC 50.000

Step 0 11/20 14:48:15

Elapsed Time minutes	INPUT 1 feet
0.0000	0.852
0.0033	2.991
0.0066	3.123
0.0100	4.234
0.0133	3.174
0.0166	3.370
0.0200	2.802
0.0233	2.543
0.0266	2.316
0.0300	2.360
0.0333	2.322
0.0500	2.088
0.0666	1.950
0.0833	1.830
0.1000	1.729
0.1166	1.615
0.1333	1.514
0.1500	1.476
0.1666	1.344
0.1833	1.268
0.2000	1.205
0.2166	1.142
0.2333	1.079
0.2500	1.022
0.2666	0.965
0.2833	0.915
0.3000	0.870
0.3166	0.826
0.3333	0.782
0.4166	0.605
0.5000	0.467
0.5833	0.366
0.6666	0.284
0.7500	0.220
0.8333	0.176
0.9166	0.138
1.0000	0.113
1.0833	0.088
1.1666	0.075
1.2500	0.063
1.3333	0.050
1.4166	0.044
1.5000	0.037
1.5833	0.031
1.6666	0.031
1.7500	0.025
1.8333	0.018
1.9166	0.018
2.0000	0.018
2.5000	0.018
3.0000	0.012
3.5000	0.006
4.0000	0.012
4.5000	0.006
5.0000	0.006

END

MW-02-033 (TEST 1)
W02033R1.HMT
SE1000C
Environmental Logger
11/19 13:41

Unit# 00000 Test 0

INPUT 1: Level (F) TOC

Reference 0.000
Linearity 0.000
Scale factor 20.000
Offset 0.000
Delay mSEC 50.000

Step 0 11/19 12:00:52

Elapsed Time minutes	INPUT 1 feet
0.0000	2.272
0.0033	2.038
0.0066	1.723
0.0100	1.331
0.0133	1.401
0.0166	1.729
0.0200	1.502
0.0233	1.388
0.0266	1.401
0.0300	1.470
0.0333	1.426
0.0500	1.382
0.0666	1.388
0.0833	1.388
0.1000	1.363
0.1166	1.363
0.1333	1.350
0.1500	1.356
0.1666	1.344
0.1833	1.338
0.2000	1.331
0.2166	1.300
0.2333	1.306
0.2500	1.312
0.2666	1.300
0.2833	1.293
0.3000	1.287
0.3166	1.281
0.3333	1.281
0.4166	1.262
0.5000	1.249
0.5833	1.205
0.6666	1.199
0.7500	1.142
0.8333	1.161
0.9166	1.136
1.0000	1.136
1.0833	1.117
1.1666	1.104
1.2500	1.085
1.3333	1.066
1.4166	1.054
1.5000	1.035
1.5833	1.022
1.6666	1.009
1.7500	0.990
1.8333	0.978
1.9166	0.965
2.0000	0.953
2.5000	0.877
3.0000	0.807
3.5000	0.738
4.0000	0.681
4.5000	0.631
5.0000	0.587
5.5000	0.542
6.0000	0.504
6.5000	0.467
7.0000	0.435
7.5000	0.403
8.0000	0.378
8.5000	0.353
9.0000	0.328
9.5000	0.303
10.0000	0.284
11.0000	0.252
12.0000	0.214
13.0000	0.195
14.0000	0.170
15.0000	0.157
16.0000	0.138
17.0000	0.126
18.0000	0.113

END

MW-02-033 (TEST 2)
W02033R2.HMT
SE1000C
Environmental Logger
11/19 13:43

Unit# 00000 Test 1

INPUT 1: Level (F) TOC

Reference 0.000
Linearity 0.000
Scale factor 20.000
Offset 0.000
Delay mSEC 50.000

Step 0 11/19 12:48:24

Elapsed Time minutes	INPUT 1 feet
0.0000	6.235
0.0033	3.149
0.0066	4.903
0.0100	1.666
0.0133	2.006
0.0166	2.372
0.0200	2.499
0.0233	2.177
0.0266	2.032
0.0300	2.234
0.0333	2.297
0.0500	2.139
0.0666	2.221
0.0833	2.126
0.1000	2.126
0.1166	2.095
0.1333	2.107
0.1500	2.076
0.1666	2.057
0.1833	2.057
0.2000	2.032
0.2166	2.032
0.2333	2.013
0.2500	2.006
0.2666	2.000
0.2833	1.988
0.3000	1.981
0.3166	1.962
0.3333	1.962
0.4166	1.924
0.5000	1.893
0.5833	1.861
0.6666	1.830
0.7500	1.798
0.8333	1.767
0.9166	1.741
1.0000	1.716
1.0833	1.685
1.1666	1.659
1.2500	1.634
1.3333	1.609
1.4166	1.584
1.5000	1.558
1.5833	1.539
1.6666	1.514
1.7500	1.495
1.8333	1.470
1.9166	1.445
2.0000	1.426
2.5000	1.300
3.0000	1.186
3.5000	1.085
4.0000	0.990
4.5000	0.908
5.0000	0.833
5.5000	0.763
6.0000	0.700
6.5000	0.643
7.0000	0.586
7.5000	0.542
8.0000	0.498
8.5000	0.460
9.0000	0.422
9.5000	0.391
10.0000	0.359
11.0000	0.309
12.0000	0.265
13.0000	0.233
14.0000	0.208
15.0000	0.176
16.0000	0.157
17.0000	0.132
18.0000	0.113
19.0000	0.107
20.0000	0.094

END

MW-02-040 (TEST 1)
W020400F1.HMT
SE1000C
Environmental Logger
11/21 16:33

Unit# 00000 Test 0

INPUT 1: Level (F) TOC

Reference 0.000
Linearity 0.000
Scale factor 20.000
Offset 0.000
Delay mSEC 50.000

Step 0 11/21 16:19:40

Elapsed Time minutes	INPUT 1 feet
0.0000	0.000
0.0033	0.000
0.0066	0.000
0.0100	-0.517
0.0133	-2.391
0.0166	-3.130
0.0200	-3.471
0.0233	-3.609
0.0266	-3.325
0.0300	-2.505
0.0333	-0.744
0.0500	-1.211
0.0666	-0.877
0.0833	-0.725
0.1000	-0.605
0.1166	-0.504
0.1333	-0.429
0.1500	-0.359
0.1666	-0.315
0.1833	-0.265
0.2000	-0.233
0.2166	-0.201
0.2333	-0.176
0.2500	-0.157
0.2666	-0.138
0.2833	-0.119
0.3000	-0.113
0.3166	-0.100
0.3333	-0.088
0.4166	-0.056
0.5000	-0.037
0.5833	-0.031
0.6666	-0.025
0.7500	-0.018
0.8333	-0.012
0.9166	-0.012
1.0000	-0.012
1.0833	-0.006
1.1666	-0.006
1.2500	-0.006
1.3333	-0.006
1.4166	-0.006
1.5000	-0.006
1.5833	-0.006
1.6666	-0.006
1.7500	0.000
1.8333	0.000
1.9166	0.000
2.0000	0.000
2.5000	0.000

END

MW-02-040 (TEST 2)
W020408R1.HMT
SE1000C
Environmental Logger
11/21 16:34

Unit# 00000 Test 1

INPUT 1: Level (F) TOC

Reference 0.000
Linearity 0.000
Scale factor 20.000
Offset 0.000
Delay mSEC 50.000

Step 0 11/21 16:25:04

Elapsed Time minutes	INPUT 1 feet
0.0000	0.000
0.0033	0.347
0.0066	1.918
0.0100	3.042
0.0133	2.070
0.0166	1.388
0.0200	1.420
0.0233	1.760
0.0266	1.735
0.0300	1.603
0.0333	1.514
0.0500	1.192
0.0666	0.946
0.0833	0.751
0.1000	0.624
0.1166	0.523
0.1333	0.441
0.1500	0.378
0.1666	0.321
0.1833	0.277
0.2000	0.246
0.2166	0.214
0.2333	0.189
0.2500	0.164
0.2666	0.151
0.2833	0.132
0.3000	0.120
0.3166	0.107
0.3333	0.101
0.4166	0.069
0.5000	0.050
0.5833	0.037
0.6666	0.031
0.7500	0.025
0.8333	0.025
0.9166	0.019
1.0000	0.019
1.0833	0.019
1.1666	0.012
1.2500	0.012
1.3333	0.012
1.4166	0.012
1.5000	0.012
1.5833	0.006
1.6666	0.012
1.7500	0.006
1.8333	0.006
1.9166	0.006
2.0000	0.006

END

MW-02-041 (TEST 1)
W02041F1.HMT
SE1000C
Environmental Logger
11/21 17:46

Unit# 00000 Test 4

INPUT 1: Level (F) TOC

Reference 0.000
Linearity 0.000
Scale factor 20.000
Offset 0.000
Delay mSEC 50.000

Step 0 11/21 17:17:56

Elapsed Time minutes	INPUT 1 feet
0.0000	0.000
0.0033	-0.012
0.0066	-1.407
0.0100	-2.170
0.0133	-2.593
0.0166	-2.915
0.0200	-2.972
0.0233	-2.770
0.0266	0.176
0.0300	-1.760
0.0333	-1.596
0.0500	-1.142
0.0666	-1.003
0.0833	-0.902
0.1000	-0.776
0.1166	-0.681
0.1333	-0.599
0.1500	-0.530
0.1666	-0.473
0.1833	-0.416
0.2000	-0.372
0.2166	-0.328
0.2333	-0.296
0.2500	-0.265
0.2666	-0.233
0.2833	-0.214
0.3000	-0.195
0.3166	-0.176
0.3333	-0.157
0.4166	-0.100
0.5000	-0.069
0.5833	-0.050
0.6666	-0.031
0.7500	-0.025
0.8333	-0.025
0.9166	-0.018
1.0000	-0.018
1.0833	-0.012
1.1666	-0.012
1.2500	-0.012
1.3333	-0.012
1.4166	-0.006
1.5000	-0.006
1.5833	-0.006
1.6666	-0.006
1.7500	-0.012
1.8333	-0.006
1.9166	-0.006
2.0000	-0.006
2.5000	-0.006
3.0000	-0.006
3.5000	-0.006
4.0000	-0.006
4.5000	-0.006
5.0000	-0.006
5.5000	0.000
6.0000	0.000

END

MW-02-041 (TEST 2)
W02041R1.HMT
SE1000C
Environmental Logger
11/21 17:47

Unit# 00000 Test 5

INPUT 1: Level (F) TOC

Reference 0.000
Linearity 0.000
Scale factor 20.000
Offset 0.000
Delay mSEC 50.000

Step 0 11/21 17:26:33

Elapsed Time minutes	INPUT 1 feet
0.0000	-0.006
0.0033	2.398
0.0066	2.013
0.0100	1.893
0.0133	1.918
0.0166	2.095
0.0200	1.962
0.0233	1.805
0.0266	1.685
0.0300	1.584
0.0333	1.521
0.0500	1.293
0.0666	1.104
0.0833	0.953
0.1000	0.826
0.1166	0.719
0.1333	0.631
0.1500	0.549
0.1666	0.479
0.1833	0.429
0.2000	0.372
0.2166	0.334
0.2333	0.296
0.2500	0.265
0.2666	0.239
0.2833	0.220
0.3000	0.195
0.3166	0.170
0.3333	0.157
0.4166	0.094
0.5000	0.063
0.5833	0.044
0.6666	0.031
0.7500	0.019
0.8333	0.012
0.9166	0.012
1.0000	0.006
1.0833	0.006
1.1666	0.006
1.2500	0.006
1.3333	0.000
1.4166	0.000
1.5000	0.000
1.5833	-0.006
1.6666	-0.006
1.7500	-0.006
1.8333	0.000
1.9166	0.000
2.0000	-0.006
2.5000	-0.006

END

MW-02-042 (TEST 1)
W02042F1.HMT
SE1000C
Environmental Logger
11/21 17:06

Unit# 00000 Test 2

INPUT 1: Level (F) TOC

Reference 0.000
Linearity 0.000
Scale factor 20.000
Offset 0.000
Delay mSEC 50.000

Step 0 11/21 16:48:56

Elapsed Time minutes	INPUT 1 feet
0.0000	-0.031
0.0033	-2.473
0.0066	-2.366
0.0100	-2.136
0.0133	-4.064
0.0166	-3.559
0.0200	-0.858
0.0233	-1.849
0.0266	-1.653
0.0300	-1.268
0.0333	-1.861
0.0500	-1.836
0.0666	-1.918
0.0833	-1.842
0.1000	-1.823
0.1166	-1.767
0.1333	-1.735
0.1500	-1.691
0.1666	-1.653
0.1833	-1.622
0.2000	-1.584
0.2166	-1.539
0.2333	-1.502
0.2500	-1.464
0.2666	-1.438
0.2833	-1.401
0.3000	-1.369
0.3166	-1.331
0.3333	-1.300
0.4166	-1.161
0.5000	-1.035
0.5833	-0.915
0.6666	-0.814
0.7500	-0.732
0.8333	-0.650
0.9166	-0.580
1.0000	-0.523
1.0833	-0.467
1.1666	-0.422
1.2500	-0.372
1.3333	-0.340
1.4166	-0.309
1.5000	-0.271
1.5833	-0.239
1.6666	-0.220
1.7500	-0.195
1.8333	-0.176
1.9166	-0.164
2.0000	-0.145
2.5000	-0.075
3.0000	-0.044
3.5000	-0.025
4.0000	-0.012
4.5000	0.000
5.0000	0.000
5.5000	0.000
6.0000	0.000

END

MW-02-042 (TEST 2)
W02042R1.HMT
SE1000C
Environmental Logger
11/21 17:08

Unit# 00000 Test 3

INPUT 1: Level (F) TOC

Reference 0.000
Linearity 0.000
Scale factor 20.000
Offset 0.000
Delay mSEC 50.000

Step 0 11/21 16:57:49

Elapsed Time minutes	INPUT 1 feet
0.0000	3.212
0.0033	2.253
0.0066	2.139
0.0100	2.101
0.0133	2.051
0.0166	2.095
0.0200	2.227
0.0233	2.215
0.0266	2.126
0.0300	2.057
0.0333	2.101
0.0500	2.032
0.0666	1.975
0.0833	1.924
0.1000	1.874
0.1166	1.830
0.1333	1.786
0.1500	1.741
0.1666	1.704
0.1833	1.666
0.2000	1.622
0.2166	1.584
0.2333	1.552
0.2500	1.521
0.2666	1.483
0.2833	1.451
0.3000	1.420
0.3166	1.382
0.3333	1.356
0.4166	1.211
0.5000	1.079
0.5833	0.965
0.6666	0.864
0.7500	0.776
0.8333	0.694
0.9166	0.618
1.0000	0.555
1.0833	0.498
1.1666	0.448
1.2500	0.403
1.3333	0.366
1.4166	0.321
1.5000	0.290
1.5833	0.258
1.6666	0.239
1.7500	0.214
1.8333	0.195
1.9166	0.176
2.0000	0.151
2.5000	0.082
3.0000	0.044
3.5000	0.025
4.0000	0.012
4.5000	0.006

END

MW-02-043 (TEST 1)
W02043R1.HMT
SE1000C
Environmental Logger
11/21 12:20

Unit# 00000 Test 8

INPUT 1: Level (F) TOC

Reference 0.000
Linearity 0.000
Scale factor 20.000
Offset 0.000
Delay mSEC 50.000

Step 0 11/21 11:42:09

Elapsed Time minutes	INPUT 1 feet
0.0000	0.006
0.0033	0.366
0.0066	4.777
0.0100	8.791
0.0133	1.420
0.0166	-0.309
0.0200	0.479
0.0233	3.610
0.0266	3.243
0.0300	0.978
0.0333	1.464
0.0500	1.849
0.0666	1.874
0.0833	1.792
0.1000	1.748
0.1166	1.704
0.1333	1.666
0.1500	1.622
0.1666	1.584
0.1833	1.546
0.2000	1.508
0.2166	1.476
0.2333	1.445
0.2500	1.426
0.2666	1.388
0.2833	1.369
0.3000	1.338
0.3166	1.312
0.3333	1.287
0.4166	1.167
0.5000	1.060
0.5833	0.971
0.6666	0.883
0.7500	0.807
0.8333	0.738
0.9166	0.675
1.0000	0.618
1.0833	0.568
1.1666	0.517
1.2500	0.473
1.3333	0.435
1.4166	0.403
1.5000	0.366
1.5833	0.340
1.6666	0.315
1.7500	0.290
1.8333	0.271
1.9166	0.246
2.0000	0.227
2.5000	0.145
3.0000	0.101
3.5000	0.069
4.0000	0.050
4.5000	0.044
5.0000	0.037
5.5000	0.031
6.0000	0.025
6.5000	0.025
7.0000	0.025
7.5000	0.025
8.0000	0.025

END

MW-02-043 (TEST 2)
W02043R2.HMT
SE1000C
Environmental Logger
11/21 12:20

Unit# 00000 Test 8

INPUT 1: Level (F) TOC

Reference 0.000
Linearity 0.000
Scale factor 20.000
Offset 0.000
Delay mSEC 50.000

Step 0 11/21 11:42:09

Elapsed Time minutes	INPUT 1 feet
0.0000	0.006
0.0033	0.366
0.0066	4.777
0.0100	8.791
0.0133	1.420
0.0166	-0.309
0.0200	0.479
0.0233	3.610
0.0266	3.243
0.0300	0.978
0.0333	1.464
0.0500	1.849
0.0666	1.874
0.0833	1.792
0.1000	1.748
0.1166	1.704
0.1333	1.666
0.1500	1.622
0.1666	1.584
0.1833	1.546
0.2000	1.508
0.2166	1.476
0.2333	1.445
0.2500	1.426
0.2666	1.388
0.2833	1.369
0.3000	1.338
0.3166	1.312
0.3333	1.287
0.4166	1.167
0.5000	1.060
0.5833	0.971
0.6666	0.883
0.7500	0.807
0.8333	0.738
0.9166	0.675
1.0000	0.618
1.0833	0.568
1.1666	0.517
1.2500	0.473
1.3333	0.435
1.4166	0.403
1.5000	0.366
1.5833	0.340
1.6666	0.315
1.7500	0.290
1.8333	0.271
1.9166	0.246
2.0000	0.227
2.5000	0.145
3.0000	0.101
3.5000	0.069
4.0000	0.050
4.5000	0.044
5.0000	0.037
5.5000	0.031
6.0000	0.025
6.5000	0.025
7.0000	0.025
7.5000	0.025
8.0000	0.025

END

MW-02-044 (TEST 1)
W02044F1.HMT
SE1000C
Environmental Logger
11/21 12:15

Unit# 00000 Test 5

INPUT 1: Level (F) TOC

Reference 0.000
Linearity 0.000
Scale factor 20.000
Offset 0.000
Delay mSEC 50.000

Step 0 11/21 10:55:39

Elapsed Time minutes	INPUT 1 feet
0.0000	-0.006
0.0033	-0.012
0.0066	-1.104
0.0100	-1.420
0.0133	-1.514
0.0166	-1.937
0.0200	-2.360
0.0233	-2.524
0.0266	-2.530
0.0300	-1.969
0.0333	-1.615
0.0500	-1.596
0.0666	-1.388
0.0833	-1.243
0.1000	-1.136
0.1166	-1.054
0.1333	-0.978
0.1500	-0.902
0.1666	-0.839
0.1833	-0.782
0.2000	-0.719
0.2166	-0.675
0.2333	-0.624
0.2500	-0.580
0.2666	-0.549
0.2833	-0.505
0.3000	-0.479
0.3166	-0.448
0.3333	-0.416
0.4166	-0.303
0.5000	-0.227
0.5833	-0.170
0.6666	-0.132
0.7500	-0.101
0.8333	-0.082
0.9166	-0.063
1.0000	-0.050
1.0833	-0.044
1.1666	-0.038
1.2500	-0.031
1.3333	-0.031
1.4166	-0.025
1.5000	-0.019
1.5833	-0.019
1.6666	-0.019
1.7500	-0.019
1.8333	-0.012
1.9166	-0.012
2.0000	-0.012

END

MW-02-044 (TEST 2)
W02044R1.HMT
SE1000C
Environmental Logger
11/21 12:16

Unit# 00000 Test 6

INPUT 1: Level (F) TOC

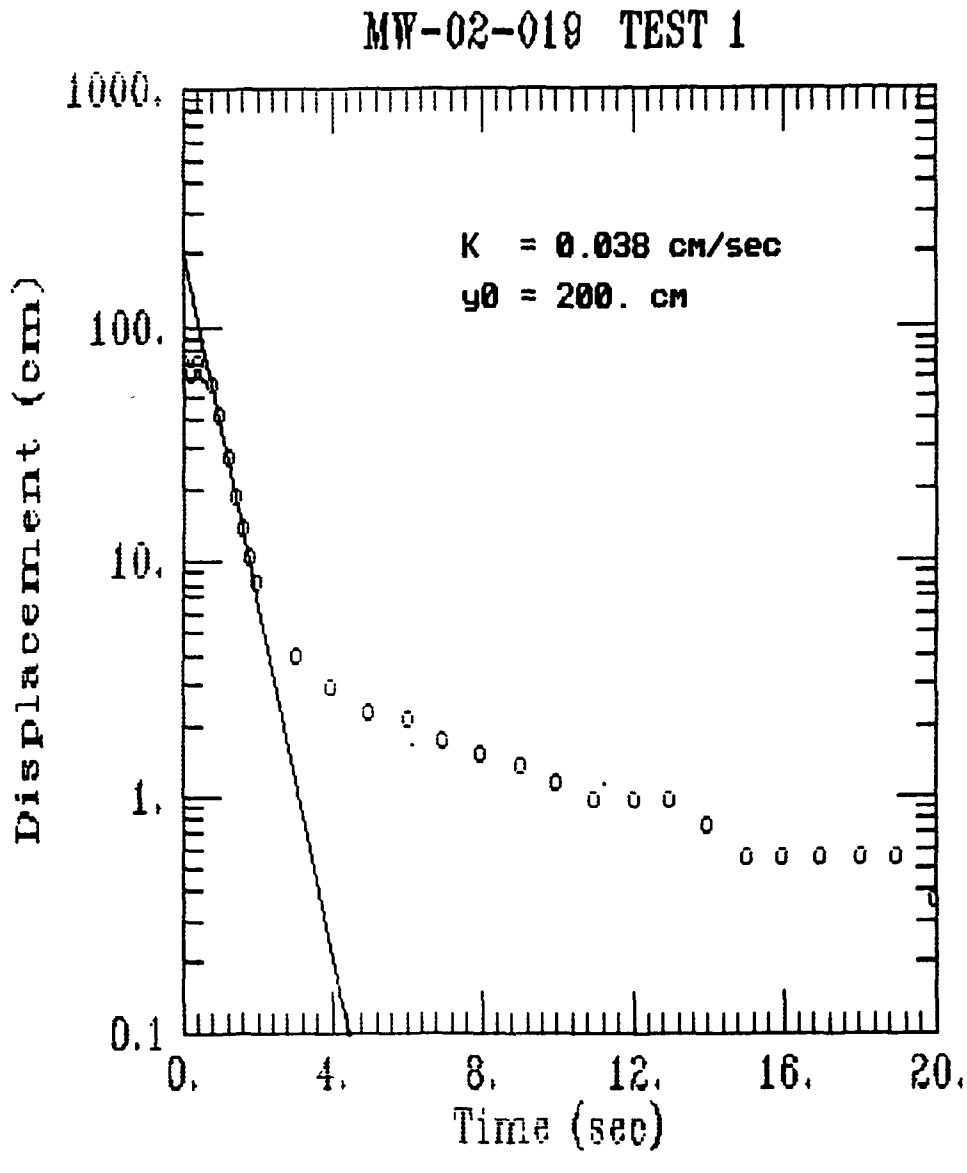
Reference 0.000
Linearity 0.000
Scale factor 20.000
Offset 0.000
Delay mSEC 50.000

Step 0 11/21 11:00:17

Elapsed Time minutes	INPUT 1 feet
0.0000	0.328
0.0033	2.448
0.0066	4.354
0.0100	1.729
0.0133	1.590
0.0166	2.013
0.0200	1.937
0.0233	1.823
0.0266	1.792
0.0300	1.773
0.0333	1.748
0.0500	1.565
0.0666	1.407
0.0833	1.287
0.1000	1.180
0.1166	1.085
0.1333	0.997
0.1500	0.927
0.1666	0.858
0.1833	0.788
0.2000	0.732
0.2166	0.681
0.2333	0.631
0.2500	0.593
0.2666	0.549
0.2833	0.511
0.3000	0.479
0.3166	0.448
0.3333	0.422
0.4166	0.302
0.5000	0.227
0.5833	0.170
0.6666	0.132
0.7500	0.107
0.8333	0.088
0.9166	0.075
1.0000	0.063
1.0833	0.056
1.1666	0.050
1.2500	0.044
1.3333	0.037
1.4166	0.037
1.5000	0.031
1.5833	0.031
1.6666	0.031
1.7500	0.025
1.8333	0.025
1.9166	0.025
2.0000	0.025

END

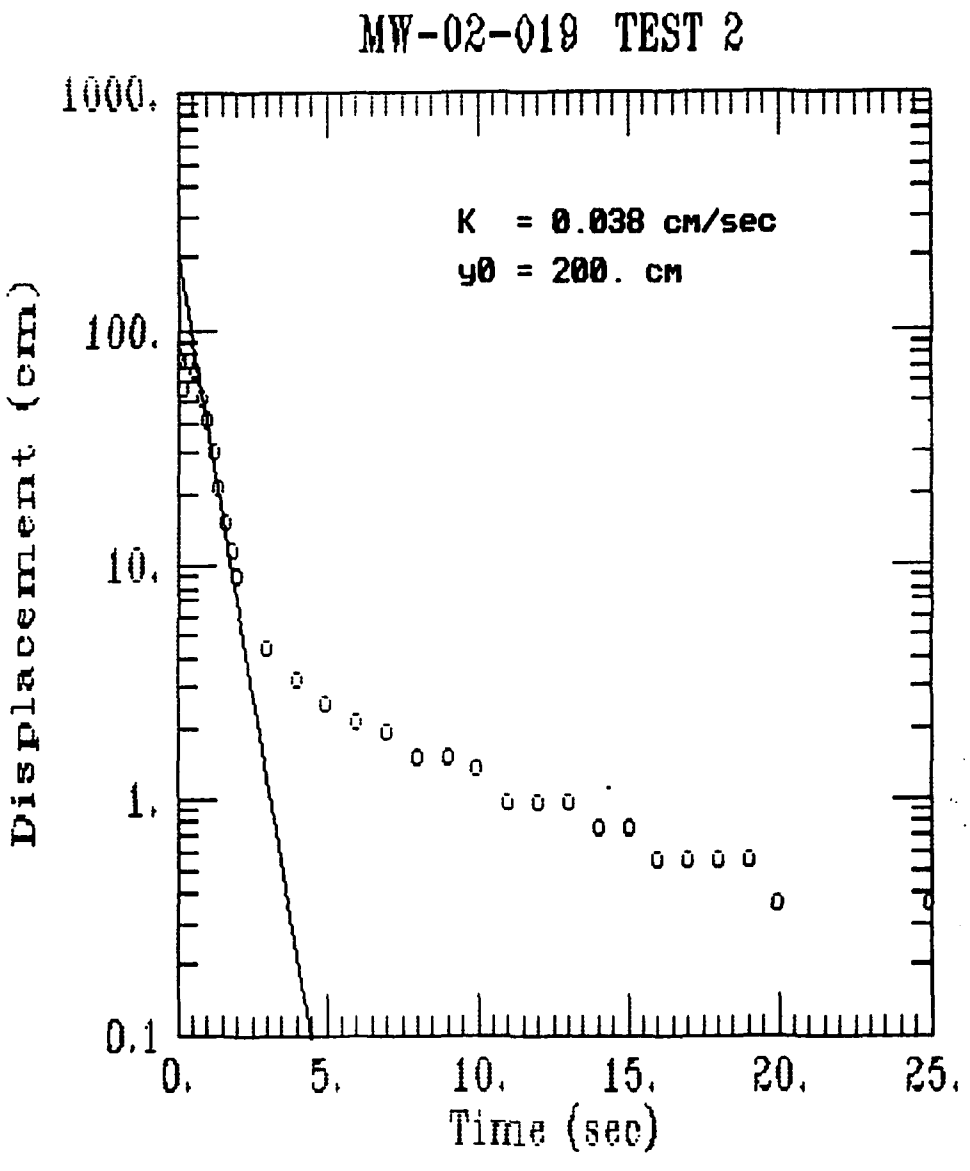
URS INDEPENDENT REVIEW OF SLUG TESTS



AQTESOLV

GERAGHTY & MILLER, INC.

Modeling Group



AQTESOLV

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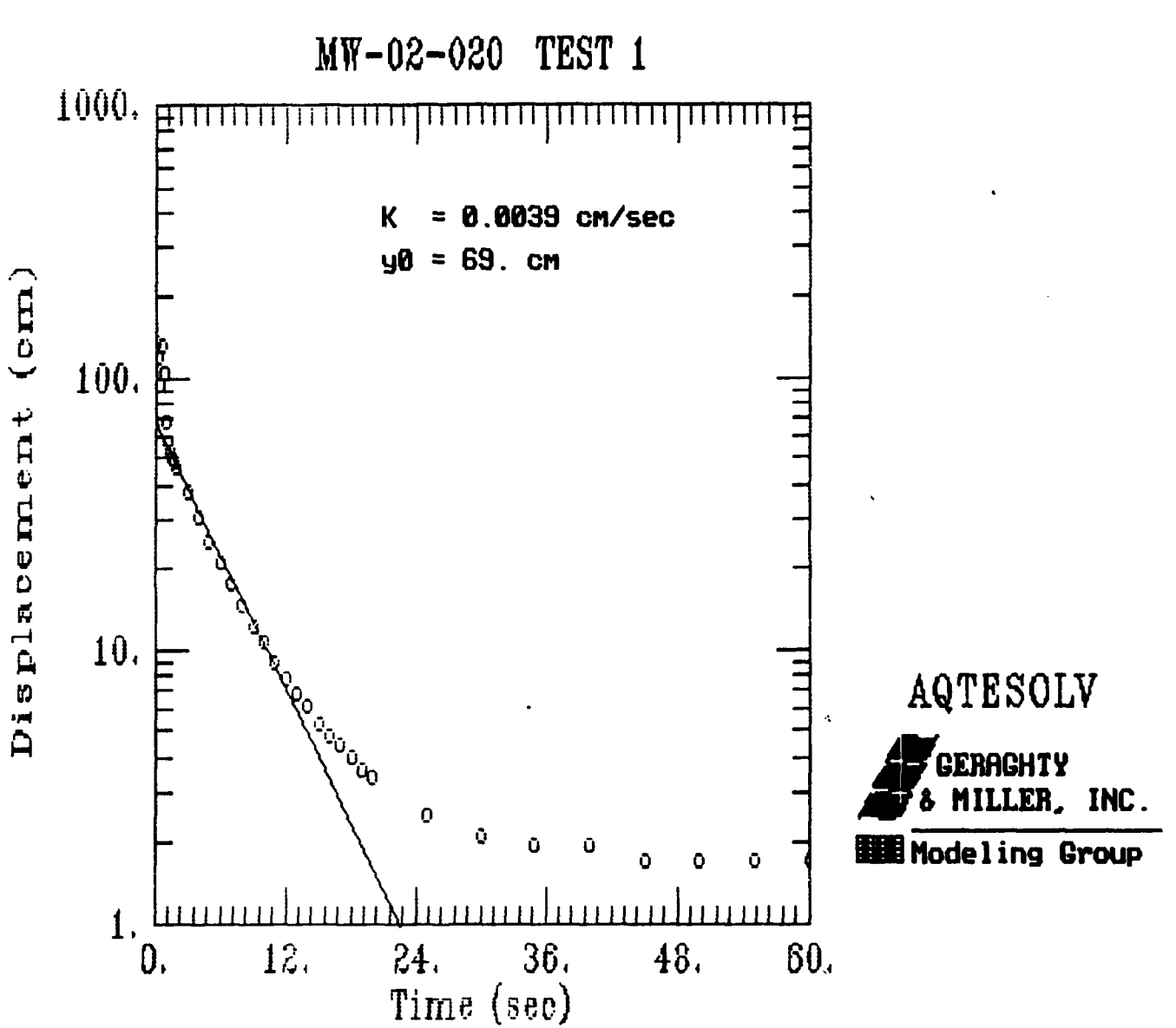
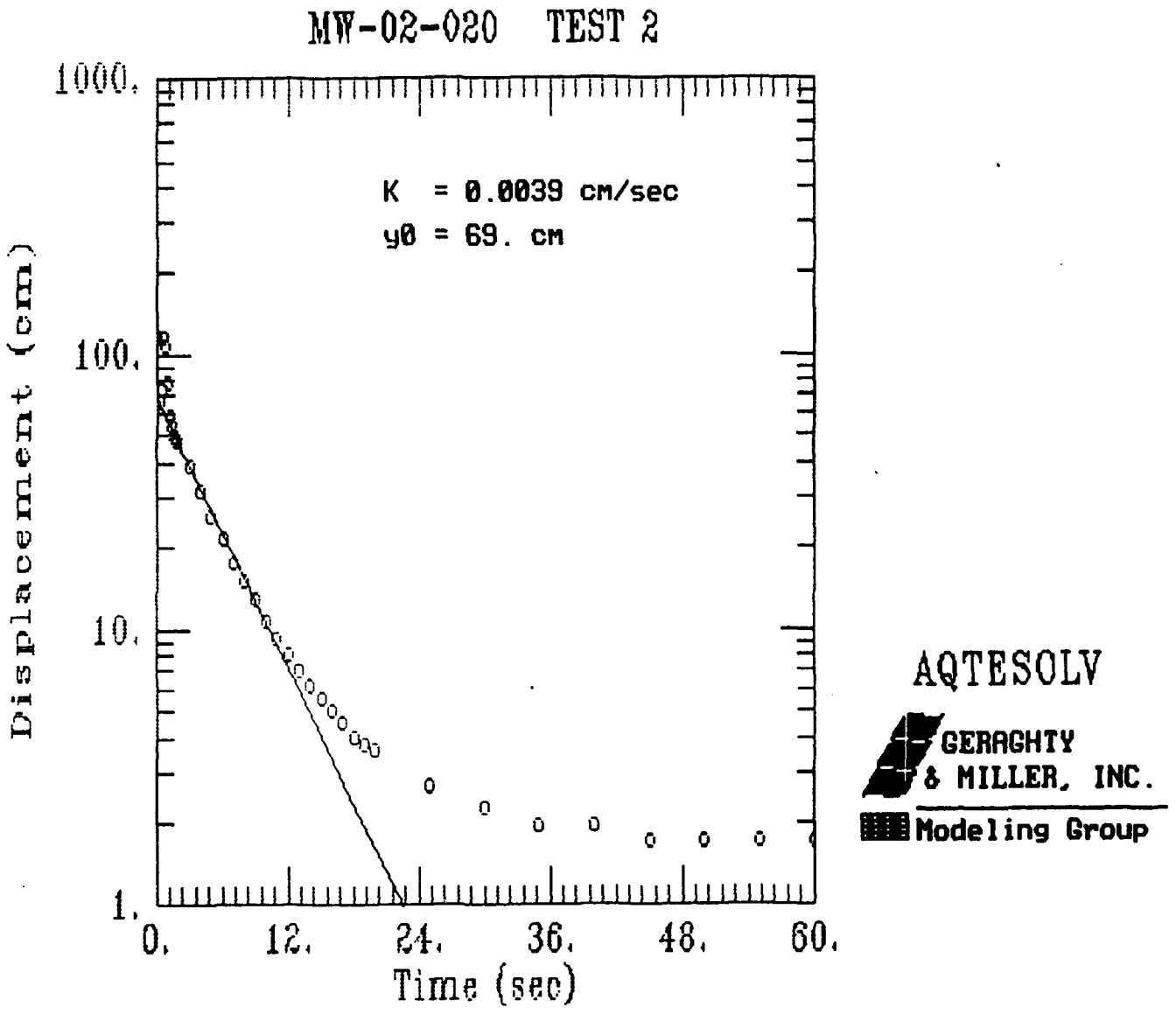

MW-02-020 TEST 1
K = 0.0039 cm/sec
y0 = 69. cm
1000.
100.
10.
1.
Displacement (cm)
0.
12.
24.
36.
48.
60.
Time (sec)
AQTESOLV
GERAGHTY & MILLER, INC.
Modeling Group



AQTESOLV

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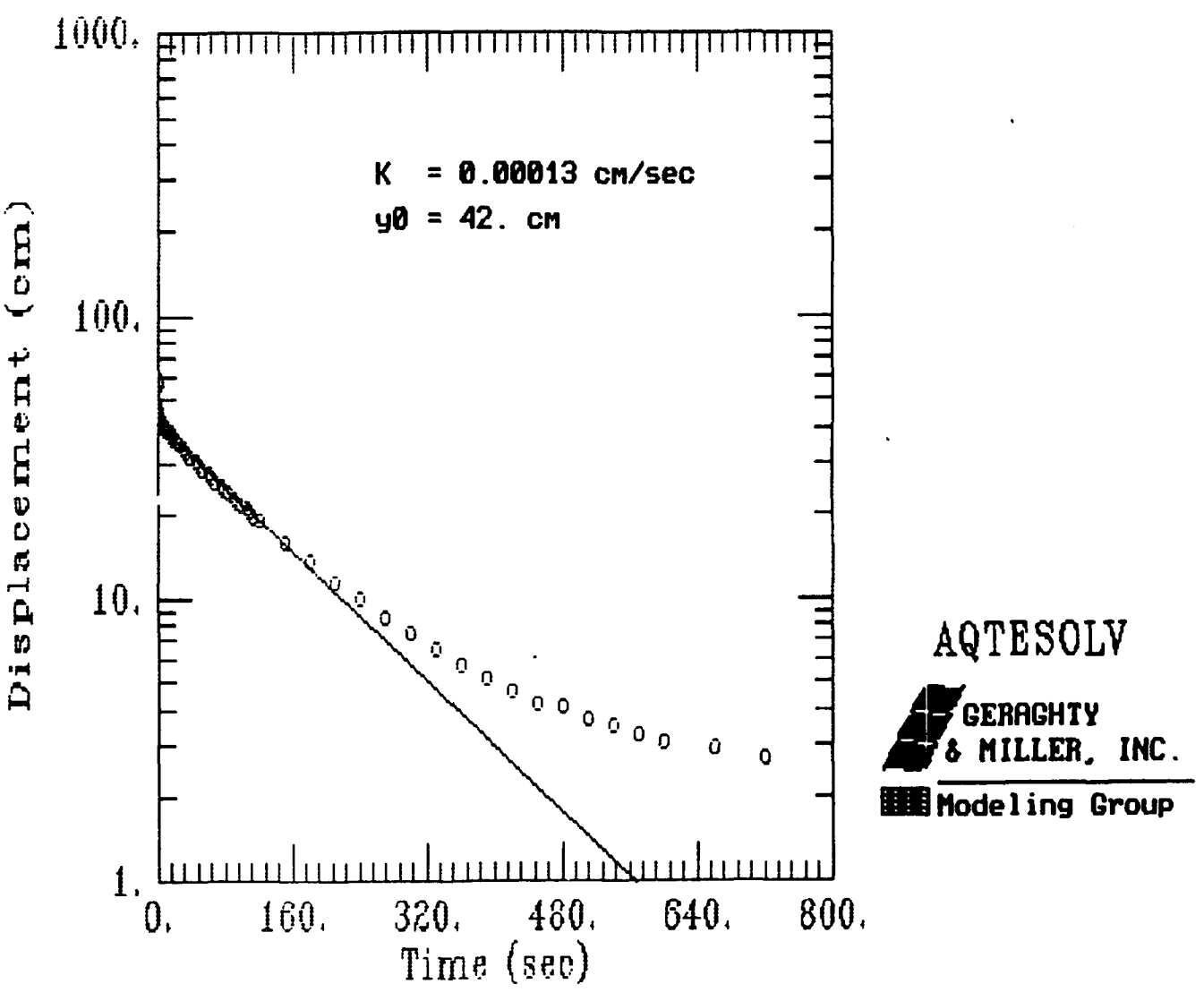
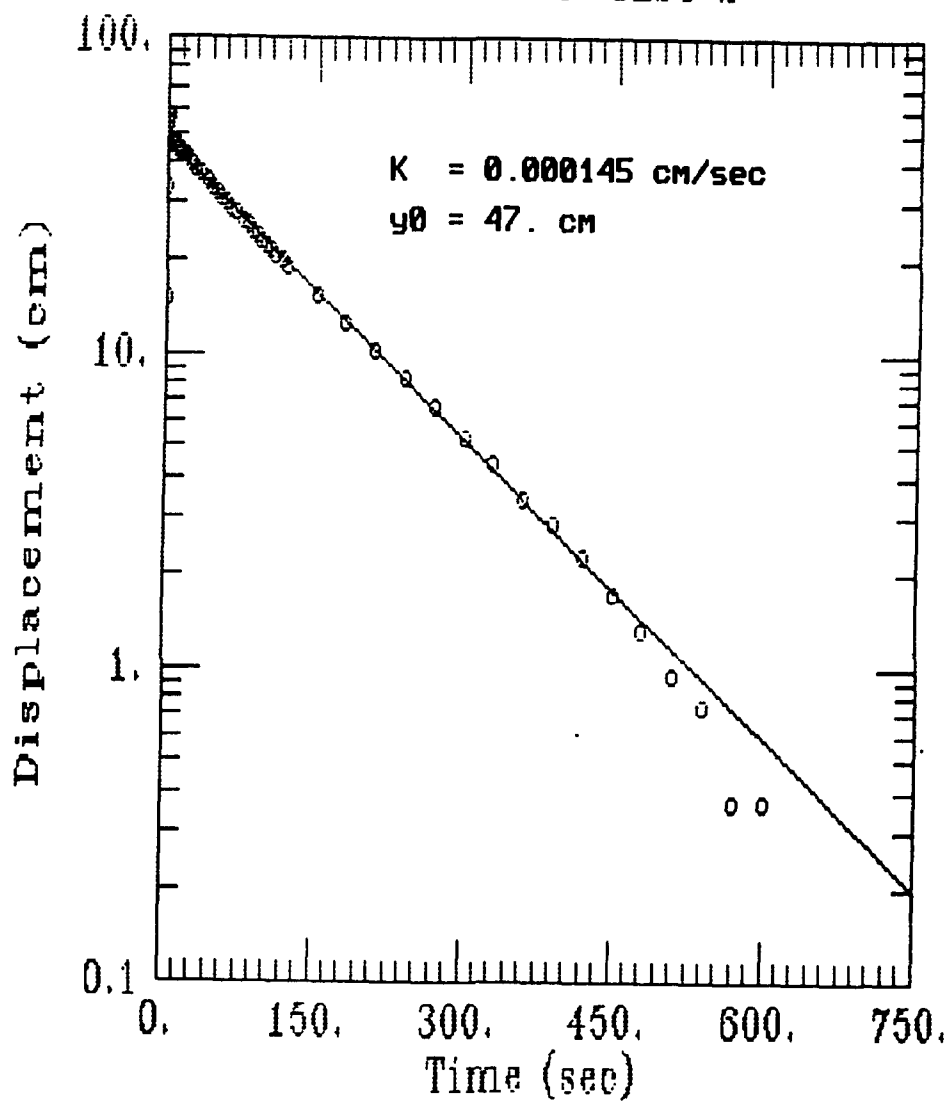
Modeling Group

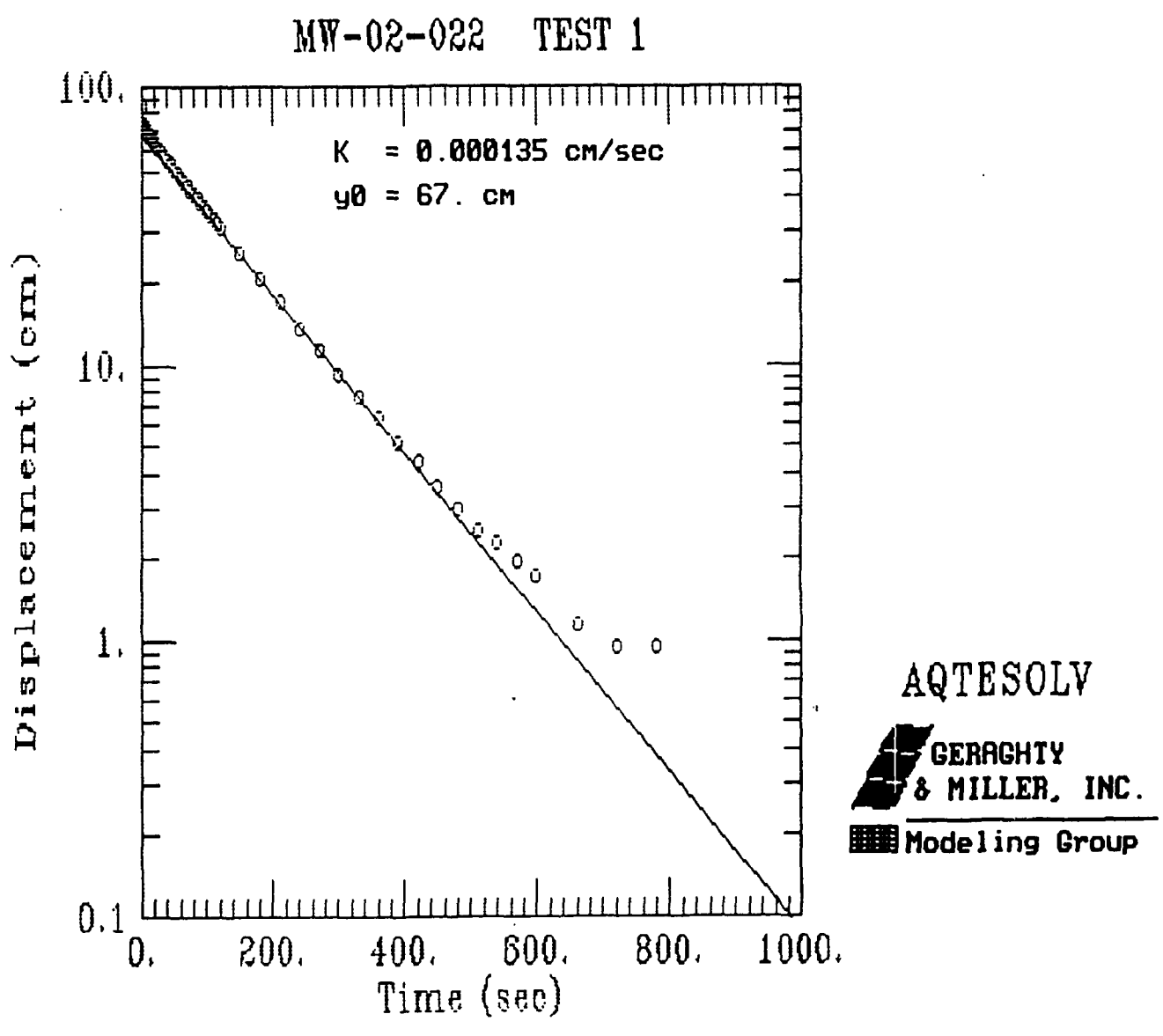

MW-02-021 TEST 1
1000.
100.
10.
1.
Displacement (cm)
K = 0.00013 cm/sec
y0 = 42. cm
0.
160.
320.
480.
640.
800.
Time (sec)
AQTESOLV
GERAGHTY
& MILLER, INC.
Modeling Group



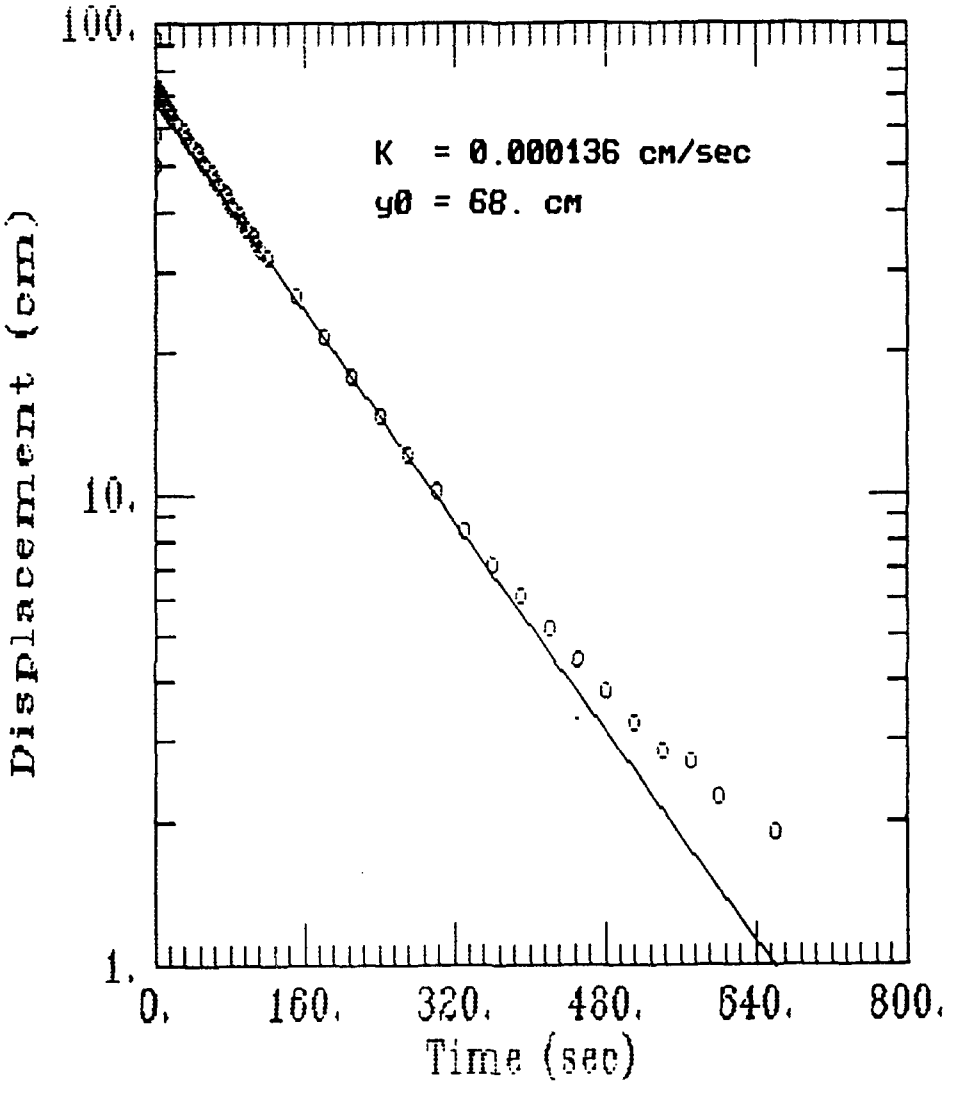
AQTESOLV

GERAGHTY & MILLER, INC.

Modeling Group


MW-02-022 TEST 1
K = 0.000135 cm/sec
y0 = 67. cm
Displacement (cm)
100.
10.
1.
0.1
0.
200.
400.
600.
800.
1000.
Time (sec)
AQTESOLV
GERAGHTY
& MILLER, INC.
Modeling Group

MW-02-022 TEST 2

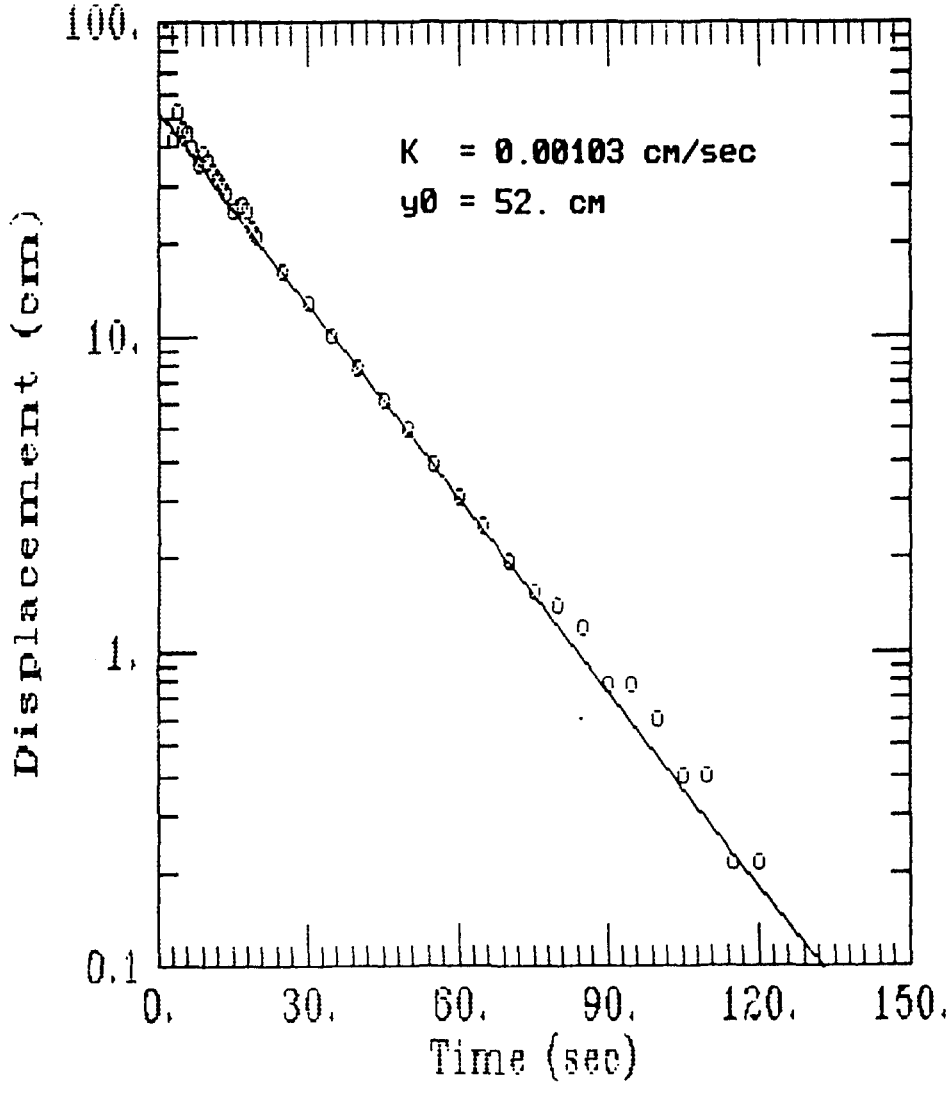


AQTESOLV

GERAGHTY & MILLER, INC.

Modeling Group

MW-02-030 TEST 1

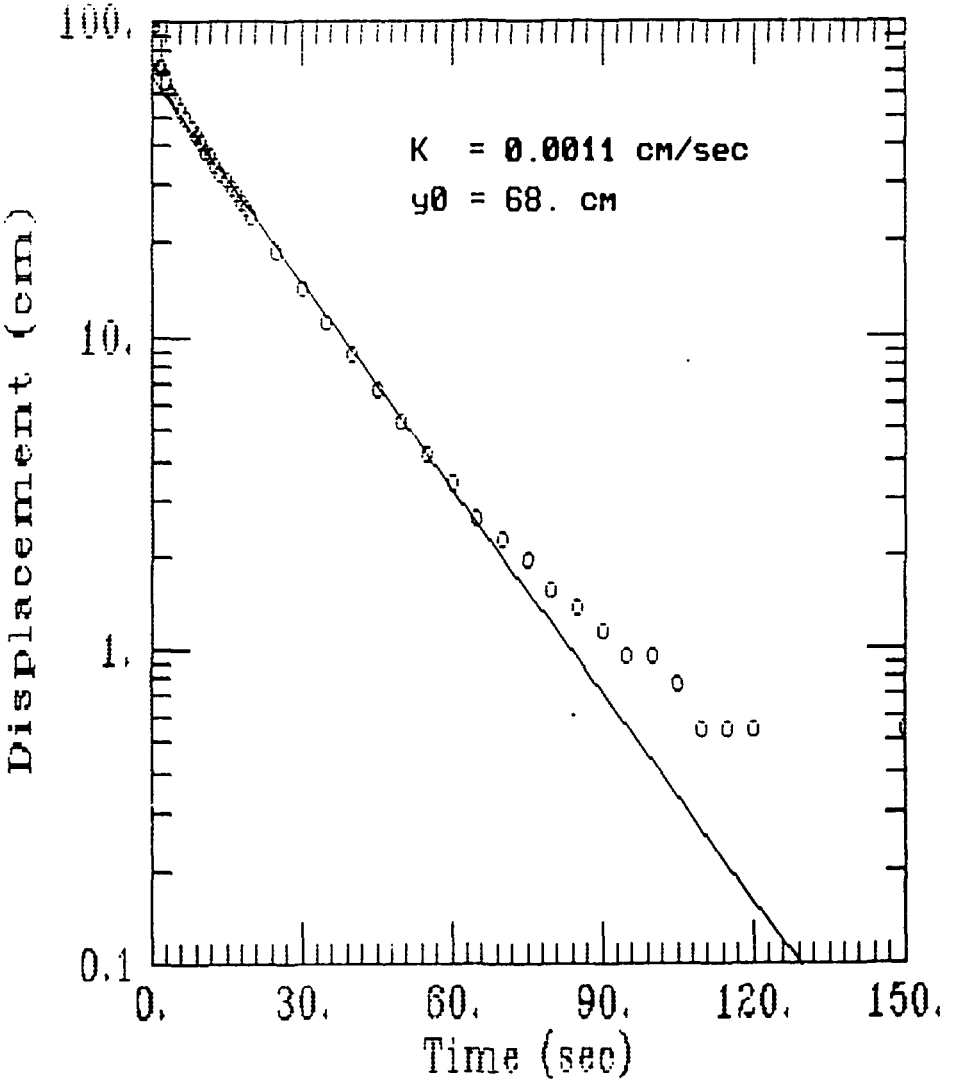


AQTESOLV

GERAGHTY & MILLER, INC.

Modeling Group

MW-02-030 TEST 2



AQTESOLV

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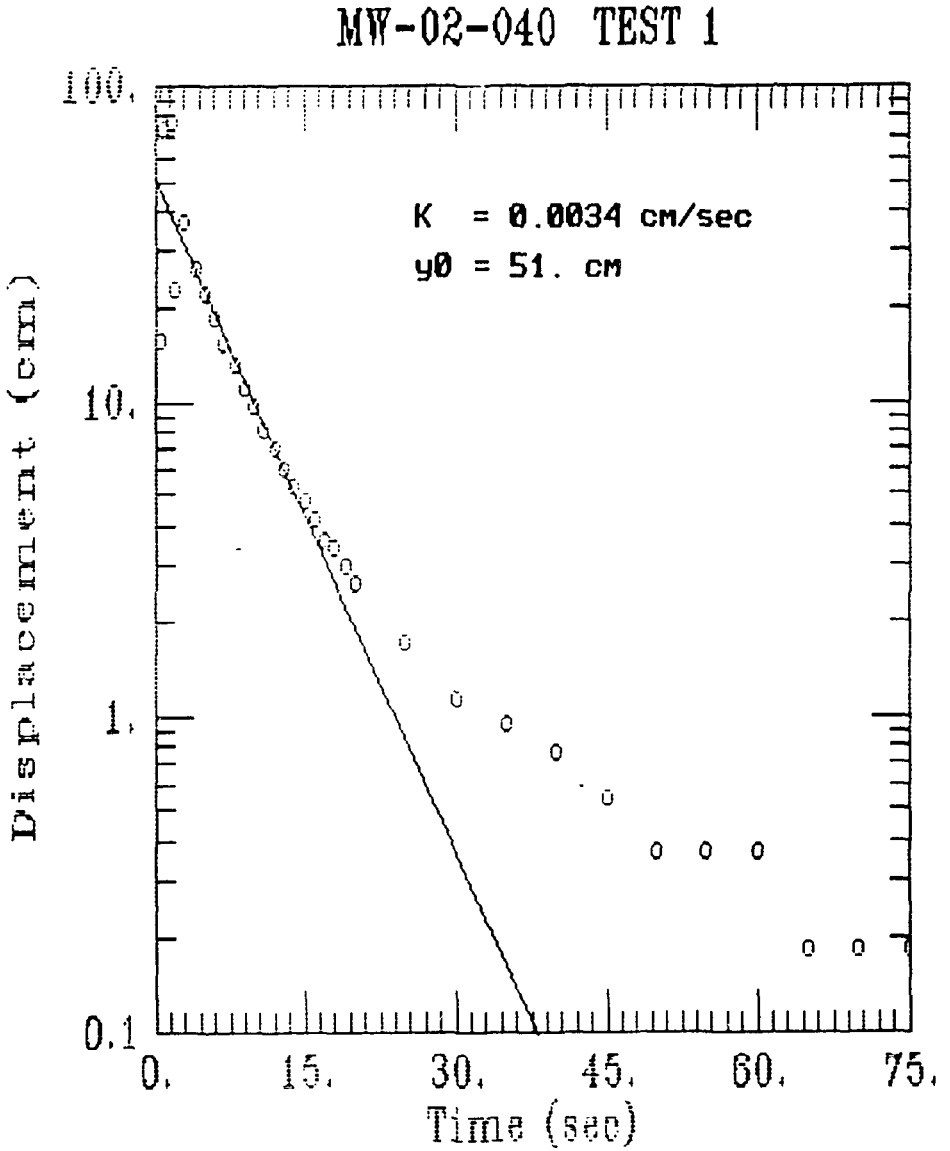
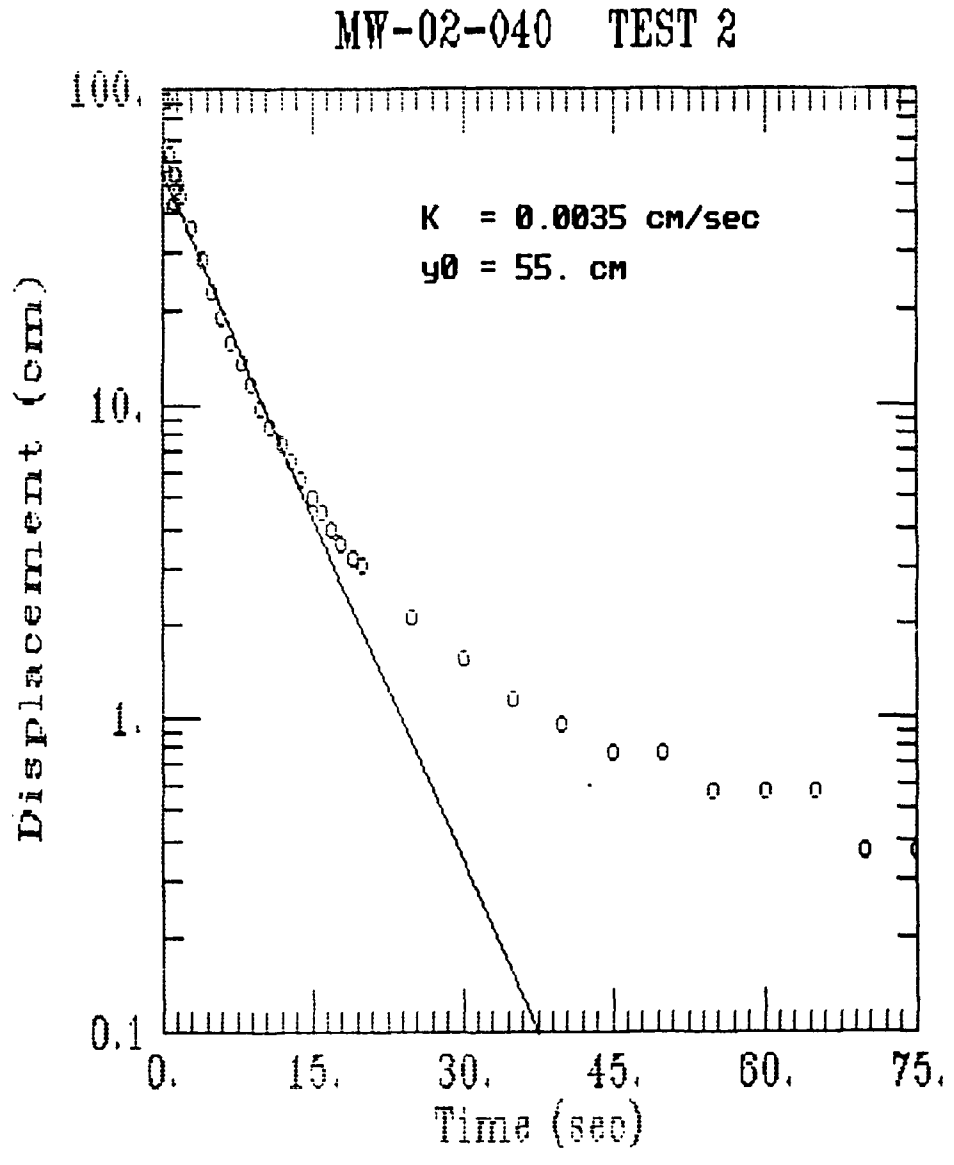


AQTESOLV

GERAGHTY & MILLER, INC.

Modeling Group

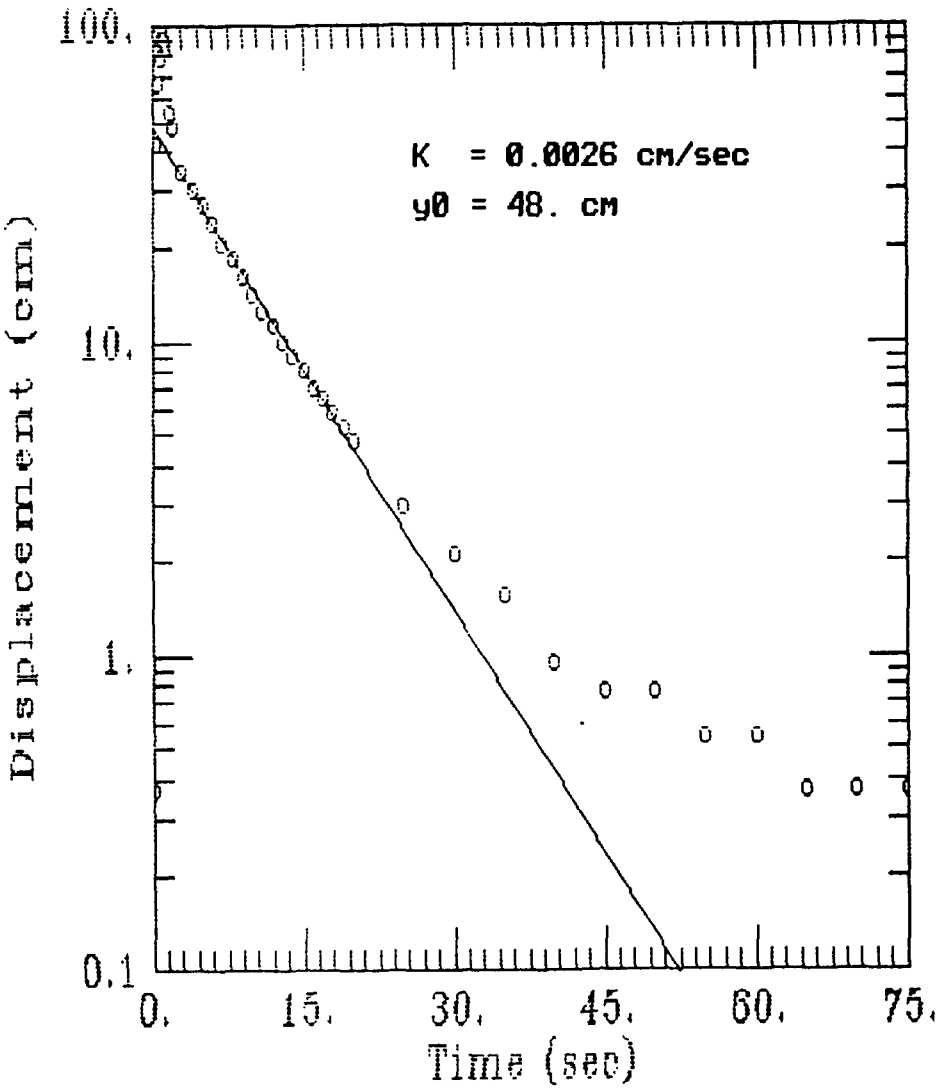


AQTESOLV

GERAGHTY & MILLER, INC.

Modeling Group

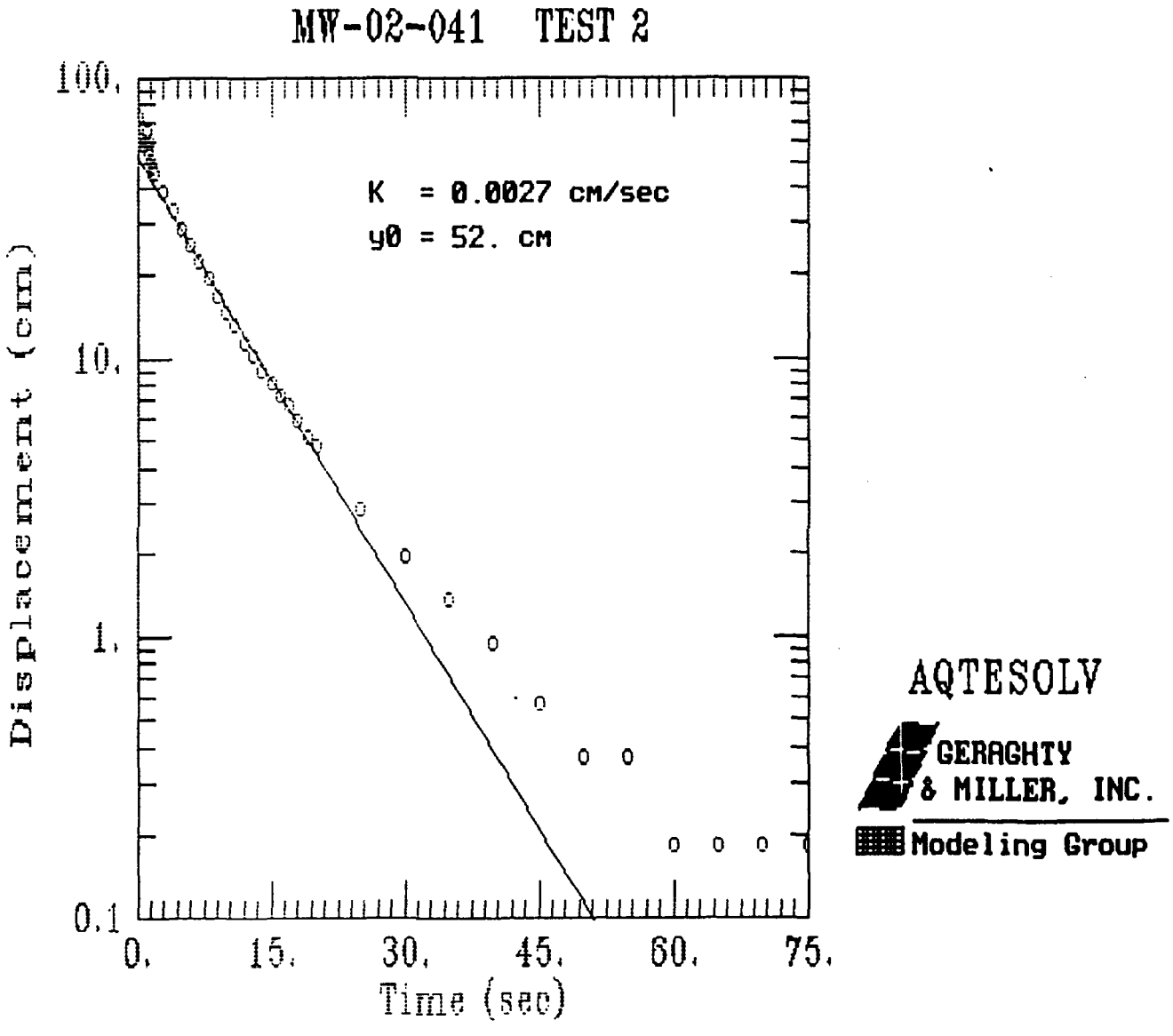
MW-02-041 TEST 1



AQTESOLV

GERAGHTY & MILLER, INC.

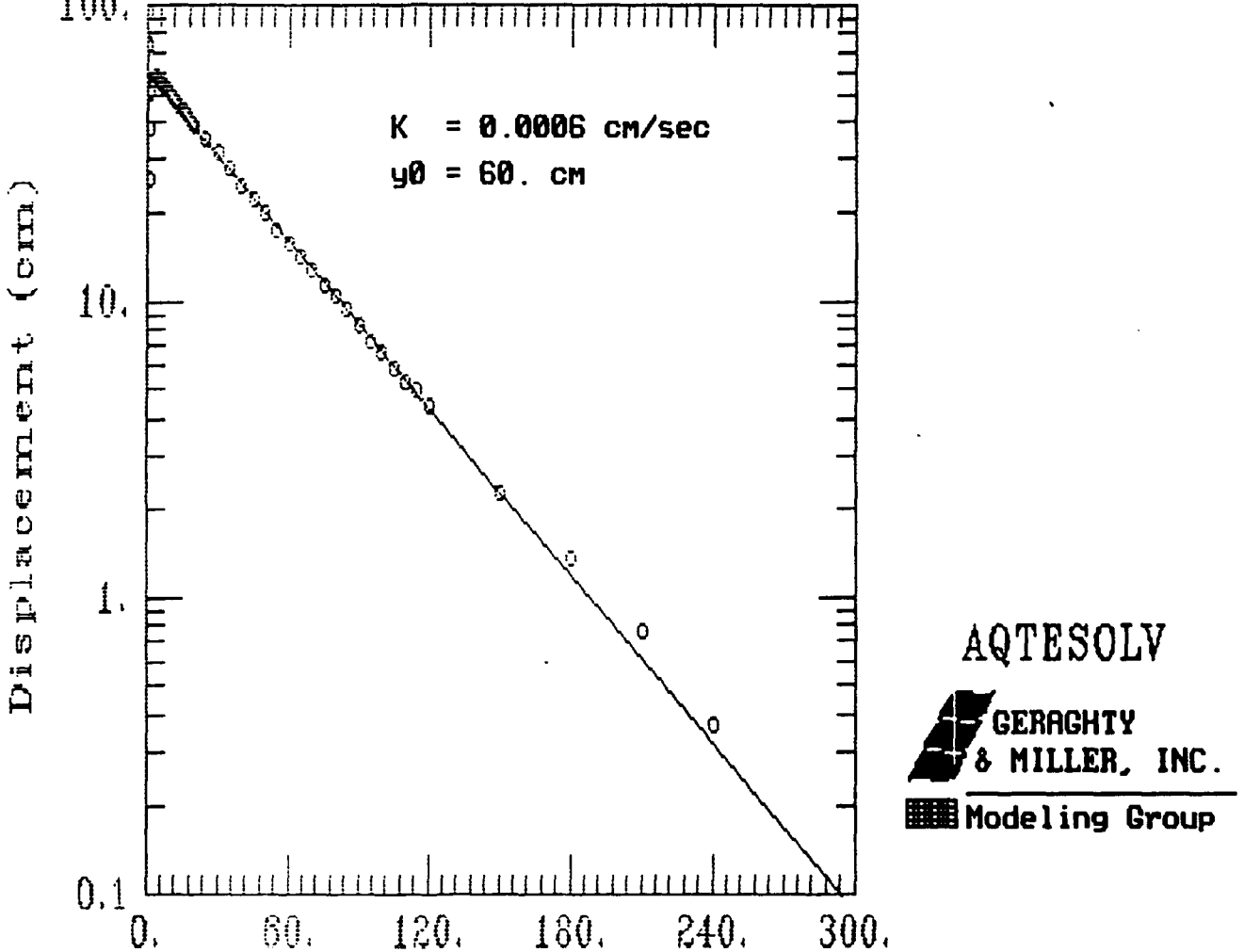
Modeling Group

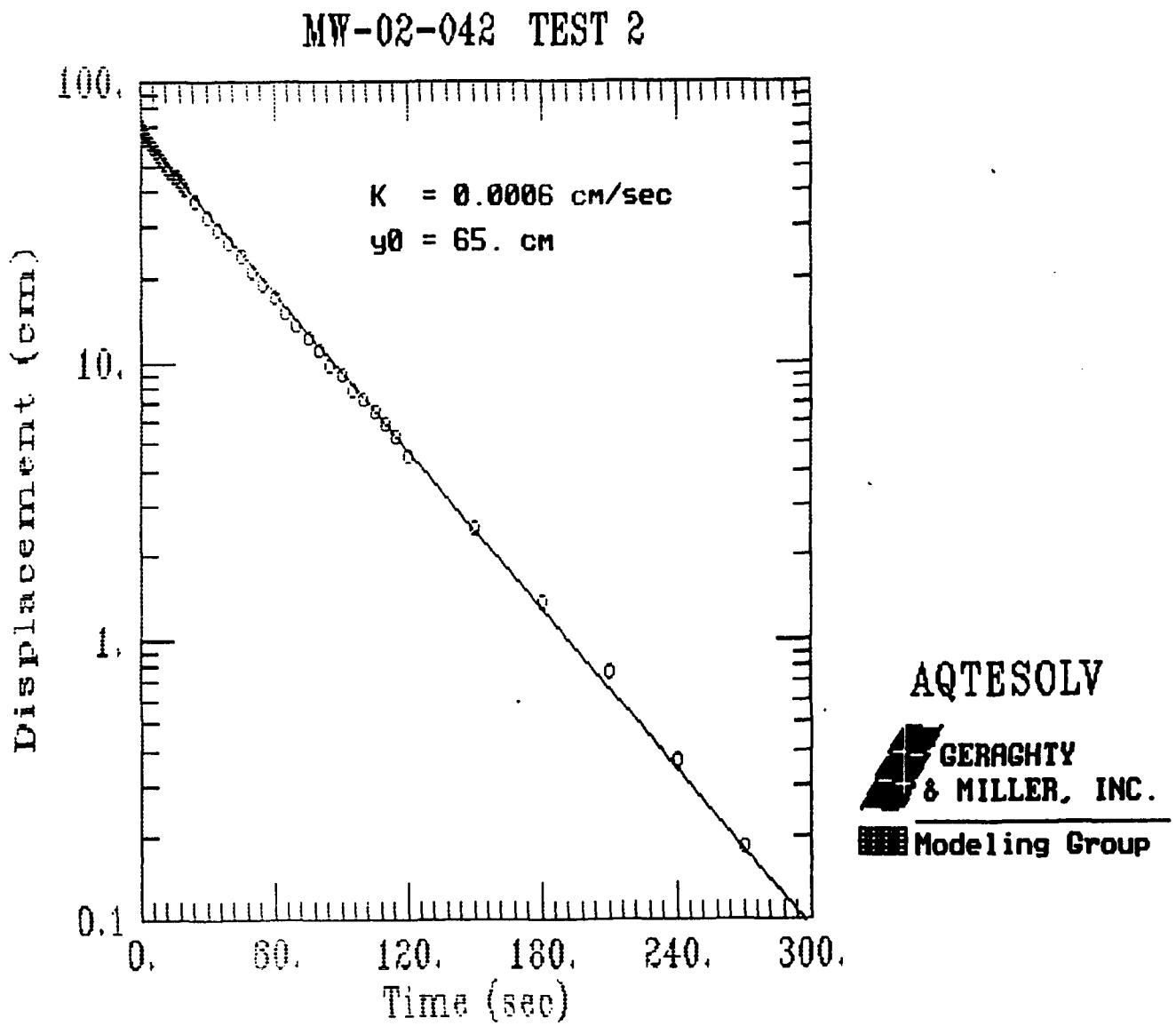


AQTESOLV

GERAGHTY & MILLER, INC.

Modeling Group

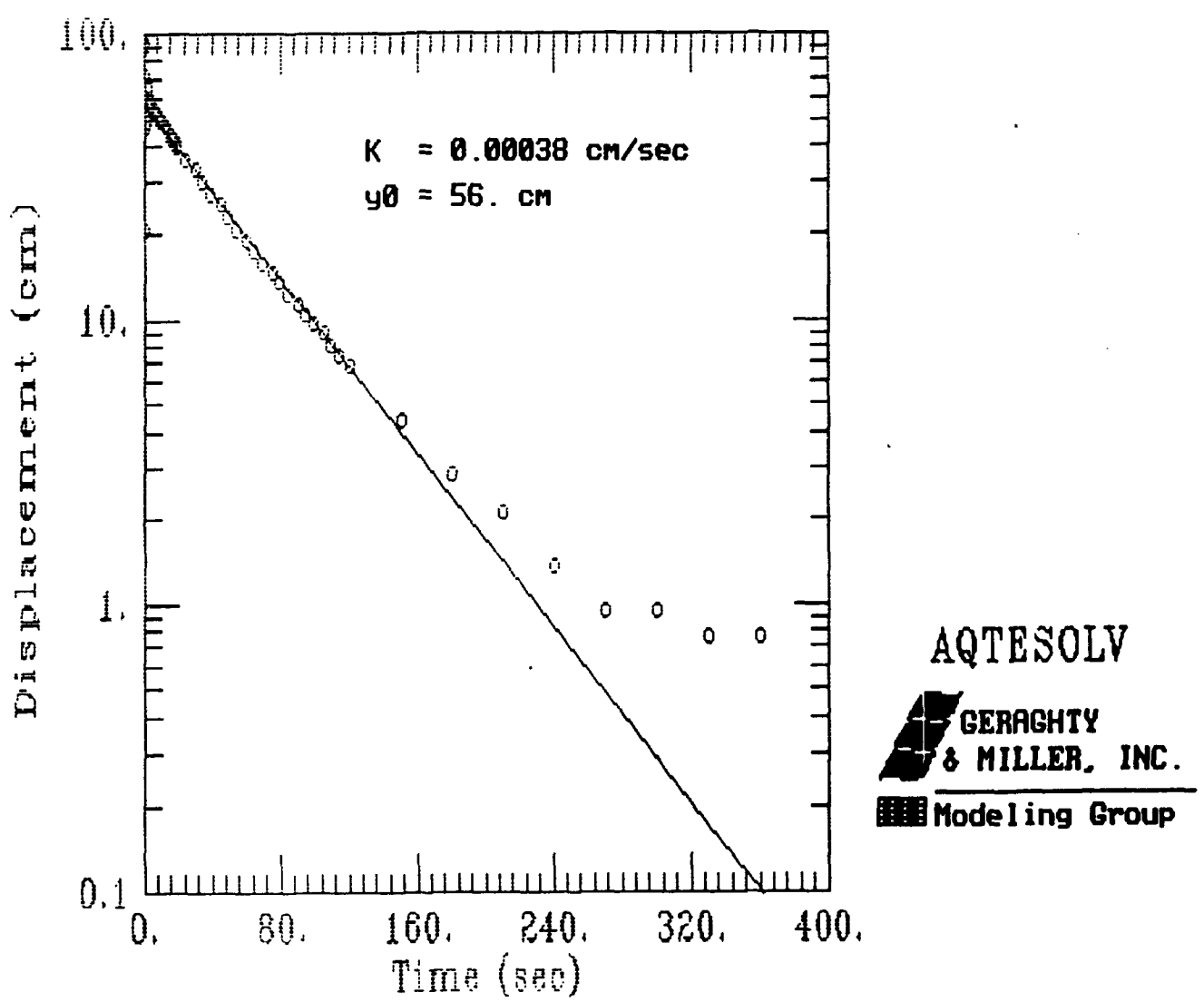

MW-02-042 TEST 1
K = 0.0006 cm/sec
y0 = 60. cm
Displacement (cm)
100.
10.
1.
0.1
0.
60.
120.
180.
240.
300.
Time (sec)
AQTESOLV
GERAGHTY & MILLER, INC.
Modeling Group

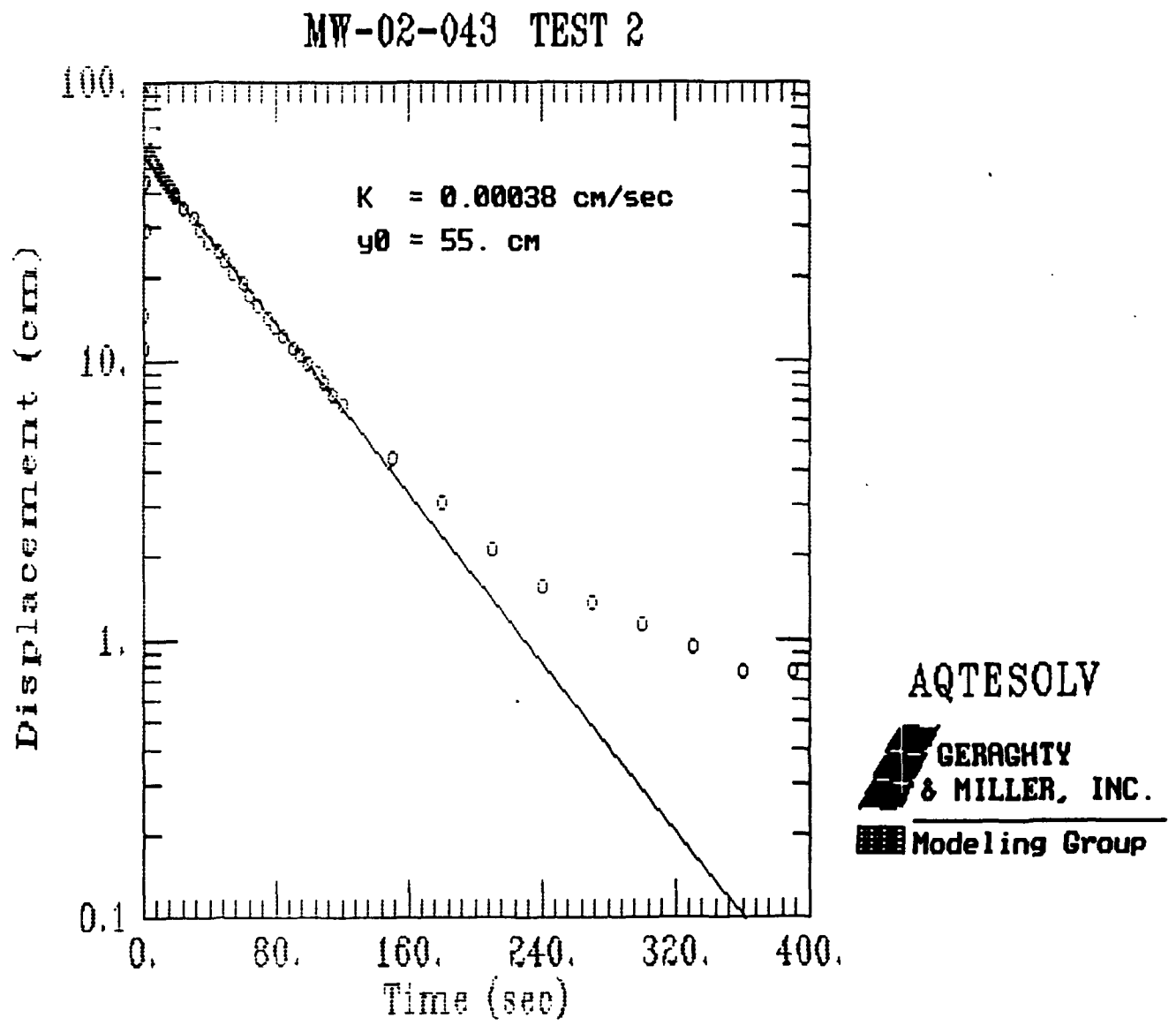


AQTESOLV

GERAGHTY & MILLER, INC.

Modeling Group


MW-02-043 TEST 1
K = 0.00038 cm/sec
y0 = 56. cm
Displacement (cm)
100.
10.
1.
0.1
0.
80.
160.
240.
320.
400.
Time (sec)
AQTESOLV
GERAGHTY & MILLER, INC.
Modeling Group



AQTESOLV

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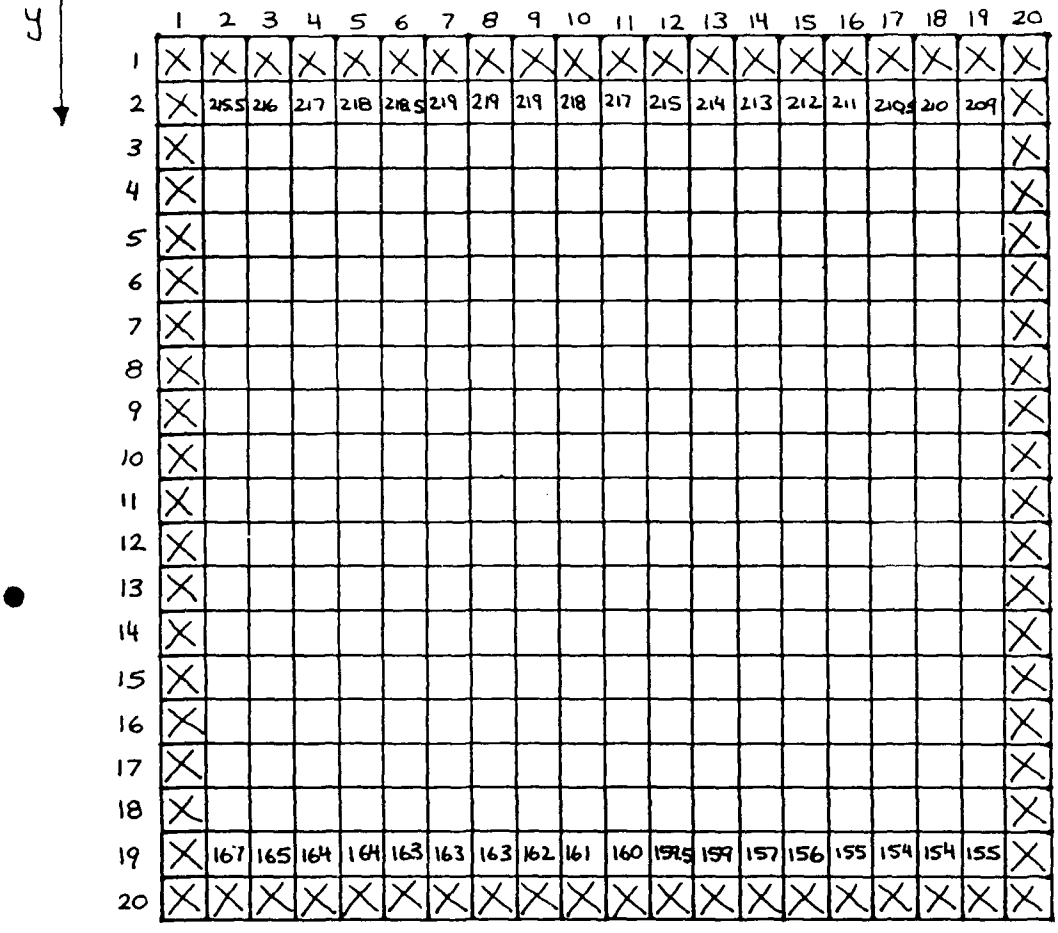
Modeling Group

APPENDIX C

BIOPLUME II MODEL INPUT AND RELATED CALCULATIONS

DIVIDER.DOC

CONSTANT HEAD MAP (Ft)



N

X = Inactive cell
167 = Constant head cell with head value

Client AFCEE
Subject Model Grid Configuration
Plattsburgh AFB site FT-002

Job No. 722450.04
By B. Crawford
Checked

Sheet of
Date 10/12/94
Rev.

AQUIFER THICKNESS MAP (Ft)

y \ x	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2	X	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	X
3	X	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	X
4	X	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	X
5	X	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	X
6	X	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	X
7	X	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	X
8	X	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	X
9	X	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	X
10	X	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	X
11	X	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	X
12	X	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	X
13	X	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	X
14	X	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	X
15	X	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	X
16	X	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	X
17	X	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	X
18	X	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	X
19	X	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	X
20	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

N

X = Inactive cell

PARSONS ENGINEERING SCIENCE, INC.

Client AFCEE
Subject Model Grid Configuration Plattsburgh AFB site FT-002
Job No. 722450.04
By B. Crawford
Checked
Sheet of
Date 10/12/94
Rev

TRANSMISSIVITY MAP

Ft^2/sec

x →
y ↓

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2	X	3	3	3	3	7	7	7	7	7	7	6	4	4	4	4	4	8	9	X
3	X	3	3	3	3	9	9	9	7	7	7	4	4	4	4	4	4	4	4	X
4	X	3	3	3	3	9	9	9	9	9	6	4	4	4	4	4	4	8	8	X
5	X	3	3	3	3	9	9	9	9	9	4	4	6	9	9	9	10	10	10	X
6	X	3	3	3	3	4	4	4	8	8	9	9	9	9	9	9	10	10	10	X
7	X	4	4	4	4	4	4	4	4	4	4	5	9	9	9	9	9	9	9	X
8	X	4	4	4	4	4	4	4	4	4	4	4	8	8	8	8	8	8	8	X
9	X	5	5	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	X
10	X	5	5	4	4	4	4	2	2	2	2	4	4	4	4	4	4	4	4	X
11	X	4	4	4	4	4	4	4	2	2	2	4	5	5	5	5	5	5	5	X
12	X	4	4	4	4	4	5	5	5	5	4	4	4	4	4	4	4	4	4	X
13	X	2	3	3	4	4	5	5	4	4	4	4	4	4	4	4	4	4	4	X
14	X	4	4	4	4	4	4	4	5	5	5	4	4	4	4	4	4	4	4	X
15	X	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	X
16	X	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	X
17	X	2	2	2	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	X
18	X	2	2	2	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	X
19	X	2	2	2	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	X
20	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

N

X = Inactive cell

transmissivity	sym	transmissivity	sym
5×10^{-5}	1	2×10^{-2}	6
5×10^{-4}	2	3×10^{-2}	7
1×10^{-3}	3	4×10^{-2}	8
5.4×10^{-3}	4	5×10^{-2}	9
1×10^{-2}	5	6×10^{-2}	10

Appendix C
Table 1
RMS Calculation for Model Calibration
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Point	x	y	Observed Head (feet)	Model Head (feet)
1	4	3	215.0	214.0
2	18	2	210.0	210.0
3	11	4	215.7	215.1
4	15	6	208.0	206.9
5	11	8	204.0	207.2
6	18	9	203.0	202.5
7	4	10	192.5	195.8
8	13	10	194.0	197.7
9	18	12	190.0	189.9
10	15	13	183.0	184.8
11	7	15	181.0	177.6
12	10	18	165.0	167.6
13	16	18	161.0	160.3

Total Head Drop = 219' - 154' = 65'
RMS = **2.14**
(2.14/65) x 100% = **3.3%**

PARSONS ENGINEERING SCIENCE, INC

Client [illegible] Job No. [illegible] Sheet 1 of 1

Subject Calculation of Dispersivity By LAB Date 10/7/94

Checked Rev. Ø

Previous solute fate and transport models completed for the [illegible] site estimated longitudinal dispersivity to be [illegible] feet (Parsons ESE, [illegible]). The models also estimated that the BTEX plume was relatively symmetric. A longitudinal movement was calculated by assuming the source area to be located at cell 11, 3

Mass	Distance from 11, 3	Mass x Distance
5,000	400	2,000,000
7,000	800	1,600,000
2,000	1200	2,400,000
1,000	1600	1,600,000
500	2000	1,000,000
10,500		8,600,000

The estimated center of mass is: $\frac{8,600,000}{10,500}$

= 819 feet (from center of 11, 3)

Assuming the longitudinal dispersivity is 0.1 the distance from the source to the centroid:

$$\frac{819}{10} \cong 82 \text{ feet}$$

∴ Longitudinal dispersivity estimates used in the Bioplume II model calibration will fall between 45 and 82 feet.

ES 008 8/5/88

```
plattsburgh afb prediction model b (no source removal)
      10        2       20       20     3600        1
       7        5      200        2        9        1
       0        2        2        0        0        1
   38.000000   1.000000E-03   3.000000E-01
60.000000
  0.000000E+00   0.000000E+00   0.000000E+00
400.000000
   400.000000   2.500000E-01   5.000000E-01
1.500000
    1.761000    1.600000    0.000000E+00
0.000000E+00
  1.000000E-03    3.100000
       11        4
       11        5
       12        7
       13        9
       13       13
       11        4  -5.000000E-04   4500.000000
0.000000E+00
       11        5  -5.000000E-04   4500.000000
0.000000E+00
        1   6.000000E-04
  0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00
  0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00
  0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00
  0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00
  0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00
  0.000000E+00    10.000000    10.000000
10.000000
    10.000000   300.000000   300.000000
300.000000
   300.000000   300.000000   300.000000
200.000000
    54.000000   54.000000   54.000000   54.000000
    54.000000   400.000000   500.000000
0.000000E+00
  0.000000E+00    10.000000    10.000000
10.000000
    10.000000   500.000000   500.000000
500.000000
   300.000000   300.000000   300.000000
54.000000
    54.000000   54.000000   54.000000   54.000000
    54.000000   54.000000   54.000000
0.000000E+00
  0.000000E+00    10.000000    10.000000
10.000000
    10.000000   500.000000   500.000000
500.000000
   500.000000   500.000000   200.000000
54.000000
    54.000000   54.000000   54.000000   54.000000
    54.000000   400.000000   400.000000
0.000000E+00
  0.000000E+00    10.000000    10.000000
10.000000
    10.000000   500.000000   500.000000
500.000000
   500.000000   500.000000    54.000000
54.000000
   200.000000   500.000000   500.000000
500.000000
   600.000000   600.000000   600.000000
0.000000E+00
  0.000000E+00    10.000000    10.000000
10.000000
    10.000000   54.000000   54.000000   54.000000
   400.000000   400.000000   500.000000
500.000000
   500.000000   500.000000   500.000000
500.000000
   600.000000   600.000000   600.000000
0.000000E+00
  0.000000E+00   54.000000   54.000000
54.000000
    54.000000   54.000000   54.000000   54.000000
    54.000000   54.000000   54.000000   100.000000
   500.000000   500.000000   500.000000
500.000000
   500.000000   500.000000   500.000000
0.000000E+00
  0.000000E+00   54.000000   54.000000
54.000000
    54.000000   54.000000   54.000000   54.000000
    54.000000   54.000000   54.000000   54.000000
   400.000000   400.000000   400.000000
400.000000
   400.000000   400.000000   400.000000
0.000000E+00
  0.000000E+00   100.000000   100.000000
54.000000
    54.000000   54.000000   54.000000   54.000000
    54.000000   54.000000   54.000000   54.000000
    54.000000   54.000000   54.000000   54.000000
    54.000000   54.000000   54.000000
0.000000E+00
  0.000000E+00   100.000000   100.000000
54.000000
    54.000000   54.000000   54.000000    5.000000
     5.000000    5.000000    5.000000   54.000000
    54.000000   54.000000   54.000000   54.000000
    54.000000   54.000000   54.000000
0.000000E+00
  0.000000E+00   54.000000   54.000000
54.000000
    54.000000   54.000000   54.000000   54.000000
     5.000000    5.000000    5.000000   54.000000
   100.000000   100.000000   100.000000
100.000000
   100.000000   100.000000   100.000000
0.000000E+00
  0.000000E+00   54.000000   54.000000
54.000000
    54.000000   54.000000   100.000000
100.000000
   100.000000   100.000000    54.000000
54.000000
    54.000000   54.000000   54.000000   54.000000
    54.000000   54.000000   54.000000
0.000000E+00
  0.000000E+00    5.000000    10.000000
10.000000
    54.000000   54.000000   100.000000
100.000000
    54.000000   54.000000   54.000000   54.000000
    54.000000   54.000000   54.000000   54.000000
```

```
    54.000000    54.000000    54.000000
0.000000E+00
  0.000000E+00    54.000000    54.000000
54.000000
    54.000000    54.000000    54.000000    54.000000
   100.000000   100.000000   100.000000
54.000000
    54.000000    54.000000    54.000000    54.000000
    54.000000    54.000000    54.000000
0.000000E+00
  0.000000E+00    54.000000    54.000000
54.000000
    54.000000    54.000000    54.000000    54.000000
    54.000000    54.000000    54.000000    54.000000
    54.000000    54.000000    54.000000    54.000000
    54.000000    54.000000    54.000000
0.000000E+00
  0.000000E+00    54.000000    54.000000
54.000000
    54.000000    54.000000    54.000000    54.000000
    54.000000    54.000000    54.000000    54.000000
    54.000000    54.000000    54.000000    54.000000
    54.000000    54.000000    54.000000
0.000000E+00
  0.000000E+00    5.000000    5.000000    5.000000
    54.000000    54.000000    54.000000    54.000000
    54.000000    54.000000    54.000000    54.000000
    54.000000    54.000000    54.000000    54.000000
    54.000000    54.000000    54.000000
0.000000E+00
  0.000000E+00  5.000000E-01  5.000000E-01
5.000000E-01
    54.000000    54.000000    54.000000    54.000000
    54.000000    54.000000    54.000000    54.000000
    54.000000    54.000000    54.000000    54.000000
    54.000000    54.000000    54.000000
0.000000E+00
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5.000000E-01
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    54.000000    54.000000    54.000000    54.000000
    54.000000    54.000000    54.000000    54.000000
    54.000000    54.000000    54.000000
0.000000E+00
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0.000000E+00
  0.000000E+00  0.000000E+00  0.000000E+00
0.000000E+00
  0.000000E+00  0.000000E+00  0.000000E+00
0.000000E+00
  0.000000E+00  0.000000E+00  0.000000E+00
0.000000E+00
     1     1.000000
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0.000000E+00
  0.000000E+00  0.000000E+00  0.000000E+00
0.000000E+00
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0.000000E+00
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0.000000E+00
  0.000000E+00    45.000000    45.000000
45.000000
    45.000000    45.000000    45.000000    45.000000
    45.000000    45.000000    45.000000    45.000000
    45.000000    45.000000    45.000000    45.000000
    45.000000    45.000000    45.000000
0.000000E+00
  0.000000E+00    45.000000    45.000000
45.000000
    45.000000    45.000000    45.000000    45.000000
    45.000000    45.000000    45.000000    45.000000
    45.000000    45.000000    45.000000    45.000000
    45.000000    45.000000    45.000000
0.000000E+00
  0.000000E+00    52.000000    52.000000
52.000000
    52.000000    52.000000    52.000000    52.000000
    52.000000    52.000000    52.000000    52.000000
    52.000000    52.000000    52.000000    52.000000
    52.000000    52.000000    52.000000
0.000000E+00
  0.000000E+00    52.000000    52.000000
52.000000
    52.000000    52.000000    52.000000    52.000000
    52.000000    52.000000    52.000000    52.000000
    52.000000    52.000000    52.000000    52.000000
    52.000000    52.000000    52.000000
0.000000E+00
  0.000000E+00    45.000000    45.000000
45.000000
    45.000000    45.000000    45.000000    45.000000
    45.000000    45.000000    45.000000    45.000000
    45.000000    45.000000    45.000000    45.000000
    45.000000    45.000000    45.000000
0.000000E+00
  0.000000E+00    45.000000    45.000000
45.000000
    45.000000    45.000000    45.000000    45.000000
    45.000000    45.000000    45.000000    45.000000
    45.000000    45.000000    45.000000    45.000000
    45.000000    45.000000    45.000000
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  0.000000E+00    45.000000    45.000000
45.000000
    45.000000    45.000000    45.000000    45.000000
    45.000000    45.000000    45.000000    45.000000
    45.000000    45.000000    45.000000    45.000000
    45.000000    45.000000    45.000000
0.000000E+00
  0.000000E+00    40.000000    40.000000
40.000000
    40.000000    40.000000    40.000000    40.000000
    40.000000    40.000000    40.000000    40.000000
    40.000000    40.000000    40.000000    40.000000
    40.000000    40.000000    40.000000
0.000000E+00
  0.000000E+00    40.000000    40.000000
40.000000
    40.000000    40.000000    40.000000    40.000000
    40.000000    40.000000    40.000000    40.000000
    40.000000    40.000000    40.000000    40.000000
```

```
    40.000000     40.000000     40.000000
0.000000E+00
  0.000000E+00     40.000000     40.000000
40.000000
    40.000000     40.000000     40.000000     40.000000
    40.000000     40.000000     40.000000     40.000000
    40.000000     40.000000     40.000000     40.000000
    40.000000     40.000000     40.000000
0.000000E+00
  0.000000E+00     40.000000     40.000000
40.000000
    40.000000     40.000000     40.000000     40.000000
    40.000000     40.000000     40.000000     40.000000
    40.000000     40.000000     40.000000     40.000000
    40.000000     40.000000     40.000000
0.000000E+00
  0.000000E+00     40.000000     40.000000
40.000000
    40.000000     40.000000     40.000000     40.000000
    40.000000     40.000000     40.000000     40.000000
    40.000000     40.000000     40.000000     40.000000
    40.000000     40.000000     40.000000
0.000000E+00
  0.000000E+00     35.000000     35.000000
35.000000
    35.000000     35.000000     35.000000     35.000000
    35.000000     35.000000     35.000000     35.000000
    35.000000     35.000000     35.000000     35.000000
    35.000000     35.000000     35.000000
0.000000E+00
  0.000000E+00     35.000000     35.000000
35.000000
    35.000000     35.000000     35.000000     35.000000
    35.000000     35.000000     35.000000     35.000000
    35.000000     35.000000     35.000000     35.000000
    35.000000     35.000000     35.000000
0.000000E+00
  0.000000E+00     35.000000     35.000000
35.000000
    35.000000     35.000000     35.000000     35.000000
    35.000000     35.000000     35.000000     35.000000
    35.000000     35.000000     35.000000     35.000000
    35.000000     35.000000     35.000000
0.000000E+00
  0.000000E+00  0.000000E+00  0.000000E+00
0.000000E+00
  0.000000E+00  0.000000E+00  0.000000E+00
0.000000E+00
  0.000000E+00  0.000000E+00  0.000000E+00
0.000000E+00
```

```
0.000000E+00  0.000000E+00  0.000000E+00
0.000000E+00
  0  0.000000E+00
  1  1.000000
  0  0  0  0  0  0
  0  0  0  0  0  0
  0  0  0  0  0  0
  0  0
  0  1  1  1  1  1
  1  1  1  1  1  1
  1  1  1  1  1  1
  1  0
  0  0  0  0  0  0
  0  0  0  0  0  0
  0  0  0  0  0  0
  0  0
  0  0  0  0  0  0
  0  0  0  0  0  0
  0  0
  0  0  0  0  0  0
  0  0  0  0  0  0
  0  0  0  0  0  0
  0  0
  0  0  0  0  0  0
  0  0  0  0  0  0
  0  0
  0  0  0  0  0  0
  0  0  0  0  0  0
  0  0  0  0  0  0
  0  0
  0  0  0  0  0  0
  0  0  0  0  0  0
  0  0
  0  0  0  0  0  0
  0  0  0  0  0  0
  0  0  0  0  0  0
  0  0
  0  0  0  0  0  0
  0  0  0  0  0  0
  0  0
  0  0  0  0  0  0
  0  0  0  0  0  0
  0  0  0  0  0  0
  0  0
  0  0  0  0  0  0
  0  0  0  0  0  0
  0  0
  0  0  0  0  0  0
  0  0  0  0  0  0
  0  0  0  0  0  0
  0  0
  0  0  0  0  0  0
  0  0  0  0  0  0
  0  0
  0  0  0  0  0  0
  0  0  0  0  0  0
  0  0  0  0  0  0
```

```
        0       0
        0       0       0       0       0       0
        0       0       0       0       0       0
        0       0       0       0       0       0
        0       0
        0       0       0       0       0       0
        0       0       0       0       0       0
        0       0       0       0       0       0
        0       0
        0       1       1       1       1       1
        1       1       1       1       1       1
        1       1       1       1       1       1
        1       0
        0       0       0       0       0       0
        0       0       0       0       0       0
        0       0       0       0       0       0
        0       0
        1     1.000000   0.000000E+00     10.000000
0.000000E+00
        0
        1     1.000000
  0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00
  0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00
  0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00
  0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00
  0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00
  0.000000E+00    215.500000    216.000000
217.000000
    218.000000    218.500000    219.000000
219.000000
    219.000000    218.000000    217.000000
215.000000
    214.000000    213.000000    212.000000
211.000000
    210.500000    210.000000    209.500000
0.000000E+00
  0.000000E+00    210.000000    210.000000
210.000000
    210.000000    210.000000    210.000000
210.000000
    210.000000    210.000000    210.000000
210.000000
    210.000000    210.000000    210.000000
210.000000
    210.000000    210.000000    210.000000
0.000000E+00
  0.000000E+00    200.000000    200.000000
200.000000
    200.000000    200.000000    200.000000
200.000000
    200.000000    200.000000    200.000000
200.000000
    200.000000    200.000000    200.000000
0.000000E+00
  0.000000E+00    200.000000    200.000000
200.000000
    200.000000    200.000000    200.000000
200.000000
    200.000000    200.000000    200.000000
200.000000
```

```
    200.000000    200.000000    200.000000
200.000000
    200.000000    200.000000    200.000000
0.000000E+00
  0.000000E+00    200.000000    200.000000
200.000000
    200.000000    200.000000    200.000000
200.000000
    200.000000    200.000000    200.000000
200.000000
    200.000000    200.000000    200.000000
200.000000
    200.000000    200.000000    200.000000
0.000000E+00
  0.000000E+00    200.000000    200.000000
200.000000
    200.000000    200.000000    200.000000
200.000000
    200.000000    200.000000    200.000000
200.000000
    200.000000    200.000000    200.000000
200.000000
    200.000000    200.000000    200.000000
0.000000E+00
  0.000000E+00    200.000000    200.000000
200.000000
    200.000000    200.000000    200.000000
200.000000
    200.000000    200.000000    200.000000
200.000000
    200.000000    200.000000    200.000000
200.000000
    200.000000    200.000000    200.000000
0.000000E+00
  0.000000E+00    200.000000    200.000000
200.000000
    200.000000    200.000000    200.000000
200.000000
    200.000000    200.000000    200.000000
200.000000
    200.000000    200.000000    200.000000
200.000000
    200.000000    200.000000    200.000000
0.000000E+00
  0.000000E+00    190.000000    190.000000
190.000000
    190.000000    190.000000    190.000000
190.000000
    190.000000    190.000000    190.000000
190.000000
    190.000000    190.000000    190.000000
190.000000
    190.000000    190.000000    190.000000
0.000000E+00
  0.000000E+00    190.000000    190.000000
190.000000
```

```
   190.000000   190.000000   190.000000
190.000000
   190.000000   190.000000   190.000000
190.000000
   190.000000   190.000000   190.000000
190.000000
   190.000000   190.000000   190.000000
0.000000E+00
  0.000000E+00   180.000000   180.000000
180.000000
   180.000000   180.000000   180.000000
180.000000
   180.000000   180.000000   180.000000
180.000000
   180.000000   180.000000   180.000000
180.000000
   180.000000   180.000000   180.000000
0.000000E+00
  0.000000E+00   180.000000   180.000000
180.000000
   180.000000   180.000000   180.000000
180.000000
   180.000000   180.000000   180.000000
180.000000
   180.000000   180.000000   180.000000
0.000000E+00
  0.000000E+00   180.000000   180.000000
180.000000
   180.000000   180.000000   180.000000
180.000000
   180.000000   180.000000   180.000000
180.000000
   180.000000   180.000000   180.000000
180.000000
   180.000000   180.000000   180.000000
0.000000E+00
  0.000000E+00   180.000000   180.000000
180.000000
   180.000000   180.000000   180.000000
180.000000
   180.000000   180.000000   180.000000
180.000000
   180.000000   170.000000   170.000000
0.000000E+00
  0.000000E+00   170.000000   170.000000
170.000000
   170.000000   170.000000   170.000000
170.000000
   170.000000   170.000000   170.000000
170.000000
   170.000000   170.000000   170.000000
170.000000
   170.000000   170.000000   170.000000
0.000000E+00
  0.000000E+00   170.000000   170.000000
170.000000
   170.000000   170.000000   170.000000
170.000000
   170.000000   170.000000   170.000000
170.000000
   170.000000   170.000000   170.000000
170.000000
```

```
   170.000000   170.000000   170.000000
0.000000E+00
  0.000000E+00   167.000000   165.000000
164.000000
   164.000000   163.000000   163.000000
163.000000
   162.000000   161.000000   160.000000
159.500000
   159.000000   157.000000   156.000000
155.000000
   154.000000   154.000000   155.000000
0.000000E+00
  0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00
  0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00
  0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00
  0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00
  0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00
      0   0.000000E+00
      1   1.000000
  0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00
  0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00
  0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00
  0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00
  0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00
  0.000000E+00    10.000000    10.000000
10.000000
    10.000000    10.000000    10.000000    10.000000
    10.000000    10.000000    10.000000    10.000000
    10.000000    10.000000    10.000000    10.000000
    10.000000    10.000000    10.000000
0.000000E+00
  0.000000E+00    10.000000    10.000000
10.000000
    10.000000    10.000000    10.000000    10.000000
    10.000000     7.000000     4.000000    10.000000
    10.000000    10.000000    10.000000    10.000000
    10.000000    10.000000    10.000000
0.000000E+00
  0.000000E+00    10.000000    10.000000
10.000000
    10.000000    10.000000    10.000000    10.000000
    10.000000     5.000000   9.000000E-01     7.000000
    10.000000    10.000000    10.000000    10.000000
    10.000000    10.000000    10.000000
0.000000E+00
  0.000000E+00    10.000000    10.000000
10.000000
    10.000000    10.000000    10.000000    10.000000
    10.000000     4.000000   5.000000E-01     1.500000
     9.000000    10.000000    10.000000    10.000000
    10.000000    10.000000    10.000000
0.000000E+00
  0.000000E+00    10.000000    10.000000
10.000000
    10.000000    10.000000    10.000000    10.000000
    10.000000     4.000000   3.000000E-01   9.000000E-
01
```

```
    4.000000     10.000000     10.000000     10.000000
    10.000000    10.000000     10.000000
0.000000E+00
  0.000000E+00     10.000000     10.000000
10.000000
    10.000000    10.000000     10.000000     10.000000
    10.000000    3.000000      1.000000E-01  1.000000E-
01
    1.900000     10.000000     10.000000     10.000000
    10.000000    10.000000     10.000000
0.000000E+00
  0.000000E+00     10.000000     10.000000
10.000000
    10.000000    10.000000     10.000000     10.000000
    10.000000    1.900000      4.000000E-01  4.000000E-
01
    1.700000     7.000000      10.000000     10.000000
    10.000000    10.000000     10.000000
0.000000E+00
  0.000000E+00     10.000000     10.000000
10.000000
    10.000000    10.000000     10.000000     10.000000
    7.000000     1.600000      5.000000E-01  5.000000E-
01
    1.500000     6.000000      10.000000     10.000000
    10.000000    10.000000     10.000000
0.000000E+00
  0.000000E+00     10.000000     10.000000
10.000000
    10.000000    10.000000     10.000000     10.000000
    4.500000     1.300000      5.000000E-01  5.000000E-
01
    1.600000     5.000000      10.000000     10.000000
    10.000000    10.000000     10.000000
0.000000E+00
  0.000000E+00     10.000000     10.000000
10.000000
    10.000000    10.000000     10.000000     10.000000
    3.000000     1.400000      8.000000E-01  7.000000E-
01
    1.500000     4.000000      9.500000      10.000000
    10.000000    10.000000     10.000000
0.000000E+00
  0.000000E+00     10.000000     10.000000
10.000000
    10.000000    10.000000     10.000000     9.500000
    3.000000     1.500000      1.200000      1.000000
    1.500000     3.000000      10.000000     10.000000
    10.000000    10.000000     10.000000
0.000000E+00
  0.000000E+00     10.000000     10.000000
10.000000
    10.000000    10.000000     10.000000     10.000000
    4.000000     1.700000      1.400000      1.400000
    1.800000     5.000000      10.000000     10.000000
    10.000000    10.000000     10.000000
0.000000E+00
  0.000000E+00     10.000000     10.000000
10.000000
    10.000000    10.000000     10.000000     10.000000
    7.000000     1.900000      1.700000      1.800000
    3.000000     5.000000      10.000000     10.000000
    10.000000    10.000000     10.000000
0.000000E+00
  0.000000E+00     10.000000     10.000000
10.000000
    10.000000    10.000000     10.000000     10.000000
    9.500000     6.000000      2.500000      3.000000
    6.000000     10.000000     10.000000     10.000000
    10.000000    10.000000     10.000000
0.000000E+00
  0.000000E+00     10.000000     10.000000
10.000000
    10.000000    10.000000     10.000000     10.000000
    10.000000    10.000000     9.000000      10.000000
    10.000000    10.000000     10.000000     10.000000
    10.000000    10.000000     10.000000
0.000000E+00
  0.000000E+00     10.000000     10.000000
10.000000
    10.000000    10.000000     10.000000     10.000000
    10.000000    10.000000     10.000000     10.000000
    10.000000    10.000000     10.000000     10.000000
    10.000000    10.000000     10.000000
0.000000E+00
  0.000000E+00     10.000000     10.000000
10.000000
    10.000000    10.000000     10.000000     10.000000
    10.000000    10.000000     10.000000     10.000000
    10.000000    10.000000     10.000000     10.000000
    10.000000    10.000000     10.000000
0.000000E+00
  0.000000E+00  0.000000E+00  0.000000E+00
0.000000E+00
  0.000000E+00  0.000000E+00  0.000000E+00
0.000000E+00
  0.000000E+00  0.000000E+00  0.000000E+00
0.000000E+00
  0.000000E+00  0.000000E+00  0.000000E+00
0.000000E+00
    1
    10      1      7      200      2      0
    0       0      0      0      10.000000
  0.000000E+00  0.000000E+00
    11      4   -5.000000E-04     4500.000000
0.000000E+00
    11      5   -5.000000E-04     4500.000000
0.000000E+00
```

plattsburgh afb prediction model c (20% source removal)

```
      10        2        20        20       3600        1
       7        5       200         2          9        1
       0        2         2         0          0        1
    38.000000   1.000000E-03   3.000000E-01
60.000000
  0.000000E+00   0.000000E+00   0.000000E+00
400.000000
   400.000000   2.500000E-01   5.000000E-01
1.500000
    1.761000      1.600000     0.000000E+00
0.000000E+00
   1.000000E-03      3.100000
       11        4
       11        5
       12        7
       13        9
       13       13
       11        4  -5.000000E-04   4500.000000
0.000000E+00
       11        5  -5.000000E-04   4500.000000
0.000000E+00
        1   6.000000E-04
  0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00
  0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00
  0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00
  0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00
  0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00
  0.000000E+00     10.000000     10.000000
10.000000
    10.000000    300.000000    300.000000
300.000000
   300.000000    300.000000    300.000000
200.000000
    54.000000     54.000000     54.000000     54.000000
    54.000000    400.000000    500.000000
0.000000E+00
  0.000000E+00     10.000000     10.000000
10.000000
    10.000000    500.000000    500.000000
500.000000
   300.000000    300.000000    300.000000
54.000000
    54.000000     54.000000     54.000000     54.000000
    54.000000     54.000000     54.000000
0.000000E+00
  0.000000E+00     10.000000     10.000000
10.000000
    10.000000    500.000000    500.000000
500.000000
   500.000000    500.000000    200.000000
54.000000
    54.000000     54.000000     54.000000     54.000000
    54.000000    400.000000    400.000000
0.000000E+00
  0.000000E+00     10.000000     10.000000
10.000000
    10.000000    500.000000    500.000000
500.000000
   500.000000    500.000000     54.000000
54.000000
   200.000000    500.000000    500.000000
500.000000
   600.000000    600.000000    600.000000
0.000000E+00
  0.000000E+00     10.000000     10.000000
10.000000
    10.000000     54.000000     54.000000     54.000000
   400.000000    400.000000    500.000000
500.000000
   500.000000    500.000000    500.000000
500.000000
   600.000000    600.000000    600.000000
0.000000E+00
  0.000000E+00     54.000000     54.000000
54.000000
    54.000000     54.000000     54.000000     54.000000
    54.000000     54.000000     54.000000    100.000000
   500.000000    500.000000    500.000000
500.000000
   500.000000    500.000000    500.000000
0.000000E+00
  0.000000E+00     54.000000     54.000000
54.000000
    54.000000     54.000000     54.000000     54.000000
    54.000000     54.000000     54.000000     54.000000
   400.000000    400.000000    400.000000
400.000000
   400.000000    400.000000    400.000000
0.000000E+00
  0.000000E+00    100.000000    100.000000
54.000000
    54.000000     54.000000     54.000000     54.000000
    54.000000     54.000000     54.000000     54.000000
    54.000000     54.000000     54.000000     54.000000
    54.000000     54.000000     54.000000
0.000000E+00
  0.000000E+00    100.000000    100.000000
54.000000
    54.000000     54.000000     54.000000      5.000000
     5.000000      5.000000      5.000000     54.000000
    54.000000     54.000000     54.000000     54.000000
    54.000000     54.000000     54.000000
0.000000E+00
  0.000000E+00     54.000000     54.000000
54.000000
    54.000000     54.000000     54.000000     54.000000
     5.000000      5.000000      5.000000     54.000000
   100.000000    100.000000    100.000000
100.000000
   100.000000    100.000000    100.000000
0.000000E+00
  0.000000E+00     54.000000     54.000000
54.000000
    54.000000     54.000000    100.000000
100.000000
   100.000000    100.000000     54.000000
54.000000
    54.000000     54.000000     54.000000     54.000000
    54.000000     54.000000     54.000000
0.000000E+00
  0.000000E+00      5.000000     10.000000
10.000000
    54.000000     54.000000    100.000000
100.000000
    54.000000     54.000000     54.000000     54.000000
    54.000000     54.000000     54.000000     54.000000
```

```
    54.000000    54.000000    54.000000
0.000000E+00
  0.000000E+00    54.000000    54.000000
54.000000
    54.000000    54.000000    54.000000    54.000000
    100.000000   100.000000   100.000000
54.000000
    54.000000    54.000000    54.000000    54.000000
    54.000000    54.000000    54.000000
0.000000E+00
  0.000000E+00    54.000000    54.000000
54.000000
    54.000000    54.000000    54.000000    54.000000
    54.000000    54.000000    54.000000    54.000000
    54.000000    54.000000    54.000000    54.000000
    54.000000    54.000000    54.000000
0.000000E+00
  0.000000E+00    54.000000    54.000000
54.000000
    54.000000    54.000000    54.000000    54.000000
    54.000000    54.000000    54.000000    54.000000
    54.000000    54.000000    54.000000    54.000000
    54.000000    54.000000    54.000000
0.000000E+00
  0.000000E+00    54.000000    54.000000    54.000000
    54.000000    54.000000    54.000000    54.000000
    54.000000    54.000000    54.000000    54.000000
    54.000000    54.000000    54.000000
0.000000E+00
  0.000000E+00   5.000000E-01   5.000000E-01
5.000000E-01
    54.000000    54.000000    54.000000    54.000000
    54.000000    54.000000    54.000000    54.000000
    54.000000    54.000000    54.000000    54.000000
    54.000000    54.000000    54.000000
0.000000E+00
  0.000000E+00   5.000000E-01   5.000000E-01
5.000000E-01
    54.000000    54.000000    54.000000    54.000000
    54.000000    54.000000    54.000000    54.000000
    54.000000    54.000000    54.000000    54.000000
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    45.000000    45.000000    45.000000    45.000000
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200.000000
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200.000000
  200.000000  200.000000  200.000000
200.000000
  200.000000  200.000000  200.000000
0.000000E+00
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200.000000
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200.000000
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200.000000
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200.000000
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200.000000
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200.000000
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200.000000
  200.000000  200.000000  200.000000
200.000000
  200.000000  200.000000  200.000000
0.000000E+00
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200.000000
  200.000000  200.000000  200.000000
200.000000
  200.000000  200.000000  200.000000
200.000000
  200.000000  200.000000  200.000000
0.000000E+00
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190.000000
  190.000000  190.000000  190.000000
190.000000
  190.000000  190.000000  190.000000
190.000000
  190.000000  190.000000  190.000000
0.000000E+00
  0.000000E+00  190.000000  190.000000
190.000000
```

```
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180.000000
   180.000000   180.000000   180.000000
180.000000
   180.000000   180.000000   180.000000
180.000000
   180.000000   180.000000   180.000000
180.000000
   180.000000   180.000000   180.000000
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180.000000
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   180.000000   180.000000   180.000000
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   180.000000   180.000000   180.000000
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180.000000
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180.000000
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   180.000000   180.000000   180.000000
180.000000
   180.000000   180.000000   180.000000
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   10.000000   4.000000   3.000000E-01   9.000000E-
01
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    10.000000     10.000000      10.000000      10.000000
    10.000000     10.000000      10.000000      10.000000
    10.000000     10.000000      10.000000
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10.000000
    10.000000     10.000000      10.000000      10.000000
    10.000000     10.000000      10.000000      10.000000
    10.000000     10.000000      10.000000      10.000000
    10.000000     10.000000      10.000000
0.000000E+00
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0.000000E+00
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APPENDIX D

BIOPLUME II MODEL OUTPUT FILES

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APPENDIX E

ESTIMATING NON-DESTRUCTIVE ATTENUATION EFFECTS

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Method for Normalizing BTEX Data for the Effects of Dispersion, Dilution, and Sorption

To correct for the effects of dispersion, dilution, and sorption of the BTEX compounds, an equation was developed that corrects the measured concentration so that the changes in BTEX concentrations are assumed to be due only to biodegradation. A convenient way of doing this is to use compounds present in the dissolved BTEX plume that have Henry's Law constants and soil sorption coefficients that are similar to those of BTEX and that are recalcitrant under anaerobic conditions. Trimethylbenzene (TMB) is useful in some, but not all, ground water environments. 1,2,3-TMB, 1,2,4-TMB and 1,3,5-TMB are the three isomers for TMB. Their Henry's Law constants and soil sorption coefficients are similar to the BTEX compounds. Also, the TMB isomers are generally present in sufficient quantities in fuel mixtures to be readily detectable when dissolved in ground water and are fairly recalcitrant under anaerobic conditions. Since TMB is contained in hydrocarbon fuels along with the BTEX compounds, the TMB can be used as a conservative tracer with respect to biodegradation. The concentration of TMB at the source of contamination will be the same as the concentration downgradient of the contaminate source within the plume, less the effects of dilution and sorption. All other physical and chemical degradation processes are assumed to be the same for the BTEX and TMB.

The equation used to estimate the mass loss of total BTEX due to biodegradation (Section 5) corrects for the effects of dispersion, dilution, and sorption between points A and B. The concentration of BTEX can be normalized according to Wiedemeier *et al.*, 1995:

$$C_{B,corr} = C_B(TMB_A/TMB_B)$$

$C_{B,corr}$ = corrected concentration of compound at Point B

C_B = measured concentration of compound at Point B

TMB_A = measured concentration of trimethylbenzenes at Point A

TMB_B = measured concentration of trimethylbenzenes at Point B.

Trimethylbenzene is slightly more hydrophobic than BTEX and therefore has a higher soil sorption coefficient. This causes preferential sorption of TMB. In addition, TMB is not entirely recalcitrant under anaerobic conditions, and appears to degrade rapidly under aerobic conditions. However, if any TMB mass is lost to the processes of biodegradation or preferential sorption, the equation presented above becomes more conservative

To take into account the effect of sorption from the source to the downgradient well, the ratio of the K_{OC} values (organic carbon partition coefficient) is used when the total organi carbon content of the aquifer is greater than 0.1 (Wiedemeier *et al.*, 1994). This ratio takes into account the different compounds affinity to sorb to organic material in the aquifer and soil. This ratio also makes a correction to the dilution

equation above, by taking into account these differences in sorption. Because TMB is sorbed more than BTEX, the above equation must be multiplied by a number less than one to correct for the differences in sorption between the TMB and the compounds of interest. The following attached two graphs illustrate the effects of correcting for non-destructive attenuation mechanism.

After correcting measured BTEX concentrations for the effects of dispersion, dilution, and sorption, it is possible to estimate the amount of BTEX removed from the system (converted to carbon dioxide and water) via biodegradation between the two points A and B using the following relationship:

Mass loss due to biodegradation = $C_{A,Obs} - C_{B,Corr}$

Table 1 shows how BTEX data for Site FT-002 were corrected for the effects of dispersion, dilution, and sorption. The import of these data are described in Section 5.

Appendix E

Table 1

Normalized BTEX Data

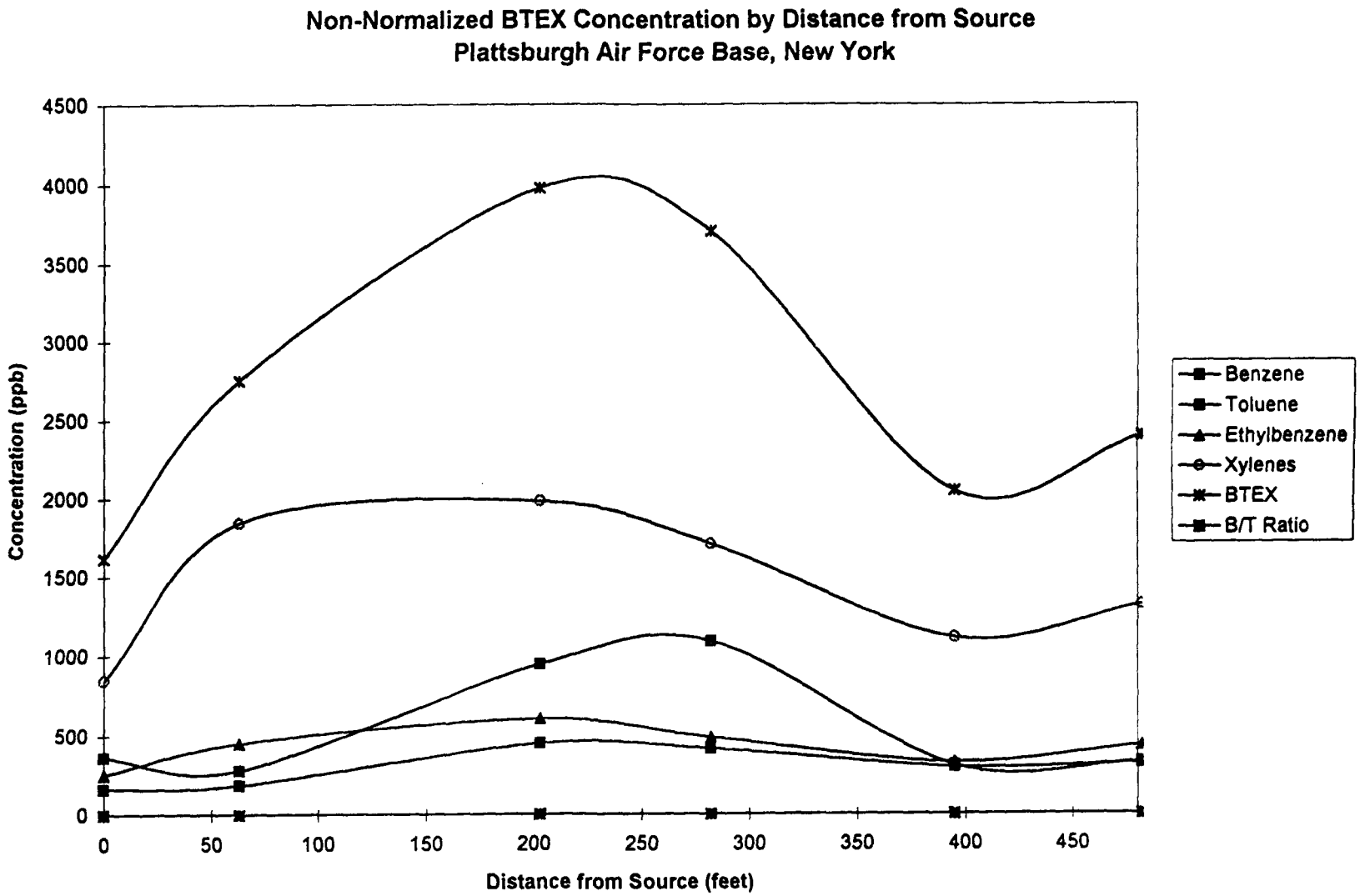
Fire Training Area, FT-002

Intrinsic Remediation EE/CA

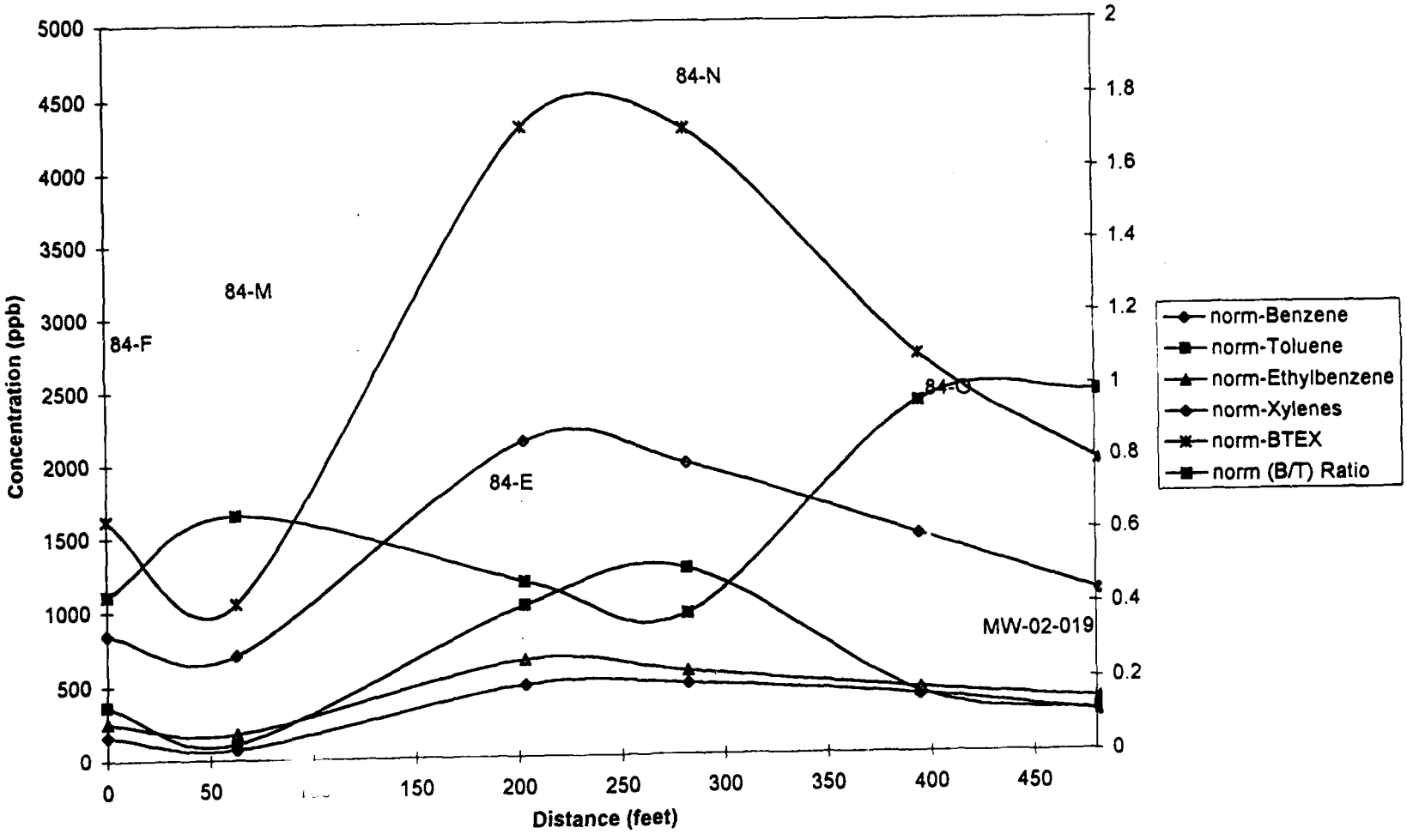
Plattsburgh Air Force Base, NY

Sample Location	Distance From Source (ft)	Benzene	Toluene	Ethylbenzene	xylenes	BTEX	B/T	1,3,5-TMB	1,2,4-TMB	1,2,3-TMB	Total TMB	fraction Location	norm-c6h	nor-tol	nor-eb	norm-xyl	BTEX	Ratio (b/t)
84F	0	161	363	250	844	1618	0.443526	29.7	97.1	49.6	176.4	1	161	363	250	844	1618	0.443526
84M	63	183	277	449	1842	2751	0.66065	88.6	242	130	460.6	0.382979	70.08511	106.0851	171.9574	705.4468	1053.574	0.66065
84E	203	448	944	606	1980	3978	0.474576	78.6	227	120	425.6	1.082237	484.8421	1021.632	655.8355	2142.829	4305.138	0.474576
84N	282	416	1090	488	1710	3704	0.381651	70.8	198	99.6	368.4	1.155266	480.5907	1259.24	563.7698	1975.505	4279.105	0.381651
84O	395	296	309	329	1112	2046	0.957929	56.9	149	71.9	277.8	1.326134	392.5356	409.7754	436.2981	1474.661	2713.27	0.957929
82-02-19	482	321	327	433	1318	2399	0.981651	65.9	179	93.2	338.1	0.92165	263.7498	268.6797	355.7746	1082.935	1971.139	0.981651

Kd	koc	koc/Ktmb
benzene	79	0.101673
toluene	190	0.24453
Ethylbenzene	468	0.602317
Xylenes	395	0.508366
TMB	777	1


Non-Normalized BTEX Concentration by Distance from Source
Plattsburgh Air Force Base, New York
Concentration (ppb)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
50
100
150
200
250
300
350
400
450
Distance from Source (feet)
Benzene
Toluene
Ethylbenzene
Xylenes
BTEX
B/T Ratio

Normalized BTEX Concentrations by Distance from Source
Plattsburgh Air Force Base, New York



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Appendix E

Table 2

Normalized Chlorinated Solvent Data

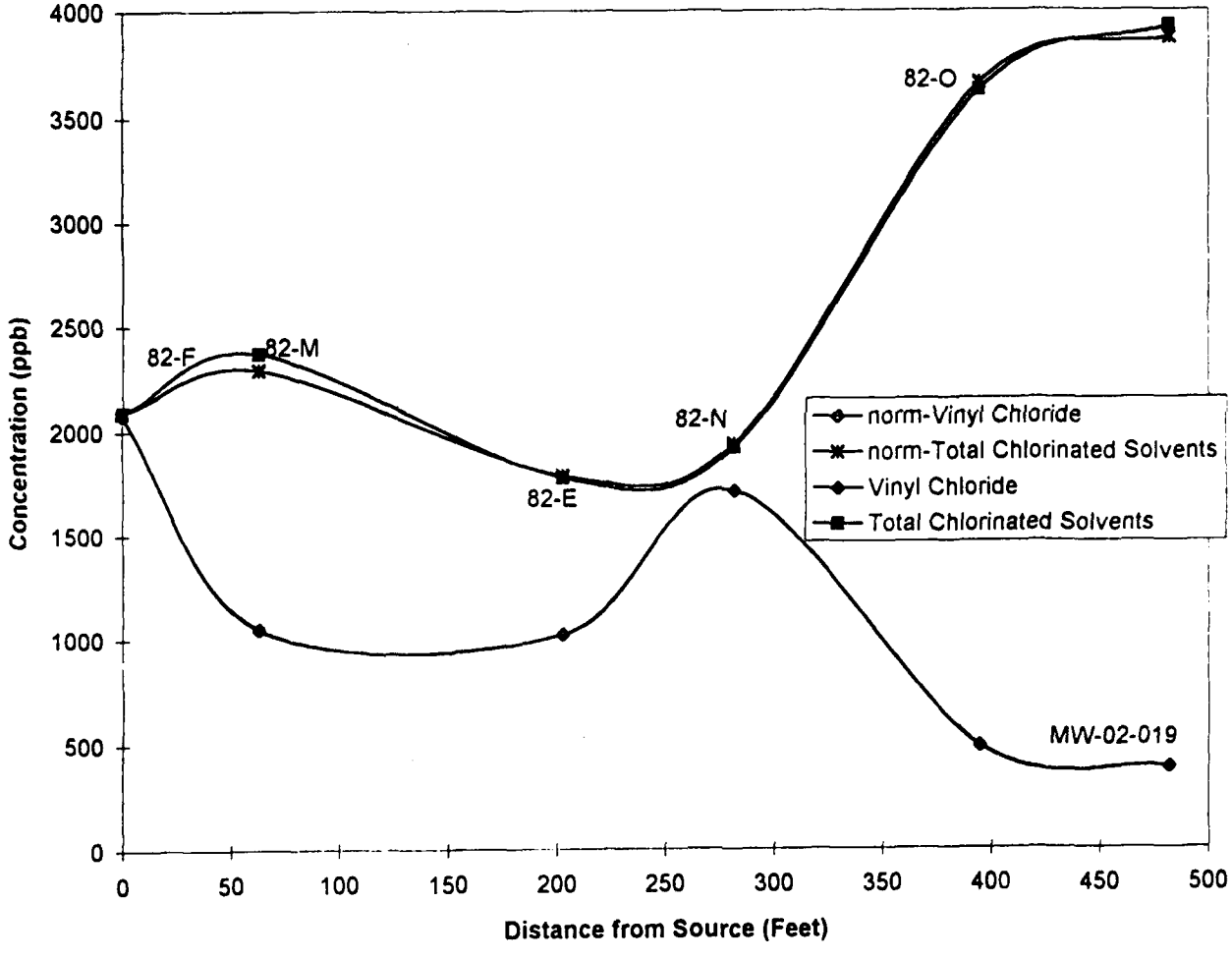
Fire Training Area, FT-002

Intrinsic Remediation EE/CA

Plattsburgh Air Force Base, NY

Sample Location	Distance From Source (ft)	Vinyl CL	Total TCE	1,3,5-TMB	1,2,4-TMB	1,2,3-TMB	Total TMB	fraction Location	norm-CL	norm-TCE
84F	0	2080	2089.1	57.4	159	80.7	297.1	1	2080	2089.1
84M	63	1050	2370	88.6	242	130	460.6	-0.55032	1046.383	2292.911
84E	203	1020	1773.7	78.6	227	120	425.6	0.075988	1020.252	1785.776
84N	282	1710	1918	70.8	198	99.6	368.4	0.134398	1710.433	1933.984
84O	395	486	3628.8	56.9	149	71.9	277.8	0.245928	487.3287	3660.428
82-02-19	482	384	3925.9	65.9	179	93.2	338.1	-0.21706	383.6667	3873.084
Kd		koc								
vinyl cl		2.455	0.00316							
Total TCE		52.1	0.067053							
TMB		777	1							

NORMALIZED CHLORINATED SOLVENTS CONCENTRATIONS BY DISTANCE FROM SOURCE
PLATTSBURGH AIR FORCE BASE, NEW YORK



CALCULATION OF RETARDATION COEFFICIENTS

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Appendix E
TABLE 3
CALCULATION OF RETARDATION COEFFICIENTS
SITE FT-002 INTRINSIC REMEDIATION EE/CA
PLATTSBURGH AFB, NEW YORK

Compound	K_{oc} (L/Kg [a/])	Maximum Fraction Organic Carbon [b/]	Minimum Fraction Organic Carbon [b/]	Average Fraction Organic Carbon [b/]	Distribution Coefficient, K_d (L/Kg) Maximum [c1/]	Minimum [c2/]	Average [c3/]	Bulk Density (Kg/L) [d/]	Effective Porosity [d/]	Coefficient of Retardation Maximum	Minimum	Average
Benzene	79	0.01	0.001	0.0055	0.790	0.079	0.435	1.60	0.30	5.21	1.42	3.32
Toluene	190	0.01	0.001	0.0055	1.900	0.190	1.045	1.60	0.30	11.13	2.01	6.57
Ethylbenzene	468	0.01	0.001	0.0055	4.680	0.468	2.574	1.60	0.30	25.96	3.50	14.73
m-Xylene	405	0.01	0.001	0.0055	4.050	0.405	2.228	1.60	0.30	22.60	3.16	12.88
0-Xylene	422	0.01	0.001	0.0055	4.220	0.422	2.321	1.60	0.30	23.51	3.25	13.38
p-Xylene	357	0.01	0.001	0.0055	3.570	0.357	1.964	1.60	0.30	20.04	2.90	11.47
				Average K_d	3.202	0.320	1.761		Average R	18.08	2.71	10.39
Vinyl Chloride [f/]	2.455	0.01	0.001	0.0055	0.025	0.002	0.014	1.60	0.30	1.13	1.01	1.07
trans-DCE [f/]	59	0.01	0.001	0.0055	0.590	0.059	0.325	1.60	0.30	4.15	1.31	2.73
TCE [f/]	95.1	0.01	0.001	0.0055	0.951	0.095	0.523	1.60	0.30	6.07	1.51	3.79
1,2,3-TMB [e/]	777	0.01	0.001	0.0055	7.770	0.777	4.274	1.60	0.30	42.44	5.14	23.79
				Average K_d	2.3338875	0.23338875	1.2836381		Average R	13.45	2.24	7.85

NOTES:

[a/] From Technical Protocol (Wiedemeier *et al., 1994)*

[b/] From site data

[c1/] K_d = Maximum Fraction Organic Carbon x K_{oc}

[c2/] K_d = Minimum Fraction Organic Carbon x K_{oc}

[c3/] K_d = Average Fraction Organic Carbon x K_{oc}

[d/] Literature values

[e/] From Jeng et al., 1992; Temperature = 20°C

[f/] From *Groundwater Chemicals Desk Reference,* Montgomery J.H. and Welkom LM.,Lewis Publishers, 1990

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CALCULATION OF THEORETICAL MAXIMUM DISSOLVED BTEX CONCENTRATIONS

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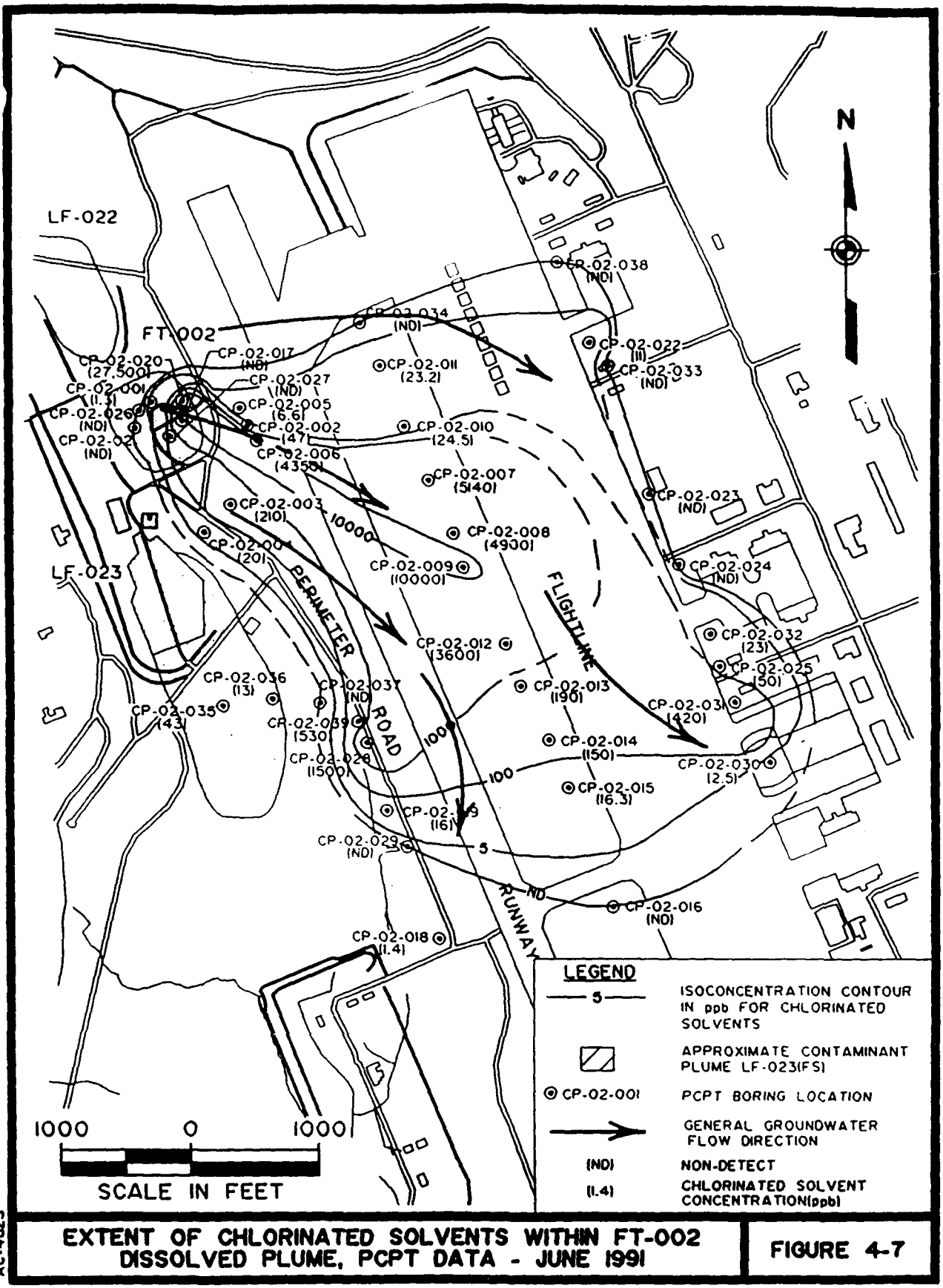
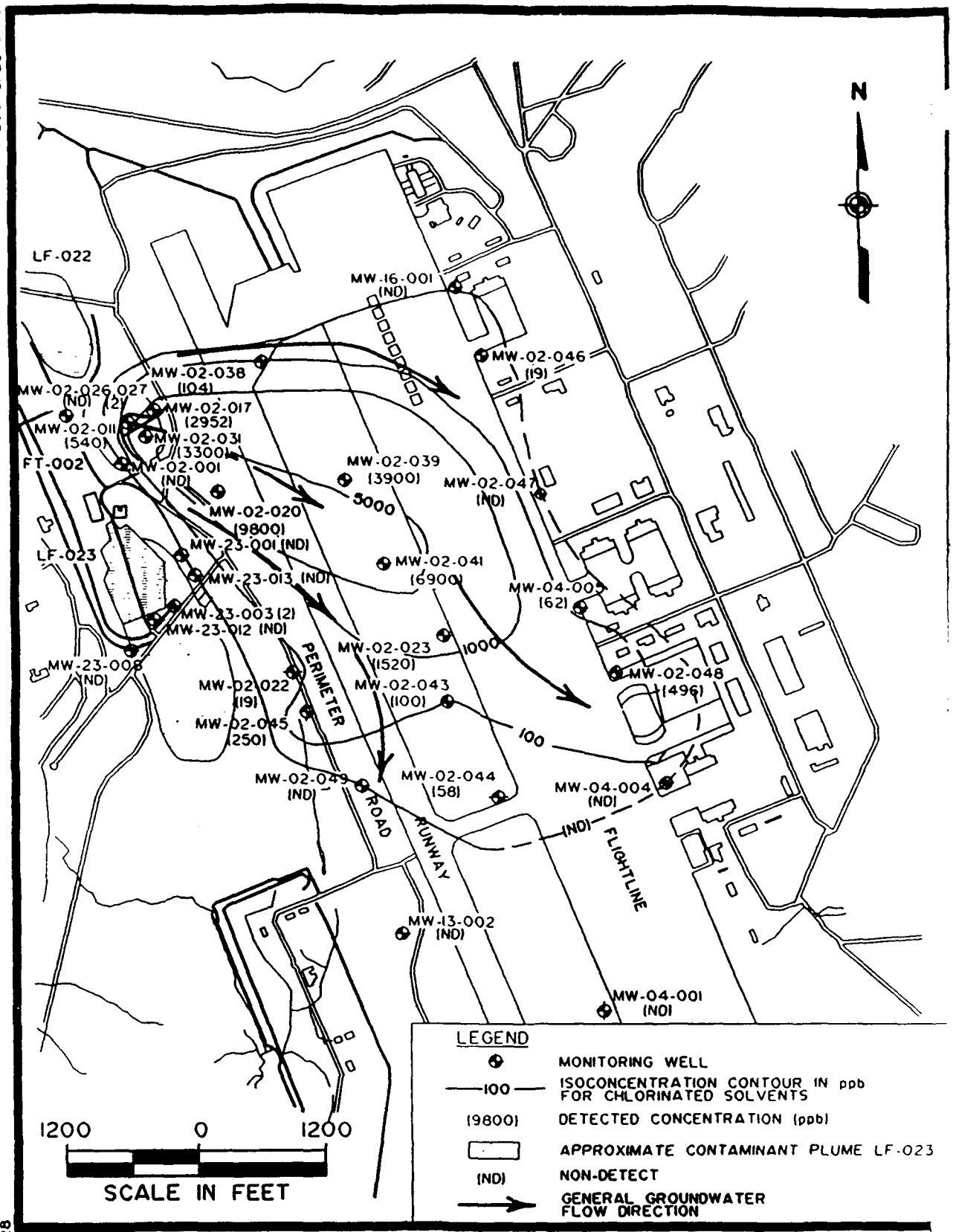


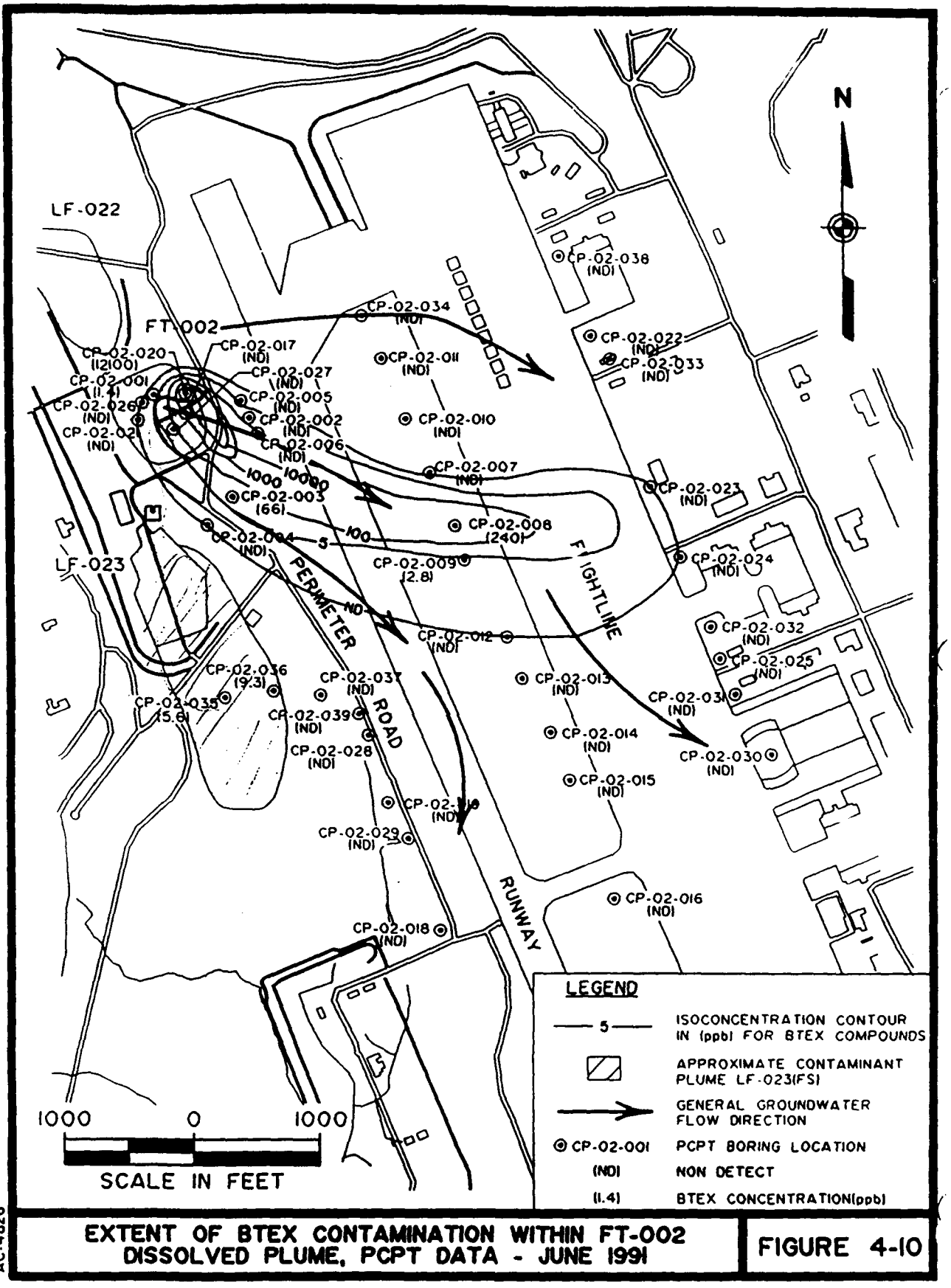
EXTENT OF CHLORINATED SOLVENTS WITHIN FT-002 DISSOLVED PLUME, PCPT DATA - JUNE 1991

FIGURE 4-7



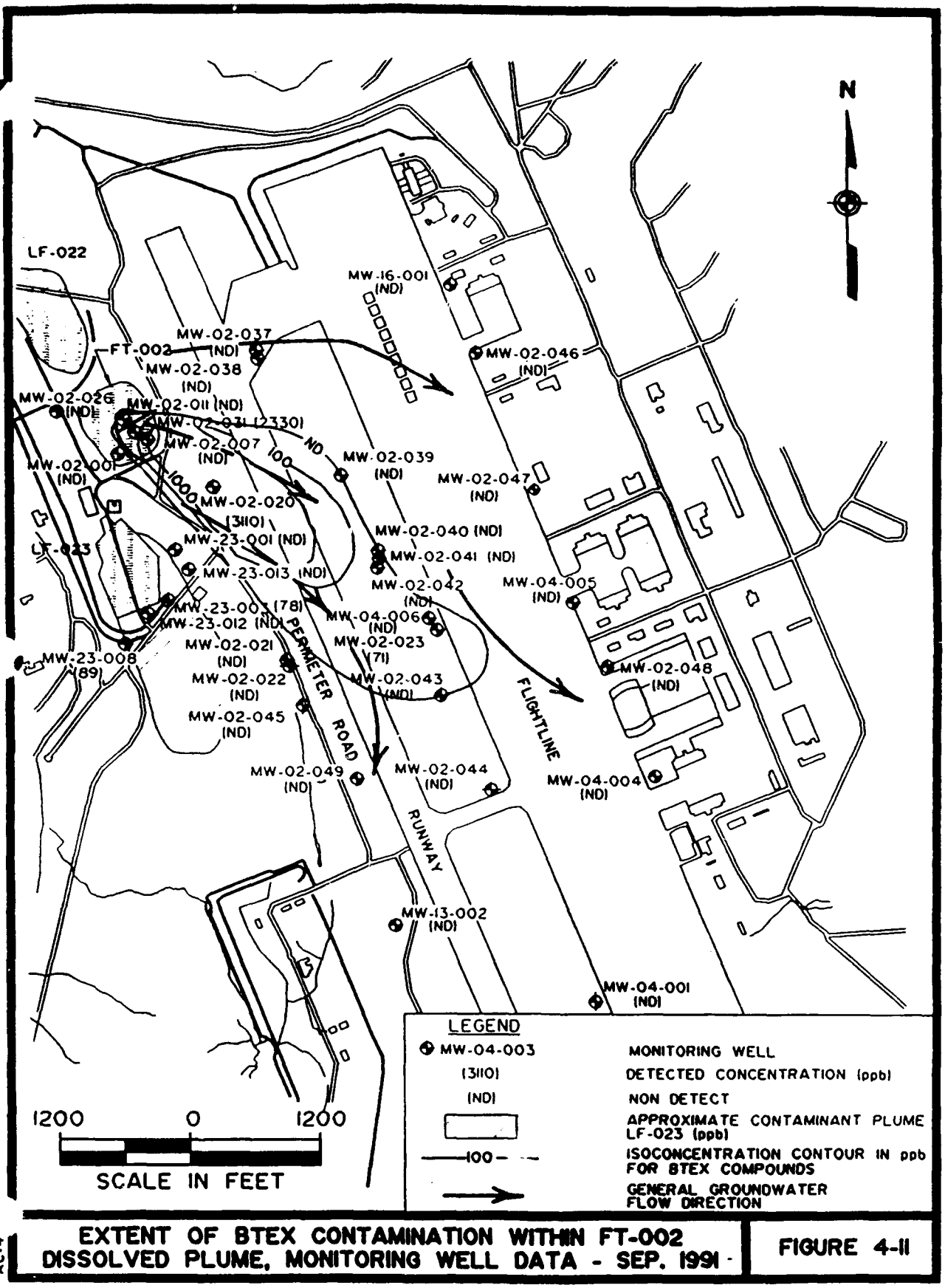
EXTENT OF CHLORINATED SOLVENT CONTAMINATION WITHIN FT-002 DISSOLVED PLUME, MONITORING WELL DATA-SEP. 1991

FIGURE 4-8



EXTENT OF BTEX CONTAMINATION WITHIN FT-002 DISSOLVED PLUME, PCPT DATA - JUNE 1991

FIGURE 4-10



EXTENT OF BTEX CONTAMINATION WITHIN FT-002 DISSOLVED PLUME, MONITORING WELL DATA - SEP. 1991

FIGURE 4-11

Appendix E
Table 4
Calculation of Fuel/ Water Partition Coefficients
Fire Training Area, FT-002
Intrinsic Remediation EE/CA
Plattsburgh Air Force Base, NY

Compound	Solubility (ppm)[a/]	Specific Density	Measured Concentration in Fuel (ppm)	Mass Fraction in Fuel (%)	Kfw[b/]	Estimated Max Conc. Dissolved in Ground Water (ppb)[c/]	Measured Max Conc. Dissolved in Ground Water (ppb)
Benzene	1780	0.8765	1,400	0.83	2.296E+02	6.097E+03	3.42E+02
Toluene	535	0.8669	8,970	5.32	9.149E+02	9.804E+03	1.56E+03
Ethylbenzene	208	0.867	5,440	3.23	2.712E+03	2.006E+03	8.08E+02
m-Xylene	170	0.8642	13,700	8.13	3.420E+03	4.006E+03	1.79E+03
o-Xylene	204	0.8802	4,570	2.71	2.773E+03	1.648E+03	7.15E+02
p-Xylene	200	0.8811	4,920	2.92	2.837E+03	1.734E+03	7.95E+02
1,2,3-trimethylbenzene	0.001	0.8944	3,560	2.11	3.540E+09	1.006E-03	3.06E+02
1,2,4-trimethylbenzene	0.001	0.8758	6,960	4.13	3.540E+09	1.966E-03	5.88E+02
1,3,5-trimethylbenzene	0.001	0.8652	4,110	2.44	3.540E+09	1.161E-03	1.80E+02
1-methylnaphthalene	25.8	1.0202	1,400	0.83	2.990E+04	4.683E+01	-
2-methylnaphthalene	24.6	1.0058	1,990	1.18	3.158E+04	6.301E+01	-
Decane	0.087	0.73	17,600	10.45	2.082E+07	8.452E-01	-
Dodecane	0.0037	0.7487	11,100	6.59	7.863E+08	1.412E-02	-
Heptane	3	0.6837	1,170	0.70	3.551E+05	3.295E+00	-
Hexane	9.5	0.6603	4,090	2.43	9.432E+04	4.336E+01	-
Naphthalene	26.72	1.162	1,370	0.81	2.872E+04	4.771E+01	-
Nonane	0.07	0.7176	15,300	9.10	2.674E+07	5.722E-01	-
Octane	0.7	0.7025	14,600	8.67	1.893E+06	7.713E+00	-
Pentadecane	0.001	0.7685	2,980	1.77	3.540E+09	8.418E-04	-
Tetradecane	0.0022	0.7628	5,490	3.26	1.430E+09	3.840E-03	-
Trichloroethene	1100	1.4642	16,400	9.74	3.994E+02	4.106E+04	1.33E+03
Tridecane	0.001	0.7564	9,320	5.53	3.540E+09	2.633E-03	-
Undecane	0.001	0.7402	12,000	7.12	3.540E+09	3.390E-03	-

a/ ppm = parts per million
b/ Kfw = fuel/ water partition coefficient
c/ ppb = parts per billion